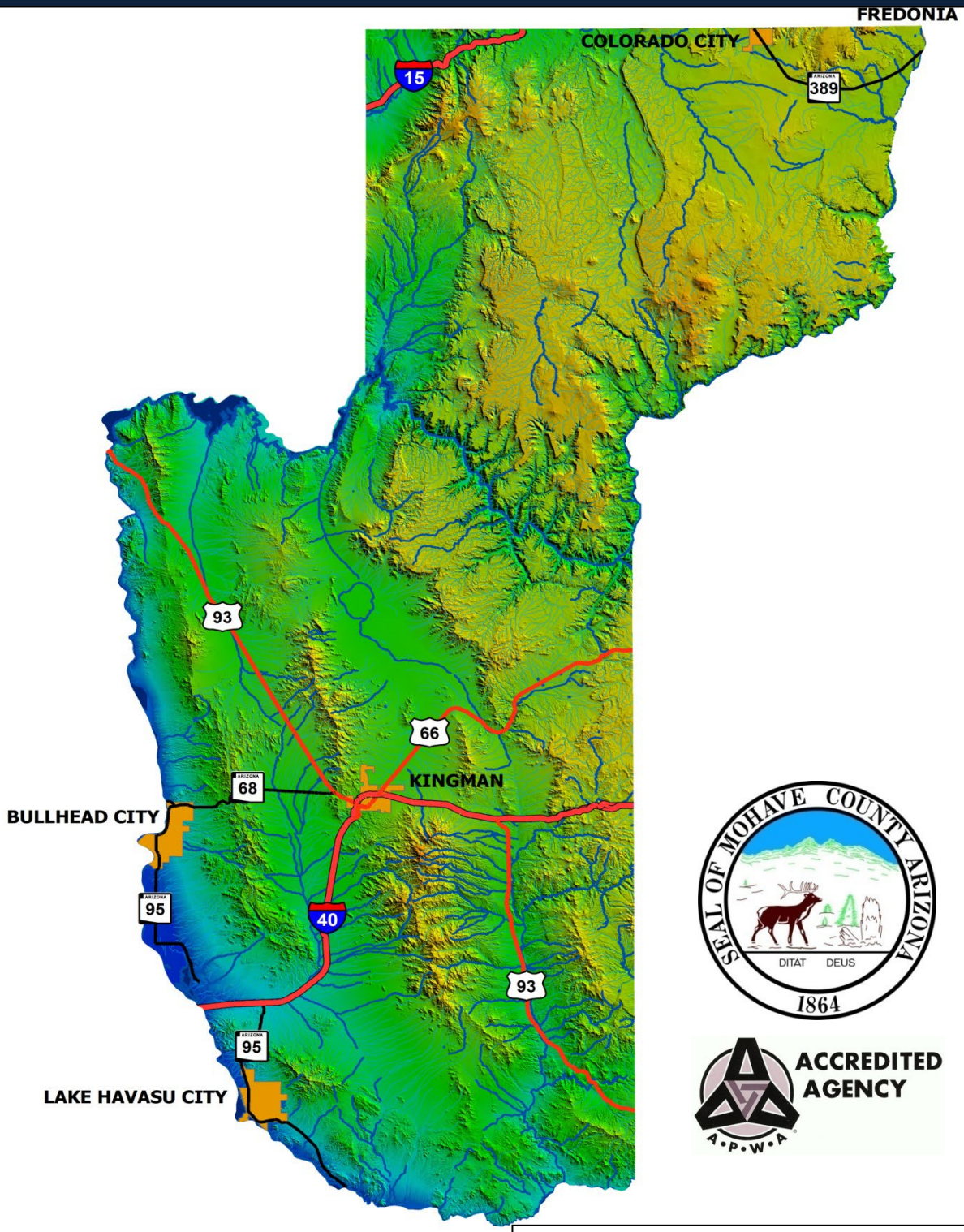
DRAINAGE DESIGN MANUAL FOR MOHAVE COUNTY



SEAL OF MOHAVE COUNTY ARIZONA
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ACCREDITED AGENCY
A•P•W•A

3rd Edition, May 2018

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ACKNOWLEDGEMENTS

The information, procedures, and recommendations that are presented in this manual are mainly the result of previously published efforts of many diligent and talented engineers and scientists. The author of this manual has made every effort to cite the original authors and researchers whose contributions to the profession are greatly appreciated.

The author of this manual is indebted to the many individuals and organizations, including the staff at Mohave County, that have supported this effort through recommendations, technical guidance, encouragement, and review of draft sections. Special thanks go to Mr. Philip Wisely, who started the process of creation of this manual while with Mohave County.

The Mohave County staff who supported and contributed to this manual throughout its development are:

Sam Elters, P.E., County Manager

Timothy M. Walsh, Jr., P.E., Development Services Director

Steven P. Latoski, P.E., Public Works Director

Kat Fish, Floodplains Program Manager

Agencies that have contributed greatly to this manual through their research efforts in producing technical material for use by the profession are:

Arizona Department of Transportation

City of Phoenix, AZ

Flood Control District of Maricopa County

Urban Drainage and Flood Control District (Denver)

US Department of Agriculture, Agricultural Research Service

US Department of Agriculture, Natural Resources Conservation Service

US Army Corps of Engineers

US Geological Survey, Arizona Water Science Center

US Department of Transportation

COMMENTS

Users of this manual are strongly encouraged to submit any comments, criticisms, or findings of errors. This information should be addressed to:

Flood Control District Engineer
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Because of ongoing legal and technical changes in the field of stormwater management, revisions to this manual will be required from time to time. Such revisions will take place on an ongoing, as needed basis and will be posted on the Mohave County Drainage Design Manual web page (Drainage Design Manual).

REVISIONS

1st Edition: August 24, 2009

November 20, 2009	Corrected typographical error in Section 1.6.
2011	Revised: 1. Section 7.2.1.1. Description of hypothetical rainfall distribution. 2. Figure 7.12, 7.14, and 7.15. 3. Table 7.8, Table 13.4 (added asphalt) 4. Equations 7.9, 7.10, 7.11, 11.4. 5. Section 8.3.4. Changed 2003 International Building Code to 2006. 6. Miscellaneous typographic errors.
June 10, 2012	Revised Rational Method C coefficients in Table 7.19 to correlate with Table 7.6 for C-1 and C-RE zoning classifications. Revised RTIMP values in Table 7.20 to correlate with Table 7.7 for M and M-X zoning classifications.

2nd Edition: December 2012

1. Changed all GIS data from US Survey feet to International feet.
2. Changed the conversion factor to compute XKSAT from K_s to 0.5.

3. Eleven of the twenty NRCS Soil Surveys were revised since the 1st edition was published. Processed all the revised soil surveys, recomputed Green and Ampt parameters for all 20 soil surveys, completely replaced the soils GIS polygons, and published revised Green and Ampt parameters. Computed new regression equations for PSIF and DTHETA and created a new regression equation to compute XKSAT for Density Factor 1.1 from XKSAT for Density Factor 1.0.
4. Revised the Unit Hydrograph Example using the new soils database. Revised the DDMSW example files and supporting soil defaults and GIS data.
5. Revised the NOAA Atlas 14 Index Maps GIS coverages and PDF file. Expanded the area covered to include the entire Mohave County DDM study area.
6. Revised the graphics for the Indirect Methods chapter.
7. Made small changes to Table 7.24.
8. Updated Chapter 2 to reflect current information for stormwater quality requirements.
9. Added new Chapter 18 and renumbered old chapters 18 through 22 to 19 through 23.
10. Addressed minor review comments from Mohave County.
11. Repaired broken web site links.
12. Section 2.3.1.6. Added latest information from FEMA including ability to apply for a LOMA online using a LOMC, and a new requirement that all Letters of Map Change must be in compliance with the Endangered Species Act (ESA).
13. Section 12.3.5.5. Added Table 12.5 to clarify design freeboard requirements and to include new criteria for design flow depth less than or equal to 1.0.
14. Chapter 20. Changed update process to allow for a 2-tier approach.
15. Changed the Mohave County internet domain to www.mohave.gov for all hyperlinks to Mohave County web pages.

3rd Edition: May 2018

1. Revised all rainfall loss parameters using NRCS soil survey data revisions that have occurred since the 2012 2nd edition. Fixed an error in program code where the limiting soil horizon used was 6 centimeters instead of 6 inches. Changes were made in Chapter 7.4, Appendix A.3, Appendix A.4, and Appendix D. The DDMSW program and the GIS soil map unit feature classes were revised to use the revised parameters.
2. Changed "Preliminary Drainage Report" to "Design Concept Report" throughout.
3. Updated the Acronyms, Glossary, and References sections.
4. Chapter 2. Updated descriptions and references to federal and state programs. Added Small MS4 description.
5. Chapter 3. Updated discussion of "Waters of the United States."
6. Chapter 5. Added a policy for lowest floor requirements within non-floodplain areas, that was only previously set forth in Section 8.3.4.
7. Chapter 7. Section 7.2.2.2: Added IDF and DDF tables, and IDF figures, for Bullhead City and Lake Havasu City. Section 7.11: Complete rewrite based on the latest USGS publication.
8. Updated references to Mohave County ordinances and documents and changed language where appropriate to "current" rather than "adopted."
9. Section 7.13.2. Added "C-Values" to table column headings.
10. Chapter 8. Updated code references, the description of FEMA, and added language that a "no rise" certification is required for development within FEMA floodways.
11. Chapter 15. Added language to clarify that offsite flows are not to be mingled with onsite retention/detention structures, as described previously only in Chapter 3. Specified an aggregate minimum impervious area requirement in Section 15.3 before retention is required.
12. Section 16.3.3. Added language requiring an applicant to check if a "Small MS4" is required for the site.
13. Checked and updated references and glossary chapters

14. Checked and updated cross references and hyperlinks and made numerous grammatical revisions.

15. Appendix A. Revised the Indirect Methods unit hydrograph check example. Complete rewrite of Appendix F.

September 2022 Revisions

1. Acknowledgements. Replaced "Michael P. Hendrix, P.E., County Administrator" with "Sam Elters, P.E., County Manager."
2. Acknowledgements. Replaced "Shannon Summers" with "Kat Fish" as the Floodplain Program Manager.
3. Section 1.4. Changed "twenty-one" to "twenty-two" chapters.
4. Section 1.5. Changed "three" to "four" documents.
5. Section 1.5.1. Changed "morphology" to "hydrology."
6. Chapter 7. Updated the summaries in the "Introduction" to include a statement about FLO-2D.
7. Section 7.3.2.5. Changed "Table 7.25" to "Table 7.24."
8. Section 8.2.1.1. Changed "the MCFCD" to "FEMA."
9. Section 9.3. Added language regarding exceptions to runoff from 100-year frequency storms.
10. Section 11.4.2. Added "elliptical" to types of pipes that can be used for Culvert Material Requirements.
11. Section 15.3.2. Updated language regarding retention requirements.
12. Section 16.3.3. Removed language that stated the County would not approve engineered grading projects nor recommend grading permit issuance without documentation that applicable state and federal permits have been obtained.
13. Section 18.2.1. Added an additional method to list of preferred numerical models for use with Mohave County.

14. Chapter 19. Updated the "Introduction" with additional language.
15. Section 19.2.2. Added an additional requirement for Design Concept Reports requesting narrative, summary tables and exhibits to be provided for each section.
16. Chapter 20. Changed "Public Works" to "Flood Control" in multiple locations.

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LIST OF ACRONYMS AND ABBREVIATIONS

The following are abbreviations used throughout the document pertaining to approvals that must be obtained before proceeding:

MOHAVE COUNTY ENGINEER: Requires written approval by the Mohave County Engineer.

COUNTY: Requires written approval by a Mohave County staff member designated by the MOHAVE COUNTY ENGINEER as having approval authority.

DISTRICT ENGINEER: Requires written approval by the Mohave County Flood Control District Director.

DISTRICT: Requires written approval by a Mohave County Flood Control District staff member designated by the DISTRICT ENGINEER as having approval authority.

COUNTY/DISTRICT: Requires written approval by either COUNTY or DISTRICT or both, at the discretion of the Mohave County Engineer.

Board of Supervisors: Requires approval action by the Mohave County Board of Supervisors.

Board of Directors: Requires approval action by the Mohave County Flood Control District Board of Directors.

The following are general abbreviations and acronyms used throughout this document:

A.R.S.	Arizona Revised Statute
ACPA	American Concrete Pipe Association
ADA	Americans with Disabilities Act
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
ADOT Standards	ADOT Standard Specifications for Road & Bridge Construction and Standard Drawings
ADWR	Arizona Department of Water Resources
AISI	American Iron and Steel Institute

APP	Aquifer Protection Permit
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AZPDES	Arizona Pollutant Discharge Elimination System
BFE	Base Flood Elevation. The elevation of the 100-year water surface
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CGP	Construction General Permit
CLOMA	Conditional Letter of Map Amendment
CLOMR	Conditional Letter of Map Revision
CLOMR-F	Conditional Letter of Map Revision Based on Fill
CSP	Corrugated Steel Pipe
CSPI	Corrugated Steel Pipe Institute
CWA	Clean Water Act
D-D-F	Depth -Duration - Frequency
DDM	Drainage Design Manual for Mohave County
DDMSW	Drainage Design Modeling System for Windows computer software by KVL Consultants, Inc. Refers to the Mohave County-specific version
DGP	De Minimis General Permit
DTHETA	Volumetric soil moisture deficit at the start of rainfall
ELEV	Elevation
EPA	U.S. Environmental Protection Agency
FCDMC	Flood Control District of Maricopa County
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration

FIRM	Flood Insurance Rate Map
FR	Federal Register
GIS	Geographical Information System
HEC-1	United States Army Corps of Engineers Hydrologic Engineering Center computer program for hydrologic modeling (DOS-based)
HEC-HMS	United States Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System computer program for hydrologic modeling (Windows-based)
HEC-RAS	United States Army Corps of Engineers Hydrologic Engineering Center River Analysis System computer program for hydraulic modeling of open channels and rivers (Windows-based)
Hydraulics Manual	FCDMC Drainage Design Manual - Hydraulics (most recent draft)
IA	Initial abstraction
I-D-F	Intensity - Duration - Frequency
LOMA	Letter of Map Amendment
LOMR	Letter of Map Revision
LOMR-F	Letter of Map Revision Based on Fill
MAG	Maricopa Association of Governments
MAG Standards	MAG Uniform Standard Specifications and Details for Public Works Construction
MCFCD	Mohave County Flood Control District
MS4	Municipal separate storm sewer systems (EPA definition)
MSGP	Multi-Sector General Permit
MUTCD	Manual on Uniform Traffic Control Devices
NFIP	National Flood Insurance Program
NMIN	HEC-1 computation time interval

NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOT	Notice of Termination
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSS	USGS National Stream Flow Statistics Program
NSTPS	HEC-1 number of computation steps for routing operations
NWP	Nationwide General Permit
NWS	National Weather Service
PMR	Physical Map Revision
PSIF	Wetting front capillary suction
R/W	Right-of-way
RGRCP	Rubber gasketed reinforced concrete pipe
RLNTH	HEC-1 routing reach length
RTIMP	Percent impervious
RUSLE	Revised Universal Soil Loss Equation
SEL	Slope of the energy grade line
SIC	Standard Industrial Classification
SMU	Soil Map Unit
SS	ADWR State Standard
SSA	ADWR State Standard Attachment
Standard Details	Uniform Standard Details for Mohave County
SWMP	Stormwater Management Plans
SWPPP	Stormwater Pollution Prevention Plans
TMDL	Total Maximum Daily Load

U.S.	United States
UDFCD	Urban Drainage and Flood Control District (Denver)
USACE	United States Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USFS	Unites States Forest Service
USGS	United States Geological Survey
WMS	Watershed Modeling System windows-based computer program by Aquaveo, LLC
XKSAT	Hydraulic conductivity at natural saturation

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1 INTRODUCTION

It is the intent of Mohave County to have a comprehensive stormwater management program that protects the health, safety and welfare of its citizens, their property, and the environment. The County's stormwater management documents include the following:

Mohave County Flood Control Ordinance

Mohave County Land Division Regulations

Mohave County Zoning Ordinance

Mohave County Engineering Design Standards, Specifications and Details

Drainage Design Manual for Mohave County (this document)

The addition of this Drainage Design Manual provides the technical basis for sound stormwater management. This is a joint document of Mohave County and the Mohave County Flood Control District (COUNTY/DISTRICT).

1.1 PURPOSE

The purpose of the Drainage Design Manual for Mohave County (DDM) is to supplement the Mohave County Land Division Regulations by providing minimum requirements and guidelines for addressing stormwater issues associated with new and existing development. A secondary purpose is to provide guidance and detail for implementation of the DISTRICT's Floodplain Ordinance. It is intended that drainage studies, plans, design reports, construction drawings and accompanying drainage/floodplain use permit applications prepared in accordance with the philosophies, policies and minimum standards contained herein will meet the minimum requirements of the governing regulations. This will expedite the review, approval and permitting processes.

The document presents the COUNTY/DISTRICT philosophy on drainage and floodplain management, and planning for drainage facilities. It contains descriptions of federal, state and county regulations pertaining to such facilities, including links to the various COUNTY/DISTRICT regulations that can be found on the Internet. Most importantly, the policies and minimum technical standards for addressing drainage and floodplain management issues are presented. These policies and standards are based on flood and erosion hazard mitigation strategies that

are intended to meet the minimum requirements under state and federal law with the effect of reducing or eliminating cumulative impacts resulting from development and enhancing public safety.

1.2 DISCLAIMER

COUNTY/DISTRICT will review and approve flood hazard delineation studies, drainage reports and plans for construction projects for conformance with the DDM, the DISTRICT's floodplain ordinance, and the COUNTY land division regulations and zoning ordinance, as appropriate under their separate authorities (refer to Chapter 2). This notwithstanding, COUNTY/DISTRICT assumes no liability for insufficient design or improper construction. Review and approval does not absolve the owner, developer, design engineer, or contractor of liability for inadequate design or poor construction. The design engineer has the responsibility to design drainage facilities that meet standards of practice for the industry and promote public safety. Compliance with the regulatory elements, and meeting the policies and minimum design standards, does not guarantee that properties will be free from flooding or flood damage. COUNTY/DISTRICT, and their officials or employees assume no liability for information, data, or conclusions prepared by private engineers or environmental professionals and make no warranty expressed or implied in their review/approval of drainage/floodplain projects or studies including stormwater quality submittals, or for use of the technical data and procedures provided in the DDM.

The Mohave County Flood Control District, a political subdivision of the State of Arizona, has compiled for its use certain information, including but not limited to, point rainfall data and soils parameters. This information is provided as public record as a part of the DDM and is available to assist in identifying general areas of concern only. The information provided should only be relied upon with corroboration of the methods, assumptions, and results by a qualified independent source. The user's reliance upon the accuracy, reliability and authority of this information is solely the user's responsibility. The user of this information releases, indemnifies and holds free the Mohave County Flood Control District and Mohave County from any and all liabilities, damages, lawsuits and causes of action that result as a consequence of his/her reliance on and use of information provided as a public record.

The Drainage Design Management System for Windows (DDMSW) computer software program is provided as a public service to aid in implementation of the technical information, data, and

procedures presented in the DDM. The user of this information releases, indemnifies and holds free the Mohave County Flood Control District and Mohave County from any and all liabilities, damages, lawsuits and causes of action that result as a consequence of his/her reliance on and use of the DDMSW computer program and the data supplied with it.

1.3 APPLICATION

Policies, standards, and philosophies set forth in this document apply to private development projects within the unincorporated areas of Mohave County, projects funded entirely by COUNTY/DISTRICT, and projects funded in cooperation with COUNTY and/or the DISTRICT and/or other agencies, or for those communities where the DISTRICT has floodplain management responsibilities. These policies and standards also apply, in an advisory capacity, to state funded and federally funded projects sponsored by COUNTY and/or the DISTRICT.

It is understood that there may be exceptions to the policies and standards that may be granted by COUNTY and/or the DISTRICT. The standards are minimum standards. There may be more stringent requirements in the event that public health, safety and welfare could be adversely affected by application of the minimum standard.

1.4 SCOPE

The Drainage Design Manual for Mohave County (DDM) is divided into twenty-two (22) chapters that address the major administrative areas of drainage and stormwater management. The intent of this manual is to provide rules and guidelines for the design of drainage and stormwater facilities. The purpose of each chapter is as follows:

Chapter 2, Legal Aspects: Federal, state and local regulatory requirements are outlined for the convenience of the user. These requirements change periodically. It is the user's responsibility to verify the content.

Chapter 3, Drainage Planning: This chapter stresses the COUNTY/DISTRICT vision for drainage and stormwater management and provides guidance for the drainage master planning process.

Chapter 4, Public Safety: The DDM is focused on public safety. Therefore, a separate chapter is provided to emphasize key policies and standards directly addressing safety issues.

Chapter 5, General Policies and Standards: The standard details and specifications accepted for use in Mohave County are listed as well as the Mohave County policy for accepting existing structures and/or facilities into the Mohave County maintenance system.

Chapter 6, Stormwater Quality: This chapter sets forth the COUNTY/DISTRICT approach to improving stormwater quality, which is based in the use of stormwater retention basins for new development.

Chapter 7, Hydrology: The design storm criteria for the various aspects of drainage design and floodplain management are defined, and the hydrologic methodologies for estimating peak discharges are set forth.

Chapter 8, Floodplain Management: Policies and standards for administering the Mohave County Flood Control Ordinance and meeting state and federal requirements for floodplain management are provided.

Chapter 9, Roadway Drainage: Policies and standards for design of surface roadway drainage, including catch basins, are provided.

Chapter 10, Storm Drains: Policies and standards for design of underground storm drains are provided.

Chapter 11, Culverts and Bridges: Policies and standards for design of culverts and bridges under roadways are provided.

Chapter 12, Open Channels: Standards for design of open channels, including lined and unlined channels, are provided.

Chapter 13, Friction Losses: Standards for estimating roughness coefficients for design of open channels, pipe culverts and storm drains, and for floodplain delineations are provided.

Chapter 14, Hydraulic Structures: Standards for design of hydraulic structures, including drop and grade control structures, and trash racks are provided.

Chapter 15, Stormwater Storage: Policies and standards for design of retention and detention basins are provided.

Chapter 16, Erosion Control During Construction: Appropriate erosion control measures at construction sites are defined.

Chapter 17, Sedimentation: The policies and standards in this chapter define the conditions where sedimentation should be considered as an important design parameter.

Chapter 18, Numerical Modeling: The purpose of this chapter is to provide general modeling guidelines for the use of one- and two-dimensional (1D, 2D) hydrologic and hydraulic models for floodplain management and drainage design purposes within Mohave County.

Chapter 19, Documentation Requirements: The requirements for preparing hydrology and hydraulics drainage reports and drainage improvement construction drawings are defined.

Chapter 20, Revision Process: The formal process for revising the DDM is described.

Chapter 21, Reference: Documents cited as references in the DDM are listed.

Chapter 22, Glossary: Technical terms used in the DDM are defined.

Various appendices are also provided containing technical documentation and examples to supplement the information in the main body of the DDM.

1.5 SOURCE REFERENCES

There are many documents cited as references in the DDM. However, there are four documents that are very important key references and warrant special acknowledgement.

1.5.1 ADOT HYDROLOGY MANUAL

The ADOT Hydrology Manual (ADOT, 1994) is the basis for Chapter 7 Hydrology. Many of the procedures are adapted from this manual and portions of the text are used with minor modifications specific to Mohave County hydrology. The user is referred to ADOT (1994) for more detailed explanations and descriptions of most hydrologic procedures, including the Clark unit hydrograph. Mohave County acknowledges the significant benefit to the citizens of the State of Arizona and its practicing civil engineering professionals from the research and extensive effort that went into creation of the ADOT Hydrology Manual. The hydrologic methodology and procedures recommended for use in Mohave County would not be possible without this document.

1.5.2 FCDMC HYDRAULICS MANUAL

The Flood Control District of Maricopa County Drainage Design Manual - Hydraulics (Hydraulics Manual) (FCDMC, 2013b) is the key reference for chapters 10 through 15, and 17. The

Hydraulics Manual is a state-of-the-art document for design of drainage facilities in arid regions and is recognized on a national level by its use and/or adoption by agencies in Arizona and outside of Arizona. The policies and standards in the listed chapters of the DDM are intended to provide Mohave County-specific guidance for application of FCDMC (2013b). The Flood Control District of Maricopa County is commended for the contribution made by creation of this document so that the public can benefit from the extensive research effort that went into its creation.

1.5.3 FCDMC EROSION CONTROL MANUAL

The Flood Control District of Maricopa County Drainage Design Manual - Erosion Control (FCDMC, 2012) is the key reference for chapter 16. FCDMC (2012) is a state-of-the-art document for "Best Management Practices" for control of erosion during construction in arid regions and is recognized on a national level by its use and/or adoption by agencies in Arizona and outside of Arizona. The policies and standards in chapter 16 of the DDM are intended to provide Mohave County-specific guidance for application of FCDMC (2012). The Flood Control District of Maricopa County is again commended for the contribution made by creation of this document so that the public can benefit from the extensive effort that went into its creation.

1.5.4 CITY OF PHOENIX STORMWATER POLICIES AND STANDARDS

Special acknowledgement is due the City of Phoenix for their *Stormwater Policies and Standards* manual (Phoenix, 2011). That manual is a key reference and source of information for Chapters 2, 3, 4, and 8 through 18. The City of Phoenix was the first agency in Maricopa County to write a stormwater policies and standards document that tailored the technical guidance in the FCDMC Drainage Design Manual to the unique characteristics and needs of their jurisdiction. The City of Phoenix thereby set a standard for other agencies within Maricopa County to follow and build on.

1.6 STATUTORY AUTHORITY

This manual is adopted pursuant to Arizona Revised Statutes (ARS) 11-251, Sections 30 and 36 and ARS 11-251.05 which authorizes the Board of Supervisors to adopt and enforce all ordinances necessary to the full discharge of the duties of the Board of Supervisors as the legislative authority of the county government; and to enforce standards for excavation, landfill

and grading to prevent unnecessary loss from erosion, flooding and landslides. This manual provides policies and standards in support of the Mohave County Land Division Regulations.

Also, sections 48-3603 and 48-3609 of the ARS direct each County Flood Control District Board of Directors to adopt and enforce floodplain regulations consistent with criteria adopted by the Director of Arizona Department of Water Resources pursuant to ARS 48-3605. Therefore, the Board of Directors of the Mohave County Flood Control District adopts these policies and standards applicable to floodplain management in support of the Mohave County Flood Control Ordinance.

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2 LEGAL ASPECTS

2.1 INTRODUCTION

This chapter is intended to provide an overview of pertinent federal and state regulations that address drainage and drainage related issues. COUNTY/DISTRICT regulations, policies and standards meet these minimum requirements. Local regulations are also included in this chapter with a description of the permitting process pertinent to the unincorporated areas of Mohave County. The differences between Federal, State, and local regulations affecting drainage and floodplain management are not set forth in this chapter.

Engineers responsible for drainage design must conform to all regulations that may affect their project including the most current effective federal, state and local acts, codes, laws, regulations, ordinances, standards and policies. Although these regulations are constantly changing, the following discussion provides some guidance as to the areas where federal, state and local governmental agencies exercise control over drainage related activities in unincorporated Mohave County.

2.2 WATER AND CULTURAL RESOURCE AGENCY CONTACT LIST

The list that follows identifies the various agencies one may need to contact to obtain information or file for permits for drainage projects. This list is provided as assistance and for information purposes only. This list may not include all agencies or environmental reviews or permits that are required for a given project. Telephone numbers and addresses are subject to change.

Table 2.1 Water and cultural resource agency contact list	
General Information	
Arizona Department of Environmental Quality (ADEQ) (602) 771-2300, Main Number (602) 771-4322, Ombudsman web site: ADEQ	Arizona Department of Water Resources (ADWR) (602) 771-8500 web site: ADWR
Environmental Protection Agency (EPA) Public Information Center: (415) 947-8000 (866) EPA-WEST web site: EPA Region 9	
Floodplain Information	
Federal Emergency Management Agency (510) 627-7100 (Oakland) (202) 566-1600 (Washington D.C.) (800) 621-FEMA web site: FEMA	Mohave County Flood Control District (928) 757-0925 Web site: Mohave County Flood Control District
Clean Water Act Section 404 Permits	
US Army Corps of Engineers (602) 640-2015 web site: USACE	
Surface Water Permits	
EPA (415) 972-3510	ADEQ (602) 771-2300
Groundwater & other Water Permits	
ADEQ (602) 771-4827	ADWR (602) 771-8500
Water Quality Certification 401 Permits	**State Species of Concern**
ADEQ (602) 771-2300	Arizona Game & Fish Department (602) 942-3000 Arizona Game & Fish
Native Plant Law	**Endangered Species Act**
Arizona Dept. of Agriculture Plant Services Division (602) 542-0994 web site: AZDA	U.S. Fish & Wildlife Service (602) 242-0210 web site: USFWS Endangered Species Arizona
Historic & Prehistoric Sites	

Table 2.1 Water and cultural resource agency contact list	
State Historic Preservation Office (602) 542-4009 web site: SHPO	
Native American Community Contacts, Mohave County	
Chemehuevi Tribal Council (760) 858-4219	Hualapai Tribe (928) 769-2216
Fort Mohave Indian Tribe (760) 629-4591	Kaibab Paiute Tribe (928) 643-7245
Havasupai Tribe (928) 448-2731	

2.3 FEDERAL

2.3.1 NATIONAL FLOOD INSURANCE PROGRAM

2.3.1.1 Introduction

The National Flood Insurance Act of 1968, as amended in 1973, provides for a federally subsidized National Flood Insurance Program (NFIP) conditioned on active management and regulation of development by states and local governments. The Federal Emergency Management Agency (FEMA) administers the NFIP as a part of its overall responsibilities in preventing and responding to natural events that damage private and public property and any life-threatening natural event including floods. The NFIP provides flood insurance at affordable rates through Federal subsidy of the insurance offered by licensed insurance agents. This insurance is designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods.

Participation in the NFIP is based on an agreement between local communities and the Federal Government. This agreement states if a community will adopt and enforce a floodplain management ordinance(s) to reduce future flood risks to new construction, the Federal Government will make flood insurance available within the community as a financial protection against flood losses.

Availability of the subsidized flood insurance is contingent upon the development of a floodplain management system by the local municipality. Prevention of flood related property damage is

achieved through the delineation of property subject to flood events and the establishment of specific rules concerning development within these identified Special Flood Hazard Areas (SFHA). FEMA publishes Flood Insurance Rate Maps (FIRM) for certain flood prone areas that delineate different SFHA's.

Mohave County has participated in the NFIP since the 1970's, received their first FIRM panels in March 1982, and has adopted floodplain regulations, through the MCFCD, and ordinances so that its citizens have access to the subsidized insurance. The role of the community is to enact and implement floodplain management ordinances required for participation in the NFIP.

2.3.1.2 Community Rating System

The NFIP Community Rating System (CRS) was implemented in 1990 as a program for recognizing and encouraging community floodplain management activities that exceed the minimum NFIP standards. The National Flood Insurance Reform Act of 1994 codified the Community Rating System in the NFIP. Under the CRS, flood insurance premium rates are adjusted to reflect the reduced flood risk resulting from community activities that meet the three goals of the CRS: (1) reduce flood losses; (2) facilitate accurate insurance rating; and (3) promote the awareness of flood insurance. Mohave County has been a member of the CRS program since 1995.

2.3.1.3 FEMA Special Flood Hazard Areas

Citizens within Mohave County are required to ascertain whether or not their respective property is located in a FEMA SFHA before commencing with any building or land disturbance activity. FEMA FIRM's are available for review at the MCFCD, Mohave County, and the Arizona Department of Water Resources. The FIRM's are used to determine if a property is located within a SFHA regulated by FEMA.

2.3.1.4 Flood Hazard Zones

The flood hazard maps are subdivided into zones that relate to flooding hazards. These are defined as follows:

1. **100-year Floodplain:** Floodplain resulting from the occurrence of the 100-year rainfall. FEMA sets its jurisdictional limits to the 100-year event, which is cited as the base flood elevation. The 100-year event is an event that has a one (1) percent chance of occurring in any given year. Jurisdictional limits are defined by horizontal flooding limits using the

base flood elevation. The 100-year floodplain is divided by FEMA into the following hazard zones for flood insurance rating purposes:

a. Zone A: No base flood elevations determined.

b. Zone AE: Base flood elevations determined.

c. Zone AH: Flood depths of 1 to 3 feet (usually areas of ponding), base flood elevations determined.

d. Zone AO: Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain), average depths determined (and velocities determined for alluvial fan floodplains).

e. Zone X (shaded): Areas of 500-year flood; areas of 100-year flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 100-year flood.

f. Zone X (unshaded): Areas determined to be outside 500-year floodplain.

2. **Floodway:** That portion of the 100-year floodplain that is required to convey the 100-year flood and that cannot be obstructed to an extent causing a rise in water surface elevation greater than 1 foot. The allowable rise and the limits of the floodway are predetermined by the governing municipality.

2.3.1.5 Application Process

Refer to Section 8.3.5 for the floodplain use permit process for a single building lot in Mohave County.

2.3.1.6 Approval Actions Taken by FEMA

If a property is determined to be located within a FEMA SFHA after reviewing the appropriate FIRM, there are several approval options available that, if desired and applicable, the landowner must process through FEMA. The landowner must select the permit option that best fits the need of the property and satisfies FEMA requirements. Each permit option requires completion of specific application forms and may require that a registered land surveyor or professional engineer complete the forms. Each permit/application form is identified below by name followed by a brief description of the approval response to be expected from FEMA.

1. **Conditional Letter of Map Amendment (CLOMA)** - A letter from FEMA stating that a proposed structure that is not to be elevated by fill would not be inundated by the 100-year flood if built to the proposed finished floor elevation.

2. **Letter of Map Amendment (LOMA)** - A letter from FEMA stating that an existing structure or parcel of land that has not been elevated by fill would not be inundated by the 100-year flood.

3. **Online Letter of Map Change (LOMC)** - An online method for requesting a LOMA. The web site is located at www.fema.gov/online-lomc. Applicants can use this new website to

electronically request a LOMA instead of applying for a LOMA using the MT-1 or MT-EZ paper forms. LOMA-eligible requests must be concerning properties on naturally high ground, which have not been elevated by fill.

4. **Conditional Letter of Map Revision Based on Fill (CLOMR-F)** - A letter from FEMA stating that a parcel of land or proposed structure that is to be elevated by fill would not be inundated by the 100-year flood if fill is placed on the parcel as proposed or the structure is built as proposed.

5. **Letter of Map Revision Based on Fill (LOMR-F)** - A letter from FEMA stating that an existing structure or parcel of land that has been elevated by fill would not be inundated by the 100-year flood.

Application forms for items 1, 3, 4, and 5 listed above can be obtained from FEMA by referencing the MT-1 FEMA FORM 81-87 SERIES. FEMA's contact address is provided at the end of this section.

1. **Conditional Letter of Map Revision (CLOMR)** - A letter from FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision.

2. **Letter of Map Revision (LOMR)** - A letter from FEMA officially revising the current FIRM to show changes to floodplains, floodways, or flood elevation. Physical changes include watershed development, flood control structures, etc.

3. **Physical Map Revision (PMR)** - A reprinted FIRM incorporating changes to floodplains, floodways, or flood elevations. Because of the time and cost involved to change, reprint, and redistribute a FIRM, a PMR is usually processed when a revision reflects increased flood hazards or large-scope changes.

Application forms for the three items listed above can be obtained from FEMA by referencing the MT-2 FEMA FORM SERIES, latest edition. FEMA's contact address is provided at the end of this section.

All Letters of Map Change listed above must now be in compliance with the Endangered Species Act (ESA). The purpose of the ESA is to conserve threatened and endangered species and the ecosystems upon which they depend. Guidance for compliance with the ESA for Letters of Map Change can be found at:

Documentation of Endangered Species Act Compliance for Conditional Letters of Map Change

Projects receiving a conditional letter must re-apply for a letter of amendment or revision upon completion of construction. The conditional letter allows financing and local approvals, and/or occupancy of the structure to take place. To initiate FEMA review for a specific activity or

location, a letter to FEMA requesting one of the "conditional" letters is sent to FEMA along with supporting data which includes a signed letter from Mohave County Flood Control District indicating its concurrence with the request. Supporting data may be in the form of improved methodology or improved survey data. Improved methodology may be a different technique (model) or adjustments to models used in the effective FIS. Improved survey data includes revised as well as new data. Floodway revisions involve any shift in the FEMA-designated floodway boundaries, regardless of whether the shift results in a change that is measurable at the scale of a DFIRM panel.

2.3.1.7 Construction in Special Flood Hazard Areas

The lowest floor of all residential structures constructed in the SFHA must be constructed to a minimum of the Base Flood Elevation (BFE)[1]. Building structures located within the SFHA (but not within the Floodway) may be protected from floods up to and including the 100-year flood by placement of fill to elevate the structure to or above the BFE. See FEMA guidelines for further specifications. Basements of residential structures located in the SFHA must be elevated above the BFE. In Arizona, the minimum elevation above the BFE is one (1) foot. The NFIP regulations allow nonresidential buildings (commercial structures, garages, warehouses, etc.) the option to flood-proof rather than elevate as a means of protection from the base flood. Non-residential structures can be flood-proofed to one (1) foot above the BFE instead of being elevated. Modular buildings, manufactured homes, and mobile homes must have the bottom of the structure (bottom of lowest beam and utilities) raised, as a minimum, to or above the BFE regardless of its use. Detached garages, barns, and storage sheds are some examples of buildings that may not have to be elevated or dry flood-proofed if openings are installed to allow floodwaters to enter or exit a structure and meet all other wet flood-proofing requirements. Wet flood-proofing requires the use of flood-resistant materials below the BFE and elevating items subject to flood damage above the BFE. Flood-proofed structures must comply with appropriate sections of the NFIP regulation 60.3.

All new construction and substantial improvements shall be constructed with electrical, HVAC, plumbing, and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding. Mechanical

[1] All new construction and substantial improvements of residential structures located within Zones A1-30, AE, and AH shall have the lowest floor, including the basement, elevated at or above the Base Flood Elevation.

and electrical equipment must be installed at or above the BFE as a minimum. Septic tanks are not allowed within floodways but are allowed within the SFHA as long as ADEQ requirements are met. All below ground tanks within the SFHA must be anchored against flotation. Above ground tanks are considered structures for floodplain management purposes.

The community must require new and replacement water supply systems within floodprone areas to be designed to minimize or eliminate infiltration of floodwaters into the systems. Wastewater disposal systems are allowed within floodplains and floodway fringe areas, but not within floodways. Septic tanks and leach fields shall be a minimum of 50 feet from a wash or channel, measured from the bank of the normal flow channel. The location and design of on-site waste disposal systems should be reviewed in order to prevent possible operational failure and potential contamination to the environment during flooding. The system should be protected from flood damage such that it can resume operation after the flood recedes. Manholes should be raised above the 100-year flood level or equipped with seals to prevent leakage. Pump stations should be located to allow access during a flood and designed to not release contamination. Automatic backflow valves should be installed to prevent sewage from backing up into buildings during a flood event.

Under no circumstances can filling or other construction activity be allowed within a floodway that may cause any rise in the water surface elevation above the designated floodway elevation.

An "Elevation Certificate" based on the latest FEMA Elevation Certificate form must be completed for each structure constructed in the SFHA prior to the electrical clearance and final inspection for that structure. One copy of the "Elevation Certificate" is to be submitted to the General Building Safety Inspector on site. See Federal Code for a complete list of requirements. The original document must be submitted to the MCFCD, which has floodplain administrator responsibilities for Mohave County.

2.3.1.8 Floodplain Requirements for Alluvial Fans

In addition to or in place of the above requirements, the following is required for alluvial fan floodplains. The lowest floor of all new construction and substantial improvements of residential structures in an AO zone SFHA shall be elevated above the highest adjacent grade at least as high as the depth number specified in feet on the FIRM (at least two feet if no depth number is specified) in accordance with the Code of Federal Regulations (CFR) Section

60.3c(7). Non-residential structures may be flood-proofed in lieu of elevation. Adequate drainage paths must be provided in accordance with Section 60.3 c(11) of the CFR.

2.3.1.9 Post Construction Review

After the proposed improvements have been constructed, the owner/developer is required, within 6-months, to submit as-built/documents of record to FEMA and the community Floodplain Administrator along with a request for a letter of map revision or amendment as appropriate.

2.3.1.10 Fees

Fees will be assessed by FEMA for its review of proposed and "as-built" projects as outlined in NFIP regulations 44 CFR Ch. 1, Part 72. In addition, Mohave County levies a fee to help defray its cost for administering floodplain management in conformance with the NFIP.

2.3.1.11 Additional Information

FEMA publishes numerous documents to inform those within or adjacent to a SFHA. Those documents can be located using FEMA's contact address at the end of this section. The most recent version of the following documents are very useful to consult if a property is determined to be within a SFHA:

1. "*National Flood Insurance Program (Regulations for Floodplain Management and Flood Hazard Identification)*", Federal Emergency Management Agency, 44 CFR, Part 1 most current revision.
2. "*Guidelines and Specifications for Flood Hazard Mapping Partners*, Federal Emergency Management Agency, April, 2003.
3. "*Technical Bulletin 2-93, Flood-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with National Flood Insurance Program*", Federal Emergency Management Agency, April, 1993.
4. "*Technical Bulletin 3-93, Non-Residential Flood Proofing Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*", Federal Emergency Management Agency, April, 1993.
5. "*Technical Bulletin 10-01, Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding in Accordance with the National Flood Insurance Program*", Federal Emergency Management Agency, May, 2001.

Other publications about the NFIP can be found online at:

FEMA Flood Insurance Program Publications

FEMA Flood Insurance Program Library.

2.3.1.12 Contact Information

Department of Homeland Security
Emergency Response and Recovery Directorate
Federal Emergency Management Agency
National Flood Insurance Program
Region IX
Federal Insurance and Mitigation Division
1111 Broadway, Suite 1200
Oakland, CA 94607-4052
(510) 627-7220
web site: FEMA Region 9

2.3.2 SECTION 404 PERMIT FOR WATERS OF THE UNITED STATES

The U.S. Army Corps of Engineers (USACE) has been involved in regulating certain activities in the nation's waterways since the 1890's (Section 10 of the River and Harbors Act of 1899). Until 1972, the primary thrust of the USACE regulatory program was the protection of navigation. As a result of the environmental movement in the 1960's, several new environmental laws and judicial decisions (Clean Water Act of 1968; Marine Protection, Research, and Sanctuaries Act of 1972), the program evolved to water resource protection which focused on the environmental (archeological, biological and the ecological) aspects of both arid and aquatic environments. The program includes one that considers the full public interest by balancing the favorable impacts against the detrimental impacts. Therefore, Section 404 of the Federal Water Pollution Control Act Amendments of 1972 insures that the physical, biological, and chemical quality of our nation's water is protected from irresponsible and unregulated discharges of dredged or fill material that could permanently alter or destroy these valuable resources.

Section 404 of the Clean Water Act regulates the discharge of dredge and fill activities in waters of the US. Any person, firm, or agency (including federal, state, and local government agencies) planning to work in or place dredged or fill material in Waters of the United States, must first obtain a permit from the USACE. The regulatory area is designated "Waters of the United States" or jurisdictional waters". Waters of the United States includes essentially all surface waters such as all navigable waters and their tributaries, all interstate waters and their tributaries, all wetlands adjacent to these waters, and all impoundments of these waters. In

Mohave County, ephemeral streams (washes) may be jurisdictional if they exhibit certain characteristics, such as the width of the wash, presence of hydraulic sorting, and the presence of riparian habitat. The regulations governing Waters of the United States (including wetlands) apply to both public and private property.

Determination of the presence and extent (if present) of jurisdictional waters should be undertaken during the early stages of project planning. A jurisdictional delineation establishes the USACE regulatory area. It is highly recommended that the inexperienced seek guidance from the USACE or other environmental professionals.

The ADOT Environmental Planning Group provides guidance on the preparation of jurisdictional delineations, Nationwide Permit preconstruction notification submittals, and Individual Permit applications. The guidance can be found at this link:

ADOT Clean Water Act Section 404/401 Guidance Manual

Although focused on ADOT highway projects, this guidance is a must resource for all practitioners involved with Section 404 permitting. The five basic steps of the Section 404/401 process, and some of the key terms and documents pertaining to each step, are summarized in Table 2.2. The following information is not inclusive. Refer the ADOT Environmental Planning Group web site for more details at this link: ADOT Environmental Planning

Table 2.2 Five basic steps of the Section 404/401 process

Step	Description
1	**Initial review of surface waters within the boundaries of the activity** • Identify types of drainages typically excluded from Corps' 404 jurisdiction
2	**Will the activity involve the discharge of dredged or fill material into surface waters?** **Have you confirmed the activity will not discharge into Waters of the US?**
3M (Maintenance Activities)	**Is a JD of Waters of the US within the activity area necessary?** • If the activity will impact less than 1/10 acre of potential Waters of the US and does not involve work in a wetland, a JD may not be needed. • If there are potential biological or cultural impacts, a JD may be necessary. Key components: aerial photograph and/or as-builts or activity design plans

Table 2.2 Five basic steps of the Section 404/401 process

Step	Description
3C (Construction Design/Planning)	**Are Waters of the US present within the boundaries of the activity?** • Is a JD necessary? • Complete a JD Key components: aerial photograph, topographic map, ground photographs, text and/or table describing activity area conditions, wetland field equipment (soil auger, shovel, etc.), *Corps Jurisdictional Delineation Form*
4	**Would the impact on Waters of the US be a temporary disturbance or a permanent loss? Would there be discharges to Waters of the US from the activity?** **What quantity of impacts (permanent and temporary) on Waters of the US will result from the activity and will the impacts be mitigated?** • Most commonly quantified in surface area/acreage, cubic yards, or linear feet **What mitigation measures would be feasible and prudent?** • Mitigation includes avoidance and minimization of impacts, and may include compensation when impacts can't be avoided.
5	**Can the activity be authorized under a NWP or is an IP necessary?** **NWP** **What type of permit is needed?** • Commonly used NWPs for regulated ADOT activities • Select from current NWPs **Is PCN necessary?** • No – Complete the Checklist for Section 404 NWP Limits and Conditions Compliance and PCN Decision Process • Yes – key components: topographic map, ENG Form 4345, plan sheets depicting impacts, General Conditions Compliance, Work Order (for maintenance activities), and mitigation plan if applicable. *Additional guidance can be found on the ADOT Environmental Services and Planning website.* **IP** • In-lieu fee mitigation • Key components: topographic map, ENG Form 4345, plan sheets depicting impacts, Section 404(b)(1) draft decision document, mitigation plan (if applicable), copy of Section 401 Individual Certification application
6	**Determine the certification under Section 401?** • Conditionally certified • Individual certification ○ Key components: vary depending on agency/tribe oversight

2.3.2.2 Permits

Physical work in a watercourse or wetland may require a USACE permit. Common activities that require Section 404 and Section 401 compliance, if conducted within waters of the US, include but are not limited to:

- Culvert installations and extensions.
- Bridge scour countermeasures and bridge abutment and pier construction.
- Channel bank protection.
- Wash realignment and channelization.
- Roadway and utility crossings.
- Geotechnical borings.
- The removal of sediment buildup from culverts if removal is through blading or bulldozing.

The program provides for the consideration of all concerns of the public, such as environmental, social, and economic aspects, in the USACE 404 permit decision-making process. As part of this responsibility, the USACE Section 404 permit program extends its jurisdiction to areas that were not regulated prior to the Clean Water Act.

Capital improvement projects undertaken on behalf of and paid for by Mohave County must coordinate their efforts with their client department[2] and/or the MCFCD prior to contacting the USACE. Joint ventures between the MCFCD or Mohave County and private entities must coordinate with the appropriate division prior to any inquiries or submittals to the USACE. Close coordination between client personnel (Mohave County staff and/or consultants, or the private entity project owner) and design personnel is critical to ensure that Section 404 and Section 401 calculations and documentation are accurate. Typically, design personnel provide important activity scope and impact information to the client for inclusion in the Section 404 and Section 401 documentation.

In addition, client personnel must be provided the opportunity to review all Section 404 or Section 401 conditions and mitigation measures applicable to an activity in order to identify

[2] Consultants should contact their client department to determine the best means of communication.

construction constraints as early as possible. Conditions and mitigation measures are ultimately included in the environmental clearance and/or project specifications, as appropriate.

Should a permit be required, there are several options depending on the type of land disturbance activity. There are essentially two types of Section 404 permits: Nationwide Permits (NWP), which are basically general permits that can be used for projects with impacts that will not exceed certain defined thresholds, and Individual Permits, which must be utilized for all projects with impacts that exceed such thresholds. Notably, the type of permit that an entity chooses to pursue, and the manner in which the permitting process is handled, can have a direct bearing on whether the project succeeds or fails.

2.3.2.3 Individual Permits

Individual permits are issued following a full public interest review of an individual application for a USACE permit. A public notice is distributed primarily to adjacent property owners and all known interested persons. After evaluating all comments and information received, final decision on the application is made.

The permit decision is generally based on the outcome of a public interest balancing process where the environmental benefits of the project are balanced against the detriments. A permit will be granted unless the project is not found to be the least environmental damaging and practicable alternative, exhibiting avoidance and minimization of impacts to the natural resources. Public interest, economics, engineering and other factors can also play a part in the final decision.

An individual permit also requires a 401 Water Quality Certification from the State of Arizona. Application forms for individual permits are available from all USACE regulatory offices. Refer to Section for information on the 401 Water Quality Certification program.

2.3.2.4 Nationwide Permits

A NWP is a form of general permit that authorizes a category of specific activities that exhibit minimal impact to the environment. These permits are valid only if the conditions applicable to the permits are met. If the conditions cannot be met, a regional or individual permit may be required. Please note that the NWP program was revised per Federal Register (FR) Vol. 82, No. 4, January 6, 2017. Refer to USACE Nationwide Permit Information. This information is subject to change so the user should check the Corps of Engineers web site periodically for changes since the date of this manual. Nationwide permits listed below may be modified to

accommodate regional conditions. Contact the USACE office using the information provided at the end of this section to obtain the most current information on the NWP program changes. The reader should contact the USACE for a complete listing, permit details, and regional limitations placed upon nationwide permits. Some activities under nationwide permits require preconstruction notification submittals to the USACE prior to the carrying out of those activities. All nationwide permits must comply with the requirements of the particular nationwide permit, and meet the general conditions required for each one, the 401 conditions (for water quality), and, if adopted, the Los Angeles District regional conditions. A list of the more pertinent, presently available, nationwide permits follows. Refer to the web link above for more information regarding Nationwide Permits.

NWP 3: Maintenance. The repair, rehabilitation, or replacement of any previously authorized, currently serviceable, structure or fill, or of any currently serviceable structure or fill authorized by 33 CFR 330.3. Discharges of dredged or fill material, including excavation, into all Waters of the United States to remove accumulated sediments and debris in the vicinity of, and within, existing structures and the placement of new or additional rip rap to protect the structure.

NWP 6: Survey Activities. Survey activities including core sampling, seismic exploratory operations, plugging of seismic shot holes and other exploratory-type bore holes, soil survey and sampling, and historic resources surveys.

NWP 7: Outfall Structures. Activities related to construction of outfall structures and associated intake structures where the effluent from the outfall is authorized, conditionally authorized, or specifically exempted, or are otherwise in compliance with regulations issued under the National Pollutant Discharge Elimination System program (NPDES) (Section 402 of the Clean Water Act).

NWP 12: Utility Line Activities. The construction, maintenance, or repair of utility lines, including outfall and intake structures and the associated excavation, backfill, or bedding for the utility lines, in all Waters of the United States, provided there is no change in preconstruction contours.

NWP 13: Bank Stabilization Projects. Bank stabilization activities necessary for erosion prevention, provided the activity meets all of the following criteria:

a. No material is placed in excess of the minimum needed for erosion protection;

b. The activity is no more than 500 feet in length along the bank, unless this criterion is waived in writing by the district engineer;

c. The activity will not exceed an average of one cubic yard per running foot placed along the bank below the plane of the ordinary high water mark or the high tide line, unless this criterion is waived in writing by the district engineer;

d. The activity does not involve discharges of dredged or fill material into special aquatic sites, unless this criterion is waived in writing by the district engineer;

e. No material is of the type, or is placed in any location, or in any manner, to impair surface water flow into or out of any water of the United States;

f. No material is placed in a manner that will be eroded by normal or expected high flows (properly anchored trees and treetops may be used in low energy areas); and,

g. The activity is not a stream channelization activity.

NWP 14: Linear Transportation Projects. Activities required for the construction, expansion, modification, or improvement of linear transportation crossings (e.g., highways, railways, trail, and airport runways and taxiways) in waters of the United State subject to acreage limitations.

NWP 18: Minor Discharges. Minor discharges of dredged or fill material into all Waters of the United States subject to volume or acreage limitations.

NWP 19: Minor Dredging. Dredging of no more than 25 cubic yards below the plane of the ordinary high water mark or the mean high water mark from navigable Waters of the United States.

NWP 20: Response Operations for Oil and Hazardous Substances. Activities required for the containment and cleanup of oil and hazardous substances which are subject to the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300) in accordance with certain state and federal requirements.

NWP 23: Approved Categorical Exclusions. Activities undertaken, assisted, authorized, regulated, funded, or financed, in whole or in part, by another Federal agency or department.

NWP 25: Structural Discharges. Discharges of material such as concrete, sand, rock, etc. into tightly sealed forms or cells where the material will be used as a structural member for standard pile supported structures, such as bridges, transmission line footings, and walkways.

NWP 29: Residential Developments. Discharges of dredged or fill material into non-tidal Waters of the United States, including non-tidal wetlands for the construction or expansion of a

single-family home and attendant features (such as a garage, driveway, storage shed, and/or septic field) for an individual permittee.

NWP 31: Maintenance of Existing Flood Control Facilities. Discharges of dredged or fill material for the maintenance of existing flood control facilities, including debris basins, stormwater storage basins, and channels. The maintenance is limited to that approved in a maintenance baseline determination made by the District Engineer.

NPW-33: Temporary Construction, Access, and Dewatering. Temporary structures, work, and discharges, including cofferdams, necessary for construction activities or access fills or dewatering of construction sites, provided that the associated primary activity is authorized by the Corps of Engineers or the U.S. Coast Guard. This NWP also authorizes temporary structures, work, and discharges, including cofferdams, necessary for construction activities not otherwise subject to the Corps or U.S. Coast Guard permit requirements. Appropriate measures must be taken to maintain near normal downstream flows and to minimize flooding. Fill must consist of materials, and be placed in a manner, that will not be eroded by expected high flows.

NWP 38: Cleanup of Hazardous and Toxic Waste. Specific activities required to effect the containment, stabilization, or removal of hazardous or toxic waste materials that are performed, ordered, or sponsored by a government agency.

NWP 39: Commercial and Institutional Developments. Discharges of dredged or fill material into non-tidal Waters of the United States for the construction or expansion of residential, commercial, and institutional building foundations and building pads and attendant features that are necessary for the use and maintenance of the structures.

NWP 40: Agricultural Activities. Discharges of dredged or fill material into non-tidal Waters of the United States for the purpose of improving agricultural production and the construction of building pads for farm buildings. Authorized activities include the installation, placement, or construction of drainage tiles, ditches, or levees; mechanized land clearing; land leveling; the relocation of existing serviceable drainage ditches constructed in Waters of the United States; and similar activities.

NWP 41: Reshaping Existing Drainage Ditches. Discharges of dredged or fill material into non-tidal Waters of the United States to modify the cross-sectional configuration of currently serviceable drainage ditches constructed in these waters. The reshaping of the ditch cannot increase drainage capacity beyond the original design capacity or expand the area drained by

the ditch as originally designed (i.e., the capacity of the ditch must be the same as originally designed and it cannot drain additional wetlands or other Waters of the United States).

NWP 42: Recreational Facilities. Discharges of dredged or fill material into non-tidal Waters of the United States, excluding non-tidal wetlands adjacent to tidal waters, for the construction or expansion of recreational facilities.

NWP 43: Stormwater Management Facilities. Discharges of dredged or fill material into non-tidal Waters of the United States for the construction and maintenance of stormwater management facilities, including activities for the excavation of stormwater ponds/facilities, detention basins, and retention basins; the installation and maintenance of water control structures, outfall structures and emergency spillways; and the maintenance dredging of existing stormwater management ponds/facilities and detention and retention basins.

NWP 44: Mining Activities. Discharges of dredged or fill material into: 1) Isolated waters, streams where the annual average flow is 1 cubic foot per second or less, and 2) non-tidal wetlands adjacent to headwater streams, for aggregate mining and other mining activities subject to certain limitations.

To apply for a nationwide permit, an application must be completed. USACE application forms for the permits are available from the local USACE regulatory offices (see contact information below).

NWP 45: Repair of Uplands Damaged by Discrete Events. This NWP authorizes discharges of dredged or fill material, including dredging or excavation, into all waters of the United States for activities associated with the restoration of upland areas damaged by storms, floods, or other discrete events. This NWP authorizes bank stabilization to protect the restored uplands. The restoration of the damaged areas, including any bank stabilization, must not exceed the contours, or ordinary high water mark, that existed before the damage occurred.

NWP-46: Discharge in Ditches. Discharges of dredged or fill material into non-tidal ditches that are: (1) Constructed in uplands, (2) receive water from an area determined to be a water of the United States prior to the construction of the ditch, (3) divert water to an area determined to be a water of the United States prior to the construction of the ditch, and (4) are determined to be waters of the United States. The discharge must not cause the loss of greater than one acre of waters of the United States.

NWP-51: Land-Based Renewable Energy Generation Facilities. Discharges of dredged

or fill material into non-tidal waters of the United States for the construction, expansion, or modification of land-based renewable energy production facilities, including attendant features. Such facilities include infrastructure to collect solar (concentrating solar power and photovoltaic), wind, biomass, or geothermal energy. Attendant features may include, but are not limited to roads, parking lots, and stormwater management facilities within the land-based renewable energy generation facility.

The discharge must not cause the loss of greater than 1/2-acre of non-tidal waters of the United States. The discharge must not cause the loss of more than 300 linear feet of stream bed, unless for intermittent and ephemeral stream beds the district engineer waives the 300 linear foot limit by making a written determination concluding that the discharge will result in no more than minimal adverse environmental effects. The loss of stream bed plus any other losses of jurisdictional wetlands and waters caused by the NWP activity cannot exceed 1/2-acre. This NWP does not authorize discharges into nontidal wetlands adjacent to tidal waters.

NWP-52: Water-Based Renewable Energy Generation Pilot Projects. Structures and work in navigable waters of the United States and discharges of dredged or fill material into waters of the United States for the construction, expansion, modification, or removal of water-based wind, water-based solar, wave energy, or hydrokinetic renewable energy generation pilot projects and their attendant features. Attendant features may include, but are not limited to, land-based collection and distribution facilities, control facilities, roads, parking lots, and stormwater management facilities.

For the purposes of this NWP, the term "pilot project" means an experimental project where the water-based renewable energy generation units will be monitored to collect information on their performance and environmental effects at the project site.

The discharge must not cause the loss of greater than 1/2-acre of waters of the United States, including the loss of more than 300 linear feet of stream bed, unless for intermittent and ephemeral stream beds the district engineer waives the 300 linear foot limit by making a written determination concluding that the discharge will result in no more than minimal adverse environmental effects. The loss of stream bed plus any other losses of jurisdictional wetlands and waters caused by the NWP activity cannot exceed 1/2-acre.

The placement of a transmission line on the bed of a navigable water of the United States from the renewable energy generation unit(s) to a land-based collection and distribution facility is

considered a structure under Section 10 of the Rivers and Harbors Act of 1899 (see 33 CFR 322.2(b)), and the placement of the transmission line on the bed of a navigable water of the United States is not a loss of waters of the United States for the purposes of applying the 1/2-acre or 300 linear foot limits.

For each single and complete project, no more than 10 generation units (e.g., wind turbines, wave energy devices, or hydrokinetic devices) are authorized. For floating solar panels in navigable waters of the United States, each single and complete project cannot exceed 1/2-acre in water surface area covered by the floating solar panels.

This NWP does not authorize activities in coral reefs. Structures in an anchorage area established by the U.S. Coast Guard must comply with the requirements in 33 CFR 322.5(l)(2). Structures may not be placed in established danger zones or restricted areas designated in 33 CFR part 334, Federal navigation channels, shipping safety fairways or traffic separation schemes established by the U.S. Coast Guard (see 33 CFR 322.5(l)(1)), or EPA or Corps designated open water dredged material disposal areas.

Upon completion of the pilot project, the generation units, transmission lines, and other structures or fills associated with the pilot project must be removed to the maximum extent practicable unless they are authorized by a separate Department of the Army authorization, such as another NWP, an individual permit, or a regional general permit. Completion of the pilot project will be identified as the date of expiration of the Federal Energy Regulatory Commission (FERC) license, or the expiration date of the NWP authorization if no FERC license is required.

NWP-53: Removal of Low-Head Dams. Structures and work in navigable waters of the United States and discharges of dredged or fill material into waters of the United States associated with the removal of low-head dams.

For the purposes of this NWP, the term "low-head dam" is defined as a dam built across a stream to pass flows from upstream over all, or nearly all, of the width of the dam crest on a continual and uncontrolled basis. (During a drought, there might not be water flowing over the dam crest.) In general, a low-head dam does not have a separate spillway or spillway gates but it may have an uncontrolled spillway. The dam crest is the top of the dam from left abutment to right abutment, and if present, an uncontrolled spillway. A low-head dam provides little storage function.

The removed low-head dam structure must be deposited and retained in an area that has no waters of the United States unless otherwise specifically approved by the district engineer under separate authorization.

Because the removal of the low-head dam will result in a net increase in ecological functions and services provided by the stream, as a general rule compensatory mitigation is not required for activities authorized by this NWP. However, the district engineer may determine for a particular low-head dam removal activity that compensatory mitigation is necessary to ensure the authorized activity results in no more than minimal adverse environmental effects.

2.3.2.5 Regional Permits

Regional permits are issued by the USACE District Engineer for a general category of activities when:

1. the activities are similar in nature and cause minimal environmental impact (both individually and cumulatively), and
2. the regional permit reduces duplication of regulatory control by State and Federal agencies.

Contact the USACE District Regulatory office in your area for information regarding regional permits.

2.3.2.6 Web Site Links

Additional web site links include:

404 Permit Application and Instructions: ADOT Clean Water Act Section 404/401 Guidance Manual

CWA Section 401 Certification: EPA Clean Water Act, Section 401 Certification

2.3.2.7 Contact Information

U.S. Army Corps of Engineers
Los Angeles District, Regulatory Branch
3636 North Central Avenue, Suite 900
Phoenix, AZ 85012-1936 (602) 640-5385
web site: US Army Corps of Engineers

2.3.3 STORMWATER QUALITY

Section 405 of the Water Quality Act of 1987 added section 402(p) of the Clean Water Act (CWA) which required the U.S. Environmental Protection Agency (EPA) to develop a phased approach to regulate stormwater discharges under the National Pollutant Discharge Elimination

System (NPDES) program. Section 402(p) of the CWA states that stormwater discharges associated with construction activities to waters of the United States must be authorized by an NPDES permit

2.3.3.1 Phase I

EPA published final regulations on the first phase of the stormwater program on November 16, 1990. These rules established permit application requirements for "stormwater discharges associated with industrial activity" (including construction activities) and for discharges from municipal separate storm sewer systems located in municipalities with a population of 100,000 or more. EPA defined the term "stormwater discharge associated with industrial activity" in a comprehensive manner to cover a wide variety of facilities. Construction activities (including clearing, grading and excavation activities) that disturb at least five acres of land (including smaller areas that are part of a larger common plan of development or sale) are defined as an "industrial activity" per 40 CFR 122.26(b)(14)(x).

EPA issued the first round of the Phase I construction general permit in September 1992. The Phase I permit was commonly referred to as the Baseline Construction General Permit and was administered by EPA as the NPDES Permitting Authority in Arizona.

2.3.3.2 Phase II

Polluted stormwater runoff is often transported to municipal separate storm sewer systems (MS4s) and ultimately discharged into local rivers and streams without treatment. EPA's Stormwater Phase II Rule establishes an MS4 stormwater management program that is intended to improve the Nation's waterways by reducing the quantity of pollutants that stormwater picks up and carries into storm sewer systems during storm events. Common pollutants include oil and grease from roadways, pesticides from lawns, sediment from construction sites, and carelessly discarded trash, such as cigarette butts, paper wrappers, and plastic bottles. When deposited into nearby waterways through MS4 discharges, these pollutants can impair the waterways, thereby discouraging recreational use of the resource, contaminating drinking water supplies, and interfering with the habitat for fish, other aquatic organisms, and wildlife.

In 1990, EPA promulgated rules establishing Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater program. The Phase I program for MS4s requires operators of "medium" and "large" MS4s, that is, those that generally serve populations of

100,000 or greater, to implement a stormwater management program as a means to control polluted discharges from these MS4s. The Stormwater Phase II Rule extends coverage of the NPDES stormwater program to certain "small" MS4s but takes a slightly different approach to how the stormwater management program is developed and implemented.

A small MS4 is any MS4 not already covered by the Phase I program as a medium or large MS4. The Phase II Rule automatically covers on a nationwide basis all small MS4s located in urbanized areas as defined by the Bureau of the Census (unless waived by the NPDES permitting authority), and on a case-by-case basis those small MS4s located outside of urbanized that the NPDES permitting authority designates.

Operators of regulated small MS4s are required to design their programs to: Reduce the discharge of pollutants to the "maximum extent practicable"; Protect water quality; and satisfy the appropriate water quality requirements of the Clean Water Act.

Implementation of the MEP standard will typically require the development and implementation of BMPs and the achievement of measurable goals to satisfy each of the six minimum control measures.

The Phase II Rule defines a small MS4 stormwater management program as a program comprising the following six elements that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving waterbodies.

1. Public Education and Outreach. Distributing educational materials and performing outreach to inform citizens about the impacts polluted stormwater runoff discharges can have on water quality.
2. Public Participation/Involvement. Providing opportunities for citizens to participate in program development and implementation, including effectively publicizing public hearings and/or encouraging citizen representatives on a stormwater management panel.
3. Illicit Discharge Detection and Elimination. Developing and implementing a plan to detect and eliminate illicit discharges to the storm sewer system (includes developing a system map and informing the community about hazards associated with illegal discharges and improper disposal of waste).
4. Construction Site Runoff Control. Developing, implementing, and enforcing an erosion and sediment control program for construction activities that disturb 1 or more acres of land (controls could include silt fences and temporary stormwater detention ponds).
5. Post-Construction Runoff Control. Developing, implementing, and enforcing a program to address discharges of post-construction stormwater runoff from new development and redevelopment areas. Applicable controls could include preventative actions such as protecting sensitive areas (e.g., wetlands) or the use of structural BMPs such as grassed swales or porous pavement.

6. Pollution Prevention/Good Housekeeping. Developing and implementing a program with the goal of preventing or reducing pollutant runoff from municipal operations. The program must include municipal staff training on pollution prevention measures and techniques (e.g., regular street sweeping, reduction in the use of pesticides or street salt, or frequent catch-basin cleaning). \\

ADEQ has NPDES Permitting Authority in Arizona.

2.4 STATE OF ARIZONA

2.4.1 FLOODPLAIN MANAGEMENT

The State of Arizona has set minimum floodplain management requirements for both areas that are not studied and areas identified by FEMA as a SFHA. The Arizona Department of Water Resources (ADWR) is responsible for floodplain management statewide and for administering the NFIP at the state level. ADWR has developed a series of State Standards to aid in floodplain management for the FEMA and non-FEMA studied areas of the state. Each State Standard has a companion document called the State Standard Attachment (SSA). The SSA is the technical document that provides the methodology and examples of how to apply the standard.

The following is a list of State Standards (SS) currently available from ADWR. It is the responsibility of each person to ensure that they have the most current version or new State Standard available. ADWR does update existing State Standards periodically and is developing new State Standards where a need exists. These standards are available online at: ADWR Surface Water State Standards.

SS 1-97 - Requirement for Flood Study Technical Documentation
SS 2-96 - Requirement for Floodplain and Floodway Delineation in Riverine Environments
SS 3-94 - State Standard for Supercritical Flow (Floodway Modeling)
SS 4-95 - State Standard for Identification of and Development within Sheet Flow Areas
SS 5-96 - State Standard for Watercourse System Sediment Balance
SS 6-05 - State Standard for Development of Individual Residential Lots within Floodprone Areas
SS 7-98 - State Standard for Watercourse Bank Stabilization
SS 8-99 - State Standard for Retention/Detention
SS 9-02 - State Standard for Floodplain Hydraulic Modeling
SS10-07 - State Standard for Hydrologic Modeling Guidelines

In addition, ADWR provides training documents in the appropriate use of the State Standards. The *Floodplain Issues in Transportation Design* training document is very appropriate for use in

conjunction with this manual. It can be found on the same web page as the State Standards listed above.

2.4.1.1 Contact Information

State of Arizona
Department of Water Resources
Flood Mitigation Section
3550 N. Central Avenue
Phoenix, AZ 85012
(602) 771-8500
web site: ADWR

2.4.2 STORMWATER QUALITY

2.4.2.1 Delegation

On December 5, 2002, ADEQ received authorization to implement the AZPDES program in Arizona. In Arizona except for Indian Community Lands, the NPDES program is administered as the AZPDES program. This authority was challenged, and on June 25, 2007, the U.S. Supreme Court upheld the authority of ADEQ to operate the NPDES Permit Program on the state level.

The AZPDES Construction General Permit (AZG2003-001) was issued for a five-year term by ADEQ in February 2003 and expired February 28, 2008. If a new permit was not re-issued by this date, those who had coverage under the 2003 permit would have an administrative extension to continue operation under that permit. However, operators of new construction sites would not be able to obtain coverage for stormwater discharges under a general permit until a new permit is issued. The new Construction General Permit (CGP) was issued on June 3, 2013. Information can be obtained at: ADEQ Permits Overview.

An AZPDES permit is required for any point source discharge of pollutants to a Water of the United States. Because stormwater runoff can transport pollutants to either municipal storm sewer systems or to Waters of the United States, permits are required for those discharges. In addition to stormwater permits, there are also NPDES/AZPDES permits required for the discharge of processed wastewater and the land application of sludge. The application process for both general permits is similar.

2.4.2.2 Permits

ADEQ issues individual and general AZPDES permits. An individual permit is tailored for a specific facility based on an individual application. ADEQ develops the permit based on this information and incorporates technology-based requirements, water quality standards and other conditions appropriate to the facility. The permit is then issued for a specified period of time not to exceed five years.

A general permit is developed and issued to cover multiple facilities within a specific category, industry or area. General permits offer a cost-effective and efficient option for agencies to cover a large number of facilities with elements in common under one permit. In addition, the permittee is ensured consistency in permit conditions for similar facilities. A general permit could be written to include all facilities within a common geographic area that:

1. Involve the same or substantially similar types of operations.
2. Discharge the same types of wastes.
3. Require the same effluent limitations or operating conditions.
4. Require the same or similar monitoring requirements.

Most stormwater discharges are permitted under various general permits. However, an individual permit is required when the general permit requirements do not accurately represent the activity at a facility/municipality and a permit is customized to the site/for the permittee.

An individual permit may be necessary if the Limitations of Coverage section of a general permit does not allow the facility's discharge to be covered within the general permit. It is the responsibility of every applicant to determine if any of the Limitations of Coverage apply to the facility seeking a general permit.

2.4.2.3 Construction Activities

Stormwater discharges generated during construction activities can cause an array of physical, chemical and biological water quality impacts. Specifically, the biological, chemical and physical integrity of the waters may become severely compromised. Water quality impairment results, in part, because a number of pollutants are preferentially absorbed onto mineral or organic particles found in fine sediment. The interconnected process of erosion (detachment of the soil particles), sediment transport and delivery is the primary pathway for introducing key pollutants such as nutrients (particularly phosphorus), metals, and organic compounds into aquatic systems.

Stormwater runoff from construction sites can include pollutants other than sediment such as phosphorous and nitrogen, pesticides, petroleum derivatives, construction chemicals and solid wastes that may become mobilized when land surfaces are disturbed. Generally, properly implemented and enforced construction site ordinances effectively reduce these pollutants.

The new Construction General Permit became effective June 3, 2013 and will expire at midnight on June 2, 2018. It replaces the expired CGP No. AZG2003-001. Information can be obtained at: AZPDES Construction Activity General Permit for Stormwater.

Permit Waivers

There is a waiver option for small construction activities provided in the stormwater Construction General Permit (CGP). To be eligible for this waiver option the operator must meet the following criteria:

- The project must disturb less than 5 acres;
- The project cannot be located within 0.25 miles of an impaired or outstanding Arizona water; and
- The project must have an "R" (or erosivity) value of less than 5. Additionally, ADOT projects are not eligible for the waiver option.

How to Obtain Coverage

Starting June 1, 2017 ADEQ established a paperless method for CGP. To obtain, modify or terminate an NOI for CGP you will need to use the myDEQ web site. Paper Applications are no longer accepted since May 31, 2017.

A SWPPP is required to be completed prior to submitting an NOI. The required annual fees are based on the number of acres being disturbed during the construction project:

Less than 1 acre disturbed | $250 *

1 – 50 acres disturbed | $350 *

Greater than 50 acres disturbed | $500 *

* $1,000 SWPPP first time review fee is required if any outfall(s) are within 1/4 mile of impaired, not-attaining, Outstanding Arizona Waters. There is a $500 SWPPP review fee for when a second review is needed

Guidance for preparation of an SWPPP can be found at: ADEQ SWPPP.

Notice of Termination

After the construction project is complete and the project's disturbed area is stabilized to at least 70 percent of natural background density or responsibility for the project has been assumed by another operator, the permittee must submit a Notice of Termination (NOT) to end participation in the AZPDES stormwater program.

2.4.2.4 Industrial Activities

Activities that take place at industrial facilities, such as material handling and storage, are often exposed to stormwater. The runoff from these activities discharges industrial pollutants into nearby storm sewer systems and water bodies. This may adversely impact water quality. The initial focus of the NPDES permitting program was to regulate discharges of industrial process wastewater and municipal wastewater treatment plants. Most industrial facilities have permit coverage under a general permit because it is the most efficient permit option. General permits contain requirements for numerous types of industrial activities, allowing a facility operator to quickly obtain permit coverage. The Multi-Sector General Permit (MSGP) is the general permit currently unavailable to facility operators.

Multi-Sector General Permit

On September 29, 2008, EPA announced in the Federal Register (Vol. 73, No. 189) publication of the 2008 MSGP. This permit replaced the 2000 MSGP, which expired on October 30, 2005. The permit was modified effective May 27, 2009 and reissued in 2015 after expiration on September 29, 2013. The 2015 MSGP is actually 44 separate general permits covering either

areas within an individual state, tribal land, or U.S. territory, or federal facilities. These 44 general permits contain provisions that require industrial facilities in 29 different industrial sectors to, among other things, implement control measures and develop site-specific stormwater pollution prevention plans (SWPPPs) to comply with NPDES requirements. In addition, the MSGP includes a thirtieth sector, available for EPA to permit additional industrial activities that the Agency determines require permit coverage for industrial stormwater discharges not included in the other 29 industrial sectors. Currently, an estimated 2,365 facilities are authorized to discharge (or are "covered") by the MSGP.

The 2015 MSGP revises the information required in NOIs to provide EPA with adequate information to determine eligibility, to determine whether additional water quality-based control measures are necessary to comply with the permit's effluent limits, and to enable EPA to inform the operator of its specific monitoring requirements. Operators now need to include location information for each stormwater outfall they discharge from, identify if the facility discharges to saltwater and the hardness of the receiving waterbody (if subject to benchmark monitoring for metals), indicate whether the facility discharges to a federal CERCLA site identified in Appendix P, as well as provide general information from their SWPPP if the SWPPP is not posted online. The EPA NPDES Electronic Reporting Tool (NeT) will use outfall latitude and longitude information for each outfall to automatically determine the receiving waters that the site discharges to and the receiving waters' impairment status. Information regarding the 2015 MSGP can be found using this link:

Permit information and forms may be obtained from the agencies provided in Section 2.4.2.6.

2.4.2.5 Other Permits

For information on other permits available through ADEQ, check out ADEQ's website at: ADEQ Water Quality Permits Information. The following is ADEQ's summary of the De Minimis Discharge Permit and the Concentrated Animal Feeding Operations program.

De Minimis Discharge Permit

ADEQ issued the 2016 DMGP (No. AZG2016-001) which succeeded the 2010 DMGP (No. AZG2010-001) on the effective date of the new permit, June 1, 2016. The permit allows for the discharge of pollutants associated with potable and reclaimed water systems, subterranean dewatering, well development, aquifer testing, hydrostatic testing of specific pipelines, residential cooling water, charitable car washes, building and street washing, and de-chlorinated

swimming pool water. The permit also allows ADEQ to review and approve other case-by-case short-term and/or low volume discharges that are considered De Minimis. By definition (DMGP, Part VII), De Minimis discharges contain relatively low levels of pollutants, are of limited flow and/or frequency, and shall not last for more than 30 days unless approved in advance by ADEQ.

The DMGP authorizes discharges where they have potential to enter a water of the U.S. Note: the AZPDES authorizing statute uses the term "navigable waters," which is defined as equivalent to the waters of the U.S. However, because the term 'navigable waters' can be confusing to the general public (i.e., the definition of 'navigable waters' also includes ephemeral washes, intermittent streams, playas, and wetlands, that may not be able to be traveled by conventional vessels), this permit references discharges to waters of the U.S.

Authorization under this permit will require the owner or operator of the discharge facility to implement various BMPs and conduct discharge monitoring based on the type of discharge activity and the type of receiving water. For further information on this permitting program, visit ADEQ's website at the following link:

De Minimis General Permit Information.

Concentrated Animal Feed Operations

ADEQ revised the AZPDES program rules (18 A.A.C. 9, Article 9) to conform with the updated federal regulations for Concentrated Animal Feeding Operations (CAFOs). The rule revisions became effective on Feb. 2, 2004. Under the new rule all CAFOs are required to apply for a permit, submit an annual report and develop and follow a plan for handling manure and wastewater. In addition, the rule moves efforts to protect the environment forward by placing controls on land application of manure and wastewater, covering all major animal agriculture sectors, and increasing public access to information through CAFO annual reports. The rule also eliminates current permitting exemptions and expands coverage over types of animals in three important ways: the rule eliminates the exemption that excuses CAFOs from applying for permits if they only discharge during large storms; second, the rule eliminates the exemption for operations that raise chickens with dry manure handling systems; and third, the rule extends coverage to immature swine and immature dairy cows. The 2004 Arizona Pollutant Discharge Elimination System (AZPDES) Concentrated Animal Feeding Operation (CAFO) General Permit expired on April 17, 2009. The current CAFO general permit will be

administratively continued and remain in effect for those granted coverage prior to the expiration date. Any permittee who was granted permit coverage before the expiration date will automatically remain covered by the administratively continued CAFO general permit until the earlier of:

- Reissuance or replacement of the permit; or
- The permittee submits a Notice of Termination (NOT); or
- ADEQ issues an individual permit for the discharge; or
- ADEQ issues a formal permit decision not to reissue the general permit.

No new Notices of Intent (NOI) for CAFO General Permit coverage will be accepted by ADEQ until the new CAFO General Permit is issued. For further information on this permitting program, visit ADEQ's website at: AZPDES Concentrated Animal Feeding Operation General Permit.

Application or approval of any permit from ADEQ does not grant approval for any other permits required by other federal, state, or local entities including the Mohave County Flood Control District (i.e. the granting of a De Minimis Discharge permit does not give anyone the right to discharge into a Mohave County structure without Mohave County's prior approval/permit. A Mohave County Public Works right-of-way permit is still required).

2.4.2.6 Contact Information

Arizona Department of Environmental Quality
1110 W. Washington Street
Phoenix, AZ 85007
(602) 771-4449
web site: ADEQ

2.4.3 SECTION 401 WATER QUALITY CERTIFICATION

2.4.3.1 General

Section 404 of the Clean Water Act establishes a permitting program to regulate excavation and the discharge of dredged and fill material into waters of the United States, including wetlands. Examples of activities that might be regulated under this program include:

- stream crossings,

- dam construction and flow regulation,
- water diversion for canals, irrigation systems, and stock tanks,
- streambed modification and stabilization, and
- building subdivisions, master planned communities, highways and airports.

The EPA and the USACE jointly administer the program. In addition, the U.S. Fish & Wildlife, the National Marine Fisheries Service and State resources agencies (e.g., Department of Environmental Quality, Game and Fish Department, Water Resources) have important advisory roles.

While the Corps issues the permit, Section 401(a) of the CWA requires the state to provide certification, including permit conditions that the draft permit is in compliance with effluent limits, the State's water quality standards and any other appropriate requirements of state law.

The basic premise of the program is that no discharge of dredged or fill material can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if the nation's waters would be significantly degraded. In applying for a permit, the applicant must show that they have:

1. taken steps to avoid wetland impacts where practicable,
2. minimized potential impacts to wetlands, and
3. provided compensation for any remaining, unavoidable impacts through activities to restore or create wetlands.

The program is jointly administered between the US Army Corps of Engineers and the EPA. The Corps' duties include:

1. administering the day-to-day program, including individual permit decisions and jurisdictional determinations,
2. developing policy and guidance, and
3. enforcing Section 404 provisions.

The EPA is responsible for:

1. Developing and interpreting environmental criteria used in evaluating permit applications,
2. Determining the scope of geographic jurisdiction.
3. Identifying activities that are exempt.
4. Review/comments on individual permit applications.

5. Has the authority to veto the Corps' permit decision.
6. Elevating specific cases.
7. Enforcing Section 404 provisions.

The Corps has a number of authorization mechanisms including permits, letters of permission, and regional or state specific permissions.

An individual permit is required for projects that have potentially significant impacts. Individual permits require an application form describing the proposed activity be submitted to the Corps. Once the application is complete, the Corps issues a public notice containing the information needed to evaluate the likely impact of the activity. Notice is sent to all interested parties including adjacent property owners, government agencies and others who have requested notice. A hearing may be requested for cause.

However, for discharges that have only minimal adverse effects, the Corps has developed general permits that can be issued on a nationwide, regional or state basis for particular types of activities (e.g., minor road crossings, utility line backfill, flood control projects). General permits are developed and require the same public notice requirements and opportunity for public hearing. Once issued, the general permit may be modified or revoked if the activities are found to have any adverse impacts. General permits are issued for a specified time period, usually five years.

Currently there are 40 NWPs. These NWPs have been CWA 401 certified by ADEQ and many contain State specific conditions in addition to the Corps requirements. Refer to Section 2.3.2 for more information.

ADEQ has authority under section 401 of the CWA to grant, deny or waive water quality certification for both individual and nationwide permits. The Corps cannot issue a permit, individual or general, where ADEQ hasn't approved or waived certification or where ADEQ has denied certification. The application form for ADEQ Water Quality Certification can be found at this link: ADEQ Clean Water Act Section 401 Certification Application.

2.4.3.2 Contact Information

Arizona Department of Environmental Quality
Water Quality, Section 401
1110 W. Washington Street
Phoenix, AZ 85007

(602) 771-4502
web site: ADEQ

2.4.4 DAMS

All dams in the state, except those owned or operated by an agency or instrumentality of the federal government, are under the jurisdiction of the Arizona Department of Water Resources (ADWR). A dam is any artificial barrier that impounds or diverts water above the natural ground surface. A detention basin or retention basin that impounds stormwater above the natural ground surface may be considered as being a dam under the authority of ADWR. The following do not fall under the authority of ADWR.

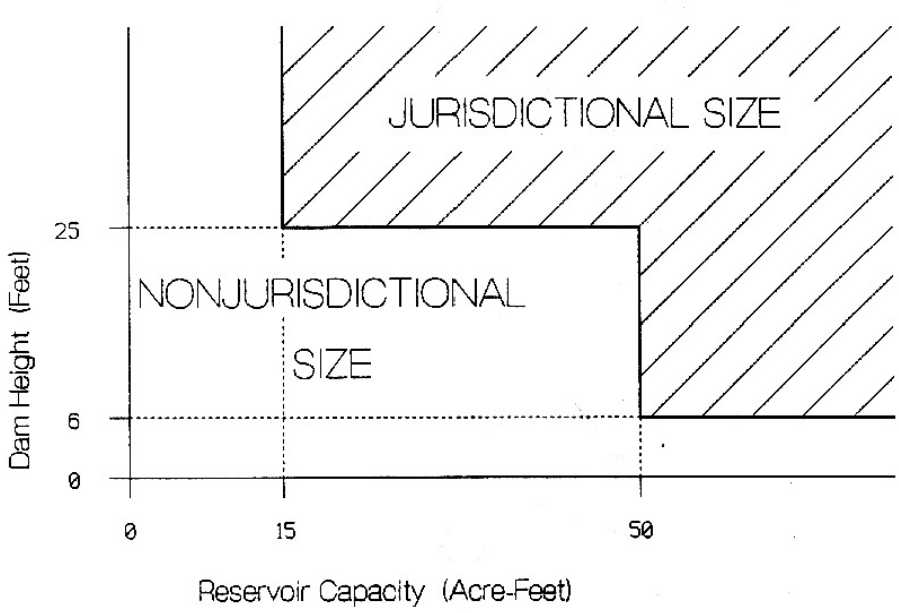
Any artificial barrier:

1. Less than 6 feet in height, regardless of storage capacity.
2. Fifteen acre-feet or less of storage capacity, regardless of height.
3. Between 6 and 25 feet in height, with a storage capacity less than 50 acre-feet.

Any impoundment or diversion structure that exceeds the criteria above will require a permit from ADWR. Individuals having questions should contact the Dam Safety Section of ADWR.

The distinction between a jurisdictional and non-jurisdictional dam is shown on Figure 2.1. A jurisdictional dam is either 25 or more feet in height or has capacity to store more than 50 acre-feet. Height is the vertical distance from the lowest point on the downstream toe (at natural ground) to the emergency spillway crest. Capacity is the maximum storage that can be impounded when there is no discharge of water.

Figure 2.1 ADWR Jurisdictional Dam Chart



2.4.4.2 Permits

A permit is required for all new dams or the repair, alteration or removal of an existing dam. Application forms are available from ADWR. An administrative review fee is required by ADWR.

2.4.4.3 Contact Information

State of Arizona
Department of Water Resources
Dam Safety Section
3550 N. Central Avenue
Phoenix, AZ 85004
(602) 771-8500
web site: ADWR

2.4.5 DRYWELL REGISTRATION

A person who owns an existing drywell that is or has been used for stormwater disposal shall register the drywell with the ADEQ. A drywell is a bored, drilled, or driven shaft or hole whose depth is greater than its width and is designed and constructed specifically for the disposal of stormwater. Drywells must be registered by completing a form from ADEQ and submitting a registration fee for each drywell.

2.4.5.1 Permits

Drywells are regulated by Arizona Revised Statute (A.R.S.) § 49-241 and § 49-331 through 336, and Aquifer Protection Permit statutes and rules. Drywells that drain areas where hazardous substances are used, stored, loaded, or treated are subject to the General Permit or full Aquifer Protection Permit (see Section 2.4.6). Specific rules regarding dry wells are found in R-18-9-102-A and R18-9-A301. Program guidance documents are available from ADEQ, and should be followed for dry well construction, maintenance, siting, investigation, decommissioning, and closure. Registration is generally not required for dry wells used in conjunction with golf course maintenance, and they are exempted from regulation under the dry well program. However, vadose zone injection wells (including dry wells) that receive stormwater mixed with reclaimed wastewater or groundwater from manmade bodies of water associated with golf courses, parks, and residential areas must be registered. In this situation, a general permit is issued by statute in lieu of an individual permit, provided that six criteria, including registration, are met (A.R.S. § 49 - 245.02).

Dry well registration and permit information and forms may be obtained from ADEQ at the location provided below.

2.4.5.2 Contact Information

Arizona Department of Environmental Quality
1110 W. Washington Street
Phoenix, AZ 85007
(602) 771-2300
web site: ADEQ

2.4.6 AQUIFER PROTECTION PERMIT

An individual will need to obtain an APP if they own or operate a dry well that discharges a pollutant either directly to an aquifer or to the land surface or the vadose zone in such a manner that there is a reasonable probability that a pollutant will reach an aquifer. ADEQ may provide an "APP Determination of Applicability Form" for dry wells in areas where hazardous substances are used, stored, loaded, or treated. Dry wells that are used solely for the disposal of stormwater runoff do not require an Aquifer Protection Permit; however, dry well registration is still a requirement.

2.4.6.1 Permits

The following APP Permits are available:

Individual Permits

Individual permits are issued for a term not to exceed the operational lifetime of the facility. Approval of individual permits can take, on average, from 6 months to 2 + years. Processing time is approximately 6 months; however, incomplete applications often result in delays.

Area-Wide Permits

Area-wide permits may be issued in lieu of an individual permit to cover facilities under common ownership in a contiguous geographic area. Discharge reduction in the pollutant management area and the demonstration that aquifer water quality standards will not be violated or further degraded can be evaluated collectively for existing facilities. This type of permit is most applicable to large mining and industrial sites.

General Permits

There are currently 15 different types of general permits. These are issued by rule or statute, and the facility is automatically permitted, provided that certain conditions are adhered to. A separate permit document is not required to operate under these conditions and no fee is required.

Information regarding APP's is available from ADEQ at the location provided below.

2.4.6.2 Contact Information

Arizona Department of Environmental Quality
1110 W. Washington Street
Phoenix, AZ 85007
602) 771-2300
web site: ADEQ

2.5 LOCAL

2.5.1 GENERAL

In addition to the Federal and state regulations discussed in Sections 2.3 and 2.4, engineers responsible for drainage design must conform to Mohave County and other local regulations that may affect their project including local acts, codes, laws, regulations, ordinances, standards

and policies. Sections 2.5.2 through 2.5.5 list the COUNTY/DISTRICT regulations that apply, and contain hyperlinks to the sites on the Internet where each document can be obtained. The links in this document may become outdated. If a link is outdated, **the most current version of each document should be located and used.** The COUNTY/DISTRICT stormwater management program, which is in the development process, is discussed in Chapter 6. The following are the Mohave County agencies that may be contacted to obtain assistance with application of these regulations.

Mohave County Environmental Quality Division
Physical: 3250 E. Kino Ave, Kingman, AZ 86409
Mailing: PO Box 7000, Kingman, AZ 86402-7000
Telephone: (928) 757-0903
web site: Mohave County Environmental Quality

Mohave County Flood Control District
Physical: 3250 E. Kino Ave, Kingman, AZ 86409
Mailing: PO Box 7000, Kingman, AZ 86402-7000
(928) 757-0925
web site: Mohave County Flood Control District

Mohave County Public Works
Physical: 3715 Sunshine Dr., Kingman, AZ 86409
Mailing: PO Box 7000, Kingman, AZ 86402-7000
(928) 757-0910
web site: Mohave County Public Works

Mohave County Development Services
Physical: 3250 E. Kino Ave, Kingman, AZ 86409
Mailing: PO Box 7000, Kingman, AZ 86402-7000
(928) 757-0903
web site: Mohave County Development Services Department

2.5.2 MOHAVE COUNTY FLOOD CONTROL ORDINANCE

The most current DISTRICT flood control ordinance can be found at this link:

Mohave County Flood Control Ordinance

2.5.3 MOHAVE COUNTY LAND DIVISION REGULATIONS

Links to the Mohave County land division regulations and associated documents can be found at: Mohave County Land Division Documents

2.5.4 MOHAVE COUNTY ZONING ORDINANCE

Links to the Mohave County zoning ordinance and associated documents and applications can be found at:

Mohave County Zoning Documents and Applications

2.5.5 MOHAVE COUNTY ENGINEERING DESIGN STANDARDS

Mohave County Engineering Design Standards, Specifications and Details can be found at this link:

Mohave County Engineering Design Standards

2.5.6 MOHAVE COUNTY FLOOD CONTROL DISTRICT PLANS AND REPORTS

Mohave County Flood Control District plans and reports, including the Flood Risk Management Plan, flood response plans, the FEMA Flood Map Viewer, and other available digital data can be found at this link:

MCFCD Plans, Reports, and Digital Data

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3 DRAINAGE PLANNING

3.1 INTRODUCTION

Stormwater runoff facilities are an integral part of public infrastructure systems and should be planned as such. The drainage engineer must be included in the formulation of both site-specific and regional drainage plans and all development planning should be coordinated from the beginning with the drainage engineer. Drainage master plans need to be carefully prepared for all local and regional flood control and flood management projects, and this same general concept should be followed for land development of all sizes. A drainage master plan, in addition to providing a unified drainage plan, should be coordinated with planning for open space and recreation facilities, planning for transportation, and other development considerations. Drainage planning should not be done after all the other decisions have been made for the layout of a new subdivision, commercial or industrial area. It is this latter approach which creates drainage problems which are costly to correct. The benefits of good drainage planning include:

- Lower construction costs for drainage facilities
- Long-term maintenance costs are reduced
- Reduced flood damages for both residents and infrastructure.
- A better community

Natural drainage ways and street drainage patterns should be coordinated to achieve the policies and design criteria presented in the DDM. Supplemental or complimentary benefits and uses from drainage facilities should be considered, including passive and active recreational uses. Any effort made towards increasing local and community-wide benefits is appropriate and is encouraged.

Consideration of multiple uses and multiple benefits in drainage planning and engineering can minimize societal costs and increase benefits to the community. A way to maximize consideration of these multiple uses is by preparing practical drainage master plans so that the overall effort is coordinated with predetermined objectives.

Planning of drainage facilities should be based upon incorporating natural waterways, artificial channels, storm drains, and other drainage works into the development of a desirable and aesthetic community, rather than attempting to superimpose drainage works on a development after it is laid out. Channels and stormwater storage facilities that are designed as a focal point of the community minimize misuse (e.g. dumping) and encourage proper maintenance.

Urban drainage should be considered on the basis of two design phases. The first is the preliminary phase where master drainage plans are developed. Work under the preliminary phase includes development of hydrology coupled with preliminary design, location, and verification of adequacy and viability of proposed drainage facilities. These facilities are planned in conjunction with land uses, street layouts and lot density and configuration. The second is the final design phase, which encompasses detailed engineering using the preliminary phase as the basis for the final design. The preliminary phase is a more global view, as discussed herein, and results in the conceptualization of an overall drainage solution. The final design phase is an extension of the first and it is here that the engineering details for the localized issues get worked out, including detailed hydraulic analyses and improvement plans.

The drainage system is the backbone of good urban planning in that a well-planned system can reduce or eliminate the need for costly underground storm drains, and it can protect the urban area from extensive property damage and loss of life from flooding. This system is generally designed for the more severe and less frequent stormwater runoff, such as the 100-year return period. It generally consists of open channels; however, large storm drains can be used. It must be remembered that the drainage system exists in a community whether or not it is planned and designed, and whether or not development is situated wisely with respect to it. Water will obey the law of gravity and will flow downhill to seek its lowest level whether development and people are in its way or not.

3.2 BENEFITS OF PLANNING

Good drainage planning is a complex process. Basic planning considerations that should be taken up early include planning for the drainage system, developing a grading concept, and planning for the environment. When planning a new subdivision for residential purposes, various drainage concepts should be evaluated before decisions are made as to street location and block layout. It is perhaps at this point of the development process where the greatest impact can be made as to the cost of drainage facilities. When flood hazards are involved, the

planner should take these hazards into consideration in land planning to avoid unnecessary complications.

Benefits that can be derived from a good drainage plan include:

1. Reduced street maintenance costs.
2. Reduced street construction costs.
3. Improved movement of traffic.
4. Lower cost open space.
5. Lower cost park areas and more recreational opportunities.
6. Development of otherwise undevelopable land.
7. Opportunities for lower building construction cost.
8. Avoidance of flood damage claims and resultant litigation.
9. Avoidance of fines and fees levied for non-compliance with federal and state regulations, including NPDES Stormwater regulations.

3.3 TYPES OF DRAINAGE PLANS

Drainage plans can be divided into two types: regional and local. Regional plans are those prepared by a governmental agency for continuity on a regional basis. Local drainage plans for private land development or public projects that must conform to the regional plan, or stand on their own merits if a regional plan has not been developed. Both of these types typically have two component phases consisting of a preliminary drainage plan and a final drainage plan. Preliminary drainage plans deal with the broad assessment of existing drainage conditions and development of conceptual alternatives to accommodate drainage. Final drainage plans provide detailed analysis of preferred preliminary solutions, and/or documentation of engineered solutions and details to support the final design of a project. This section describes the two types of plans and their respective component phases.

3.3.1 REGIONAL DRAINAGE PLANS

On a watershed basis, regional master drainage plans are prepared to identify areas of existing flooding problems and present potential alternative solutions. Regional conceptual drainage plans provide detailed hydrologic and hydraulic computer models that are used to identify drainage and flooding problem areas. Solutions typically include an array of stormwater conveyance and storage alternatives. These plans are generally an excellent source for hydrology and hydraulic information. The regional master drainage plan is typically a more

detailed study providing more robust flood prevention designs and recommended drainage and floodplain management solutions. A watercourse master plan is similar to a regional master drainage plan, except that it has more of a focus on the management of a particular watercourse and associated flood hazard zones.

Developers should check with the MCFCD to determine if new floodplains, regulations, or projects have been identified or developed as part of a regional drainage plan for the area of concern. Construction projects that are defined as a part of a regional drainage plan typically have a Final Drainage Design Report for documenting the basis for the design. Regional drainage planning now also typically includes stormwater quality plans or plan components.

3.3.2 LOCAL DRAINAGE PLANS

Drainage plans are also prepared for land development and public projects. Here, the focus is to identify existing flooding conditions and to develop approaches to prevent the proposed development from exacerbating existing flooding conditions while protecting the proposed development. Within the unincorporated areas of Mohave County, drainage plans are required as described below. Drainage plans for developments or drainage improvements should also consider water quality components to their site development to prevent stormwater runoff water quality concerns.

3.3.2.1 Large Developments

Large developments, which require a Development Master Plan as described below, are typically considered to be greater than or equal to 640 acres in size. However, any significant development divided into phases may be considered a large development. Each development phase shall be designed to function as a standalone development and not dependent on a drainage feature constructed with a later phase. Stormwater quality concerns should be met on a phased basis. It would not be appropriate to address stormwater quality at the final phase of development. By phasing or implementing stormwater BMPs upfront water quality concerns will be met. The drainage plans required for large developments are:

Drainage Master Plan

A Drainage Master Plan is a conceptual plan that establishes the drainage approach and system to be used for the entire development. It also establishes how and when the various drainage system components will be constructed. This in turn has a significant impact on the size and

orientation of lot and street layouts. Preparation of a Drainage Master Plan and the overall development plan is an iterative process between the developer, the developer's land planner and drainage engineer, and the regulating agency. The Drainage Master Plan will often significantly impact the definition of development units and phases.

The first step in preparing a Drainage Master Plan is studying the hydrology of the watersheds that contribute stormwater runoff to the master plan study area, and the hydrology of the onsite area.

The second step is definition of existing 100-year floodplains and base flood elevations for watercourses within the development where FEMA regulatory base flood elevations have not been established. This is to be done in accordance with Chapter 8. The definition of erosion hazards and an assessment of the drainage system sediment balance are to be done where necessary in conformance with Chapter 17.

The third step is definition and evaluation of drainage system alternatives, and recommendation of a drainage scheme. The key to preparing Drainage Master Plans for land developments is developing an approach to intercept offsite flow and identifying a workable means of conveying the flow through the project. The method for discharging to the downstream drainage network (whether natural or man-made) is established in a manner that returns the flow to its historical flow path without changing the pre-development flow characteristics. Drainage Master Plans for land developments also identify locations for stormwater storage facilities to accommodate on-site runoff, and identify a stormwater quality plan for the development. Offsite flows are not allowed to drain through the onsite conveyance or storage facilities. The above principles remain valid for conceptual drainage plans for all parcels regardless of size.

Drainage Master Plans are to be prepared in conformance with the report outline presented in Chapter 19 for the technical (Hydrology and Hydraulics) portions of the report document.

Design Concept Report

A Design Concept Report is a conceptual drainage plan for an individual unit or phase of the master planned development. It implements the drainage system recommended in the Drainage Master Plan to the specific unit in question. Adjustments are made to the Drainage Master Plan hydrology and hydraulics, if necessary, and alternatives for drainage facilities specific to the unit/phase are defined that meet the guidelines defined in the Drainage Master

Plan. The alternatives are analyzed and a recommended drainage system, including parameters for use during final design, is presented. These parameters include:

1. Design discharges and design storage volumes.
2. Definition of stormwater conveyance methods, including:
   a. channel locations, geometry, lining types and recommended slope ranges;
   b. storm drain locations, including preliminary sizes and material types;
   c. natural floodplains to be left undisturbed; and
   d. guidelines for use of street sections for stormwater conveyance.
3. Definition of methods to be used for erosion and scour protection.
4. Location, size, and recommended geometry of proposed stormwater storage basins.
5. Recommended stormwater quality design parameters.
6. Proof that the Drainage Master Plan recommendations for handling stormwater along the master-planned area boundaries are being met. This must include any needed addendum to the Drainage Master Plan for revised recommendations for future unit/phases.
7. Stormwater quality concerns must be addressed on a unit or phase basis as construction of the development occurs. In Mohave County, this is normally accomplished by providing the required stormwater storage facilities set forth in Chapter 15.

Design Concept Reports are to be prepared using the report outline presented in Chapter 19.

Final Drainage Design Report

A Final Drainage Design Report constitutes a final drainage plan component. It is the final documentation of the detailed drainage design shown on contract construction drawings for the development project. Refer to Section 3.3.3 for a description of a Final Drainage Design Report, which is common to both the government agency and private land development types of drainage plans.

3.3.2.2 Local Developments

Local developments are typically considered to be less than 640 acres in size. The drainage plans required for local developments are:

Design Concept Report

A Design Concept Report is a conceptual drainage plan for a private or agency project. For simple projects with minimal drainage considerations, the detail and length of the report is intended to be minimal. For larger projects with significant drainage considerations, the

submittal requirements and level of detail may be a combination of the Drainage Master Plan and Design Concept Report for Large Developments as described above.

Final Drainage Design Report

A Final Drainage Design Report for Local Developments is the same as for Large Developments. The level of detail required is commensurate with the complexity of the drainage design.

3.3.3 FINAL DRAINAGE DESIGN REPORT

A Final Drainage Design Report constitutes a final drainage plan component and includes the final hydraulic analyses for detailed drainage designs presented on the construction plans. Final drainage construction drawings provide engineered solutions and details to implement the final drainage design of a project. The Final Drainage Design Report documents the supporting calculations and design assumptions the construction drawings are based on. The hydrology and hydraulics of the selected approach from the Drainage Master Plan and Design Concept Report is further refined and documented to apply to the specifics of the chosen drainage solution. The project may be a regional capital improvement project to alleviate existing flooding conditions or improvements resulting from land development. The design report documentation is to be prepared in accordance with Chapter 19.

3.4 INFORMATION FOR DRAINAGE PLANNING

There is a significant amount of existing information available to the hydrologist or drainage engineer that should be considered when undertaking a drainage plan. The following table highlights some of these.

Table 3.1 Types of available drainage information

Item	Source	Description
Flood Insurance Studies	FEMA, ADWR, MCFCD	Watershed peak discharges, floodwater levels, flood risk.
Regional conceptual and master drainage Plans	MCFCD & Municipalities	Watershed hydrographs and peak discharges, conceptual storage and conveyance solutions.

Table 3.1 Types of available drainage information

Item	Source	Description
Watercourse master plans WCMP)	MCFCD & Municipalities	Management of a particular watercourse and its associated flood and erosion hazards.
Studies & plans from existing flood control projects	MCFCD, USACE, USBR, NRCS	
Transportation Plans & Studies	ADOT, Mohave County, Municipalities	Corridor studies address existing and proposed drainage conditions. Plans depicting drainage improvements.
Land Use Zoning Maps	Municipality, Mohave County	Provides insight to future runoff characteristics. Zoning may limit type of drainage solution.
Soil Maps	NRCS & USFS	Identifies runoff characteristics and engineering limitations.
Aerial Photography	public & private	Identifies watershed and existing land-use characteristics.
Topographic Mapping	public & private	Used to determine watershed boundaries, slopes, and watercourse hydraulic characteristics.
ALTA Surveys	Mohave County Recorder's Office	Land ownership, boundary & utility easements (if available).
Drainage plans from adjacent developments	Municipalities/Mohave County/Land Developer/Home Owners Assoc.	Depicts existing or proposed conditions for adjacent properties that may affect the site under study.
Utility Plans	Utility companies	Depicts the location of underground and above ground utilities that may affect the location of drainage facilities and the routing of stormwater.

3.5 MASTER DRAINAGE PLANNING PROCESS

3.5.1 PLAN DEVELOPMENT

The master drainage planning process requires the collection and assimilation of information from most of the sources identified above. Consideration must be given to regulations, permitting, environmental impacts, ordinances, open space, zoning, regional hydrology, flood hazards, safety, and cost. As part of the initial layout design, the designer must consider and accommodate the future need of vehicular access for maintenance purposes. The preliminary design should minimize long-term maintenance requirements.

3.5.2 WATERS OF THE UNITED STATES

The 2015 revised regulatory definition of "waters of the United States" has been stayed by the U.S. Court of Appeals for the Sixth Circuit. In response to this stay, EPA, Department of Army, and Army Corps of Engineers resumed nationwide use of the agencies' prior regulations defining the term "waters of the United States." On February 28, 2017, the President of the United States issued an Executive Order directing EPA and Department of the Army to review and rescind or revise the 2015 Rule. EPA, Department of Army, and the Army Corps of Engineers are in the process of reviewing the 2015 rule and considering a revised definition of "waters of the United States" consistent with the Executive Order.

Since the definition of "waters of the united states" is under review, it is recommended the user research and track the progress the review. The latest approved definition by the federal government controls. Refer to the following link for more information:

Current Implementation of Waters of the United States

Waters of the United States, for the purposes of the Section 404 program (refer to Section 2.3), are drainage ways meeting certain criteria that define them by federal law as being under the jurisdiction of the U.S. Army Corps of Engineers. Waters of the United States are often referred to as jurisdictional waters. Construction activities that impact jurisdictional waters require a permit issued through the USACE. For most areas under study, jurisdictional waters exist. Therefore, drainage plans must consider the nuances of jurisdictional waters (See Chapter 2, and Section 5.3). The professional undertaking a drainage plan must have knowledge of 404 requirements to apply to the planning objective or have the jurisdictional waters delineated prior to delving too far into the drainage planning process. It is likely that the jurisdictional

waters will have a significant impact on the overall drainage plan, remediation, and on-going maintenance activities.

3.5.3 REGULATIONS, POLICIES, AND STANDARDS

All drainage plans and construction drawings shall meet COUNTY/DISTRICT regulations. The policies and standards are intended to be an implementation guide for preparing drainage plans and drainage designs that are in conformance with the regulations. The time required for the review process is normally less, and review comments minimized, if the drainage plans are prepared in conformance with the policies and standards. Sometimes additional documentation may be required for submittal and review by the COUNTY/DISTRICT to prove conformance with the regulations. These policies and standards also establish the minimum guidelines for capital improvement projects, both public and private.

3.5.4 WATERCOURSE OPEN SPACE

The concept of combined flood control, environmental considerations, and recreational uses can be applied to drainage corridors (watercourses). Natural or semi-structural drainage/greenbelt corridors can be developed with landscaping, stormwater quality improvements, and multi-use trails incorporated into the drainage design to provide recreation opportunities. This concept can be applied to new drainage channels that are utilized for recreation uses, and existing open channels that currently do not provide recreation opportunities. The multi-use trails should be located above the channel banks to avoid impacting Waters of the United States (Section 404), to minimize effects of erosion, to minimize interaction with nuisance flows, and to minimize maintenance requirements. The COUNTY/DISTRICT stresses the establishment of natural or semi-structural drainage/greenbelt corridors. Utilizing natural/greenbelt corridors to accommodate stormwater is the DISTRICT preferred approach for several reasons, including:

1. Watercourses make excellent natural open spaces of high scenic quality due to their associated vegetation, wildlife and landforms.
2. Natural features such as topography, and natural processes such as erosion, have defined the land along natural watercourses as a drainage and stormwater runoff corridor.
3. Desert adapted vegetation is dependent on natural watercourses for water supply and seed disbursement and germination.
4. Many desert wildlife species are adapted to seek watercourse areas for food and shelter.
5. Impacts to watercourses have environmental consequences such as habitat loss, reduced flood conveyance, loss of a valuable landscape amenity, and reduced ground water recharge and impaired stormwater quality.

6. Impacts to watercourses have public safety consequences adjacent, upstream and downstream of the impact area.
7. Impacts to watercourses often have decreased property value implications as environmental impacts diminish abutting land value.
8. Designating open space along watercourses is often more cost effective for the developer due to the high risk of flooding in these corridors.

3.5.5 STORMWATER STORAGE

In the planning process, it is a COUNTY/DISTRICT goal that stormwater storage basins be combined where feasible with open space, parks, and trails to create focal points for the community instead of isolated tracts. These combined uses should be planned and designed to augment Mohave County parklands. The benefits of this approach are an enhanced sense of community and increased open space with landscape amenities. The COUNTY/DISTRICT encourages combined use of drainage and recreation facilities on both public and private lands. It is recommended that these drainage facilities be non-geometrically designed. Also, design of stormwater storage facilities should be coordinated with the COUNTY/DISTRICT to assure compliance with stormwater quality requirements.

3.5.5.1 Public Stormwater Storage Basins

Given the demand for organized sports fields such as soccer and ball fields, basins may serve multi-use purposes. It is recommended to avoid siting recreational facilities at the very bottom of stormwater storage basins. It is further recommended these basins be designed with tiers or gentle slopes to allow for the collection and conveyance of nuisance water around fields to allow for dry field areas under normal conditions.

The desired location for stormwater storage basins is adjacent to parks to increase the open space. Integrating non-geometric basins into park design is encouraged for both active and passive recreation purposes, subject to meeting Mohave County aesthetic and safety standards.

3.5.5.1 Private Stormwater Storage Basins

The COUNTY/DISTRICT recommends non-geometric designs for stormwater basins in private development projects. In these developments, the use of open space in combination with stormwater storage basins is encouraged in order to provide a more natural and aesthetically pleasing method of addressing runoff, stormwater storage, and stormwater quality. This practice can provide measurable benefits to the residents of the development when a sufficient recreation area is provided. These areas should be made focal points of the community instead

of isolated tracts, which helps create a sense of community. Other design considerations include access, multi-use trails and habitat connectivity.

3.5.6 ZONING

Zoning often dictates the nature of watercourse development and open space requirements for land development projects. Rezoning land to address flooding or erosion hazards, either through the use of an overlay or replacement zoning district (such as the City of Phoenix Flood Hazard And Erosion Management District), or through conditions of zoning approval that limit the use of such land, is intended to provide a natural or limited structural design approach to watercourse management. Generally, this results in ideally situated open space. Even small washes lend themselves to regulation in the same manner as larger watercourses if the identification of the flood hazard and erosion impact is initiated early enough. Where regional master drainage plans have been completed, approved implementation plans may dictate land-use/drainage design options. In other areas, individual rezoning applications or zoning overlay districts may include stipulations or design guidelines that address watercourse treatment and the degree to which the watercourse may be altered or disturbed.

3.5.7 DESIGN HYDROLOGY AND HYDRAULICS

The drainage engineer should determine if there is existing hydrologic and hydraulic information available for the upstream watershed and project site that is suitable for use in design of the project improvements. This includes researching the information sources listed in Table 3.1. In particular, review of available regional master drainage plans that encompass the project area provides the design team with valuable information pertaining to the magnitude of stormwater discharges and volumes affecting the project. The design engineer must either concur with the regional master drainage plan by statement, or submit additional documentation addressing and substantiating differences. The FEMA Flood Insurance Rate Maps (FIRM) should also be reviewed to establish if regulated floodplains cross the project. Where existing studies are not available, the drainage engineer should contact the MCFCD to determine if any regional studies are in progress. In-progress information is often available, and if not, staff experience is extensive.

In the event there is insufficient hydrology or hydraulic information available, then the drainage engineer will have to generate new information using the procedures defined herein. At the preliminary drainage plan level, the drainage engineer should concentrate on quantifying off-

site flows that may impact the project and determine the means for conveying that flow through the project site. A reasonable estimate of the design peak discharge is necessary to approximate the channel or drainage structure capacity and size. Again, the improvements presented in a drainage plan shall not adversely impact adjacent property owners.

3.5.8 OTHER HAZARD CONSIDERATIONS

Drainage plans need to focus on more than flood levels derived from open channel hydraulic analyses. Aggradation of channel beds and overbanks via sedimentation and degradation of channels from erosive processes are threats to the performance of drainage systems that should be considered. In addition, the lateral migration of watercourses may threaten public safety, health and welfare, unless proper erosion hazard zones are identified, prohibiting development in these areas unless remediation of the hazard is accomplished. ADWR (1996b) should be considered and addressed in the planning process. The determination of flood levels on alluvial piedmonts is particularly challenging because of active geomorphic processes. The plan should consider the Flood Control District of Maricopa County's *Piedmont Flood Hazard Assessment for Flood Plain Management for Maricopa County* (Hjalmarson, 2003) or most current version, and the National Research Council (1996), when drainage planning on alluvial piedmonts. Finally, ponding areas up gradient of elevated roads, railroads, and irrigation canals must be considered during the development of the drainage plan to assess finished floor elevations, outfall hydraulics, and compensation for volume displacement.

3.5.9 SAFETY

A basic tenet of any capital improvement project is the promotion of public safety. Public safety must be a consideration throughout the development of a drainage plan. Excessive stormwater depth, velocity, erosion, sedimentation, and/or poor stormwater quality pose a threat to safety and public health.

3.5.10 COST

During the development of a drainage plan, initial capital costs, long term maintenance costs, and stormwater treatment cost should be considered. Ideally, the least societal costs necessary to provide the required level of protection to the public is the desired goal. Attainment of this goal is fostered by adherence to the COUNTY/DISTRICT's policies and standards.

3.6 APPROACH TO DRAINAGE PLANNING

3.6.1 OPEN CHANNEL CONVEYANCE

The alignment of a planned drainage system is often set by following the natural watercourse flow line or low flow channel. In these cases, the alignment need only be defined on available topographic mapping or aerial photographs. In many areas about to be urbanized, the runoff has been so minimal, or is sheet flow, that well-defined natural channels do not exist. However, low flow channels nearly always exist which provide an excellent basis for location of improved channels. Use of these channels to convey stormwater is likely to reduce development costs and minimize drainage problems. In some cases, the wise utilization of natural watercourses in the development of a drainage system will eliminate the need for an underground storm drain system. Where WCMP's have been completed, setbacks for erosion hazard zones may have been identified. If setbacks have not been defined as part of the WCMP, then erosion hazard areas should be approximated following the methodologies identified in ADWR (1996b) and Chapter 17. Detailed lateral migration and long-term erosion analyses would be performed as part of final design in those circumstances.

The preliminary drainage plan is where major decisions are made as to design velocities, location of structures, means of accommodating conflicting utilities, and the potential alternate uses in the case of an open channel. The choices of channel types available to the design team are numerous, depending only upon good hydraulic practice, environmental design (including stormwater quality control and treatment), sociological impact, and basic project requirements. However, from a practical standpoint, the basic choice to be made initially is whether or not the channel is to be lined for higher velocities or if a natural channel and floodplain already exists that can be effectively utilized with considerations to erosion setbacks and the 100-year flooding limits.

A more natural approach is preferred. The more desirable setting for the channel and overbank floodplain combination is an undisturbed one. The benefits of such a channel are that:

1. Velocities are usually lower, resulting in longer concentration times and lower downstream peak flows.
2. Natural channel and overbank floodplain storage tends to decrease peak flows.
3. Maintenance needs are usually less than artificial channels.

4. The natural channel and overbank floodplain provides desirable open space and recreational area adding significant social benefits. The more closely the character of an artificial channel can be made to emulate that of a natural channel with overbank floodplain, generally the higher the quality of the artificial channel.

For a drainage plan, the level of analysis necessary to establish artificial channel widths varies. If the artificial channel is for a watercourse with a 100-year peak discharge of 500 cfs or greater, a detailed floodplain analysis may be required (see Chapter 8). The level of analysis is also dependent upon the existing or proposed land-use and whether encroachments, such as road culvert embankments, affect the flow regime. Otherwise, simple "normal depth flow" calculations may suffice. Where channel slopes exceed 0.5% to 1.0%, supercritical flow analysis may be warranted.

Another key component of planning for a channel at the preliminary drainage plan level is the transitioning of flow into and out of a proposed channel. Arizona state law requires that proposed facilities do not exacerbate flooding conditions for adjoining properties. Thus, any drainage improvement must not increase water levels or result in erosive velocities greater than pre-development conditions. Interceptor channels, especially in sheet flow areas, may be required to funnel offsite flow into an onsite channel. Similarly, spreading basins or engineered channel expansions may be necessary to transition from an artificial channel to the existing downstream floodplain.

3.6.2 STORAGE

The preliminary drainage plan is where decisions need to be made on the use of stormwater storage facilities and their location. The siting of storage facilities where topography is favorable to the construction of embankments and/or excavation of basins will provide significant benefits including the reduction of peak flows and the settling out of sediment and debris. The latter can help to improve the quality of water downstream.

For conceptual sizing of stormwater storage facilities, a storage per unit area relationship along with a safety factor can be utilized to derive an approximate stormwater volume for storage and stormwater quality treatment. The storage per unit area is primarily dependent upon the land-use of the proposed project within the proposed project area only and upon the design rainfall depth for the area in question. **Offsite flows are not allowed to mix with onsite storage facilities**.

For land development projects involving large acreage, establishing the contributing drainage area prior to final design can be problematic for the inexperienced. Overlaying the proposed site plan with existing topography allows for the development of a conceptual or preliminary grading plan. Establishing proposed grade breaks for mass grading consistent with existing drainage divides is the preferred method. Taking this approach wherever possible during the drainage planning effort provides an additional benefit in that it minimizes earthwork and storm sewer expenditures pursuant to final design. Undertaking such an approach supports the basis for preliminary stormwater storage design and will tend to minimize the necessity for dramatic design revisions resulting from unforeseen drainage requirements during final design.

3.6.3 ENVIRONMENTAL PROTECTION

There are numerous federal, state, and local regulations that must be adhered to during plan development and implementation. At the federal and state level, Section 404 of the Clean Water Act (Waters of the U.S.) and Section 401 (water quality) permitting are typically required during the project approval process and may be required for maintenance or other activities proposed in conjunction with the drainage facilities. For the MCFCD, the plan must comply with the Federal NPDES (40 CFR 122), the state AZPDES stormwater quality programs, and also any action or restriction they consider reasonably necessary to meet their obligations, if any, to comply with local, state or federal water quality laws. Taking the requirements of these regulations into account during the development of the drainage plan will streamline the design and implementation process. For example, recognition of the trigger points in 404 permitting will provide guidance in developing mitigation plans (see Chapter 2, Federal and State Regulations). The COUNTY/DISTRICT strongly endorses minimizing disturbances to natural watercourses in order to lessen the impacts on ecology.

3.7 FINAL DESIGN CONSIDERATIONS

The drainage plan serves as the framework for final design. A thorough drainage plan streamlines the final design process. That is not to say that changes will not occur during final design. However, wholesale changes should not occur due to drainage issues.

It is during final design that street drainage is analyzed and catch basins/storm drains are designed. The specifics and supporting analysis for open channels including culverts and bridges, and the influences of sedimentation and scour, are developed during final design. It is here that stormwater storage facility details, including pump stations if appropriate, are

enumerated to permit review by the COUNTY/DISTRICT and subsequent construction. During final design, the design engineer applies the DDM to minimize capital cost and long term maintenance of the drainage improvements while accommodating safety and health concerns.

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4 PUBLIC SAFETY

Designs for drainage must address the issue of public safety. This chapter is provided to emphasize the importance of safety considerations for design of drainage improvements, whether it be for open channels, stormwater storage basins, or gutter flow in a roadway. The following sections contain safety-related standards and requirements for design of drainage facilities.

4.1 SPECIAL HAZARDS

The designer should determine if the site is subject to special hazards including, but not limited to, erosion hazards, alluvial fans, or distributary flow areas, and any other special hazards identified by the MOHAVE COUNTY ENGINEER. Alluvial fans and distributary flow areas can be identified using guidance provided by Appendix G of FEMA (2003) and Hjalmarson (2003). Engineering analysis and design are required for development within special hazard areas.

4.2 FLOOD WARNING

The DISTRICT owns and maintains a county-wide flood warning system consisting of rain gages, stream flow gages and weather stations. This system is for the benefit of all Mohave County residents and is a part of the Arizona statewide flood warning system. The flood warning system has multiple benefits and is used by both the public and other government agencies for various purposes that benefit the public. The DISTRICT has an ongoing program for improving and expanding the system. To enhance this effort, new developments may be required to assist by allowing installation of gages within the development on a dedicated parcel or within a dedicated easement that grants the DISTRICT access to install and maintain the gage site. New master planned developments that are one (1) square mile or greater in area are required to fund the purchase and installation (by DISTRICT personnel) of at least one rain gage, and at least one stream flow gage for washes with a 100-year peak discharge of 5,000 cfs or greater. This includes furnishing a parcel or easement for access, installation and ongoing maintenance. Additional weather station devices may also be required as a part of the rain or flow gage installation.

If low water roadway crossings of washes with a 100-year peak discharge of 500 cfs or greater are approved for a development, then signage, barricades or other flood warning devices may

be required for public safety and welfare. The citizens of the new development will benefit from all these flood warning facilities and they are considered part of the public infrastructure for public safety.

4.3 PROTECTION RELATED TO DEPTH AND VELOCITY

4.3.1 GENERAL

The designer shall carefully consider public safety where standing water depths, and water flow depths and velocities pose a hazard. This should be done for design of all drainage facilities, including stormwater storage facilities, channels, storm drains and street systems. Figure 4.1 and Figure 4.2 (USBR 1988) can be used in this regard to aid in defining the level of hazard, based on criteria such as the type and frequency of use of the facility by the public, access concerns for emergency response vehicles, the statistical frequency of hazardous storm events, and risks associated with public access combined with the frequency of the hazard. Engineering judgment shall be applied in assessing the risks and determining which areas require special attention. With the areas of concern defined, the designer should include mitigation measures appropriate to the risk to discourage or prevent public access to these facilities during a flood event. The measures could include, but are not limited to:

1. Mitigating design criteria such as maximum flow rates and depths.
2. Signage to alert the public to the hazard and/or physical barriers, such as fencing or railings.
3. Flood warning alarm or announcement systems.
4. Higher minimum technical standards for design of drainage facilities.

Figure 4.1 Depth-velocity flood danger relationship for adults

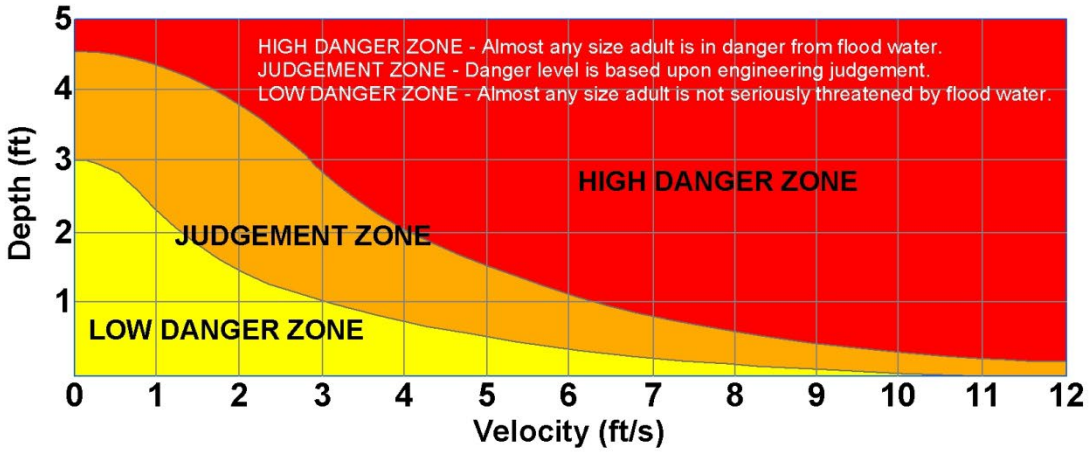
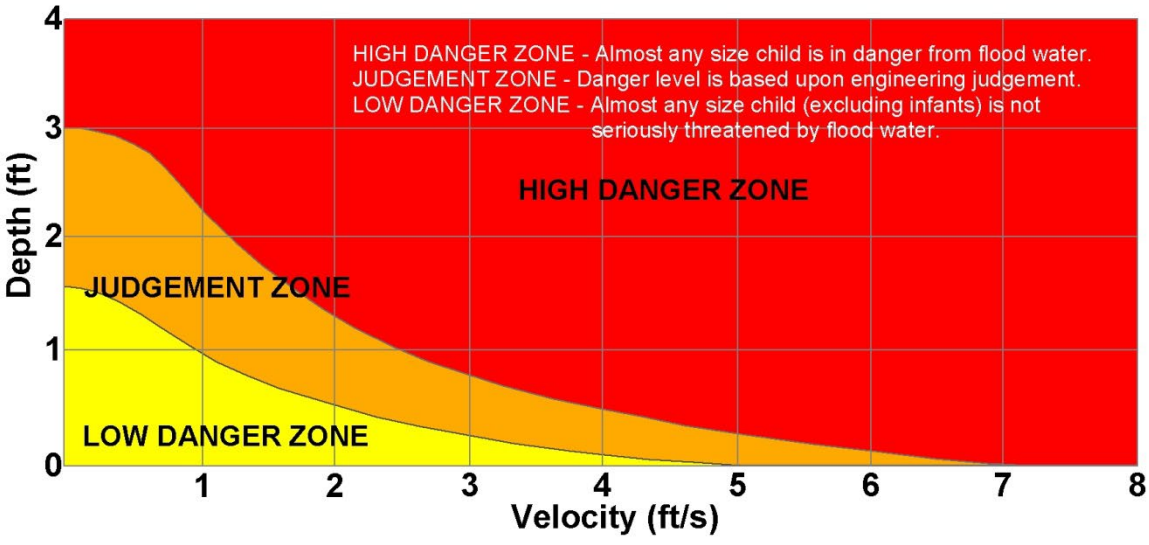


Figure 4.2 Depth-velocity flood danger relationship for children



4.3.2 ENGINEERED OPEN CHANNELS

4.3.2.1 General

For engineered portions of channels with actual water depths greater than three (3) feet in the 100-year event; and for shallow, fast-flowing, engineered channels where the product of maximum depth and average velocity exceeds ten (10) ft^2/sec for the 100-year event:

1. Appropriate measures shall be designed to warn the public and keep them away from these locations.
2. Adequate fencing or railings must be provided along all walls, such as wing walls or training walls, excluding vertical drops in the channel bottom.

4.3.2.2 Channel Drop Structures

For channel drop structures, the maximum vertical drop height from invert crest to invert toe for any single step shall be 2.5 feet. A six-foot-wide (minimum) horizontal apron shall be provided for every 2.5 feet of vertical drop in a "stair step" fashion. Drop structures constructed of concrete or shotcrete shall have a roughened surface to discourage inappropriate recreational use.

4.3.2.3 Emergency Escape Stairs

All concrete, shotcrete, or smooth sided soil cement channels with design flow depth greater than three feet shall have emergency escape stair steps formed; alternating every 300 feet from one side of the channel to the other.

4.3.2.4 Walkways

Walkways shall meet the Americans with Disabilities Act (ADA) requirements and be elevated at least one foot above the invert of any low flow channel.

4.3.3 STORMWATER STORAGE FACILITIES

4.3.3.1 Depth Criteria for Ponds with a Permanent Water Body

For stormwater storage ponds with a permanent water body in the bottom, the pond edge shall be designed to minimize safety hazards. Water depth should be limited to 1.5 to 2 feet within eight feet of the edge of the water feature, and gradually get deeper as needed.

4.3.3.2 Securing Amenities

Amenities placed within the inundation area of a stormwater facility shall be adequately secured to prevent them from becoming waterborne debris. Methods for securing items shall be documented in the design report and shown on the approved construction plans.

4.3.3.3 Fencing

Where basins are accessible by the public, adequate fencing is required along portions of engineered basins where the design maximum ponding depth is greater than three-feet deep and side-slopes are steeper than 3:1.

4.3.4 CULVERTS AND STORM DRAINS

Trash racks may be required on the entrances and access barriers on outlets to conduits or other hydraulic structures. Where such barriers are required, they shall be placed on both the inlet and outlet ends. They are required in areas where debris potential and/or public safety indicate they are necessary, such as in developed areas or where a person could likely be injured or trapped. Refer to Table 4.1 for additional guidelines within such areas. An additional reference for design of debris barriers, particularly for larger hydraulic structures, is FHWA (2005a).

Table 4.1 Conduit and Hydraulic Structure Trash Rack and Access Barriers

Facility Description	Diameter or Cross-Sectional Area (per barrel)	Length	Inlet Trash Rack Required	Outlet Access Barrier Required
Culverts and Storm Drains	Dia < 24" Area < 3.14 sf	All	No	No
Outlets from multiple-use stormwater storage facilities.	Dia≥ 24" Area ≥ 3.14 sf	All	Yes	Yes

Table 4.1 Conduit and Hydraulic Structure Trash Rack and Access Barriers

Facility Description	Diameter or Cross-Sectional Area (per barrel)	Length	Inlet Trash Rack Required	Outlet Access Barrier Required
Culverts and Storm Drains with sufficient bend that the opposite end cannot be clearly seen when looking into the structure.	Dia ≥ 24″ Area ≥ 3.14 sf	All	Yes	Yes
Culverts and Storm Drains, other than noted above	Dia ≥ 24″ 3.14 sf < Area ≤ 15 sf	L < 200 ft L ≥ 200 ft	No Yes	No Yes
Culverts and Storm Drains, other than noted above	Area > 15 sf	All	No	No

4.3.5 ACCESS TO DRAINAGE FACILITIES

All drainage facilities must be readily accessible by emergency or ordinary maintenance vehicles (e.g., pickup truck, loader, backhoe, dump truck, water truck, etc).

1. For engineered channels and stormwater storage facilities/basins with geometric depths greater than three feet deep, access ways to the channel or basin and ramps into the channel or basin shall be required.
2. For engineered channels or stormwater storage facilities/basins with geometric depths of three feet deep or shallower with a portion of side slope set at 6:1 or flatter along at least one side to allow emergency or ordinary maintenance vehicle access, ramps into the channel or basin are not required.
3. For all other small engineered channels such as swales, roadside drainage ditches, etc., reasonable access for emergency and ordinary maintenance vehicles shall be provided.
4. For natural washes, a minimum 16-feet wide accessible clear-zone area for emergency and ordinary maintenance vehicle access shall be provided.
5. Access ramps shall be a minimum of 12 feet wide with a longitudinal slope no steeper than 10%. Access ways approaching channels or basins shall be a minimum of 12 feet wide

within a clear 16-feet wide tract such that emergency and ordinary maintenance vehicles can freely maneuver.

6. At a minimum, hard surface paving (such as concrete, soil cement, etc.) shall be required for the portions of access ramps that will be inundated in the 100-year event and shall be properly "toed-in" to protect the ramp from erosion during storm events.
7. Portions of access ways or ramps may be combined with portions of multi-use trails, subject to approval by COUNTY.
8. The design engineer may propose other means of providing access for maintenance by ordinary maintenance equipment subject to approval by COUNTY.

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5 GENERAL DRAINAGE POLICIES AND STANDARDS

5.1 STANDARD DETAILS AND SPECIFICATIONS

All hydraulic drainage structures are to be designed and constructed, as a minimum, in conformance with the *Uniform Standard Specifications and Details for Public Works Construction* (MAG Standards) by the Maricopa Association of Governments, latest edition, including any Mohave County amendments. Use of the *ADOT Standard Specifications for Road & Bridge Construction* and *Standard Drawings* (ADOT Standards), latest edition of both including any Mohave County amendments, is permissible where the MAG Standards do not provide a standard. Additional details and specifications may be necessary or required, and in all cases, the final approved construction documents, compliant with current design standards, shall control. The latest edition of the *Uniform Standard Details for Mohave County* (Standard Details) is also referenced herein and the drainage policies and standards are tied to the roadway classifications defined in that document.

5.2 ACCEPTANCE OF EXISTING STRUCTURES/FACILITIES

Prior to the acceptance by Mohave County to incorporate existing structures and/or facilities for maintenance, such structures and/or facilities shall be refurbished for the life cycle specified by the MOHAVE COUNTY ENGINEER and constructed or reconstructed as a minimum, in conformance with these policies and standards, and the MAG Standards, latest edition, including any Mohave County amendments. Use of the ADOT Standards, latest edition including any Mohave County amendments, is also permissible provided there is not an applicable MAG Standard. Additional details and specifications may be necessary or required, and in all cases, the final approved construction documents, compliant with current design standards, shall control.

5.3 PERMITS

There are a myriad of federal, state, and county permits that may be required prior to the start of construction of a project (see Chapter 2 and Chapter 8). It is not the COUNTY/DISTRICT's responsibility to ensure that the plans for a proposed project satisfy state and federal permit requirements. It is the COUNTY/DISTRICT's policy that all such permits must be obtained, but it is the owner's responsibility to determine which permits are required and to obtain them as

appropriate for the timing of the project. COUNTY/DISTRICT-issued permits may be withheld pending written proof that required State and/or Federal permits have been obtained.

5.4 LOWEST FLOOR REQUIREMENTS WITHIN NON-FLOODPLAIN AREAS

The lowest floor elevation for dwelling units not within FEMA and NON-FEMA 100-year floodplain areas shall be controlled by the provisions of the International Building Code adopted by Mohave County.

6 STORMWATER QUALITY

The DISTRICT has established a minimum level of control for new development at which stormwater pollution prevention practices are put in place. This minimum standard is "First Flush" and consists of retaining the first 0.5 inches of direct runoff from a storm event. This minimum level of control is met by following the County retention requirement (Chapter 15). In the event that normal County retention standards are waived (100-year, 2 hour storm), or a surface based bleed off for the retention basin is proposed, the following first flush provisions shall apply to stormwater runoff from new development that drain into a stormwater facility (channels or stormwater storage basins) that is owned or operated by the DISTRICT:

The First Flush requirement can be addressed by:

1. Retaining the required minimum First Flush volume, as defined below, or
2. Treating the first flush discharge, or
3. Utilizing a combination of both approaches.

The minimum First Flush volume is calculated as follows:

$$V_{FF} = C\left({}^{P_{FF}}/_{12}\right)A \qquad 6.1$$

where:

V_{FF} = minimum First Flush volume in ac-ft,
C = runoff coefficient (set = 1),
P_{FF} = first 0.5 inches of direct runoff, and
A = area of project site, in acres.

The minimum First Flush treatment discharge is calculated as follows:

$$Q_{FF} = CI_{FF}A \qquad 6.2$$

where:

Q_{FF} = minimum First Flush discharge in cfs,
C = runoff coefficient (set =1),
I_{FF} = maximum first flush intensity in in/hr
where: $I_{FF} = \frac{P_{FF}}{T_c}$
P_{FF} = 0.5 inches
T_c is the Time of Concentration of the upstream watershed in hours.
A = area of project site, in acres

This first flush standard is the result of ARS 48-3622 where the DISTRICT may require any action or impose any restriction that the DISTRICT considers reasonably necessary to meet the DISTRICT's obligations, if any, to comply with local, state or federal water quality laws.

For all other cases the COUNTY, when considering a waiver of the stormwater retention policy, encourages the voluntary implementation of the First Flush provisions.

7 HYDROLOGY

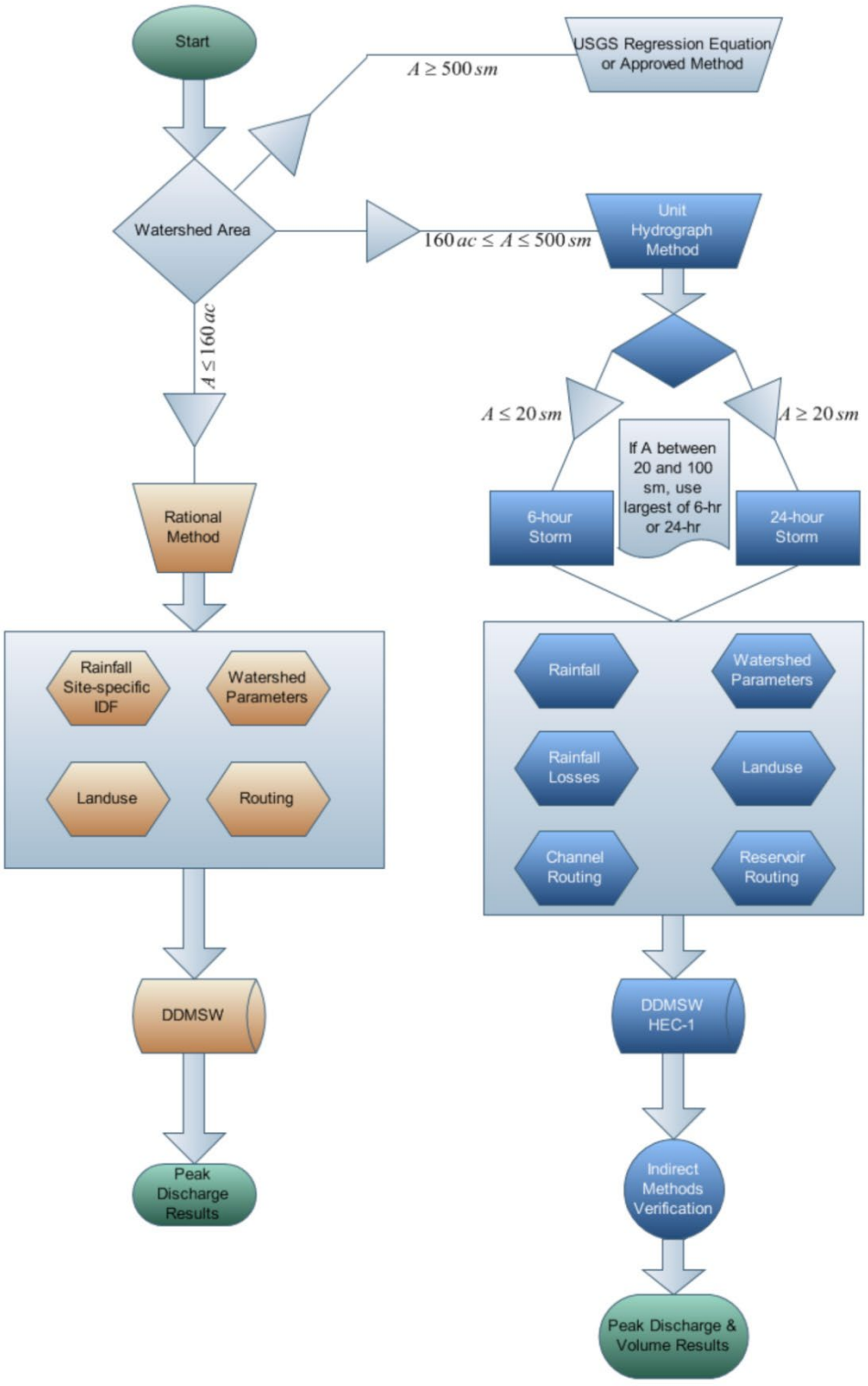
7.1 INTRODUCTION

The hydrologic methodology for Mohave County is based on methods that are accepted state-wide in Arizona. The hydrologic methods are adapted from the Arizona Department of Transportation *Highway Drainage Design Manual, Hydrology* (ADOT, 1993). Some aspects of the methodology are also adapted from the Flood Control District of Maricopa County *Drainage Design Manual for Maricopa County, Hydrology*, 2009 (FCDMC, 2013a). The user is referred to both documents for background information and more detailed technical documentation than is contained herein. The methods set forth in this chapter are summarized as follows:

1. Rainfall. The NOAA Atlas 14 is accepted for use in Mohave County. In general, the median values should be used. Point precipitation data should not be obtained from the NOAA Atlas 14 web site. The specific version of NOAA Atlas 14 adopted for use in Mohave County is included as a part of the DDMSW (KVL, 2009) computer program, shown on isopluvial maps included herein in Appendix B, and available from the Mohave County Flood Control District web site.
2. Rational Method. The Rational Method should be used for estimating peak discharge for various frequency storms when the watershed area is less than or equal to 160 acres. The method includes provision for multiple sub-basins and is implemented using DDMSW. The hand computation method can also be applied.
3. Rainfall Losses. The Green and Ampt method is accepted for use with the Unit Hydrograph Method.
4. Unit Hydrograph Method. The Clark unit hydrograph is accepted for use in Mohave County.
5. FLO-2D is Accepted for use in Mohave County.
6. Flood Frequency Analysis. Flood frequency analysis methods may be used for estimating peak discharges, particularly when the watershed area exceeds 500 square miles.
7. Hydrologic Routing and Verification. Guidance is provided for channel and storage routing of hydrographs and for verification of model results using indirect methods.

A flow chart depicting the general process for applying Mohave County hydrologic methodology is shown in Figure 7.1.

Figure 7.1 Hydrologic method flow chart



7.2 RAINFALL

7.2.1 INTRODUCTION

7.2.1.1 General Discussion

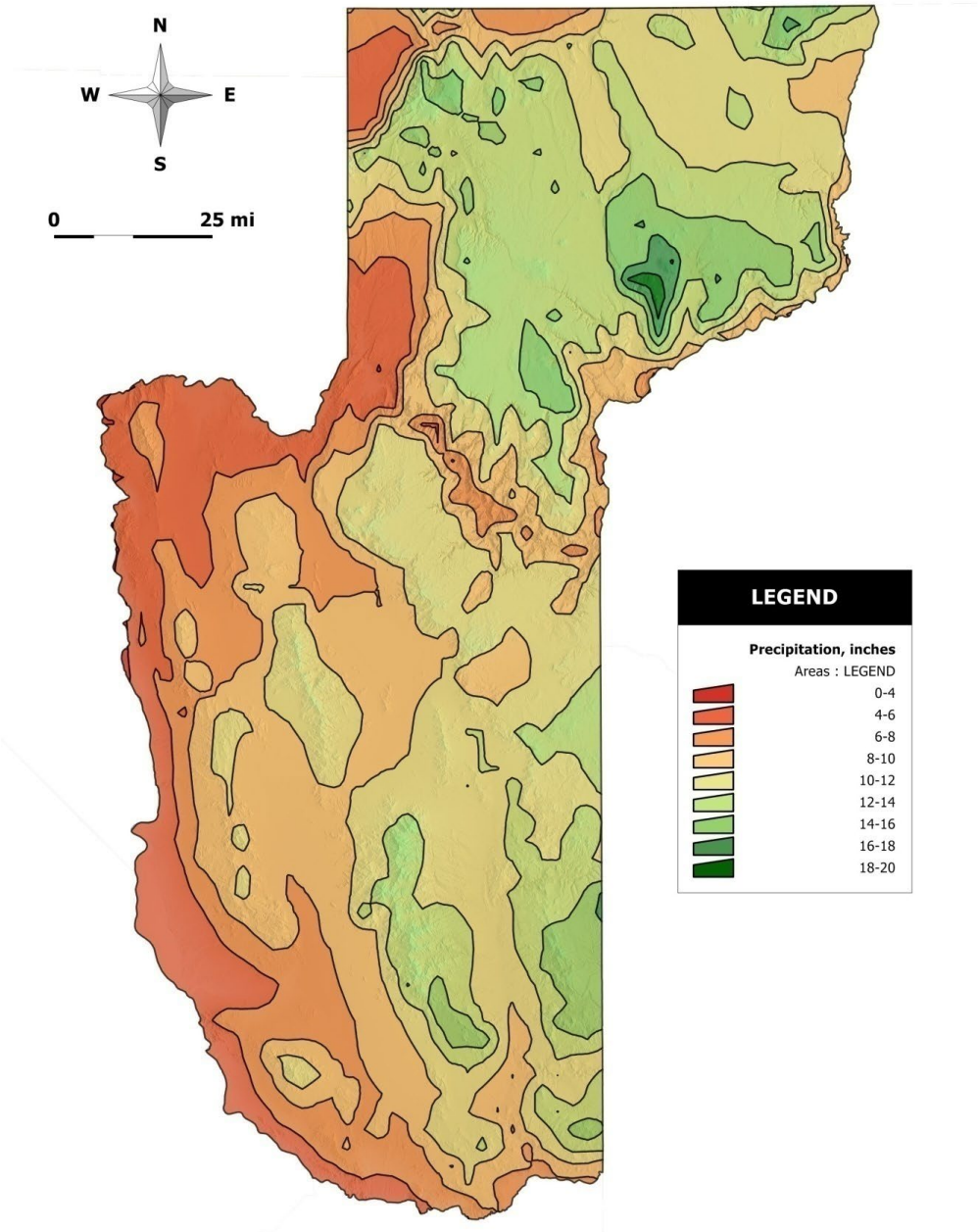
Precipitation in Mohave County is strongly influenced by variation in climate, changing from a warm and arid desert environment at lower elevations to a seasonally cool and moderately humid mountain environment. Mean annual precipitation ranges from 4-inches along western Mohave County to 20-inches in the mountain regions of Mohave County (refer to Figure 7.2). Precipitation is typically divided into two seasons of comparative rainfall depths: summer (June through October) and winter (December through March). Warm, moist tropical air can move into Arizona at any time of the year, but most often does so in the summer months, resulting in severe convective storms and local flooding. Storms of large areal extent are usually associated with frontal or convergence storm activity that may result in long duration rainfall and flooding of major drainage watercourses. These types of storms and flooding usually occur in the winter, but occasionally occur in the summer. The design storm methodology for Mohave County is designed to simulate the peak discharge resulting from both types of storms.

Analytic methods for rainfall-runoff modeling including the Rational Method and the Unit Hydrograph Method require the definition of the rainfall for the desired flood frequency. For the Rational Method, a rainfall intensity-duration-frequency (I-D-F) table or graph is required. Site-specific I-D-F tables or graphs are to be used with the Rational Method in Mohave County. The standard method for developing a site-specific I-D-F and applying the Rational Method is to use the DDMSW computer program developed by KVL Consultants, Inc. for Mohave County. Manual computation methods may also be used.

For rainfall-runoff modeling using the Unit Hydrograph Method, the temporal and spatial distribution of the design rainfall must be provided. For drainage studies in Mohave County, a site-specific rainfall distribution developed from NOAA Atlas 14 point rainfall values of 5- and 15-minutes, and 1-, 2-, 3-, 6-, 12-, and 24-hour durations is used. The point rainfall values are symmetrically nested around the middle of the storm (ie. at 3-hours for a 6-hour storm, and 12-hours for a 24-hour storm). The most intense rainfall is placed at the middle, with decreasing rainfall from the middle to the beginning, and from the middle to the storm end. That rainfall distribution is called the hypothetical distribution and is applied using the US Army Corps of

Engineers HEC-1 computer program (USACE, 1998), with input data created using DDMSW. Refer to Section 7.2.2.3.

Figure 7.2 Average annual precipitation for Mohave County



7.2.1.2 Source of Design Rainfall Information

The rainfall depth-duration-frequency statistics for Mohave County are derived from information in *NOAA Atlas 14 (*Bonnin, G.M. et al, 2004). The NOAA Atlas 14 data is used to generate the site-specific D-D-F and I-D-F data for use with the Rational Method and the point precipitation values for use with the Unit Hydrograph Method. The depth-area reduction curves for use with Unit Hydrograph Method are from NWS Hydro-40 for zone C. Temporal rainfall distributions for various durations and frequencies are derived from NOAA Atlas 14 and applied using the US Army Corps of Engineers hypothetical distribution.

The NOAA Atlas 14 web site may not be used for obtaining design rainfall information for use in Mohave County. Mohave County has adopted the specific version of NOAA Atlas 14 listed above. Geographical Information System (GIS) coverages of the specific version of NOAA Atlas 14 adopted by Mohave County are available for download from the Mohave County web site at: MCFCD Drainage Design Manual Rainfall Data. The most current version of NOAA Atlas 14 on the NOAA web site may be a newer version than adopted by Mohave County. Mohave County will review and possibly adopt the most current version of NOAA Atlas 14, at its discretion. But until a newer version is officially adopted, the version posted on the Mohave County web site is to be used for all drainage and floodplain studies in Mohave County.

7.2.1.3 Applications and Limitations

The rainfall statistics that are developed by procedures in this section are dependent upon the information that is provided in the *NOAA Atlas 14* (Bonnin, G.M. et al, 2004). It is recommended that the user become familiar with the assumptions, limitations and theoretical and technical basis for NOAA Atlas 14 prior to applying these procedures. NOAA Atlas 14 is the most current and comprehensive precipitation frequency atlas available for Arizona and will be used for drainage design and floodplain delineation studies in Mohave County.

The hypothetical distribution is a simplified and idealized representation of the temporal distribution of rainfall. It is intended for use in estimating design discharges for drainage facilities and floodplain delineations. It does not necessarily represent the temporal distribution of any historical storm in Mohave County. The use of the hypothetical distribution for design purposes does provide reasonable assurance that design discharges of specified frequency are produced regardless of the size of the watershed.

For very large watersheds (possibly as large as or larger than 500 square miles), where the time of concentration (T_c) exceeds 24 hours, a longer duration hypothetical distribution (or other project specific distribution) should be developed and used. Procedures for estimating the watershed time of concentration are contained in Section 7.5.2.2.

In general, the hypothetical distribution can be used as input to the HEC-1 program for drainage design purposes in Mohave County. Similarly, site-specific I-D-F graphs generated using NOAA Atlas 14 (see Section 7.2.2.2) can be used with the Rational Method, within the limitations specified in that section, for most small watersheds less than 160 acres in area within Mohave County.

7.2.2 DESIGN RAINFALL CRITERIA

7.2.2.1 Modeling Methods

Rational Method

A site-specific I-D-F graph is used when estimating the design rainfall intensity.

Unit Hydrograph Modeling

The storm duration to be used depends on the total watershed area as follows:

1. Stormwater Storage Facilities. The 100-year 2-hour rainfall shall be used, as a minimum, for the design of stormwater storage facilities in Mohave County, regardless of watershed area.
2. Stormwater Conveyance Facilities and Floodplain Delineation. The storm frequency for design of stormwater conveyance facilities, including open channels, bridges, culverts, storm drains, and roadway drainage, varies with the application. Refer to the appropriate chapter for each type of facility for design storm frequency standards. Floodplain delineation studies shall be done using the 100-year storm frequency, as a minimum. The design storm duration varies with watershed size as follows:
    a. If the total watershed area is less than or equal to 20 square miles, the design storm duration is 6-hours.
    b. If the total watershed area is between 20 and 100 square miles, the maximum discharge from the 6- or 24-hour storm is to be used.
    c. If the total watershed area is greater than or equal to 100 square miles, the design storm duration is 24-hours.

7.2.2.2 Site-Specific I-D-F

A site-specific I-D-F may be generated using one of the following three methods, in order of decreasing accuracy:

1. The DDMSW GIS method. If the user has a digital polygon of the study area in ESRI shape file format, DDMSW can be used to generate a site-specific I-D-F. The shape file must be properly georeferenced using the standard Mohave County specification (State Plane Coordinate System, Arizona West, NAD83, and U.S. Survey feet). DDMSW will then overlay a series of ESRI grid file surfaces for the appropriate storm durations and frequencies and generate an I-D-F for the study area. DDMSW will generate point precipitation estimates for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval storms for durations of 5-, 10-, 15-, and 30-minutes and 1-, 2-, 3-, 6-, 12-, and 24-hours.

2. The DDMSW Manual Method. The user may use maps in PDF format that can be viewed from DDMSW to select the approximate location of the subject watershed. Given the section and township and range, the user can use the provided maps to select the map and index grid numbers that cover the study area. DDMSW then generates a site-specific I-D-F for the study watershed using the recurrence intervals and durations listed for method 1.

3. Manual Method. The user may use the isopluvial maps in Appendix B.1 through Appendix B.6 to estimate the point precipitation values for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval storms for durations of 5-, 10-, 15-, and 30-minutes and 1-, 2-, 3-, 6-, 12-, and 24-hours. The user can then tabulate the values as a depth-duration-frequency (D-D-F) table. An example for the Kingman area is shown in Table 7.1, developed using the DDMSW GIS Method. The D-D-F values are then used to compute rainfall intensity and prepare an I-D-F table (Table 7.2). The values in the Table 7.2 are computed by dividing each point precipitation value in Table 7.1 by the corresponding duration in hours. An I-D-F graph of the computed rainfall intensities versus duration for each storm frequency can then be hand plotted on log-log paper or using a computer spreadsheet such as Microsoft Excel. Blank tables and blank graph paper for tabulating and plotting point precipitation values and computed rainfall intensities are contained in Appendix B.7. An example of an I-D-F graph based on the data in Table 7.2 is shown on Figure 7.3.

D-D-F and I-D-F tables and an I-D-F graph for Bullhead City are provided as Table 7.3, Table 7.4, and Figure 7.4, respectively. D-D-F and I-D-F tables and an I-D-F graph for Lake Havasu City are provided as Table 7.5, Table 7.6, and Figure 7.5, respectively.

An exercise that will help the user understand the process is to use the maps in Appendix B.1 through Appendix B.6 to obtain rainfall values for Kingman and then compare the values read from the figures against the values in Table 7.2, which were taken from the more detailed NOAA Atlas 14 GIS data.

7.2.2.3 Temporal Rainfall Distribution

The temporal rainfall distributions for use with the Unit Hydrograph Method are to be the hypothetical distribution generated in HEC-1 (USACE, 1988) using the PH record option. This method provides a site-specific rainfall distribution for each storm frequency modeled as described in U.S. Army Corps of Engineers, Training Document No. 15 (USACE, 1982). An example of a site-specific 100-year 24-hour hypothetical distribution for Mohave County rainfall gage 1570 at Hualapai Mountain is shown graphically in Figure 7.6 compared with the NRCS Type 2 24-hour rainfall distribution. The two distributions are very similar.

The hypothetical distribution is implemented in HEC-1 using the PH record. The PH record field structure and a sample PH record are shown in Figure 7.7. Refer to the HEC-1 User Manual (USACE, 1988). Field 0 is mandatory and defines the record type. Fields 1 and 2 are for studies using TP-40, which is not the case for Mohave County. Both fields are to be left blank. Fields 3 through 10 define the point precipitation values for the storm frequency being modeled. Each value corresponds to the listed duration from the site-specific D-D-F. Fields 3 through 8 are completed, and field 9 and 10 are left blank, when modeling a 6-hour storm. Fields 3 through 10 are completed when modeling a 24-hour storm. An example PH record is shown using the D-D-F from Table 7.1 for Kingman, AZ.

Table 7.1 Rainfall Depth-Duration-Frequency for Kingman, AZ						
	Rainfall Depth, in inches					
	Storm Frequency, in years					
Duration	2	5	10	25	50	100
5-min	0.252	0.354	0.427	0.526	0.599	0.676
10-min	0.383	0.539	0.651	0.800	0.912	1.029
15-min	0.475	0.669	0.807	0.992	1.131	1.276
30-min	0.640	0.901	1.087	1.336	1.523	1.719
1-hour	0.792	1.115	1.345	1.654	1.886	2.127
2-hour	0.870	1.230	1.509	1.894	2.211	2.545
3-hour	0.932	1.300	1.598	2.022	2.379	2.766
6-hour	1.097	1.506	1.832	2.304	2.691	3.114
12-hour	1.280	1.752	2.133	2.656	3.086	3.540
24-hour	1.580	2.168	2.625	3.272	3.789	4.340

Table 7.2 Rainfall Intensity-Duration-Frequency for Kingman, AZ						
	Rainfall Intensity, in inches/hour					
	Storm Frequency, in years					
Duration	2	5	10	25	50	100
5-min	3.024	4.248	5.124	6.312	7.188	8.112
10-min	2.298	3.234	3.906	4.800	5.472	6.174
15-min	1.900	2.676	3.228	3.968	4.524	5.104
30-min	1.280	1.802	2.174	2.672	3.046	3.438
1-hour	0.792	1.115	1.345	1.654	1.886	2.127
2-hour	0.435	0.615	0.755	0.947	1.106	1.273
3-hour	0.311	0.433	0.533	0.674	0.793	0.922
6-hour	0.183	0.251	0.305	0.384	0.449	0.519
12-hour	0.107	0.146	0.178	0.221	0.257	0.295
24-hour	0.066	0.090	0.109	0.136	0.158	0.181

Figure 7.3 Site-Specific I-D-F for Kingman, AZ

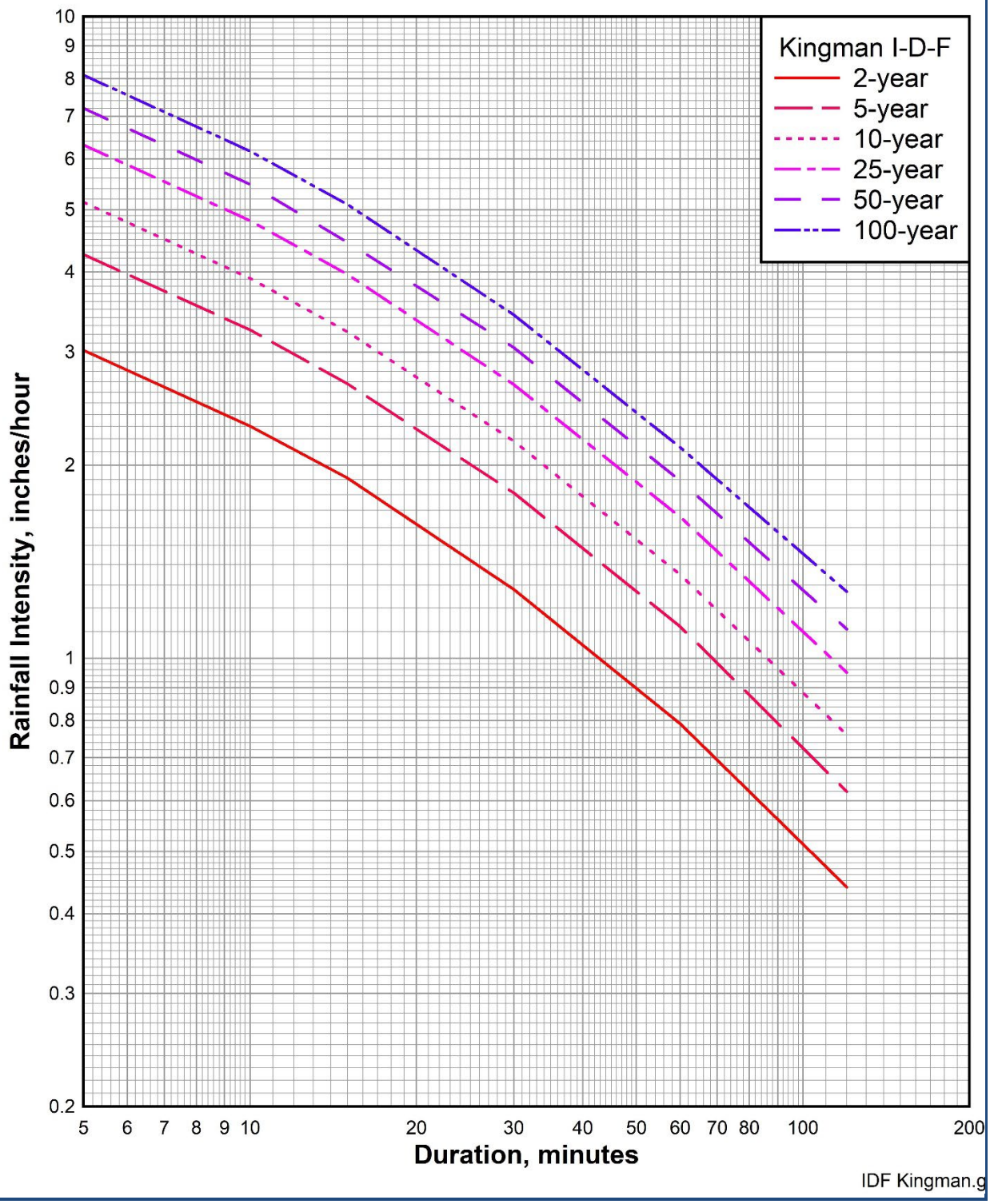


Table 7.3 Rainfall Depth-Duration-Frequency for Bullhead City, AZ						
	Rainfall Depth, in inches					
	Storm Frequency, in years					
Duration	2	5	10	25	50	100
5-min	0.169	0.254	0.322	0.425	0.513	0.614
10-min	0.258	0.386	0.490	0.647	0.782	0.934
15-min	0.320	0.479	0.608	0.802	0.969	1.160
30-min	0.431	0.645	0.819	1.080	1.310	1.560
1-hour	0.533	0.798	1.010	1.340	1.620	1.930
2-hour	0.635	0.942	1.200	1.580	1.920	2.300
3-hour	0.698	1.020	1.290	1.680	2.020	2.410
6-hour	0.836	1.200	1.500	1.930	2.300	2.700
12-hour	0.986	1.410	1.740	2.210	2.600	3.020
24-hour	1.240	1.710	2.080	2.600	3.030	3.490

Table 7.4 Rainfall Intensity-Duration-Frequency for Bullhead City, AZ						
	Rainfall Intensity, in inches/hour					
	Storm Frequency, in years					
Duration	2	5	10	25	50	100
5-min	2.028	3.048	3.864	5.100	6.156	7.368
10-min	1.548	2.316	2.940	3.882	4.692	5.604
15-min	1.280	1.916	2.432	3.208	3.876	4.640
30-min	0.862	1.290	1.638	2.160	2.620	3.120
1-hour	0.533	0.798	1.010	1.340	1.620	1.930
2-hour	0.318	0.471	0.600	0.790	0.960	1.150
3-hour	0.233	0.340	0.430	0.560	0.673	0.803
6-hour	0.139	0.200	0.250	0.322	0.383	0.450
12-hour	0.082	0.118	0.145	0.184	0.217	0.252
24-hour	0.052	0.071	0.087	0.108	0.126	0.145

Figure 7.4 Site-Specific I-D-F for Bullhead City, AZ

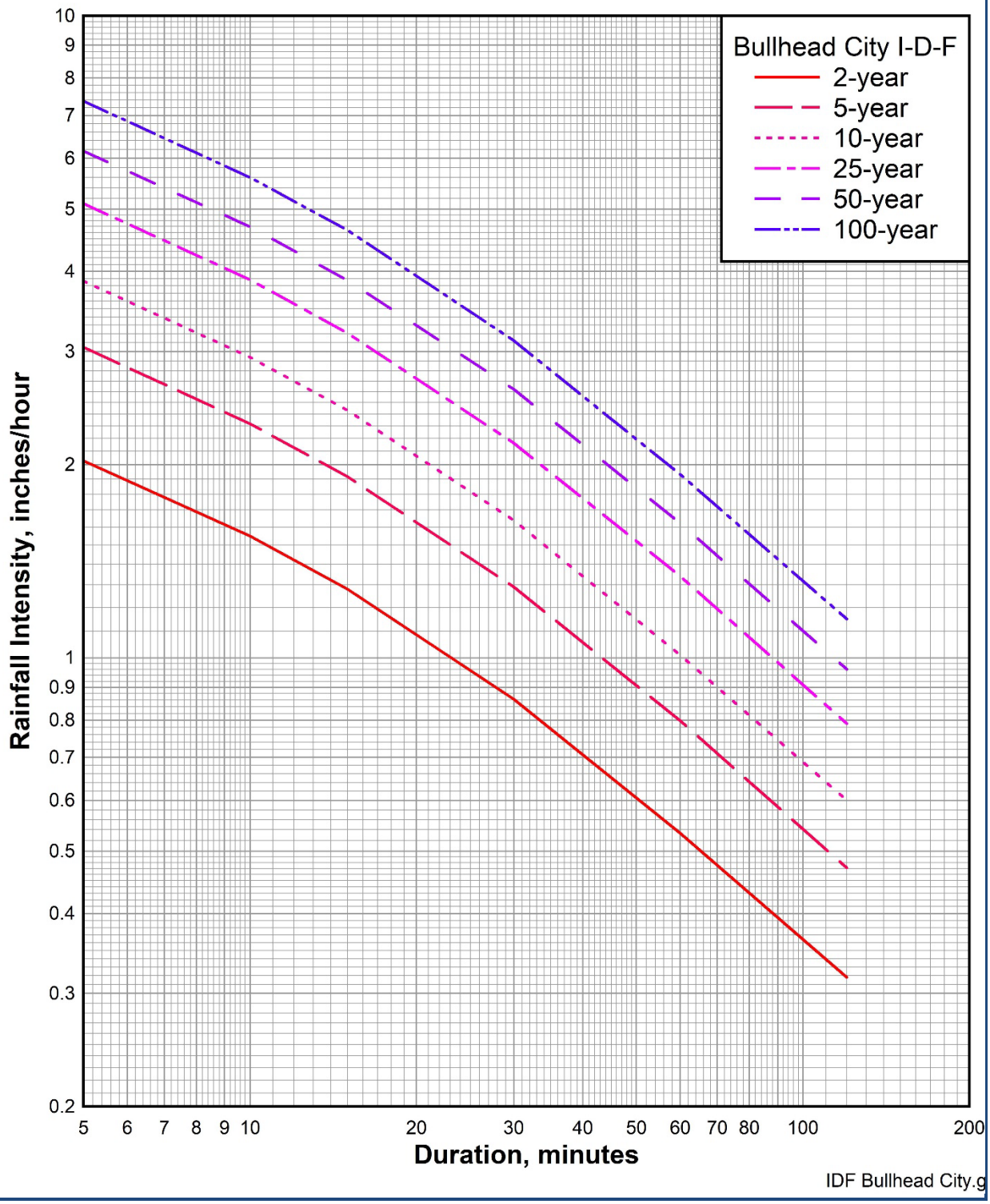


Table 7.5 Rainfall Depth-Duration-Frequency for Lake Havasu City, AZ						
	Rainfall Depth, in inches					
	Storm Frequency, in years					
Duration	2	5	10	25	50	100
5-min	0.186	0.276	0.347	0.449	0.537	0.633
10-min	0.283	0.420	0.528	0.684	0.817	0.963
15-min	0.351	0.520	0.654	0.848	1.010	1.190
30-min	0.472	0.700	0.881	1.140	1.360	1.610
1-hour	0.584	0.866	1.090	1.410	1.690	1.990
2-hour	0.682	1.010	1.270	1.660	1.990	2.360
3-hour	0.756	1.100	1.390	1.810	2.160	2.570
6-hour	0.902	1.290	1.610	2.070	2.450	2.870
12-hour	1.080	1.540	1.900	2.420	2.850	3.300
24-hour	1.160	1.600	1.940	2.440	2.870	3.330

Table 7.6 Rainfall Intensity-Duration-Frequency for Lake Havasu City, AZ						
	Rainfall Intensity, in inches/hour					
	Storm Frequency, in years					
Duration	2	5	10	25	50	100
5-min	2.232	3.312	4.164	5.388	6.444	7.596
10-min	1.698	2.520	3.168	4.104	4.902	5.778
15-min	1.404	2.080	2.616	3.392	4.040	4.760
30-min	0.944	1.400	1.762	2.280	2.720	3.220
1-hour	0.584	0.866	1.090	1.410	1.690	1.990
2-hour	0.341	0.505	0.635	0.830	0.995	1.180
3-hour	0.252	0.367	0.463	0.603	0.720	0.857
6-hour	0.150	0.215	0.268	0.345	0.408	0.478
12-hour	0.090	0.128	0.158	0.202	0.238	0.275
24-hour	0.048	0.067	0.081	0.102	0.120	0.139

Figure 7.5 Site-Specific I-D-F for Lake Havasu City, AZ

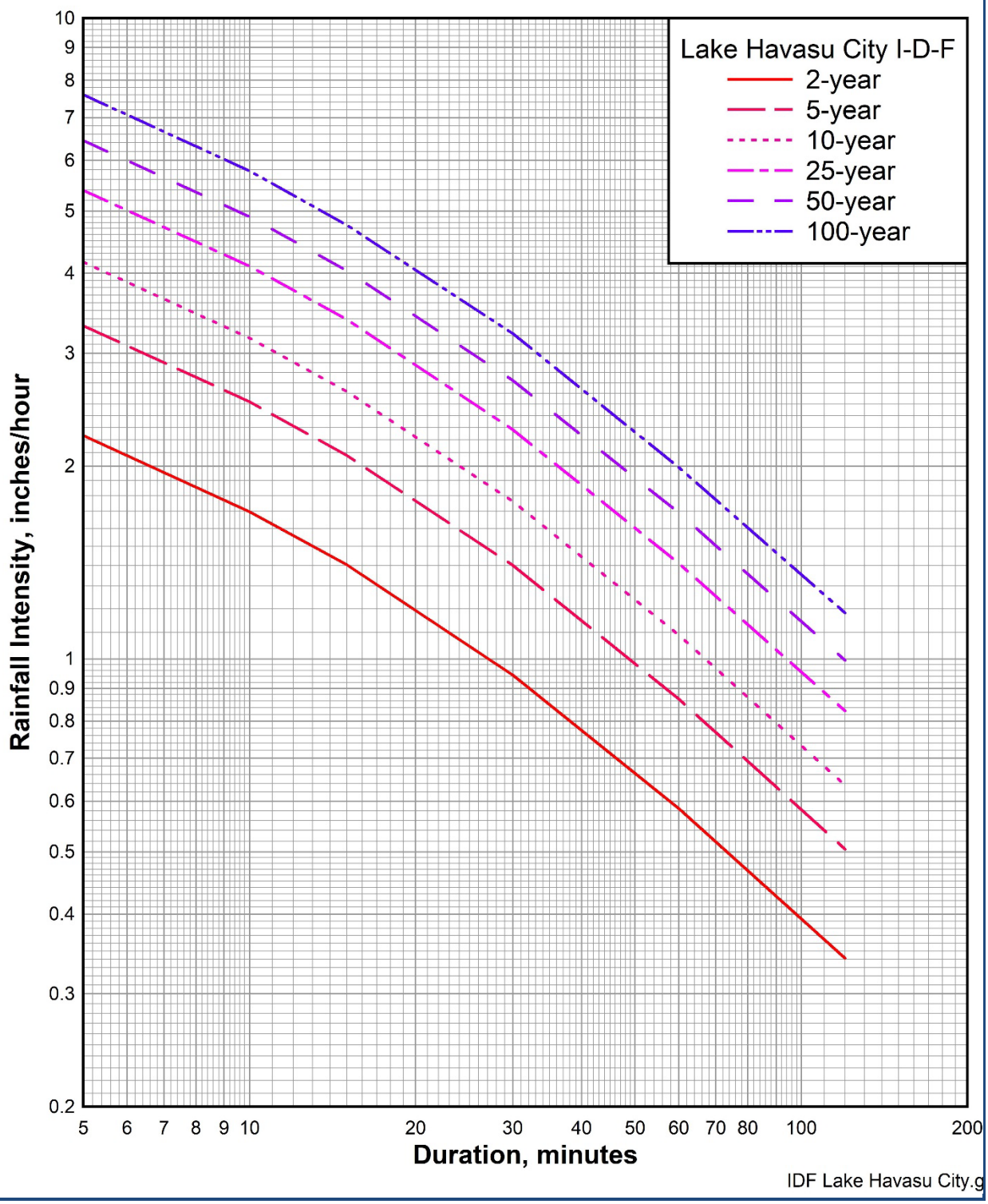


Figure 7.6 Typical hypothetical distribution compared with NRCS Type 2

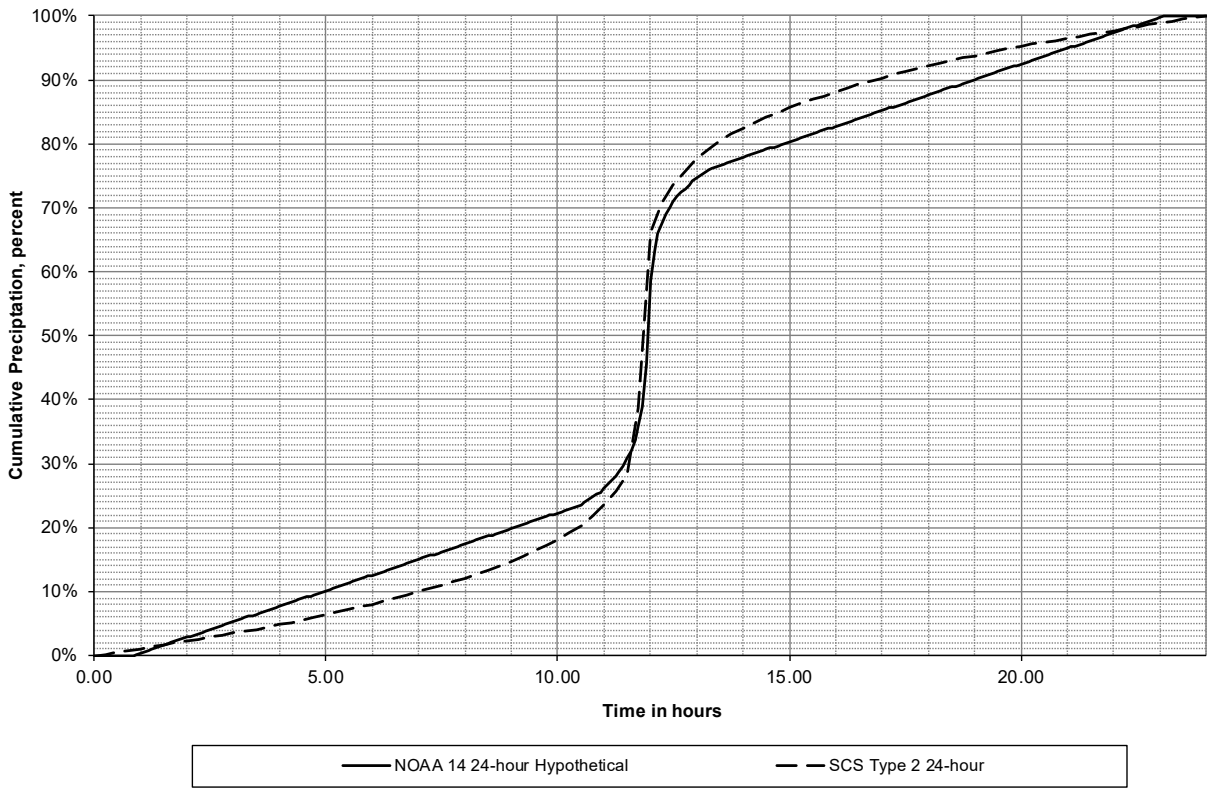


Figure 7.7 PH record field structure and example

HEC-1 PH Record Data Fields										
0	1	2	3	4	5	6	7	8	9	10
PH	PREQ	TRSDA	PNHR(1)	PNHR(2)	PnHR(3)	PNHR(4)	PNHR(5)	PNHR(6)	PNHR(7)	PNHR(8
			5-min	15-min	1-hour	2-hour	3-hr	6-hour	12-hour	24-hour
Example PH Record for Kingman										
PH			0.68	1.28	2.13	2.55	2.77	3.11	3.54	4.3

7.2.2.4 Depth-Area Relation

The rainfall depths from the isopluvial maps in Figure B.1 through Figure B.60 of Appendix B.1 are point rainfalls for specified frequencies and durations. This is the depth of rainfall that is expected to occur at a point or points in a watershed for the specified frequency and duration. However, this depth is not the areally-averaged rainfall over the basin that would occur during a storm. Estimating the areally-average rainfall requires a two-step process.

First, an average point rainfall value for the watershed must be estimated. This can be done by examination of the appropriate isopluvial map and visual estimation of the average value. If there is a high degree of variation in point rainfall across the watershed, the user may need to lay a grid over the watershed, assign a point rainfall value to each grid and then average the rainfall amounts. DDMSW has two methods for accomplishing this, as discussed in Appendix A.1.

Second, a reduction factor is used to convert the watershed average point rainfall to an equivalent uniform depth of rainfall over the entire watershed. As the watershed area increases, the reduction factor decreases, reflecting the greater non-homogeneity of rainfall for storms of larger areas.

Regional research by the Agricultural Research Service, U.S. Department of Agriculture, for the Walnut Gulch Experimental Watershed near Tombstone, Arizona, indicated that local storms are characterized by relatively small areas of high intensity rainfall resulting in depth-area reduction curves that decrease rapidly with increasing area. For local storms (6-hour duration), the depth-area reduction curve that is to be used in Mohave County is shown in Table 7.7 and Figure 7.8. For the 24-hour general storm, the depth-area reduction curve that is to be used in Mohave County is shown in Table 7.7 and Figure 7.9. These curves are taken from Figure 15 of the National Weather Service HYDRO-40 (Zehr and Myers, 1984). Use the factors to adjust the point precipitation values by multiplying the factor times the point value.

For design storms other than what is specified in this manual, the depth-area reduction and temporal distribution will need to be developed on a case-by-case basis depending on the purpose of the study, location of the watershed, and other meteorological and hydrological factors.

7.2.2.5 Examples

Refer to Appendix A.1 for an example of development of a site-specific D-D-F and I-D-F and an example of preparation of rainfall data for use with the Unit Hydrograph Method. The results of the manual method are compared with those prepared using DDMSW.

Table 7.7 Depth-Area curves for Mohave County			
6-hour storm		24-hour storm	
Area, sq-mi	Depth-Area Factor	Area, sq-mi	Depth-Area Factor
0	1.000	0	1.000
5	0.909	10	0.950
10	0.851	20	0.919
15	0.811	30	0.900
20	0.785	40	0.887
25	0.766	50	0.877
50	0.715	60	0.870
75	0.676	70	0.863
100	0.649	80	0.857
---	---	90	0.852
---	---	100	0.848
---	---	110	0.844
---	---	120	0.841
---	---	130	0.838
---	---	140	0.835
---	---	150	0.833
---	---	200	0.820
---	---	250	0.820
---	---	300	0.812
---	---	400	0.806
---	---	500	0.796

Figure 7.8 6-hour storm depth-area reduction curve

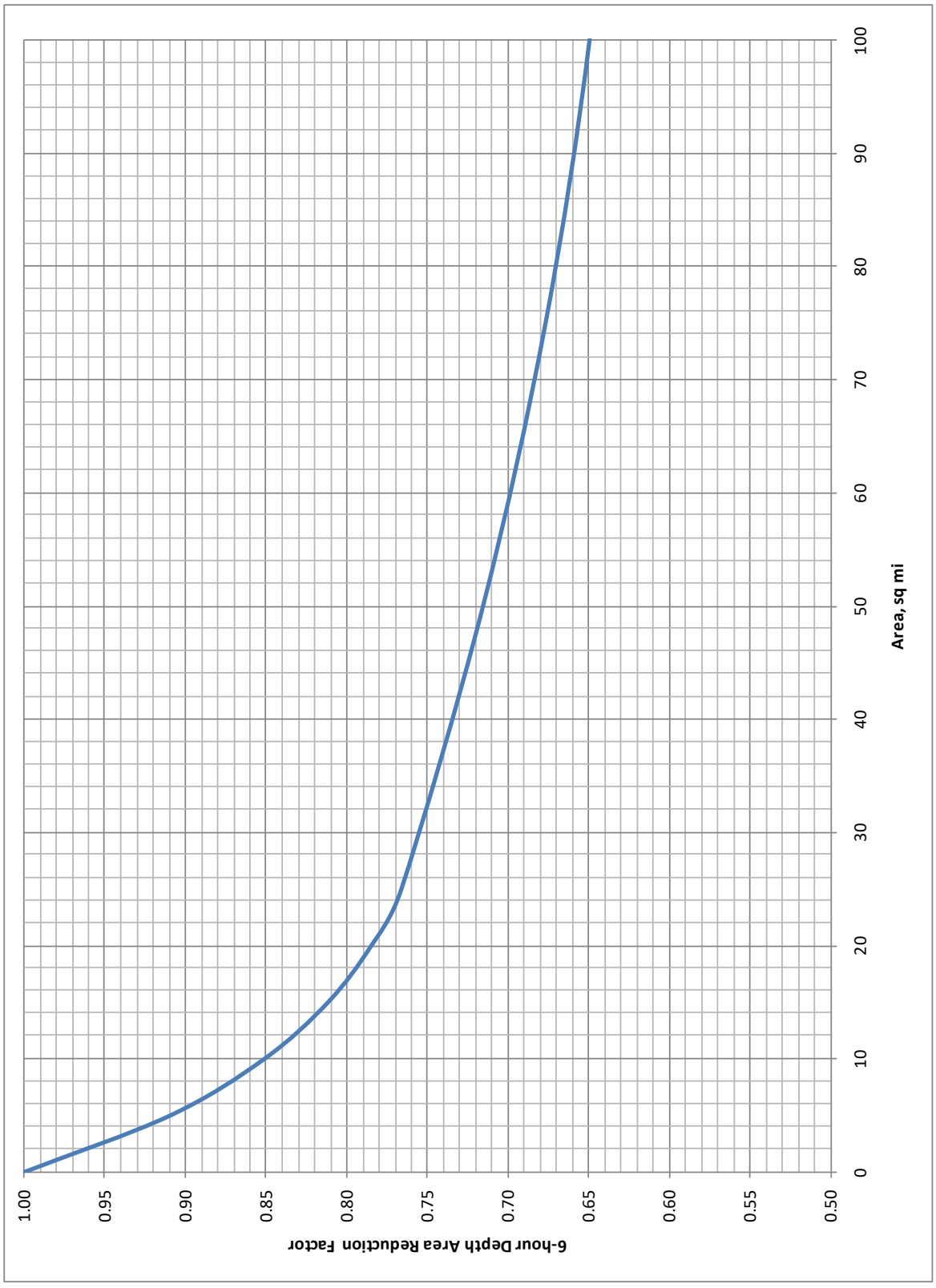
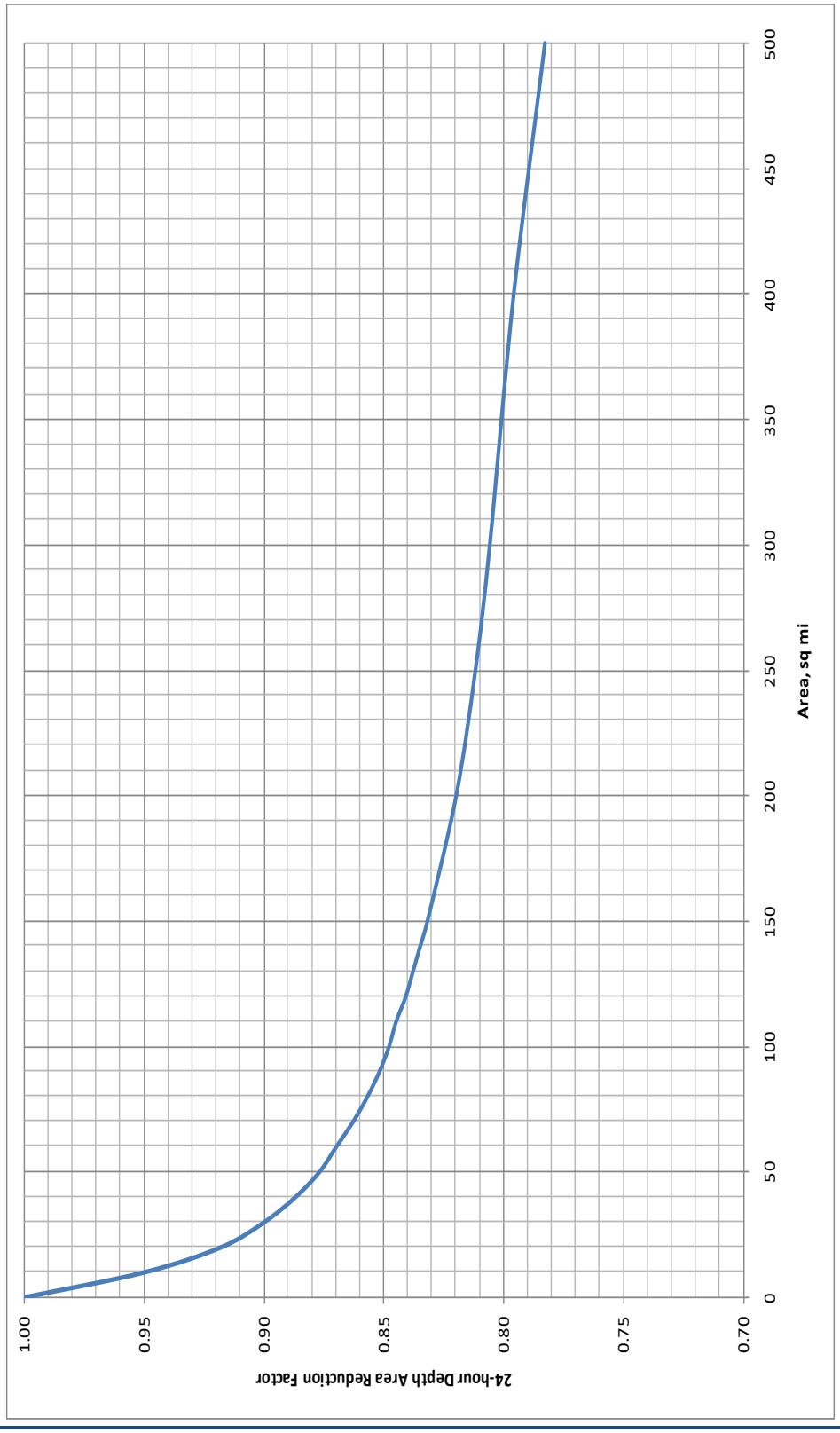


Figure 7.9 24-hour storm depth-area reduction curve



7.2.3 APPLICATION

7.2.3.1 Instructions for Preparing a Site-Specific I-D-F

1. Determine the location of the center of the subject watershed. Locate by section, township and range, or using world coordinates (latitude and longitude).
2. Assemble copies of Figures B.1 through B.60 and make copies of the D-D-F and I-D-F forms contained in Appendix B, Section B.8.
3. Locate centroid of the watershed on Figure B.1. If the watershed is large (> 5 sm) and there is significant variation in point rainfall across the watershed, it may be necessary to draw the watershed at scale on a copy of the isopluvial map
4. Interpolate a point rainfall value for the 2-year 5-minute storm using the rainfall isopluvials shown on the figure. Write the 2-year 5-minute point rainfall value on the D-D-F form.
5. Repeat this process for Figures B.2 through B.60. Tabulate the results on the D-D-F form.
6. Compute the I-D-F values for each duration and frequency and tabulate the results on the I-D-F form.

7.3 RATIONAL METHOD

7.3.1 INTRODUCTION

The Rational Method relates rainfall intensity, a runoff coefficient and a drainage area size to the direct runoff from the drainage basin.

Basic assumptions of the Mohave County implementation of the Rational Method are:

1. The frequency of the storm runoff is the same as the frequency of the rainfall producing the runoff (i.e., a 25-year runoff event results from a 25-year rainfall event).
2. The peak runoff occurs when all parts of the drainage basin are contributing to the runoff.
3. Rainfall is uniform over the watershed.
4. The peak discharge rate corresponding to a given intensity would occur only if the rainfall duration is at least equal to the time of concentration.
5. The calculated runoff is directly proportional to the rainfall intensity.
6. The runoff coefficient increases as storm frequency decreases.

The Rational Method, as presented herein, can be used to estimate peak discharges, the runoff hydrograph shape, and runoff volume for small, uniform drainage areas that are not larger than 160 acres in size. The method is usually used to size drainage structures for the peak discharge of a selected return period.

The Rational Method is based on the equation:

$$Q = C\mathrm{iA} \qquad 7.1$$

where: Q = the peak discharge, in cfs, of the selected return period,

C = the runoff coefficient,

i = the average rainfall intensity, in inches/hr, of calculated rainfall duration for the selected rainfall return period, and

A = the contributing drainage area, in acres.

7.3.2 PROCEDURE

7.3.2.1 Overview

Applicability

- The total drainage area must be less than or equal to 160 acres.
- T_c shall not exceed 60 minutes.

- The land-use of the contributing area should be fairly consistent over the entire area; that is, the area should not consist of a large percentage of two or more land-uses, such as 50 percent commercial and 50 percent undeveloped. This will lead to inconsistent estimates of T_c (and therefore i) and errors in selecting the most appropriate C coefficient.

- The contributing drainage area cannot have drainage structures or other facilities in the area that would require flood routing to correctly estimate the discharge at the point of interest.

- Drainage areas that do not meet the above conditions will require the use of the unit hydrograph method implemented through the HEC-1 Program to estimate flood discharges.

Key Analysis Parameters

A	Watershed area, in acres.
C	The Rational Method runoff coefficient.
i	The average rainfall intensity, in inches/hour.
K_b	The watershed resistance coefficient.
L	The length of the longest hydraulic flow path, in miles.
P	The rainfall depth, in inches.
Q	The estimated peak discharge, in cubic feet per second.
S	The slope of the longest hydraulic flow path, in ft/mile.
T_c	Time of Concentration, in hours.
V	The estimated runoff volume, in acre-feet.

7.3.2.2 General Considerations

1. Depending on the intended application, the runoff coefficient (C) should be selected based on the character of the existing land surface or the projected character of the land surface under future development conditions. For development projects, it will be necessary to estimate C for both existing and future conditions.
2. Land-use must be carefully considered because the evaluation of land-use will affect both the estimation of C and also the estimation of the watershed time of concentration (T_c).
3. The peak discharge (Q) is generally quite sensitive to the calculation of T_c and care must be exercised in obtaining the most appropriate estimate of T_c.
4. Both C and the rainfall intensity (i) will vary if peak discharges for different flood return periods are desired.

5. The T_c equation is a function of rainfall intensity (*i*); therefore, T_c will also vary for different flood return periods.

7.3.2.3 Estimation of Area (*A*)

An adequate topographic map of the drainage area and surrounding land is needed to define the drainage boundary and to estimate the watershed area (*A*), in acres. The map should be supplemented with aerial photographs, if available, especially if the area is developed. If the area is presently undeveloped but is to undergo development, the land development plan and design condition topographic maps should be used to determine the developed condition watershed boundaries.

The delineation of the drainage boundary needs to be carefully determined. The contributing drainage area for a lower intensity storm does not always coincide with the drainage area for more intense storms. This is particularly true for urban areas where roads can form a drainage boundary for small storms, but more intense storm runoff can cross roadway crowns, curbs, etc. resulting in a larger contributing area. Roads on alluvial fans (active and inactive) and in distributary flow systems can result in increased contributing drainage areas during larger and more intense storms. It is generally prudent to consider the largest reasonable drainage area in such situations.

7.3.2.4 Estimation of Rainfall Intensity (*I*)

The intensity (*I*) in Equation 7.1 is the average rainfall intensity in inches/hour for the period of maximum rainfall of a specified return period (frequency) having a duration equal to the time of concentration (T_c) for the drainage area. The frequency is usually specified according to a design criteria or standard for the intended application. The rainfall intensity (i) is obtained from an intensity-duration-frequency (I-D-F) table or graph. Three methods can be used for obtaining I-D-F information as described in Section 7.2.2.2. Procedures for developing a site-specific I-D-F graph are also described in Section 7.2.2.2.

The intensity (*I*) in Equation 7.1 is the average rainfall intensity for rainfall of a selected return period from an I-D-F graph tor a rainfall duration that is equal to the time of concentration (T_c) as calculated according to the procedure described below. A minimum rainfall duration of 5-minutes is to be used if the calculated T_c is less than 5 minutes. The Rational Method should not be used if the calculated T_c is greater than 60 minutes.

7.3.2.5 Estimation of Time of Concentration (T_c)

Time of concentration (T_c) is to be calculated by Equation 7.2:

$$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38} \quad 7.2$$

Note: Reference Papadakis and Kazan, 1987

where: T_c = the time of concentration, in hours,

L = the length of the longest hydraulic flow path, in miles,

K_b = watershed resistance coefficient,

S = the slope of the longest hydraulic flow path, in ft/mile, and

i = the average rainfall intensity, in inches/hr, for a duration of rainfall equal to T_c (the same (*i*) as Equation 7.1) unless T_c is less than 5-minutes, in which case the (*i*) of Equation 7.1 is for a 5-minute duration).

The longest hydraulic flow path will be estimated from the best available map and the length (L) measured from the map. This is the flow path with the longest travel time, which is not necessarily the longest in length.

The slope (S), in ft/mile, will be calculated by one of two methods:

1. If the longest flow path has a uniform gradient with no appreciable grade breaks, then the slope is calculated by Equation 7.3;

$$S = \frac{H}{L} \quad 7.3$$

where: H = the change in elevation, in feet, along L, and

L = as defined in Equation 7.2.

2. If the longest flow path does not have a uniform gradient or has distinct grade breaks, then the slope is calculated by Equation 7.4:

$$S = 5{,}280\left(\frac{d}{j}\right)^2 \quad 7.4$$

where: d = 5,280 x L, and

$$j = \sum\left(\frac{d_i^3}{H_i}\right)^{1/2} \quad 7.5$$

Source: Pima County (1979).

and d_i = an incremental change in length, in feet, along the longest hydraulic flow path, and

H_i = an incremental change in elevation, in feet, for each length segment, d_i.

General values of resistance coefficient (K_b) may be selected from Table 7.8. Refer to Section 7.13.2, Table 7.24 for specific K_b values for use in unincorporated Mohave County. Use

of Table 7.8 requires a landform classification and a determination of the nature of runoff; whether in a defined drainage network of rills, gullies, channels, etc., or predominantly as overland flow. The values in Table 7.24 are specific to Mohave County zoning and land use classifications.

The solution of Equation 7.2 is an iterative process since the determination of (I) requires the knowledge of the value of T_c. Therefore, Equation 7.2 will be solved by a trial-and-error procedure. After L, K_b, and S are estimated and after the appropriate I-D-F graph is selected or prepared, a value for T_c is estimated (a trial value) and (I) is then read from the I-D-F graph for the corresponding value of duration = T_c. That (I) is then used in Equation 7.2 and T_c is calculated. If the calculated value of T_c does not equal the trial value of T_c, the process is repeated until the calculated and trial values of T_c are acceptably close (a difference of less than 10 percent is normally acceptable).

7.3.2.6 Selection of Runoff Coefficient (C)

The runoff coefficient (C) is dependent on many variables, including soil infiltration characteristics, vegetation cover, slope, land use and the percentage of impervious area of that land use, and storm frequency. The Mohave County implementation of the Rational Method is focused on two key characteristics: land use and storm frequency. The effects of the other characteristics of C are lumped into the values specified for use in Mohave County. The range of values of C provided should produce conservative results when estimating peak discharges for design of drainage facilities, which is important for public safety considerations.

General land use descriptions for Mohave County are listed in Table 7.9. These descriptions are intended to provide the necessary information to allow correlation with agencies zoning code categories. The land use codes correspond with the general land use categories listed in Table 7.10. Table 7.10 contains the range of (C) values for each general land use category by storm frequency. Refer to Section 7.13.2 for specific values for use in unincorporated Mohave County. If the area of concern is within a municipality in Mohave County, refer to that jurisdiction for guidance on (C) values specific to the jurisdictions zoning code.

Table 7.8 Resistance coefficient (K_b) for use in the Rational Method T_c Equation

Derived from: ADOT, 1994

Description of Landform	K_b	
	Defined Drainage Network	**Shallow Overland Flow Only**
Mountain, with forest and dense ground cover (overland slopes – 50% or greater)	0.15	0.30
Mountain, with rough rock and boulder cover, and sparse vegetation (overland slopes – 50% or greater)	0.12	0.25
Foothills (overland slopes – 10% to 50%)	0.10	0.20
Alluvial fans, Pediments and Rangeland (overland slopes – 10% or less)	0.05	0.10
Irrigated Pasture [a]	---	0.20
Tilled Agricultural Fields [a]	---	0.08
Urban		
Residential/ Commercial/Industrial, L < 1,000 ft [b]	0.04	---
Residential/ Commercial/Industrial, L > 1,000 ft [b]	0.025	---
Grass; parks, cemeteries, etc. [a]	---	0.20
Bare Ground; playgrounds, etc. [a]	---	0.08
Paved; parking lots, etc. [a]	---	0.02
Notes: a – No defined drainage network. b – L is the length in the T_c equation (eqn 7.2). Roadways serve as drainage network.		

The values in Section 7.13.2 are the default values used in the DDMSW computer program. The user may select a non-default value provided the selection is within the range of values provided in Table 7.10, and engineering justification is provided and approved by Mohave County or the controlling jurisdiction.

The user should delineate sub-basins around areas with a single land use, where possible. When that is not practical, then an area-averaged (C) value should be computed for the sub-basin using Equation 7.6.

$$C_{comp} = \left(\sum_{i=1}^{n} C_i A_i\right) \Big/ A_t \qquad 7.6$$

where: C_{comp} = the area-averaged value of (C),

n = the number of different land use polygons within the sub-basin,

C_i = the value of (C) corresponding to each land use in the sub-basin,

A_i = the area in acres of the corresponding land use within the sub-basin, and

A_T = the total area of the sub-basin in acres.

Table 7.9 General land use category descriptions for Mohave County

Land Use Code	Land Use Category Description
VLDR	Residential: 40,000 square feet and greater lot size
LDR	Residential: 12,000 - 40,000 square feet lot size
MDR	Residential: 6,000 - 12,000 square feet lot size
MFR	Residential: 1,000 - 6,000 square feet lot size
C1	Commercial: Light, Neighborhood, Residential
C2	Commercial: Central, General, Office, Intermediate
I1	Industrial: Light to General
I2	Industrial: General to Heavy
P	Paved Areas: asphalt and concrete, sloped rooftops
GR	Graded Areas: graded and compacted, treated and untreated
AG	Agricultural: tilled fields, irrigated pastures, slopes < 1%
LP1	Landscaped Park 1: *RTIMP* = 0-10%, irrigated vegetation = 0-20%
LP2	Landscaped Park 2: *RTIMP* = 0-10%, irrigated vegetation = 20-80%
LP3	Landscaped Park 3: *RTIMP* = 0-10%, irrigated vegetation >80%
L1	Landscaping 1: with impervious under treatment
L2	Landscaping 2: without impervious under treatment
NDR	Natural Desert Rangeland: little topographic relief, slopes < 5%
NHS	Natural Hillslope: moderate topographic relief, slopes > 5%
NMT	Natural Mountain: high topographic relief slopes, slopes > 20%

Table 7.10 Rational Method general runoff coefficients for Mohave County

Derived from ADOT (1994) and FCDMC (2013a)

Land Use Code	Land Use Category	Runoff Coefficients by Storm Frequency							
		2-10 Year		25-year		50-year		100-year	
		min	max	min	max	min	max	min	max
VLDR	Very Low Density Residential[1]	0.33	0.45	0.36	0.50	0.40	0.60	0.45	0.65
LDR	Low Density Residential[1]	0.42	0.48	0.46	0.55	0.50	0.64	0.53	0.70
MDR	Medium Density Residential[1]	0.48	0.65	0.53	0.72	0.58	0.78	0.60	0.80
MFR	Multiple Family Residential	0.65	0.75	0.72	0.83	0.78	0.90	0.82	0.94
C1	Commercial 1	0.55	0.65	0.61	0.72	0.66	0.78	0.69	0.81
C2	Commercial 2	0.75	0.85	0.83	0.94	0.90	0.95	0.94	0.95
I1	Industrial 1	0.60	0.70	0.66	0.77	0.72	0.84	0.75	0.88
I2	Industrial 2	0.70	0.80	0.77	0.88	0.84	0.95	0.88	0.95
P	Pavement and Rooftops	0.75	0.85	0.83	0.94	0.90	0.95	0.94	0.95
GR	Gravel Roadways & Shoulders	0.60	0.70	0.66	0.77	0.72	0.84	0.75	0.88
AG	Agricultural	0.10	0.20	0.11	0.22	0.12	0.24	0.13	0.25
LP1	Landscaped Park 1	0.30	0.45	0.35	0.48	0.36	0.50	0.38	0.55
LP2	Landscaped Park 2	0.20	0.35	0.25	0.40	0.30	0.45	0.35	0.50
LP3	Landscaped Park 3	0.10	0.25	0.11	0.28	0.12	0.30	0.15	0.35
L1	Desert Landscaping 1	0.55	0.85	0.61	0.94	0.66	0.95	0.69	0.95
L2	Desert Landscaping 2	0.30	0.40	0.35	0.45	0.36	0.48	0.38	0.50
NDR	Undeveloped Desert Rangeland	0.30	0.40	0.35	0.45	0.36	0.48	0.38	0.50
NHS	Hillslopes, Sonoran Desert	0.40	0.55	0.45	0.60	0.48	0.66	0.50	0.70
NMT	Mountain Terrain	0.50	0.70	0.65	0.80	0.70	0.90	0.75	0.90
1	Based on NDR (undeveloped desert rangeland) terrain class. Values should be increased for NHS and NMT terrain classes by the difference between NHS or NMT and the NDR C values, up to a maximum of 0.95. Engineering judgment should be used.								

7.3.2.7 Volume Calculations

Rational method runoff volume estimations should be computed using Equation 7.7. In the case of volume calculations for stormwater storage facility design, *P* in Equation 7.7 equals the 100-year, 2-hour depth, in inches. Refer to Section 7.2.

$$V = C\left(\frac{P}{12}\right)A \qquad 7.7$$

Source: Maricopa County (2013a)

where: V = runoff volume, in acre-feet,
C = runoff coefficient (or C_{comp}),
P = rainfall depth, in inches, and
A = drainage area, in acres.

7.3.2.8 Runoff Hydrographs

If a runoff hydrograph is needed for design purposes, the Rational Method should not be used. The Unit Hydrograph Method (Section 7.5) should be used for that case.

7.3.3 APPLICATION

The Rational Method can be used to calculate the generated peak discharge from drainage areas less than 160 acres. Procedures for calculating peak discharge for single and multiple sub-basins are provided in the following sections.

7.3.3.1 Instructions for Single Basin Approach

1. Area: Determine the area of the watershed in question using a suitable topographic map. Define the land uses present in each sub-basin and compute the area of each.
2. C: Select the Runoff Coefficient (C) from Table 7.24. If the drainage area contains subareas of different runoff characteristics, and thus different C coefficients, arithmetically area-weight the values of C using Equation 7.6.
3. T_c Parameters.
   a. L: Determine the T_c flow path and measure the value of L.
   b. S: Inspect the T_c path on the topographic map of the watershed and assess if there are significant changes in slope along the T_c path. If there are, plot a profile of the T_c path and determine the break locations. Compute an adjusted slope using Equation 7.4. If the profile is uniform, use Equation 7.3. The slope cannot be adjusted by calculation within DDMSW. If DDMSW is being used, and the slope needs to be adjusted, compute the adjusted slope manually using Equation 7.4 then enter the adjusted slope directly into DDMSW.
   c. K_b: Determine the K_b parameter from Table 7.24. If the drainage area contains subareas of different K_b values, arithmetically area-weight the values of K_b using Equation 7.6 and substituting K_b for C.
   d. I-D-F: Tabulate the depth-duration-frequency (D-D-F) statistics for the project site using the figures in Appendix B.1 through B.6 on the form in Appendix B.7. Compute the Intensity-Duration-Frequency (I-D-F) data and tabulate and plot the results using the form and graph paper in Appendix B.7.

4. T_c: Calculate the time of concentration. This is to be done as an iterative process.
   a. Make an initial estimate of the duration and read the corresponding intensity i from the I-D-F curve plot for the desired frequency. The initial estimate of duration can be made by assuming an average velocity in feet per second and dividing it into L in feet, and converting the result to minutes.
   b. Compute an estimated T_c using Equation 7.2. If the computed T_c is reasonably close to the estimated duration (i.e. within 10%), then proceed to Step 5; otherwise, repeat this step with a new estimate of the duration. T_c should not be less than 5-minutes or more than 60-minutes. If the final T_c is greater than 60-minutes, re-delineate the watershed into smaller sub-basins or use the Unit Hydrograph Method. Use the final T_c as the duration and read a final value of i from the I-D-F plot.
5. Q: Determine the peak discharge Q by using the above value of i in Equation 7.1.
6. As an alternative to the above procedure, the DDMSW program may be used to calculate peak discharge.

7.3.3.2 Multiple Basin Approaches

The Rational Method can be used to compute peak discharges at intermediate locations within a drainage area that is less than 160 acres in size. A typical application of this approach is a local storm drain system where multiple sub-basins are necessary to compute a peak discharge at each proposed inlet location. Consider the schematic example watershed shown in Figure 7.10. A peak discharge is needed for all three individual sub-basins, sub-basins A and B combined at Concentration Point 1 and sub-basins A, B and C combined at Concentration Point 2.

There are two accepted methods in Mohave County for computing peak discharges for multiple basins using the Rational Method. The first method is the traditional approach that relies upon combining the sub-basin areas into a single watershed, computing a new T_c, an arithmetically area-weighted value of C for the combined sub-basins, and then computing the peak discharge. This approach is referred to as the "Combined Watershed Approach." The second method is the "Triangular Hydrograph Approach." A triangular hydrograph is created for each sub-basin where the time-to-peak is assumed equal to T_c and the hydrograph time base is equal to $2.67T_c$, as shown on Figure 7.11. Referring to Figure 7.10 for example, the ordinates of hydrographs for sub-basins A and B at CP 1 are added to obtain the total flow hydrograph at CP 1. That hydrograph is then lagged downstream to CP 2 by the estimated travel time in the roadway, pipe, or channel. The lagged hydrograph is then added to the sub-basin C hydrograph to obtain the peak discharge at CP 2. Only the Triangular Hydrograph Method is implemented in the DDMSW computer program. The Combined Hydrograph Method may be used when the engineer/hydrologist does not have access to a computer running DDMSW.

Figure 7.10 Example watershed

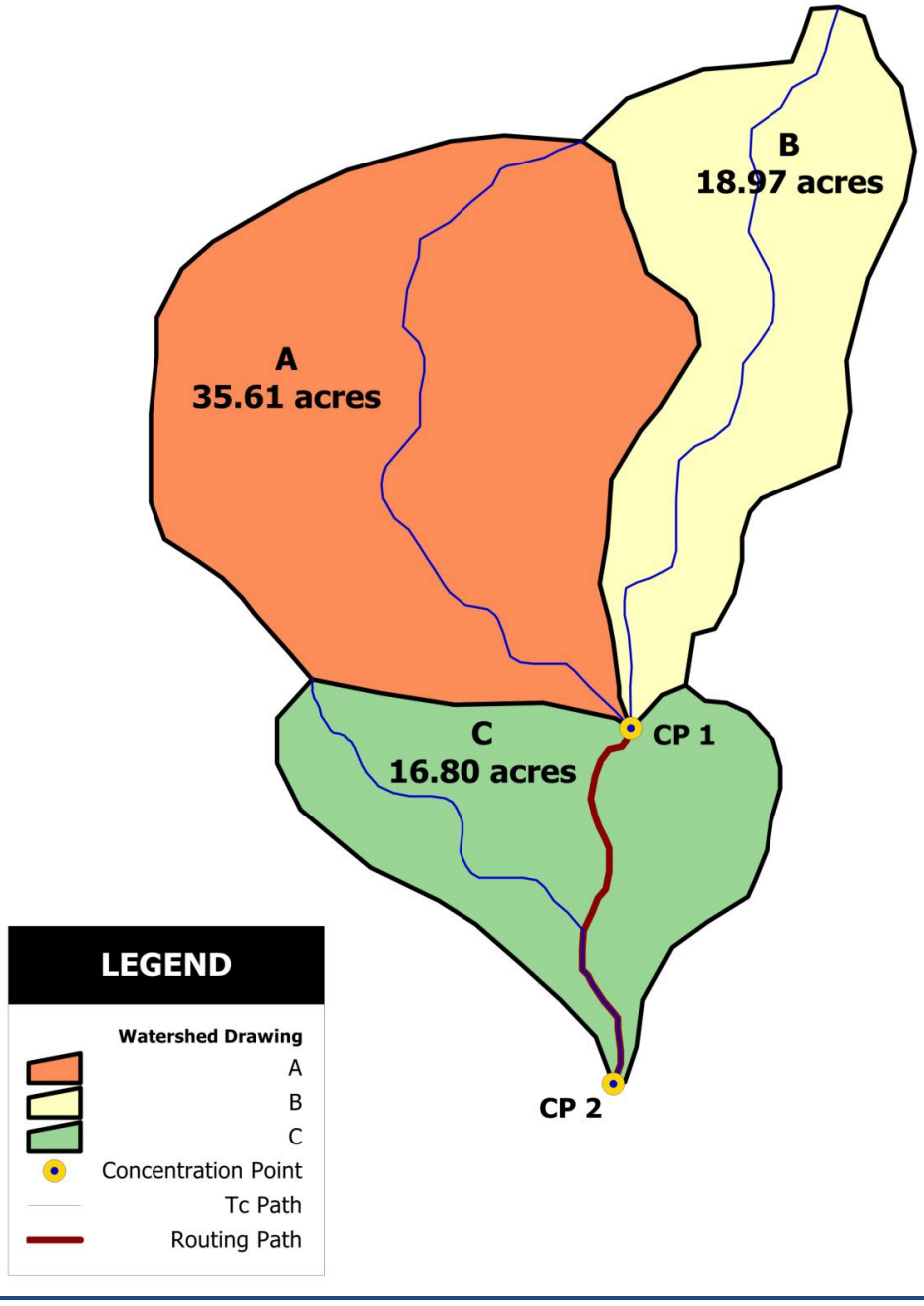
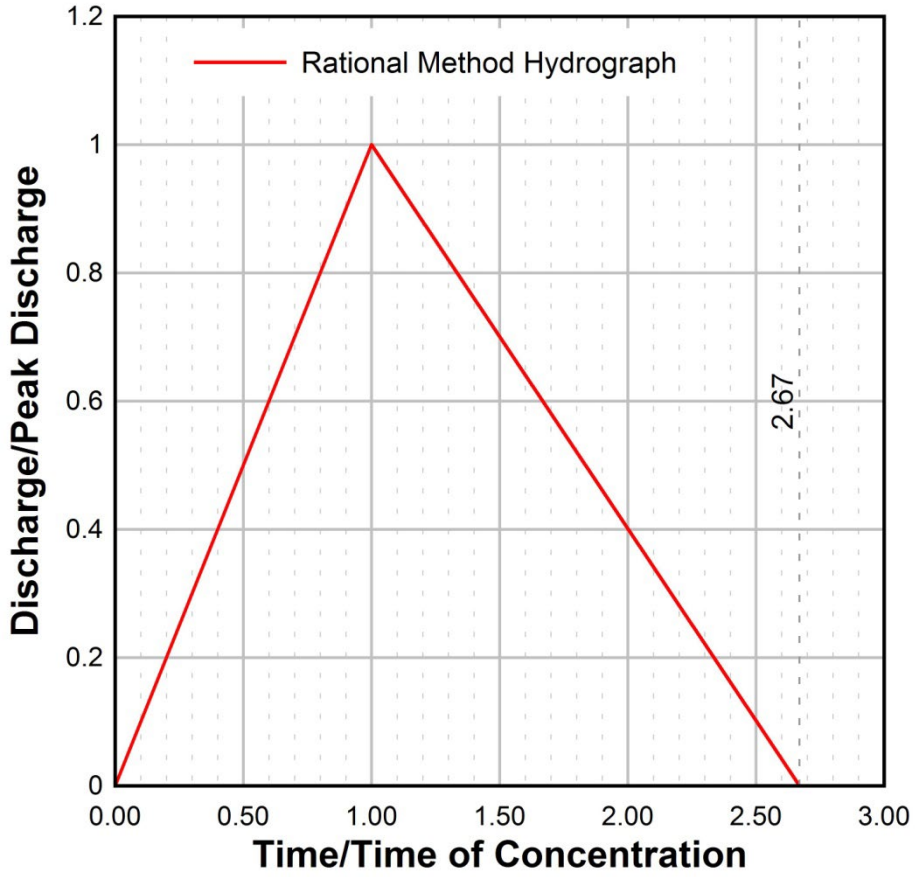


Figure 7.11 Triangular hydrograph for use with the Rational Method

Derived from: *Highway Hydrology* (FHWA, 2002)

(modified based on analysis of urban flow gage hydrograph data for short duration high intensity storms on watersheds less than 160 acres in Maricopa County)



Instructions for Combined Watershed Approach

1. Compute the peak discharge for each individual sub-basin using steps 1 through 5 from Section 7.3.3.1.
2. Compute the arithmetically area-weighted value of *C* for combined sub-basins A and B.
3. Follow step 4 from Section 7.3.3.1 to calculate the T_c for the combined area of sub-basins A and B at CP 1.
4. Compare the T_c values from sub-basins A and B to the T_c value for the combined area at CP 1. Compute the peak discharge at CP 1 using the *i* for the longest T_c from step 3. If the combined peak discharge is less than the discharges for the individual sub-basins, use

the largest discharge as the peak discharge at CP 1. The design peak discharge SHOULD NOT DECREASE going downstream in a conveyance system unless storage facilities are used to attenuate peak flows.

NOTE: If there are more than two watersheds being combined, and the combined peak discharge is less than any of the individual sub-basin peak discharges, another check needs to be made. A long narrow watershed having a long T_c may not be representative of the majority of the combined watershed and could be the reason the combined sub-basin peak discharge is too low. A combination of the other sub-basins may be more appropriate, using a computed T_c for the new combination. The T_c cannot be greater than 60 minutes.

5. Compute the arithmetically area-weighted value of C for combined sub-basins A, B and C.
6. Calculate the T_c for the combined area at CP 2 using the following two methods (T_c cannot be greater than 60 minutes):
   a. Method 1 - Follow step 4 from Section 7.3.3.1 to calculate the T_c for the single basin composed of all three sub-basins.
   b. Method 2 - Compute the travel time from CP 1 to CP 2 using the Manning equation or other appropriate technique and hydraulic parameters for the conveyance path. Add the computed travel time for the conveyance path to the T_c from CP 1.
7. Using the T_c values from Methods 1 and 2 as well as the T_c from sub-basin C, calculate the peak discharge at CP 2 as follows:
   a. If the T_c value from Method 1 is the longest, compute the total peak discharge using the Method 1 intensity, the arithmetically area-weighted value of C for all three subareas and the total contributing drainage area at CP 2.
   b. If the T_c value from Method 2 is the longest, determine i directly from the D-D-F statistics from step 3 of Section 7.3.3.1. Compute the total peak discharge at CP 2 using the arithmetically area-weighted value of C for all three sub-basins and the total contributing drainage area at CP 2.
   c. If the T_c from subarea C is the longest, compute the total peak discharge using the i for sub-basin C, the arithmetically area-weighted value of C for all three sub-basins and the total contributing drainage area at CP 2.

Instructions for Triangular Hydrograph Approach

1. Compute the peak discharge for each individual sub-basin using steps 1 through 5 from Section 7.3.3.1.
2. Plot triangular hydrographs for sub-basins A and B on a single sheet of graph paper using the dimensionless triangular hydrograph shown in Figure 7.11 as the model. The peak discharge occurs at time T_c and the hydrograph time base is $2.67T_c$.
3. Add the hydrograph ordinates from sub-basins A and B to produce and plot a combined hydrograph at CP 1.
4. Compute the travel time from CP 1 to CP 2 using the Manning equation or other appropriate technique and hydraulic parameters for the conveyance path.

5. Plot the hydrograph for sub-basin C on a new piece of graph paper, starting at time = 0.0. Plot the hydrograph for CP 1 starting at time = travel time from CP 1 to CP 2.
6. Add the hydrograph ordinates from CP 1 and sub-basin C to produce and plot a combined hydrograph at CP 2.
7. As an alternative to the above procedure, the DDMSW program may be used to calculate the peak discharge at intermediate locations.

7.3.3.3 Example

Refer to Appendix A.2 for an example of application of the Rational Method.

7.4 RAINFALL LOSSES

7.4.1 INTRODUCTION

Rainfall excess is that portion of the total rainfall depth that drains directly from the land surface by overland flow. By a mass balance, rainfall excess plus rainfall losses equals total rainfall.

This chapter is only applicable when performing rainfall runoff modeling with the HEC1 program. The design rainfall is determined from the procedures in Section 7.2, and this chapter provides procedures to estimate the runoff from the applied rainfall. When using the Rational Method, it is not necessary to estimate rainfall losses by the procedures in this chapter because the C factor accounts for the effect of rainfall loss on the peak discharge and runoff volume.

One of two methods shall be used to estimate rainfall losses; the primary method is to be used for the majority of cases, and the secondary method is to be used only for special cases when it is determined that the primary method is inappropriate. The primary method requires the estimation of the rainfall infiltration loss by the Green and Ampt equation. This model, first developed in 1911 by W.H. Green and G.A. Ampt, has since the early 1970's received increased interest for estimating rainfall infiltration losses. A sound and concise explanation of the Green and Ampt equation is provided by Bedient and Huber (1988) and Chow, Maidment and Mays (1988).

The secondary method requires the estimation of the initial loss and a uniform loss rate (IL+ULR method). The secondary method is to be used for watersheds or sub-basins where rainfall losses are known to be controlled by factors other than soil texture and vegetation cover, or for watersheds that are predominantly composed of sand or volcanic cinder overlain by forest duff where the Green and Ampt equation is not appropriate. Infiltration is not controlled by soil texture in such watersheds and infiltration rates may be as high as 5 inches per hour or more. Use of the secondary method requires adequate data or appropriate studies to verify the IL+ULR parameters or to calibrate the model of the watershed.

Both methods are described in detail in the following sections.

7.4.2 GREEN AND AMPT METHOD

7.4.2.1 General

Use of the Green and Ampt equation as coded in HEC-1 involves the simulation of rainfall loss as a two-phase process, as illustrated in Figure 7.12. The first phase is the simulation of the surface retention loss. This loss is called the initial loss (IA) in HEC-1. During this first phase, all rainfall is lost (zero rainfall excess generated) during the period from the start of rainfall up to the time that the accumulated rainfall equals the value of IA. It is assumed, for modeling purposes that no infiltration of rainfall occurs during the first phase. The second phase of the rainfall loss process is the infiltration of rainfall into the soil matrix. For modeling purposes, the infiltration begins immediately after the surface retention loss (IA) is completely satisfied, as illustrated in Figure 7.12.

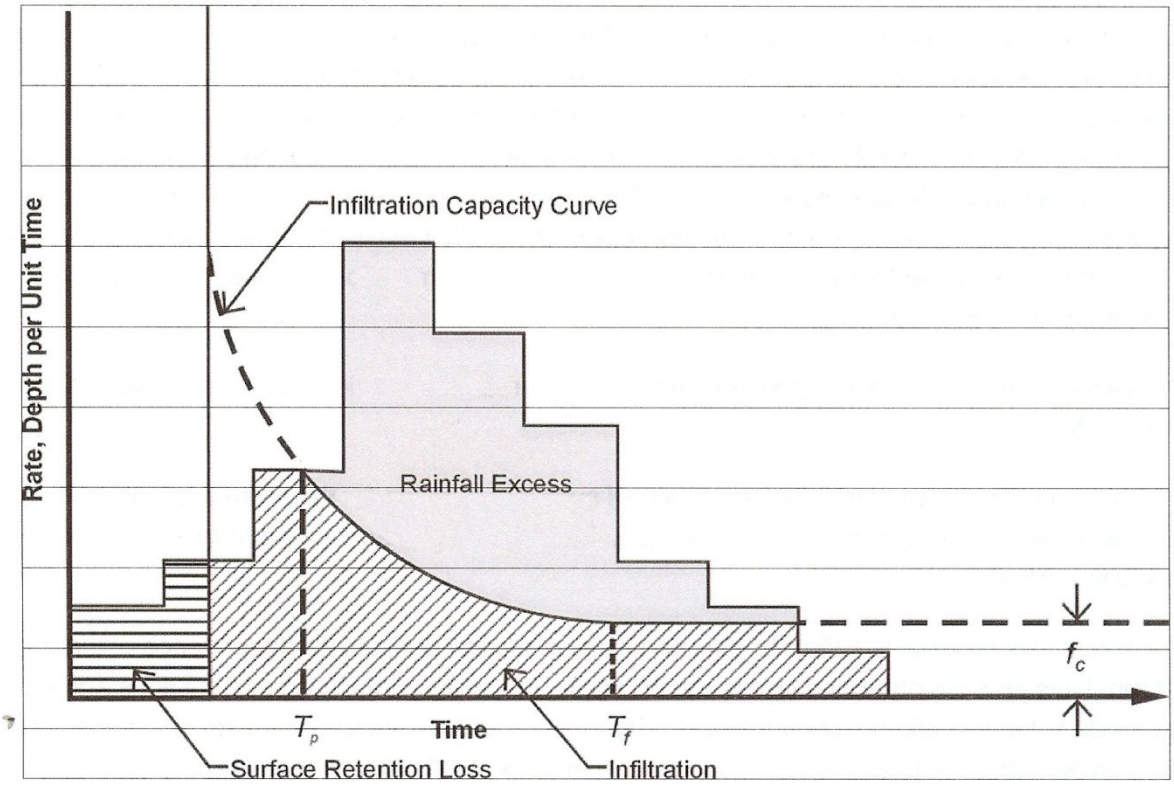
7.4.2.2 Applicability

The Green and Ampt infiltration equation, along with an estimate of the surface retention loss can be used to estimate rainfall losses for most areas of Mohave County with confidence. Most soils in Mohave County are loamy sand, sandy loam, loam, or silt loam for which the Green and Ampt infiltration equation parameters should apply. Silt, as a soil texture, is relatively rare and it is not expected that significant areas will be encountered. The finer soil textures (those with 'clay" in the classification name) occur in Mohave County but not usually over large areas; however, these soils have relatively low infiltration rates (*XKSAT*). Use of the Green and Ampt Infiltration equation parameters for the finer soil textures may be somewhat conservative, and therefore their use should be appropriate for most design flood estimation purposes. Sand, as a soil texture, is also relatively rare and it has a very high infiltration rate (*XKSAT*). Therefore, when encountering large areas that have soils that are classified as sand, it is possible that estimates of rainfall losses with the Green and Ampt Equation would be too large and the IL+ULR method should be used.

In general, the Green and Ampt Infiltration equation with an estimate of the surface retention loss should be used for most drainage areas in Mohave County. The IL+ULR method should be used for drainage areas where soil texture does not control the infiltration rate (such as volcanic cinder) or where the soil texture of the drainage area is predominantly sand. Calibration data or results of regional studies are necessary to justify the selection of parameters for the IL+ULR method.

The Green and Ampt equation should be applied for the one percent storm (100-year) and more frequent storms. This method is also suitable for use with less frequent storms but the parameters IA and volumetric storage of infiltrated rainfall may not be significant for large rainfall amounts associated with storms less frequent than the one percent storm.

Figure 7.12 Simplified representation of rainfall losses (a function of surface retention losses plus infiltration)



7.4.2.3 Method Description

The first phase of the rainfall loss process is simulated with the Surface retention loss (IA) parameter. The second phase is simulated with the Green and Ampt equation. Implementation of both phases of the rainfall loss process for rainfall runoff modeling in Mohave County is discussed in the following sections.

Surface Retention Loss, IA

Surface retention loss, as used herein, is the summation of all rainfall losses other than infiltration. The major component of the surface retention loss is depression storage; relatively minor components of surface retention loss are due to interception and evaporation. Depression storage is considered to occur in two forms. First, in-place depression storage occurs at, and in the near vicinity of, the raindrop impact. The mechanism for this depression storage is the micro relief of the soil and soil cover. The second form of depression storage is the retention of surface runoff that occurs away from the point of the raindrop impact in surface depressions such as puddles, roadway gutters and swales, roofs, irrigation bordered fields and lawns, and so forth. A relatively minor contribution by interception is also considered as a part of the total surface retention loss.

Estimates of surface retention loss are difficult to obtain and are a function of the physiography and land-use of the area. The surface retention loss on an impervious surface has been estimated to be in the range 0.0625 inch to 0.125 inches by Tholin and Keefer (1960), 0.11 inches for 1 percent slopes to 0.06 inches for 2.5 percent slopes by Viessman (1967), and 0.04 inches based on rainfall-runoff data for an urban watershed in Albuquerque by Sabol (1983). Hicks (1944) provides estimates of surface retention losses during intense storms as 0.20 inches for sand, 0.15 inches for loam, and 0.10 inches for clay. Tholin and Keefer (1960) estimated the surface retention loss for turf to be between 0.25 and 0.50 inches. Based on rainfall simulator studies on undeveloped alluvial plains in the Albuquerque area, the surface retention loss was estimated at 0.1 to 0.2 inches (Sabol and others, 1982a). Rainfall simulator studies in New Mexico result in estimates of 0.39 inches for eastern plains rangelands and 0.09 inches for pinon-juniper hill slopes (Sabol and others, 1982b). Chow (1964) quotes Horton (1935) as stating that initial detention (IA) "commonly ranges from 1/8 to 3/4 inch for flat areas and 1/2 to 1.5 inches for cultivated fields and for natural grass lands or forests." Further research for estimating values of IA for various land uses and land surfaces is needed. All known reference sources for values of IA for use with the Green and Ampt equation are listed above and have been used in developing the data listed in Table 7.11.

IA is primarily a function of land-use and surface cover, and recommended values of IA for use with the Green and Ampt equation are presented in Table 7.11. For example, about 0.25 inches of rainfall will be lost to runoff due to surface retention for mountain terrain where there is high topographic relief (slopes > 10%) in Mohave County. For unincorporated Mohave

County, standard values for the natural and developed condition IA for each zoning category is provided in Table 7.25. The engineer or hydrologist should, in general, use the standard default values from Table 7.25, which are also built into the DDMSW computer program. The engineer/hydrologist should first examine the watershed characteristics to be sure the default values are appropriate.

Table 7.11 *IA* and *RTIMP* estimates for various land uses
(Source: Derived from ADOT, 1993; FCDMC, 2013a)

Land-use and/or Surface Cover (1)		Surface Retention Loss (*IA*), inches (2)	*RTIMP*, percent	
			Mean (3)	Range (4)
Natural				
Natural grasslands (flat slope)		0.50		
Rangeland, flat slope (moderate vegetation)		0.35	varies	varies
Rangeland, hill slopes (moderate vegetation)		0.15	varies	varies
Mountain, flat slope (vegetated)		0.50	varies	varies
Mountain, steep slopes (vegetated)		0.25	varies	Varies
Developed (Residential and Commercial)				
Single Family Residential	1/4 acre	0.25	40	25-55
	1/3 acre	0.25	30	20-40
	1/2 acre	0.25	23	15-30
	1 acre	0.30	18	10-25
	>=2 acres	0.30	15	5-25
Multi-Family Residential		0.25	50	40-60
Commercial		0.10	75	50-95
Industrial		0.20	70	50-90
Non-irrigated Landscape		0.10	varies	varies
Lawn and Turf		0.20	0	0
Pavement and Roof Tops		0.05	95	95
Agricultural				
Tilled fields irrigated pasture		0.50	0	0

Green and Ampt Parameters

The second phase of the rainfall loss process is simulated with the Green and Ampt equation and an estimate of watershed impervious area (*RTIMP*). The three Green and Ampt equation infiltration parameters as coded in HEC-1 are:

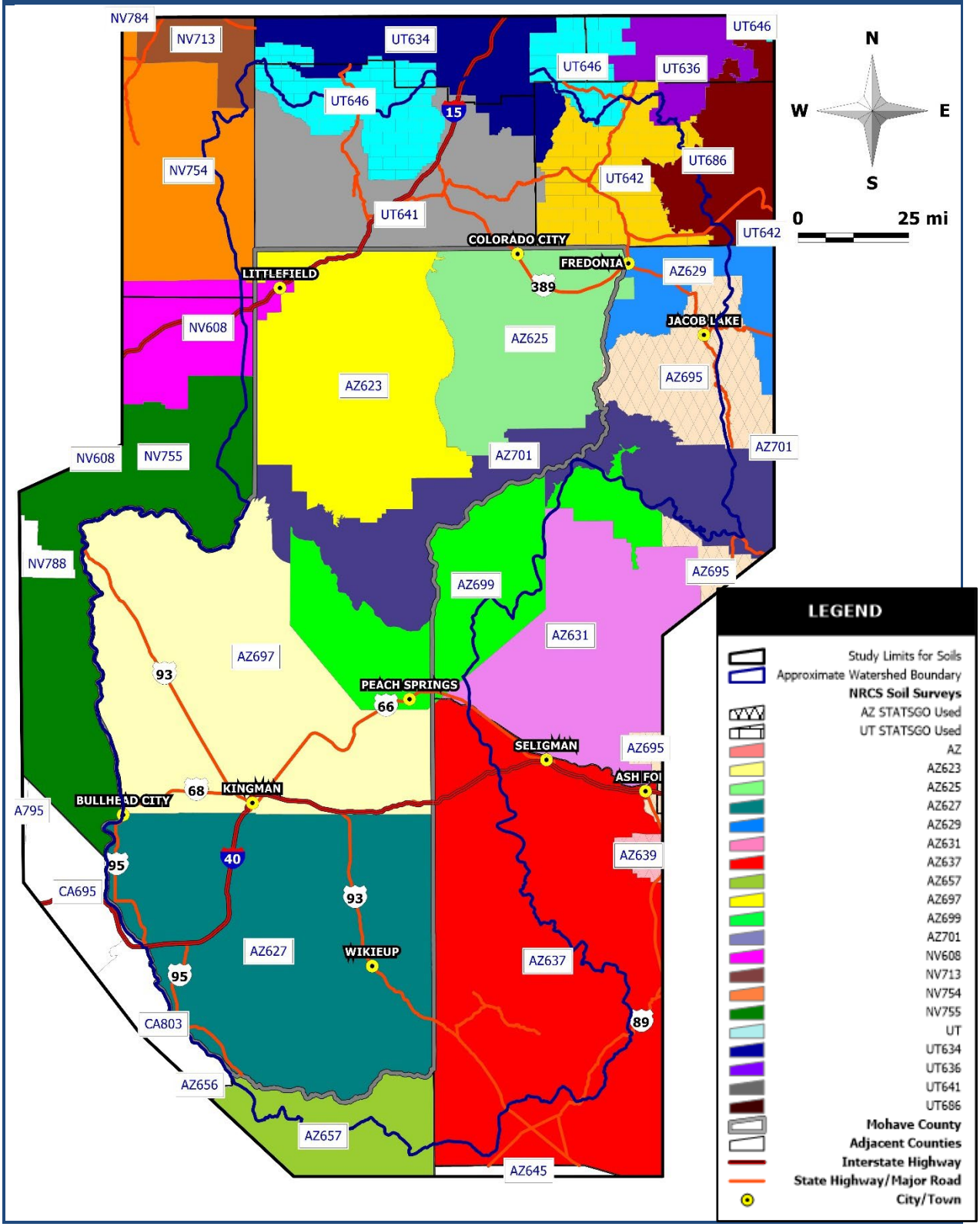
1. hydraulic conductivity at natural saturation (*XKSAT*);
2. wetting front capillary suction (*PSIF*); and
3. volumetric soil moisture deficit at the start of rainfall (*DTHETA*).

The three infiltration parameters are functions of soil characteristics, ground surface characteristics, and land management practices.

The soil characteristics of interest are particle size distribution including the percentage of sand and clay, gravel fractions, organic matter, and porosity. The primary soil surface characteristics are vegetation canopy cover, ground cover, and soil crusting.

Values of Green and Ampt equation parameters as a function of soil characteristics alone (bare ground condition) have been computed for soil map units from soil surveys prepared by the Natural Resources Conservation Service (NRCS) (NRCS Web Soil Survey). Refer to Figure 7.13 for the spatial location of the soil surveys used. A soil map unit, as defined in the Soil Taxonomy handbook (NRCS, 1999) is an individual polygon identified on a soil map by a map unit symbol and/or name that defines a three-dimensional soil body of a specified area, shape, and location on the landscape. The three-dimensional soil body is an aggregate of all soil delineations in a soil survey area that have a defined set of similar soil characteristics.

Figure 7.13 NRCS soil surveys used to estimate Green and Ampt parameters



GIS coverages of soil survey maps that define the geospatial location, limits and characteristics of soil map units for Mohave County and watersheds that drain into Mohave County, were obtained. Physical characteristics and soil properties available in database format as a part of the GIS coverages were used to compute average Green and Ampt parameters for each soil map unit. The computations were done using the equations and methods set forth in Saxton and Rawls (2006). These equations are based on values of percent sand, clay, gravel, organic matter, and porosity rather than a general texture classification as used in ADOT (1994) and the FCDMC (2013a).

The Saxton and Rawls (2006) equations produce a true saturated hydraulic conductivity, K_s. The Green and Ampt equation uses *XKSAT*, which is hydraulic conductivity at natural saturation. K_s must be adjusted to compute an estimate of *XKSAT* using Equation 7.8. The correction factor is necessary to adjust for entrapped air and other physical effects of a natural setting that limit infiltration effectiveness.

$$XKSAT = \mathrm{CF} * \mathrm{K_s} \qquad 7.8$$

Three sources are available for estimating the correction factor *CF*. The first is Bouwer (1966), which recommends a value of 0.5. This the correction factor adopted by ADOT and Maricopa County. The second is Morel-Seytoux and Khanji (1974), who furthered Bouwer's work and introduced a correction factor that varies with soil type and ponding depth, ranging from 0.6 to 0.9, with an average of 0.7. The Desert Research Institute (DRI) has recently begun investigating the relationship between K_s and XKSAT in partnership with the Flood Control District of Maricopa County. The research is focused on in the southwestern U.S. and may ultimately provide a much better understanding of this relationship. A recent DRI publication in this regard (Chen et al, 2010), for a watershed in Maricopa County, indicates the correction factor varies from less than 0.1 to 0.7. Until further research covering a larger range of soil types is completed, the single 0.5 correction factor is specified for use in Mohave County. Other correction factors may be used if substantiated by watershed specific infiltration studies. The testing methods used in such studies must be pre-approved by Mohave County.

The Saxton and Rawls (2006) equations include a compaction adjustment. For Mohave County, soils in an undisturbed natural condition are assumed to be at a compaction rating of "normal", which corresponds to a density factor (*DF*) of 1.0. Soils within developed areas that have been graded and re-compacted, or are subject to compaction from human activities, are assumed to

be at a compaction rating of "dense", which corresponds to a *DF* of 1.1. Two separate values for K_s and *XKSAT* were computed for each SMU using the density factors. $XKSAT_N$ refers to the natural condition *XKSAT*, and $XKSAT_D$ is the developed condition *XKSAT*. $XKSAT_N$ and $XKSAT_D$ are assigned by land use as listed in Table 7.25.

Refer to Appendix D for a description of the data sources and procedures used to compute the soil map unit Green and Ampt parameters for use in Mohave County. A single GIS polygon soils coverage, and five smaller (5) sub-area coverages, for Mohave County were prepared and are available for download from the Mohave County web site at: MCFCD Drainage Design Manual. These GIS coverages can be used as a stand-alone source for the Green and Ampt parameter *XKSAT*, or the Mohave County version of the DDMSW computer program can be used. Refer to Figure 7.14 for a map depicting the spatial variation of *XKSAT* for Mohave County watersheds. The *XKSAT* for all loamy sands and sands is set at a maximum of 2.0 inches/hour.

There are many soil map unit component soil types within the NRCS soil surveys for which values of the percentage of sand and clay are not provided. A soil texture was assigned using methods described in Appendix D.2.5 and then the value of *XKSAT* for the assigned texture was taken from Table 7.12. Where insufficient information is available for assigning a soil texture, conservative values of *XKSAT* were assigned. The engineer/hydrologist should check for the presence of any miscellaneous component soil types as the conservative assumption for *XKSAT* could significantly affect model results. For these cases, the areas where the miscellaneous soil types occur should be physically inspected and the default value of *XKSAT* adjusted to match observed conditions if necessary. A geotechnical investigation may need to be performed to obtain representative soil physical characteristics, including the percentages of sand, clay, gravel and organic matter. The Saxton and Rawls (2006) *Soil Water Characteristics* computer program may then be used to compute the value of K_s, which must then be corrected as described above to estimate XKSAT. The miscellaneous component soils requiring field verification are listed in Appendix D, Table D.4 with the NRCS soil surveys they occur in. The assumptions made for each miscellaneous component soil are listed in Appendix D, Table D.5. The general location of miscellaneous component soils is shown on Figure 7.15. Rock outcrop areas are also treated as miscellaneous component soils since soil parameters are also not provided for rock out crop component soil types. Rock outcrop is not shown on Figure 7.15. Refer to Figure 7.19. SMU's with rock outcrop should be carefully evaluated for reasonableness for the watershed being studied and estimates of rock outcrop field verified.

PSIF and *DTHETA* are assumed to be a function of *XKSAT*, as discussed in Appendix D. A value of *PSIF*, $DTHETA_{dry}$ and $DTHETA_{normal}$ were computed for every component soil and every component soil horizon used in the preparation of the Mohave County GIS soil coverage. A nonlinear regression analysis was then performed to provide equations for computing *PSIF* and *DTHETA* as a function of *XKSAT*. The equations computed are:

$$PSIF = 11.63103 * 0.15801^{XKSAT} \quad (7.9)$$

$$DTHETA_{Dry} = 0.36180 + 0.03953 * \log_e XKSAT \quad (7.10)$$

$$DTHETA_{Normal} = 0.28536 + 0.060058 * LOG_e(XKSAT) - 0.001009 * LOG_e(XKSAT)^2 - 0.000615 * LOG_e(XKSAT)^3 \quad (7.11)$$

These equations are plotted on Figure 7.16 and Figure 7.17. The average values of *XKSAT* and *PSIF* for each of the twelve general soil texture classes are shown in columns (2) and (3) of Table 7.12. Equations 7.9, 7.10, and 7.11 or Figure 7.16 and Figure 7.17 should be used for computation or selection of values of *PSIF* and *DTHETA* based on bare ground *XKSAT*. The values of *XKSAT* and *PSIF* from Table 7.12, Figure 7.16 and Figure 7.17 could be used for smaller studies being done by hand without the benefit of DDMSW or GIS; however, the use of DDMSW is recommended.

The *XKSAT* and *PSIF* parameter values that are shown in Table 7.12 for loamy sand and sand are very high. Using those parameters values for drainage areas can result in the generation of no rainfall excess which may or may not be correct. Incorrect results could cause serious consequences for flood control planning and design. Therefore, it is recommended to use a XKSAT equal to 2.0 inches/hour for watersheds consisting of relatively small subareas of sand. PSIF and DTHETA should be determined using Figure 7.16 and Figure 7.17, respectively. If the area contains a large portion of sand, the Green and Ampt method should be used with the stated parameter values or the Initial and Uniform Loss method should be used with the appropriately determined values for the parameters.

The methods presented herein can be accomplished using hand computation techniques including hard copy maps and use of a planimeter or other suitable method for estimating the areas of irregular polygons. The DDMSW computer program is the preferred method. DDMSW can be used for detailed studies where GIS polygons for the watershed sub-basins are available, and for relatively small areas by selecting the watershed location using maps provided within

DDMSW and letting it estimate average Green and Ampt parameters. More complex watersheds with detailed soils mapping including numerous polygons defining multiple soil textures may, from a practical standpoint, require analysis using DDMSW in combination with ESRI ArcMap GIS software.

Figure 7.14 Spatial variation of *XKSAT* for Mohave County watersheds

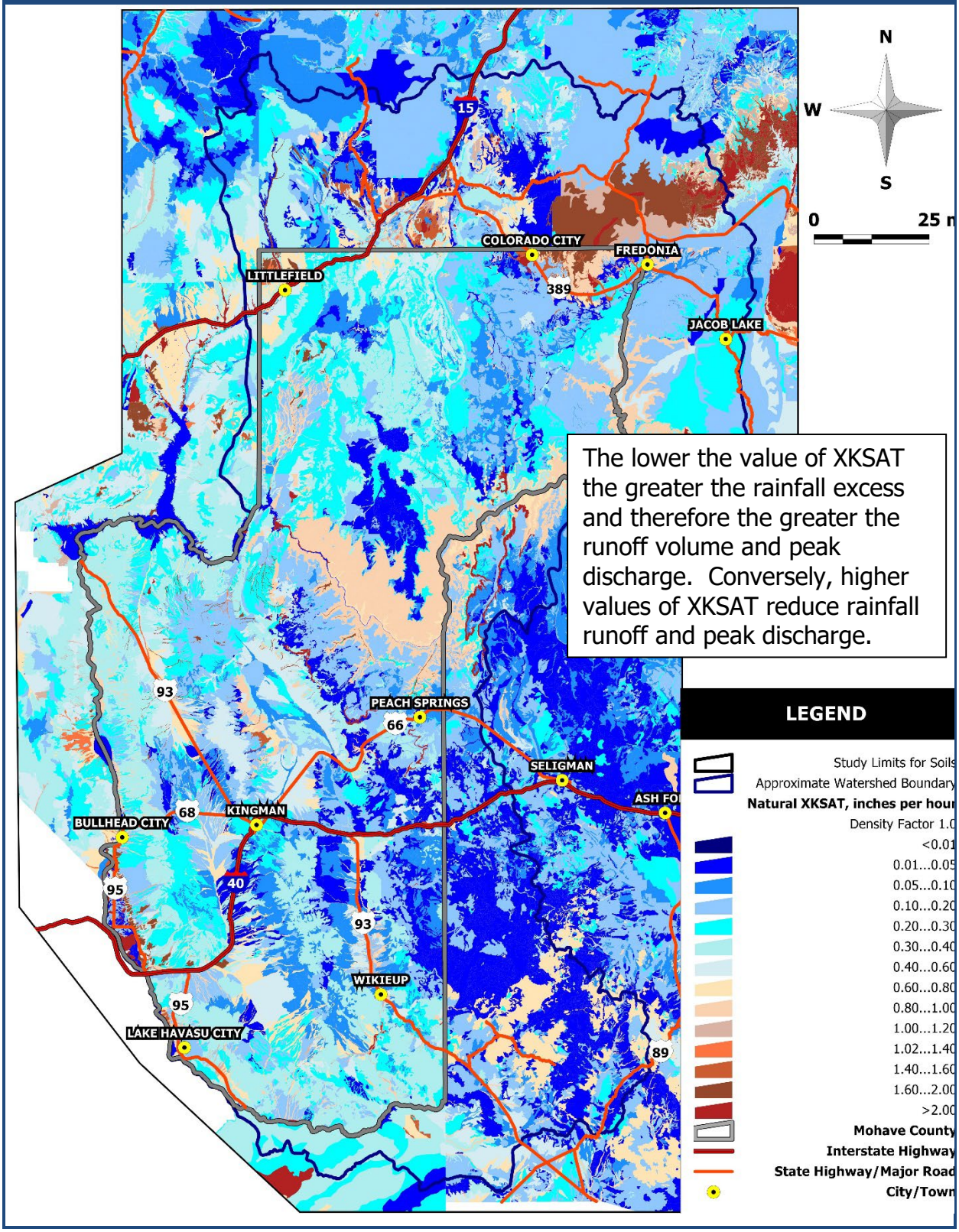


Figure 7.15 Miscellaneous component soils for Mohave County watersheds

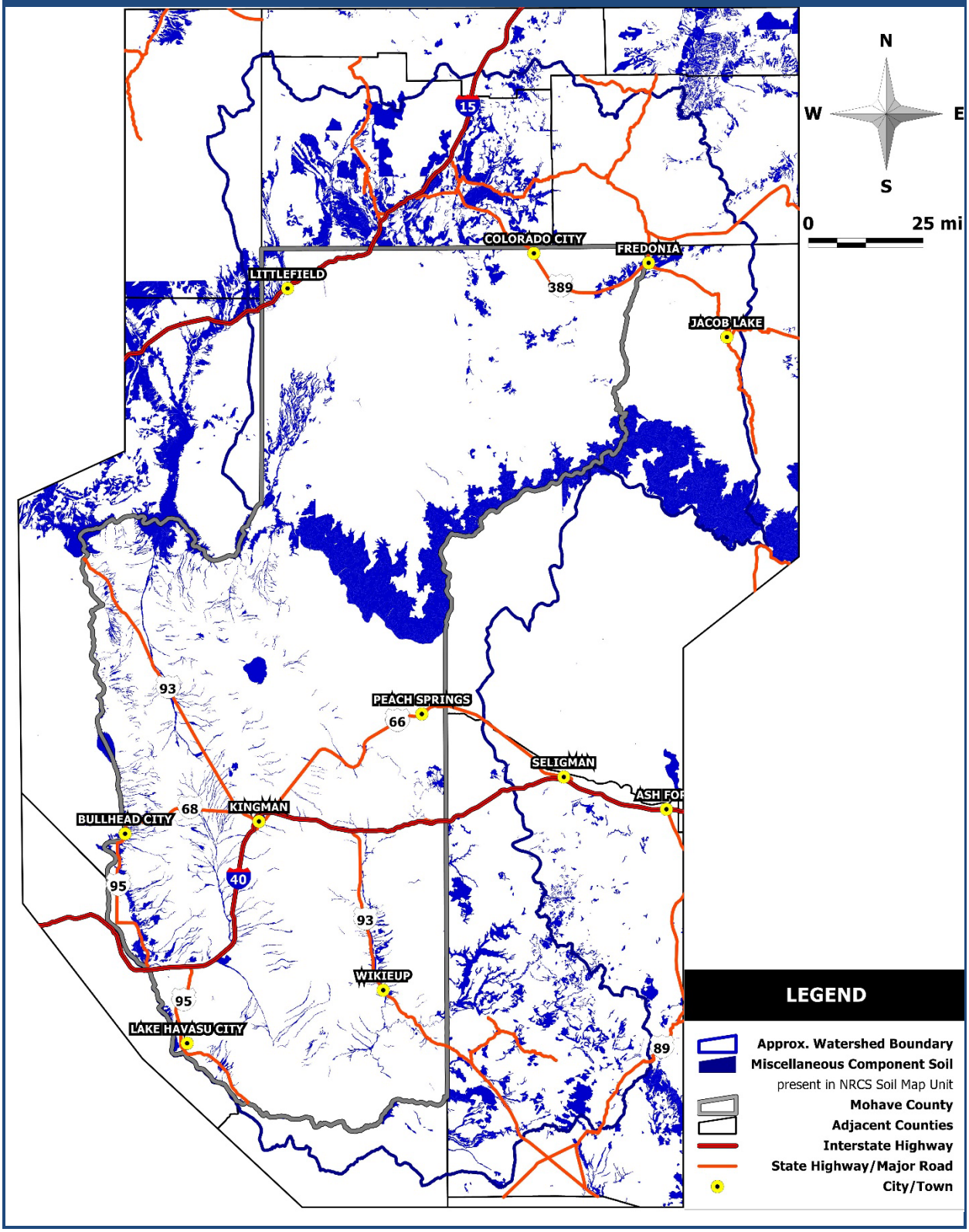


Figure 7.16 *PSIF* as a function of *XKSAT*

(computed from Mohave County watersheds NRCS soils data using information in Saxton and Rawls, 2006)

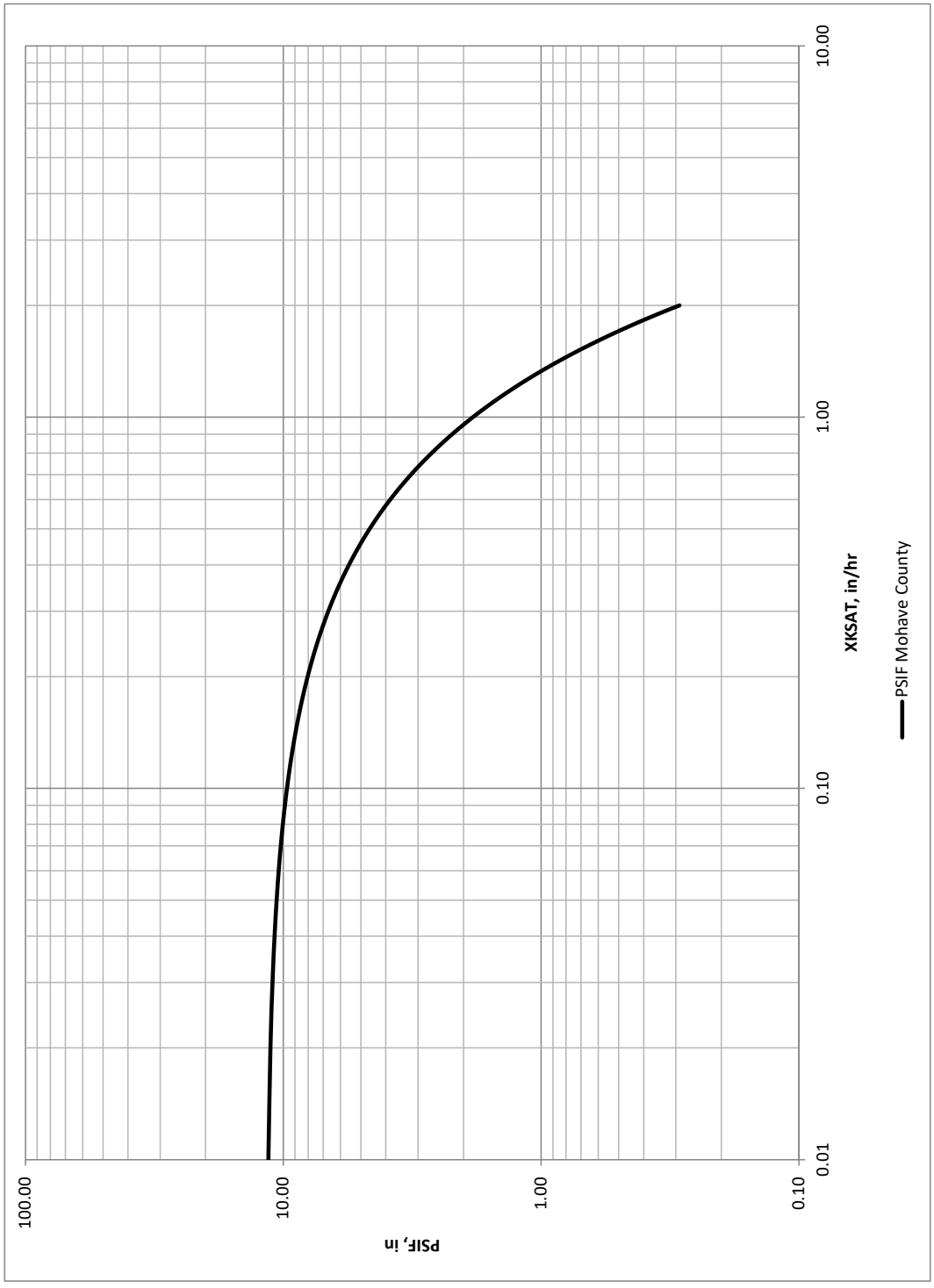


Figure 7.17 ***DTHETA*** **as a function of** ***XKSAT***

(computed from Mohave County watersheds NRCS soils data using information in Saxton and Rawls, 2006)

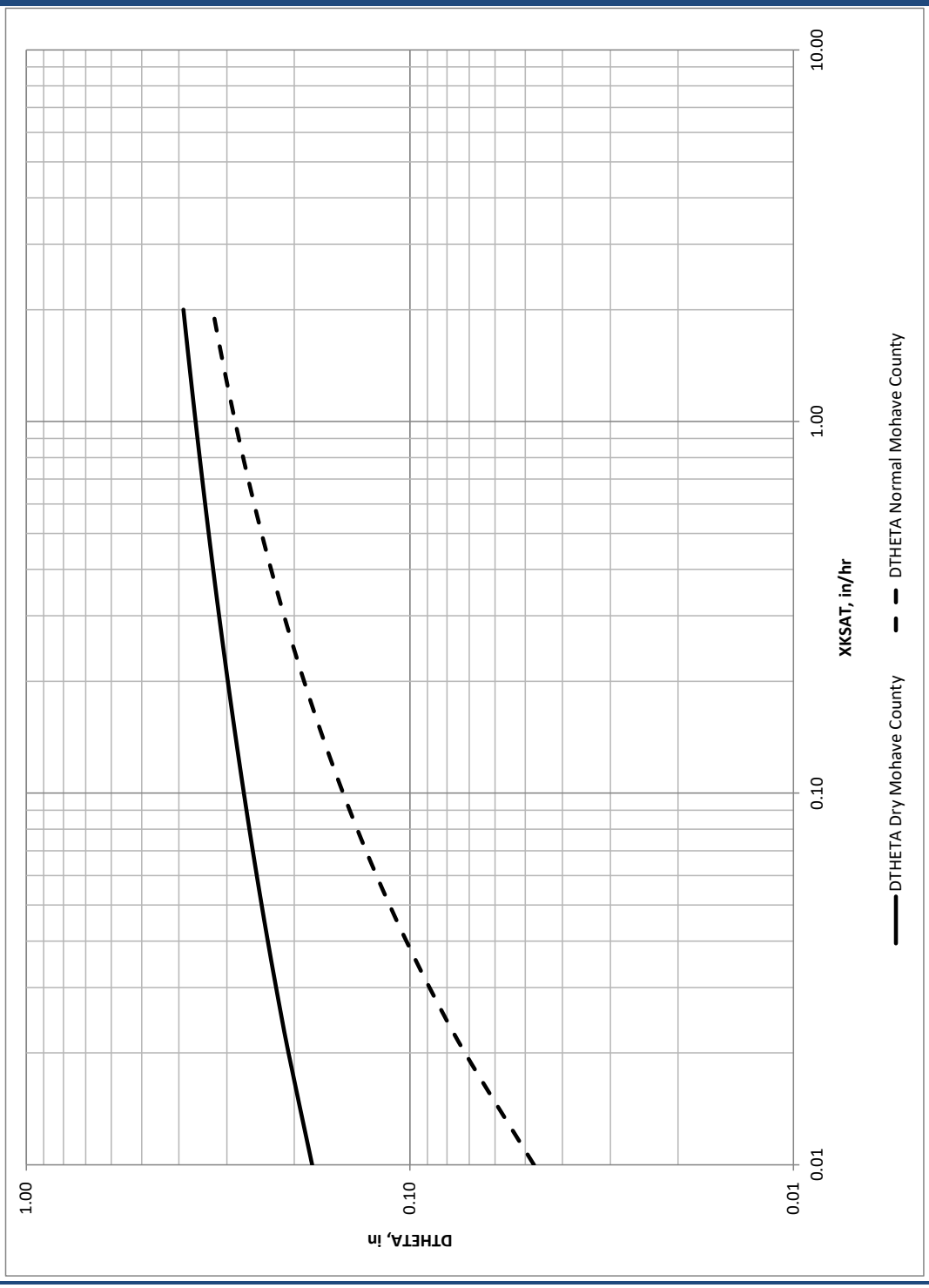


Table 7.12 Green and Ampt equation bare ground loss rate parameter values

(Source: derived from Saxton and Rawls, 2006)

Soil Texture Classification	K_s	$XKSAT_N$	*PSIF*	*DTHETA*[a]		
	in/hr	in/hr	inches	Dry	Normal	Saturated
(1)	(2)	(3)	(4)	(5)	(6)	(7)
sand[b]	4.03 (4.64)[c]	2.00	0.29 (0.38-9.98)	0.39 (0.35-0.48)	0.33	0.00
loamy sand	3.60 (1.18)	1.80	0.42 (0.53-11.00)	0.39 (0.33-0.48)	0.32	0.00
sandy loam	1.92 (0.43)	0.96	1.98 (1.05-17.90)	0.36 (0.28-0.54)	0.28	0.00
loam	0.61 (0.13)	0.30	6.69 (0.52-23.38)	0.31 (0.33-0.53)	0.21	0.00
silt loam	0.63 (0.26)	0.32	6.44 (1.15-37.56)	0.32 (0.39-0.58)	0.22	0.00
silt	0.80	0.40	5.56	0.33	0.23	0.00
sandy clay loam	0.44 (0.06)	0.22	7.75 (1.74-42.52)	0.30 (0.24-0.43)	0.19	0.00
clay loam	0.17 (0.04)	0.09	9.85 (1.89-35.87)	0.27 (0.28-0.50)	0.14	0.00
silty clay loam	0.23 (0.04)	0.12	9.32 (2.23-51.77)	0.28 (0.35-0.52)	0.16	0.00
silty clay	0.15 (0.02)	0.08	10.03 (2.41-54.88)	0.26 (0.33-0.51)	0.14	0.00
sandy clay	0.06 (0.02)	0.03	11.00 (1.61-55.20)	0.22 (0.21-0.44)	0.09	0.00
clay	0.04 (0.01)	0.02	11.21 (2.52-61.61)	0.21 (0.27-0.50)	0.07	0.00

[a] Selection of *DTHETA*:

Dry:	for non-irrigated lands such as desert and rangeland
Normal:	for irrigated lawn, turf, and permanent pasture
Saturated:	for irrigated agricultural lands

[b] The use of the Green and Ampt Infiltration Equation for drainage areas or sub-basins that are predominately sand or loamy sand should be avoided and the IL+ULR method should be used.

[c] Values in parentheses are from Rawls, Brakensiek and Miller (1983)

For sand and Loamy sand texture classes, use the following:

$XKSAT_N$ = 2.00 in/hr

PSIF = 0.29 in

$DTHETA_{dry}$ = 0.39 in

$DTHETA_{normal}$ = 0.33 in

Values of K_s can vary significantly within a given texture class as shown in the following table. These values were generated using Saxton and Rawls (2006) *Soil Water Characteristics* computer program.

Soil Texture Classification	K_s (in/hr)
sand[b]	3.36-9.61
loamy sand	1.54-6.71
sandy loam	0.43-4.56
loam	0.12-1.35
silt loam	0.07-1.81
silt	0.09-0.55
sandy clay loam	0.09-0.76
clay loam	0.05-0.17
silty clay loam	0.06-0.10
silty clay	0.05-0.07
sandy clay	0.00-0.09
clay	0.00-0.05

Adjusting Bare Ground *XKSAT* for Vegetation Cover

The bare ground value of *XKSAT* can be affected by several factors besides soil texture. For example, hydraulic conductivity is reduced by soil crusting, increased by tillage, and increased by the influence of ground cover and canopy cover. The values of *XKSAT* that are presented for bare ground as a function of soil texture alone should be adjusted under certain soil cover conditions. Ground cover, such as grass, litter, and gravel, will generally increase the infiltration rate over that of bare ground conditions. Similarly, canopy cover such as from trees, brush, and tall grasses can also increase the bare ground infiltration rate. The procedures and data that are presented above for estimating the Green and Ampt parameters are applicable for bare ground conditions. Past research has shown that *PSIF* is relatively insensitive in comparison with *XKSAT*; therefore, only the hydraulic conductivity parameter is adjusted for the influences of cover over bare ground.

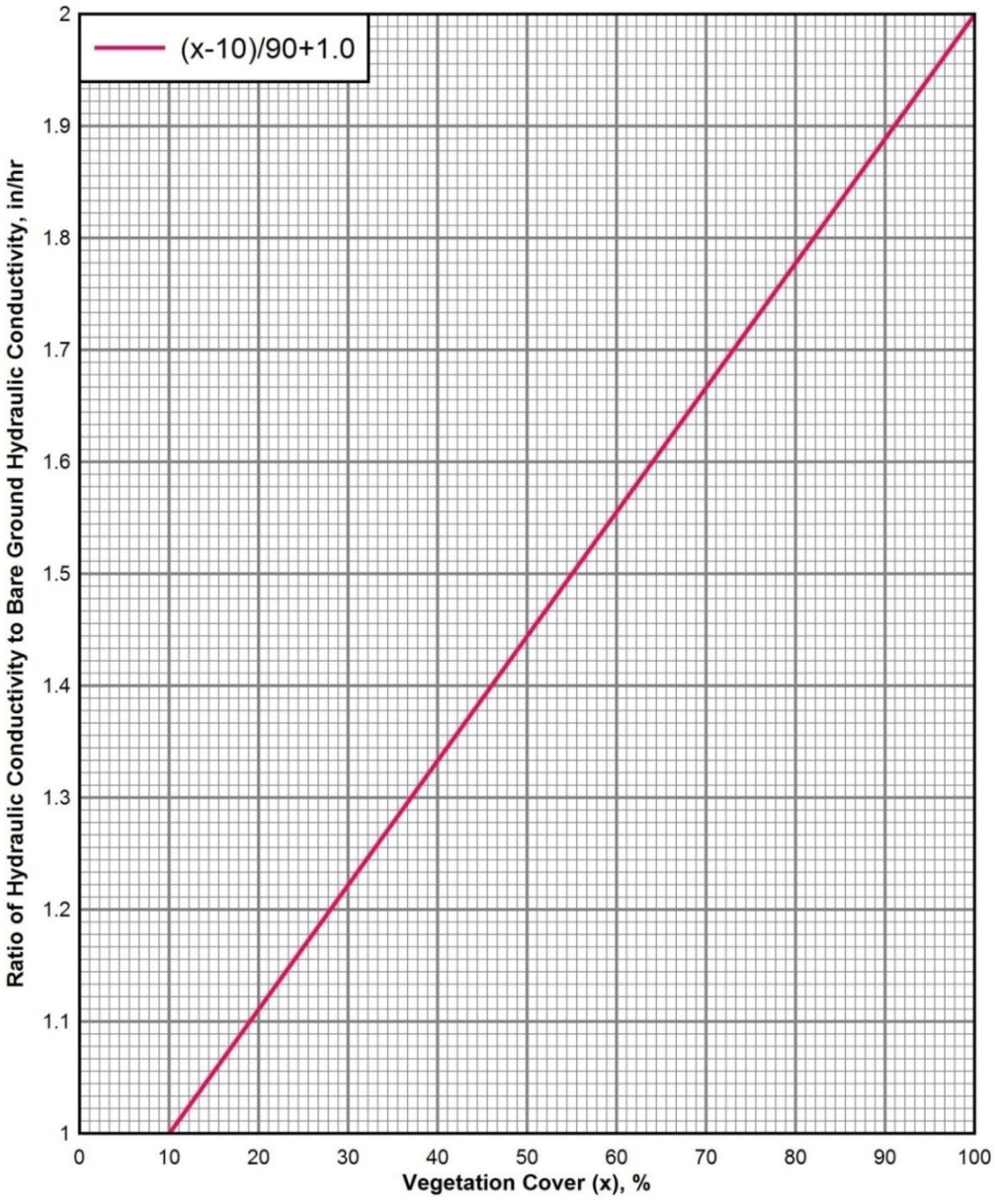
Procedures have been developed (Rawls and others, 1989) for incorporating the effects of soil crusting, ground cover, and canopy cover into the estimation of hydraulic conductivity for the Green and Ampt equation; however, those procedures are not recommended for use in Mohave County at this time. A simplified procedure to adjust the bare ground hydraulic conductivity for vegetation cover is shown in Figure 7.18. This figure is based on the documented increase in hydraulic conductivity due to various soil covers as reported by investigators using rainfall simulators on native western rangelands (Kincaid and others, 1964; Sabol and others, 1982a; Sabol and others, 1982b; Bach, 1984; Ward, 1986; Lane and others, 1987; Ward and Bolin, 1989). This correction factor can be used based on an estimate of vegetation cover as provided by the NRCS in soil surveys; that is, vegetation cover is evaluated on basal area for grass and forbs and is evaluated on canopy cover for trees and shrubs. Note that this correction can be applied only to soils other than sand and loamy sand.

The influence of tillage results in a change in total porosity and therefore a need to modify the three Green and Ampt equation infiltration parameters. The effect of tillage systems on soil porosity and the corresponding changes to hydraulic conductivity, wetting front capillary suction, and water retention is available (Rawls and Brakensiek, 1983). Although this information is available, it is not presented in these guidelines, nor is it recommended that these adjustments be made to the infiltration parameters for design purposes in Mohave County. For most flood estimation purposes, it cannot be assumed that the soil will be in any particular state of tillage at the time of storm occurrence and therefore the base condition

infiltration parameters, as presented, should be used for flood estimation purposes. However, appropriate adjustment to the infiltration parameters can be made, as necessary, for special flood studies such as reconstitution of storm events.

Figure 7.18 Effect of vegetation cover on hydraulic conductivity

Source: FCDMC (2013a)



Note: For all soil textures other than Sand and Loamy Sand. Do not use for *XKSAT*>2.00 in/hr.

Correction of *XKSAT* for vegetation cover using Figure 7.18 is made after the composite value of bare ground *XKSAT* is estimated for a basin or sub-basin. A procedure for estimating vegetation canopy cover density for natural watersheds is presented in Appendix C.

For unincorporated Mohave County, standard values for the natural and developed condition vegetation cover density for each terrain class and zoning category are provided in Table 7.25. The engineer or hydrologist may use the standard default values from Table 7.25, which are also built into the DDMSW computer program. If values other than the standard defaults are more appropriate, the engineer/hydrologist should estimate new values using the procedure in Appendix C or other method approved by Mohave County.

The rainfall loss estimation process also includes the parameter "effective impervious area." In HEC-1, this parameter is coded as the variable *RTIMP*. An estimate of *RTIMP* is needed for each sub-basin. HEC-1 computes no rainfall losses for the percentage of sub-basin area input for *RTIMP*.

Effective Impervious Area, *RTIMP*

Impervious area (or nearly impervious area) is composed of rock outcrop, paved roads, parking lots, roof tops, and so forth. When performing watershed modeling with the HEC-1 program, the impervious area is to be the effective (directly connected) impervious area. For urbanized areas, the effective impervious area should be estimated from aerial photographs with guidance as provided in Table 7.11. For unincorporated Mohave County, standard values for the natural and developed condition *RTIMP* for each zoning category are provided in Table 7.25. The engineer or hydrologist may use the standard default values from Table 7.25, which are also built into the DDMSW computer program. If values other than the standard defaults are more appropriate, the engineer/hydrologist should estimate new values based on estimates of actual *RTIMP* measured by field survey or from aerial photographs. For areas that are presently undeveloped but for which flood estimates are desired for future urbanized conditions, estimates of effective impervious area should be obtained based on regional planning and land-use zoning as determined by the local jurisdiction. Estimates of the effective impervious area for urbanizing areas should be selected from local guidance, if available, along with the general guidance that is provided in Table 7.11, and the more detailed guidance in Table 7.25.

For undeveloped areas, the effective impervious area is often 0 percent. However, in some watersheds there could be extensive rock outcrop or areas of water such as reservoirs that

would greatly increase the imperviousness of the watershed. Refer to Figure 7.19 for an overview of the percentage of rock outcrop present in each SMU. Care must be exercised when estimating effective impervious area for rock outcrop. Often the rock outcrop is relatively small (in terms of the total drainage area) and is of isolated units surrounded by soils of relatively high infiltration capacities. Relatively small, isolated rock outcrop may not be effective impervious area because runoff must pass over pervious surfaces before reaching the point of discharge concentration. However, impervious areas that are not hydraulically directly connected may still be included in the estimate of sub-basin *RTIMP* if the intended result includes a conservative estimate of rainfall runoff volume. Often, the *RTIMP* value for such areas is reduced by a factor determined using engineering judgment.

For watersheds that have significant, contiguous rock outcrop, it may be necessary to establish those areas as separate sub-basins so that the direct runoff can be estimated and then routed (with channel transmission losses, if appropriate) to the point of interest. Paved roads through undeveloped watersheds will not normally contribute to effective impervious area unless the road serves as a conveyance to the watershed outlet.

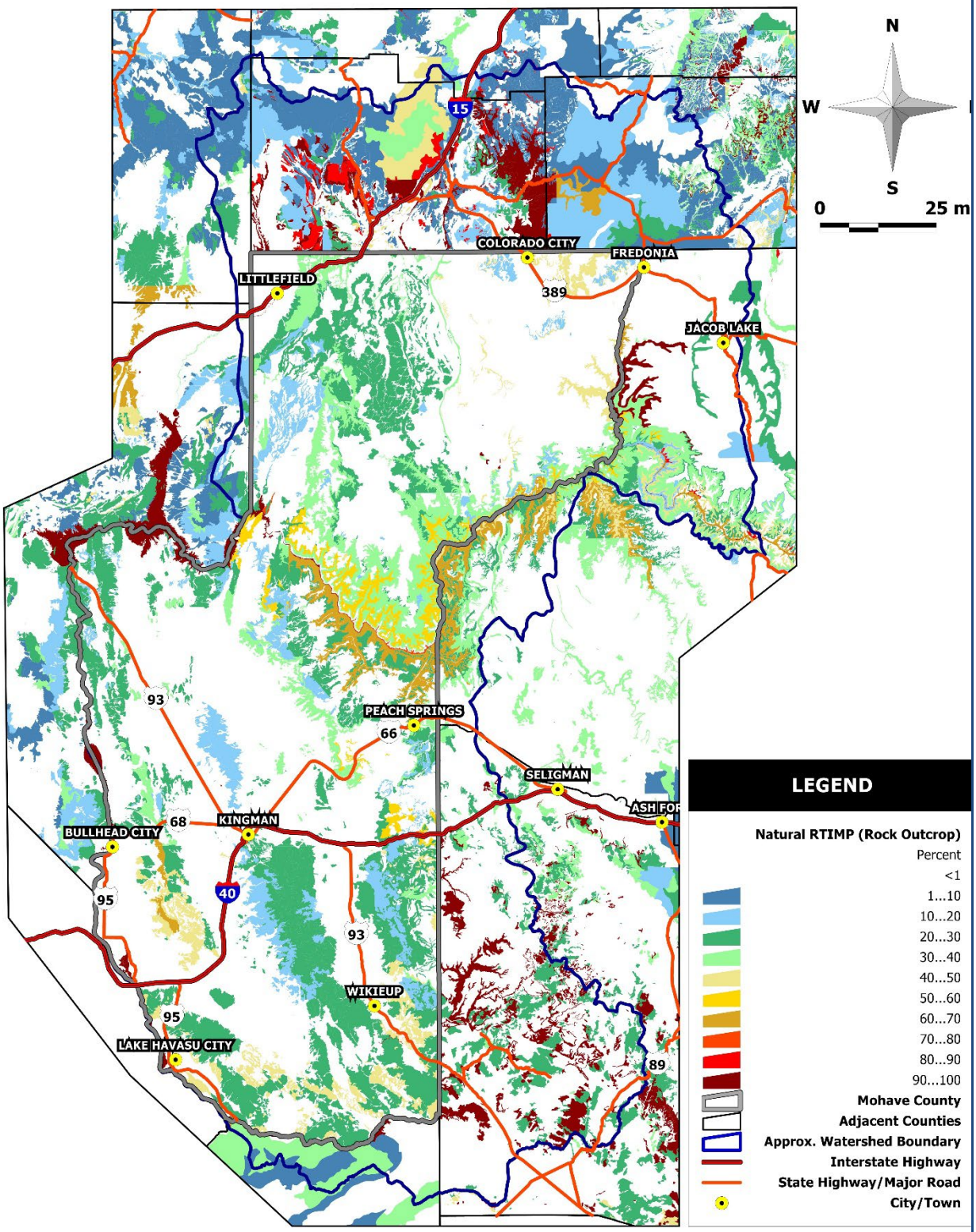
Sensitivity of Green and Ampt Equation Parameters

It is important for the modeler to be aware of the sensitivity of the Unit Hydrograph Method to the various input parameters. More time and effort is warranted for the sensitive parameters than for the less sensitive parameters. The possible effects of each of the parameters discussed above on computation of rainfall excess and peak discharge is shown in Table 7.13 relative to the one percent chance storm.

Table 7.13 Sensitivity of rainfall runoff computations to G&A parameters

Parameter	Storm Frequency		
	More Frequent	One Percent Storm	Less Frequent
IA	Moderate	Moderate-Low	Low
Bare Ground XKSAT	High-Very High	Moderate-High	Low-Moderate
XKSAT Adjustment for Vegetation	High-Very High	Moderate-High	Low-Moderate
PSIF	Directly related to XKSAT		
DTHETA	Low-Moderate	Low	Very Low
RTIMP	High-Very High	High	Moderate-High

Figure 7.19 Rock outcrop (natural RTIMP) for Mohave County



7.4.3 INITIAL LOSS PLUS UNIFORM LOSS RATE METHOD (IL+ULR)

7.4.3.1 General

This is a simplified rainfall loss estimation method that is often used, and generally accepted, for flood hydrology. It is assumed that the rainfall loss process can be simulated as a two-step procedure, as illustrated in Figure 7.20. The two steps are:

Step 1: All rainfall is lost to runoff until the accumulated rainfall is equal to the initial loss (STRTL).

Step 2: After the initial loss is satisfied, a portion of all future rainfall is lost at a uniform rate (CNSTL). All the rainfall is lost (runoff does not occur) if the rainfall intensity is less than the uniform loss rate.

The HEC-1 implementation of this method requires input of the three parameters: STRTL, CNSTL, and *RTIMP*.

7.4.3.2 Applicability

This method is acceptable for use when modeling very infrequent storms with high amounts of precipitation. It is also an acceptable method for more frequent storms when the dominate soils in the watershed are sand and/or loamy sand, or drainage areas where soil texture does not control the infiltration rate, such as areas of volcanic cinders. This method should not generally be used for the one percent and more frequent storms.

7.4.3.3 Method Description

Initial Loss

The initial loss, STRTL, can be assumed to consist of two components, the surface retention loss, IA, from the Green and Ampt method, and the initial infiltration, II. After the IA is satisfied, II includes all other losses that occur until the soil profile is saturated and a stabilized, uniform infiltration condition occurs. Therefore, STRTL is the sum of IA and II. IA can be estimated using Table 7.11. II can be estimated using Table 7.14.

Uniform Loss

The uniform loss parameter, CNSTL, is equivalent to the Green and Ampt method bare ground *XKSAT* parameter adjusted for vegetation cover and can be estimated using the procedures for adjusted *XKSAT*.

Table 7.14 IL+ULR Parameter values for bare ground

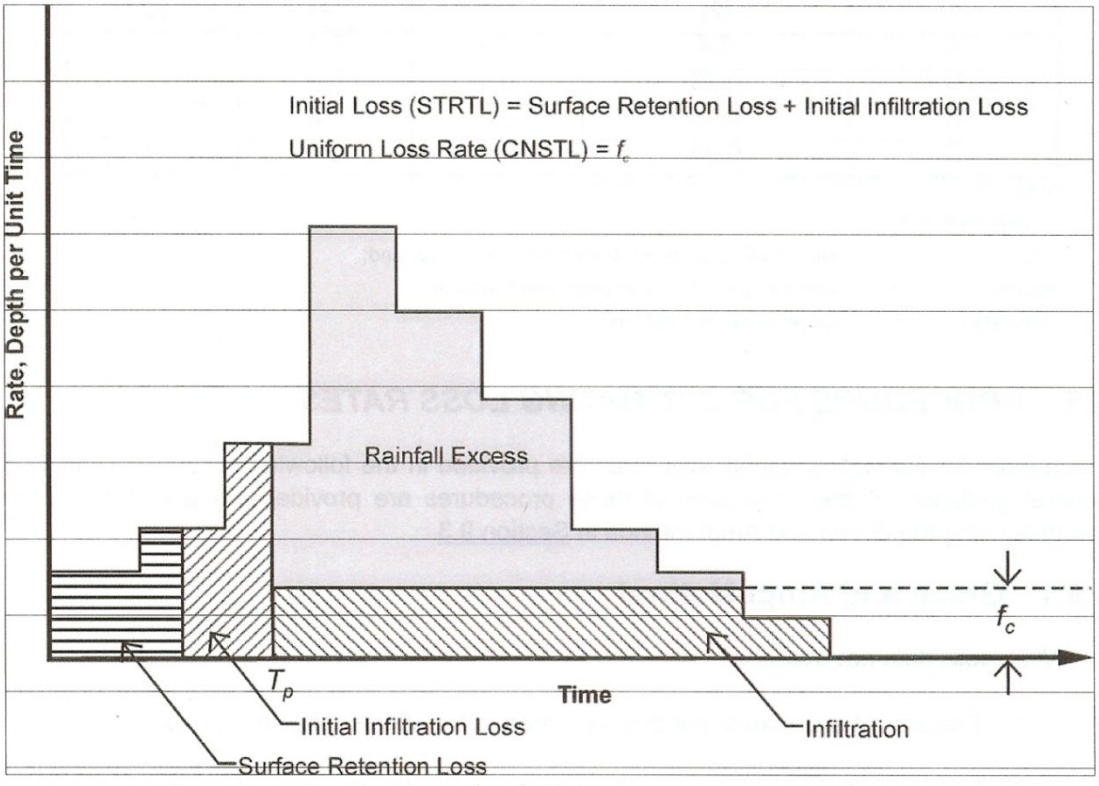
Source: FCDMC (2013a)

Uniform Loss Rate (CNSTL), in/hr	Initial Infiltration (II), inches[1]		
	Dry	Normal	Saturated
(1)	(2)	(3)	(4)
0.30 – 1.20	0.6	0.5	0
0.15 – 0.30	0.5	0.3	0
0.05 – 0.15	0.5	0.3	0
0.00 – 0.05	0.4	0.2	0

Notes:
[1] Selection of II:
Dry = Non-irrigated lands, such as mountain, hillslope and rangeland.
Normal = Irrigated lawn, turf, and permanent pasture.
Saturated = Irrigated agricultural land.

Figure 7.20 Simplified representation of rainfall losses for the IL+ULR method

Source: FCDMC (2013a)



Effective Impervious Area, *RTIMP*

RTIMP for the Initial and Uniform Loss method is identical to the parameter used with the Green and Ampt method. The procedures defined for estimating *RTIMP* for the Green and Ampt method should be used for the Initial and Uniform Loss Rate method.

7.4.4 PROCEDURE FOR GREEN AND AMPT METHOD

7.4.4.1 Overview

Applicability

- For use with the Unit Hydrograph Method.
- All areas where soil texture controls the infiltration rate (*XKSAT* <= 2 inches/hour).

Key Analysis Parameters

$DTHETA_{dry}$	Volumetric soil moisture deficit (soil moisture at wilting point) at start of rainfall, in inches.
$DTHETA_{normal}$	Volumetric soil moisture deficit (soil moisture normal) at start of rainfall, in inches.
$DTHETA_{sat}$	Volumetric soil moisture deficit (soil moisture saturated) at start of rainfall, in inches.
IA	Initial abstraction, in inches.
$XKSAT_{BG}$	Bare ground hydraulic conductivity at natural saturation, in inches/hour.
$XKSAT_{adj}$	Hydraulic conductivity at natural saturation, adjusted for the effects of vegetation canopy cover, in inches/hour.
PSIF	Wetting front capillary suction, in inches.
RTIMP	Effective impervious area, in percent.
VCD	Estimated vegetation canopy cover, in percent.

7.4.4.2 General

In general, the following steps are used to compute rainfall loss parameters for the Green and Ampt method. The sets of instructions following these general steps are specific to computing parameter values for each sub-basin. The descriptions below use GIS procedures to describe the process. Whether or not GIS is used to perform the data sorting and computations, the

basic processes are the same for hand computations and use of CADD or other software applications. The DDMSW computer program automates most of the computations. The GIS process was selected for these descriptions because the NRCS detailed soil data are mostly available in only a GIS or PDF format and the NRCS is only publishing new studies in these formats. To perform the computations by hand or using other software, the GIS data must first be converted to a scaled paper map or converted to another digital format more convenient to the user. Additional descriptions are provided where the hand computation process differs from the GIS procedure.

1. Sub-basin Delineation. Prepare a base map of the drainage area and delineate modeling basins for the concentration points of interest. Delineate sub-basins for each basin so that the sub-basins are reasonably homogeneous in terms of area and/or time of concentration characteristics, and surface characteristics and/or soil type. Delineate large impervious areas as separate sub-basins. Create GIS polygon coverages for each basin and sub-basin and calculate the area of each basin and sub-basin.
2. Subarea Delineation. Delineate subareas for each sub-basin for the purpose of assigning IA and *RTIMP* estimates. The polygons from NRCS soil surveys delineating soil map units also are subareas, and often are used as subareas for estimation of IA and *RTIMP*, based on soil characteristics. Create GIS polygon coverages for each subarea and calculate the area of each subarea within each sub-basin.
3. Subarea Parameters. Assign estimates of IA and *RTIMP* for each subarea.
4. Estimate Composite IA for each Sub-basin.
5. Estimate Composite *RTIMP* for each Sub-basin.
6. Estimate Bare Ground *XKSAT* for each Soil Map Unit (subarea).
7. Estimate Composite Bare Ground *XKSAT* for each Sub-basin.
8. Estimate *PSIF* and *DTHETA* for each Sub-basin based on Composite Bare Ground *XKSAT*
9. Estimate Adjusted Composite *XKSAT* for each Sub-basin.
10. HEC-1 Loss Rate Record. Enter the composite values of IA, *DTHETA*, *PSIF*, adjusted *XKSAT*, and *RTIMP* for the drainage area or each sub-basin on the LG record of the HEC-1 input file.

7.4.4.3 Instructions for Sub-basin Composite IA

1. Assign an IA Estimate to Sub-Basin Subareas: Sub-basins may have to be divided into subareas based on land use and/or surface characteristics. The NRCS soil map units may also be used. An estimate of IA can be made for each soil map unit, entered into the GIS table for each soil map unit, and then area averaged as described in step 2. NRCS soil map units are further described under the Saturated Hydraulic Conductivity, *XKSAT* section.
2. Compute a Composite Value of IA: If there are multiple subareas within a sub-basin, calculate an area-weighted value of IA using Equation 7.12.

$$\overline{IA} = \left(\frac{\sum A_i IA_i}{A_T} \right) \qquad 7.12$$

where:

$\overline{IA}$ = composite value of IA, inches

IA_i = IA of each subarea, inches

A_i = size of IA subarea

A_T = size of the watershed or sub-basin

7.4.4.4 Instructions for Sub-Basin Composite *XKSAT*

1. Intersect the GIS Soils Coverage: Use the ArcMap intersect tool to divide the soil map unit polygon coverage so that the soil map unit polygon boundaries are divided by the watershed sub-basin boundaries. This is done by using the soil map unit polygon coverage as the input feature and the watershed sub-basin GIS coverage as the clip feature. The results are soil map unit polygons completely contained within each sub-basin polygon.
2. Simplify the GIS Soils Coverage: Use the ArcMap dissolve tool to simplify the soil map unit polygons within each watershed sub-basin, based on the soil map unit identifier field. When completed, there will only be one polygon for each soil map unit within each sub-basin polygon. When performing this step by hand, identify all polygons that have the same *XKSAT* value and then color code the *XKSAT* polygons.
3. Compute a Composite Bare Ground *XKSAT* Value for Each Sub-basin: Standard values of *XKSAT* for each soil map unit are listed in Appendix D. Use ArcMap to compute the area of each soil map unit within each sub-basin. Then either use ArcMap to apply Equation 7.13, or export the soil map unit number, *XKSAT* value and area information for each sub-basin into a Microsoft Excel spreadsheet and apply Equation 7.13 within the spreadsheet. When performing these computations by hand, planimeter each color-shaded polygon to obtain the total area of each *XKSAT* value within the sub-basin. Then apply Equation 7.13 by hand or within a spreadsheet.

$$\overline{XKSAT} = 10^{\left(\frac{\sum A_i \log_{10} XKSAT_i}{A_T} \right)} \qquad 7.13$$

where:

$\overline{XKSAT}$ = composite bare ground hydraulic conductivity for the watershed sub-basin, inches/hour

$XKSAT_i$ = bare ground hydraulic conductivity of the soil map unit within a sub-basin, inches/hour

A_i = area of soil map unit subarea within a sub-basin

A_T = total area of the watershed or sub-basin

7.4.4.5 Instructions for *PSIF* and *DTHETA*

1. Read Values of *PSIF* and *DTHETA* from Figure 7.16 and Figure 7.17: Enter the x-axis of Figure 7.16 with the composite bare ground value of *XKSAT* for each sub-basin. Read the corresponding value of *PSIF* on the y-axis. Enter the x-axis of Figure 7.17 with the composite bare ground value of *XKSAT* for each sub-basin. Read the corresponding value of *DTHETA* dry or normal, as appropriate, on the y-axis. As an alternative, Equations 7.9, 7.10, and 7.11 may be used to compute values of *PSIF* and *DTHETA*. Where subareas of differing *DTHETA* are present in a sub-basin, when natural and developed land uses are both present for example, an area-weighted value of *DTHETA* should be computed using Equation 7.14.

$$\overline{DTHETA} = \left(\frac{\sum A_i DTHETA_i}{A_T} \right) \qquad 7.14$$

where:

$\overline{DTHETA}$ = composite value of *DTHETA*, inches

$DTHETA_i$ = *DTHETA* of each subarea, inches

A_i = size of *DTHETA* subarea

A_T = size of the watershed or sub-basin

7.4.4.6 Instructions for Adjusting *XKSAT* for Vegetation Canopy Cover

1. Estimate Vegetation Cover Density (VCD) for Each Sub-basin: Determine an estimate of average vegetation cover density (canopy cover) for each land use classification using aerial photographs supplemented by field verifications as described in Appendix C. Compute an area-averaged value of VCD for each sub-basin using Equation 7.15.

$$\overline{VCD} = \left(\frac{\sum A_i VCD_i}{A_T} \right) \qquad 7.15$$

where:

$\overline{VCD}$ = composite value of VCD, inches

VCD_i = VCD of each subarea, inches

A_i = size of VCD subarea

A_T = size of the watershed or sub-basin

2. Obtain the Bare Ground *XKSAT* Adjustment Factor from Figure 7.18: Enter Figure 7.18 on the x-axis with the estimated vegetation cover density for each sub-basin. Read the ratio of adjusted *XKSAT* to bare ground *XKSAT* on the y-axis.
3. Compute Adjusted *XKSAT*: Multiply the sub-basin bare ground *XKSAT* estimate by the factor from the y-axis of Figure 7.18 to obtain the adjusted *XKSAT* value.

Equation 7.16 may be used in lieu of Figure 7.18.

$$XKSAT_{adj} = \overline{XKSAT}_{BG}\left(\frac{\overline{VCD} - 10}{90} + 1\right) \qquad 7.16$$

where:

$XKSAT_{adj}$ = $\overline{XKSAT}_{BG}$ adjusted for effects of vegetation canopy cover, inches/hour

$\overline{XKSAT}_{BG}$ = Sub-basin composite bare ground *XKSAT*, inches/hour

$\overline{VCD}$ = Sub-basin composite value of vegetation canopy cover, percent

7.4.4.7 Instructions for Sub-Basin Composite *RTIMP*

1. Assign an *RTIMP* Estimate to Sub-basin Subareas: Sub-basins may have to be divided into subareas based on land use and/or surface characteristics. *RTIMP* consists of any impervious surface that is hydraulically connected to the watershed outlet, including large areas of natural rock, large bodies of pooled water, asphalt and concrete pavement, rooftops, etc. Normally, naturally occurring RTIMP ($RTIMP_N$) is defined separately from developed condition RTIMP ($RTIMP_D$). A composite RTIMP is computed for each sub-basin for natural and developed conditions. Then the two are added to obtain a total composite RTIMP for the sub-basin. Aerial photographs can be used to aid in the process of defining subareas, particularly for developed watersheds. Planning and zoning maps may also be used for developed or developing areas. The NRCS soil map units may be used to aid in estimating *RTIMP* for natural areas. Standard values of natural *RTIMP* are provided for each soil map unit in Appendix D but should be field verified if significant.
2. Compute a Composite Value of *RTIMP*: If there are multiple subareas within a sub-basin, calculate an area-weighted value of *RTIMP* using Equation 7.17. Use this equation for computing both $RTIMP_N$ and $RTIMP_D$.

$$\overline{RTIMP} = \left(\frac{\sum A_i RTIMP_i}{A_T}\right) \qquad 7.17$$

where:

$\overline{RTIMP}$ = composite value of *RTIMP*, inches

$RTIMP_i$ = *RTIMP* of each subarea, inches

A_i = area of *RTIMP* subarea

A_T = area of the watershed or sub-basin

7.4.4.8 Green and Ampt Method Example

Refer to Appendix A.3.1 for an example of application of the Green and Ampt Method.

7.4.5 PROCEDURE FOR INITIAL LOSS AND UNIFORM LOSS RATE METHOD

7.4.5.1 Overview

Applicability

- This method is acceptable for use when modeling very infrequent storms with high amounts of precipitation.
- This method is an acceptable method for more frequent storms when the dominate soils in the watershed are sand and/or loamy sand, or drainage areas where soil texture does not control the infiltration rate, such as areas of volcanic cinders.
- This method should not generally be used for the one percent and more frequent storms.

Key Analysis Parameters

IA	Initial abstraction, in inches.
II	Initial infiltration, in inches.
STRTL	The total of IA and II, in inches.
CNSTL	Uniform loss rate, equivalent to bare ground hydraulic conductivity at natural saturation, in inches/hour.
RTIMP	Effective impervious area, in percent.

7.4.5.2 General

In general, the following steps are used to compute rainfall loss parameters for the Initial Loss and Uniform Loss Rate Method. The sets of instructions following these general steps are specific to computing parameter values for each sub-basin.

1. Sub-basin Delineation. Prepare a base map of the drainage area and delineate modeling basins for the concentration points of interest. Delineate sub-basins from each basin so that the sub-basins are as homogeneous as possible in terms of area and/or time of concentration characteristics, and surface characteristics and/or soil type. Delineate large areas of impervious area as separate sub-basins. Create GIS polygon coverages for each basin and sub-basin and calculate the area of each basin and sub-basin.
2. Subarea Delineation. Delineate subareas for each sub-basin for the purpose of assigning IA and *RTIMP* estimates. The polygons from NRCS soil surveys delineating soil map units also are subareas, and often are used as subareas for estimation of IA and *RTIMP*. Create GIS polygon coverages for each subarea and calculate the area of each subarea.
3. Subarea Parameters. Assign estimates of IA, II and *RTIMP* for each subarea.

4. Estimate Bare Ground *XKSAT* for each soil map unit (subarea). Follow the procedure in Section 7.4.4.4.
5. Estimate CNSTL for Each Sub-basin. Compute composite bare ground *XKSAT* for each sub-basin, adjust for vegetation cover, and assign as CNSTL.
6. Estimate STRTL for Each Sub-basin. Compute STRTL by summing composite IA and an estimate of II.
7. Estimate Composite *RTIMP* for each Sub-basin. Follow the procedures in Section 7.4.4.7.
8. HEC-1 Loss Rate Record. Enter the composite values of STRTL, CNSTL, and *RTIMP* for the drainage area or each sub-basin on the LU record of the HEC-1 input file.

7.4.5.3 Instructions for STRTL

1. Compute a Composite Value of IA: Use the procedures defined for the Green and Ampt method to compute a composite value of IA for each sub-basin.
2. Compute a Composite Value of II: Use the sub-basin composite estimate of CNSTL (see below) to estimate a value of II from Table 4.
3. Compute an Estimate of STRTL for each Sub-basin: Add IA and II to obtain an estimate of STRTL.

7.4.5.4 Instructions for CNSTL

1. Compute a Composite Value of CNSTL: Use the procedures defined for the Green and Ampt method to compute a composite value of *XKSAT* adjusted for vegetation cover for each sub-basin and use those values for CNSTL.

7.4.5.5 Initial Loss and Uniform Loss Method Example

Refer to Appendix A.3.2 for an example of application of the Initial Loss and Uniform Loss Method.

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7.5 UNIT HYDROGRAPHS

7.5.1 INTRODUCTION

7.5.1.1 General Discussion

A unit hydrograph is defined as the hydrograph of one inch of direct runoff from a storm of a specified duration for a watershed. Every watershed will have a different unit hydrograph that reflects the physiography, topography, land-use, and other unique characteristics of the individual watershed. Different unit hydrographs will be produced for the same watershed for different durations of rainfall excess. For example, a unit hydrograph for a watershed can be developed for a rainfall excess duration of 5-minutes, or 15-minutes, or 1-hour, or 6-hours, etc. Any duration can be selected for unit hydrograph development if an upper limit for the unit hydrograph duration is not exceeded. Guidelines for the determination of the upper limit of unit hydrograph duration are provided in Section 7.5.2.5.

Only a few watersheds in Arizona will have an adequate data base (rainfall and runoff records) from which to develop unit hydrographs. Therefore, indirect methods usually will be used to develop unit hydrographs. Such unit hydrographs are called synthetic unit hydrographs. Several procedures are available to develop synthetic unit hydrographs, and virtually all of these procedures are empirical. The selection of a synthetic unit hydrograph procedure should be made such that the data base for the empirical development is representative of the study watershed.

The unit hydrograph itself is a lumped parameter in that it represents the composite effects of all of the watershed and storm characteristics that dictate the rate of rainfall excess runoff from the watershed. Although there are numerous watershed and storm characteristics that determine the shape of a unit hydrograph, only a limited number of those characteristics can be quantified and used to calculate a unit hydrograph. One or more unit hydrograph parameters (depending on the selection of a synthetic unit hydrograph procedure) are needed to calculate a unit hydrograph.

The concept of the unit hydrograph is used to route the time increments of rainfall excess from the watershed (or modeling sub-basin) to the watershed outlet (or modeling concentration point). The synthetic unit hydrograph procedure that is recommended for use in Mohave County is the Clark unit hydrograph. Procedures are provided herein to estimate the three Clark unit

hydrograph parameters, and these are entered on the UC and UA records of HEC-1. Unit hydrograph procedures other than the Clark procedure can be used for specific applications; however, this will require justification and approval by DISTRICT for such use.

7.5.2 PROCEDURE

The Clark unit hydrograph requires the estimation of three parameters; the time of concentration (T_c), the storage coefficient (R), and a time-area relation. Sections 7.5.2.1 through 7.5.2.6 describe the procedures that are to be used to calculate these parameters, and the guidelines that are to be used to select the unit hydrograph duration and computation interval (NMIN).

7.5.2.1 Overview

Applicability

- The Clark unit hydrograph, as described herein, can be used for virtually any watershed that will be encountered in Mohave County.
- The Unit Hydrograph Method is normally applied for watersheds greater than 160 acres in area and when a runoff hydrograph is needed.

Key Analysis Parameters

A	Watershed area, in square miles.
L	The length of the longest hydraulic flow path, in miles.
L_{ca}	Length measured from the concentration point along L to a point on L that is perpendicular to the watershed centroid, in miles.
Q	The estimated peak discharge, in cubic feet per second.
R	Storage coefficient, in hours.
$RTIMP$	Effective impervious area, in percent.
S	The slope of the longest hydraulic flow path, in ft/mile.
T_c	Time of Concentration, in hours.

7.5.2.2 Time of Concentration

Time of concentration is the travel time, during the corresponding period of most intense rainfall excess, for a flood wave to travel from the hydraulically most distant point in the watershed to the point of interest (concentration point). Three T_c equations are to be used depending on the type of watershed; desert/mountain, agricultural fields, or urban. The recommended T_c equations are:

desert/mountain

$$T_c = 2.4A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.2} \quad (7.18)$$

agricultural fields

$$T_c = 7.2A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.2} \quad (7.19)$$

urban

$$T_c = 3.2A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.14}RTIMP^{-0.36} \quad (7.20)$$

where:

T_c	=	time of concentration, in hours,
A	=	area, in square miles,
S	=	watercourse slope, in feet/mile,
L	=	length of watercourse to the hydraulically most distant point, in miles,
L_{ca}	=	length measured from the concentration point along L to a point on L that is perpendicular to the watershed centroid, in miles, and
$RTIMP$	=	effective impervious area, in percent.

In using Equations 7.18 through 7.20, the following points should be noted and observed:

1. The area (A) will be determined from the best available map. The delineation of the drainage boundary needs to be carefully performed, and special care must be taken where there is little topographic relief. In urban areas, land grading and road construction can produce drainage boundaries that separate runoff from contributing areas during small and lower intensity storms. However, larger and more intense storms, such as the design storm from this manual, can produce runoff depths that can cross these intermediate drainage boundaries resulting in a larger total contributing area. Similarly, floods on alluvial fans (active and inactive) and in distributary flow systems can result in increased contributing areas during larger and more intense storms. For such areas, it is generally prudent to consider the largest reasonable drainage area in these situations.

2. Determination of the hydraulically most distant point will define both *L* and *S*. Often, the hydraulically most distant point is determined as the point along the watershed boundary that has the longest flow path to the watershed outlet (or sub-basin concentration point). This is generally true where the topography is relatively uniform throughout the watershed. However, there are situations where the longest flow path (L) does not define the hydraulically most distant point. Occasionally, especially in mountainous areas, a point with a shorter flow path may have an appreciably flatter slope (*S*) such that the shorter flow path defines the hydraulically most distant point. For watersheds with multiple choices for the hydraulically most distant point, the T_c should be calculated for each point and the largest T_c should be used.
3. Slope (*S*) is the average slope calculated by dividing the difference in elevation between the hydraulically most distant point and the watershed outlet by the watercourse length (*L*). This method will usually be used to calculate *S*. However, there are situations where special consideration should be given to calculating *S* and to dividing the watershed into sub-basins. For example, if there is dramatic change in watercourse slope throughout the watershed, then the use of a multiple sub-basin model should be considered with change in watercourse slope used as criteria in delineating the sub-basins. There will also be situations where the watercourse contains vertical or nearly vertical drops (mountain rims, headcuts, rock outcrop, and so forth). In these situations, plotting of the watercourse profile will usually identify nearly vertical changes in the channel bed. When calculating the average slope, subtract the accumulative elevation differential that occurs in nearly vertical drops from the overall elevation differential prior to calculating S.
4. L_{ca} is measured along L to a point on L that is essentially perpendicular to the watershed centroid. This is a shape factor in the T_c equation. Occasionally, the shape of agricultural fields or urban sub-basins is nearly rectangular, and this may result in two different dimensions for L_{ca}. In the case of such nearly rectangular (and therefore, nearly symmetrical) watersheds or sub-basins, L_{ca} can usually be satisfactorily estimated as 0.5*L*.
5. *RTIMP* is the effective impervious area. This is the same value that was determined for the watershed by the procedures in Section 7.4.2.3. *RTIMP* is used to estimate T_c for urban watersheds only (Equation 7.20).
6. Ideally, the selection of the watershed or sub-basin boundaries can be made so that the area represents a hydrologically uniform region that is essentially all desert/mountain, or agricultural fields, or urban, and for those situations, the T_c equations (Equations 7.18 through 7.20) can be applied directly. However, there will be situations where the watershed or modeling sub-basin is a mixture of two or three of those types. In those cases, the T_c equation (Equations 7.18 through 7.20) is selected based on the watershed type that contains the greatest portion of *L*. The effects of a mixture of watershed types are accounted for by the selection of the time-area relation (to be discussed in Section 7.5.2.4).

7.5.2.3 Storage Coefficient

The storage coefficient is a Clark unit hydrograph parameter that relates the effects of direct runoff storage in the watershed to unit hydrograph shape. The equation for estimating the storage coefficient (*R*) is:

$$R = 0.37{T_c}^{1.11}L^{0.80}A^{-0.57} \quad 7.21$$

where: R is in hours and the variables are as defined for the T_c equations.

7.5.2.4 Time-Area Relation

The time-area relation is a graphical parameter that specifies the accumulated area of the watershed that is contributing runoff to the outlet of the watershed at any time. Two methods can be used to develop a time-area relation:

1. by analysis of the watershed to define incremental runoff producing areas that have equal incremental travel times to the outflow location, or
2. by use of synthetic time-area relations.

The development of a time-area relation by analysis of the watershed is a difficult task and well-defined and reliable procedures for this task are not available. Unless the watershed has an extremely unusual shape or has several distinct areas of dramatically different land-use, this analysis should not be undertaken. In general, synthetic time-area relations can be used in Mohave County. If it is necessary to develop a site-specific time-area relationship for a watershed, refer to FCDMC (2013a), Section 5.5.3, for a description of the procedure

The dimensionless, synthetic time-area relations that can be used in Mohave County are listed in Table 7.15 and shown graphically in Figure 7.21. Curve A should be used if the land-use in the watershed or sub-basin is urban or predominantly urban. Curve C should be used if the land-use in the watershed or sub-basin is desert/rangeland or is mostly desert/rangeland with some mountains in the watershed and/or some irrigated agricultural fields interspersed in the lowlands. Curve B should be used for all other situations.

Curve B is the default time-area relation in HEC-1 and will be used with the Clark unit hydrograph if a time-area relation (UA record) is not supplied. Curves A and C are dimensionless, and these curves are input to HEC-1 by inserting the percent of total area values from Table 7.15 in the UA record.

Table 7.15 Values of the dimensionless synthetic time-area relations

Source: ADOT (1994)

Travel Time as a percent of T_c	Contributing Area, as a Percent of Total Area[a]		
	A	B[b]	C
(1)	(2)	(3)	(4)
0	0	0.0	0
10	5	4.5	3
20	16	12.6	5
30	30	23.2	8
40	65	35.8	12
50	77	50.0	20
60	84	64.2	43
70	90	76.8	75
80	94	87.4	90
90	97	95.5	96
100	100	100.0	100

[a] The dimensionless Synthetic Time-Area relations should be selected as follows:

A - The land-use in the watershed or sub-basin is urban or predominantly urban.

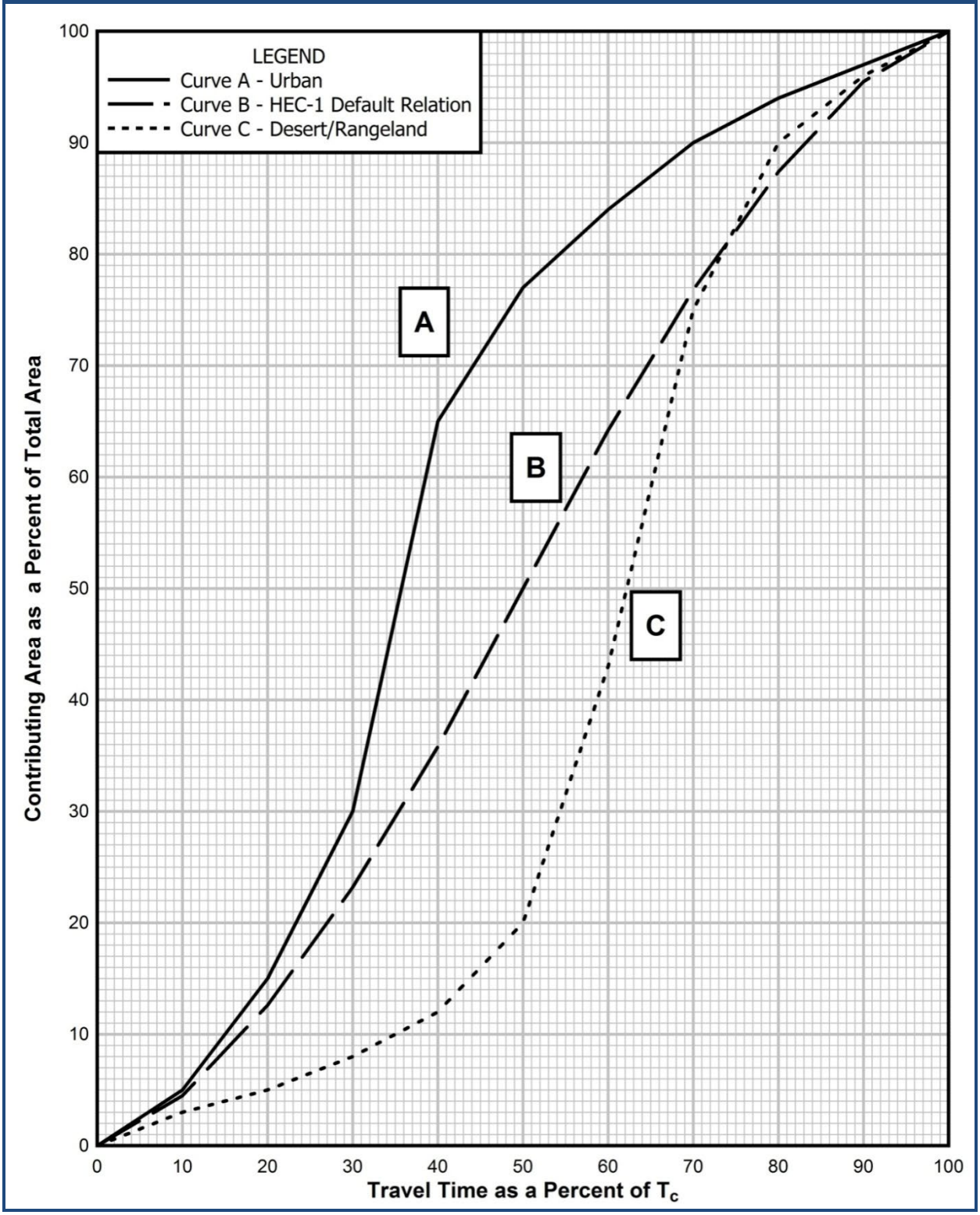
B - All watersheds or sub-basins other than those defined for use of curves A or C.

C - The land-use in the watershed or sub-basin is desert/rangeland or is mostly desert/rangeland with some mountains in the watershed and/or some irrigated agricultural fields interspersed in the lowlands.

[b] Curve B is the HEC-1 default Time-Area relation and the UA record is not needed as input to the HEC-1 model.

Figure 7.21 Synthetic Time-Area Relation

Source: ADOT (1994)



7.5.2.5 Duration

The duration of the unit hydrograph (or all unit hydrographs in a multiple sub-basin model) is specified in HEC-1 on the IT record as NMIN. In general, NMIN will be selected according to the following criteria:

NMIN = 2 minutes for a 6-hour storm duration (drainage area less than or equal to 1.0 square mile), and

NMIN = 5 minutes for a 24-hour storm duration (drainage area greater than 1.0 square mile).

Note: *NMIN* should not exceed 0.25 T_c for the sub-basin with the shortest T_c.

However, there may be special situations (see Section 7.5.2.2, Time of Concentration, for using HEC-1) where a NMIN, other than as defined above, is to be used. In those situations, the following rules should be considered:

1. *NMIN* = 0.15 T_c provides adequate definition of the hydrograph peak with an optimum number of hydrograph coordinate calculations.
2. *NMIN* = 0.25 T_c is the maximum value for NMIN.
3. *NMIN* for a multiple sub-basin model should be selected based on the smallest T_c value for any of the sub-basins in the model.

7.5.2.6 Applications and Limitations

The Clark unit hydrograph, as described herein, can be used for virtually any watershed that will be encountered in Mohave County. However, there may be situations where use of another unit hydrograph will be warranted. For example, rainfall and runoff data may be available for the watershed or a nearby hydrologically similar watershed to develop a unit hydrograph, and in those cases, the developed unit hydrograph would be input to HEC-1 by use of UI records. In other situations, a unit hydrograph at or near the desired location may have been developed for another project. That unit hydrograph or unit hydrograph procedure may be preferable to the recommended Clark unit hydrograph procedure for that application. If other unit hydrographs or unit hydrograph procedures are determined to be more applicable for a certain situation, they should be used. However, deviations from the procedures in this Manual should be discussed with DISTRICT and approval received for deviations from the recommended procedures before incorporating such deviations into the project hydrology analysis.

Equations 7.18 through 7.20 were derived for use in estimating the time of concentration for floods with design return periods that are typical for roadway drainage structures (25-year to 100-year). Use of these equations may result in time of concentration estimates that are too short for floods of return period less than 25-year and too long for floods of return periods appreciably greater than 100-year. This is because of the effect that runoff magnitude has on the hydraulic efficiency (runoff velocity) of watersheds. Therefore, if Equations 7.18 through 7.20 are used to estimate the time of concentration for floods of return period appreciably greater than the 100-year, then the time of concentration should be reduced (by as much as 25 percent for very large. rare floods); similarly, for estimating the time of concentration for floods of return period less than the 25-year, the time of concentration should be increased (by as much as 100 percent for very frequent flooding, such as the 2-year). Since R (Equation 7.21) is a function of T_c, the R value should be recalculated if T_c is adjusted for a given return period.

7.5.3 INSTRUCTIONS FOR UNIT HYDROGRAPH METHOD

1. Delineate the watershed boundaries on the watershed base map.
2. Trace the paths of the major watercourses in the watershed on the base map.
3. If the watershed has more than one land-use, define the areas of the different land-use types:
    a. Urban,
    b. desert/rangeland,
    c. mountain, and
    d. irrigated agriculture.
4. Determine whether the watershed can be treated as a single, hydrologically homogeneous watershed, or if it must be divided into modeling sub-basins. This decision should consider the following factors:
    a. topography (and channel slope),
    b. land-use,
    c. diversity of soil texture (from Section 7.4.2.3),
    d. occurrence of rock outcrop,
    e. existence of drainage and flow control structures within the watershed such as detention/retention basins, elevated highway cross-drainage structures, channelized and improved watercourses, etc.,
    f. shape of the watershed, and
    g. needs for use of the hydrologic model, such as investigation and planning for future development and downstream drainage structures.

5. If the watershed is to be divided into modeling sub-basins, use the information from Steps 2, 3, and 4 to delineate the sub-basin boundaries.
6. For the watershed or each modeling sub-basin, determine the following:

   A - area, in square miles,

   L - length of the flow path to the hydraulically most distant point, in miles,

   L_{ca} - length along L to a point opposite the centroid, in miles,

   S - average slope of L, in feet/mile, and

   RTIMP - effective impervious area, in percent.

7. Calculate T_c depending on the type of watershed:

   desert/mountain

   $$T_c = 2.4A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.2} \quad (7.18)$$

   agricultural fields

   $$T_c = 7.2A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.2} \quad (7.19)$$

   urban

   $$T_c = 3.2A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.14}RTIMP^{-0.36} \quad (7.20)$$

8. Calculate *R*:

   $$R = 0.37{T_c}^{1.11}L^{0.80}A^{-0.57} \quad (7.21)$$

9. Enter the values of T_c and *R* in the UC record for the watershed or each sub-basin.
10. Determine whether the time-area relation will be developed from an analysis of the watershed or whether a dimensionless synthetic time-area relation will be used.
    a. If the time-area relation is to be determined by analytic means, proceed with the analysis and input the incremental areas (or percentages of total area) in the UA record.
    b. If the dimensionless synthetic time-area relations are to be used (Figure 7.21 and Table 7.15):
       i. use the values for Curve A in the UA record if the watershed or sub-basin is urban or predominantly urban,
       ii. use the values for Curve C in the UA record if the watershed or sub-basin is desert/rangeland or is mostly desert/rangeland with some mountains and/or some irrigated agricultural fields interspersed in the lowlands, and

iii. use Curve B for all other applications (Curve B is the HEC-1 default relation and the UA record is not needed).

7.5.3.1 Example: Clark Unit Hydrograph Method Parameters

Refer to Appendix A.4 for an example of development of parameters for application of the Clark Unit Hydrograph Method.

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7.6 CHANNEL ROUTING

7.6.1 INTRODUCTION

Channel routing describes the movement of a flood wave (hydrograph) down a watercourse. As a flood wave passes through a river reach, the peak of the outflow hydrograph is usually attenuated and delayed due to flow resistance in the channel and the storage capacity of the river reach. Channel routing is used in flood hydrology models, such as HEC-1, when the watershed is modeled with multiple sub-basins and runoff from the upper sub-basins must be routed through a channel, or system of channels, to the watershed outlet. Several methods are available for channel routing. The method that is recommended for the majority of channel routing applications for drainage in Mohave County is the Normal Depth method.

7.6.2 PROCEDURE

7.6.2.1 Overview

Applicability

- Channel routing is to be used in multiple sub-basin models when the runoff from the upper sub-basins passes through a relatively long watercourse, or a system of watercourses, to the watershed outlet.

Key Analysis Parameters

ANCH Manning's roughness coefficient for the main channel (dimensionless).

ANL Manning's roughness coefficient for the left overbank (dimensionless).

ANR Manning's roughness coefficient for the right overbank (dimensionless).

ITYP Specifies type of initial starting condition; either storage, discharge, or elevation.

NMIN Integer number of minutes in the hydrograph tabulation interval.

NSTPS Number of steps to be used in the storage routing.

RSVRIC Value of route starting condition; either storage in acre-feet, discharge in cubic feet per second, or elevation in feet.

RLNTH Reach length, in feet.

SEL Estimated slope of the energy grade line, in ft/ft.

7.6.2.2 Method

The recommended method for routing is the Normal Depth method and that method should be used unless there is good cause for deviation from this recommendation. The following procedure is for the Normal Depth method; however, the information can often be used to assist in defining routing input for other methods. For Normal Depth routing, data must be provided for the number of steps in the routing calculation, the initial condition of the flow in the channel, channel resistance coefficients, and channel geometry. Much of this data is normally obtained from appropriate maps and/or field survey data.

7.6.2.3 Number of Computation Steps (NSTPS)

This is the number of computation steps that will be used in the Normal Depth routing calculation. The Normal Depth route operation in HEC-1 is accomplished by use of a single 8-point cross section which is selected to be typical of the routing reach. Storage routing is accomplished by using wedge-storage for sub-reaches. The sub-reach length is the distance traveled by the flood wave during one computation time interval (*NMIN*). The number of necessary sub-reaches corresponds to NSTPS, which must be an integer. *NSTPS* can be estimated by reach length/average velocity/*NMIN*. Refer to Section 7.9.2 for guidance for using HEC-1, and Section 7.9.2.9, for additional guidance in selecting *NSTPS*.

7.6.2.4 Initial Flow Condition (ITYP and RSVRIC)

These variables define the initial condition of the flow in the channel at the start of the routing computation. Normally the initial condition that is used is the discharge in the channel and this will typically be '0' (dry channel) for channels in Mohave County. If the channel is expected to have flow prior to the modeled storm, or a baseflow, then enter the appropriate discharge data. The channel water surface elevation at the start of the routing computation option can be used, if desired instead of the initial discharge condition option.

7.6.2.5 Routing Reach Length (RLNTH)

This is the length of the channel or major flow path. The length is to be measured on the best available map. The units of *RLNTH* are feet. It is the length of the flow path following the dominate velocity vector, which can vary with storm frequency.

7.6.2.6 Energy Grade Line Slope (*SEL*)

This is the slope of the energy grade line and is not normally known. For normal flow, it is parallel to the channel bed slope. It is usually estimated as the channel bed slope, calculated by dividing the difference in bed elevation between the upper and lower ends of the watercourse by the routing reach length. The units of *SEL* are feet/foot.

7.6.2.7 Manning's Roughness Coefficient (*n*)

The Manning's roughness coefficient, *n*, is a measure of the flow resistance of a channel or overbank flow area. The flow resistance is affected by many factors including size of bed material, bed form, irregularities in the cross section, depth of flow, vegetation, channel alignment, channel shape, obstructions to flow, and quantity of sediment being transported in suspension or as bed load. In general, all factors that retard flow and increase turbulent mixing tend to increase n. Manning's *n* must be assigned for the main channel and the left and right overbanks for application of the normal depth channel route method. The Manning's roughness coefficient for the main channel is designated as *ANCH*, for the left overbank it is *ANL*, and for the right overbank it is *ANR* according to HEC-1 nomenclature. Refer to Section 13 for guidance in assigning n-values to the main channel and overbanks.

7.6.2.8 Channel Geometry

The channel geometry is to be provided by an 8-point cross section. That cross section is to be representative of the hydraulic characteristics throughout the routing reach. Considerable judgment is necessary in defining the representative 8-point cross section. The guidance in the HEC-1 User's Manual should be followed. The coordinates (X and Y) can be to any base datum. Specifically, the vertical dimensions (Y) do not need to correspond to land surface elevation or any elevation for any location along the routing reach.

7.6.3 APPLICATIONS AND LIMITATIONS

Channel routing is to be used in multiple sub-basin models when the runoff from the upper sub-basins passes through a watercourse, or a system of watercourses, to the watershed outlet. Routing should be used in models when a major component of watershed runoff (an inflow hydrograph) enters a relatively long channel and must flow through that channel to the watershed outlet or to a point along the channel where a flood hydrograph is desired. In those

situations, the peak of the outflow hydrograph is usually attenuated and delayed compared with that of the inflow hydrograph.

The Normal Depth method, that is available in the HEC-1 program, is usually an appropriate routing method for use with watercourses in Mohave County. It should be used where routing effects (peak attenuation and delay) are expected. Other methods may be more appropriate or more practical in certain applications. For example, the Kinematic Wave channel routing method can often be used with comparable accuracy for constructed urban channels, including storm drains, and for short, steep natural channels. The Muskingum method may be appropriate for certain rivers if data are available to determine the two parameters (*K* and *X*) by analysis, or by HEC-1 optimization from recorded hydrographs, or if other information is available to yield reliable estimates of *K* and *X*. The Muskingum-Cunge method is also available and it can be used in certain applications. However, the Muskingum-Cunge method can produce unreliable results, particularly for wide, shallow water courses, especially with steep slopes. The use of the Muskingum-Cunge method must be applied with caution, and results carefully reviewed before acceptance. Also, the Muskingum-Cunge method is not amenable for channel routing if channel transmission losses (by the recommended method, see Section 7.8) are to be included in the watershed model. In general, however, the Normal Depth method is to be used. If other methods are considered, technical guidance can be found in FHWA (2002), Chapter 7, USACE (1998), and Hoggan (1997). Use of other methods requires prior approval by COUNTY/DISTRICT.

One of the most critical aspects of watershed modeling using sub-basins and channel routing is the selection of channel routing lengths (*RLNTH*). The numeric procedure used in routing calculations requires that the travel time through each routing reach be a multiple of the selected computation interval (*NMIN*). For this reason, the selection of too short a *RLNTH* could result in the computation of zero travel time through the routing reach (instantaneous translation of the flood wave through the reach). This could result in erroneously large peak discharges at downstream concentration points in the watershed model. A watershed model of numerous small sub-basins and connecting short routing reaches can result in progressively larger overestimation of peak discharges in a downstream direction producing grossly overestimated peak discharge at the watershed outlet. Section 7.9.2.4, Routing Lengths, should be consulted prior to watershed delineation to avoid problems with channel routing lengths that are too short.

7.6.4 INSTRUCTIONS FOR CHANNEL ROUTING

The following steps should be used with the Normal Depth routing method:

1. From the watershed base map, identify the routing reaches. (See Section 7.9.2.9, Routing Lengths, for additional guidance.)
2. Compile information on the characteristics of those reaches (detailed topographic maps to define channel geometry, photographs of the channels and overbanks, other hydrologic reports for the area, etc.)
3. Conduct a field reconnaissance of the watershed and routing reaches, if practical. Observe and note the characteristics of the routing reaches; variations in the channel cross sections, irregularity of the channel, and degree of meandering of the main channel. Determine the hydraulically representative section of the routing reaches. Make note of and photograph the representative sections paying particular attention to flow resistance characteristics; bed material, obstructions to flow (rock outcrop, boulders, debris, etc.), and vegetation in the channel and overbank floodplains. If adequate maps are not available to define the channel geometry of the representative sections, field surveys or field measurements can be made of the channel and overbank floodplains.
4. Prepare a sketch of the representative section of each routing reach, and prepare the channel geometry input (RX and RY records).
5. Estimate the main channel roughness coefficient, *ANCH*, using the information and procedures in Chapter 13.
6. If an 8-point cross section is used that contains overbank floodplains, select the *n* for each of the overbanks (*ANL* and *ANR*), also using the information and procedures in Chapter 13.
7. Measure the routing reach length, *RLNTH*, from the base map.
8. Estimate the energy gradient (*SEL*) by calculating the channel bed slope from the base map.
9. Input the routing information into the RS, RC, RX and RY records.

7.6.5 NORMAL DEPTH CHANNEL ROUTING EXAMPLE

Refer to Appendix A.5 for an example of development of parameters for application of the Normal Depth channel routing method.

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7.7 STORAGE ROUTING

7.7.1 INTRODUCTION

Storage routing will be used when inflow to a structure is temporarily detained by the storage capacity and/or outlet characteristics of the structure such that the outflow is significantly different than the inflow in terms of flow rate and time. Storage routing is required when flow is routed through retention/detention basins; where flow passes through drainage facilities such as roadway cross-drainage structures (particularly where the road is elevated on earthen fill); where culverts, railroad drainage facilities, and some bridges restrict flow rates; and pump stations.

Level-pool reservoir routing is typically used for these applications. Information must be provided on various combinations of HEC-1 input records to describe the storage capacity and discharge relations of the structure and its outlet works.

7.7.2 PROCEDURE

For storage routing, topographic, design, and/or as-built information must be available to prepare the necessary input. Because of the diversity of structures for which storage routing can be performed, only general guidance is provided for this method.

7.7.2.1 Overview

Applicability

- Routing of runoff hydrographs through volumetric storage structures.

Key Analysis Parameters

Q	Discharge for each point on a stage versus discharge curve controlling outflow from the storage structure, in cubic feet per second.
ITYP	Specifies type of initial starting condition; storage, discharge, or elevation.
RSVRIC	Value of route starting condition; either storage in acre-feet, discharge in cubic feet per second, or elevation in feet.
NSTPS	Number of steps to be used in the storage routing (normally set to 1).
NMIN	Integer number of minutes in the hydrograph tabulation interval.

V Volume for each point on a stage versus storage curve for the storage structure, in acre-feet.

ELEV Elevation for each point on a stage versus storage or stage versus discharge curve for the storage structure, in acre-feet.

7.7.2.2 Stage-Storage Relation

A relation describing the storage volume that is obtained with a specified water surface elevation must be provided. This is accomplished by one of two methods: 1) water stage (SE record) and corresponding storage volume (SV record), or 2) water stage (SE record) and corresponding surface area for the water stored to that elevation (SA record). Ether method is acceptable and to some extent the selection depends upon the information that is available. If surface area data (SA records) are provided, the storage volume is calculated during the execution of the HEC-1 program.

7.7.2.3 Stage-Discharge Relation

A relation describing the discharge through the structure as a function of stage of water behind the structure must be provided. Discharges are entered on SQ records that correspond to water stages of the SE records. Stage-discharge relations are established by hydraulic analysis of the hydraulic control structure or from design reports.

7.7.2.4 Structure Overtopping

There are situations where structures can be overtopped due to inflow that exceeds the stage-storage-discharge relations. This can happen in a variety of situations including elevated roadway embankments with cross drainage structures that cannot pass the required inflow. Often in such cases, the excess inflow will overtop the structure, and in those cases the ST record can be used to model the flow that would pass over the structure; however, an overtopping discharge rating curve is the recommended method. The SQ record, in that case, is for the combined discharge through the structure plus overtopping discharge.

7.7.2.5 Pump Stations

A pump station may be included as a part of storage routing to withdraw water from the structure at that point. Pumped water leaves the study area unless it is retrieved and inserted in the model at another point. This can occur at depressed road intersections where the

pumped water is released to a drainage structure outside of the intersection drainage boundaries. Pump stations can be modeled with WP and WR records. Pump station operation where multiple pumps and/or variable pump capacity is required to be modeled cannot be adequately modeled with HEC-1. In such cases, more sophisticated pump station models should be used. The HEC-1 model can usually be used successfully to provide the inflow hydrograph for the pump station analysis. The hydrograph diversion operation could also be used to simulate a pump station.

7.7.3 INSTRUCTIONS FOR STORAGE ROUTING

1. Define the stage-storage relation from the most appropriate maps and input the relation in SE and SV records, or in SE and SA records.
2. Define the stage-discharge relation for the outflow through the structure by use of the SQ record. Care must be taken if the structure is subject to emergency spillway flows or overtopping. The use of an SO record will suppress all data entered on an SS record (spillway characteristics). However, flows taken from an SQ record will be added to any flows computed from the ST record (top-of-dam overflow).

   The recommended approach is to use SQ/SE records to define the complete discharge rating curve for all types of discharge through (or over) the structure. These input calculations should be performed manually for each of the different types of discharge that could occur. A composite discharge rating curve should then be developed by adding together all applicable discharges that occur at any given elevation. This discharge rating curve should extend above the maximum reservoir water surface elevation achieved during the routing operation.
3. If pump stations are included, and if the pump station capability of the HEC-1 program is adequate for the analysis, provide pump station information in WP and WR records, or simulate using a diversion operation.

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7.8 TRANSMISSION LOSSES

7.8.1 INTRODUCTION

Storm runoff and floods in Mohave County are usually attenuated through the effects of channel and storage routing, but they are often also diminished due to the percolation of water into the bed, banks, and overbank floodplains of the watercourses. These losses in the watercourses are transmission losses and are losses that accrue in the watershed in addition to the rainfall losses on the land surface. Transmission losses can, and often do, result in a significant reduction in the runoff volume. Often, transmission losses only result in a relatively small reduction in flood peak discharge; however, there are situations, such as very long, wide channels with high percolation rates, where the flood peak discharges are dramatically reduced.

The magnitude of transmission loss (both volumetric and peak discharge) is dependent upon the antecedent conditions of the watercourse; characteristics of the bed, bank, and overbank materials; channel geometry (wetted perimeter); depth to bedrock; depth to the ground water table; duration of flow; and hydrograph shape. For a watercourse that is initially dry and is composed of coarse, granular material, the initial percolation rate can be very high; however, the percolation rate diminishes during passage of the flood and would eventually reach a steady-state rate if the flow continues long enough.

Although it is recognized that transmission losses can be an important element in performing rainfall-runoff modeling, particularly for ephemeral watercourses in Mohave County, procedures and reliable data for estimating transmission losses are poor. Therefore, except for situations where transmission losses should clearly be incorporated in the analysis, the estimation of these losses will not usually be incorporated in rainfall runoff models. The incorporation of transmission losses in a watershed rainfall-runoff model should be approved in advance by Mohave County and the procedure and assumptions clearly documented.

Two options in the HEC-1 program are available for estimating transmission losses. Both options use the RL record. The recommended option uses an estimated channel percolation rate (*PERCRT*) and must be used with the Normal Depth channel storage routing option (RS/RC record). The second option estimates the transmission loss as a constant loss (*QLOSS*), in cfs, plus a ratio (*CLOSS*) of the remaining flow after subtracting *QLOSS*. The second method can be used with any of the HEC-1 channel routing options; however, that method is not recommended for general use because of the very subjective decisions that will need to be

made in selecting *QLOSS* and *CLOSS*. The recommended method is physically-based and should result in better estimates of transmission losses, if adequate estimates can be made of the percolation rate and if the necessary storage routing information can be satisfactorily represented.

7.8.2 PROCEDURE

7.8.2.1 Overview

Applicability

- This approach should not normally be applied for design studies.
- This approach may be applied for flood insurance studies, but only after careful consideration of all the points listed in Section 7.8.2.2. Use of this approach requires prior approval by COUNTY/DISTRICT.

Key Analysis Parameters

PERCRT Percolation rate for the wetted surface of the channel, in cfs/acre.

QLOSS Constant discharge loss for entire routing in cfs. Subtracted from every ordinate of the inflow hydrograph.

7.8.2.2 Method

The following conditions should be met for the consideration of the incorporation of transmission losses into a rainfall-runoff model of a watershed:

1. The bed, banks, and overbank floodplains of the watercourse are composed of coarse, granular material. Materials such as cobble, gravel, sandy gravel, gravelly sand, sand, and sandy loam are all indicators that appreciable transmission losses can occur.
2. There is a relatively long total length of watercourse that is composed of coarse, granular material.
3. The watercourse is ephemeral, and it is prudent to assume that the watercourse is dry before the onset of the storm.
4. The bed of the watercourse is not underlain by material, such as bedrock, that would inhibit the sustained percolation of water into the bed of the watercourse.
5. The depth to ground water is great enough to not inhibit the sustained percolation of water into the bed of the watercourse.

If the above conditions are met, then the incorporation of transmission losses into the model should be considered. At this point, two other factors should be considered before proceeding:

1. Incorporation of transmission losses requires a multiple sub-basin model with defined routing reaches. Transmission losses are calculated for the routing reaches. Use of the recommended option for calculating transmission losses with the HEC-1 program requires normal depth storage routing. Transmission losses are to be considered only if a multiple sub-basin model is acceptable.
2. Adequate information must be available to provide input for the storage routing method, and the percolation rate can be satisfactorily estimated.

If the above conditions are met, and if it is determined that modeling of transmission losses are vital and practical to the development of a rainfall-runoff model, then proceed to incorporate transmission losses in the model. This will require input of the necessary normal depth storage routing information on RC, RX, and RY records. The elevation of the channel invert (*ELVINV*) must correspond to the lowest elevation that is used in the 8-point cross section for that routing reach.

The transmission loss will be calculated using information from the RL record (*PERCRT* and *ELVINV*). Very little guidance is available for estimating the percolation rates (*PERCRT*), which can vary from more than 5 inches per hour to less than an inch per hour. Table 7-1 provides some guidance for the percolation rate that can be expected in channels of various bed materials. The *XKSAT* values for the NRCS soil map units covering the wash in question can also be used as an estimate for *PERCT*. However, the engineer/hydrologist should be aware that the values presented in Section 7.4.2.3 and Appendix D are based on a maximum value for *XKSAT* of 2.0 inches per hour. The true value of *XKSAT* for sands and gravels, estimated using the equations in Saxton and Rawls (2006), should be used for estimating transmission losses. These values should correspond well with the general guidelines presented in Table 7.16.

Table 7.16 Percolation rates for various channel bed materials

(from NRCS (2007))

Bed Material	Transmission Loss Class	Percolation Rate, *PERCT* Inches/hour
(1)	(2)	(3)
1. Very clean gravel and large sand.	Very High	>5
2. Clean sand and gravel, field conditions.	High	2.0 - 5.0
3. Sand and gravel mixture with low silt-clay content.	Moderately High	1.0 - 3.0
4. Sand and gravel mixture with high silt-clay content.	Moderate	0.23 -1.0
5. Consolidated bed material; high silt-clay content.	Insignificant to Low	0.001 - 0.10

7.9 MODELING TECHNIQUES

7.9.1 INTRODUCTION

7.9.1.1 General Discussion

Practical application of the rainfall-runoff modeling procedures in this manual can be accomplished through use of the HEC-1 Flood Hydrograph Package (U.S. Army Corps of Engineers, 1998). This computer program, which is available from the U.S. Army Corps of Engineers Hydraulic Engineering Center web site at: USACE Hydrologic Engineering Center, the National Technical Information Service, and several commercial program vendors, provides modeling capability for the hydrologic procedures that are specified in this manual. This program is a working part of the DDMSW computer program, which is the Mohave County standard tool for implementing the hydrologic methodology. This section contains an overview of the major theoretical assumptions upon which the HEC-1 computer program is based, and the resultant limitations. Watershed modeling techniques are presented, and these are related to some of the common coding errors that are often made when using the HEC-1 program. A modeler's/reviewer's HEC-1 checklist is presented in Appendix E, Checklist 2, for use by both Mohave County engineers and consulting engineers in developing and reviewing HEC-1 watershed models.

A user's working knowledge of the following areas is assumed:

1. Surface water hydrology and watershed modeling.
2. Basic input data structure for the HEC-1 program.
3. Procedures presented in this manual.

7.9.1.2 Applicable HEC-1 Versions

There are many versions of the HEC-1 computer program available and in use. Care should be taken by the user to obtain and use a version containing the desired capabilities. The HEC-1 program was originally developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC) in 1968. Since that time, there have been five significant updates and numerous error corrections. The program was originally written for main frame computers and has since been ported to a number of different platforms. This discussion is specific to the Microsoft Windows versions. The following is a brief synopsis of the releases made since 1988:

1988 Version -

1. The Green-Ampt infiltration equation was added as an option.
2. The Kinematic Wave runoff computations were improved.
3. All the main-frame computer options were made available in the PC version.
4. A program bug is present in the application of the Green and Ampt equation in combination with the JD record option.

1990 Version -

1. Muskingum-Cunge channel routing was added as an option.
2. Detention basin modeling capabilities were improved.
3. The Green and Ampt error from the 1988 version was corrected.
4. A program bug is present in the Kinematic Wave runoff procedure when using the JR record option. Hydrographs do not combine properly.

1991 Version -

1. This version is specific to the 80386/80486 microprocessors and requires a minimum of 2.5 megabytes of total memory, or 640 kilobytes of memory and 3 megabytes of disk space.
2. The Kinematic Wave error from the 1990 version was fixed.
3. The number of hydrograph ordinates available was increased from 300 to 2,000 (1998 Version).

The functional differences between the 1990 version of HEC-1 and the 1998 version are not significant. Several small errors were corrected.

The 1998 version of the HEC-1 program should be used for Mohave County rainfall-runoff watershed modeling purposes.

7.9.1.3 Assumptions and Limitations of HEC-1

Proficiency in use of the HEC-1 program requires an understanding and appreciation of the basic underlying assumptions and limitations. The key assumptions of the program are as follows:

Deterministic

The rainfall-runoff process is stochastic (non-deterministic); however, the HEC-1 program treats the process as deterministic. Randomness of the process (within both the temporal and spatial domain) is not considered. The effects of natural variability can be investigated by making numerous runs of a HEC-1 model using a systematic approach to varying critical input variables.

Lumped Parameters

Many of the model parameters, for example the Green and Ampt infiltration parameters represent spatial averages. These are "lumped" parameters that are intended to represent average conditions for a watershed subarea, not values at a point in the watershed.

Unsteady Flow

The flow rates forecasted by the model vary with time. The key limitations of the program are as follows:

1. **Single Storm**: A single storm event is modeled. Provisions are not available for soil moisture recovery between independent storms or between bursts of rainfall within a single storm.
2. **Hydrologic Routing**: All routing (channel and storage) is by hydrologic methods. Hydraulic routing (the use of the St. Venant equations) is not performed.
3. **Results**: The results are in terms of discharges and runoff volumes. Accurate water stages are not provided for channel flow. The water stages for reservoir routing do meet the standards of the profession for accuracy (except in the tailwater reach of the reservoir where gradually varied flow would exist).

7.9.2 WATERSHED MODELING

7.9.2.1 Instructions for Watershed Modeling Process

The following general steps are encouraged in performing rainfall-runoff modeling:

1. Collect all pertinent information for the watershed, including:
   a. maps,
   b. aerial photographs,
   c. soil surveys,
   d. land-use maps/reports,
   e. reports of flooding,
   f. streamflow data (if available), and
   g. reports of other flood studies (FEMA, county, etc.).
2. Prepare a watershed base map using the best available topographic map and most practical map scale.
3. Perform a preliminary sub-basin delineation.
4. Conduct a field reconnaissance.
5. Finalize the sub-basin delineation.
6. Prepare the rainfall input.
7. Prepare the rainfall loss input.

8. Prepare the unit hydrograph input.
9. Prepare all routing input.
10. Prepare a preliminary logic diagram.
11. Prepare HEC-1 input file.
12. Debug the model, using the HEC-1 checklist in Appendix E as a guide.
13. Optimize the hydrograph routing operation NSTPS parameter.
14. Calibrate the model, where possible.
15. Execute the HEC-1 model.
16. Check results using indirect methods for discharge verification (Section 7.11).
17. Evaluate the model and results based on available information.
18. Revise the model, as appropriate, to best represent actual watershed conditions. Model sophistication, such as incorporation of transmission losses, is usually added to the model at this point, but could be part of steps 13 and 14.
19. Execute the final HEC-1 model.
20. Make final model verifications and evaluations.
21. Revise the logic diagram.
22. Prepare a report.

7.9.2.2 HEC-1 Logic Diagram

A schematic diagram for multiple sub-basin models should be prepared and included as a part of the final report. This diagram symbolically depicts the order of combining and routing hydrographs. The data to be included are:

1. sub-basin data (sub-basin name, area, T_c,)
2. channel routing data (length, slope, average "n" value, base width and/or other dimensions, average velocity, transmission loss rate, peak discharge), and
3. storage routing data (maximum stage, maximum storage).

7.9.2.3 Model Time Base and Computation Interval

The model time base and computation interval are controlled by the NMIN and NQ variables, which are input in the IT record. These variables are defined as:

NMIN The integer number of minutes in the tabulation interval used to define the temporal spacing of the hydrograph ordinates. This variable sets the definition of the hydrograph. Too large a value will result in inaccuracies in peak discharge and runoff volume estimates. NMIN should be in the range of 0.10 to 0.25 times the shortest

sub-basin T_c in the HEC-1 model. NMIN must be evenly divisible into 60 and MUST be an integer.

The following general criteria are recommended for NMIN:

NMIN = 1 or 2 minutes for a 6-hour storm duration (drainage area less than or equal to 20.0 square miles), and

NMIN = 5 minutes for a 24-hour storm duration (drainage area greater than 20.0 square miles).

NQ NQ is the integer number of hydrograph ordinates to be computed. There is a maximum of 2,000 allowed for the 1998 version of HEC-1. The total time base for the model is therefore NQ x NMIN, and this product must be greater than the total storm duration specified on the PH record plus the total routed travel through the watershed.

When using a 6-hour storm duration and NMIN = 2 minutes, NQ can usually be set at 200. If NMIN is larger than 2 minutes, NQ can be less than 200. If NMIN is 1 minute, then NQ must be at least greater 360, up to a maximum of 2,000.

When using a 24-hour storm duration and NMIN = 5 minutes, NQ will normally be 300. If NMIN is larger than 5 minutes, NQ can often be less than 300. If NMIN is less than 5 minutes, then NQ must be greater than 300, up to a maximum of 2,000.

Refer to Appendix E for a HEC-1 checklist that contains guidance on inspection of HEC-1 output for determination of the adequacy of the NMIN and NQ values, and guidance on alterative selections of NMIN and NQ.

7.9.2.4 Sub-Basin Delineation

The process of breaking down a watershed into sub-basins should be done with careful consideration given to several critical factors. Defining these factors prior to beginning the delineation will help to ensure that the model remains within the limitations of the methodology used. It will also help avoid extensive revisions after the fact. These factors are as follows:

Concentration Points

Identify locations where peak flow rates or runoff volumes are desired. The following locations, at a minimum, should be considered:

1. confluences of watercourses where a significant change in peak discharge may occur,

2. drainage structures and flood retarding structures,
3. crossing of watercourses with major collector or arterial roadways, and
4. jurisdictional boundaries.

Sub-Basin Size

Using the concentration point locations, estimate a target average sub-basin size to strive for, and estimate the smallest expected sub-basin.

Time of Concentration, NMIN, NQ

Estimate the time of concentration (T_c) for the smallest sub-basin. Using this value, determine the integer number of minutes (NMIN) for the computation interval, which should be in the range of $0.1T_c$ to $025T_c$. Then estimate the number of hydrograph ordinates (NQ) required to provide an adequate time base for the HEC-1 model. As a minimum, NQ should be greater than the longest T_c value plus the total reach route travel time for the model. This should capture all the time to peak for each hydrograph operation. Ideally, NQ should be greater than the sum of the storm duration and the total reach route travel time for the model.

Homogeneity

Considerations for sub-basin homogeneity in order to meet the Lumped Parameter assumption are:

1. The sub-basin sizes should be as uniform as possible.
2. Each sub-basin should have nearly homogeneous land-use and surface characteristics. For example, mountain, hillslope, and valley areas should be separated into individual sub-basins wherever possible.
3. Soils and vegetation characteristics for each sub-basin should be as homogeneous as reasonably possible.

The average sub-basin size may need to be adjusted (addition of concentration points) as required, in order to satisfy the key assumptions upon which the HEC-1 model is based.

Routing Lengths

The length of the channel reaches defined as a result of the delineation should be considered while breaking down the watershed. A key parameter used in routing a hydrograph through a channel reach is the number of steps (NSTPS). Although this is most important for channel storage routing using the Normal Depth option, it is also a good check to use when applying the Muskingum Cunge method. The minimum reach length should satisfy the following expression:

$$L = (NSTEPS)(V_{avg})(60)(NMIN) \quad 7.22$$

where:

L = the minimum reach length, in feet.

NSTPS = an integer with a minimum value of 1, but preferably more than 1.

V_{avg} = an estimate of the average velocity, in feet/second.

NMIN = the integer number of minutes for the computation interval.

Equation 7.22 is intended to be used as a guide in estimating the minimum channel routing length ($RLNTH_{min}$) before delineating sub-basins in a multi-basin watershed model. The use of Equation 7.22 to estimate the minimum reach length in the model can improve modeling accuracy and will minimize routing instability warnings in the model output. Section 7.6.3 should be consulted for discussion of problems that may result if this recommendation is not followed.

7.9.2.5 Precipitation and Rainfall Distributions

Precipitation and rainfall distributions for watershed modeling in Mohave County are implemented in HEC-1 using the PH and JD records. The PH record, without JD records, may be used for a single basin model and for multiple basin models with a small total watershed area not requiring areal reduction (less than 5 square miles total). JD records are used in conjunction with the PH record for multiple basin models with a total watershed area greater than 1 to 5 square miles, at the discretion of the modeler. Field 1 of the PH record is left blank for HEC-1 models using NOAA Atlas 14 point precipitation data. Field 2 is to be left blank because the TP-40 depth-area reduction curves are not used for Mohave County. The point precipitation values entered in fields 3 through 10 should be reduced manually for single basin models of a large watershed (greater than 1 to 5 square miles) using the depth-area reduction curves in Table 7.7.

If design discharges are needed at existing internal concentration points in multiple basin models, then the JD record option is to be used. Instructions in USACE (1998) for use of the JD record option in conjunction with the PH record for rainfall should be consulted. Insert the correct unreduced precipitation values in Fields 3 through 8 of the PH record for a 6-hour storm or use Fields 3 through 10 of the PH record for a 24-hour storm. Implement the depth-area reduction factors from Table 7.7 using JD records.

7.9.2.6 Rainfall Losses

Keep in mind that the rainfall loss parameters are averages, assumed to be evenly distributed, for the sub-basin. The percent impervious value (*RTIMP*) is the percent of the sub-basin area for which one hundred percent runoff will be computed. This means that the impervious area is assumed to be hydraulically connected to the concentration point. This parameter should be used with care. For urban areas, *RTIMP* is the effective impervious area which is usually less than the actual total impervious area. Rock outcrop is not often directly connected to the watershed outlet. Care must be exercised when estimating *RTIMP* for rock outcrop.

7.9.2.7 Time of Concentration

Certain watersheds may require estimation of several T_c's for different hydraulically most distant points. Use the largest T_c value that is calculated for the different flow paths that are considered. Since the Unit Hydrograph Method is extremely sensitive to the T_c parameter, every time of concentration estimate should be checked for reasonableness. Because of the numerous watershed characteristics that influence T_c, verification of this parameter can be difficult. However, an evaluation of average flow velocities through a sub-basin can yield worthwhile information on the validity of the computed T_c value.

Any attempt to verify T_c calculations by using an average flow velocity analysis should be pursued with caution. Due to the large influence that overland flow travel time has on the sub-basin T_c, an average flow velocity that is computed as simply L/T_c, where L is the length of the sub-basin watercourse to the hydraulically most distant point, will normally yield an average velocity that will appear unrealistically low for the open channel flow component of the T_c value. Since overland flow velocities are normally on the order of a few tenths of a foot per second, they can consume a very large proportion of the time of concentration for a sub-basin.

Case studies have shown that it is not unusual for a simple L/T_c calculation to produce average flow velocities that are on the order of 2 to 3 fps for channels with slopes in excess of three percent. Such low velocities would not normally be considered reasonable for such steep-sloped channels.

Accordingly, a velocity analysis approach should consider separating the open channel flow contribution of T_c from the overland flow portion of T_c. Average velocities can be computed for each flow regime and then applied to the flow path length that would be associated with each of these regimes. By dividing the flow path length for each regime by the average velocity for

each regime, a travel time can be computed for each flow regime. The total sub-basin travel time computed by such an approach should be similar in magnitude to the estimated T_c value.

The following guidelines are suggested for computing the travel times for each flow regime:

Open Channel Flow

1. Use a 4-point trapezoidal cross-section to approximate the average main channel geometry for the sub-basin. The approximate cross-sectional geometry, depth, and roughness should be based on field inspections whenever possible.
2. Record the channel slope value that was used for the T_c calculation.
3. Apply the data from Steps 1 and 2 to Manning's equation to compute the average channel velocity that is associated with the bankfull discharge of the channel.
4. Record the length (L) of the sub-basin watercourse that was used for the T_c calculation.
5. Compute the open channel travel time by dividing the watercourse length from step 4 by the average velocity from Step 3.

Overland Flow

1. Compute the overland flow travel time with the following equation:

$$T_{OF} = 0.007(nL)^{0.8}/(P_2)^{0.5}S^{0.4} \qquad 7.23$$

where:

T_{OF} = overland flow travel time (hours)
n = overland flow roughness
L = overland flow length (feet)
P_2 = 2-year, 24-hour rainfall (inches]
S = overland flow slope (feet/foot)

Equation 7.23 is taken from NRCS (1986). Guidelines for selecting the overland flow roughness (n) are provided in the NRCS reference, as well as in the HEC-1 User's Manual. Overland flow lengths are generally less than 300 feet.

7.9.2.8 Hydrograph Combine and Divert Operations

The primary hydrograph operations available with the HEC-1 program, other than routing options, are combining and diverting of hydrographs. The combine operation is performed on the number of specified hydrographs starting with the most recent operation and extending sequentially back to previous operations. Key points to remember when using this operation are:

1. The maximum number of hydrograph locations that can be displayed using the DIAGRAM option of HEC-1, maintained in the computation stream, is nine.
2. The maximum number of hydrographs which can be combined at one time is five.
3. The total watershed area of the combined hydrographs may be entered manually in Field 2 of the HC record.

Hydrograph diversions may be used to simulate flow splits such as might occur at roadway intersections, over elevated highways, or at distributary channel apexes. Key points to remember about this operation are:

1. The split is done using a discharge rating table for the diversion with a maximum volume cutoff option.
2. The hydrograph that continues downstream in the model should be the one associated with the primary, dominant, flow channel for the wash. The diverted hydrograph should be the smaller side wash that is diverting away from the main, more dominant, channel.
3. It is very important to check the shape of diversion hydrographs for oscillations and to verify that the expected results are obtained.
4. When a diverted hydrograph is recalled into the stack, the drainage area associated with the hydrograph is zero. The HEC-1 summary tables will reflect incorrect areas unless the area is corrected using the manual area input option (Field 2 of the HC record) for the first combine operation downstream of the recalled hydrograph.

7.9.2.9 Hydrograph Channel Routing Operations

The channel routing option specified for use in this manual is the Normal Depth method. The following are considerations for use of the Normal Depth channel routing option:

Number of Calculation Steps

The NSTPS parameter must be selected with care. Normally, this parameter may be estimated iteratively as follows (this is the same approach used by DDMSW to optimize NSTPS):

1. Make an initial estimate of NSTPS for each reach using an assumed average velocity for the peak discharge. Use a rearrangement of Equation 7.22 as follows:

$$\text{NSTPS} = \frac{L}{(V_{avg})(60)(NMIN)} \qquad 7.24$$

where:

L = the minimum reach length, in feet.

NSTPS = an integer with a minimum value of 1, but preferably more than 1.

V_{avg} = an estimate of the average velocity, in feet/second.

NMIN = the integer number of minutes for the computation interval.

2. Run the model and calculate the discharge velocity for each reach. This velocity can be approximated by the following method:

   Estimate the discharge velocity by dividing the routing length on the RC record by the difference between "Time of Peak" at the upstream and downstream routing limits. The "Time of Peak" values are listed in the Runoff Summary of the HEC-1 output file.

   The times to peak are based on multiples of the user selected computation interval (*NMIN*). This method is generally accurate to plus or minus one time step because of program rounding protocol when printing the "Time of Peak".
3. Estimate the new *NSTPS* values for each reach based on the calculated discharge velocity. Update and run the HEC-1 model
4. Perform Steps 2 and 3 until the *NSTPS* values converge. This normally occurs within three iterations.

Channel Geometry

Considerations, which should be checked by field reconnaissance when possible, for the Normal Depth method are:

1. All eight points on the cross section should be meaningful.
2. Be sure there is sufficient hydraulic capacity to convey the peak flow without overtopping the section.
3. Be sure that the cross section is representative of the average characteristics of the reach. If there are significant variations in section geometry, the reach should be broken down into multiple shorter reaches.
4. Verify that the Manning's n-values for the cross section are representative of the average characteristics of the reach. If there are significant variations in roughness, the reach should be broken down into multiple shorter reaches.

HEC-1 Warnings

A common warning message is the following:

WARNING Modified Puls Routing May Be Numerically Unstable For Outflows Between "Q_1" to "Q_2".

When this warning occurs, the following steps should be taken:

1. Examine the outflow hydrograph for oscillations and check the outflow peak against the inflow peak to be sure that the routed peak did not increase in magnitude. If these checks are satisfactory, then the warning can generally be considered to be satisfactorily addressed.
2. The *NMIN* variable can be reduced until the warning message goes away, or the calculated peak lies outside the specified range. However, when changing the *NMIN* value remember that this may affect other input parameters such as *NQ* and *NSTPS*.

7.9.2.10 Reservoir Routing

Modeling of reservoirs and detention basins can be accomplished using the modified Puls storage routing option of HEC-1. It is recommended that low level outlets, spillways, and structure overtopping be modeled using a discharge rating curve (SQ and SE records). The rating curve should be developed using appropriate calculation methods including using an appropriate computer program such as HEC-RAS, HY-8 (FHWA, 2016), or manual methods.

7.10 FLOOD FREQUENCY ANALYSIS

Flood frequency analysis is a procedure for computing flood magnitude frequency relations where systematic stream gaging records of sufficient length are available. The result of such an analysis can include a graph of peak discharge as a function of return period. This graph can be used to estimate the flood magnitude for selected return periods, generally between 2-year and 100-year. The resulting flood magnitude-frequency relation can be used to (1) estimate the design flood peak discharge, (2) provide estimates of flood peak discharges for the calibration or verification of rainfall-runoff models, (3) provide regional estimates of flood magnitudes that can be used to check or substantiate other methods to estimate flood magnitudes or to develop regional flood discharge relations, or (4) perform other hydrologic studies, such as the investigation of flood magnitudes from snowmelt to be used as baseflow to a watershed rainfall-runoff model. Flood gage records are sparse in Mohave County, but the period and quantity of records is increasing as Mohave County and the USGS continue to operate and monitor stream flow gages within the county. The engineer/hydrologist with a need to perform a flood frequency analysis for watersheds in Mohave County is referred to ADOT (1994), Chapter 9, "Flood Frequency Analysis", for a detailed procedure. The USGS National Stream Flow Statistics Program (NSS) web site at USGS NSS should also be studied.

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7.11 INDIRECT METHODS FOR DISCHARGE VERIFICATION

7.11.1 INTRODUCTION

The estimation of peak discharges by analytic methods (the Rational Method or by rainfall-runoff modeling using the unit hydrograph method) is based on various assumptions, and particularly in the case of HEC-1 modeling, requires the correct input of numerous model parameters. Therefore, the resulting peak discharges that are computed by analytic methods should always be verified, to the extent possible, to guard against erroneous design discharges that can result from questionable assumptions and/or faulty model input.

Since the majority of discharge estimates are made for ungaged watersheds, usually only indirect methods can be used to check the reasonableness of discharge estimates obtained from either the Rational Method or rainfall-runoff modeling. When the watershed is gaged, or is near a gaging station, a flood frequency analysis can be performed, and the results of that analysis can be used for design or used to check the results from analytic methods. The results of flood frequency analyses, because of variability of flooding in both the time and space regime, and because of uncertainties in the data and the analytic procedures, should also be checked by indirect methods.

True verification of design discharges cannot be made by any of the methods (analytic methods, flood frequency analyses, or indirect methods) because for none of these methods is there "absolute assurance" that the discharges that are obtained are the "true" representations of the flood discharge for a given frequency of flooding. However, the results of the various methods, when compared against each other and when qualitatively evaluated, can provide a basis for either acceptance or rejection of specific estimates of design discharges for watersheds in Mohave County.

In this chapter, three indirect methods are presented for checking the reasonableness of flood discharges that are obtained by either analytic methods or by flood frequency analyses. Results by either analytic methods or flood frequency analysis should always be compared and evaluated by indirect methods. There may be cases, for certain watersheds, where the flood discharges by all three methods (analytic, flood frequency analysis, and indirect) can be obtained and compared prior to selecting a design discharge.

7.11.2 PROCEDURE

7.11.2.1 General Considerations

Three procedures are provided for obtaining indirect estimates of peak discharges for watersheds in Mohave County:

1. A graph of unit peak discharge versus drainage area curves,
2. Graphs of estimated discharges versus drainage area for multiple storm frequencies for gaged watersheds in Arizona, and
3. Regression equations and data graphs for multiple storm frequencies for flood regions in Mohave County.

In general, all three procedures should be used when verifying the results of analytic methods and/or flood frequency analyses.

7.11.2.2 Indirect Method No.1 - Unit Peak Discharge Curves

Eight unit peak discharge relations and envelope curves are shown on Figure 7.22. A brief description of each of those curves follows:

A - An envelope curve, based on a compilation of unusual flood discharges in the United States and abroad (data prior to 1941), by Craeger and others (1945).

B - An envelope curve of extreme floods in Arizona and the Rocky Mountain region developed by Matthai and published by Roeske (1978).

C - An envelope curve of peak streamflow data developed for Arizona by Malvick (1980).

D - An envelope curve of peak streamflow data for the Little Colorado River basin in Northern Arizona developed by Crippen (1982).

E - An envelope curve of peak streamflow data for Central and Southern Arizona developed by Crippen (1982).

F - An envelope curve of the largest floods in the semi-arid Western United States developed by Costa (1987).

G - An envelope curve of peak discharges for Arizona, Nevada and New Mexico developed by the U.S. Army Corps of Engineers (1988).

H - An envelope curve of maximum peak discharges from USGS gages in Arizona from *Methods for Estimating Magnitude and Frequency of Floods in Arizona, Developed with Unregulated and*

Rural Peak-Flow Data through Water Year 2010, Paretti, Kennedy, Turney, and Veilleux (2014). A cloud of common values that this curve is based on is shown on Figure 7.23. The data and graphs for Figure 7.22 and Figure 7.23 were obtained courtesy of the Flood Control District of Maricopa County.

When using Figure 7.22, it must be noted that the curves represent data sets for different hydrologic regions. The curves represent envelopes of maximum observed flood discharges. The curves of most interest in evaluating 100-year peak discharges for Mohave County are C, D, G, and H. These curves are most appropriate for evaluating extreme events.

7.11.2.3 Indirect Method No .2 – USGS Data for Arizona

Indirect Methods Numbers 2 and 3 are based on Paretti, Kennedy, Turney, and Veilleux (2014). Data can be obtained from the USGS StreamStats website for Arizona at: USGS StreamStats and SIR 2014-5211. The U.S. Geological Survey (USGS) collected annual peak-flow data through water year 2010 compiled from 448 unregulated streamflow-gaging stations in Arizona, hereafter referred to as stream gages, having a minimum of 10 years of record.

Per Paretti, Kennedy, Turney, and Veilleux (2014), the USGS first computed flood frequency estimates with station (or at-site) skew using the Expected Moments Algorithm with a multiple Grubbs-Beck test to identify multiple potentially influential low flows to fit a Pearson Type III distribution. Next, a multiple step Bayesian least-squares-regression approach was used to determine a new statewide regional skew of −0.09. No basin characteristics analyzed were statistically significant in explaining the variation in skew and as a result, the constant model was chosen as the best regional skew model for the Arizona study area. The mean square error used in Bulletin 17B (B17B) of the Interagency Advisory Committee on Water Data was used to describe the precision of the regional skew. The constant model had a mean square error equal to 0.08, which corresponds to an effective record length of 85 years. This is a marked improvement over a previous Arizona regional skew analysis from USGS Water Supply Paper 2433, Thomas, Hjalmarson, and Waltermeyer (1997), which reported a mean square error of 0.31, for a corresponding effective record length of approximately 17 years. Thus, the new regional model had almost five times the information content (as measured by effective record length) of that calculated in Thomas, Hjalmarson, and Waltermeyer (1997), or the value of 0.302 reported in the B17B generalized skew map.

The flood frequency estimates were recalculated using a weighted skew of the station and regional skew. Station flood frequency estimates for each stream gage were published for the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probabilities in Paretti, Kennedy, Turney, and Veilleux (2014) along with the maximum recorded discharge for each station. Plots of peak discharge versus drainage area for stations with drainage areas smaller than 10,000 square miles are shown on Figure 7.24 through Figure 7.29 for the 2-, 10-, 25-, 50-, 100- and 500-year storm frequencies. The data that the figures are based on is listed in Table F.2 of Appendix F. This table includes USGS streamflow-gaging station numbers, the associated drainage areas and the 2-, 10-, 25-, 50, 100-, and 500-year flood peak discharge estimates using a Log-Pearson type 3 (LP3) probability distribution.

A non-linear best-fit line was created for this data for each storm frequency. The equations for the best-fit line for each storm frequency are listed in equations 7.25 through 7.30. The data and graphs for **Error! Reference source not found.**, Figure 7.22 through Figure 7.23 , and equations 7.25 through 7.30 were obtained courtesy of the Flood Control District of Maricopa County.

$$Q_2 = (37.297)A^{0.617} \quad 7.25$$

$$Q_{10} = (179.148)A^{0.600} \quad 7.26$$

$$Q_{25} = (305.531)A^{0.582} \quad 7.27$$

$$Q_{50} = (477.836)A^{0.549} \quad 7.28$$

$$Q_{100} = (670.977)A^{0.526} \quad 7.29$$

$$Q_{500} = (1090.053)A^{0.560} \quad 7.30$$

where:

Q is the peak discharge in cubic feet per second.

A is the drainage area in square miles.

Also shown on Figure 7.24 through Figure 7.29 are the 90 percent upper and lower confidence bounds about the LP3 frequency discharge line from equations 7.25 through 7.30.

Watershed characteristics for each of these gaging stations are provided in Paretti, Kennedy, Turney, and Veilleux (2014). A map of Arizona showing the locations of the gaging stations for this data compilation are shown on Figure 7.30.

Figure 7.22 Peak discharge relations and envelope curves

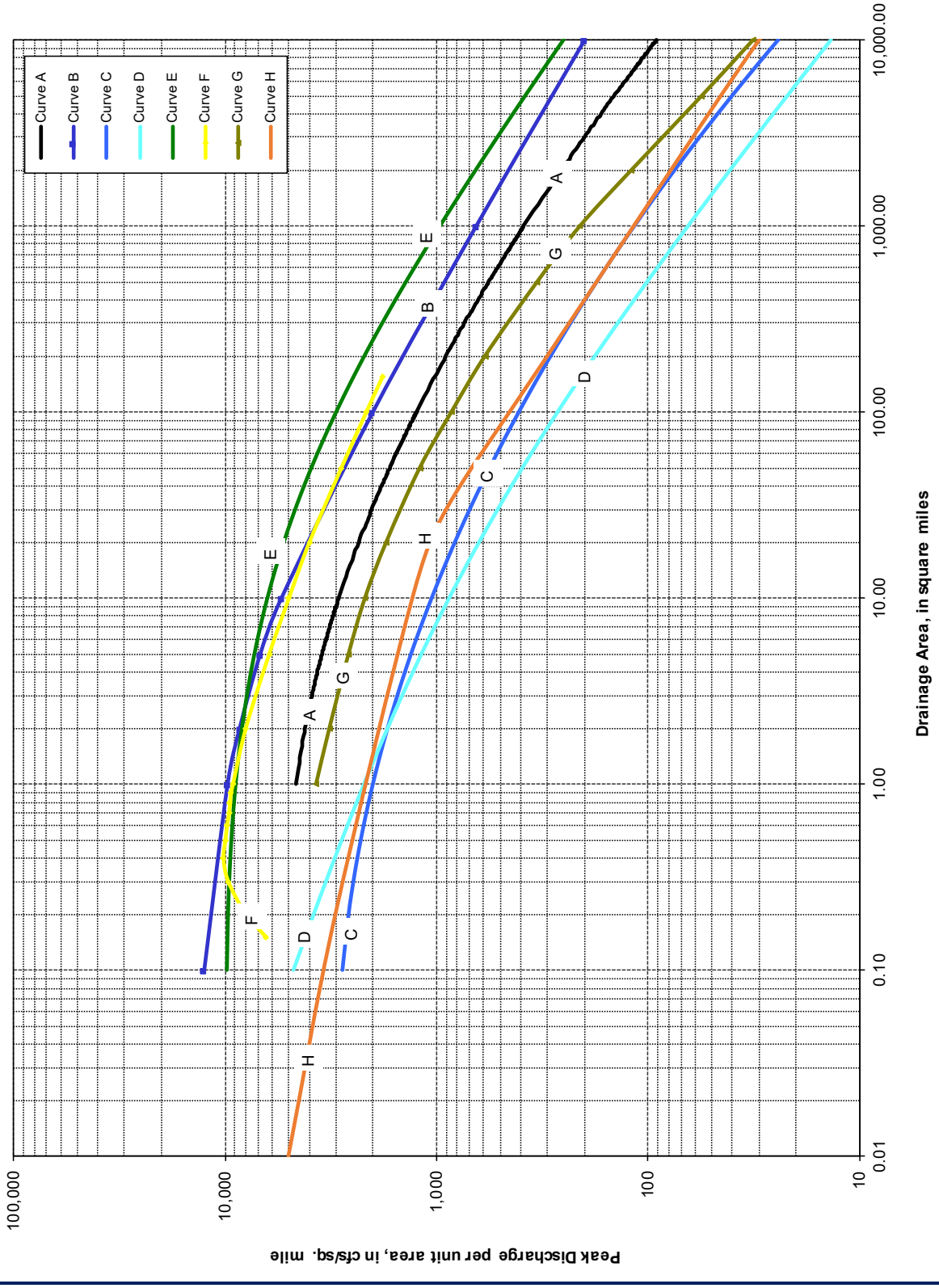


Figure 7.23 Cloud of common values for AZ max peak discharges

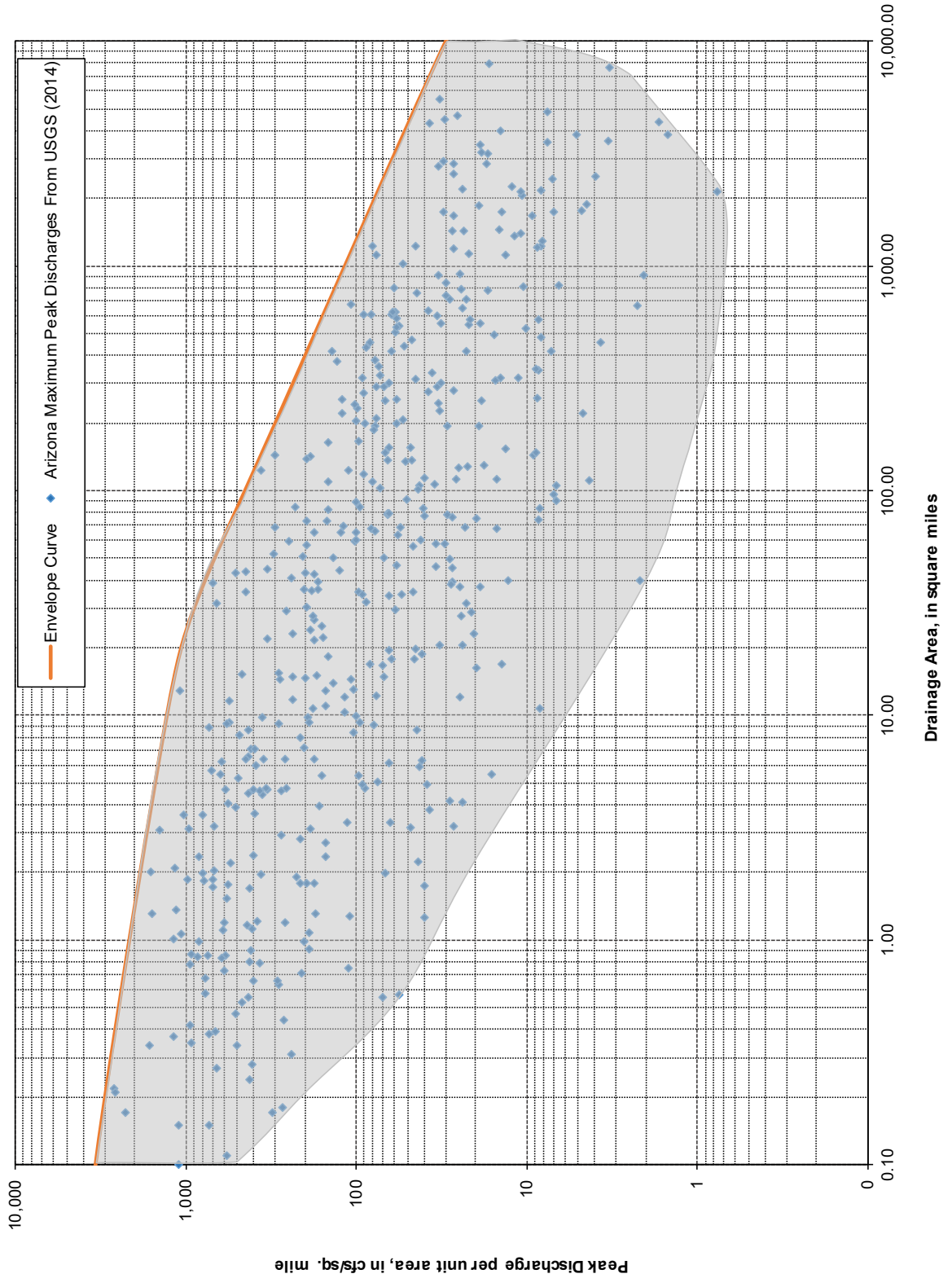


Figure 7.24 2-year peak discharges for Arizona by LP3 analysis

Source: Derived from Paretti, Kennedy, Turney, and Veilleux (2014)

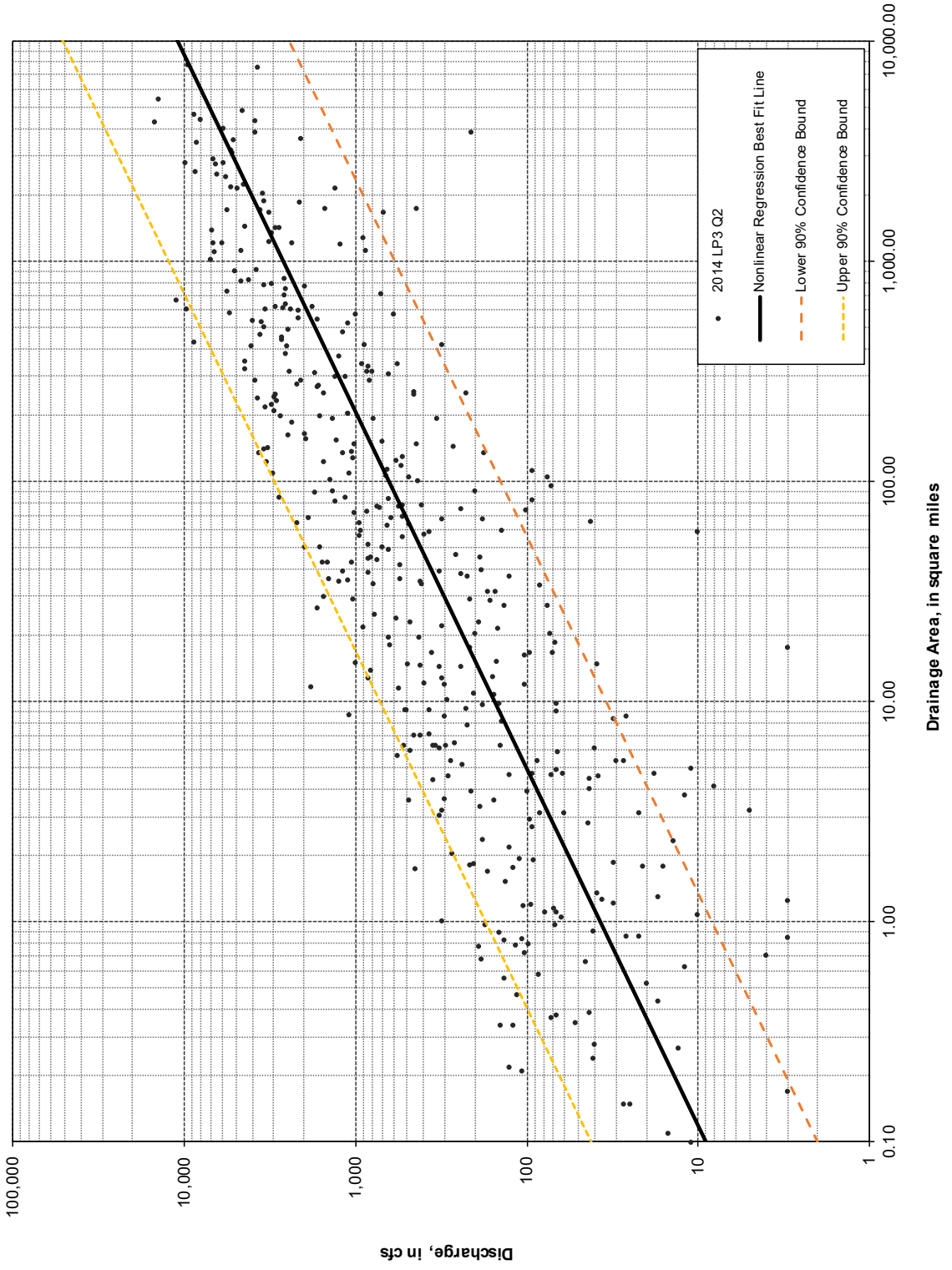


Figure 7.25 10-year peak discharges for Arizona by LP3 analysis

Source: Derived from Paretti, Kennedy, Turney, and Veilleux (2014)

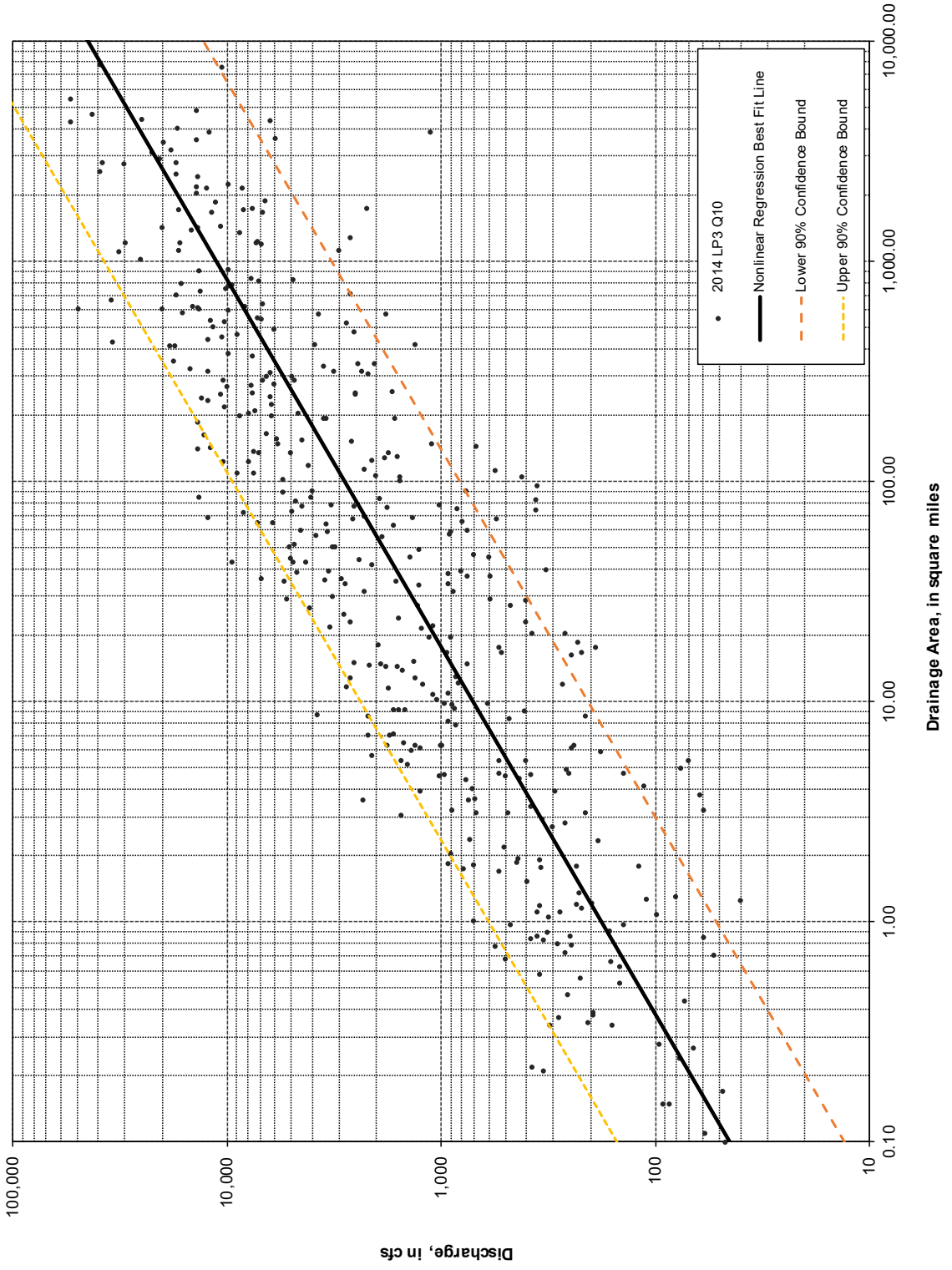


Figure 7.26 25-year peak discharges for Arizona by LP3 analysis

Source: Derived from Paretti, Kennedy, Turney, and Veilleux (2014)

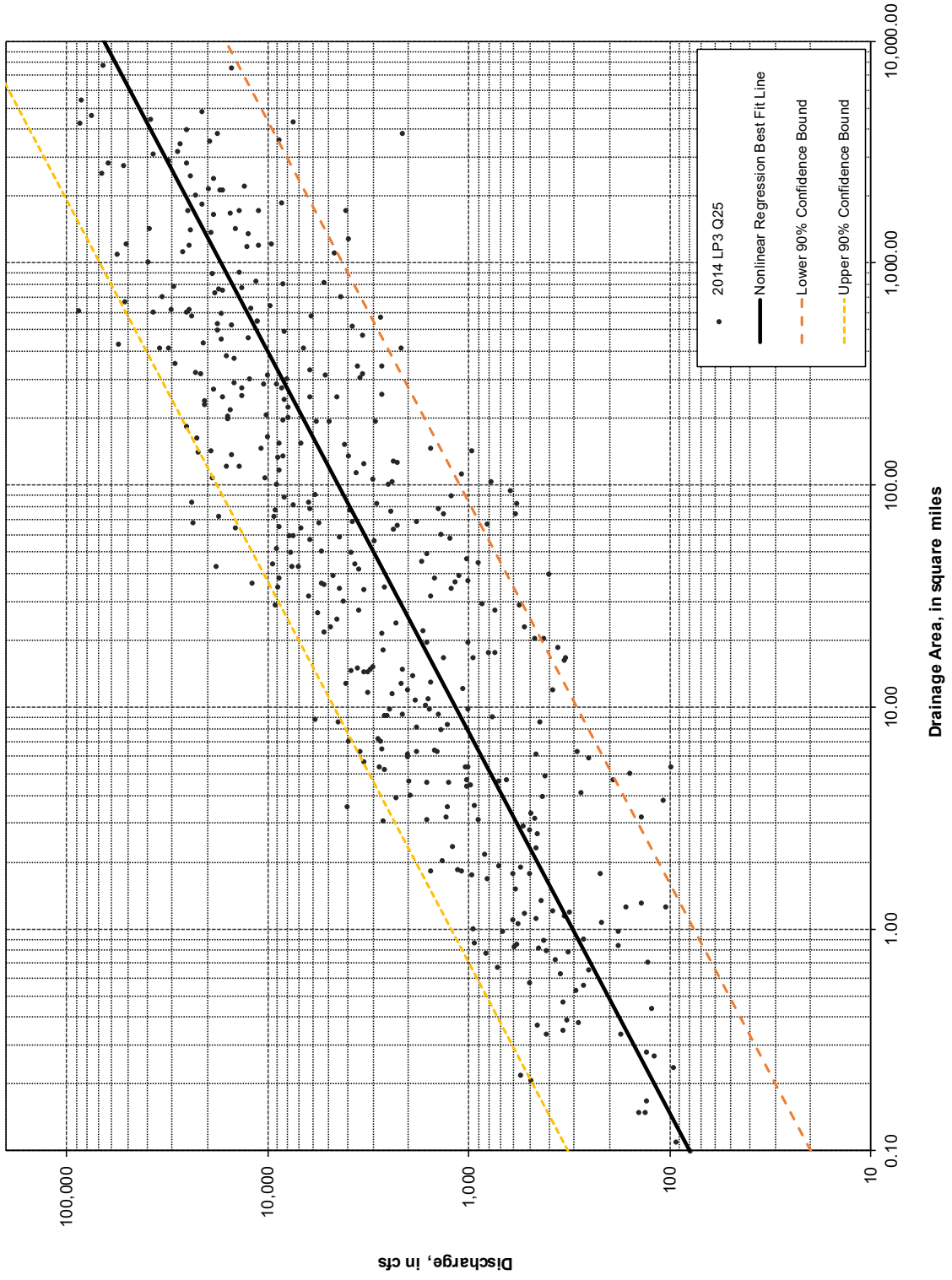


Figure 7.27 50-year peak discharges for Arizona by LP3 analysis

Source: Derived from Paretti, Kennedy, Turney, and Veilleux (2014)

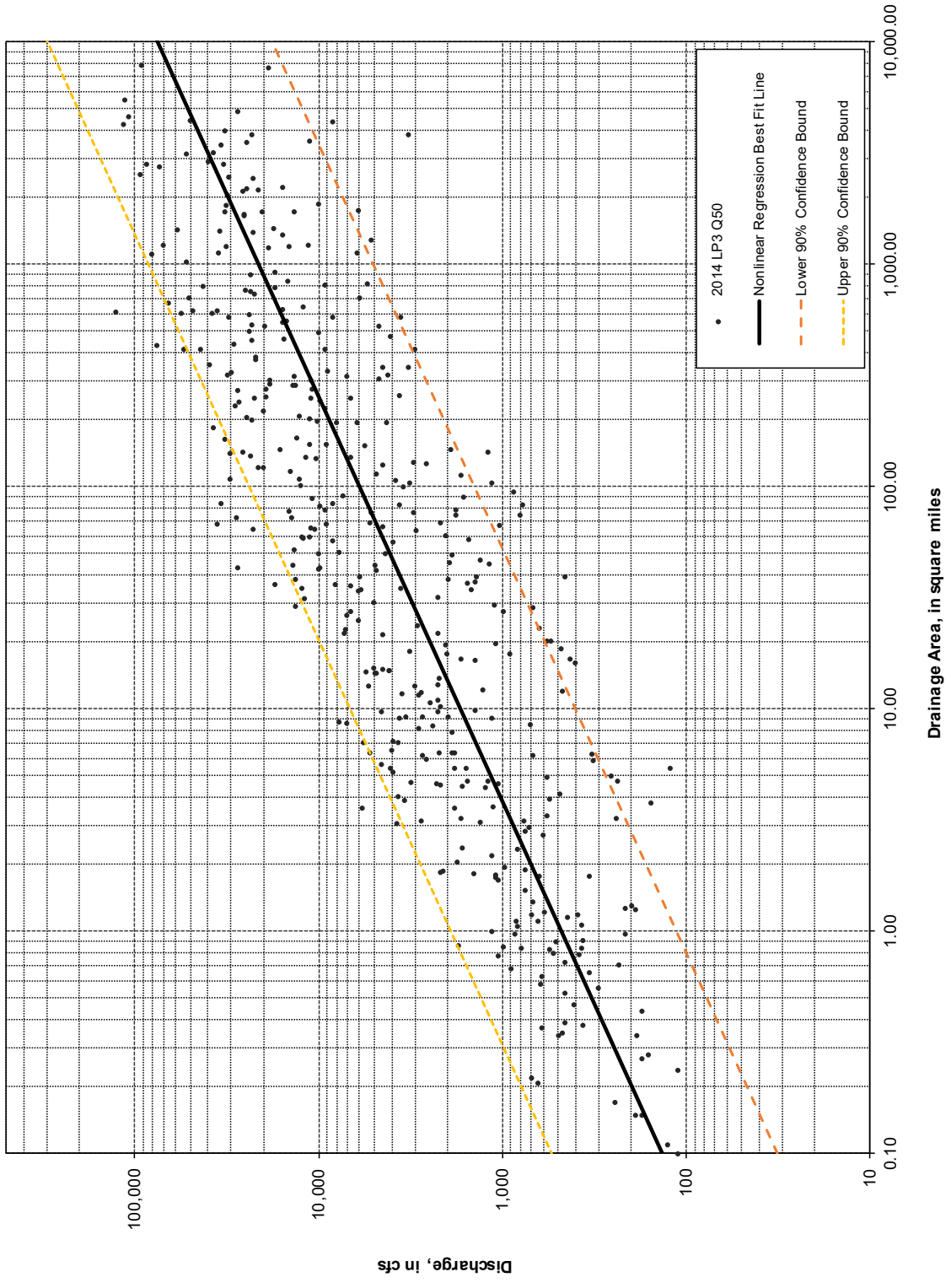


Figure 7.28 100-year peak discharges for Arizona by LP3 analysis

Source: Derived from Paretti, Kennedy, Turney, and Veilleux (2014)

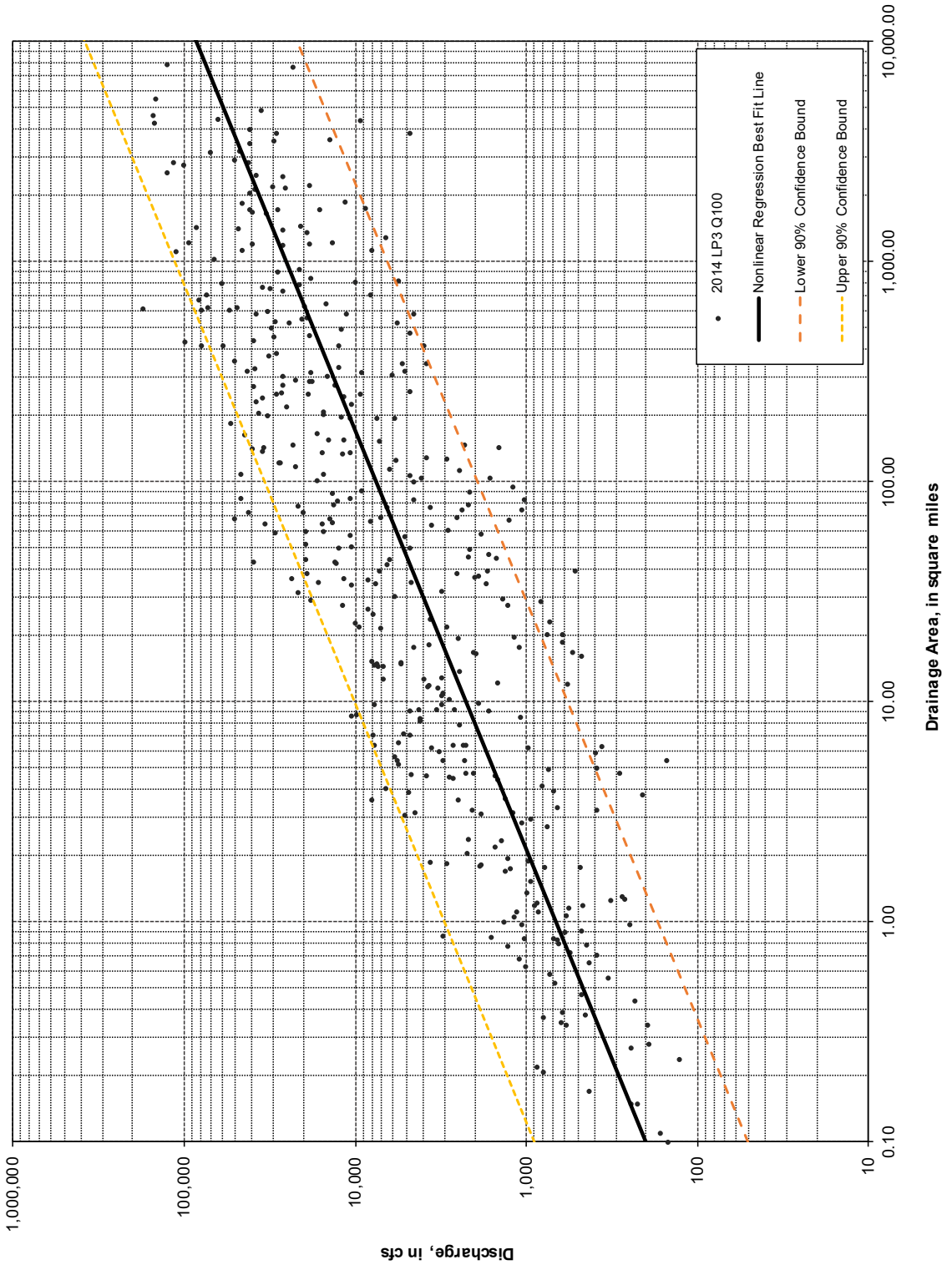


Figure 7.29 500-year peak discharges for Arizona by LP3 analysis

Source: Derived from Paretti, Kennedy, Turney, and Veilleux (2014)

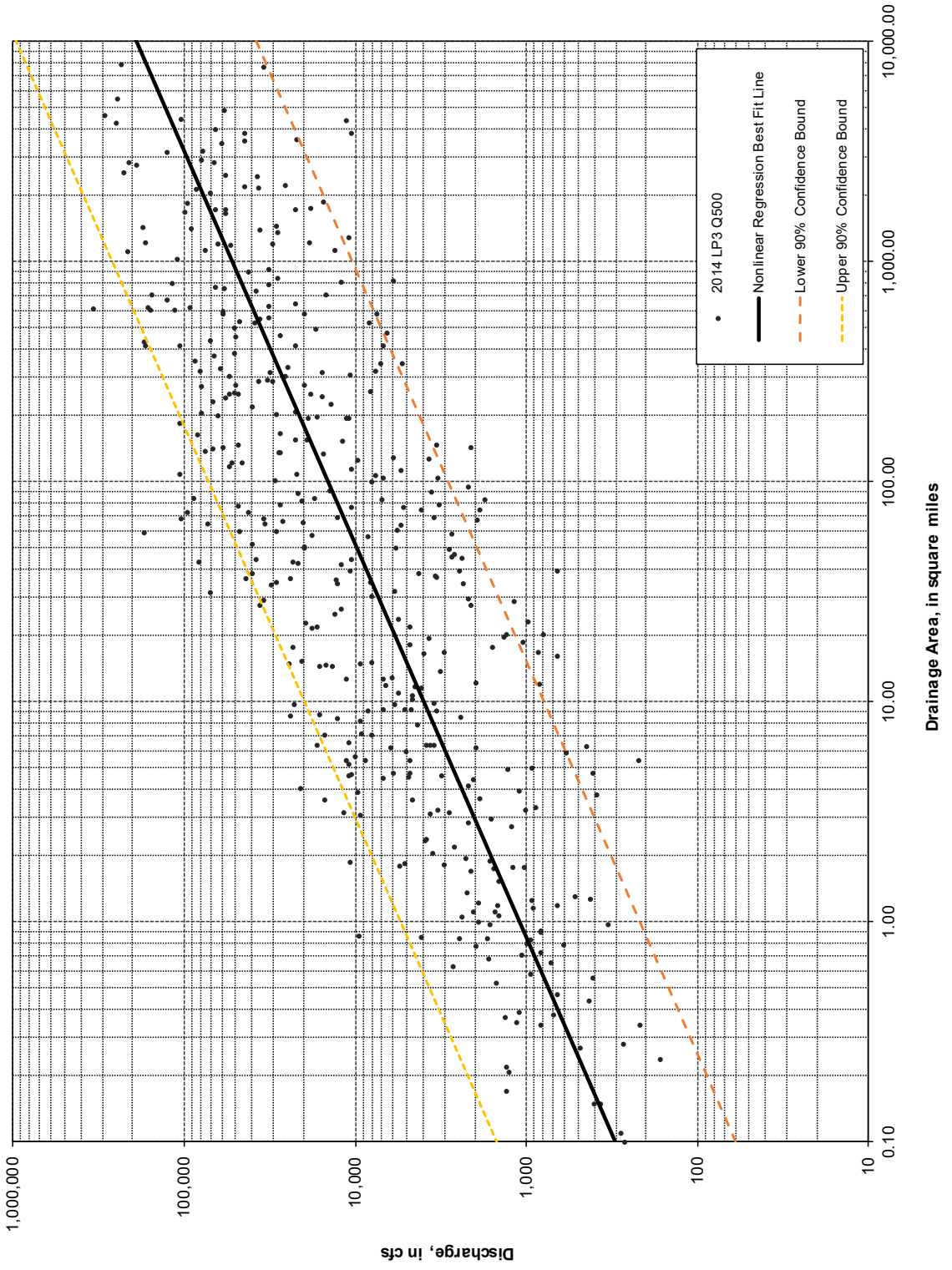
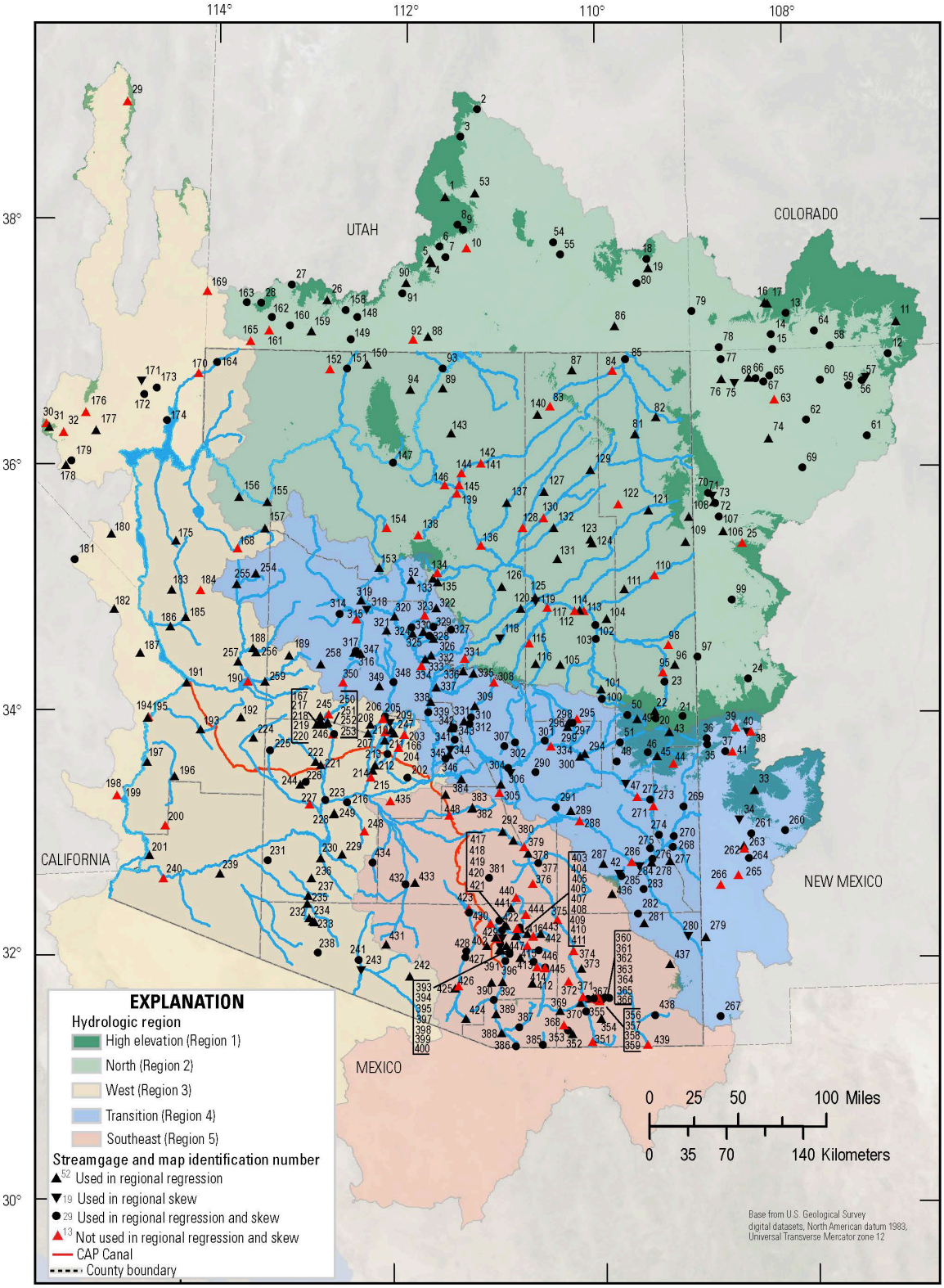


Figure 7.30 Location of USGS gaging stations



7.11.2.4 Indirect Method No.3 – Regional Regression Equations

An analysis was performed by the USGS of streamflow data for a study area comprised of Arizona, and parts of California, Nevada, Colorado, Utah, New Mexico, and Sonora, Mexico. Refer to Paretti, Kennedy, Turney, and Veilleux (2014). That analysis resulted in five sets of regional regression equations for the study area. Four of those regions (R1, R2, R3, and R4) cover Mohave County as shown on Figure 7.31. The locations of the stream gages in and adjacent to Mohave County used in the regression analyses are shown on Figure 7.32.

The regional regression equations can be used to estimate flood magnitude-frequencies for watersheds in, and adjacent to, Mohave County. Regression equations are provided for all four regions to estimate flood peak discharges for frequencies of 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-years. The regression equations for regions R1, R2, R3, and R4 are functions of drainage area, and some are also functions of mean basin elevation and/or average annual precipitation. These are referred to as independent variables. The two independent variables used for Region 3 and Region 4 are: *PRECIP*, the average annual precipitation; and *ELEV*, the average basin elevation divided by 1,000. Note that there are no independent variables for the Region 1 and Region 2 regression equations. A map of average annual precipitation for Mohave County is shown on Figure 7.33. The list of USGS streamflow gages and independent variable estimates applied for each is contained in Table F.2 of Appendix F.

The regression equations for the four regions are provided in Table 7.19, Table 7.20, Table 7.21, and Table 7.22, respectively. Use of the regression equations is recommended only if the values of the independent variables for the watershed of interest are within the range of the data used to derive the specific regression equation. In general, the equations are applicable to unregulated watersheds with drainage areas greater than 0.1 square miles and less than 1,000 square miles although data is plotted for up to 10,000 square miles. Scatter diagrams with clouds of common values of the independent variables are available as shown on the figures listed in Table 7.17. The tables and graphs for Regions 3 and 4 were obtained courtesy of the Flood Control District of Maricopa County.

Table 7.17 Regression equation independent variables figures listing

Independent Variable	Region 1 (R1)	Region 2 (R2)	Region 3 (R3)	Region 4 (R4)
(1)	(2)	(3)	(4)	(5)
Mean basin precipitation (*PRECIP*)	None	None	Figure 7.34	Figure 7.36
Mean basin elevation (*ELEV*)	None	None	Figure 7.35	Figure 7.37

Graphs of LP3 peak discharge for each set of regression equations and all recurrence intervals except the 5-year and 200-year are provided on the figures listed in Table 7.18. The 5-year and 200-year frequencies are not normally used for drainage design or floodplain delineations. Points depicting the relation between peak discharge (computed from the regional regression equation) and drainage area are also shown on these figures. The figures are based on data provided in Paretti, Kennedy, Turney, and Veilleux (2014) available at USGS SIR 2014-5211.

Table 7.18 Regression equation peak discharge figures by frequency

Flood Region	Flood Frequency, years					
	2	10	25	50	100	500
(1)	(2)	(3)	(4)	(5)	(6)	(7)
R1	Figure 7.38	Figure 7.39	Figure 7.40	Figure 7.41	Figure 7.42	Figure 7.43
R2	Figure 7.44	Figure 7.45	Figure 7.46	Figure 7.47	Figure 7.48	Figure 7.49
R3	Figure 7.50	Figure 7.51	Figure 7.52	Figure 7.53	Figure 7.54	Figure 7.55
R4	Figure 7.56	Figure 7.57	Figure 7.58	Figure 7.59	Figure 7.60	Figure 7.61

The scatter diagrams and graph figures available for Indirect Methods 1, 2 and 3 can be used as an additional check of the reasonableness of modeled peak discharges by plotting the model results for watersheds located within a specific flood region on the appropriate scatter diagram and graph. Reasonable model results should plot within the cloud of common values, below the envelope curve, and within the scatter of data points used for the regression equations.

Figure 7.31 Flood regions affecting Mohave County

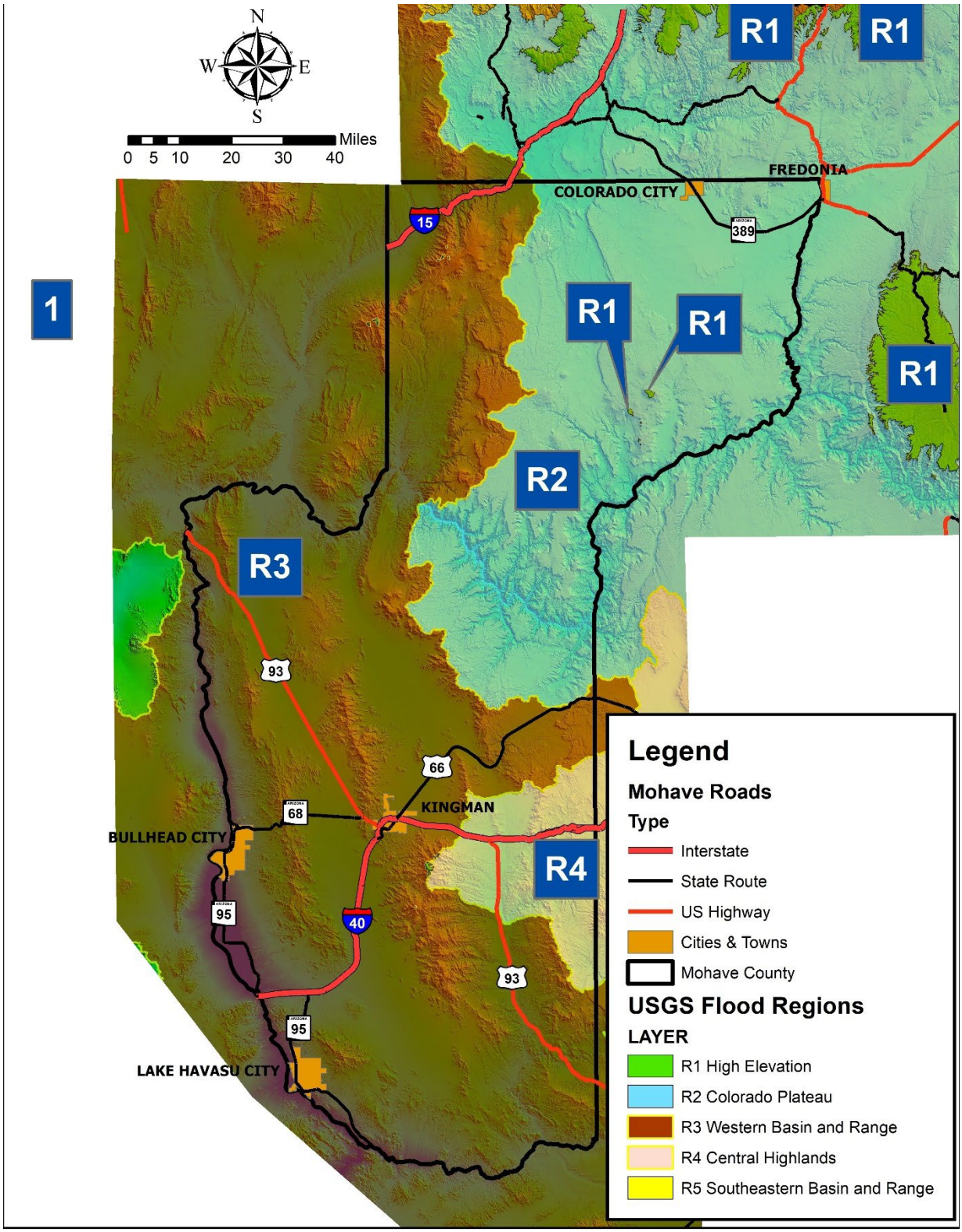


Figure 7.32 USGS stream gage locations for flood frequency equations

(Prepared using data contained in USGS(12998)

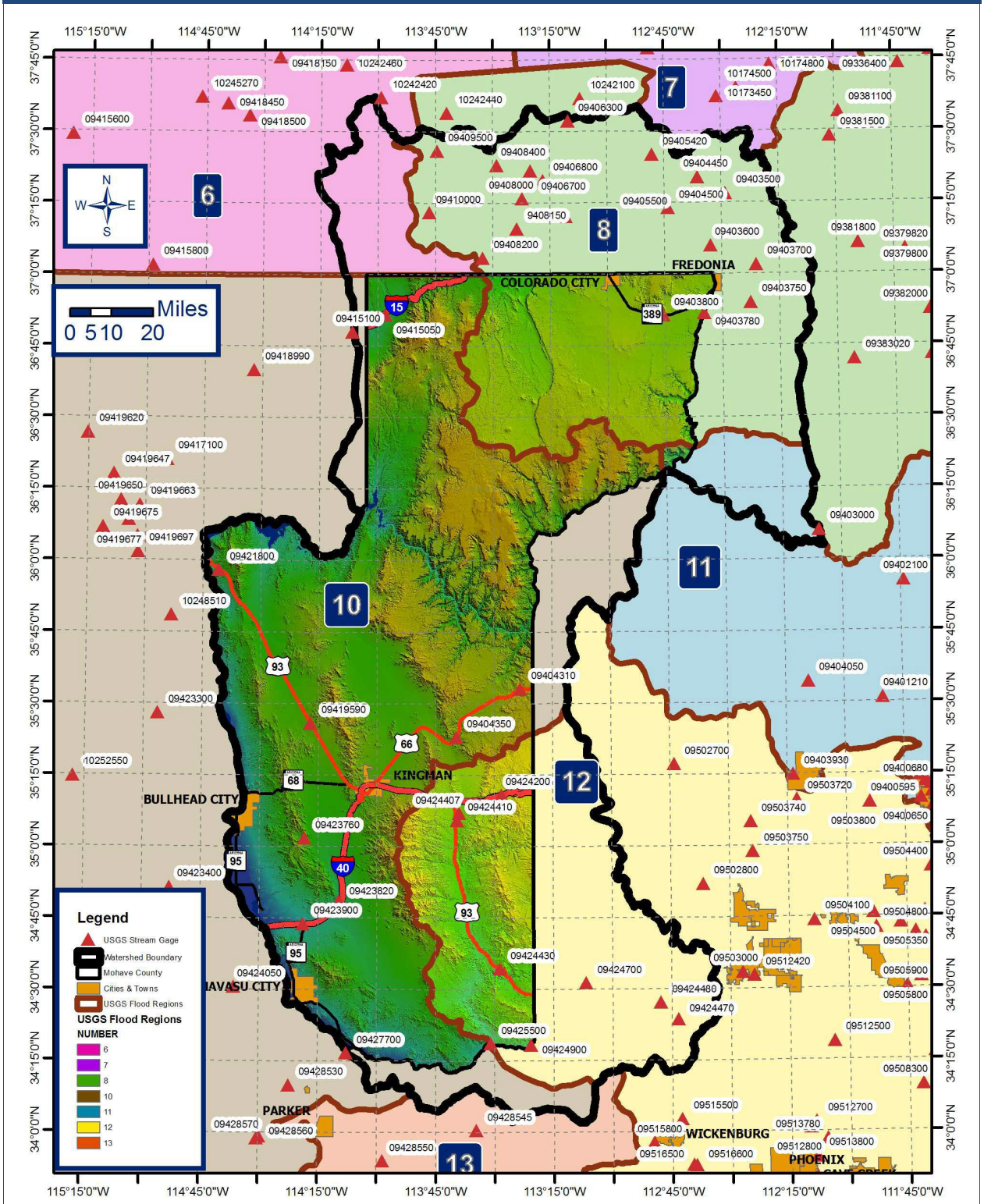


Figure 7.33 Mean annual precipitation for Mohave County

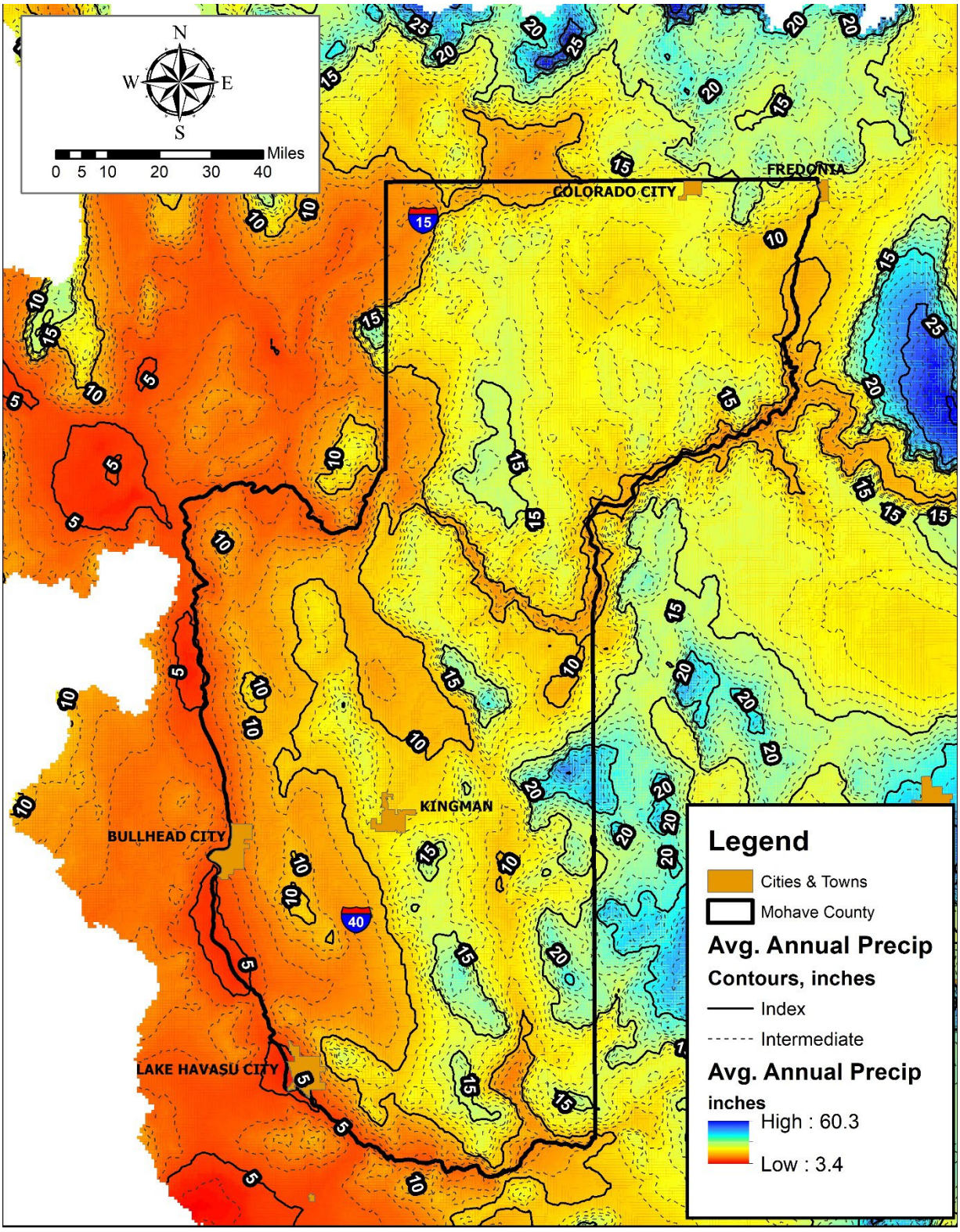


Table 7.19 Regression equations for Region 1 High Elevation (R1)
(Source: Paretti, Kennedy, Turney, and Veilleux, 2014)

Recurrence Interval, in years	Equation	Estimated standard error of model, in percent
(1)	(2)	(3)
2	$Q = 17.4AREA^{0.655}$	83.1
5	$Q = 42.1AREA^{0.625}$	62.2
10	$Q = 65.5AREA^{0.613}$	56.1
25	$Q = 103AREA^{0.604}$	52.9
50	$Q = 136AREA^{0.601}$	53.0
100	$Q = 173AREA^{0.599}$	54.0
200	$Q = 215AREA^{0.599}$	56.1
500	$Q = 279AREA^{0.599}$	60.0

Table 7.20 Regression equations for Region 2 Colorado Plateau (R2)
(Source: Paretti, Kennedy, Turney, and Veilleux, 2014)

Recurrence Interval, in years	Equation	Estimated standard error of model, in percent
(1)	(2)	(3)
2	$Q = 53.2AREA^{0.505}$	119.8
5	$Q = 142AREA^{0.476}$	85.4
10	$Q = 236AREA^{0.460}$	74.1
25	$Q = 406AREA^{0.442}$	67.1
50	$Q = 573AREA^{0.431}$	65.0
100	$Q = 778AREA^{0.421}$	65.6
200	$Q = 1{,}028AREA^{0.413}$	67.1
500	$Q = 1{,}429AREA^{0.403}$	71.0

Table 7.21 Regression equations for Region 3 Western Basin & Range (R3)
(Source: Paretti, Kennedy, Turney, and Veilleux, 2014)

Recurrence Interval, in years	Equation	Estimated standard error of model, in percent
(1)	(2)	(3)
2	$Q = 2.78AREA^{0.462}PRECIP^{2.229}10^{(-0.351*ELEV)}$	103.2
5	$Q = 12.8AREA^{0.474}PRECIP^{1.706}10^{(-0.208*ELEV)}$	49.4
10	$Q = 26.7AREA^{0.479}PRECIP^{1.447}10^{(-0.132*ELEV)}$	30.2
25	$Q = 89.1AREA^{0.495}PRECIP^{0.839}$	27.3
50	$Q = 129AREA^{0.505}PRECIP^{0.831}$	27.9
100	$Q = 183AREA^{0.516}PRECIP^{0.812}$	36.5
200	$Q = 256AREA^{0.527}PRECIP^{0.789}$	49.4
500	$Q = 384AREA^{0.539}PRECIP^{0.758}$	68.1

Figure 7.34 Scatter diagram of independent variable *PRECIP* for Region 3
(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

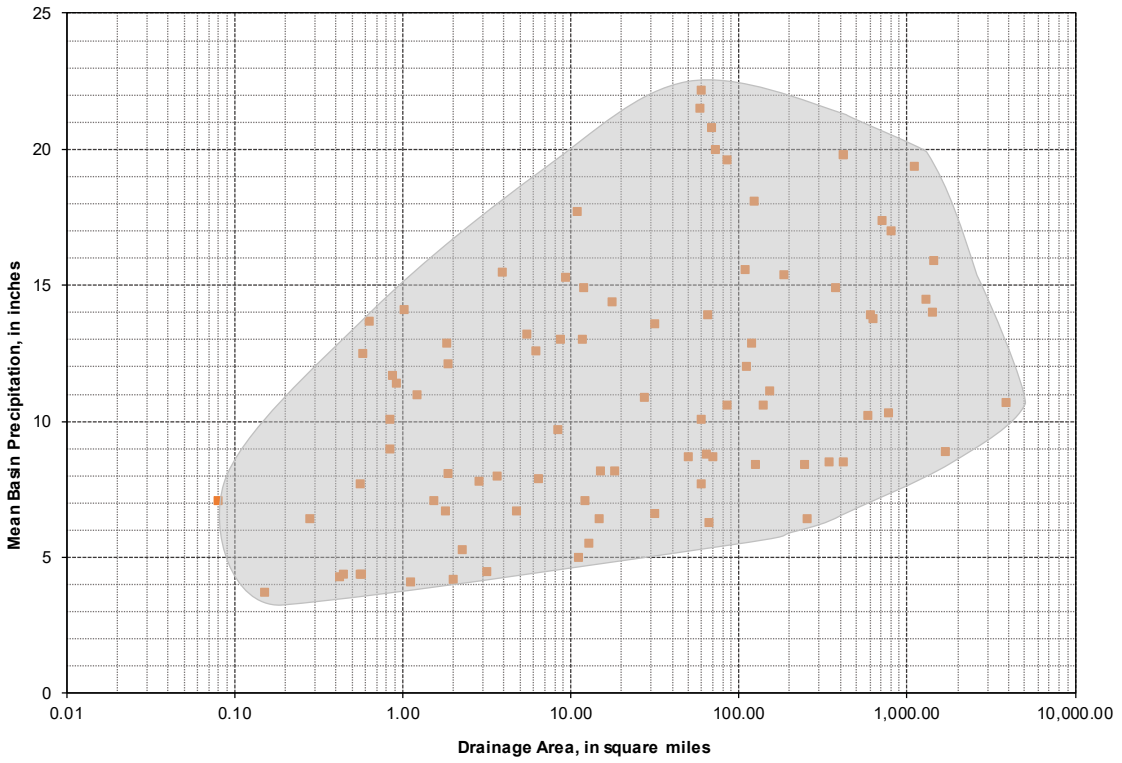


Figure 7.35 Scatter diagram of independent variable *ELEV* for Region 3

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

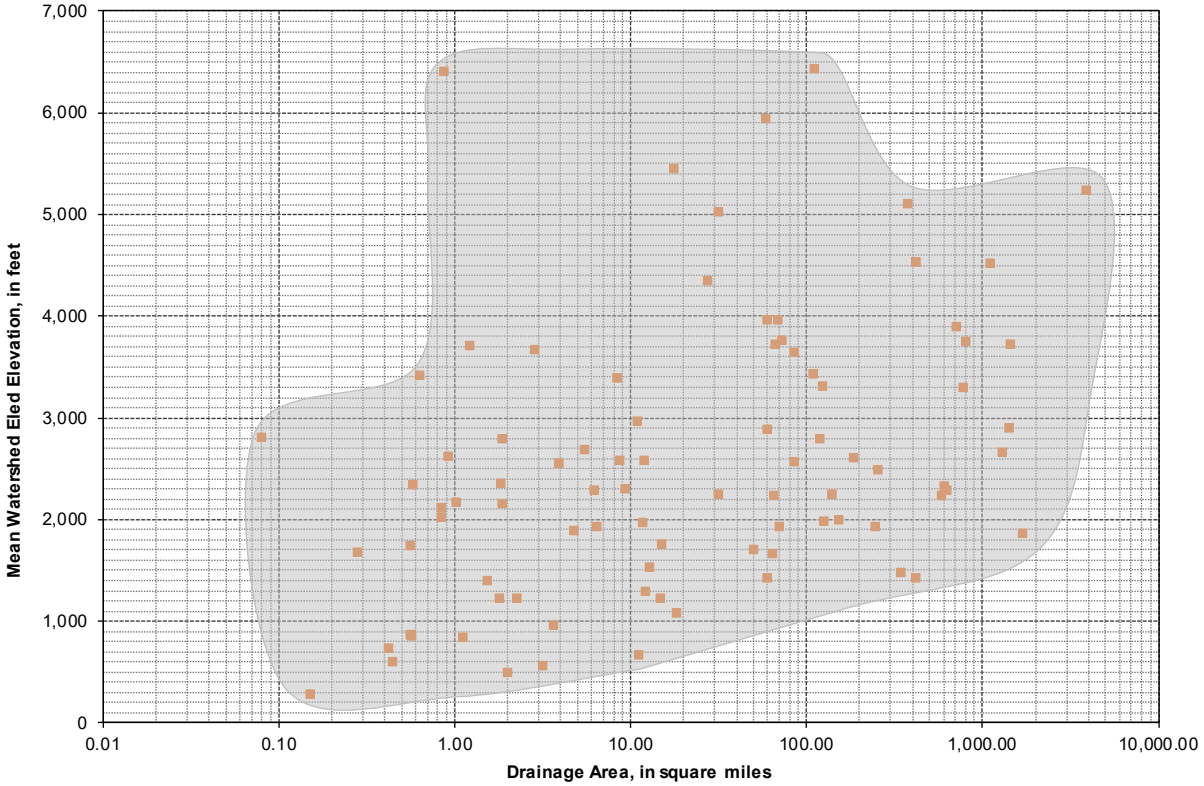


Table 7.22 Regression equations for Region 4 Central Highlands (R4)
(Source: Paretti, Kennedy, Turney, and Veilleux, 2014)

Recurrence Interval, in years	Equation	Estimated standard error of model, in percent
(1)	(2)	(3)
2	$Q = 54.7AREA^{0.664}$	99.2
5	$Q = 51.2AREA^{0.658}PRECIP^{0.903}10^{(-0.135*ELEV)}$	54.7
10	$Q = 43.2AREA^{0.643}PRECIP^{1.204}10^{(-0.150*ELEV)}$	38.2
25	$Q = 33.6AREA^{0.624}PRECIP^{1.528}10^{(-0.160*ELEV)}$	26.7
50	$Q = 30.8AREA^{0.614}PRECIP^{1.687}10^{(-0.161*ELEV)}$	24.6
100	$Q = 30.0AREA^{0.605}PRECIP^{1.805}10^{(-0.161*ELEV)}$	24.4
200	$Q = 30.6AREA^{0.598}PRECIP^{1.893}10^{(-0.161*ELEV)}$	25.9
500	$Q = 33.3AREA^{0.591}PRECIP^{1.976}10^{(-0.160*ELEV)}$	31.9

Figure 7.36 Scatter diagram of independent variable *PRECIP* for Region 4
(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

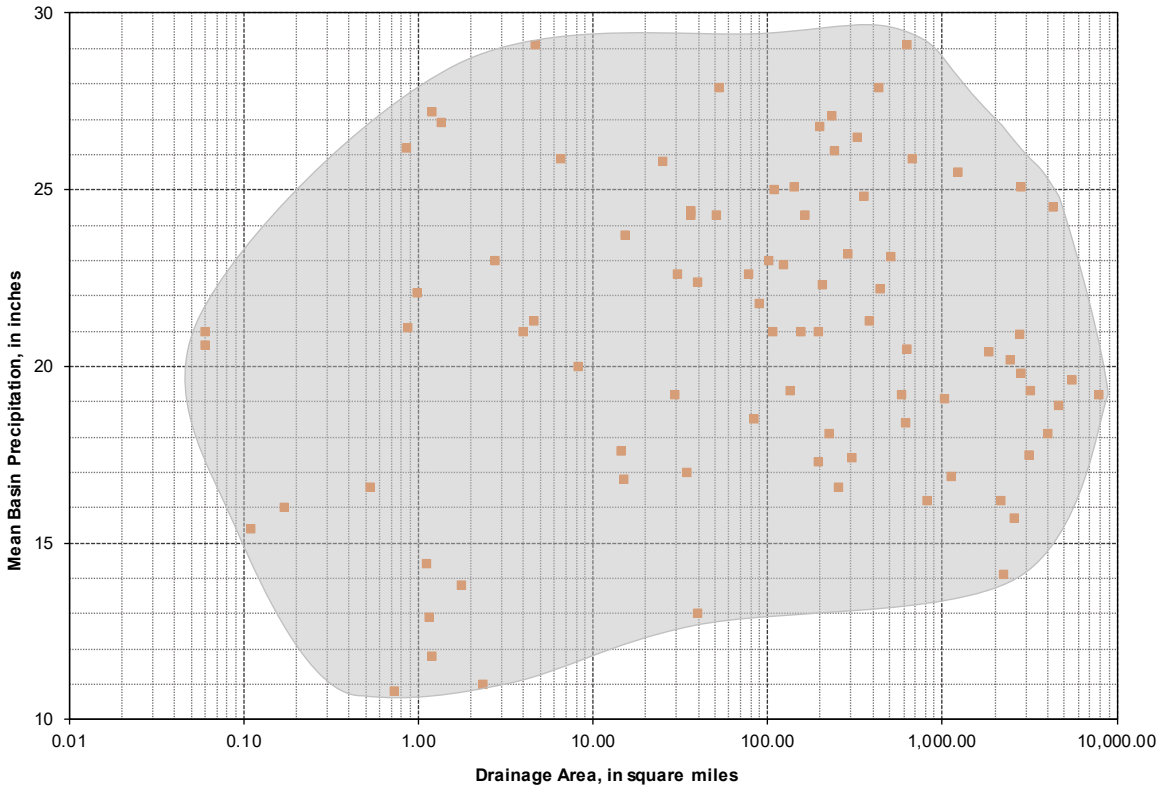


Figure 7.37 Scatter diagram of independent variable *ELEV* for Region 4

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

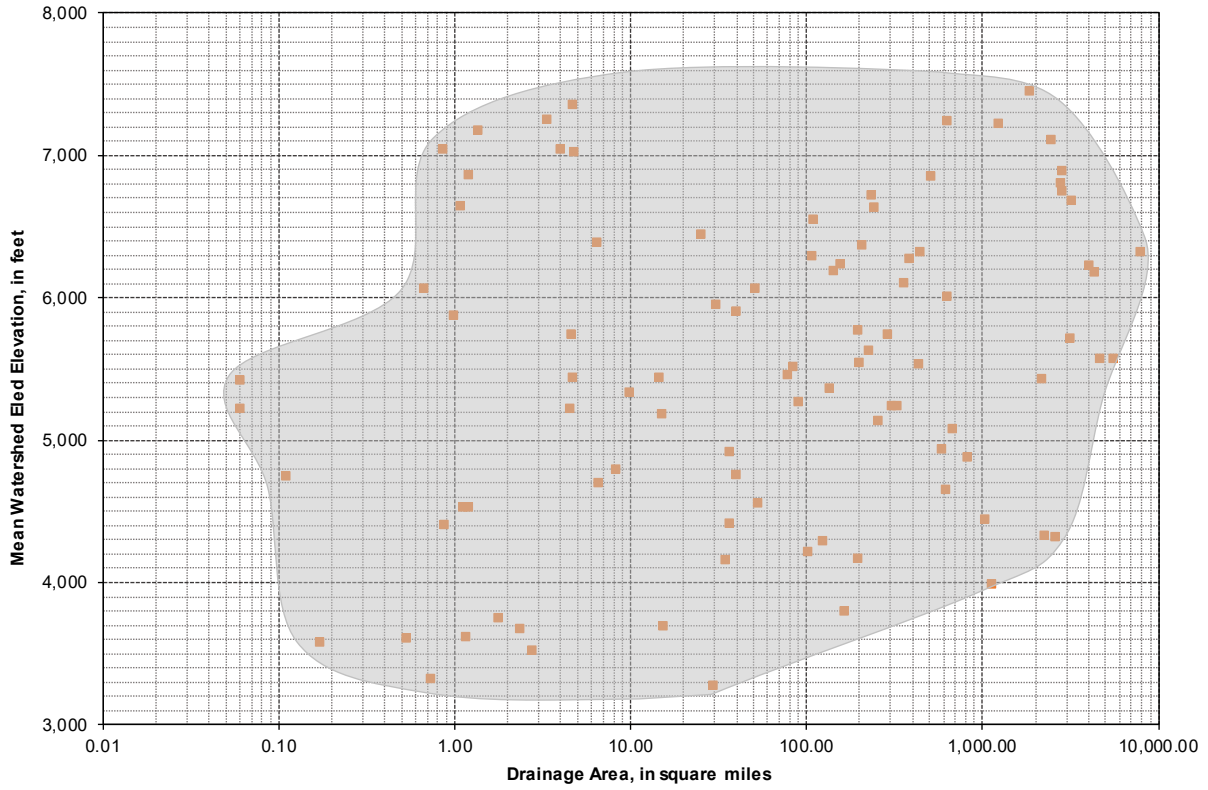


Figure 7.38 2-year peak discharge relation for Region 1 (R1)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

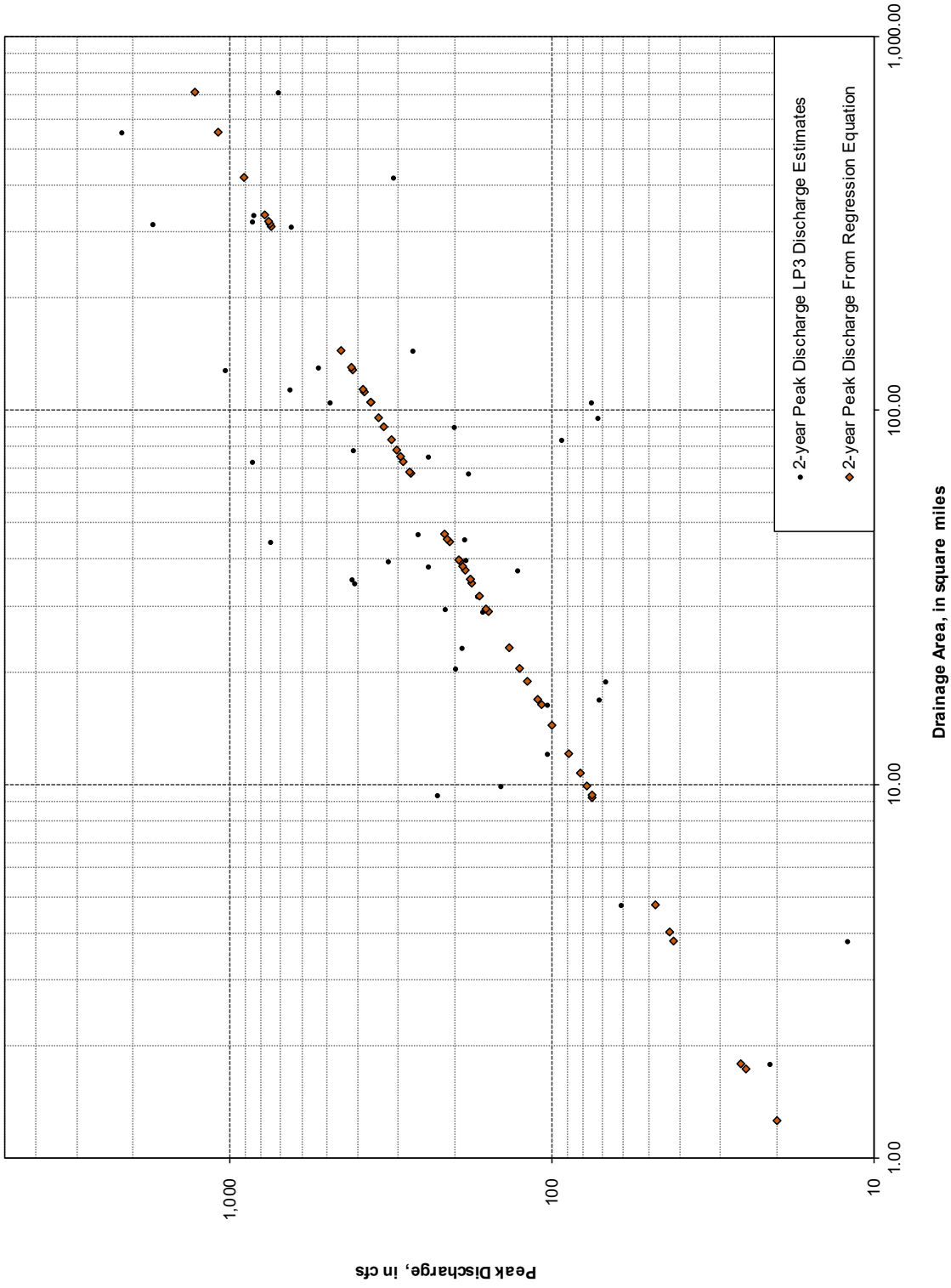


Figure 7.39 10-year peak discharge relation for Region 1 (R1)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

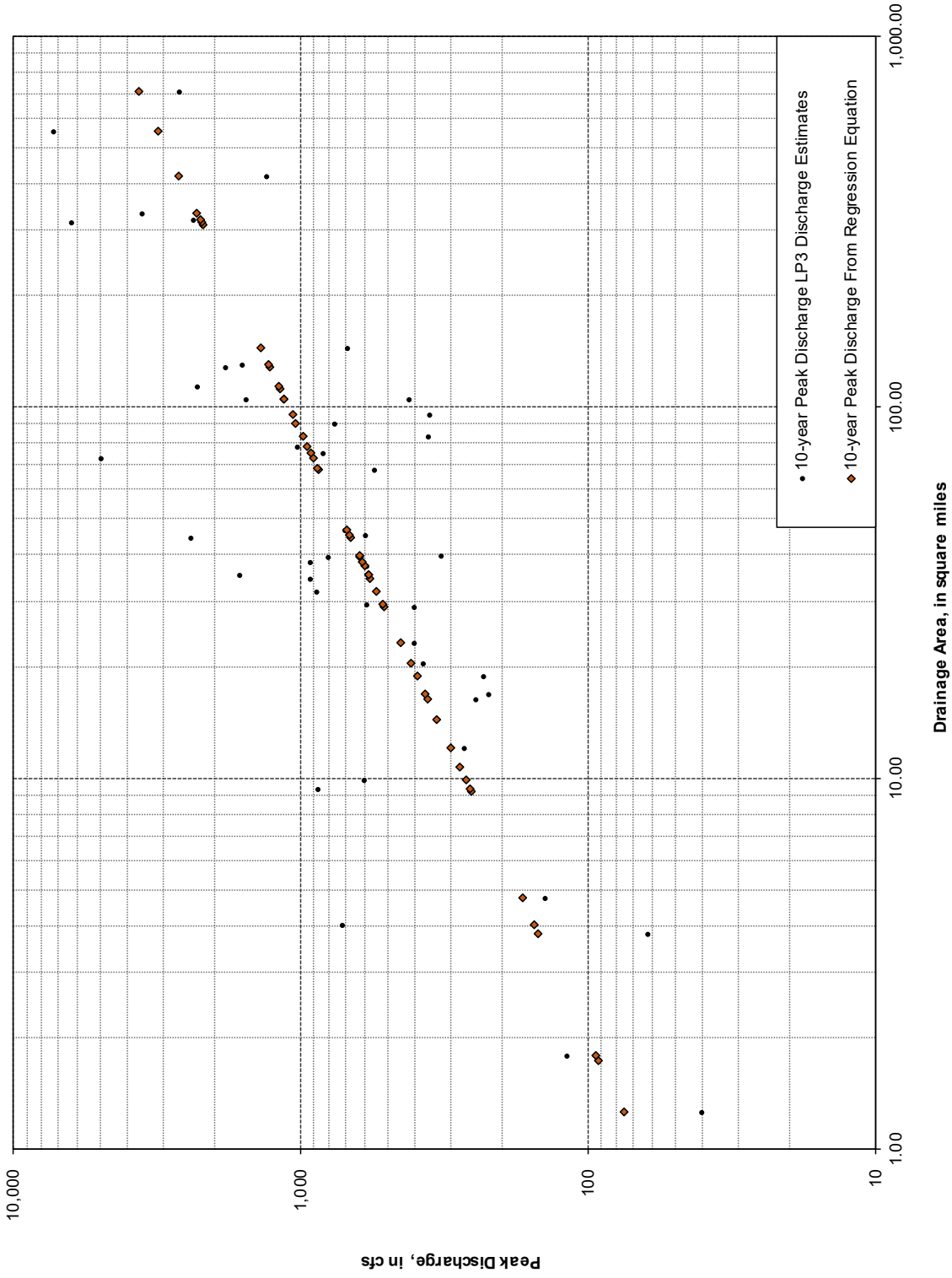


Figure 7.40 25-year peak discharge relation for Region 1 (R1)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

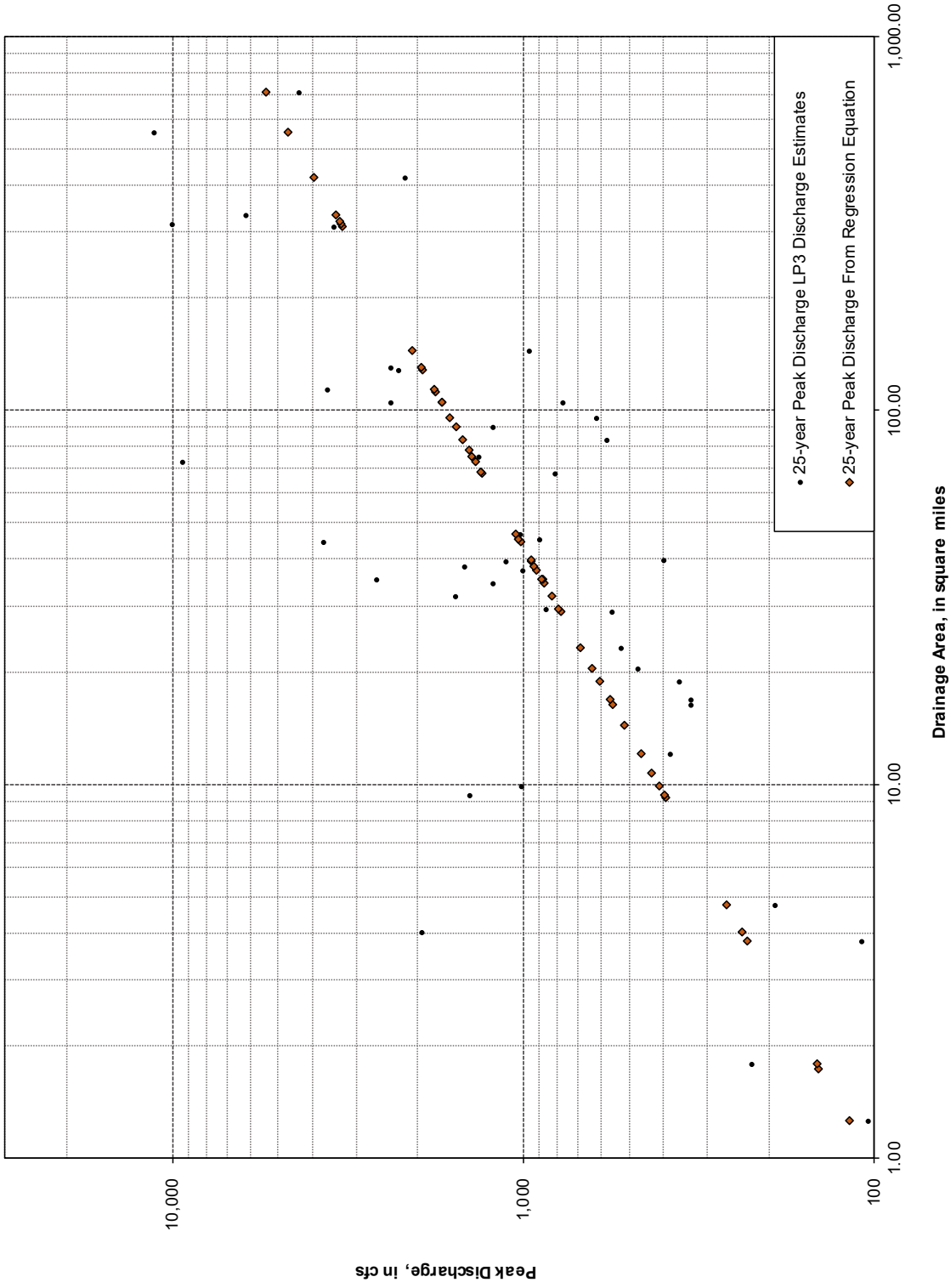


Figure 7.41 50-year peak discharge relation for Region 1 (R1)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

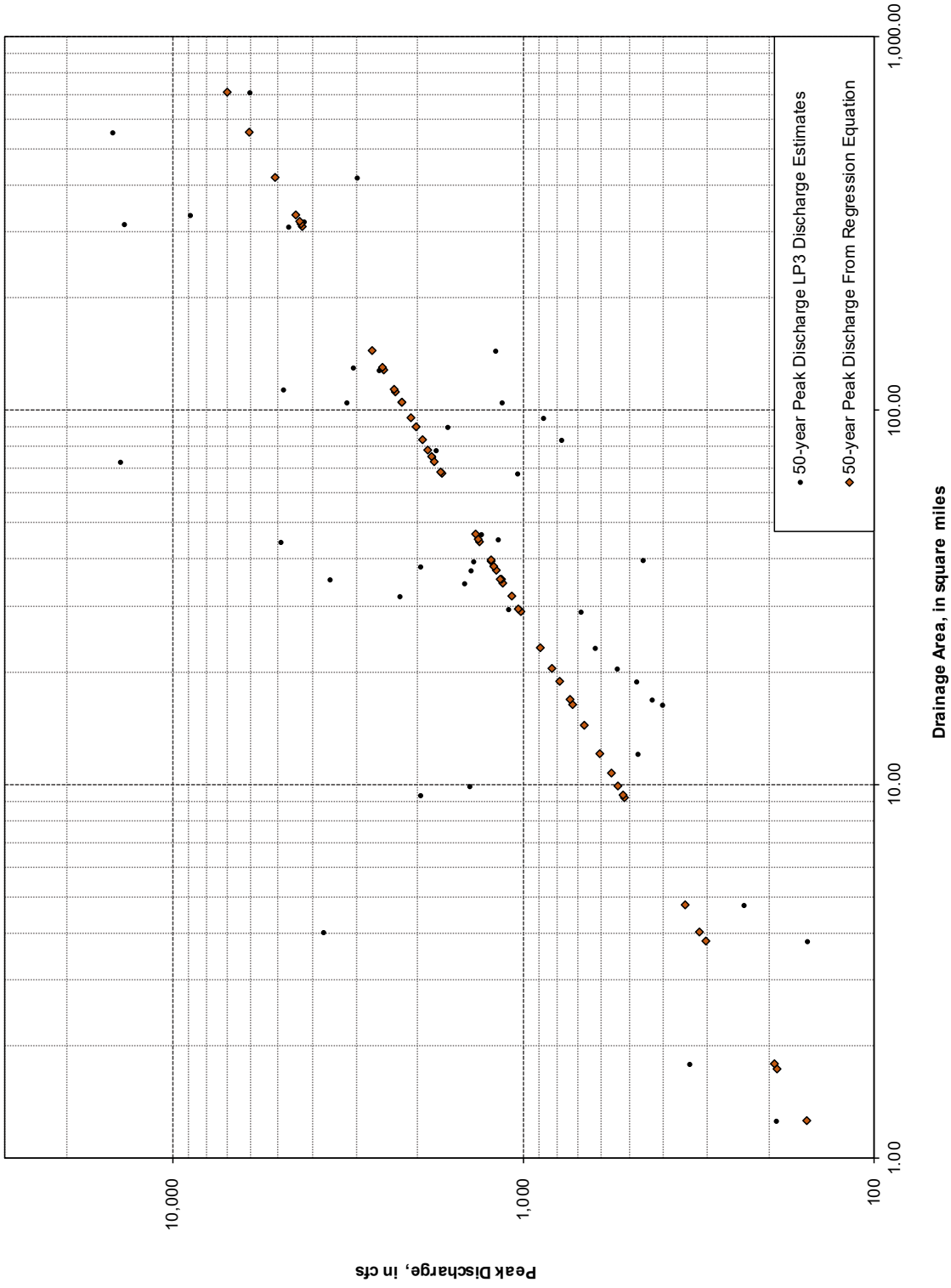


Figure 7.42 100-year peak discharge relation for Region 1 (R1)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

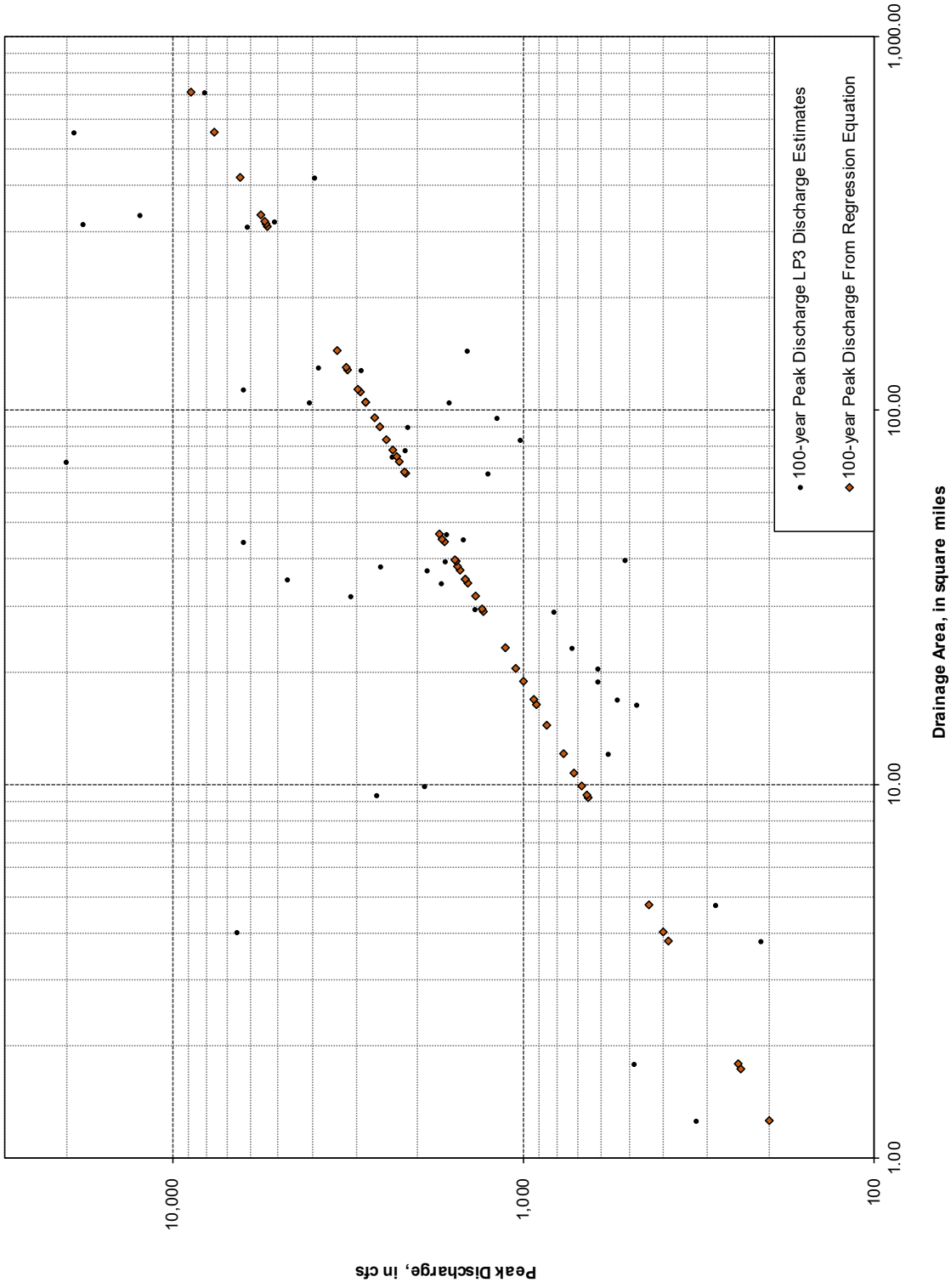


Figure 7.43 500-year peak discharge relation for Region 1 (R1)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

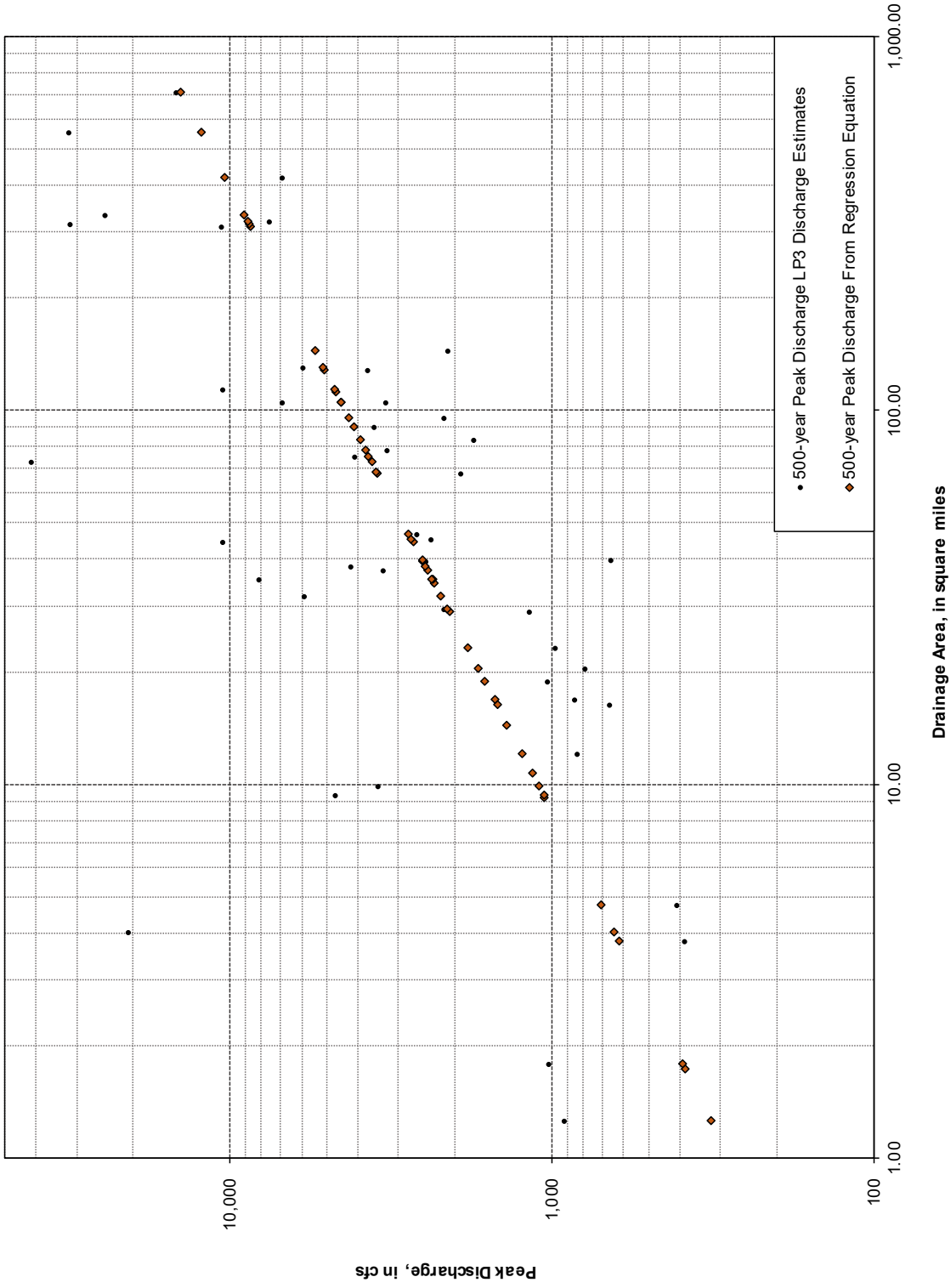


Figure 7.44 2-year peak discharge relation for Region 2 (R2)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

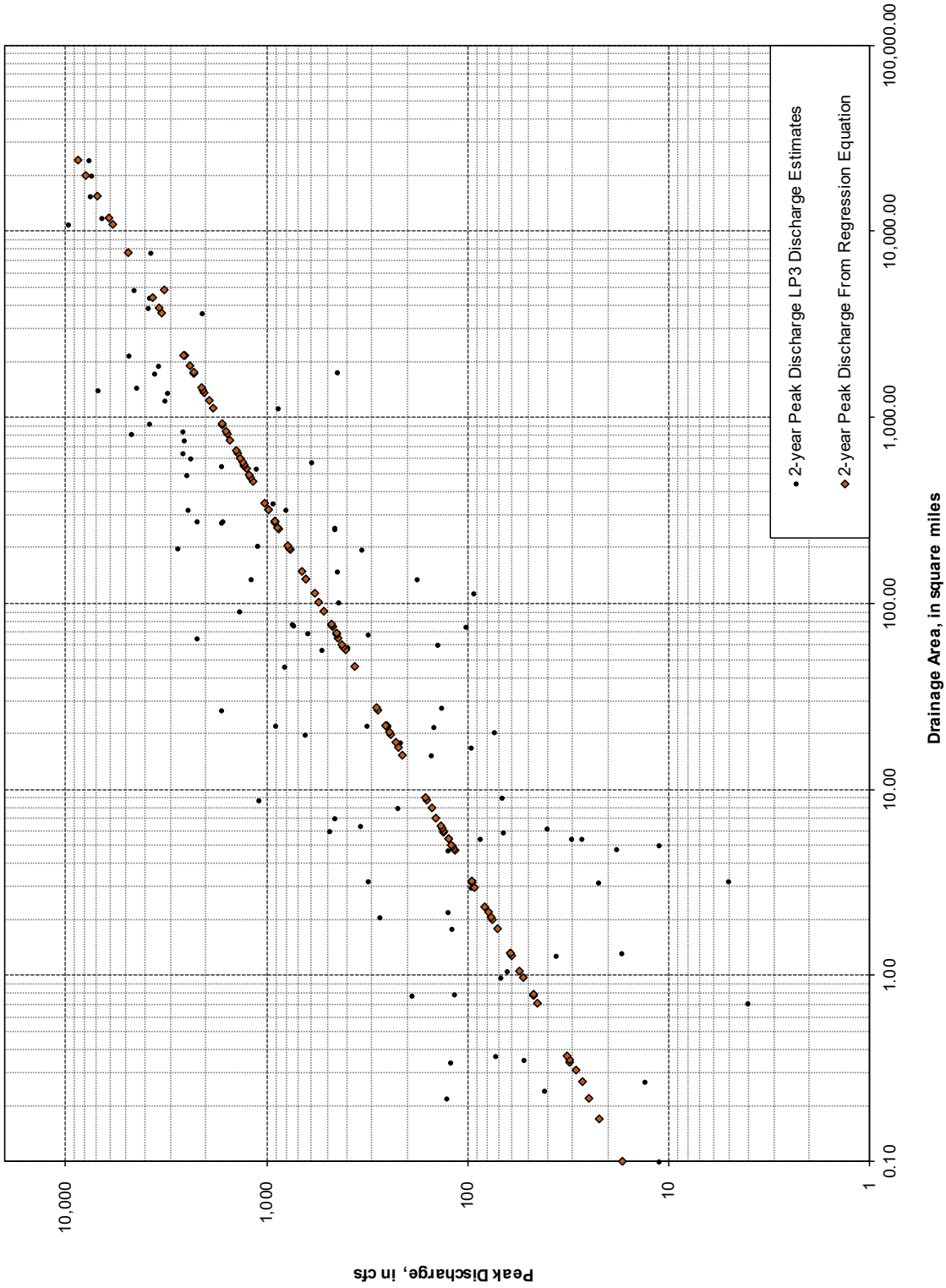


Figure 7.45 10-year peak discharge relation for Region 2 (R2)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

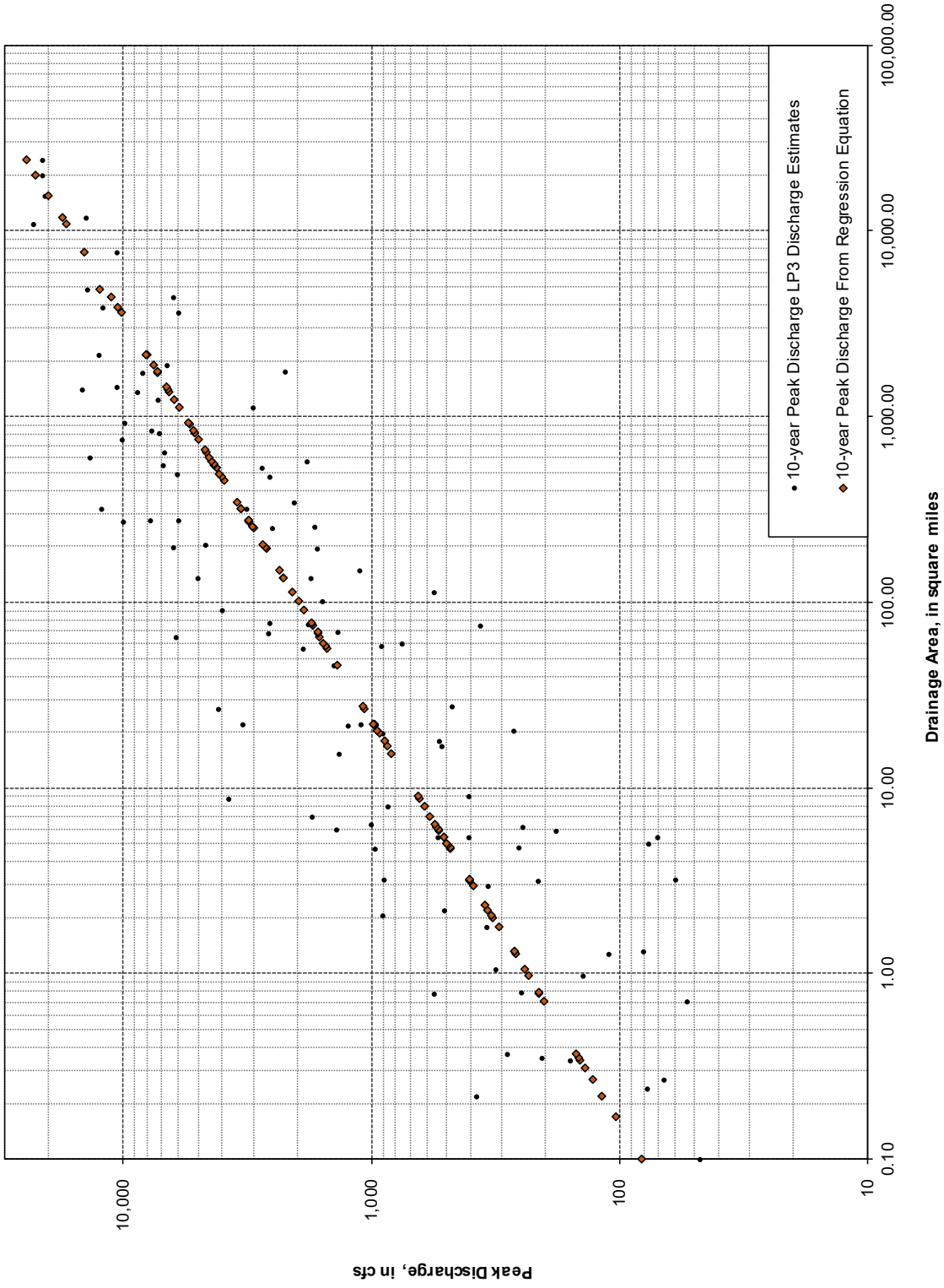


Figure 7.46 25-year peak discharge relation for Region 2 (R2)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

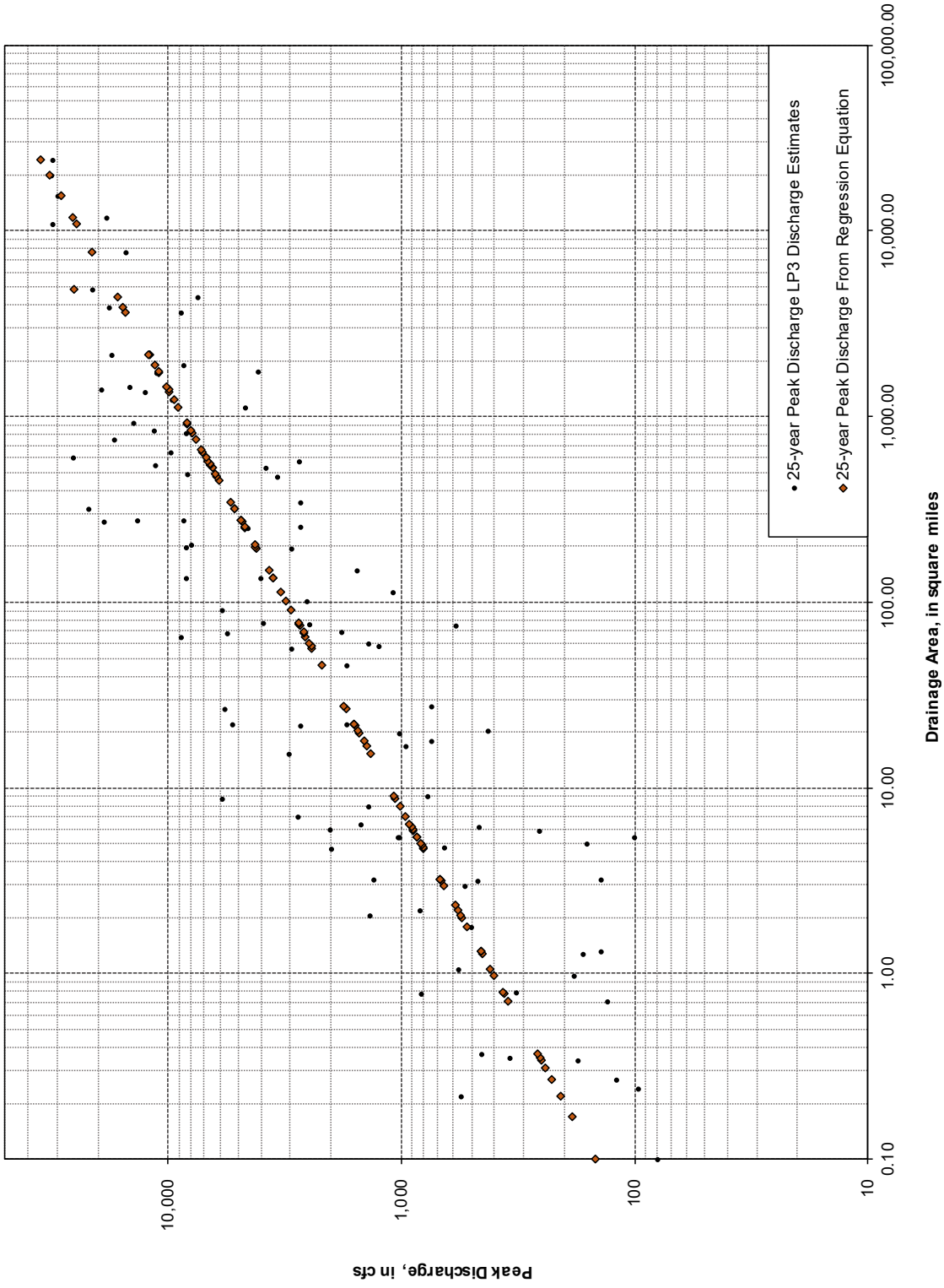


Figure 7.47 50-year peak discharge relation for Region 2 (R2)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

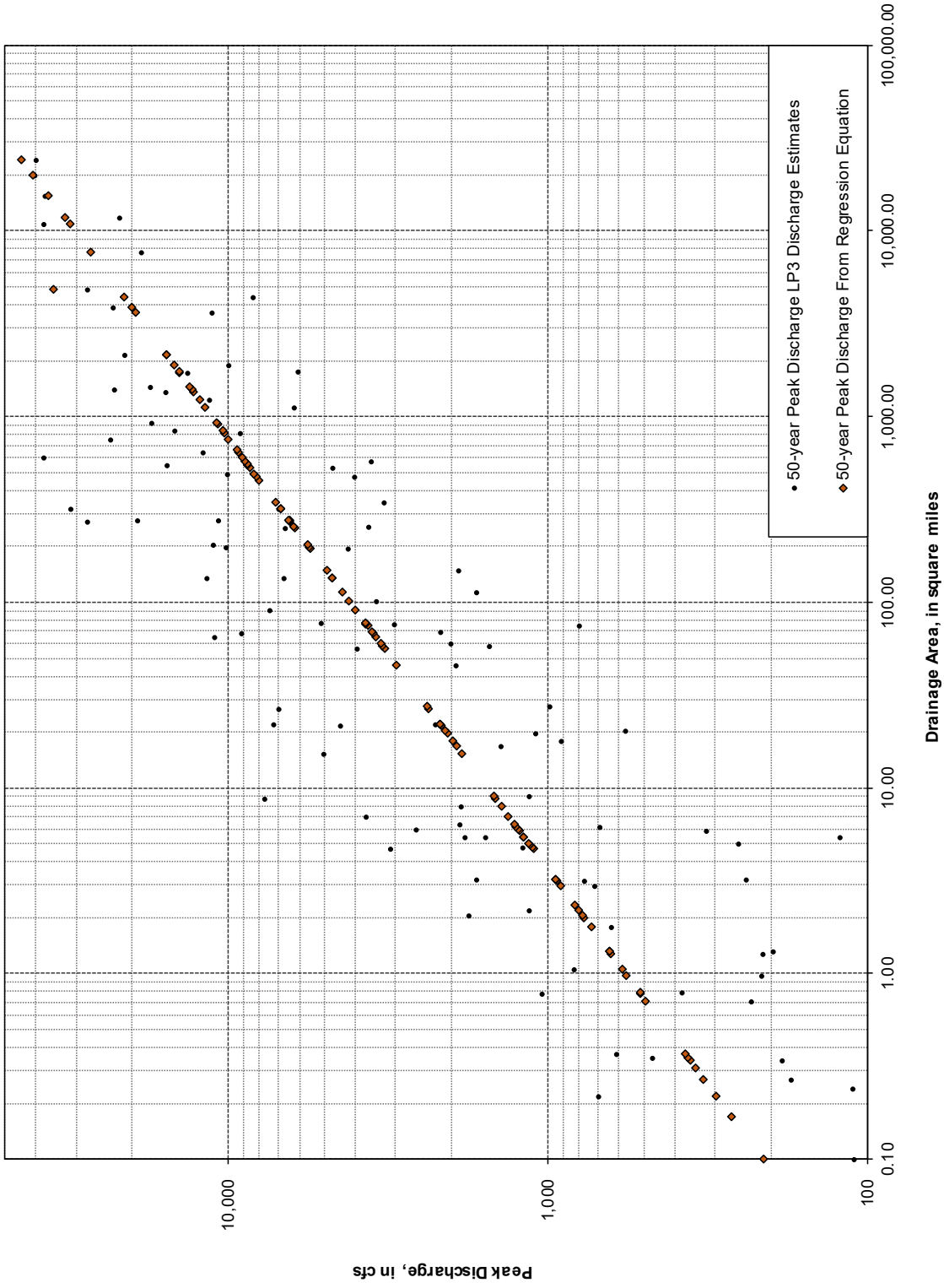


Figure 7.48 100-year peak discharge relation for Region 2 (R2)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

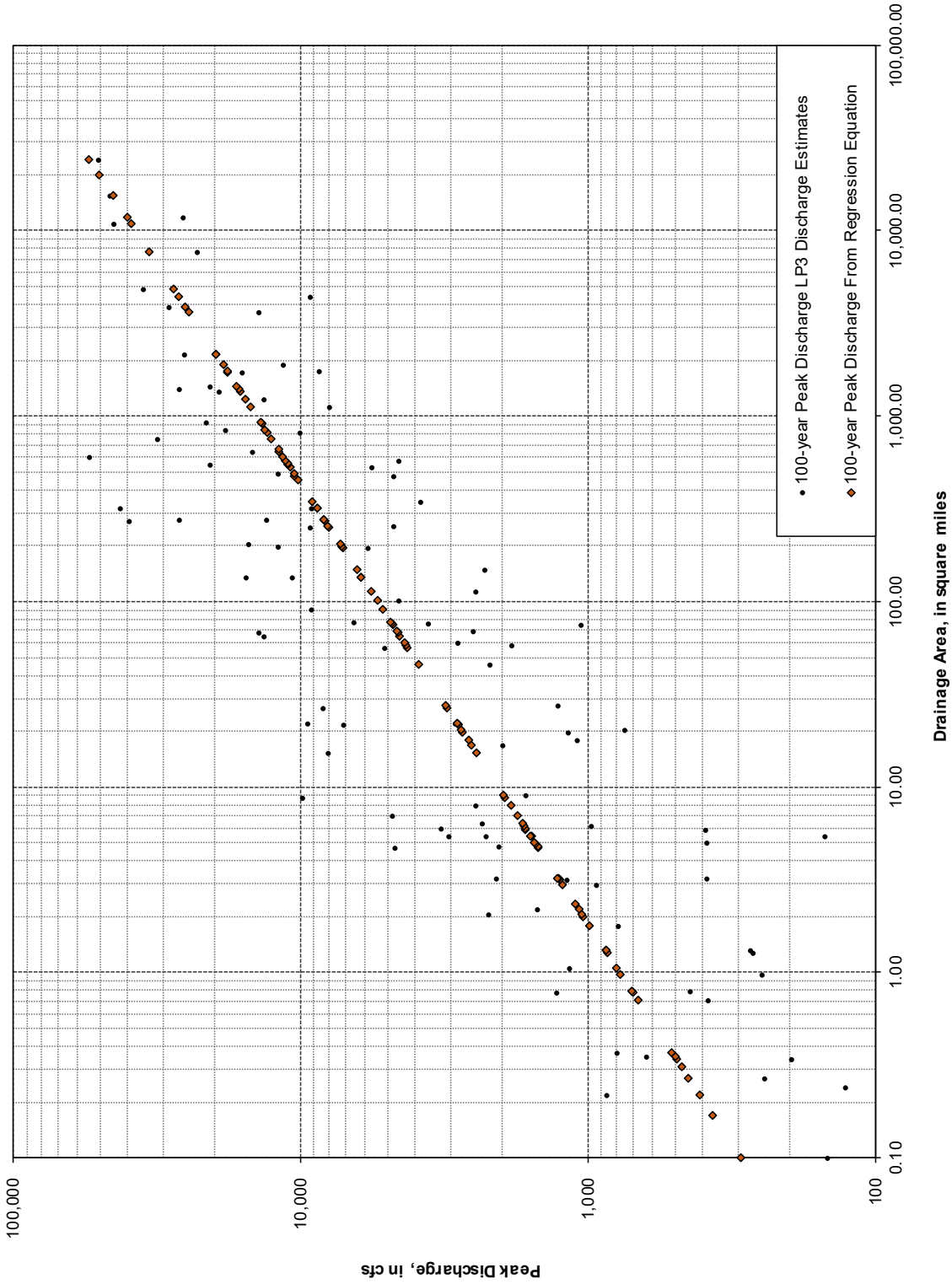


Figure 7.49 500-year peak discharge relation for Region 2 (R2)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

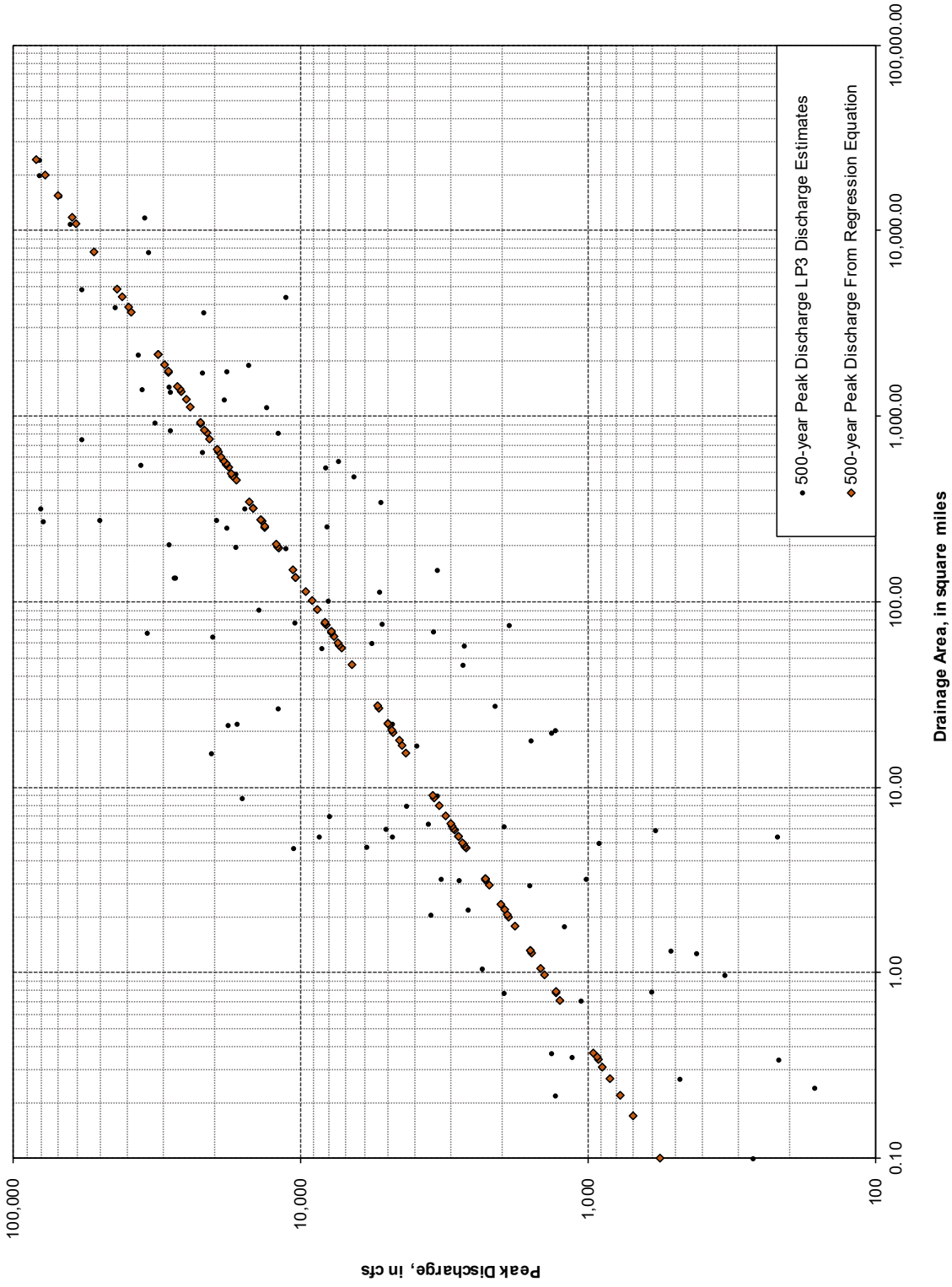


Figure 7.50 2-year peak discharge relation for Region 3 (R3)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

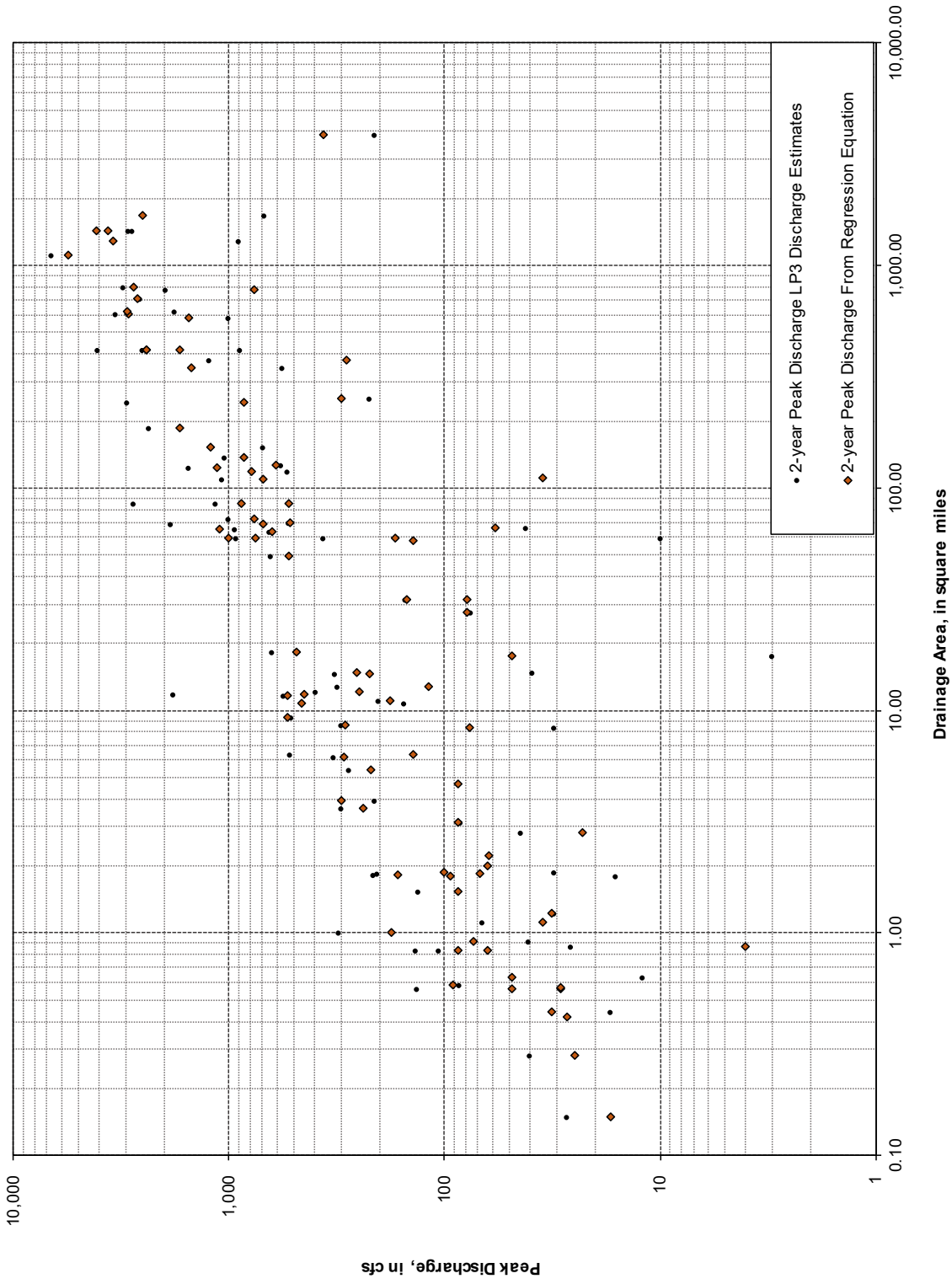


Figure 7.51 10-year peak discharge relation for Region 3 (R3)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

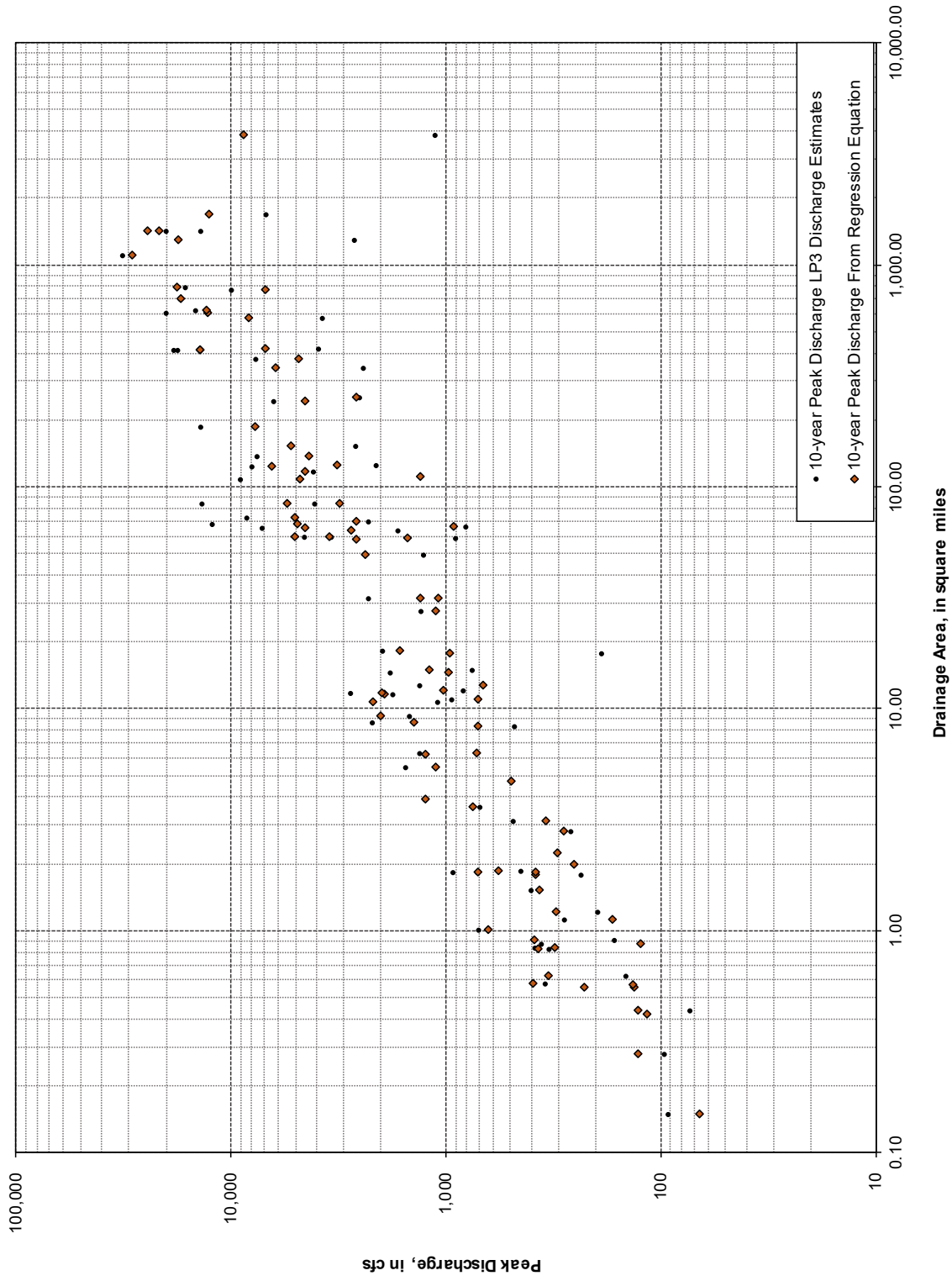


Figure 7.52 25-year peak discharge relation for Region 3 (R3)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

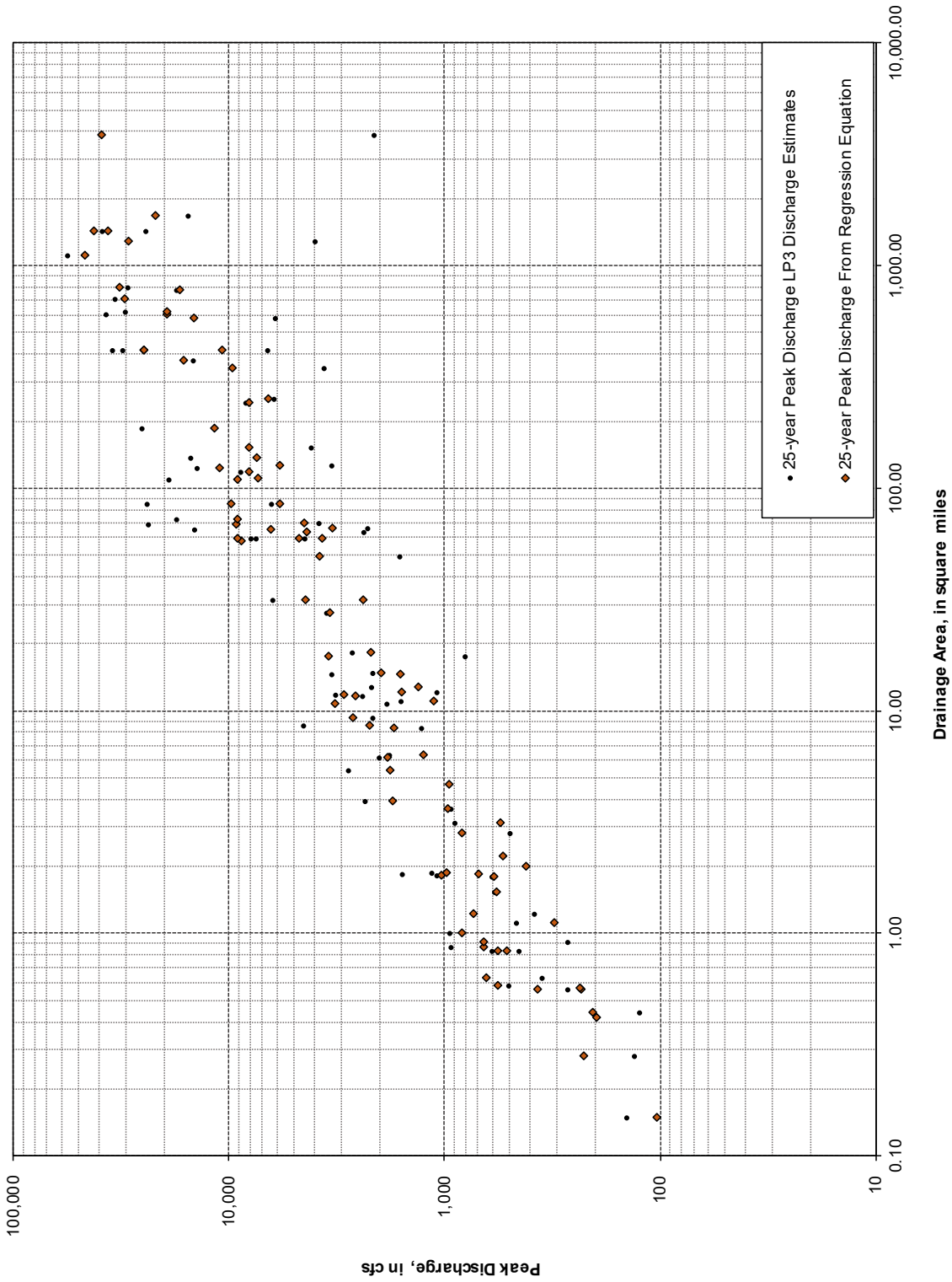


Figure 7.53 50-year peak discharge relation for Region 3 (R3)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

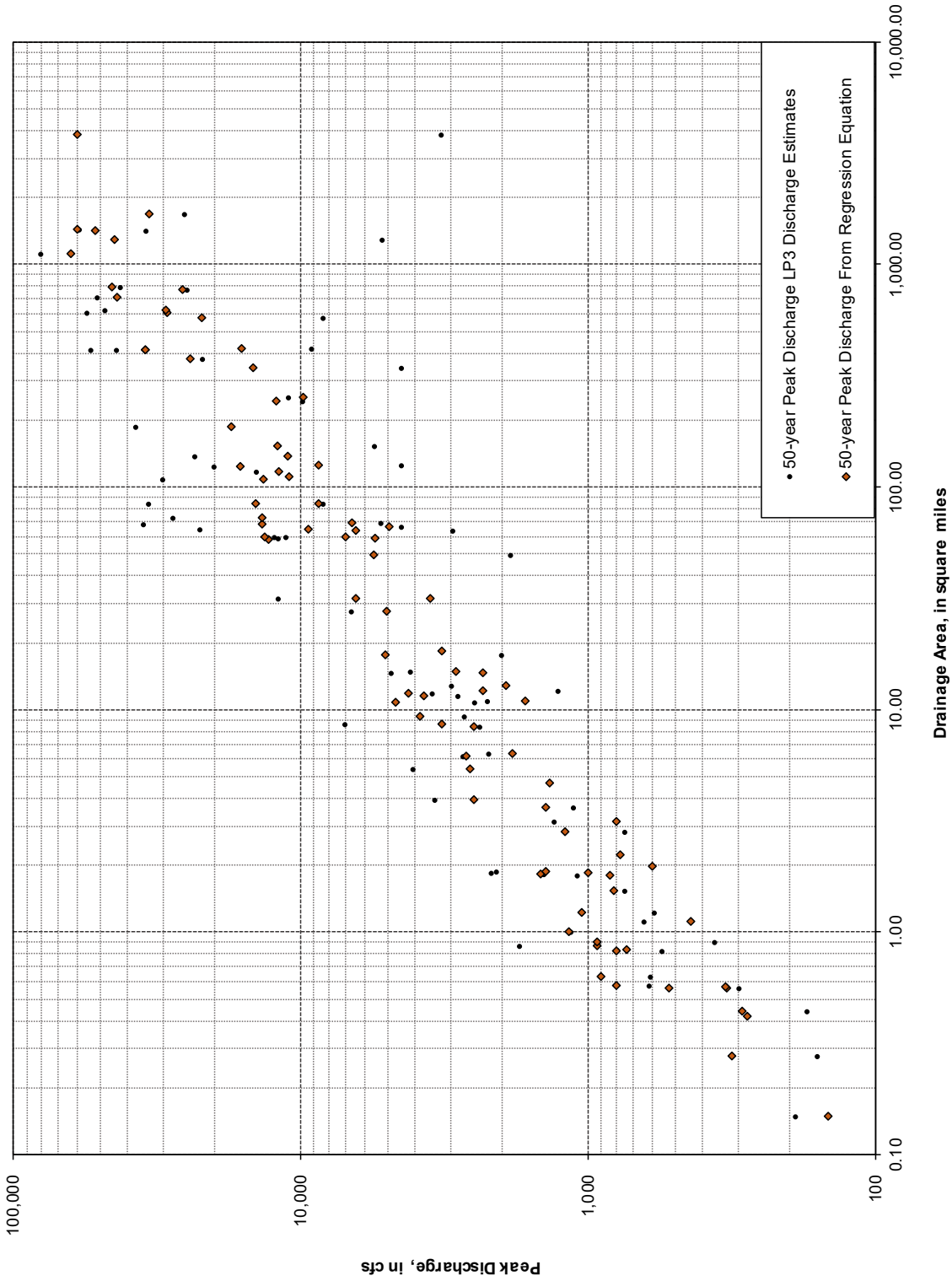


Figure 7.54 100-year peak discharge relation for Region 3 (R3)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

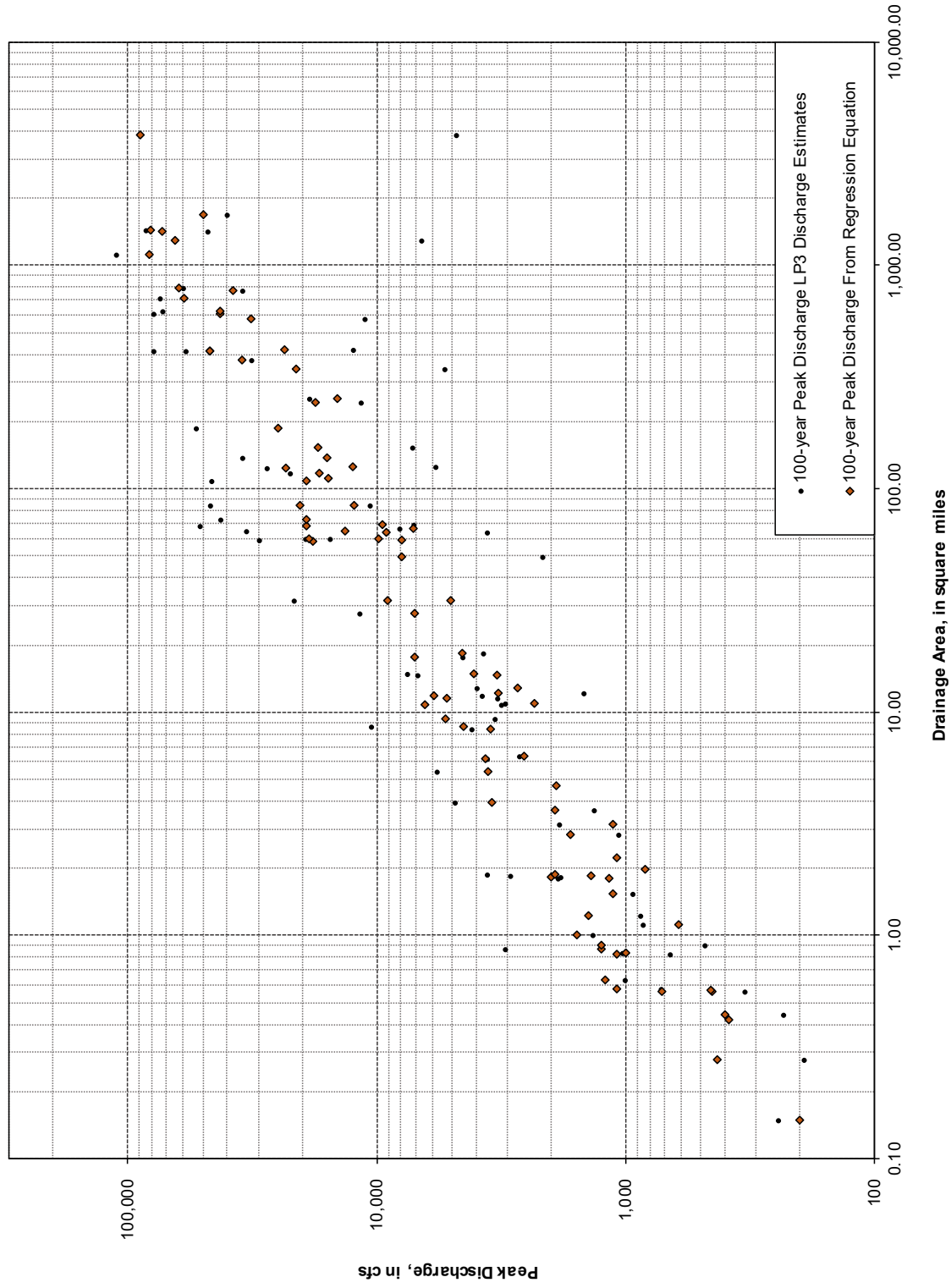


Figure 7.55 500-year peak discharge relation for Region 3 (R3)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

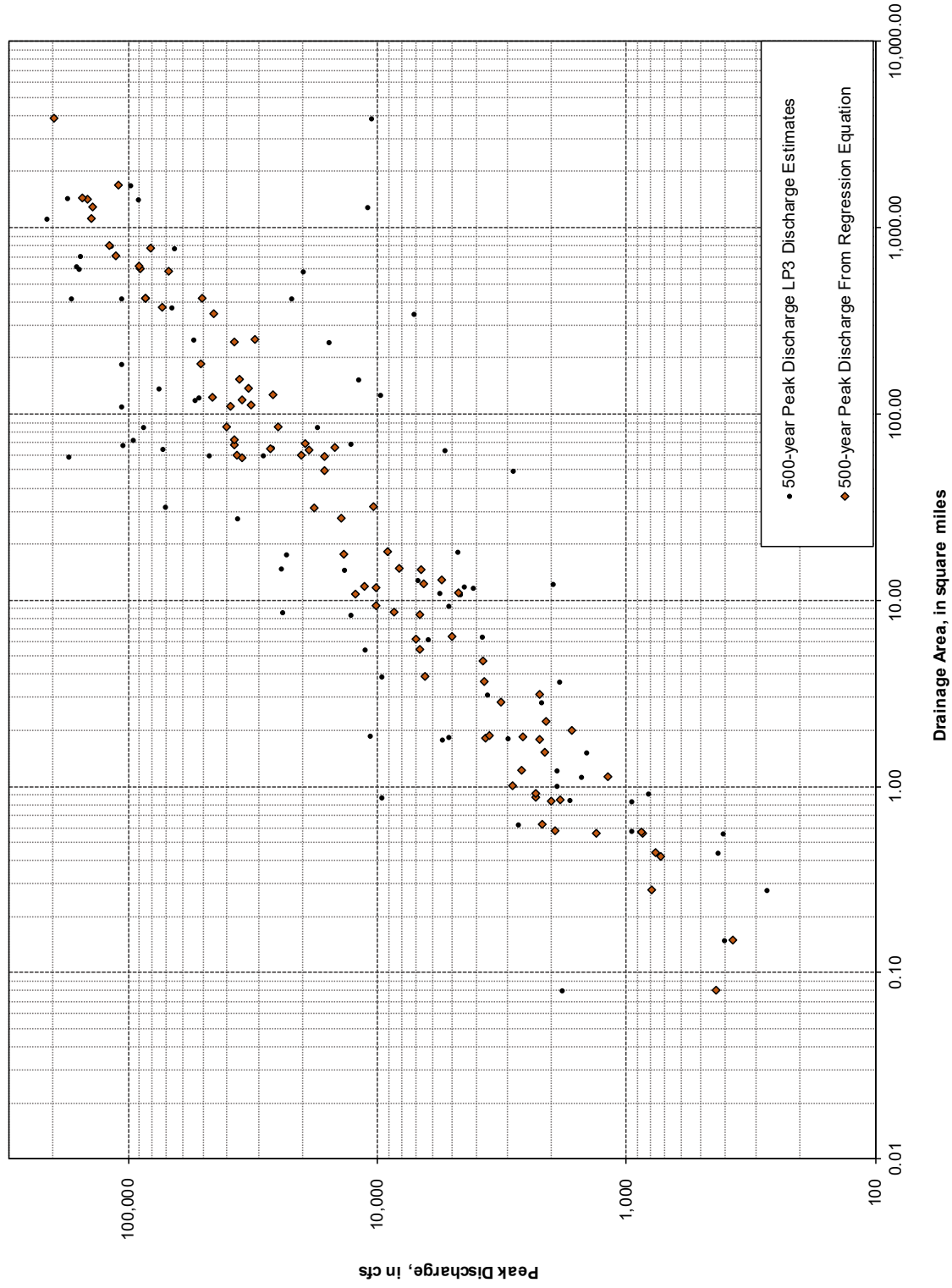


Figure 7.56 2-year peak discharge relation for Region 4 (R4)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

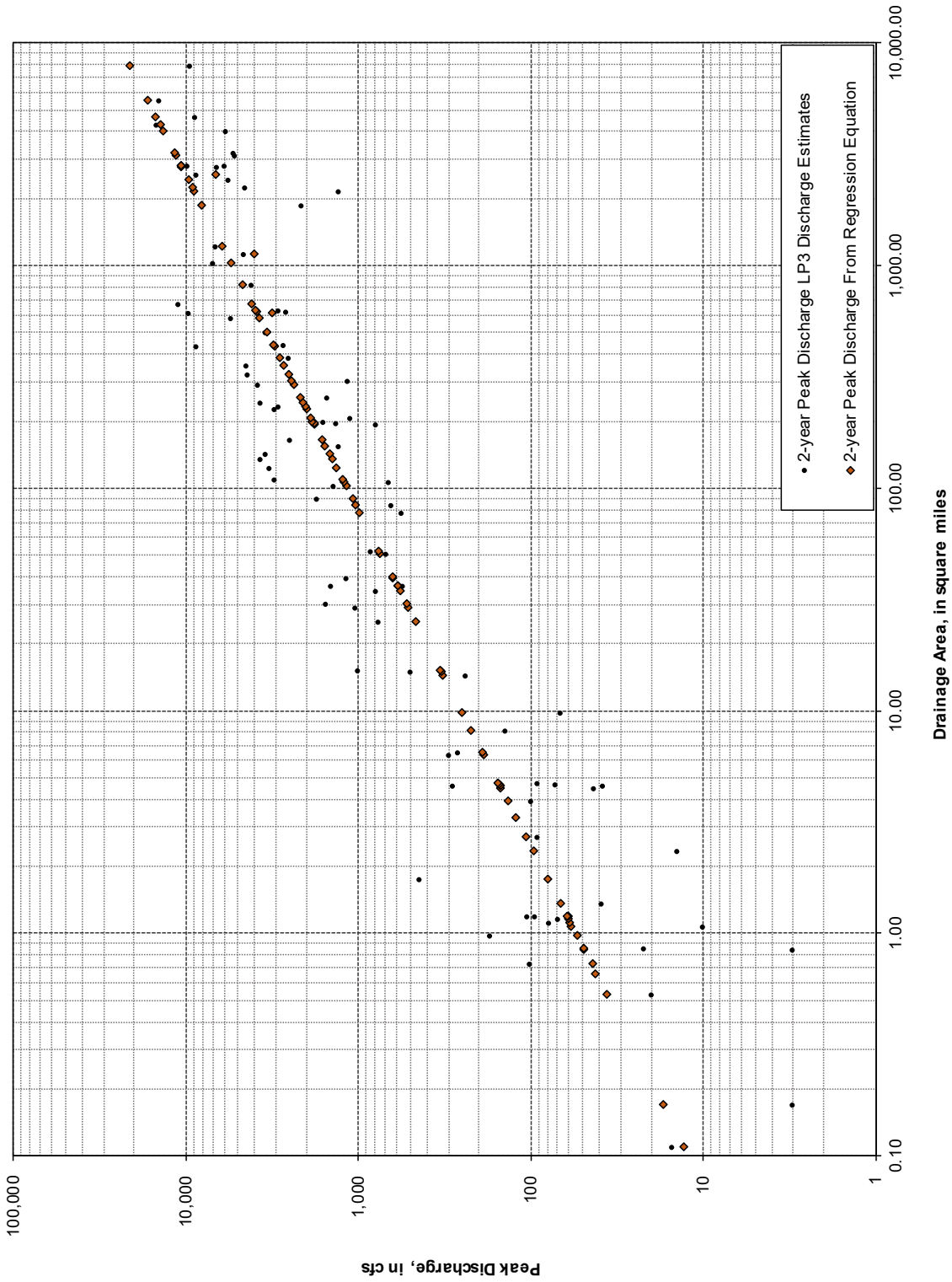


Figure 7.57 10-year peak discharge relation for Region 4 (R4)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

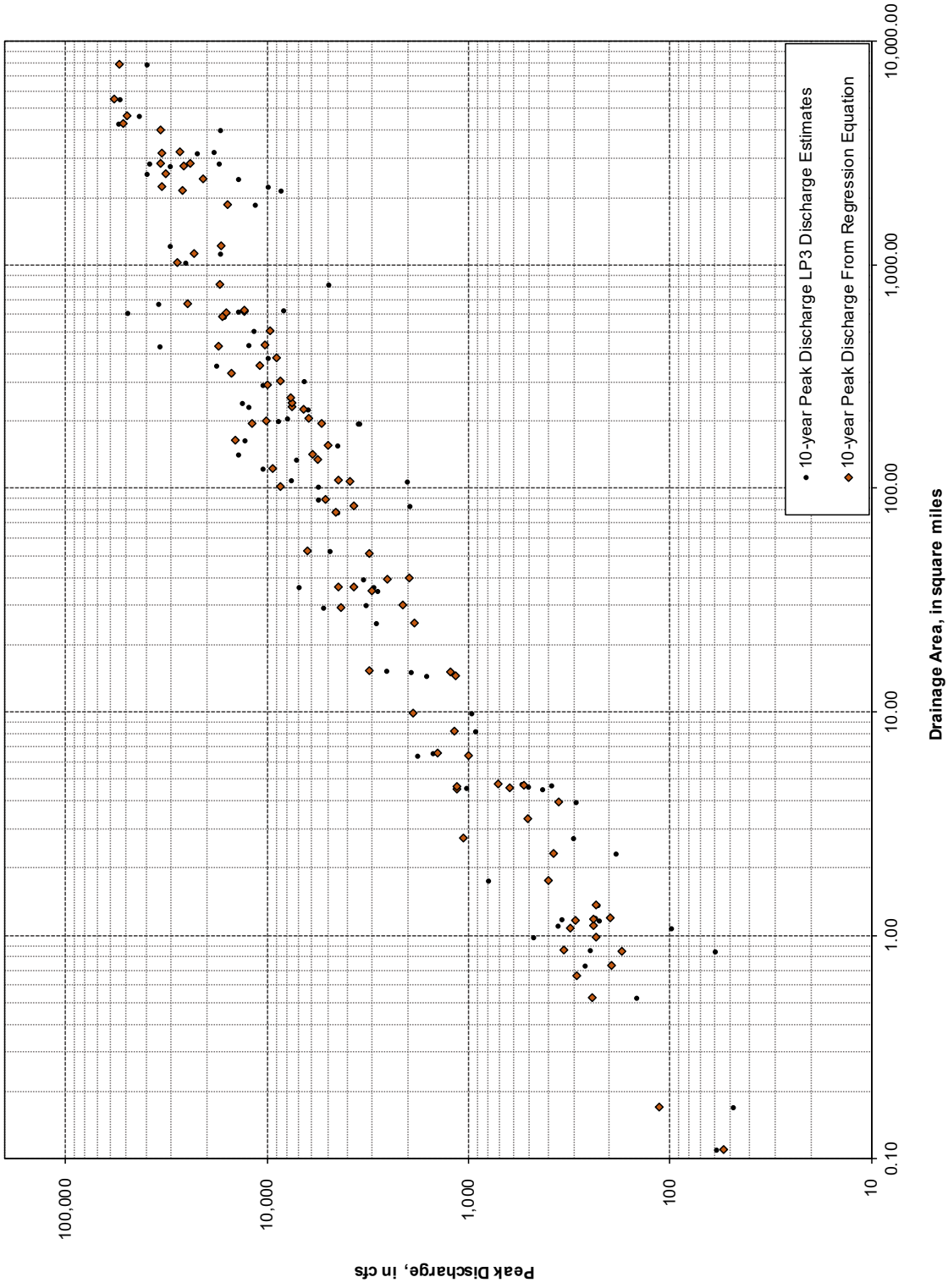


Figure 7.58 25-year peak discharge relation for Region 4 (R4)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

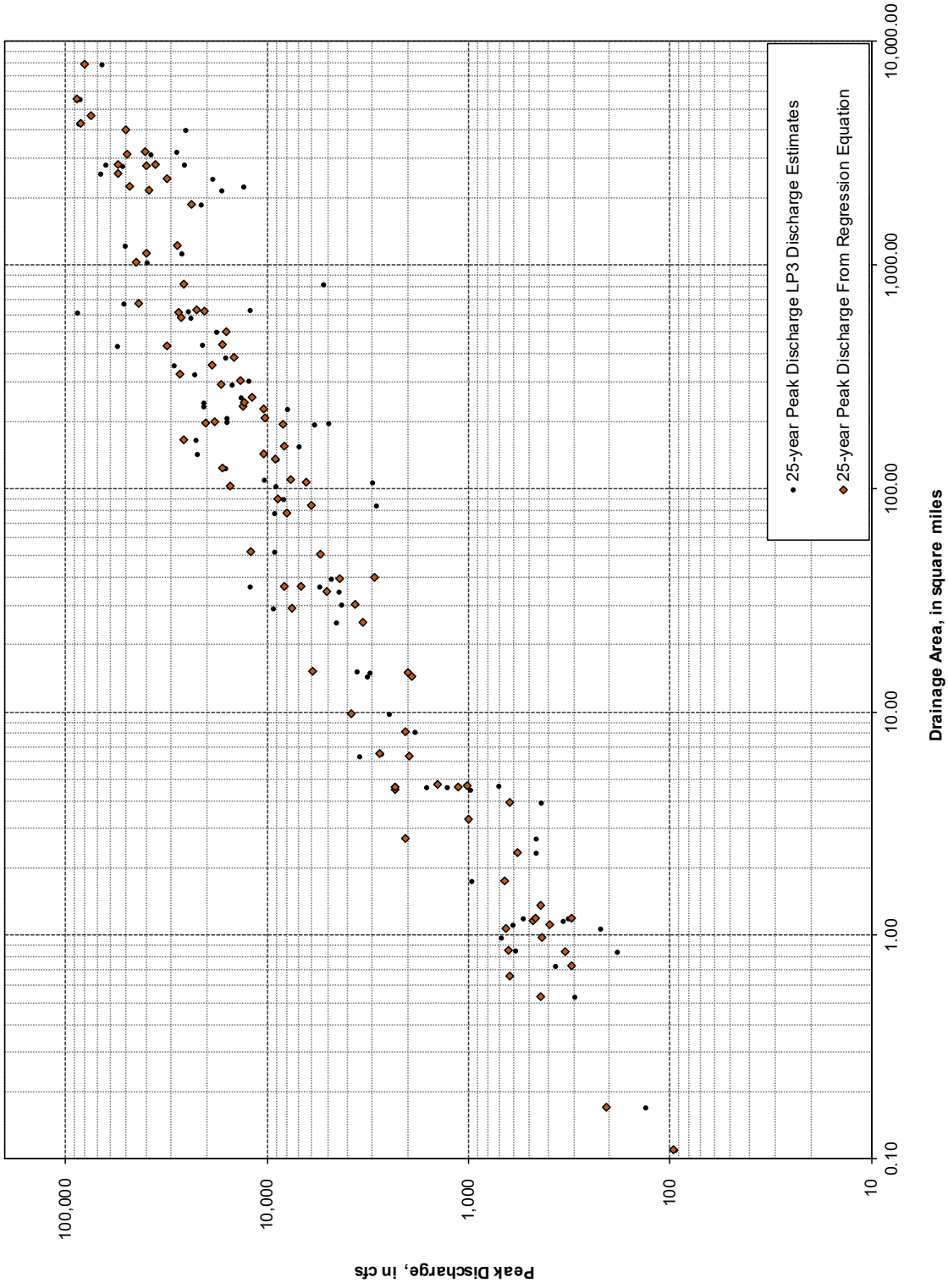


Figure 7.59 50-year peak discharge relation for Region 4 (R4)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

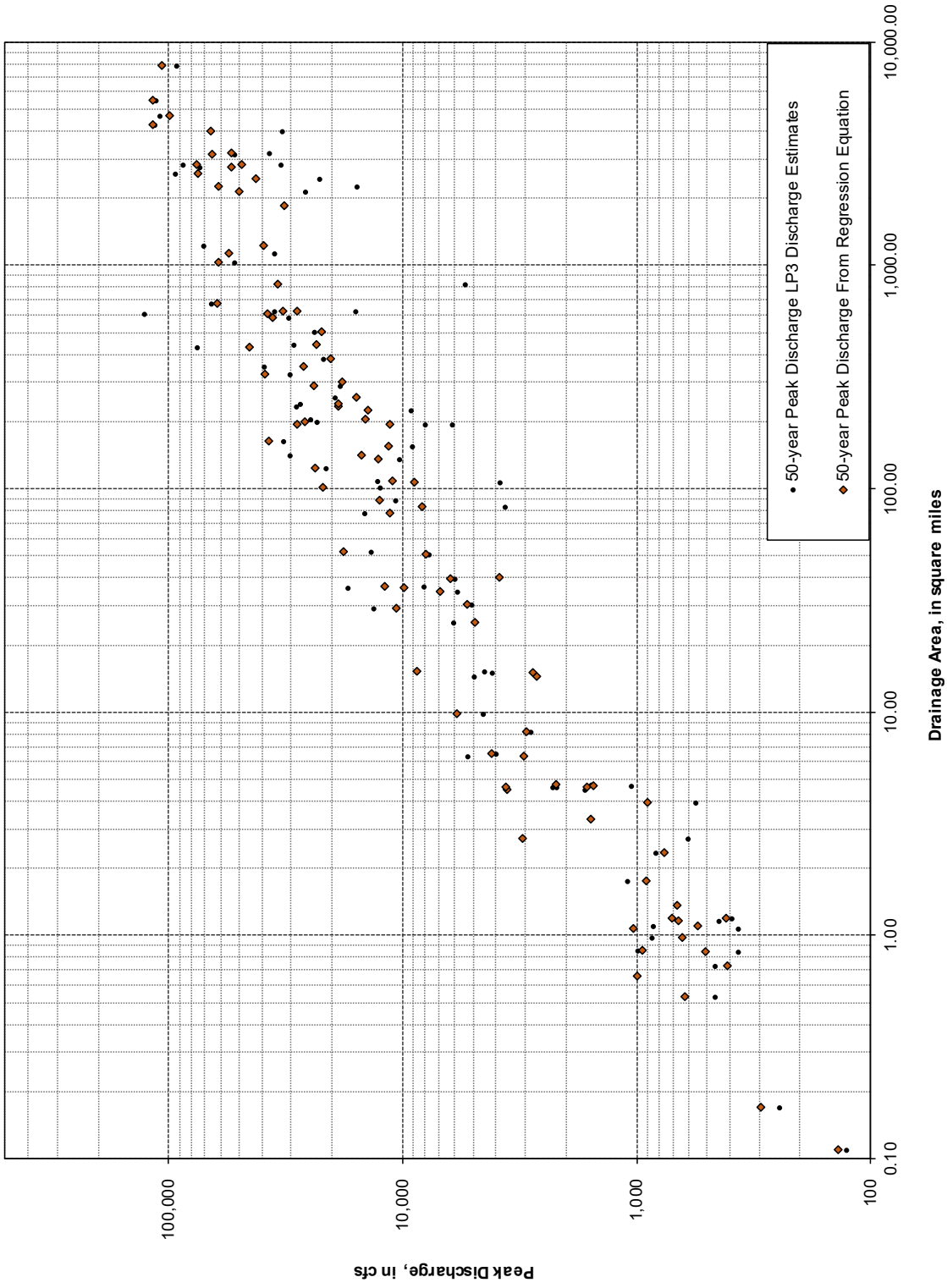


Figure 7.60 100-year peak discharge relation for Region 4 (R4)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)

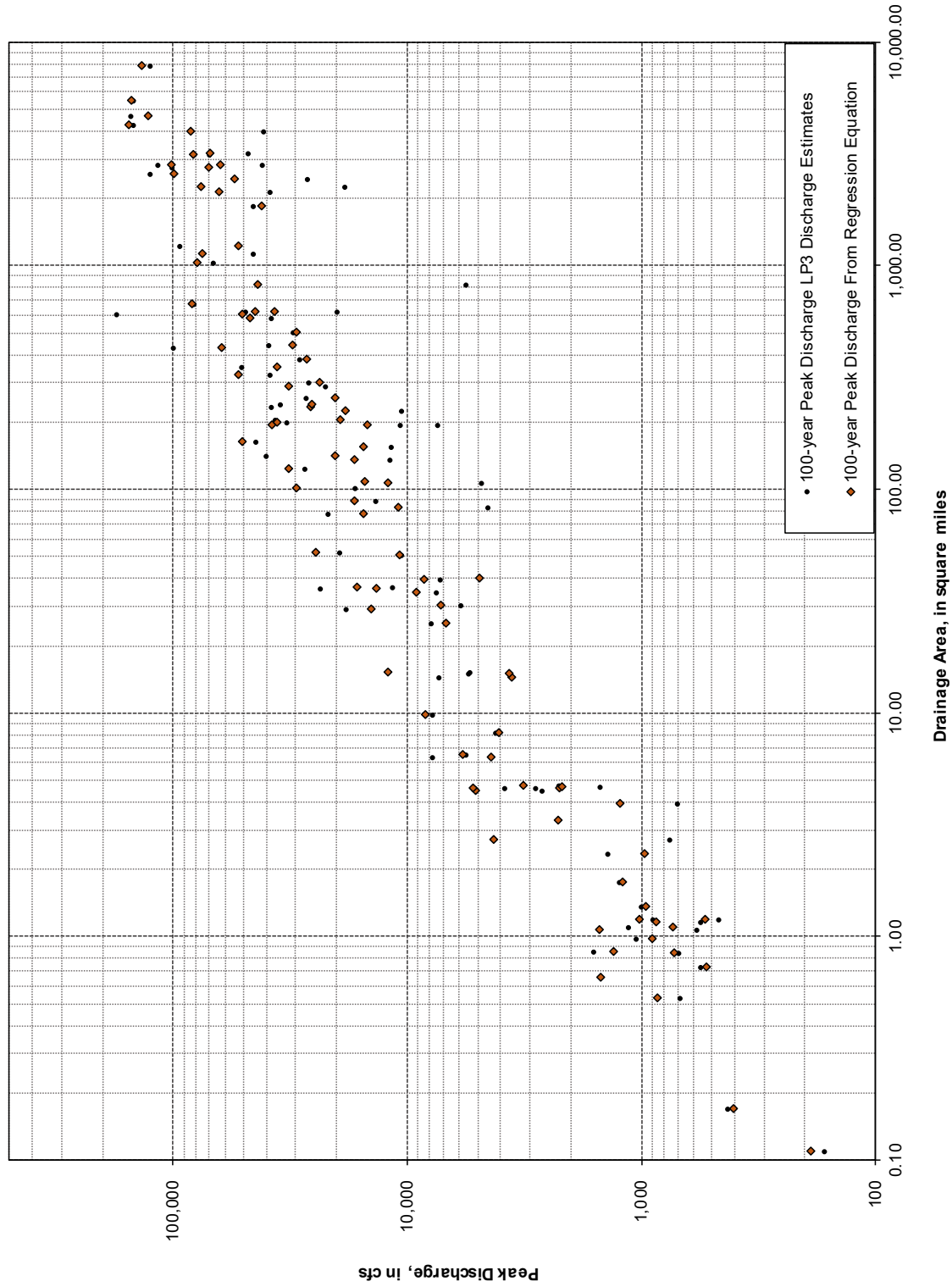
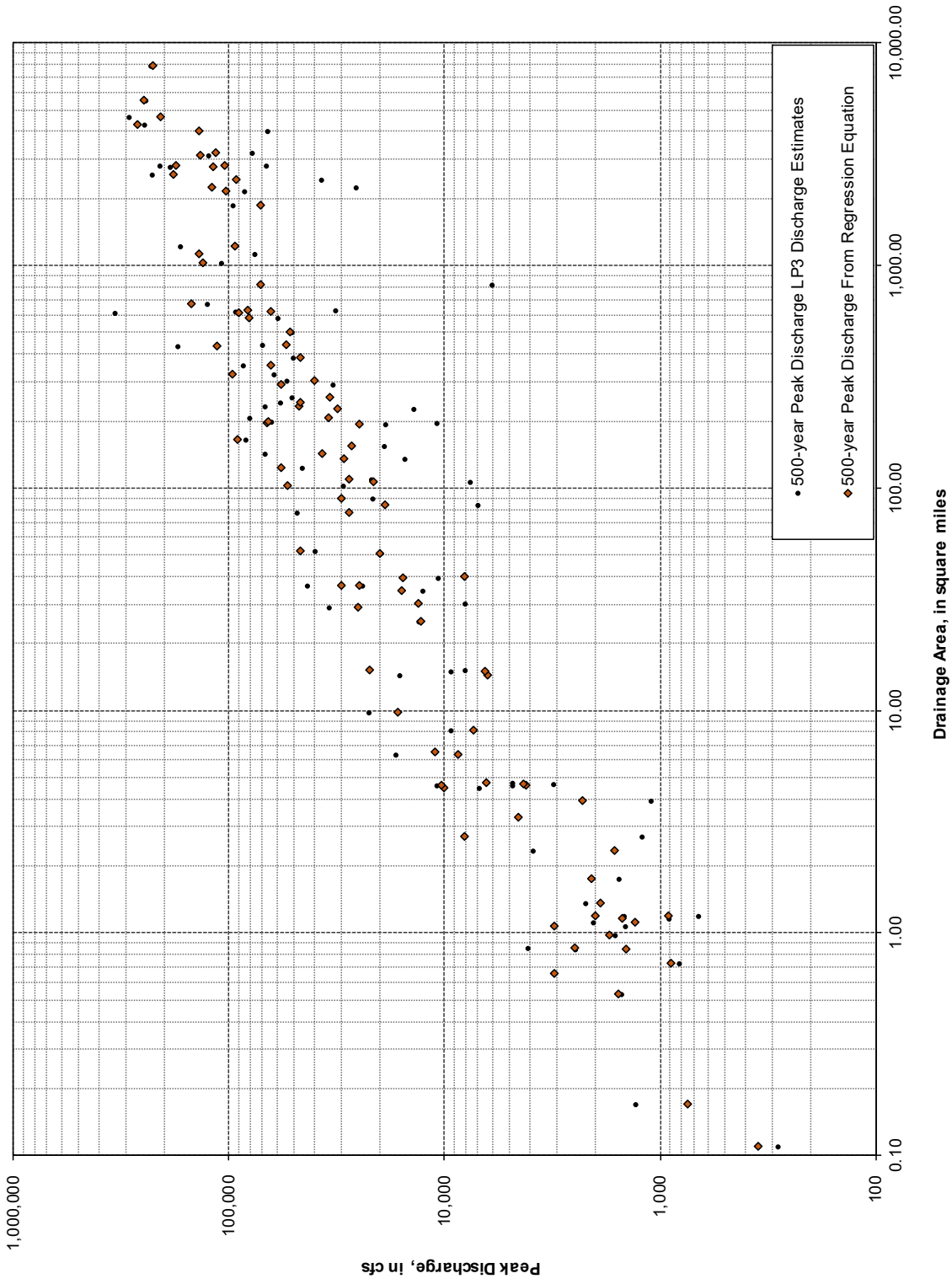


Figure 7.61 500-year peak discharge relation for Region 4 (R4)

(Adapted from: Paretti, Kennedy, Turney, and Veilleux, 2014)



7.11.3 APPLICATIONS AND LIMITATIONS

The three indirect methods can be applied to any watershed in Mohave County gaged or ungaged. Limitations exist for the use of the Regional Regression Equations based on values of the watershed characteristics as compared to the values of watershed characteristics that were used to derive these regional regression equations. The interpretation and evaluation of the results of these methods must be conducted with awareness of several factors.

1. It must be noted that these are empirical methods and the results are only applicable to watersheds that are hydrologically similar to the data base used to derive that particular method.
2. Most of the data in all three of these methods are for undeveloped, unregulated watersheds. Urbanized watersheds can have significantly higher discharges than the results that are predicted by any of these methods.
3. These methods (other than envelope curves) produce discharge values that are statistically based averages for watersheds in the database. Conditions can exist in any watershed that would produce flood discharges, either larger than or smaller than, those indicated by these methods. Watershed characteristics that should be considered when comparing the results of indirect methods to results by analytic methods and/or flood frequency analysis are:
    a. the occurrence and extent of rock outcrop in the watershed,
    b. watershed slopes that are either exceptionally flat or steep,
    c. soil and vegetation conditions that are conducive to low rainfall losses, such as clay soils, thin soil horizons underlain by rock or clay layers, denuded watersheds (forest and range fires), and disturbed land,
    d. soil and vegetation conditions that are conducive to high rainfall losses, such as sandy soil, tilled agricultural land, and irrigated turf,
    e. land-use, especially urbanization, but also mining, large scale construction activity, and over-grazing,
    f. transmission losses that may occur in the watercourses,
    g. the existence of distributary flow areas, and
    h. upstream water regulation or diversion.

7.11.4 INSTRUCTIONS FOR INDIRECT METHODS

The following instructions should be followed for verifying peak discharges that are derived by analytic methods, (Rational Method or rainfall-runoff modeling).

1. Verification with Indirect Method 1, Unit Peak Discharge Curves:
    a. For a given watershed of drainage area (A), in square miles, divide the 100-year primary peak discharge estimate by (A).

b. Plot the unit peak discharge on a copy of Figure 7.22. Note the location of the plotted point in relation to the various curves in that figure.

2. Verification with Indirect Method 2, USGS Data for Arizona:

   a. Calculate the peak discharge estimate for the desired storm frequency using the methods set forth herein.

   b. Select the appropriate figure corresponding to the storm frequency in question from Figure 7.24 through Figure 7.29, and plot the peak discharge estimate on a copy of that figure.

   c. Using watershed drainage area as a guide, identify gaged watersheds of the same approximate size from Appendix F. Tabulate the peak discharge statistics and watershed characteristics for those gaged watersheds by using the USGS report (Paretti, Kennedy, Turney, and Veilleux, 2014). Compare these to the computed peak discharge estimates and watershed characteristics for the watershed of interest.

3. Verification with Indirect Method 3, Regional Regression Equations:

   a. Determine the flood region (Figure 7.31).

   b. If the watershed is within Region 3 or Region 4, calculate the mean basin elevation ($ELEV$) and/or mean basin average annual precipitation (*PRECIP*). *ELEV* can be estimated by placing a transparent grid over the largest scale topographic map available. The grid spacing should be selected such that at least 20 elevation points are sampled. The elevation at each grid point is determined and the elevations are then averaged. *PRECIP* can be estimated using Figure 7.33. Check the watershed using the appropriate scatter diagram to determine if the areas of the subject subbasins are within the "cloud of common values." Proceed with the analysis regardless of the outcome, but clearly note if the variable values are not within the "cloud of common values."

   c. Calculate the peak discharge estimates using the applicable regression equations for the appropriate flood region and storm frequency.

   d. Plot the peak discharge estimate on a copy of the appropriate discharge relation graph.

1. For all three Indirect Methods:

   a. Quantitatively and qualitatively analyze the results of the three indirect method checks. Address watershed characteristics that may explain modeled peak discharge values that do not compare well with the indirect method checks.

   b. Prepare a summary of results by all methods and a qualitative evaluation of the results.

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7.12 HYDROLOGY POLICIES

7.12.1 SOURCE OF PEAK DISCHARGE AND RUNOFF VOLUME INFORMATION

The following is the preferred order of hierarchy for obtaining peak discharges and runoff volumes for various floodplain and drainage design purposes:

1. The first choice is to obtain accepted peak discharges and runoff volumes of record from Mohave County drainage master plans or flood insurance studies. The results from these studies must be evaluated to determine if the assumptions made are still valid and appropriate for the intended purpose. Such studies may only provide information for the 100-year storm. Information for other storm frequencies may be obtained by appropriate revision of the existing computer models using the procedures defined in the Drainage Design Manual for Mohave County.
2. The second choice is the drainage plans and design reports from adjacent properties. This information may be used where available and if approved by the reviewing agency for use on the project.
3. If choices 1 and 2 above are not available options, or are deemed inappropriate, then peak discharges and runoff volumes should be estimated in accordance with the procedures in Section 7.

7.12.2 ORDER OF PREFERENCE FOR HYDROLOGIC PROCEDURES

The following is the preferred hierarchy for applying the three hydrologic methods presented herein:

1. Watershed area less than or equal to 160 acres: The Rational Method should normally be used.
2. Regional Regression equations from Section 7.11.2.4 should be used, within the limitations of the data (watershed area and elevation) and assumptions used to create them, and if hydrographs are not needed. If hydrographs are needed or there are multiple concentration points requiring routing and combining of hydrographs, then the Unit Hydrograph Method should be used.
3. Watershed area greater than 160 acres and less than a total of 500 square miles: Unit Hydrograph Method.

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7.13 HYDROLOGY STANDARDS

The following sections contain specific Mohave County technical standards for application of the hydrologic methodology set forth herein.

7.13.1 DESIGN STORM DURATION CRITERIA

Table 7.23 Design storm duration criteria for unincorporated Mohave County

Purpose/Method	Criteria
Retention Basins	100-year, 2-hour rainfall
Analysis for undisturbed drainageways and design of engineered channels, bridges, and culverts:	
Drainage Area: 0 to 160 acres (Rational Method or Unit Hydrograph Method)	If only design peak discharges are needed, then the Rational Method is acceptable.
Drainage area: 160 acres to 20 square miles (Unit Hydrograph Method)	6-hour local storm. Engineering judgment may dictate use of a 24-hour storm depending on soil conditions, or other hydrologic parameters or criteria. Mohave County may require analysis of both the 6-hour and 24-hour storms and require that the larger peak discharge be utilized.
Drainage area: 20 to 100 square miles (Unit Hydrograph Method)	Either a critically centered 6-hour local storm or a 24-hour general storm. Mohave County requires analysis of both the 6-hour local storm and the 24-hour general storm and requires that the larger peak discharge and runoff volume be utilized.
Drainage area.100 to 500 square miles (Unit Hydrograph Method)	24-hour general storm.

7.13.2 RATIONAL METHOD CRITERIA

Table 7.24 Rational Method parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	K_b	C Values by Storm Frequency, in years					
			2	5	10	25	50	100
Agriculture								
390	Agriculture (AG)	0.08	0.12	0.15	0.18	0.20	0.22	0.25
Commercial								
120	A-D: Airport Development (1 acre minimum, C2)	0.04	0.75	0.80	0.85	0.88	0.92	0.95
220	C-1: Neighborhood Commercial (6,000 sf minimum, C1)	0.025	0.60	0.63	0.65	0.70	0.75	0.80
230	C-2: General Commercial (6,000 sf minimum, C2)	0.025	0.75	0.80	0.83	0.90	0.93	0.95
240	C-2H: General Commercial Highway Frontage (1-acre minimum, C2)	0.025	0.75	0.80	0.83	0.90	0.93	0.95
250	C-RE: Commercial Recreation (1 acre minimum, C1)	0.025	0.57	0.60	0.62	0.67	0.72	0.77
260	C-M: Commercial Manufacturing (1 acre minimum, C2)	0.025	0.75	0.80	0.83	0.90	0.93	0.95
270	C-MO: Commercial Manufacturing/ Open Lot Storage (1 acre minimum, C2)	0.025	0.75	0.80	0.83	0.90	0.93	0.95
Industrial								
280	M: General Manufacturing (1 acre minimum, I1)	0.025	0.70	0.70	0.70	0.75	0.80	0.85
290	M-X: Heavy Manufacturing (1 acre minimum, I2)	0.025	0.80	0.80	0.80	0.85	0.92	0.95
Natural								
500	Undeveloped Desert Rangeland. Little topographic relief, slopes <5%	0.08	0.33	0.35	0.38	0.40	0.42	0.45
510	Hillslopes, Sonoran Desert. Moderate topographic relief, slopes >5%	0.15	0.45	0.50	0.53	0.55	0.60	0.65

Table 7.24 Rational Method parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	K_b	C Values by Storm Frequency, in years					
			2	5	10	25	50	100
520	Mountain Terrain. High topographic relief, slopes >20%	0.20	0.55	0.60	0.65	0.70	0.75	0.80
Open Space								
300	R-P: Regional Parks (LP3)	0.20	0.15	0.20	0.25	0.28	0.30	0.35
310	C-P: Community Parks (LP2)	0.20	0.25	0.30	0.35	0.40	0.45	0.50
320	N-P: Neighborhood Parks (LP1)	0.20	0.35	0.40	0.45	0.48	0.50	0.55
350	General Open Space (Open space where no detail available, NDR)	0.08	0.33	0.35	0.38	0.40	0.42	0.45
360	Golf Courses (LP3)	0.20	0.15	0.20	0.25	0.28	0.30	0.35
370	Passive Open Space (NDR)	0.08	0.33	0.35	0.38	0.40	0.42	0.45
400	Landscaping with impervious under treatment	0.08	0.60	0.70	0.80	0.85	0.90	0.92
410	Landscaping w/o impervious under treatment	0.08	0.33	0.35	0.38	0.40	0.42	0.45
Other								
380	Water	0.02	0.98	0.98	0.98	0.98	0.98	0.98
Residential								
110	A: General (> 20 acre minimum, VLDR)	0.05	0.35	0.37	0.39	0.44	0.46	0.50
112	A: General (5-20 acre minimum, VLDR)	0.05	0.36	0.38	0.40	0.46	0.50	0.55
114	A-R, R-E, R-1, R-MH, R-TT, R-M, R-O, R-O/A (2-5 acre minimum, VLDR)	0.04	0.37	0.40	0.42	0.48	0.55	0.60
130	A-R, R-E, R-1, R-MH, R-TT, R-M, R-O, R-O/A (1-2 acre minimum, VLDR)	0.04	0.40	0.42	0.45	0.50	0.60	0.65
140	R-E, R-1, R-MH, R-TT, R-M, R-O (20,000 sf – 1 acre minimum, LDR)	0.04	0.42	0.45	0.48	0.51	0.56	0.58
150	R-1, R-MH, R-TT, R-M, R-O (10,000-20,000 sf minimum, MDR)	0.04	0.50	0.55	0.58	0.59	0.60	0.65
160	R-1, R-MH, R-TT, R-M, R-O (7,000-10,000 sf minimum, MDR)	0.025	0.52	0.55	0.60	0.65	0.70	0.75

Table 7.24 Rational Method parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	K_b	C Values by Storm Frequency, in years					
			2	5	10	25	50	100
170	R-1, R-MH, R-TT, R-M, R-O (6,000-7,000 sf minimum, MDR)	0.025	0.55	0.60	0.63	0.70	0.75	0.78
180	R-1, R-MH, R-TT, R-M, R-O with lot coverage increase waiver (6,000 sf minimum, MFR)	0.025	0.70	0.73	0.75	0.80	0.87	0.92
210	S-D: Special Development (MFR)	0.025	0.70	0.73	0.75	0.80	0.87	0.92
Transportation								
330	General Transportation (Transportation where no detail available; P, GR)	0.02	0.70	0.75	0.80	0.85	0.90	0.92
340	Transportation (Includes railroads, rail-yards, transit centers, freeways; P, GR)	0.02	0.65	0.70	0.75	0.80	0.85	0.90
420	Pavement and Rooftops (P)	0.02	0.85	0.85	0.85	0.90	0.93	0.95
430	Gravel Roadways & Shoulders (GR)	0.03	0.70	0.70	0.70	0.75	0.80	0.85

7.13.3 UNIT HYDROGRAPH METHOD CRITERIA

Table 7.25 Unit hydrograph parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	Vegetation Cover	*RTIMP*	IA	*DTHETA* Cond.	*XKSAT*[3]
Agriculture						
390	Agriculture (AG)	85	0	0.50	SATURATED	N
Commercial						
120	A-D: Airport Development (1 acre minimum, C2)	20	90	0.25	NORMAL	D
220	C-1: Neighborhood Commercial (6,000 sf minimum, C1)	65	80	0.10	NORMAL	D
230	C-2: General Commercial (6,000 sf minimum, C2)	75	90	0.10	NORMAL	D

[3] N: Use $XKSAT_N$; D: Use $XKSAT_D$

Table 7.25 Unit hydrograph parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	Vegetation Cover	*RTIMP*	IA	*DTHETA* Cond.	*XKSAT*[3]
240	C-2H: General Commercial Highway Frontage (1 -acre minimum, C2)	75	90	0.10	NORMAL	D
250	C-RE: Commercial Recreation (1 acre minimum, C1)	60	80	0.10	NORMAL	D
260	C-M: Commercial Manufacturing (1 acre minimum, C2)	60	90	0.10	NORMAL	D
270	C-MO: Commercial Manufacturing/ Open Lot Storage (1 acre minimum, C2)	60	90	0.10	NORMAL	D
Industrial						
280	M: General Manufacturing (1 acre minimum, I1)	60	80	0.15	NORMAL	D
290	M-X: Heavy Manufacturing (1 acre minimum, I2)	60	90	0.15	NORMAL	D
Natural						
500	Undeveloped Desert Rangeland. Little topographic relief, slopes <5%	varies	varies	0.35	DRY	N
510	Hillslopes, Sonoran Desert. Moderate topographic relief, slopes >5%	varies	varies	0.15	DRY	N
520	Mountain Terrain. High topographic relief, slopes >20%	varies	varies	0.25	DRY	N
Open Space						
300	R-P: Regional Parks (LP3)	60	10	0.20	NORMAL	varies
310	C-P: Community Parks (LP2)	80	15	0.20	NORMAL	D
320	N-P: Neighborhood Parks (LP1)	80	15	0.20	NORMAL	D
350	General Open Space (Open space where no detail available, NDR)	10	10	0.10	DRY	N
360	Golf Courses (LP3)	90	5	0.20	NORMAL	D
370	Passive Open Space (NDR)	20	10	0.10	DRY	
400	Landscaping with impervious under treatment	30	95	0.10	NORMAL	D

Table 7.25 Unit hydrograph parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	Vegetation Cover	*RTIMP*	IA	*DTHETA* Cond.	*XKSAT*[3]
410	Landscaping w/o impervious under treatment	30	0	0.20	NORMAL	D
Other						
380	Water	0	100	0.00	SATURATED	n/a
Residential						
110	A: General (> 20 acre minimum, VLDR)	30	5	0.30	NORMAL	N
112	A: General (5-20 acre minimum, VLDR)	30	10	0.30	NORMAL	N
114	A-R, R-E, R-1, R-MH, R-TT, R-M, R-O, R-O/A (2-5 acre minimum, VLDR)	50	15	0.30	NORMAL	N
130	A-R, R-E, R-1, R-MH, R-TT, R-M, R-O, R-O/A (1-2 acre minimum, VLDR)	50	20	0.25	NORMAL	D
140	R-E, R-1, R-MH, R-TT, R-M, R-O (20,000 sf – 1 acre minimum, LDR)	50	25	0.25	NORMAL	D
150	R-1, R-MH, R-TT, R-M, R-O (10,000-20,000 sf minimum, MDR)	50	35	0.25	NORMAL	D
160	R-1, R-MH, R-TT, R-M, R-O (7,000-10,000 sf minimum, MDR)	50	50	0.25	NORMAL	D
170	R-1, R-MH, R-TT, R-M, R-O (6,000-7,000 sf minimum, MDR)	50	60	0.25	NORMAL	D
180	R-1, R-MH, R-TT, R-M, R-O with lot coverage increase waiver (6,000 sf minimum, MFR)	50	70	0.25	NORMAL	D
210	S-D: Special Development (MFR)	60	75	0.25	NORMAL	D
Transportation						
330	General Transportation (Transportation where no detail available; P, GR)	0	95	0.05	NORMAL	D

Table 7.25 Unit hydrograph parameters for unincorporated Mohave County

DDMSW ID	Mohave County Zoning Classification	Vegetation Cover	*RTIMP*	IA	*DTHETA* Cond.	*XKSAT*[3]
340	Transportation (Includes railroads, rail-yards, transit centers, freeways; P, GR)	0	95	0.05	NORMAL	D
420	Pavement and Rooftops (P)	0	95	0.05	NORMAL	D
430	Gravel Roadways & Shoulders (GR)	0	5	0.05	NORMAL	D

7.13.4 SOILS XKSAT VALUES FOR UNIT HYDROGRAPH METHOD

The standard procedure is to use the Green and Ampt and Initial and Uniform Loss method parameters supplied with the DDMSW computer program and the standard soils GIS shape files provided on the Mohave County Flood Control District web site. However, the engineer/hydrologist is strongly encouraged to field verify the soils physical characteristics present in the watershed being modeled. If the engineer/hydrologist determines that the soil physical properties differ significantly from those provided by the NRCS, a site-specific geotechnical investigation is encouraged. Such an investigation should include determination of the sand, clay, gravel and clay content of the soils in the top 6-inch soil horizon. Sufficient tests should be taken to provide a representative set of average values for a specific spatial extent. Aerial photographs, field reconnaissance, geomorphologic techniques, and engineering judgment should be used to determine the spatial extent of individual soil types. The Saxton and Rawls (2006) *Soil Water Characteristics* computer program may then be used to compute an estimate of K_s for each soil type identified. K_s should then be corrected using Equation 7.8 to obtain XKSAT. This same process should be followed if there are Miscellaneous Component soils present in the watershed. Refer to Section 7.4.2.3.

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8 FLOODPLAIN MANAGEMENT

8.1 INTRODUCTION

Mohave County participates in the National Flood Insurance Program (NFIP) which provides flood insurance to its citizens, flood mitigation assistance and emergency assistance to flood victims. FEMA oversees the NFIP. FEMA has regulations pertaining to floodplain management that must be followed for Mohave County to continue as a member of the NFIP.

Mohave County has local policies to manage floodplains in a uniform and consistent manner. These policies are categorized as being FEMA related and non-FEMA related in nature. The policies strictly adhere to State of Arizona and Federal regulations governing floodplains and drainage design.

8.2 FLOODPLAIN MANAGEMENT POLICIES

8.2.1 FEMA

The Federal Emergency Management Agency (FEMA) is an agency of the United States Department of Homeland Security, initially created by Presidential Reorganization Plan No. 3 of 1978 and implemented by two Executive Orders on April 1, 1979. The agency's primary purpose is to coordinate the response to a disaster that has occurred in the United States and that overwhelms the resources of local and state authorities. Since its founding in 1979, FEMA's mission has been clear: To reduce loss of life and property and protect our nation's critical infrastructure from all types of hazards, including flooding, through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery.

As a part of FEMA's mission, it administers the National Flood Insurance Program (NFIP). The NFIP provides the maps and regulatory basis for local floodplain management. It is also the primary source of insurance protection for floodprone properties. It depends on the people responsible for administering its mapping, regulatory and insurance aspects, which includes local governments such as Mohave County. As a part of the NFIP, FEMA identifies floodplain areas and defines floodways.

The Mohave County policies pertaining to FEMA regulatory floodways and floodplains are as follows:

8.2.1.1 Floodways

No development shall be allowed in a FEMA Regulatory Floodway that results in any increase in flood levels during the occurrence of the base flood discharge. A "Regulatory Floodway" means the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. In Arizona, that height is one (1) foot. Mohave County requires a "no rise" certification for any development within a FEMA Regulatory Floodway. A certification form may be obtained from FEMA.

8.2.1.2 Basements

Basements shall not be allowed in Special Flood Hazard Areas for residential structures. Non-residential structures are allowed basements below the base flood elevation (BFE) if a registered professional engineer certifies all required "floodproofing" for the structure.

8.2.1.3 Levees, berms, or floodwalls

Levees, berms, or floodwalls while discouraged, must comply with FEMA standards and be reviewed and approved by Mohave County prior to construction. Levees or berms should not obstruct side or interior drainage to a channel.

8.2.1.4 Variances

Variances may be granted in conformance with the Mohave County Flood Control Ordinance, most current version.

8.2.2 NON-FEMA

8.2.2.1 Lowest Floor Elevation

The lowest floor elevation for dwelling units not within 100-year floodplain areas shall be controlled by the provisions of the most recent version of the International Building Code adopted by Mohave County.

8.2.2.2 Base Flood Elevation Establishment

In locations where a FEMA regulatory BFE does not exist and the 100-year discharge exceeds 500 cfs, a BFE shall be established using the standards and procedures herein and shall require DISTRICT approval.

8.2.2.3 Erosion Setback

In locations where the 100-year discharge in a wash exceeds 500 cfs and is contained within the existing channel banks, erosion setbacks consistent with ADWR State Standard 5-96 (ADWR, 1996b) shall be required for all properties developed where watercourses are to be left in an undisturbed state.

Any variances to the Mohave County floodplain policies shall require approval by the MOHAVE COUNTY ENGINEER.

8.3 FLOODPLAIN MANAGEMENT STANDARDS

8.3.1 FEMA

It is the intent of the DISTRICT that floodplains and floodways be delineated for areas meeting the criteria in the following sections, and that those delineations be submitted to FEMA for approval. The COUNTY/DISTRICT will require a developer to delineate floodplains and floodways for areas that meet these criteria. Delineations may also be done by the DISTRICT as funding permits. The Floodplain Administrator may elect to temporarily not submit a delineation to FEMA due to extenuating circumstances.

The DISTRICT will only regulate floodplains based on FEMA FIRM maps or best available information developed based on these standards. The Mohave County standards pertaining to FEMA regulatory floodways and floodplains are as follows:

8.3.1.1 Floodplain Delineation Requirement

At a minimum, delineation of the 100-year floodplain and submittal to FEMA for approval shall be required for new developments where:

1. Q_{100} >= 500 cfs, and
2. Watershed areas >= 1 sq. mi., or
3. Developments meeting criteria 1 or 2 that are 5 acres in area or greater or will have 50 or more lots.

Floodplains shall be delineated in accordance with the most current version of ADWR State Standard 9-02 (ADWR, 2002).

8.3.1.2 Floodway Delineation Requirement

Delineation of the 100-year floodway and submittal to FEMA for approval may be required when a floodplain delineation is required under Section 8.3.1.1. Floodways shall be delineated in conformance with the most current version of ADWR State Standard 9-02 (ADWR, 2002). If the DISTRICT elects to not require delineation of a floodway, the provisions of Section 8.3.1.4 shall apply. The provisions of ADWR State Standard 3-94 (ADWR, 1994) shall apply when defining floodways for supercritical or near supercritical flow conditions.

8.3.1.3 Technical Documentation Requirement for Submittal to FEMA

A Technical Data Notebook shall be prepared in conformance with ADWR State Standard 1-97 (ADWR, 1997) requirements if the DISTRICT requires that the 100-year floodplain delineation be submitted to FEMA for approval.

8.3.1.4 Existing FEMA Floodplains without a Designated Floodway

An Administrative Floodway analysis is required in conformance with ADWR State Standard 2-96 (ADWR, 1996a) where a FEMA floodplain exists without a designated floodway. At minimum, an assessment of flood depth and velocity should be performed, and structures should not be placed within the area where the following criteria are exceeded unless mitigation measures are constructed to protect the dwelling from flooding and erosion hazards, and flow conveyance is maintained as approved by COUNTY/DISTRICT:

1. Houses built on foundations: Depth x Velocity > 10 and Depth > 2.5 ft.
2. Mobile homes: Depth x Velocity > 6 and Depth > 1.5 ft.

8.3.1.5 Lowest Floor Elevation Requirement

The lowest floor elevation of a dwelling shall be a minimum of 1-foot above the highest adjacent Base Flood Elevation. Note that to file a CLOMR-F with FEMA and remove the dwelling from the floodplain for flood insurance purposes, the grade adjacent to the dwelling must be at or above the Base Flood Elevation prior to construction of the structure.

8.3.2 NON-FEMA

The COUNTY shall require, as part of a subdivision and/or drainage review, that all runoff impacting a development be identified and that all structures within the proposed development

be free from flooding during a 100-year storm event. The provisions of ADWR State Standard 2-96 (ADWR, 1996a) shall apply for these areas.

8.3.2.1 Floodplain Delineation Requirement

In all cases, the 100-year floodplains shall be delineated, and 100-year water surface elevations calculated, for developments meeting the following criteria:

1. Contributing watershed of 0.25 sm or greater, or
2. 100-year peak discharge of 500 cfs or greater, whichever is the most restrictive.

The procedures for Level 1, 2, or 3 from ADWR State Standard 2-96 (ADWR,1996a) shall be used, as approved by the COUNTY/DISTRICT.

8.3.2.2 Floodway Delineation Requirement

An administrative floodway is required using the procedures specified in Section 8.3.1.4.

8.3.2.3 Lowest Floor Elevation Requirement

The lowest floor elevation of a dwelling located within a floodplain delineated under Section 8.3.2.1 shall be elevated a minimum of 12-inches above the highest adjacent 100-year water surface elevation (base flood elevation).

8.3.3 GRADING AND DRAINAGE PLAN AND FINAL PLAT REQUIREMENTS

The 100-year floodplain, water surface elevations, and floodways delineated as required under both the FEMA and NON-FEMA requirements listed above shall be shown on the Grading and Drainage Plans and the Final Plat.

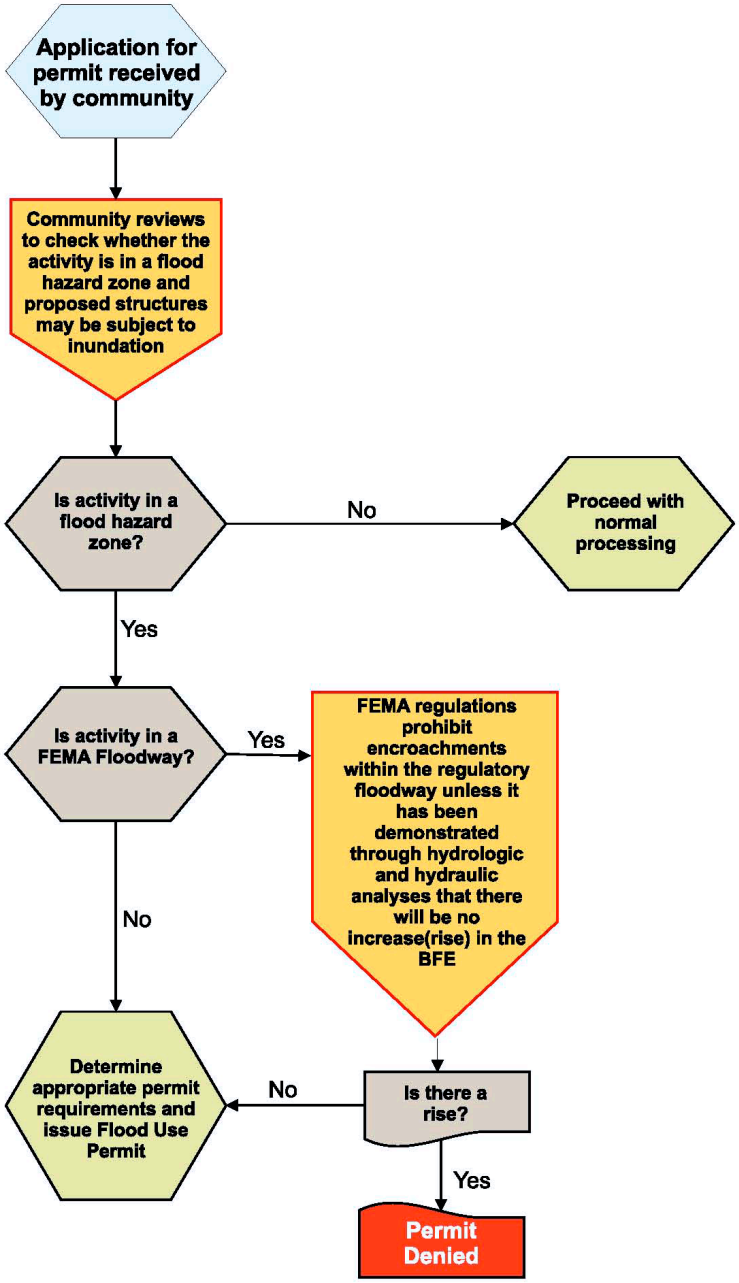
8.3.4 LOWEST FLOOR REQUIREMENTS WITHIN NON-FLOODPLAIN AREAS

The lowest floor elevation for dwelling units not within 100-year floodplain areas defined above shall be controlled by the provisions of the most recent version of the International Building Code adopted by Mohave County.

8.3.5 PERMITTING PROCESS

Figure 8.1 contains a flow chart of the floodplain use permit review process employed by the DISTRICT.

Figure 8.1 Floodplain use permit process



9 ROADWAY DRAINAGE

9.1 INTRODUCTION

The primary purpose of roadways is to serve transportation needs. Accommodation of roadway drainage is provided so that motorists and emergency vehicles have a reasonable level of access and safety during storm events. Stormwater flowing within or across a roadway shall be managed in accordance with the Drainage Design Manual for Mohave County.

9.2 HYDRAULIC TECHNICAL DESIGN CRITERIA

Technical guidance for design of roadway and street drainage shall be in accordance with the street drainage chapter of the Hydraulics Manual. Specific design policies and standards for Mohave County needed for application of the technical information contained in the Hydraulics Manual are defined herein.

9.3 ROADWAY DRAINAGE POLICIES

1. Roadways shall be designed to convey stormwater runoff so as to provide motorists and emergency vehicles access and safety during a storm event.
2. Roadways will be designed to convey stormwater in conformance with Section 9.4.
3. Roadway flow velocities more than those established in Section 9.4 shall require prior approval by the County.
4. Inverted crown roadways shall not be permitted for County Highway or arterial roadways. Inverted crowns on collector/distributor and local roadways shall require prior approval.
5. Historic drainage divides should be retained wherever possible.
6. All runoff from the 100-year frequency storm shall be conveyed within the roadway right-of-way. Any exceptions will require approval from District Engineer and will require drainage easements.

9.4 ROADWAY DRAINAGE STANDARDS

9.4.1 GENERAL

The conveyance of stormwater in a roadway is influenced by the typical roadway cross-section, cross-slope, longitudinal slope and roadway material. The following are standards to be used in the evaluation of roadway drainage conveyance:

9.4.1.1 Lowest Floor Elevations

Lowest floor elevations of buildings adjacent to the roadway right-of-way shall be elevated to provide a minimum of 12-inches of freeboard above the 100-year water surface elevation.

9.4.1.2 Hydrologic Method for Catch Basin Sizing

Runoff calculations for the sizing of storm drain catch basin inlets and connector pipes shall be based on the Rational Method.

9.4.1.3 Street Drainage n-value

A Manning's "n" value of 0.015 shall be used for roadway flow on paved roadways unless special conditions exist.

9.4.1.4 Valley Gutters

Valley gutters are only allowed on local and collector roadways. For valley gutters crossing collector roadways, the valley gutters shall provide mild slope transitions (maximum 5% total algebraic break over) to provide smooth vehicular ride across them and shall be at least seven-feet wide.

9.4.1.5 Curb Returns

Curb returns should have a minimum slope of 0.01 foot of fall for every one foot of curb radius. For example, a 25 foot radius curb return should have at least 0.25 foot of fall from one end to the other.

9.4.1.6 Catch Basins on Continuous Grade

Catch basins on continuous grade are not required to intercept 100% of the design flow rate. 100% interception of the design flow rate may be required at roadway intersections.

9.4.1.7 Catch Basin Design

The curb opening for a catch basin shall not be greater than six (6) inches in height. Permissible catch basins are contained in the MAG Standard Details. The reduction factors, as identified in Table 9.1, shall be applied to the theoretical catch basin capacity to obtain the interception capacity used for design. The use of grated catch basins is discouraged within roadway sections. If a grated catch basin is used within a roadway section, only those grate types with bars transverse to traffic, or reticuline types, are acceptable. The reduction factors

shall be applied to the design peak discharge to obtain the required interception capacity used for design.

9.4.2 DESIGN FREQUENCY, DEPTH AND VELOCITY REQUIREMENTS

The following are the drainage design standards for each roadway functional classification as defined in the Standard Details. The term "All-weather Access" refers to roadways designated by the COUNTY as providing primary access to a specific area for emergency ingress and egress purposes during extreme weather conditions. The roadway classifications "Cul-de-Sacs" and "Hillside/Frontage" defined in the Standard Details are included under the Local Roadway classification for the purposes of these standards. The frequency, such as 10-year or 100-year, refers to the conveyance of the stormwater runoff peak discharge corresponding to the listed storm frequency (i.e. a 100-year storm has a one percent probability of occurring or being exceeded in any given year). Peak discharges for roadway drainage design are normally estimated using the Rational Method (Section 7.3.2). Peak discharges estimated using the Unit Hydrograph Method may also be used where appropriate, particularly where runoff from large offsite watersheds is conveyed in a channel within the roadway right-of-way. Maximum flow depth and velocity criteria are for any location within the roadway travel lanes, as defined on the Standard Details. The maximum velocity is for all design storms up to and including the 100-year storm frequency.

The 100-year flow depth may not exceed the road right-of-way limits. If flows exceed the hydraulic carrying capacity of the street within the right-of-way limits, then additional drainage conveyance will be required. Such additional drainage conveyance may include but is not limited to: 1) a permanent drainage channel within an easement or dedicated drainage parcel adjacent to the street right-of-way; 2) storm sewer under or adjacent to the street; 3) other appropriate good engineering design practice. Additional depth-velocity criteria are specified in the following sections.

When analyzing flow entering streets or within the street section, superelevation effects on the water surface due to bends must be taken into account and calculated to ensure adequate freeboard for all flows turning into cross streets at an intersection, or street curves.

9.4.2.1 Roadways with Curb and Gutter:

Channel and/or storm drain systems are to be installed as needed to meet the following roadway drainage criteria for depth and velocity.

1. County Highway/Arterial/All-weather Access:
    a. Inverted crowns are not allowed.
    b. 10-year: One 12-foot dry lane each direction, and flow depth shall not exceed curb height.
    c. 100-year: Maximum flow depth between curbs <= 8-inches
    d. Maximum velocity = 8 fps.
2. Collector/Distributor/Local Roadways:
    a. Inverted crowns are allowed.
    b. 10-year: Flow depth shall not exceed curb height.
    c. 100-year, normal crown: Maximum flow depth between curbs <= 8-inches
    d. 100-year, inverted crown: Maximum flow depth between curbs <= 12-inches
    e. Maximum velocity = 8 fps.

9.4.2.2 Roadways without Curb and Gutter:

1. All Roadway Classifications: 100-year peak discharge shall be contained in a channel with the maximum design storm flow depth not to exceed the outside shoulder hinge point shown on the Standard Details.

9.4.3 CATCH BASINS

Capacity reduction factors for catch basins are listed in Table 9.1. The reduction factors shall be applied to the theoretical catch basin capacity to obtain the interception capacity used for design.

Table 9.1 Inlet Capacity Reduction Factors

Condition	Inlet Type	Reduction Factor
Sump	Curb Opening	0.80
Sump	Grated	0.50
Sump	Combination	0.65
Continuous Grade	Curb Opening	0.80
Continuous Grade	Longitudinal Bar Grate Longitudinal Bar Grate with recessed transverse bars Longitudinal Bar Grate with transverse bars Reticuline Grate	0.75 0.60 0.40 0.35
Continuous Grade	Combination	Apply factors separately to grate and curb opening
Shallow Sheet Flow (1)	Slotted Drains	0.80

(1) Slotted drains are most effective for shallow sheet flow conditions. With greater depths and flows, a different type of inlet should be used.

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10 STORM DRAINS

10.1 INTRODUCTION

This chapter contains technical standards that should be used for the hydraulic design of a storm drain system. In this manual, a storm drain system refers to a coordinated group of inlets, underground conduits, manholes, and various other appurtenances which are designed to collect stormwater runoff from the design storm and convey it to a point of discharge into a major or regional drainage outfall. Storm drains should generally only be considered for minor watercourses in urban areas. The use of storm drains is generally discouraged for unincorporated Mohave County primarily because of maintenance issues associated with sedimentation. Storm drains typically are not economical for the flows conveyed within larger watercourses. Therefore, the storm drain system will collect runoff to a point where storm drains become too large to be economical and will then discharge into a major or regional watercourse outfall consisting of a man-made channel, or natural watercourse.

10.2 HYDRAULIC TECHNICAL DESIGN CRITERIA

Technical guidance for design of storm drains shall be in accordance with the storm drains chapter of the Hydraulics Manual. Specific design standards for Mohave County needed for application of the technical information contained in the Hydraulics Manual are defined herein.

10.3 STORM DRAIN STANDARDS

The following minimum standards including the requirements in Table 10.1 are to be met for the design of storm drains that will be placed into the Mohave County Public Works or Mohave County Flood Control District maintenance systems.

10.3.1 HYDRAULIC DESIGN REQUIREMENTS

10.3.1.1 Design Discharge

The design discharge (Q_{design}) shall be the peak discharge that must be conveyed in the storm drain in order to meet the roadway drainage design criteria for depth and velocity specified in Section 9.4.2.1. Storm drains with slopes less than 0.5%, and flow velocities less than five fps for Q_{design} or in excess of 15 fps shall require special approval by the COUNTY/DISTRICT.

Table 10.1 Storm drain hydraulic design standards

Design Variable	Design Standard
Minimum Velocity.	5 fps for Q_{design} The lesser of 3 fps for 0.5 x Q_{design} or 3 fps at flow depth = 1'
Maximum Velocity w/o structural analysis to justify design.	15 fps
Minimum Slope	0.005 ft/ft
Minimum Pipe Size. Main Line (straight horizontal and vertical alignment) Main Line (curved horizontal and/or vertical alignment) Lateral and Connectors	 18-inches 24-inches 15-inches
Pipe Diameter Changes.	The elevation of pipe crowns, not inverts, are to be matched at manholes and structures.
Pipe Joint Deflections: Main Line Lateral and Connectors	Maximum of 0.5 times the manufacturer's recommended tolerance. Not allowed
Maximum Distance to First Catch Basin.	The first catch basin should be placed where the roadway drainage hydraulic criteria from Section 9.4.2.1 is first exceeded.
Manhole Spacing (SD = Storm Drain Diameter).	≤30 inches SD (straight) = 330 feet max 33-45 inches SD = 440 feet max 48-84 inches SD = 660 feet max >84 inches SD = 1,320 feet max
Maximum Hydraulic Grade Line Elevation, Q_{design}.	Shall not be higher than 12 inches below inlet gutter flowline elevation
Maximum Energy Grade Line Elevation, Q_{design}.	Shall not exceed gutter flowline elevation

10.3.1.2 Hydraulic and Energy Grade Lines

Storm drain systems shall be designed for Q_{design} so that the hydraulic grade line is at least 12 inches below the inlet gutter flowline elevation, and the energy grade line shall not exceed the elevation of the gutter flowline. Hydraulic and energy grade line information for all main line and connector storm drain pipes shall be prepared by the design engineer and submitted to the COUNTY/DISTRICT for approval. The information shall be provided in tabular and profile

format and shall include: pipe stationing, pipe size, pipe discharge (Q), pipe velocity, pipe material, hydraulic grade line, energy grade line, and finish grade over pipe.

10.3.1.3 Storm Drain Pipe Materials

Pipe culverts are to be corrugated steel pipe (CSP) or rubber gasket reinforced concrete pipe (RGRCP). Pipe wall thickness, corrugations, and linings are to be determined based on engineering analysis using the design guidelines provided by the Corrugated Steel Pipe Institute (CSPI) and the American Iron and Steel Institute (AISI), *Handbook of Steel Highway and Drainage Construction Products* (CSPI, 2002), and the American Concrete Pipe Association (ACPA) *Concrete Pipe Design Manua*l (ACPA, 2007).

If soil resistivity readings are below 1500 ohms per cubic centimeter, CSP will not be allowed.

The minimum gauge for CSP storm drain pipe shall be 14 gage. The specific gage specified, in addition to meeting loading requirements, shall provide a design life of at least 75 years to first perforation based on soil conditions (see Figure 10.1).

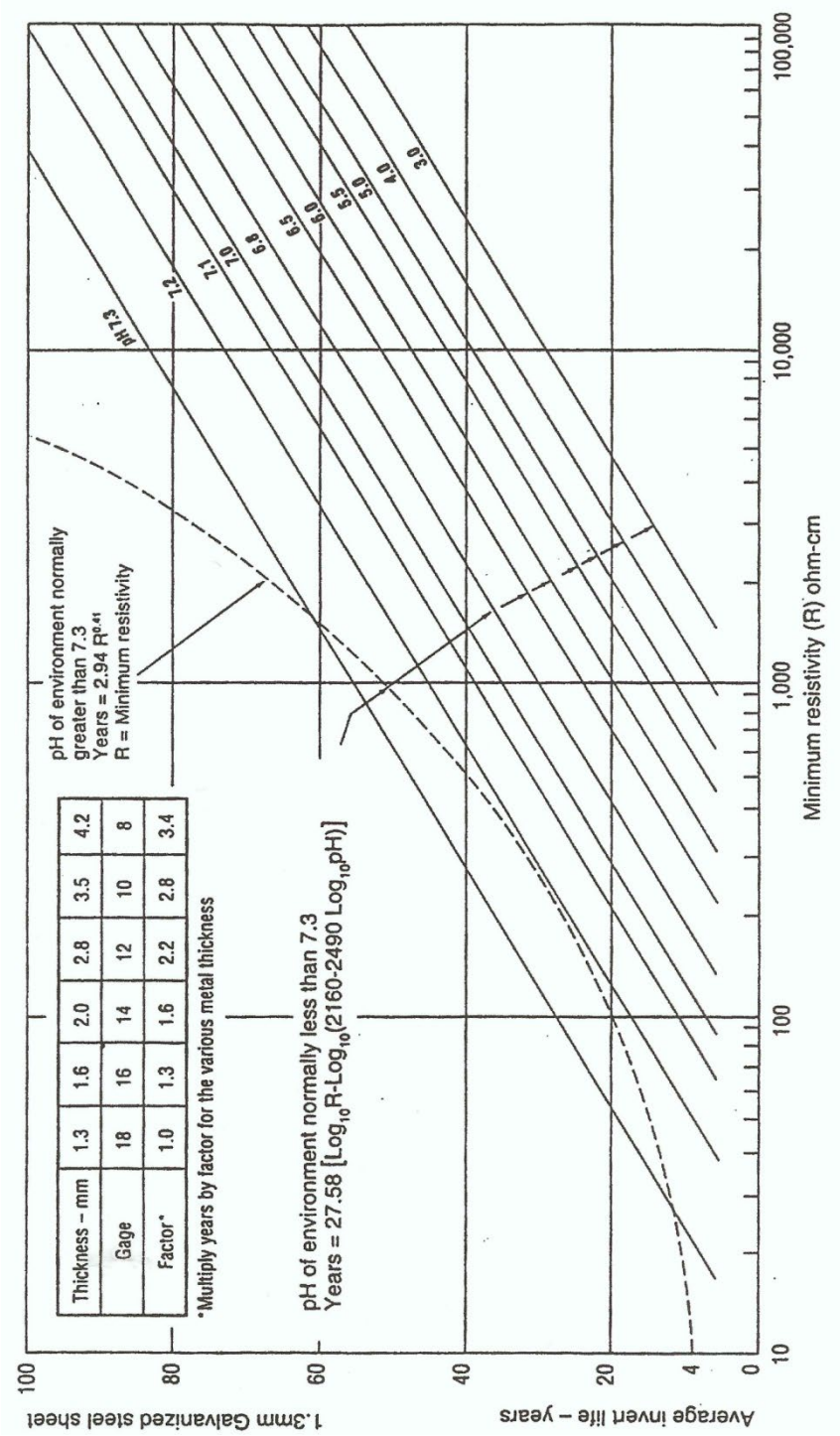
RGRCP should be designed to fall within the allowable ranges identified in the "D" load table (see Figure 10.2). The use of Figure 10.2 will provide a conservative design. If a more economical design is deemed necessary, the Direct Design Method set forth in ACPA (2007) may be used. D-Load requirements shall be determined using a 140 pcf earth load. In ordinary soil conditions, the "positive projected condition" shall be used for up to ten feet of cover. "Trench condition" shall be used for deeper trenches in ordinary soil conditions. If the soil information indicates unstable soil, the positive projected condition shall be used exclusively in determining D-Load requirements.

10.3.1.4 Minimum Cover Requirements

Minimum cover of fill over storm drains should be at least four (4) feet in order to minimize conflicts with other utilities. A lesser minimum cover may be may allowed if engineering justification is submitted and approved by COUNTY/DISTRICT.

Figure 10.1 Minimum gage thickness for CSP

(from CSPI, 2002, pg 350)

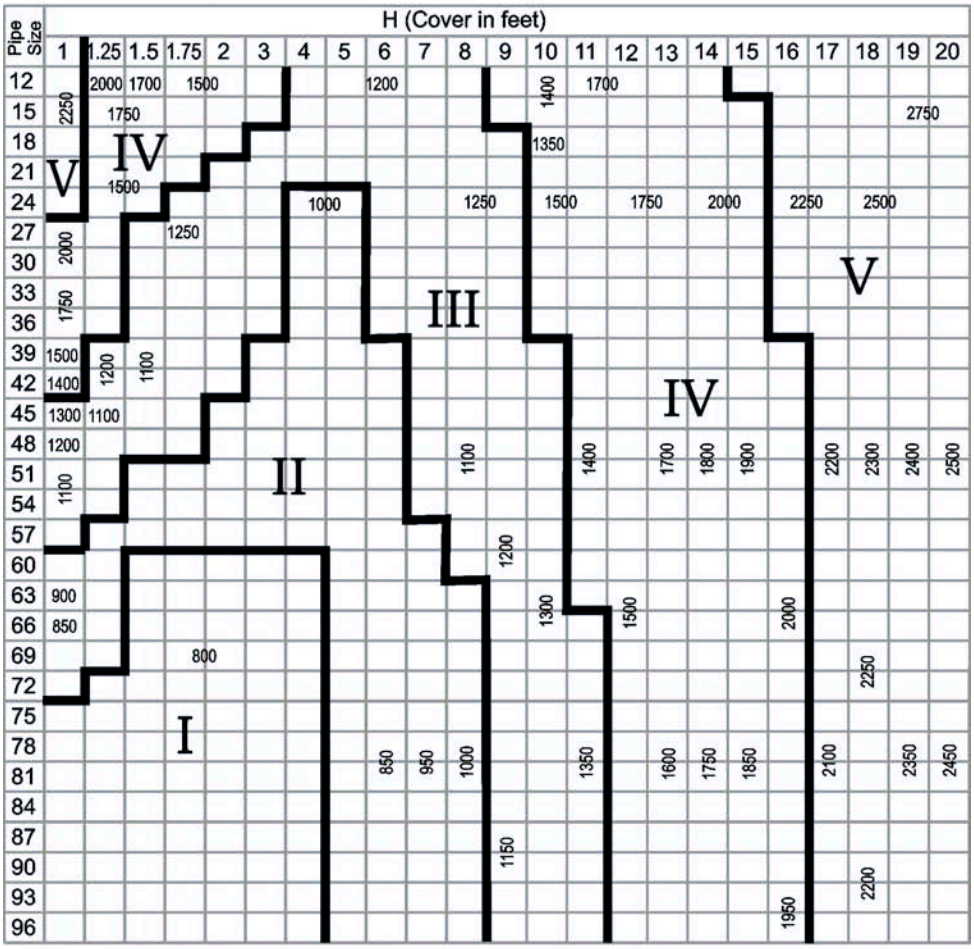


Thickness – mm	1.3	1.6	2.0	2.8	3.5	4.2
Gage	18	16	14	12	10	8
Factor*	1.0	1.3	1.6	2.2	2.8	3.4

Figure 10.2 Required "D" Load for reinforced concrete pipe

(from City of Phoenix, 2011)

Required "D" Load For Reinforced Concrete Pipe
Positive Projection Condition
(140 P.C.F. Earth Load)



Structural Notes:

1. Ku = 0.1924
2. For H< 10, P = 1.0, He/Bc = 1.7
3. For H> 10, P = 0.5, He/Bc = 1.4
4. Dead Load Factor = 1.9
5. Safety Factor = 1.0
6. Earth Loading = 140 pcf (Marston's Formula)
7. Live Loading: H-20, S-16 Truck, AASHO Impact

10.3.1.5 Manhole Requirements

Manholes are required for all mainline storm drain pipe size changes, vertical grade breaks, horizontal angle deflections greater than five (5) degrees, mainline pipe intersections, and periodic locations for access and maintenance. Maximum manhole spacing shall conform to the requirements in Table 10.1. Typically, when mainline pipe size changes, the inside top of pipe elevations (pipe crowns) shall be matched. In the event where the downstream pipe is smaller than the upstream (such as when a required 6-inch oversized alternate pipe is attached to RGRCP), then the pipe invert elevations shall be matched.

10.3.1.6 Connector Pipe Requirements

Catch basin connector pipes shall be connected to new mainline storm drain pipes with prefabricated tees. One catch basin connector pipe may be joined to the mainline at a manhole if the standard required mainline manhole spacing provides a convenient location for it. If there are two directly opposing catch basins to connect to the mainline at a manhole, only one connector pipe may connect to the manhole and the second connector pipe shall connect to the mainline by way of a prefabricated tee at least 5-feet downstream of the manhole. Where connector pipes are to be joined to existing mainline storm drains, they shall be connected by manhole. Connection of new mainline pipe to new mainline pipe or existing mainline pipe shall be by manhole or special junction structure depending on size and feasibility of manhole or special junction structure installation.

To minimize head loss and maintain structural integrity of the mainline pipe, the following shall apply:

1. Opposing catch basin connector pipes connecting to a mainline storm drain pipe shall be offset a minimum of five feet horizontally as measured from the centerline of each connector pipe.
2. Opposing storm drain laterals greater than 24 inches in diameter shall be joined by a special junction structure designed to minimum HS-20 loading by a registered professional engineer. The junction structure shall be designed to be hydraulically efficient.

10.3.1.7 Pipe Deflections and Bends

The minimum diameter for pipes designed on a horizontal or vertical curve shall be 24-inch. Joint deflections used to form horizontal and vertical curves in mainline storm drain pipe shall not exceed 0.5 times the manufacturer's recommended maximum tolerance. Connector pipes for laterals to catch basins shall not be curved. Specifications for horizontal deflection using this

method shall be noted on the construction plans, citing manufacturer's requirements. An angular bend in catch basin connector pipe (horizontal or vertical), up to, and including 22½ degrees may be accomplished by using a standard MAG Detail 505 pipe collar. Prefabricated pipe bends shall be required for deflections in catch basin connector pipes greater than 22½ degrees. In addition, the maximum angle for a catch basin connector pipe to exit any wall of a catch basin shall be 22½ degrees from perpendicular.

10.3.1.8 Outlet Protection Requirements

Storm drain outlet requirements shall conform to the requirements set forth in Section 11.4.12.

10.3.1.9 Construction Plan Requirements

Storm drain pipes and manholes shall be shown in plan and profile along with existing and proposed grades of the pipeline and both the existing and proposed ground surface above the pipeline. Catch basin and connector pipe profiles shall also be provided in the design drawings. The pipe size and slope to four significant figures shall be shown. All existing utilities, including water and sanitary sewer, crossing the proposed storm drain shall be shown in plan, and in profile at their proper elevation. Proposed new utilities shall be labeled and shown at anticipated locations and standard depths when exact information is not yet known. Clearance with water and sewer facilities require a minimum of six feet horizontally and one foot vertically. Clearance with other utilities shall be a minimum of one foot both horizontally and vertically.

Refer to Section 19.3 for additional construction drawing requirements.

10.3.1.10 Soil Boring Requirement

Soil boring information is required for all pipe materials. Soil boring logs shall be provided with the design documentation for all storm drains within public right-of-way. Storm drains in excess of 660 feet in length shall have multiple borings at intervals not to exceed 660 feet. Boring depths shall be at least two feet below the proposed pipe invert. If cemented or rock material is encountered during drilling which results in refusal, then the geotechnical engineer shall determine the specific limits of rock and identify the type and extent of refusal to at least two feet below the proposed pipe invert.

Borings shall be shown in plan and profile view and tied to the same vertical datum as the proposed project. Resistivity and pH testing of the soils shall be required to support pipe design in terms of alternate pipe material selection. If resistivity readings fall below 1500 ohms per

cubic centimeter, additional readings shall be made at intervals of not less than 25 feet or more than 100 feet until the limits of the area of low resistance soil are fully defined.

Boring log data shall include the following information:

1. The name of the company that produced the soil report.
2. The name of the project that the borings apply to.
3. The date the test boring was made.
4. The type of equipment used to drill the hole and take the samples.
5. The size of the auger used.
6. The vertical datum used.
7. A description of caving that occurred during the excavation, if any.
8. Horizons of each type of soil encountered.
9. Description of the soil.
10. Classifications by the Unified Soil Classification System.
11. Plasticity index.
12. Percent passing No. 200 sieve.
13. Water encountered.
14. Pavement structure (AC thickness, sub-base thickness, if applicable).
15. Relative moisture content (specify depth taken).
16. Representative unit weight of native material (specify depth taken)
17. Laboratory calculated optimum moisture content.
18. Resistivity and pH readings.

10.3.1.11 Parcel or Easement Requirement

A County owned property, dedicated right-of-way, privately owned drainage parcel, or drainage easement shall be a minimum of 16 feet wide for underground storm drains if not under a designated road right-of-way. Additional width may be required for large storm drains, large trench depths, and/or equipment access needs.

11 CULVERTS AND BRIDGES

11.1 INTRODUCTION

Bridges are defined as structures designed to span a watercourse, including bridges for vehicular roadways and pedestrian-only uses. Culverts are buried pipe or box hydraulic conveyance structures designed to convey stormwater from one side of a roadway, embankment, or service area to the other side. The following are minimum policies and standards to be employed in the design of culverts and bridges that will be placed into the Mohave County maintenance system. These policies and standards may also apply to private streets and roadways.

11.2 HYDRAULIC TECHNICAL DESIGN CRITERIA

Technical guidance for design of roadway culverts and bridges shall be in accordance with the culverts and bridges chapter of the Hydraulics Manual. Additional guidance may be obtained from FHWA (2005c). Specific design policies and standards for Mohave County needed for application of the technical information contained in the Hydraulics Manual are defined herein. General recommended practices for culvert design and construction are:

- A single more hydraulically efficient culvert should be used instead of multiple smaller culverts when possible. This is desirable to minimize cost and to facilitate maintenance.
- Multiple culverts should be used when mimicking natural hydraulic conditions and large width to depth ratios need to be maintained. Multiple culverts may also be necessary when there is a need to minimize backwater effects.
- Pipe inlet and outlets should extend past the toe of the backfill or necessary slope protection unless headwalls or end sections are provided and properly situated.
- The combination of culvert vertical alignment and hydraulic characteristics should be carefully designed to facilitate sediment conveyance and to minimize scour and head cutting.
- New roadway crossings requiring culverts should be designed perpendicular to the natural drainage whenever possible.

- Culverts shall be checked for both inlet and outlet control conditions and the design based on the condition with the highest headwater depth at the inlet.
- Culverts shall be properly bedded and backfilled in conformance with MAG Standards and Specifications.

11.3 CULVERT AND BRIDGE POLICIES

The following are Mohave County policies related to culverts and bridges.

11.3.1 CULVERT/BRIDGE BACKWATER PONDING

A county-owned property, right-of-way, or privately-owned drainage tract or easement shall be provided for the area inundated by backwater from the culverts for the peak 100-year event. The 100-year floodplain limits are to be delineated and shown on the subdivision Final Plat or Map of Dedication. If the culvert or bridge lies within a FEMA-delineated 100-year floodplain, the encroachment shall not result in a rise in 100-year water surface elevation above the Regulatory Flood Elevation or a change in the Regulatory Floodway without processing of a CLOMR and a LOMR.

11.4 CULVERT AND BRIDGE STANDARDS

11.4.1 REQUIREMENT TO PROVIDE CULVERTS OR BRIDGES

Except where low water crossings are allowed as specified herein, watercourses found to meet the following conditions are to be culverted or bridged:

1. A watercourse with a 100-year peak discharge of 25 cfs or greater,
2. A watercourse that is a regulatory area designated as "Waters of the United States" under Section 404 of the Clean Water Act (refer to Section 2.3.2), or
3. As necessary to preserve natural flow patterns and prevent adverse impacts on adjacent, upstream and downstream properties.

11.4.2 CULVERT MATERIAL REQUIREMENTS

Pipe culverts are to be corrugated steel pipe (CSP), rubber gasket reinforced concrete pipe (RGRCP), and reinforced concrete box culverts (RCBC). CSP and RGRCP may be either circular, elliptical, or arch pipes. Steel structural plate pipes or arches may also be used but require prior approval by COUNTY/DISTRICT. Concrete pipes and box culverts may be either precast or

cast-in-place. Pipe wall thickness, corrugations, and linings are to be determined based on engineering analysis using the design guidelines provided by the Corrugated Steel Pipe Institute (CSPI) and the American Iron and Steel Institute (AISI), *Handbook of Steel Highway and Drainage Construction Products* (CSPI, 2002). Refer to Section 10.3.1.3 for resistivity and minimum pipe thickness or design class requirements for storm drains, which also apply to CSP and RGRCP used for culverts.

11.4.3 DESIGN STORMS

Culverts are to be designed to convey, as a minimum, the design storm frequency peak discharge listed below by roadway classification with the design storm maximum water surface not to exceed the shoulder hinge point as defined for each roadway classification in the Standard Details.

1. County Highway/Arterial/All-weather Access:
   - 4-lanes 50-year peak discharge
   - 2-lanes 25-year peak discharge
2. Collector/Distributor and Local: 10-year peak discharge.
3. All roadway classifications:
   a. Roadway Overtopping. The maximum depth in the roadway travel lanes in dip sections for the 100-year peak discharge shall be 12-inches. If culvert overtopping flow does not cross the road, but turns and drains down the roadway, the maximum depth of flow within the roadway travel lanes shall be 8-inches.
   b. Bridges. Runoff to be conveyed under the road with 2-feet of freeboard below the bridge low chord, including the effects of pier clogging.
   c. Driveway Culverts within Mohave County Right-of-Way: Sized so the design storm criteria for the roadway classification are met.

11.4.4 MINIMUM PIPE DIAMETER

1. All roadway classifications: 24-inch minimum
2. Driveway culverts in Mohave County Right-of-Way: 18-inch minimum.

11.4.5 MINIMUM COVER REQUIREMENTS

Minimum cover of fill over culverts should be at least eighteen (18) inches. A lesser minimum cover may be may allowed if engineering justification is submitted and approved by COUNTY.

11.4.6 CLOGGING FACTORS

1. **Culverts**. In high debris/sediment areas, COUNTY may elect to require the following clogging factors be applied to the design cross section area of the culvert opening.

Culvert Size	Clogging Factor
Equivalent diameter <= 48 inches	Reduce available opening area by 50%
Equivalent diameter > 48 inches	Reduce available opening area by 20%

2. **Bridges**.

   Floating Debris Allowance for Bridge Modeling and Design:

   Hydraulic Analysis of Bridges: Bridge pier sizes shall be modeled as twice their structural width or 1 foot on each side, whichever is greater. When warranted by the potential for debris from the watershed, larger debris width increases may be required.

   Hydraulic Analysis of Box Culverts: When warranted by the potential for debris from the watershed, an allowance of 1 foot of debris on each side of box culvert inlets at interior walls shall be considered when calculating the hydraulic capacity of box culverts.

   Bridge Pier Modeling for Local Scour Calculations: The following minimum modifications to the pier shape shall be applied in hydraulic models for structural design purposes to calculate pier local scour depth and water pressure on piers. These minimum modifications are intended to supplement AASHTO LRFD Bridge Design Specifications (AASHTO, 2004), unless otherwise directed by COUNTY/DISTRICT.

   a. To account for drift/debris build-up, increase pier column width/diameter, within the top 12 feet of water depth (per ADOT Bridge Design Guidelines), to twice the design value, but no less than two feet on each side.

   b. Larger pier width increases up to half span length on each side may be considered when warranted by the potential for debris from the watershed.

   c. For deep drilled shaft foundations, in the area below the bottom of casing, increase the shaft design diameter by one foot on each side.

3. **Trash and Debris Racks**. Where trash and/or debris racks are required under Chapter 4, culvert design capacity shall be adjusted as defined in the Hydraulics Manual.

11.4.7 LOW WATER CROSSINGS

1. Low water crossings are allowable for long areas of shallow or distributary flow where the MOHAVE COUNTY ENGINEER determines that construction of culverts is impractical, would significantly change historical flow patterns, or would result in significant adverse impacts to properties.
2. Low water crossings shall have erosion protection sufficient to withstand the impacts of a 100-year flood.
3. Low water crossings shall be signed in accordance with Mohave County Public Works requirements.
4. The maximum flow depth in the travel lanes for the 100-year peak discharge is 12-inches for all roadway classifications.

11.4.8 PONDING OUTSIDE OF RIGHT-OF-WAY

Backwater ponding limits that extend outside of the roadway right-of-way shall be delineated and a drainage easement or right-of-way obtained from the property owner. Drainage easements shall be recorded and attached to the deed for the property.

11.4.9 HEADWALL REQUIREMENTS

Headwalls are required at the inlet and outlet of all culvert installations unless otherwise approved by COUNTY. Pipe sizes of 48-inch or greater shall have concrete headwalls. Pipe sizes less than 48-inch shall have concrete headwalls if trash racks are required to comply with safety requirements specified in Section 4. Otherwise, pipe sizes less than 48-inch shall have flared end sections or concrete/masonry headwalls.

11.4.10 MAINTENANCE ACCESS

Ramped, vehicular access for maintenance is required at the upstream and downstream ends of all culverts that are not accessible from the roadway. The maintenance access route shall be within public right-of-way or a COUNTY approved easement and shall have a minimum drivable width of twelve (12) feet and a maximum slope of 20%.

11.4.11 VELOCITY REQUIREMENTS

1. Design velocity and slope requirements shall conform to those specified in Table 11.1.
2. Culverts are to be designed with consideration to the guidelines presented in the Culverts and Bridges, and Sedimentation chapters in the Hydraulics Manual.
3. The culvert shall be designed so minimum velocities facilitate sediment transport to keep the culvert clean.
4. The maximum velocity in the culvert should be consistent with channel stability requirements at the culvert outlet. Aggradation or degradation at culvert crossings shall be examined in the design of culverts.

Table 11.1 Culvert hydraulic design standards	
Design Variable	**Design Standard**
Minimum Velocity.	5 fps for Q_{design} The lesser of 3 fps for 0.5 x Q_{design} or 3 fps at flow depth = 1’
Maximum Velocity.	15 fps
Minimum Slope	0.005 ft/ft
Pipe Curvature	Not allowed.

11.4.12 OUTLET PROTECTION REQUIREMENTS

11.4.12.1 General

Culvert outlet protection requirements shall conform to the design criteria set forth in Table 11.2. Design guidelines for the types of outlet protection listed in Table 11.2 can be found as follows:

Cut-off Walls: See Section 11.4.12.2.

Riprap Aprons: See Section 11.4.12.3.

Riprap Basins: See Chapter 8, Section 8.4.3 of the Hydraulics Manual

Concrete Outlet Structures: See Section 8.4.4 of the Hydraulics Manual.

Table 11.2 Design criteria for culvert outlets

Outlet Protection Type	Froude Number Criteria	Velocity Criteria ($V_{max} = 15\ fps$)	
		Natural Channel	Artificial Channel
None	$F_r \leq 1.0$ and: Scour analysis shows outlet protection is not necessary		
Cut-off wall	$F_r \leq 1.0$	Up to 1.3 times existing channel velocity	Up to maximum allowable velocity for channel lining
Simplified Riprap Apron Method (single culvert installations only)	$F_r \leq 2.5$ Circular culverts 60-inches and smaller where: $\frac{Q}{D_c^{2.5}} \leq 6$	1.3 to 2.5 times existing channel velocity. A limiting velocity at the downstream end of the apron of 5 fps.	1.0 to 2.5 times allowable channel lining velocity
Detailed Riprap Apron Method (single and multiple culvert installations)	$F_r \leq 2.5$ Circular culverts where: $\frac{Q}{D_c^{2.5}} \leq 6$ Box culverts where: $\frac{Q}{WH^{1.5}} \leq 8$		
Riprap Basin	$F_r \leq 2.5$		
Concrete Outlet Structure	n/a	Velocities greater than 2.5 times existing channel velocity	Velocities greater than 2.5 times allowable channel lining velocity

where:
F_r = Froude number in culvert barrel at outlet
D_c = culvert diameter, in feet
W = box culvert opening width, in feet
H = box culvert opening height, in feet

11.4.12.2 Cut-Off Walls

Culverts with headwalls shall have cut-off walls where dictated by scour depth. If cut-off walls are determined to be necessary, then minimum cut-off wall depths shall be as indicated in Table 11.3. For pipes larger than 24 inches, cut-off wall depth shall be dictated by the greater of the depth shown in the table or that depth calculated using the depth of scour equation identified in Chapter 5 of the Hydraulics Manual. Cut-off walls will normally be concrete in conformance with the MAG Standards. Riprap may be used as an alternative. When riprap is used, multiply the depth specified in Table 11.3 by 1.25. Extend the riprap horizontally a minimum of one pipe diameter upstream from the culvert outlet at that depth.

Table 11.3 Design criteria for culvert cut-off walls

MAG Standard Pipe Diameter	Minimum Inlet & Outlet Cutoff Wall Depth (feet)
24" to 48"	2.0
48" to 84"	4.0

11.4.12.3 Riprap Aprons

Most culvert outlet protection designs will utilize a riprap apron approach. For riprap aprons, the riprap rock size and apron length may be designed for single circular culverts less than or equal to 60-inches in diameter using the Simplified Riprap Apron Method. This method will provide a conservative design for most applications. If a less conservative design is desired, the design requires the use of a box culvert or multiple culverts, or culvert sizes greater than 60-inch are required, the Detailed Riprap Apron Method should be applied, or a riprap basin approach used.

Detailed Riprap Apron Method

The most commonly used device for conduit/culvert outlet protection is a riprap apron. The procedures presented in this section are derived from *Urban Drainage and Flood Control District Drainage Criteria Manual* (UDFCD, 2001). Scour resulting from highly turbulent, rapidly decelerating flow is a common problem at conduit outlets. The riprap apron protection design protocol is suggested for conduit and culvert outlet Froude numbers up to 2.5 where the channel and conduit slopes are parallel with the channel gradient and the conduit outlet invert is flush with the rip-rap channel protection. Here, Q is the discharge in cfs, D_c is the diameter

of a circular conduit in feet and *W* and *H* are the width and height, respectively, of a rectangular conduit in feet.

The procedure in this section was evaluated by the FHWA in HEC-14, Appendix D (FHWA, 2006). It was found to be an acceptable procedure, but less conservative than the procedure recommended in Chapter 10 of HEC-14. The procedure in this section allows for design of culvert outlet protection for both circular and box culverts, while the FHWA HEC-14 Chapter 10 procedure only addresses circular pipe culverts. The selection was made based on the need for an acceptable procedure applicable to both circular and box culverts, the need for a more definitive method of defining the extent of protection required than the FHWA HEC-14 Chapter 10 provides, and the need for a procedure that is safe but not overly conservative. An example schematic of an apron from UDFCD (2001) is shown in Figure 11.1. Figure 11.1 illustrates typical riprap protection of culverts and major drainageway conduit outlets. The additional thickness of the riprap just downstream from the outlet is to assure protection from turbulent flow conditions that might precipitate rock movement in this region. The procedures in this section should only be applied for the outlets of circular pipes 72-inch in diameter or smaller, box culverts with an opening height of 72-inches and smaller, and for a riprap d_{50} requirement of 24-inches or less, within the limitations shown on Figure 11.2 and Figure 11.3. The procedure may be applicable to other situations, but the designer should receive prior approval from COUNTY/DISTRICT before applying it. For conduits/culverts that do not meet the requirements of this procedure, a riprap basin or concrete outlet structure should be used (refer to Hydraulics Manual Section 8.4.3 or Section 8.4.4).

Required Rock Size. The required rock size may be selected from Figure 11.2 for circular conduits and from Figure 11.3 for rectangular conduits. Figure 11.2 is valid for $Q/D_c^{2.5}$ of 6 or less and Figure 11.3 is valid for $Q/WH^{1.5}$ of 8.0 or less. The parameters in these two figures are:

1. $Q/D_c^{1.5}$ or $Q/WH^{0.5}$ in which Q is the design discharge in cfs, D_c is the diameter of a circular conduit in feet, and W and H are the width and height of a rectangular conduit in feet.
2. Y_t/D_c or Y_t/H in which Y_t is the tailwater depth in feet, D_c is the diameter of a circular conduit in feet, and H is the height of a rectangular conduit in feet. In cases where Y_t is unknown or a hydraulic jump is suspected downstream of the outlet, use $Y_t/D_c = Y_t/H = 0.40$ when using Figure 11.2 and Figure 11.3.
3. The riprap size requirements in Figure 11.2 and Figure 11.3 are based on the non-dimensional parametric Equation 11.1 and Equation 11.3 (Steven, Simons, and Watts

1971, and Smith 1975). Both equations are solved for d_{50} to produce Equation 11.2 and Equation 11.4.

Circular culvert:

$$\frac{\left(\frac{d_{50}}{D_c}\right)\left(\frac{Y_t}{D_c}\right)^{1.2}}{\frac{Q}{D_c^{2.5}}} = 0.023 \qquad 11.1$$

Solving for d_{50}:

$$d_{50} = \frac{0.023 Q D_c^{-1.5}}{\left(\frac{Y_t}{D_c}\right)^{1.2}} \qquad 11.2$$

where:

d_{50} = median rock size, in feet
D_c = culvert diameter, in feet
Y_t = tailwater depth, in feet
Q = design peak discharge, in cfs

Rectangular culvert:

$$\frac{\left(\frac{d_{50}}{H}\right)\left(\frac{Y_t}{H}\right)}{\frac{Q}{WH^{1.5}}} = 0.014 \qquad 11.3$$

Solving for d_{50}:

$$d_{50} = \frac{0.014 Q H^{0.5}}{W Y_t} \qquad 11.4$$

where:

W = width of rectangular culvert, in feet
H = height of rectangular culvert, in feet

The rock size requirements were determined assuming that the flow in the culvert barrel is sub-critical. It is possible to use Equation 11.1, Equation 11.2, Equation 11.3 and Equation 11.4 when the flow in the culvert is supercritical and less than full if the value of D_c or H is modified for use in Figure 11.2 and Figure 11.3. Whenever the flow is supercritical in the culvert, substitute D_a for D_c and H_a for H, in which D_a is defined as:

$$D_a = \frac{(D_c + Y_n)}{2} \qquad 11.5$$

in which the maximum value of D_a shall not exceed D_c, and

$$H_a = \frac{(H + Y_n)}{2} \qquad 11.6$$

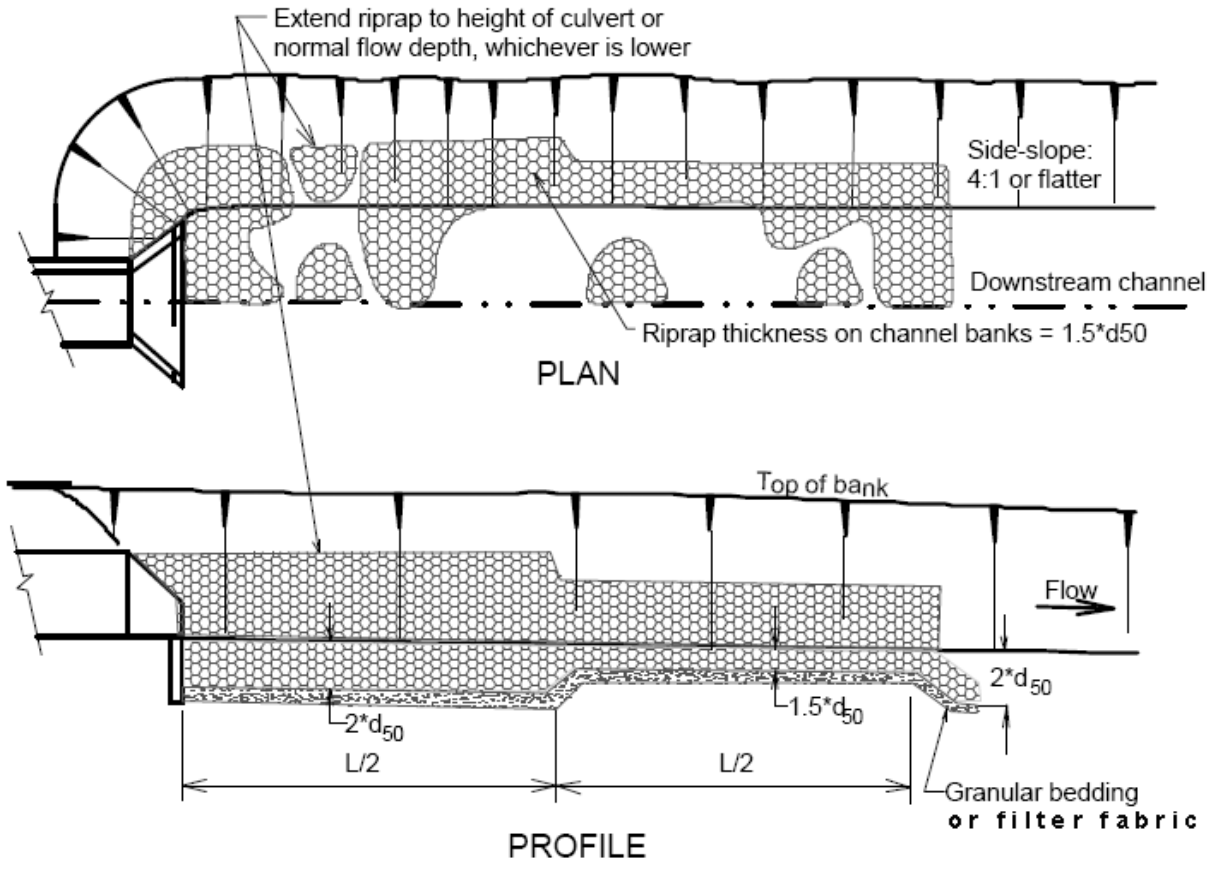
in which the maximum value of H_a shall not exceed H, and

where:

D_a = parameter to use in place of D_c in Figure 11.2 when flow is supercritical
D_c = diameter of circular culvert, in feet
H_a = parameter to use in place of H in Figure 11.3 when flow is supercritical
H = height of rectangular culvert, in feet
Y_n = normal depth of supercritical flow in the culvert

Figure 11.1 Culvert and pipe outlet riprap apron

(from UDFCD, 2001)



NOTES: 1. Headwall with wingwalls or flared end section required at all culvert outlets.
2. Cutoff wall required at end of wingwall aprons and end section.
Minimum depth of cutoff wall = 2*d50 or 3-feet, whichever is deeper.
3. Provide joint fasteners for flared end sections.

The designer should use Figure 11.2 and Figure 11.3 to estimate a riprap designation (Type VL, L, M, H, or VH) and corresponding d_{50}. The class of riprap to be specified is that which has a d_{50} greater than or equal to the required minimum size from Table 11.4. The designer should specify a gradation that is available in the area and in conformance with the gradation ranges specified in Table 11.5, which was derived from Table 12.4. Refer to the Riprap Quality and Riprap Layer Characteristics portions of Section 12.3.5.2 for required riprap quality specifications and characteristics. An underlying granular filter blanket, filter fabric, or combination of the two is required for riprap apron installations, in conformance with Chapter 8 of the Hydraulics Manual.

The riprap size may also be determined using the procedure built-in to the HY-8 computer program (FHWA, 2016). The apron configuration shall be designed in conformance with this section.

Table 11.4 Classification and gradation of ordinary riprap

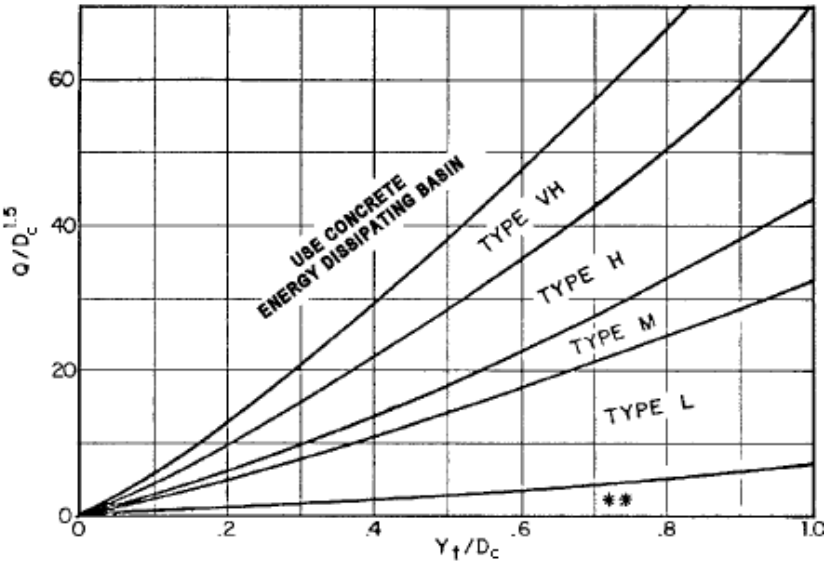
Riprap Classification	D_{50} (inches)
Type VL	6
Type L	9
Type M	12
Type H	18
Type VH	24

Table 11.5 Gradation ranges for ordinary riprap classifications

Percent of Gradation Smaller Than	Range of Stone Size				
	Riprap Classification				
	Type VL	Type L	Type M	Type H	Type VH
100	9.0-10.2	13.5-15.3	18.0-20.4	27.0-30.6	36.0-40.8
85	7.2-8.4	10.8-12.6	14.4-16.8	21.6-25.2	28.8-33.6
50	6.0-6.9	9.0-10.4	12.0-13.8	18.0-20.7	24.0-27.6
15	2.4-3.6	3.6-5.4	4.8-7.2	7.2-10.8	9.6-14.4

Figure 11.2 Riprap protection at circular conduit outlets

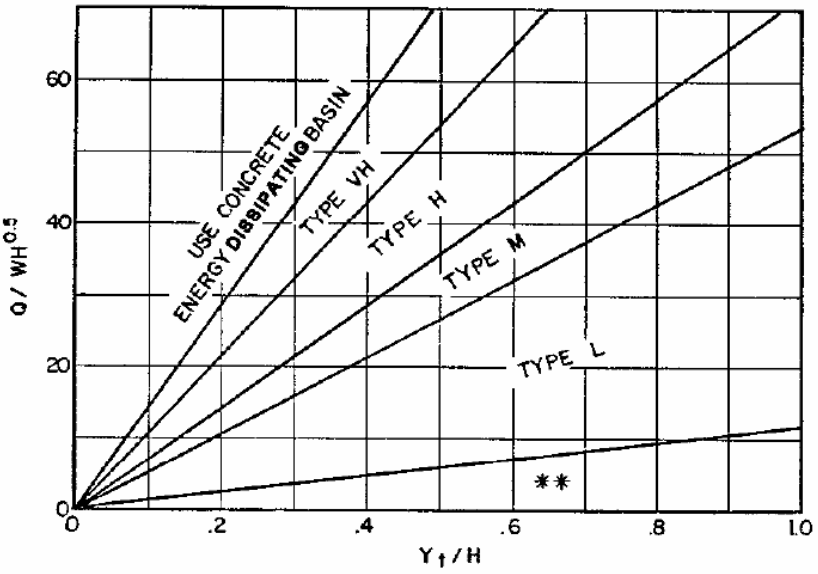
(from UDFCD, 2001)



Use D_a instead of D whenever flow is supercritical in the barrel.
** Use Type L for a distance of 3D downstream.

Figure 11.3 Riprap protection at rectangular conduit outlets

(from UDFCD, 2001)



Use H_a instead of H whenever culvert has supercritical flow in the barrel.
**Use Type L for a distance of 3H downstream.

Figure 11.4 Apron expansion factors for circular conduits

(from UDFCD, 2001)

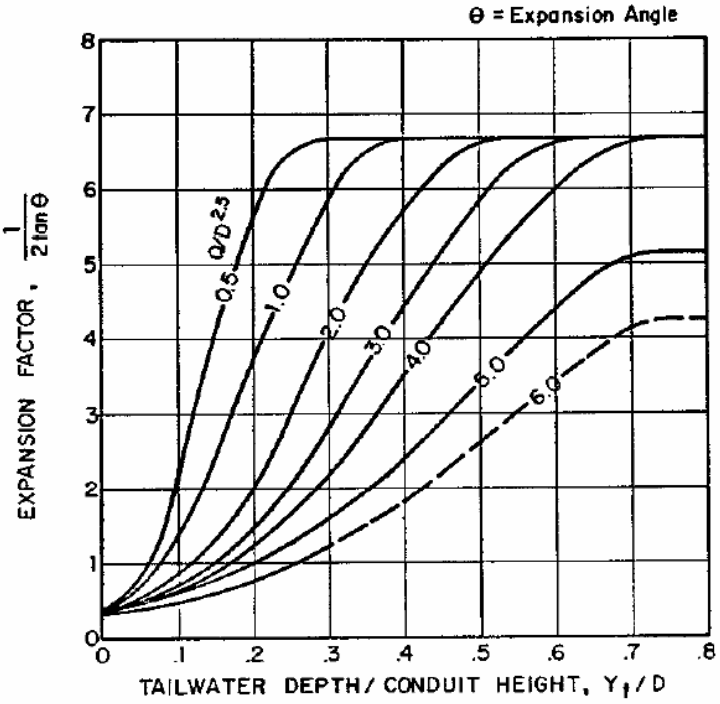
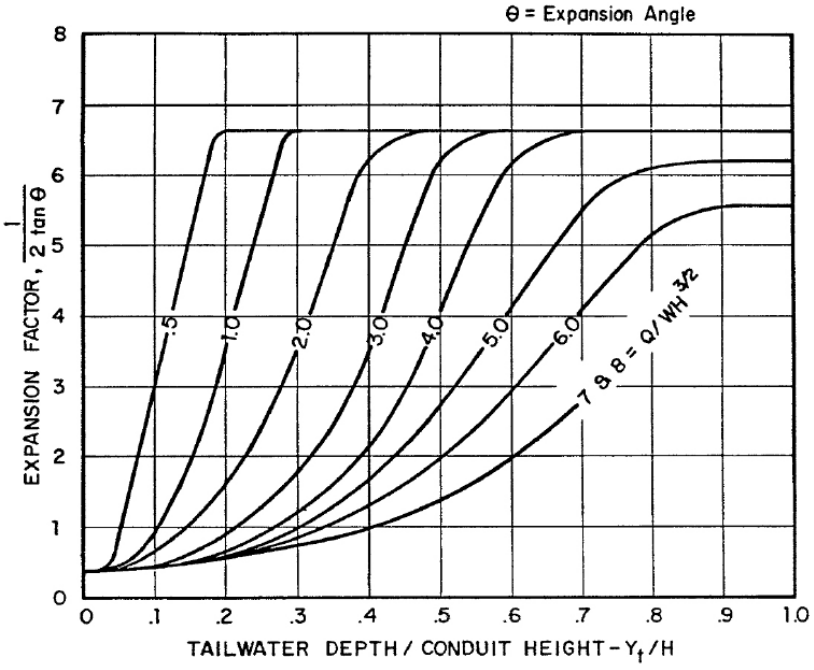


Figure 11.5 Apron expansion factors for rectangular conduits

(from UDFCD, 2001)



Extent of Protection. The length of the riprap protection downstream from the outlet depends on the degree of protection desired. If it is necessary to prevent all erosion, the riprap must be continued until the velocity has been reduced to an acceptable value. For purposes of outlet protection during major floods, the acceptable velocity is set at 3.5 ft/sec for very erosive soils and at 6.0 ft/sec for erosion resistant soils. The rate at which the velocity of a jet from a conduit outlet decreases is not well known. For the procedure recommended here, it is assumed to be related to the angle of lateral expansion, Θ, of the jet. The velocity is related to the expansion factor, ($1/(2\tan\Theta)$), which can be determined directly using Figure 11.4 or Figure 11.5, assuming that the expanding jet has a rectangular shape. The apron length (L), can then be computed using Equation 11.7:

$$L_p = \left(\frac{1}{2\tan\theta}\right)\left(\frac{A_t}{Y_t} - W\right) \qquad 11.7$$

where:

L_p = length of protection, in feet
W = width of the conduit, in feet (use diameter for circular conduits)
Y_t = tailwater depth, in feet
Θ = the expansion angle of the culvert flow

and:

$$A_t = \frac{Q}{V} \qquad 11.8$$

where:

Q = design discharge, in cfs
V = the allowable non-eroding velocity in the downstream channel, in ft/sec
A_t = required area of flow at allowable velocity, in ft²

In certain circumstances, Equation 11.7 may yield unreasonable results. Therefore, in no case should L_p be less than $3H$ or $3D_c$, nor does L_p need to be greater than $10H$ or $10D_c$ whenever the Froude parameter, $Q/WH^{1.5}$ or $Q/D_c^{2.5}$, is less than 8.0 or 6.0, respectively. Whenever the Froude parameter is greater than these maximums, increase the maximum L_p required by ¼ D_c or ¼ H for circular or rectangular culverts, respectively, for each whole number by which the Froude parameter is greater than 8.0 or 6.0, respectively.

Multiple Conduit Installations. The procedures outlined above can be used to design outlet erosion protection for multi-barrel culvert installations by hypothetically replacing the multiple barrels with a single hydraulically equivalent rectangular conduit. The dimensions of the equivalent conduit may be established as follows:

1. Distribute the total discharge, Q, among the individual conduits. Where all the conduits are hydraulically similar and identically situated, the flow can be assumed to be equally distributed; otherwise, the flow through each barrel must be computed.
2. Compute the Froude parameter $Q_i/D_{ci}^{2.5}$ (circular conduit) or $Q_i/W_iH_i^{1.5}$ (rectangular conduit), where the subscript i indicates the discharge and dimensions associated with an individual conduit.
3. If the installation includes dissimilar conduits, select the conduit with the largest value of the Froude parameter to determine the dimensions of the equivalent conduit.
4. Make the height of the equivalent conduit, H_{eq}, equal to the height, or diameter, of the selected individual conduit.
5. The width of the equivalent conduit, W_{eq}, is determined by equating the Froude parameter from the selected individual conduit with the Froude parameter associated with the equivalent conduit, $Q/W_{eq}H_{eq}$ and solving for W_{eq}.

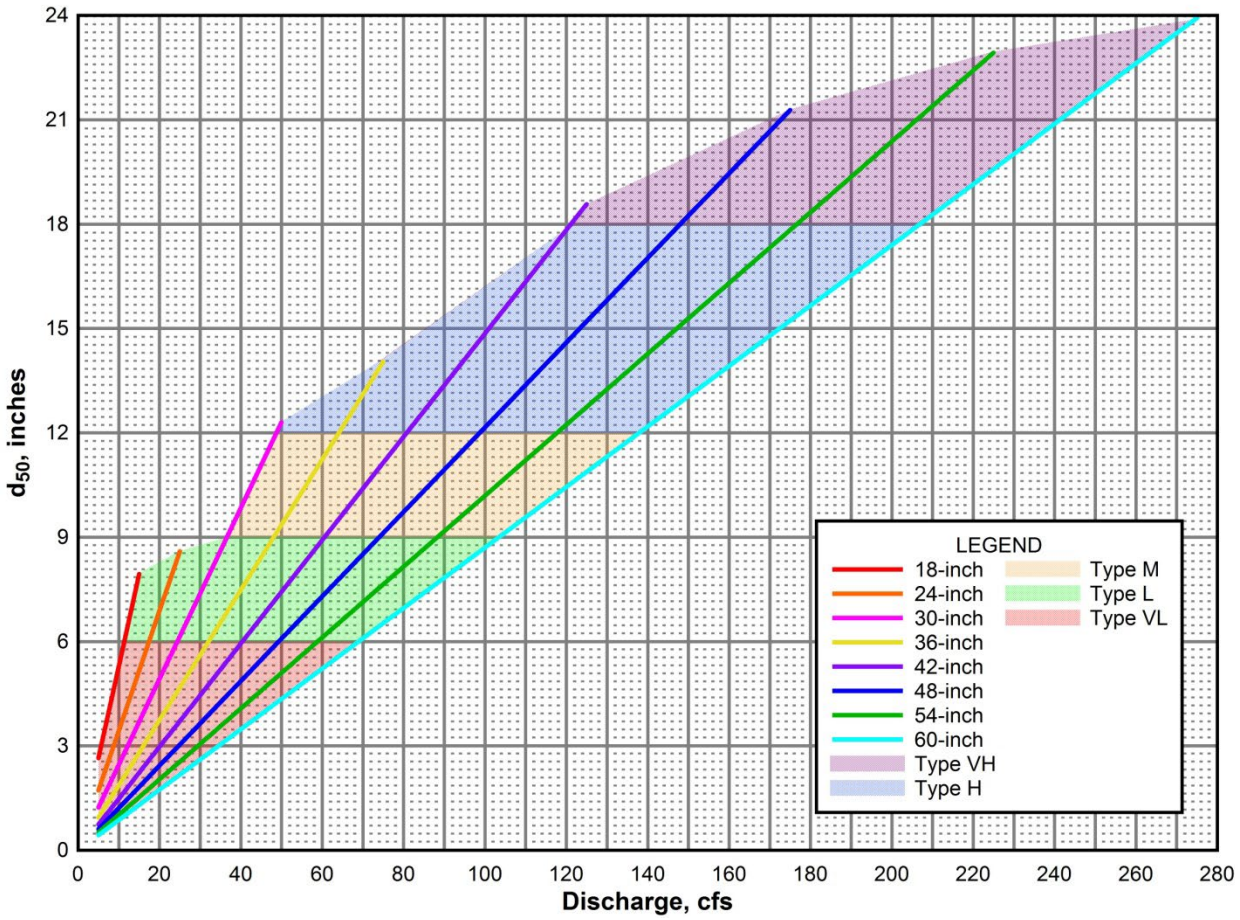
Simplified Riprap Apron Method

Determine the riprap size using Figure 11.6. Determine the apron length using Figure 11.7 or Figure 11.8. The simplified riprap apron method is based on the following:

1. Figure 11.6 is based on the following criteria:
   a. Pipe full flow velocity <= 15 fps.
   b. $Q/D_c^{2.5}$ <= 6.0
   c. Y_t/D_c = 0.35; where Y_t = tailwater depth in feet and D_c = culvert diameter in feet.
   d. A single pipe culvert installation. Refer to the Detailed Riprap Apron Method for riprap sizing for multiple conduit installations.
2. Figure 11.6 is derived using the methodology set forth in the Detailed Riprap Apron Method section, which is based on UDFCD (2001).
3. The riprap gradation class from Figure 11.6 may be used, within the limits specified, without detailed sizing computations. For most designs, this will be a conservative approach. If a more economical design is needed, the more detailed procedures defined in the Detailed Riprap Apron Method section shall be used to refine the sizing selection.
4. Where Type VL is acceptable per Figure 11.6, use Type L for a minimum length of 3 times the pipe diameter immediately downstream of the outlet, then use Type VL for the remainder of Length, L.
5. Culvert outlet riprap apron designs with parameters falling outside the color shaded limits shown on Figure 11.6 shall be designed using the Detailed Riprap Apron Method, or using the riprap basin approach from Section 8.4.3 of the Hydraulics Manual.

6. The length (L) on Figure 11.7 or Figure 11.8 is based on a limiting velocity at the end of the apron of 5 fps. If the soils are highly erosive, the Detailed Riprap Apron Method shall be used.

Figure 11.6 Riprap apron sizing chart for circular culvert outlets



The length (L) from Figure 11.1 of the riprap apron can be estimated using Figure 11.7 or Figure 11.8. These charts correspond with the riprap sizing chart shown on Figure 11.6. Riprap materials shall be in conformance with Section 12.3.5.2. Riprap gradations shall conform to Table 11.5. An underlying granular filter blanket, filter fabric, or combination of the two is required for riprap apron installations, in conformance with Chapter 8 of the Hydraulics Manual.

In the absence of a defined channel downstream from the culvert outlet, a trapezoidal apron configuration should be used. The minimum required expansion ratio of the apron sides (Ratio: width to length) is shown on Figure 11.9 and Figure 11.10.

Figure 11.7 Riprap apron length for circular pipes (18-inch - 36-inch)

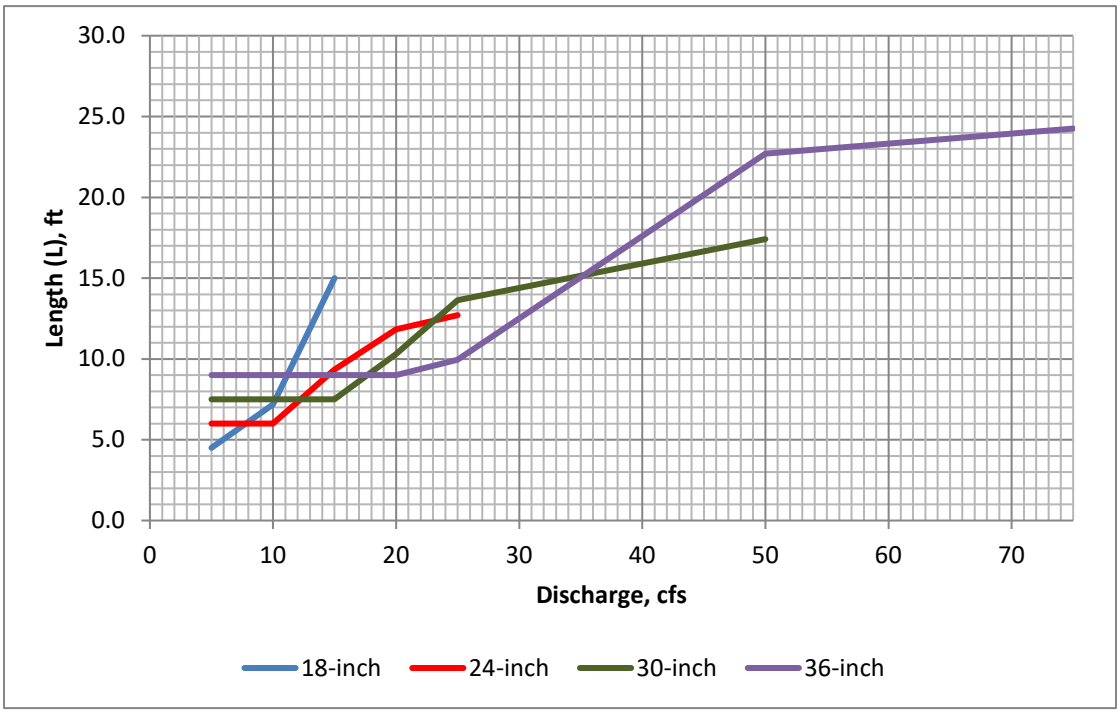


Figure 11.8 Riprap apron length for circular pipes (42-inch - 60-inch)

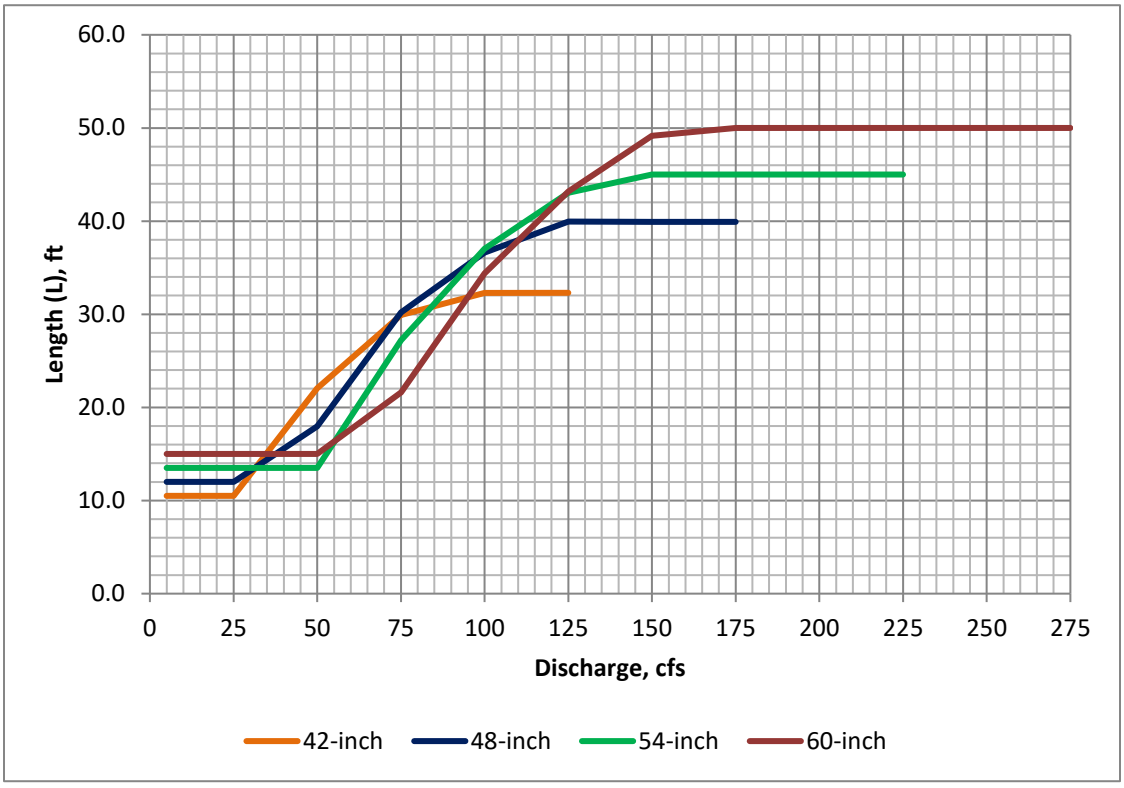


Figure 11.9 Riprap apron side expansion ratio (18-inch - 36-inch)

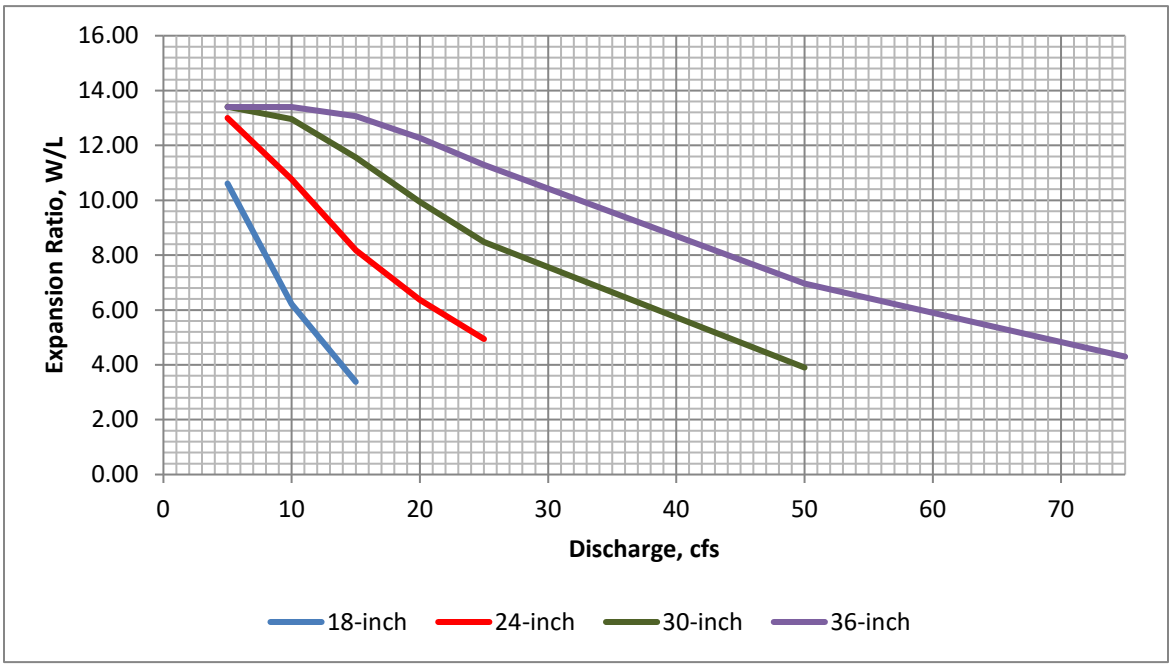
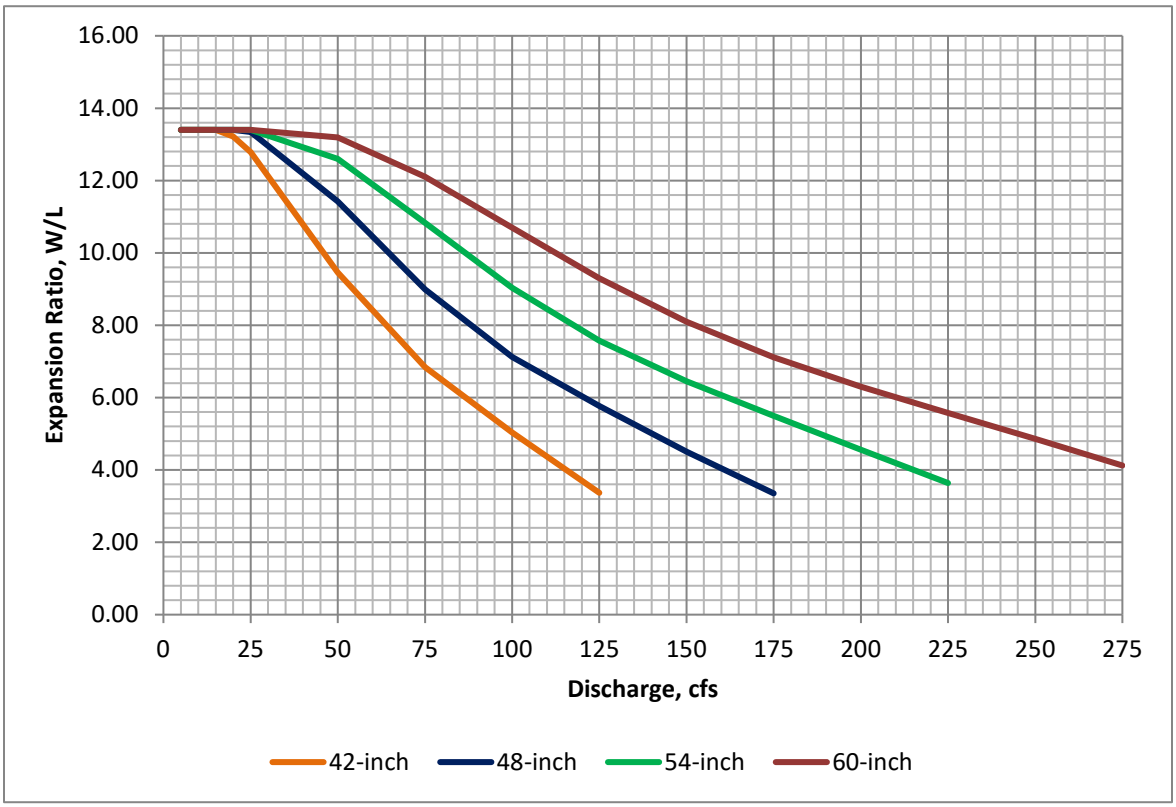


Figure 11.10 Riprap apron side expansion ratio (42-inch - 60-inch)



11.4.13 BRIDGE DESIGN EROSION REQUIREMENTS

If structural erosion protection is proposed, a comprehensive sediment transport analysis that assesses sediment transport in time and space (i.e. dynamic modeling consistent with 3 tier analyses identified in the Sedimentation chapter of the Hydraulics Manual) shall be undertaken to support the design and show that there are no adverse impacts to adjacent properties. The study may also be required to show that use of a similar design for other potential future crossings within limits of a study reach established by Mohave County do not result in cumulative adverse impacts within the study reach.

11.4.14 SUPERCRITICAL FLOW REQUIREMENTS

1. For channels functioning in a supercritical flow regime for the design discharge, there shall be no reduction in cross sectional area at bridges or culverts, or any obstructions (including bridge piers) in the flow path, up to the maximum practical span for the structure type as approved by COUNTY. For cases where bridge piers must be constructed because of maximum practical span considerations, piers shall be placed in the areas of lowest velocity whenever possible.

2. Bridge freeboard below the low chord elevation shall be the greater of 2 feet or the computed velocity head ($\frac{V^2}{64.4}$) using the channel velocity.

12 OPEN CHANNELS

12.1 INTRODUCTION

An open channel is a conveyance system in which water flows with a free surface at the water atmosphere interface. The channel may be either a natural watercourse or an artificial, "engineered" conveyance. Natural streams typically consist of a main flow channel and adjacent floodplains. Artificial channels are used for a wide variety of applications varying in scale from modest roadside ditches to large conveyance facilities that can be up to several hundred feet wide. This chapter provides technical standards for design of artificial channels.

12.2 HYDRAULIC TECHNICAL DESIGN CRITERIA

Technical guidance for design of open channels shall be in accordance with the open channels chapter of the Hydraulics Manual. Addition guidance may be obtained from FHWA (2005b). Specific design standards for Mohave County needed for application of the technical information contained in the Hydraulics Manual are defined herein.

12.3 OPEN CHANNELS STANDARDS

12.3.1 DESIGN WATER SURFACE ELEVATIONS

Design water surface elevations for excavated channels are to be below adjacent natural ground, including design freeboard.

12.3.2 MAXIMUM PERMISSIBLE VELOCITIES

Maximum permissible design velocities in open channels shall be governed by Table 12.1, Table 12.2, and Table 12.3.

Table 12.1 Maximum permissible velocities for unlined channels (from FHWA, 1961)	
Soils Type of Lining (Earth, No Vegetation)	**Maximum Permissible Velocity [1], ft/s**
Fine Sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (noncolloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Pans	6.0
(1) For channels, multiply permissible velocity by:	0.95 for slightly sinuous; 0.90 for moderately sinuous; and 0.80 for highly sinuous.

Table 12.2 Maximum permissible velocities for grass-lined channels	
Channels with Uniform Stand of Various Grass Cover and Well Maintained [1] [2] (adapted from FHWA 1961)	
Cover	**Maximum Permissible Velocity, fps**
Bermuda Grass	6.0
Desert Salt Grass and Vine Mesquite	5.0
Lehman Lovegrass, Big Galleta, Purple Threeawn, Sand Dropseed	3.5
(1) Use velocities over 5 fps only where good covers and proper maintenance can be obtained. (2) Grass is accepted only if an irrigation system is provided.	

Table 12.3 Design criteria for artificial channels		
Type of Channel Lining [1]	**Maximum Side Slope, H:V (%)**	**Maximum Velocity, fps [2]**
Structural Concrete	Vertical	15
Pneumatically Placed Concrete [3]	1.5:1 (67%) [7]	10
Soil Cement	2:1 (50%)	7[4]
Riprap	3:1 (33%)	9[5]
Grouted Riprap	2:1 (50%)	9[5]
Gabion Baskets	[6]	9[5]
Erosion Protection Mat	[6]	[6]
Grass (irrigated & maintained)	4:1 (25%)	2.5 to 6.0
Earth	6:1 (16.7%)	2.5 to 6.0[8]

Table 12.3 Design criteria for artificial channels

Type of Channel Lining (1)	Maximum Side Slope, H:V (%)	Maximum Velocity, fps (2)

(1) The values in this table are for channel sections with the same lining material for bottom and sides. For conditions where the bottoms and sides of the channels are different, the most critical applicable criteria are to be used.
(2) Maximum velocities listed for erodible linings are to be checked in each design to assure that erosion will not occur.
(3) Pneumatically Placed Concrete is allowed, but must be reinforced per a structural concrete design. Fiberglass reinforcement may be used with supporting design calculations.
(4) Higher velocities for soil cement lined channels/drop structures are acceptable upon submittal of a geotechnical analysis that assesses the suitability of the in-situ materials for soil cement applications and presents cement mixture specifications for the in-situ soils for the proposed maximum design velocities. The submittal shall be sealed and signed by a PE. Velocities greater than 15 fps are not recommended. Energy dissipaters may be required.
(5) Guideline only. Strict limits have not been set because this manual recommends that these channels be designed for subcritical flow.
(6) Per manufacturer's specifications.
(7) Channel side slope shall not exceed the soil natural angle of repose.
(8) A sediment transport analysis may be required by Mohave County to substantiate design of unlined channels.
Note: The criteria listed in this table are boundary values. The designer is responsible for determining the adequacy of criteria for each specific application. For design of lining materials, analyses of soil conditions and subsurface drainage may be required.

12.3.3 CONSTRUCTION PLANS

Construction plans for open channel drainage improvements are to meet the requirements of Section 19.3.

12.3.4 ENCROACHMENT REQUIREMENTS IN FEMA FLOODPLAINS

All channelization and/or floodplain encroachments within FEMA mapped floodplains must be designed so that the cumulative effect of the encroachment does not raise the 100-year water surface (or energy grade line for supercritical flow) above the floodway water surface elevation, or more than 1 foot for FEMA mapped floodplains without a defined floodway. In addition, when determining encroachments of fill or other development, the "equal conveyance from both sides of channel" rule shall apply. The maximum 1-foot rise in water surface may not come from one side of the channel at the expense of the adjacent property owner. Encroachment and/or stabilization on one bank may result in increased erosion potential on the opposite bank. Such adverse effects shall be evaluated and mitigated as a part of the design.

In the event that the rise criteria will be exceeded, and the construction of levees are proposed, the levees shall be designed and constructed in accordance with, and certified to meet, FEMA and DISTRICT criteria as a minimum. Although FEMA freeboard height criteria is the minimum

standard, levee design freeboard shall be based on risk and uncertainty analysis methodology as established by the USACE. A government agency shall also agree in writing to maintain the levee system. COUNTY/DISTRICT strongly discourages the construction of levees for flood control purposes.

12.3.5 CHANNEL LINING REQUIREMENTS

12.3.5.1 Concrete Lined Channels

Concrete and pneumatically placed concrete lined channels shall be evaluated for the need for continuous reinforcement extending both longitudinally and transversely. Pneumatically placed concrete channels are to be designed to the same structural integrity as concrete channels.

All sloping and flat concrete, pneumatically placed concrete, and soil cement linings are preferred to have roughened surfaces (e.g. embedded rock, grooves, etc.) to discourage inappropriate recreational use.

The lining for channel bottoms that will require maintenance vehicle access must be designed for a minimum of 18 kip axle loads assuming one loading per week for the design life of the channel.

12.3.5.2 Riprap Lined Channels

Common riprap can be an effective lining material if properly designed and constructed. The choice of riprap usually depends on the availability of graded rock with suitable material properties and at a cost that is competitive with alternative lining systems. Riprap design involves the evaluation of five performance areas. These areas include the evaluation of:

1. riprap quality;
2. riprap layer characteristics;
3. hydraulic requirements;
4. site conditions; and
5. river conditions.

In Arizona, site requirements and river conditions are important factors in the protection of bridge structures and flood control channels.

Riprap Quality

Riprap quality determination refers to the physical characteristics of the rock particles that make up the bank protection. Qualities determined to be most important include density, durability, and shape. Requirements for each of these properties are summarized in this section.

Specific Gravity (Density). The design stone size for a channel depends on the particle weight, which is a function of the density or specific gravity of the rock material. A typical value of specific gravity in Mohave County is 2.4. All stones composing the riprap should have a specific gravity equal to or exceeding 2.4, following the standard test American Society for Testing and Materials (ASTM) C127.

Durability. Durability addresses the in-place performance of the individual rock particles, and also the transportation of riprap to the construction site. In-place deterioration of rock particles can occur due to cycles of freezing and thawing or can occur during transportation to the site. The rock particles must have sufficient strength to withstand abrasive action without reducing the gradation below specified limits. Qualitatively, a stone that is hard, dense, and resistant to weathering and water action should be used. Rocks derived from igneous and metamorphic sources provide the most durable riprap. Laboratory tests should be conducted to document the quality of the rock. Specified tests that should be used to determine durability include: the durability index test and absorption test (see ASTM C127). Based on these tests, the durability absorption ratio (DAR) is computed as follows:

$$DAR = \frac{Durability\ Index}{Percent\ Absorption + 1} \qquad 12.1$$

The following specifications are used to accept or reject material:

1. DAR greater than 23, material is accepted;
2. DAR less than 10, material is rejected;
3. DAR 10 through 23:
    a. Durability index of 52 or greater, material is accepted; and,
    b. Durability index of 51 or less, material is rejected.

Shape. There are two basic shape criteria. First, the stones should be angular when not enclosed in wire-tied or gabion baskets. Angular stones with relatively flat faces will form a mass having an angle of internal friction greater than rounded stones, and therefore will be less susceptible to slope failures. Second, not more than 25 percent of the stones should have a length more than 2.5 times the breadth. The shape of the riprap stone should be cubical, rather than elongated. Cubical stones nest together and are more resistant to movement. The length is the longest axis through the stone, and the breadth is the shortest axis perpendicular to the length. Angularity is a qualitative parameter which is assessed by visual inspection. No standard tests are used to evaluate this specification. If the engineer is faced with a supply of rounded river rock without a crusher to create angular rock, stone size should be increased 25% and side slopes decreased (USACE, 1994).

Riprap Layer Characteristics

The major characteristics of the riprap layer include: characteristic size; gradation; thickness; and filter-blanket requirements.

Characteristic Size - The characteristic size in a riprap gradation is the d_{50}. This size represents the average diameter of a rock particle for which 50 percent of the gradation is finer, by weight.

Gradation - To form an interlocked mass of stones, a range of stone sizes must be specified. The object is to obtain a dense, uniform mass of durable, angular stones with no apparent voids or pockets. The recommended maximum stone size is 2 times the d_{50} and the recommended minimum size is one-third of the d_{50}. The gradation coefficient, G, should equal 1.5.

$$G = 0.5(d_{84}/d_{50} + d_{50}/d_{16}) \qquad 12.2$$

Table 12.4 provides a recommended design gradation for riprap. As a practical matter, the designer should check with local quarries and suppliers regarding the classes and quality of riprap available near the site.

Table 12.4 Recommended riprap gradation limits from FHWA (1989)		
Stone Size Range, ft	**Stone Weight Range, lb**	**Percent of Gradation Smaller Than**
$1.5d_{50}$ to $1.7d_{50}$	$3.0W_{50}$ to $5.0W_{50}$	100
$1.2d_{50}$ to $1.4d_{50}$	$2.0W_{50}$ to $2.75W_{50}$	85
$1.0d_{50}$ to $1.15d_{50}$	$1.0W_{50}$ to $1.5W_{50}$	50
$0.4d_{50}$ to $0.6d_{50}$	$0.1W_{50}$ to $0.2W_{50}$	15

Thickness - The minimum thickness of riprap linings shall be the greater of d_{100} or 2.0 times d_{50} for hand-placed material, and 3.0 times d_{50} for dumped material in accordance with ADWR (7-1998). Refer to the Hydraulics Manual Chapter 11 for determining stone size requirements.

Where only the channel banks are lined, the riprap at the toe shall be designed to minimze the effect of scour as required in Section 6.5.7 of the Hydraulics Manual. At a minimum, the key-in width and depth shall be 3 feet, extending out from the toe of the channel bank and below the channel bottom.

Filter Blanket Requirements - Filter blankets, filter fabric, or a combination of the two, are required to underlie riprap installations. Refer to the Hydraulics Manual Section 6.6.3 for guidance in the design of both granular and filter fabric types.

12.3.5.3 Hydraulic Stability Requirements

Due to safety concerns with excessively high velocities and the high potential for structural failure and unanticipated hydraulic jump locations, the recommended upper limit of Froude Number (F_r) shall be 2.0.

The limiting Froude Number for all types of channel linings designed for the subcritical flow regime shall be $F_r < 0.86$.

For concrete, soil cement, and pneumatically placed concrete lined channels designed to function in the supercritical flow regime, the additional range of $1.13<F_r<2.0$ is allowed, provided a sediment analysis is approved that substantiates that sediment loading will not change the flow regime from supercritical to subcritical. These linings shall be structurally designed to resist the hydrodynamic forces present during the design peak discharge with a safety factor of two (2.0).

At locations where there are to be planned hydraulic jumps, concrete, soil cement, and pneumatically placed concrete lined channels may pass through $0.86>F_r<1.13$.

A 100-year floodplain delineation based on subcritical conditions will be required if a channel designed to be supercritical may change flow regimes unpredictably due to sedimentation issues and flow will exceed the channel banks for the subcritical condition.

12.3.5.4 Curved Channel Radius Requirement

For channels with Froude Numbers less than 0.86, the ratio of the channel radius, r_c, (at the centerline) to the design width of the water surface shall be greater than 3.0.

For channels with Froude Numbers greater than or equal 1.2 and less than 2.0, the minimum radius of curvature should be computed using Equation 12.3.

$$r_{sc} = C\left(\frac{V^2W}{0.5g}\right) \qquad 12.3$$

where:

r_{sc} = minimum radius of channel centerline curvature in ft,
C = coefficient,
V = mean channel velocity in ft/s,
W = channel width at elevation of centerline water surface in feet, and
g = acceleration due to gravity in ft/s^2.

Equation 12.3 incorporates an allowance for superelevation and standing waves for supercritical flow in rectangular and trapezoidal channels with rigid lining and using a simple circular curve to define channel horizontal alignment transitions. For these conditions, use a value of C equal to one. This will limit the total superelevation to 0.5 feet. The normally determined freeboard requirements listed in Section 12.3.5.5 are adequate when used in conjunction with Equation 12.3. Equation 12.3 is derived from Section 2-5 of USACE (1994).

Curved channels should not be used when $0.86<F_r<1.2$. Extra care shall be taken in the design of bank protection on both the inside and outside of curves, using estimates of maximum velocity and considering eddies. The guidance in Chapters 8 and 11 of the Hydraulics Manual shall be carefully followed and applied. If a less conservative radius of curvature is needed, refer to guidance in Section 2-5 of USACE (1994).

12.3.5.5 Freeboard Requirements

Freeboard Equation. Required freeboard for both subcritical and supercritical flow conditions is computed according to the following formula:

$$FB = 0.25\left(\mathrm{Y} + \frac{\mathrm{V}^2}{2\mathrm{g}}\right) \qquad 12.4$$

where:

FB = freeboard in feet,
Y = depth of flow in feet,
V = velocity of flow in ft/s; and
g = acceleration due to gravity in ft/s^2.

Freeboard Requirements. The minimum freeboard value for straight rigid channels shall be as specified in Table 12.5. If the minimum channel radius requirements of Section 12.3.5.4 are to be reduced as a part of a more detailed design, the freeboard requirements are to be added to the superelevated water surface elevation at channel bends for both subcritical and supercritical flow conditions, as computed using guidance in Sections 2-5 and 2-6 of USACE (1994). Freeboard exceeding the minimum standard is strongly recommended. Using a smaller freeboard in specific cases requires prior approval by COUNTY.

Table 12.5 Minimum Freeboard Requirements

Channel Type	Flow Depth at Design Discharge, feet	Required Minimum Freeboard by Flow Regime, feet	
		Subcritical	Supercritical
Straight and rigid	<=1.0	0.5	1.0
	>1.0	1.0	2.0
Curved and rigid	<=1.0	1.0	1.5
	>1.0	1.5	2.5

Levees. Although strongly discouraged, levees must meet FEMA and USACE design and freeboard requirements as a minimum. Freeboard design shall be based on USACE risk and uncertainty analysis methodology.

FEMA Floodplains. In all FEMA jurisdictional floodplains, the greater of the above equation or FEMA's freeboard requirement shall prevail for design use in open channels.

Freeboard Allowance for Vegetation. Every constructed channel that is capable of supporting vegetation growth is to be designed for an appropriate range of n-values in conjunction with an approved vegetation maintenance plan. The procedures in the Hydraulics Manual Chapter 7 and Chapter 13 herein shall be followed. The maintenance plan shall include an agreement, approved by the COUNTY/DISTRICT, for perpetual maintenance of the channel. If this is not feasible, then additional freeboard shall be required. For this case, standard freeboard requirements shall be added to the water surface elevation for the design storm hydraulics computed using the expected worst-case roughness condition assuming no on-going maintenance of vegetation.

12.3.6 MODELING HYDRAULIC FLOW SPLITS

12.3.6.1 General

Hydraulic flow splits are locations where a stream splits apart into two or more streams. Examples can include:

1. Distributary flow networks where streams can split and diverge and may or may not rejoin the main channel downstream.
2. Splits in rivers around an island or high ground.
3. Overtopping of a levee.
4. Overtopping of a watershed divide.
5. Diversion structures such as lateral weirs and spillways.
6. Street intersections where low flow patterns are dictated by the gutter, but less frequent higher discharges may be diverted into two or more streets downstream of the intersection.

12.3.6.2 Natural Channels

An example of a natural channel split, which could be a simple distributary flow split or a riverine split around an island, is shown on Figure 12.1. One-dimensional steady flow hydraulic modeling approaches can be used to estimate the percentage of peak discharge in each channel downstream of the junction. If multiple channels are involved, such as for distributary flow networks with unconfined flow, then two-dimensional modeling techniques are recommended. The computation process can be complicated; therefore, it is not recommended

that hand computations be used. Instead, the US Army Corps of Engineers HEC-RAS computer program is recommended for situations that can be modeled using one-dimensional techniques. Using HEC-RAS, the optimization can be based on balancing energy or momentum. The energy-based method neglects the effects of the angle of the split. The momentum approach accounts for force effects due to the angle of the bifurcation. The following are the most common analysis situations for modeling flow splits:

- Energy-based, one-dimensional, steady state, subcritical
- Energy-based, one-dimensional, steady state, supercritical
- Momentum-based, one-dimensional, steady state, subcritical
- Momentum-based, one-dimensional, steady state, supercritical

HEC-RAS is also capable of applying a mixed-flow approach for each of the above. For most natural channel situations, the energy-based subcritical approach will be used. The following example describes the process for using HEC-RAS to compute flow split hydraulics using a trial and error procedure. HEC-RAS also has the capability of performing the entire optimization procedure automatically. Refer to USACE (2016b) pg 4-22 and USACE (2016a) Chapter 15.

The energy-based approach is generally applicable when flow is solidly subcritical (USACE, 2016b). Therefore, the energy-based approach should be applied where F_r<0.6 and/or the bifurcation angle is 45 degrees or smaller. For other conditions, the momentum-based approaches should be used. The energy-based method should not be used for supercritical flow.

Energy-Based, One-Dimensional, Steady-State, Subcritical

A common natural channel flow split is a single channel diverging into two channels downstream where the flow regime is dominantly subcritical. The following procedure is from USACE (2016b), pgs 4-10 through 4-12. Key assumptions for this approach are:

- Normal depth computations are appropriate.
- Subcritical flow.
- The split flow boundaries are fixed and do not erode or change over time.

Cross sections used to define the split hydraulics should be assigned as close to the junction as is practical. For example, Cross Section A (CS A) on Figure 12.1 is the upstream cross section

and contains the total flow entering the junction. CS B and CS C are cross sections assigned to the channels immediately downstream in each leg of the split. The computational procedure is a trial and error approach, involving determining the flow rate in each downstream cross section corresponding to the same energy.

1. Build an HEC-RAS model of the junction using the cross section layout approach shown in Figure 12.1, including additional cross sections upstream and downstream as appropriate based on engineering judgment.
2. Assume an initial flow split at the junction (i.e. Make an initial estimate of peak discharge in each downstream channel).
3. Compare the energy at CS B and CS C. If they differ by a significant magnitude (usually more than 1-2 percent), then the flow distribution is incorrect. Re-distribute the flow by putting more flow into the reach that had the lower energy and reducing the flow in the other.
4. Run HEC-RAS again and compare the energies. If the energy at CS B and CS C still differ significantly, then redistribute the flow again. Repeat this process until the energies converge.

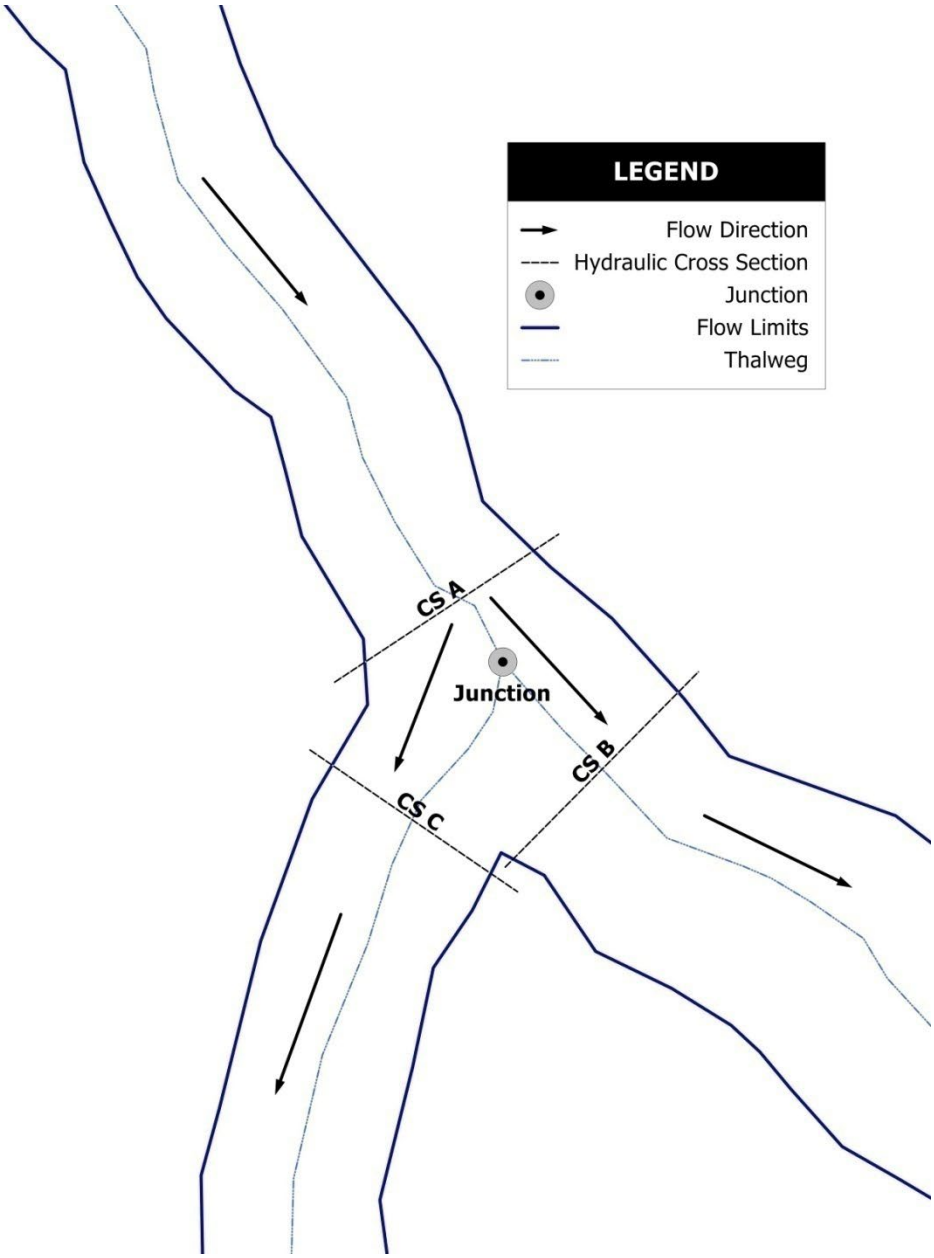
Energy-Based, One-Dimensional, Steady-State, Supercritical

Follow the procedure set forth in USACE (2016b), pg 4-13.

Momentum-Based, One-Dimensional, Steady-State, Subcritical and Supercritical

Follow the procedures set forth in USACE (2016b), pgs 4-14 through 4-19.

Figure 12.1 Hydraulic flow split schematic



12.3.6.3 Diversion Structures

Diversion structures, including lateral weirs and spillways, and even levees, should be modeled as described in USACE (2016a) Chapter 15 and USACE (2016b) Chapter 8.

12.3.6.4 Street Intersection

Conservative overdesign of street conveyance within the subdivision to handle the maximum offsite and onsite flows would eliminate the need to perform detailed flow split hydraulic Analyses. Conservative overdesign is to design the subdivision street cross section hydraulic carrying capacity assuming 100% of the upstream flow entering any intersection can flow in any downstream direction leaving the intersection.

For those cases where the downstream street cross section hydraulic carrying capacity is not designed to handle 100% of the upstream flow entering any intersection, HEC-RAS, or other pre-approved applicable program, shall be used. The momentum approach shall be used rather than the energy approach. For HEC-RAS, follow the procedures set forth in USACE (2016b) pgs 4-14 through 4-19.

12.3.7 IRRIGATION CANALS

Irrigation canals may not be used as an outfall for stormwater runoff without written approval by the agency that owns the facility.

12.3.8 MINIMUM EASEMENT WIDTH REQUIREMENT FOR CONSTRUCTED CHANNELS

A dedicated right-of-way, or privately-owned drainage parcel shall be a minimum of the top width of an appropriately sized open channel plus 2 feet contiguous on both sides. For washes with a 100-year design peak discharge of 50 cfs or greater, and vehicular maintenance access is not provided within the channel bottom, add 16 feet of width to the easement on one side to cover a maintenance access road.

12.3.9 MINIMUM LANDSCAPE AND MAINTENANCE GUIDELINES

1. Landscaping and revegetation must not impede access for maintenance.
2. The vegetation must comply with the design intent of the channel in terms of conveyance and freeboard.
3. Landscaped channels must be designed using minimum and maximum expected n-values for the interval between maintenance operations, with minimum freeboard as specified above.

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13 FRICTION LOSSES

13.1 INTRODUCTION

The primary difficulty in using the Manning equation in practice is accurately estimating an appropriate value of the resistance coefficient, n. Selecting a value of *n* means represents an estimate of the resistance to flow in a channel or pipe, thus accounting for energy loss due to friction. Appropriate assignment of n-values requires an exercise in sound engineering judgment, due to the many intangibles.

This section provides guidance for selection of Manning's n-values for use when modeling the hydraulics of surface runoff, natural or designed channels and when modeling or designing pipe culverts and storm drains. Manning's n-values for these situations are provided for various conditions as a convenient reference for the engineer/hydrologist, and for the purposes of providing uniformity and reproducibility of assignment for hydraulic modeling in Mohave County. Assignment of n-values does require sound engineering judgment, so the source references for the values presented should be carefully studied and kept available for use when preparing models and designing drainage facilities. These references provide guidance in application that is not provided in this section. In addition, technical guidance for estimation of friction losses shall be in accordance with the Friction Losses chapter of the Hydraulics Manual.

13.2 FRICTION LOSSES STANDARDS

13.2.1 MANNING'S N-VALUES FOR NATURAL CHANNELS

The Manning's roughness coefficient, n, is a measure of the flow resistance of a channel or overbank flow area. The flow resistance is affected by many factors including size of bed material, bed form, cross section irregularities, flow depth, vegetation, channel alignment, channel shape, obstructions to flow, and quantity of sediment being transported in suspension or as bed load. In general, all factors that retard flow and increase turbulent mixing tend to increase n.

Per Phillips and Tadayon (2006), the *n* for a channel can be computed by:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m_5 \qquad 13.1$$

where:

n_0 = the base value for a straight, uniform, stable channel.

n_1 = is a value for the effect of surface irregularities,

n_2 = is a value to account for obstructions to flow,

n_3 = is a value for vegetation effects,

n_4 = is a value to account for variations in channel cross section, and

m_5 = is a correction factor to account for meandering of the main channel.

The value for n_o can be selected from Table 13.1. The adjustment factors (n_1, n_2, n_3, n_4, and m_5) can be selected from Table 13.2. Extensive guidance for this method is provided in Phillips and Tadayon (2006), which is included in the Hydraulics Manual as Chapter 7. The engineer/hydrologist is encouraged to study this reference. Table 13.1 and Table 13.2 assume a stable channel bed. For unstable channels bottoms, Phillips and Tadayon (2006) should be consulted for guidance.

For overbank floodplains where agriculture is present, or where the above procedure may be impractical, the composite value of n may be selected from Table 13.3. Composite values of n for stable constructed channels may be selected from Table 13.4.

Table 13.1 Base values of Manning's n for channels considered stable (from Phillips and Tadayon, 2006)

Channel Material	Size of Bed Material		Base Values, n_0	
	Millimeters	Inches	Benson and Dalrymple (1967)	Chow (1959)
(1)	(2)	(3)	(4)	(5)
Firm earth	—	—	0.025–0.032	0.020
Coarse sand	1–2	—	0.026–0.035	—
Fine gravel	—	—	—	0.024
Gravel	2–64	0.08–2.5	0.028–0.035	—
Coarse gravel	—	—	—	0.028
Cobble	64–256	2.5–10.5	0.030–0.050	—
Boulder	> 256	> 10	0.040–0.070	—

Table 13.2 Adjustment factors used to determine Manning's *n* values (from Phillips and Tadayon, 2006)

Channel Conditions	Manning's *n* Adjustment	Example
***n1*, Degree of irregularity (0.000-0.020)**		
Smooth	0.000	Smoothest channel attainable in a given bed material.
Minor	0.001–0.005	Channels with slightly scoured or eroded side slopes.
Moderate	0.006–0.010	Channels with moderately sloughed or eroded side slopes.
Severe	0.011–0.020	Channels with badly sloughed banks; unshaped, jagged, and irregular surfaces of channels in rock.
***n2*, Variation in channel cross section (0.000-0.015)**		
Gradual	0.000	Size and shape of channel cross sections change gradually.
Alternating occasionally	0.001–0.005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-section shape.
Alternating frequently	0.010–0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-section shape.
***n3*, Effect of obstructions (0.000-0.060)**		
Negligible	0.000–0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, which occupy less than 5 percent of the channel.
Minor	0.005–0.015	Obstructions occupy from 5 to 15 percent of the cross-section area and spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved, smooth-surfaced objects than are used for sharp-edged, angular objects.
Appreciable	0.020–0.030	Obstructions occupy from 15 to 50 percent of the cross-section area, or the space between obstructions is small enough to cause the effects of severe obstructions to be additive, thereby blocking an equivalent part of a cross section.

Table 13.2 Adjustment factors used to determine Manning's *n* values (from Phillips and Tadayon, 2006)

Channel Conditions	Manning's *n* Adjustment	Example
Severe	0.040–0.060	Obstructions occupy more than 50 percent of the cross-section area, or the space between obstructions is small enough to cause turbulence across most of the cross section.
***n4*, Amount of vegetation (0.000-0.200)**		
Negligible	0.000–0.002	Grass, shrubs, or weeds were permanently laid over during flow.
Small	0.002–0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation where the vegetation is not laid over. Trees, such as willow, cottonwood, or salt cedar, growing where the average depth of flow is at least three times the height of the vegetation. Flow depth is about two times the tree height, and the trees are laid over.
Medium	0.010–0.025	Moderately dense grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees growing along the banks. A few 8 to 10-year old willow, cottonwood, mesquite, or palo verde, which blocks flow by approximately 1 to 10 percent, and spheres of influence or turbulence do not overlap.
Large	0.025–0.050	8- to 10-year-old willow, cottonwood, mesquite or palo verde trees (block flow by approximately 10 to 30 percent where the spheres of influence overlap) intergrown with some weeds and brush where the hydraulic radius exceeds 2 feet.
Very large	0.050–0.100	Bushy willow trees about 1-year old intergrown with weeds alongside slopes or dense cattails growing along the channel bottom; trees intergrown with weeds and brush. Moderately dense (blocks flow by approximately 30 to 50 percent and the spheres of influence overlap) 8- to 10-year old trees spaced randomly throughout channel where depth of flow approximates height of vegetation.

Table 13.2 Adjustment factors used to determine Manning's *n* values (from Phillips and Tadayon, 2006)

Channel Conditions	Manning's *n* Adjustment	Example
Extremely large	0.100–0.200	Mature (greater than 10 years old) willow trees and tamarisk intergrown with brush and blocking flow by more than 70 percent of the flow area, causing turbulence across most of the section. Depth of flow is less than average height of the vegetation. Dense stands of palo verde or mesquite that block flow by 70 percent or more and hydraulic radius is about equal to or greater than average height of vegetation.
***m5*, Degree of meandering (1.00-1.30)**		
Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
Severe	1.30	Ratio of the channel length to valley length is greater than 1.5.

Table 13.3 Values of Manning's *n* for agriculture or overbank areas

(from Phillips and Tadayon, 2006)

Description	Manning's n		
	Minimum	Normal	Maximum
Pasture, no brush			
Short grass	0.025	0.030	0.035
High grass	0.030	0.035	0.050
Cultivated areas			
No crop	0.020	0.030	0.040
Mature row crops	0.025	0.035	0.045
Mature field crops	0.030	0.040	0.050
Shrubs			
Scattered shrubs, heavy weeds	0.035	0.050	0.070
Light shrubs and trees, in winter	0.035	0.050	0.060
Light shrubs and trees, in summer	0.040	0.060	0.080
Medium to dense shrubs, in winter	0.045	0.070	0.110
Medium to dense shrubs, in summer	0.070	0.100	0.160
Trees			
Dense willows, mesquite, salt cedar	0.110	0.150	0.200
Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
Same as above, but heavy growth of sprouts	0.050	0.060	0.080
Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
Same as above, but with flood stage reaching branches	0.100	0.120	0.160

13.2.2 MANNING'S N-VALUES FOR CONSTRUCTED CHANNELS

Table 13.4 Composite values of *n* for stable constructed channels

[excerpt from: Simon, Li and Associates (1981). Adapted from: Chow (1959), Aldridge and Garret (1973), FHWA (2005b), and Phillips and Tadayon (2006)]

Description	Manning's n		
	Minimum	Normal	Maximum
A. Lined or built-up channels			
a. Concrete			
1. Finished	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Unfinished	0.014	0.017	0.020
4. Shotcrete, good section	0.016	0.019	0.023
5. Shotcrete, wavy section	0.018	0.022	0.025
b. Soil cement	0.018	0.020	0.025
c. Asphalt	0.013	0.015	0.016
d. Gravel mulch (1-inch, flow depth 0.5-3.3 ft)	0.031	0.033	0.040
e. Gravel mulch (2-inch, flow depth 0.5-3.3 ft)	0.038	0.042	0.056
f. Cobble (2.5"<=d_{50}<=5", flow depth <= 2 ft)	0.040	0.045	0.049
g. Riprap (5"<=d_{50}<=22", flow depth <= 1-6 ft)	0.040	0.070	0.100
h. Grouted riprap	0.028	0.030	0.040
i. Gabions	Same as for cobble and riprap linings		
j. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
B. Evacuated or dredged channels			
a. Earth, straight and uniform			
1. Clean, after weathering	0.018	0.022	0.025
2. Gravel, uniform section, clean	0.022	0.025	0.033
b. Earth, winding and sluggish			
1. Earth bottom and rubble sides	0.028	0.030	0.035
2. Stony bottom	0.025	0.035	0.040
3. Cobble bottom and clean sides	0.030	0.040	0.050
c. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050

13.2.3 MANNING'S N-VALUES FOR CONDUITS

Manning's n-values for hydraulic conveyance structures such as culverts and storm drains are listed in Table 13.5 for concrete pipes and box culverts, and in Table 13.6 for corrugated steel pipes and pipe arches. For guidance in proper application of these tables, refer to Chow (1959), AISI (1980), AISI (2007), Mays (1999), and Mays (2001). The publications of the American Concrete Institute should also be reviewed.

Table 13.5 Manning's *n* for concrete pipe flowing partly full

(from Chow, 1959)

Description	Manning's n		
	Minimum	Normal	Maximum
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016
Unfinished, rough wood form	0.015	0.017	0.020

Table 13.6 Values of *n* for corrugated steel pipe

[from AISI (1980)]

Corrugations	Annular	Helical										
	2⅔ in	1½ x ¼ in.	2⅔ x ½ in.									
Flowing:	**Diameters**	**8 in.**	**10 in.**	**12 in.**	**15 in.**	**18 in.**	**24 in.**	**30 in.**	**36 in.**	**42 in.**	**48 in.**	**54 in. and larger**
Full Unpaved	0.024	0.012	0.014	0.011	0.012	0.013	0.015	0.017	0.018	0.019	0.020	0.021
Full 25% Paved	0.021						0.014	0.016	0.017	0.018	0.020	0.019
Part Full Unpaved	0.027			0.012	0.013	0.015	0.017	0.019	0.020	0.021	0.022	0.023
Flowing:	**Pipe-Arch**				**17 x 13**	**21 x 15**	**28 x 20**	**35 x 24**	**42 x 29**	**49 x 33**	**57 x 38**	**64 x 43 and larger**
Full Unpaved	0.026				0.013	0.014	0.016	0.018	0.019	0.020	0.021	0.022
Part Full	0.029				0.018	0.019	0.021	0.023	0.024	0.025	0.025	0.026

	Annular	Helical												
	3 x 1 in.	3 x 1 in.												
Flowing:									**36 in.**	**42 in.**	**48 in.**	**54 in.**	**60 in.**	**66 in.**	**72 in.**	**78 in. and larger**
Full Unpaved	0.027								0.022	0.022	0.023	0.023	0.024	0.025	0.026	0.027
25% Paved	0.023								0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023

	Annular	Helical												
	5 x 1 in.	5 x 1 in.												
Flowing:											**48 in.**	**54 in.**	**60 in.**	**66 in.**	**72 in.**	**78 in. and larger**
Full Unpaved	0.025										0.022	0.022	0.023	0.024	0.024	0.025
25% Paved	0.022										0.019	0.019	0.020	0.021	0.021	0.022

All pipe with	All Diameters
smooth interior*	0.012

* Includes full paved, concrete lined, spiral rib and double wall pipe. Per deGrout and Boyd (1983) modified for lower values of n for helical pipe.

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14 HYDRAULIC STRUCTURES

14.1 INTRODUCTION

Hydraulic structures are used in drainage and flood control works to control water flow characteristics such as velocity, direction and depth. Structures may also be used to control the elevation and slope of a channel bed, as well as the general configuration, stability and maintainability of the waterway. The use of hydraulic structures can increase the capital cost of drainage facilities while lowering O&M costs. The use of hydraulic structures should be limited by careful and thorough hydraulic engineering practices to locations and functions justified by prudent planning and design. On the other hand, use of hydraulic structures can reduce initial and future maintenance costs by changing the characteristics of the flow to fit the project needs, and by reducing the size and cost of related facilities.

Hydraulic structures include channel drop structures, spillways, grade control structures, energy dissipaters, bridges, transitions, chutes, bends and many other specific drainage works. This chapter is oriented toward control structures for drainage channels, outlets for storm drains and culverts, and spillways for non-jurisdictional dams.

14.2 HYDRAULIC TECHNICAL DESIGN CRITERIA

Technical guidance for design of hydraulic structures shall be in accordance with the hydraulic structures chapter of the Hydraulics Manual. Specific design standards for hydraulic structures needed for application of the technical information contained in the Hydraulics Manual are defined herein.

14.3 HYDRAULIC STRUCTURES STANDARDS

The following standards shall be utilized in the design of hydraulic structures:

14.3.1 TRASH RACK CLOGGING FACTOR

A clogging factor of 50 percent of the rack area shall be used in the hydraulic analysis of all trash racks.

14.3.2 SIPHONS

The use of siphons for stormwater conveyance is strongly discouraged. A siphon may be allowed provided it is demonstrated there is no other feasible option and adequate provisions for on-going maintenance are in-place. Approval by the MOHAVE COUNTY ENGINEER is required for the use of siphons.

14.3.3 DROP STRUCTURES

At drop structures, a hydraulic jump analysis shall be conducted for a range of flows, since flow characteristics at the drop may vary with discharge. This analysis is to be used to support the design of the structure and erosion control measures.

Due to a high failure rate and excessive maintenance costs, drop structures having loose riprap on a sloping face are not permitted.

Open channels are recommended in lieu of pipes for conveyance of low flows through drop structures. Pipes, if approved by COUNTY/DISTRICT for conveying low flows through drop structures, shall be no smaller than 24 inches in diameter.

14.3.4 CONSTRUCTION PLANS

Construction plans for hydraulic structure drainage improvements are to meet the requirements of Section 19.3.

15 STORMWATER STORAGE

15.1 INTRODUCTION

Land development can convert natural pervious areas into impervious or otherwise altered surfaces. These activities may cause an increase in runoff volume and/or peak discharge. The temporary storage of stormwater runoff can decrease downstream peak discharges and associated impacts to drainage infrastructure. Two types of stormwater storage approaches are considered for use in Mohave County. The primary method, which shall be used as the standard method, is stormwater retention. Stormwater retention is a basin or reservoir where water is stored for regulating a flood; however, it does not have significant gravity-flow outlets for discharging stored runoff. The stored water is disposed by other means such as infiltration into the soil, evaporation, injection (or dry) wells, low flow outlets, or pumping systems. The low flow outlets have a relatively constant discharge rate under ponded conditions (much less than existing peak discharges) and are intended to drain the basin between 24 and 36 hours after the storm ends.

The design intent for retention and detention basins is to capture the runoff volume for the design storm frequency and duration only from the subject property. Off-site flows are to be safely passed through the project without entering on-site storage facilities and released at their natural occurring location at the predevelopment condition flow depth, width and velocity for the 100-year peak discharge. The natural channel or conveyance system is to be maintained through the project site whenever possible.

A detention basin uses gravity-flow outlets for discharging the stored runoff. Detention facilities do not reduce the volume of runoff, they do however lengthen the time flow will be present in the watercourse downstream of the facility. Due to the longer duration of flow downstream of detention basins, their use requires greater analysis to verify that peak discharges are not increased downstream. Care must be taken not to size the outlet too large, and a range of flood frequency events shall be considered in the analysis. The design intent for the outlet is for post development peak outflows to be equal or less than pre-development flows for the design storm event(s).

The following are COUNTY/DISTRICT policies related to stormwater storage:

15.2 HYDRAULIC TECHNICAL DESIGN CRITERIA

Technical guidance for design of stormwater storage facilities shall be in accordance with the stormwater storage chapter of the Hydraulics Manual. Specific design policies and standards for Mohave County needed for application of the technical information contained in the Hydraulics Manual are defined herein.

15.3 STORMWATER STORAGE POLICIES

15.3.1 STORMWATER RETENTION FOR DEVELOPMENTS

All development (residential and non-residential subdivisions, and single non-residential parcels) shall make provisions to retain stormwater runoff falling within its boundaries.

15.3.2 ON-LOT STORAGE

On-lot retention is not an acceptable method to comply with Section 15.3.1 above. Centrally located retention is required to comply and shall be contained in an drainage easement or drainage parcel.

15.3.3 MULTI-USE FEATURES

The designers of stormwater storage areas in residential subdivisions are encouraged to incorporate multi-use features and to design the basin grading with varying side slopes/land features that are aesthetically pleasing while accommodating safety features. Aesthetics as well as functionality are to be considered in the design of stormwater storage and conveyance facilities.

Siting recreational facilities, particularly playground equipment for children, at the very bottom of stormwater storage basins is to be avoided. It is recommended these basins be designed with tiers or gentle slopes to allow for the collection of nuisance water and conveyance around fields and play areas to keep them safe from inundation during the more frequent rainfall events, such as the one- or two-year storm.

15.3.4 DRAINAGE OF STORAGE FACILITIES

Storage facilities shall be designed to drain in accordance with the procedures in the Hydraulics Manual and Section 15.4.1.4. All stormwater storage facilities shall be designed to drain to appropriate outfall facilities.

15.3.5 UNDERGROUND STORAGE FACILITIES

Underground storage facilities are allowed but not encouraged. Such facilities must be designed in accordance with Section 15.4.1.

15.4 STORMWATER STORAGE STANDARDS

15.4.1 STORMWATER RETENTION

15.4.1.1 Minimum Design Storm

All new developments, regardless of lot size, shall make provisions to retain the entire stormwater runoff from a 100-year, 2-hour duration storm falling within its boundaries. This requirement is waived if the total new impervious area on the site, in aggregate since August 24, 2009 (the original date of release of the DDM), is 500 square feet or less.

15.4.1.2 Guidelines for Retention within Parking Lots

The maximum depth of ponded water within any parking lot location is recommended to be 1 foot. Parking lot retention areas should not be adjacent to buildings and not be sited in travel lanes. No more than 25% of the parking lot area should be used for stormwater storage. The minimum longitudinal slope recommended within parking lot storage facilities is 0.005 ft/ft, unless concrete valley gutters are provided. With concrete valley gutters, a minimum longitudinal slope of 0.002 ft/ft is recommended.

15.4.1.3 Underground Storage

Underground storage is allowed but not encouraged. It shall meet the drain time requirements.

15.4.1.4 Drain Time

All stormwater storage facilities shall be designed so that the stored runoff is emptied completely from the facility within 36 hours after the runoff event has ended. The drainage

system for retention facilities shall be accomplished using one of the following methods, listed in order of preference

1. Percolation.
2. Dry wells or a combination of percolation and dry wells.
3. Gravity bleed-off to the existing surface drainage system.
4. Pumping to an approved facility.

Percolation. Procedures used to determine the design percolation rate shall be one of the following two methods, listed by order of preference:

Method 1. ASTM D 3385-03, Double Ring Infiltrometer. If the soils present are outside the accepted range for application of ASTM D 3385-03, then method 2 shall be applied. Soils outside the acceptable range for ASTM D3385-03 are typically very pervious or very impervious with a saturated hydraulic conductivity greater than about 14 inches/hour or less than about 0.0014 inches/hour. Very impervious soils that are outside the range of applicability for ASTM D3385-03 are not suitable for stormwater percolation disposal system applications. Dry wells may be a better choice for these conditions. If there is a question regarding the applicability of this method for the soils at a particular site, ASTM D 3385-03 should be applied and the results checked against the acceptable range of values of hydrologic conductivity. ASTM D 3385-03 may also not be applicable for dry or stiff soils that will fracture when the rings are installed, or gravels that do not allow penetration by the rings.

Method 2. EPA Falling Head Percolation Test Procedure from Design Manual - Onsite Wastewater Treatment and Disposal Systems (EPA, 1980). An adaptation of this procedure is outlined in Table 15.1.

Table 15.1 Falling head percolation test procedure

Step	Description
Number and Location of Tests	A minimum of two percolation tests shall be performed within the area proposed for an absorption system. Test holes are to be spaced uniformly throughout the area proposed for percolation, as defined in Table 15.2. If soil conditions are highly variable, more tests will be required with quantity and location based on engineering judgment.

Table 15.1 Falling head percolation test procedure	
Step	**Description**
Preparation of Test Hole	The diameter of each test hole are to be a uniform dimension of 12 inches, dug or bored to the proposed depth of the absorption system or to the most limiting soil horizon. Each test hole shall have a minimum depth of 18-inches. To expose a natural soil surface, the sides of the hole are to be scratched with a sharp pointed instrument and the loose material removed from the bottom of the test hole. Two inches of 1/2 to 3/4 inch gravel are to be placed in the hole to protect the bottom from scouring action when the water is added.
Soaking Period	The hole is to be carefully filled to a depth of 12 inches with clear water. This depth of water shall be maintained for at least 4 hours and preferably overnight if clay soils are present. A funnel with an attached hose or similar device may be used to prevent water from washing down the sides of the hole. Automatic siphons or float valves may be employed to automatically maintain the water level during the soaking period. It is extremely important that the soil be allowed to soak for a sufficiently long period of time to allow the soil to swell to obtain accurate results. In sandy soils with little or no clay, soaking is not necessary. If, after filling the hole twice with 12 inches of water, the water seeps completely away in less than ten minutes, the test can proceed immediately.
Measurement of the Percolation Rate	Except for sandy soils, percolation rate measurements should be made 15 hours but no more than 30 hours after the soaking period begins. Any soil that sloughed into the hole during the soaking period is to be removed and the water level adjusted to 6 inches above the gravel (or 8 inches above the bottom of the hole). At no time during the test should the water level be allowed to rise more than 6 inches above the gravel. Immediately after adjusting the depth to 6-inches, the water level is to be measured from a fixed reference point to the nearest 1/16 inch at 30 minute intervals. The test shall be continued until two successive water level drops do not vary by more than 1/16 inch. At least three measurements are to be made. After each measurement, the water level is to be readjusted to the 6 inch level. The last water level drop shall be used to calculate the percolation rate. In sandy soils or soils in which the first 6 inches of water added after the soaking period seeps away in less than 30 minutes, water level measurements are to be made at 10 minute intervals for a 1 hour period. The last water level drop shall be used to calculate the percolation rate.

Table 15.1 Falling head percolation test procedure	
Step	**Description**
Calculation of the Percolation Rate	The percolation rate is calculated for each test hole by dividing the magnitude of the last water level drop by the time interval used between measurements. The percolation calculation results should be in terms of inches per hour (in/hr). Example: If the last measured drop in water level after 30 minutes is 5/8 inch, the percolation rate = (5/8 in) /(0.5 hrs) = 1.25 in/hr) To determine the percolation rate for the area, the lowest rate obtained from all tests in the basin shall be selected.

Number of Tests (each test includes one soil log hole and one percolation test):

- A minimum of two (2) tests is required per retention basin.
- Each soil log boring hole shall extend at least 10-feet below the bottom of the proposed basin. A soil horizon log shall be prepared for each boring to obtain the approximate soil texture of each soil layer (horizon) observed and to identify soil horizons that may impede percolation.
- Additional tests shall be performed based on proposed basin floor percolation area as set forth in Table 15.2.

Method 2 may be applied using a 12-inch diameter bore hole where it is not practical to excavate a pit for performing the test at the proposed bottom of retention basin. The same procedures shall be applied as set forth in Table 15.1, except that measurements shall be taken with a water level sounder with a measuring tape that meets or exceeds federal specification US GGG-T-106E, with a vertical accuracy of at least 0.008%. The measuring tape shall be able to be accurately read to 0.01 foot. In the event the bore hole is unstable and must be lined, a pit shall be excavated to facilitate use of Method 1 or Method 2.

Table 15.2 Minimum quantity of soil log hole/percolation tests required	
Retention Basin Bottom Area, sf	**Minimum Number of Tests Required**
<10,000	2
≥10,00 and <20,000	3
≥20,000 and <30,000	4

Table 15.2 Minimum quantity of soil log hole/percolation tests required	
Retention Basin Bottom Area, sf	**Minimum Number of Tests Required**
≥30,000 and ≤43,560	5
>43,560	A minimum of 5. Additional percolation tests may be required if the soil borings indicate variation in soil texture within the proposed percolation area.
The tests should be distributed evenly throughout the retention basin using engineering judgment. For example, when 5 tests are required, the typical distribution assuming a square basin would be a test in each corner and one in the middle.	

Field percolation test values should be reduced by a safety factor when designing any percolation facility (Stahre and Urbonas, 1990). This is necessary because soils will tend to clog with time, which has proven to be a significant cause for basin failure to drain within 36-hours in Maricopa County and other locations throughout the United States. The Method 2 percolation test includes measurement of sidewall infiltration. The desired design percolation rate must be for the basin bottom only. Therefore, the measured percolation rate must be adjusted to negate the sidewall infiltration. This is done by applying a sidewall correction factor. For a 12-inch diameter test hole with a 6-inch water depth, the sidewall correction factor is determined using Equation 15.1.

$$CF_{sw} = \frac{1}{A_b / (A_b + A_{sw})} \qquad 15.1$$

$$CF_{sw} = \frac{1}{(3.1416)(6^2) \Big/ \big((3.1416)(6^2) + (3.1416)(12)(6)\big)}$$

$$CF_{sw} = \frac{1}{0.333} = 3.0$$

where:

CF_{sw} = Sidewall correction factor,
A_b = Area of the bottom of the test hole, in in^2, and
A_{sw} = Area of the test hole sidewalls for a 6-inch water depth, in in^2.

The design factor to be applied shall be selected from Table 15.3 for the percolation test method used, and the subsurface conditions identified by the soil boring holes. The measured

percolation rate shall then be adjusted for design using Equation 15.2. The tests shall be performed by a testing laboratory, and the results sealed by a civil engineer, licensed to practice in the State of Arizona. Stormwater disposal by percolation is not allowable if the percolation rate, after application of the design factor, is less than 0.5 inches per hour. Stormwater disposal by percolation is also not allowable if groundwater or an impermeable layer is encountered within 4-feet below the bottom of the basin.

Table 15.3 Percolation design factors for design

Condition	Design Factor			
	Method 1 (ASTM) Design Factor	Method 2 (EPA, 1980)		
		Sidewall Correction Factor	De-rating Factor	Design Factor (3)*(4)
(1)	(2)	(3)	(4)	(5)
No groundwater or impermeable layer is encountered within 10-feet below the bottom of the basin, and the soils are of similar texture to those where the percolation test is taken. The geotechnical engineer may specify a higher de-rating factor based on analysis of the soil conditions below the basin bottom.	2	3	2	6
Groundwater or an impermeable layer is encountered within 4-feet to 10-feet below the bottom of the basin	4	3	4	12

$$P_d = \frac{P}{D_r} \qquad 15.2$$

where:

P_d = Design percolation rate, in inches/hour,
P = Lowest measured percolation rate, in inches/hour, and
D_r = Design factor from Table 15.3.

Basin drain time is estimated by using Equation 15.3.

$$T_d = \frac{V}{A_p \frac{P_d}{12}} \qquad 15.3$$

where:

T_d = Retention basin drain time in hours,
A_p = Percolation area (basin bottom), in acres
P_d = Design percolation rate, in inches/hour, and
V = Retention basin design storage volume, in acre-feet.

Only the bottom area of the retention basin may be used for computing the basin drain time by infiltration/percolation. The side slope areas shall not be used in the drain time computation unless the basin configuration is "V" shaped without a flat bottom. For a "V" shaped basin without a flat bottom, the bottom area assumed available for percolation shall be computed using Equation 15.4.

$$A_p = \frac{2 * (D/3) * SS * L}{43{,}560} \qquad 15.4$$

where:

A_p	=	Percolation area (approximate), in acres,
D	=	Design ponding depth, in feet,
SS	=	Basin side slope, in feet/foot, and
L	=	Length of retention basin, in feet.

Dry Wells. Drywells shall be designed, operated, and maintained in conformance with the most current ADEQ guidelines. The above Method 1 or Method 2 percolation test procedures may be used for estimating initial design percolation rates for dry wells. The final design rate shall be based on a constant-head percolation test performed on each completed well at the site. The test results for each well shall be de-rated based on the in-situ soil conditions. A de-rating factor of 2 shall be applied for coarse-grained soils (cobbles, gravels and sands). A de-rating factor of 3 shall be applied for fine grained soils (silts and loams). A de-rating factor of 5 shall be applied for clay soils. These de-rating factors are required to compensate for deterioration of the percolation capacity over time in addition to providing a factor of safety for silting and grate obstruction. The accepted design disposal rate for a dry well, after application of the de-rating factor, shall not be less than 0.1 cfs per well. The maximum allowable rate, after application of the de-rating factor, shall not exceed 0.5 cfs per drywell in any case for design purposes. It shall be the owner's, or owner's representatives', responsibility to clean and maintain each dry well to ensure that each remains in proper working order. Under no condition shall the regular maintenance schedule exceed 3-years. Drywells that cease to drain a retention basin with 36-hours shall be replaced or refurbished by the owner or his representative. Maintenance requirements shall be written in the CC&R's for subdivisions where dry wells are used to drain retention basins. In accordance with ADEQ requirements, the installation of any subsurface drainage structure must be located into a permeable porous strata at least 10-feet above saturated soils and 100-feet away from any water supply well.

Gravity Bleed-off. Where bleed-off pipes are to be used as the primary means of draining a retention-type stormwater storage basin, the pipe shall drain the 100-year (design) stormwater storage volume within 36 hours, but in no less than 24 hours.

As a part of the design of the bleed-off system, the design engineer shall evaluate and show that discharge flow rate post-development times of concentration do not adversely affect downstream peak discharges.

Retention systems using a bleed-off method shall meet the first flush requirements of Chapter 6.

The proposed diameter of a basin drain pipe should be rounded up to the nearest standard size made by pipe manufacturers. The minimum allowable pipe size for primary outlet structures is 18-inches in diameter. A permanently attached, hinged orifice plate shall be used to meter the outflow, in conformance with Figure 8.5 of the Hydraulics Manual. Bleed-off time shall be calculated by the Modified Puls storage routing method. Refer to the Hydraulics Manual for example computations.

The required basin drain time may be extended, with prior approval by the COUNTY/DISTRICT, for major storage basins (> 50 acre-feet). Vector control provisions will be one of the requirements for approval of an extended drain time.

Field investigations shall be performed and shall include soil borings and percolation tests taken at the bottom of the proposed basin to obtain percolation rates for use in the design of the stormwater storage facility.

15.4.2 STORMWATER DETENTION

15.4.2.1 Allowable Use

The use of a detention basin in lieu of a retention basin is not allowed without approval in writing by the MOHAVE COUNTY ENGINEER. In the special case where approval is granted by the MOHAVE COUNTY ENGINEER to waive the requirement to retain the 100-year 2-hour runoff volume, the stormwater quality requirements (Chapter 6) must still be met.

Possible special cases where the retention requirement may be waived in favor of detention are as follows:

1. A major drainageway or watercourse is available to accept runoff from the subject site that has sufficient hydraulic capacity to safely convey the 100-year pre-development peak discharge. To be approved: 1) watershed timing issues must be studied and determined to not be an issue for downstream properties, 2) system sediment balance must not be significantly affected, and 3) cumulative impacts of applying such a policy throughout the watershed must not be detrimental to public safety or property.
2. An approved Area Drainage Master Plan for the area states application of detention basins is acceptable.
3. Sensitive riparian vegetation in a downstream watercourse would be adversely affected by application of the retention basin requirement.

15.4.2.2 Minimum Design Storm Criteria

Post-development peak discharges shall not exceed pre-development peak discharges for the 2-, 10-, 50-, and 100-year storm events for the design of detention basins.

15.4.3 STORMWATER STORAGE BASIN DESIGN

15.4.3.1 Basin Depth

Stormwater retention basins should typically have a maximum water depth of 3 feet for the 100-year, 2-hour storm event. Deeper water depths for the design event shall address safety issues.

15.4.3.2 Adjacent to Streets

The required stormwater retention volume shall not intrude upon the public road right-of-way and shall be set back a minimum of 5-feet from the right-of-way (R/W).

15.4.3.3 Berms

Berms are not to be placed closer than 13 feet from the back of the curb, or 8 feet from the back of the sidewalk. Berms are not to be higher than 2-feet above grade on the downhill side. Berms must have a minimum top width of 8 feet. An overflow area (emergency spillway) shall be provided.

15.4.3.4 Side Slopes

Side slopes of stormwater retention facilities are to be no steeper than 3:1 unless prior approval by COUNTY/DISTRICT is received for a steeper slope, considering safety issues and erosion control. Stormwater retention basin sides, edges, or top of slopes should be varied to provide an esthetically pleasing appearance.

15.4.3.5 Protective Measures

Protective measures shall be required for all constructed drainage basins located in developed areas, with side-slopes steeper than 3:1 or depths exceeding three (3) feet, unless provisions are made for safe exit from the facility during flooding conditions, or other deterrents to access during unsafe conditions are provided. Determining the type of protection measures shall be based on sound engineering judgment for the intended application and must be sealed by an Arizona registered civil engineer.

15.4.3.6 Sediment Storage Requirement

Sedimentation basins, which may be required, are to be located at the upstream (inlet) portions of stormwater storage facilities. The sediment settling basins shall be easily accessible by maintenance equipment (such as backhoes) and should have a minimum storage volume equivalent to the 2-year watershed sediment yield, in addition to suitable storage volume and conveyance capacity to ensure transfer of the 100-year 2-hour runoff volume and the 100-year peak discharge into the retention facility, or the 100-year design storm volume and peak discharge into the detention facility.

15.4.3.7 Emergency Spillway Requirement

Emergency spillways shall be provided for all stormwater storage basins. For basins with all the design storage volume situated below existing grade (i.e. without a berm/dam), the spillway may be nothing more than grading to ensure that basin overflow will follow the downstream predevelopment drainage pattern in a safe manner.

Emergency spillways shall be designed to safely convey the peak discharge from the storm listed in Table 15.4, exclusive of the attenuation effects of the basin.

Table 15.4 Emergency spillway design capacity requirements

For an embankment berm/dam that is not regulated by ADWR	
Berm/Dam Height	**Spillway Design Capacity**
H < 6 ft.	Unattenuated 100-year inflow
6 ft. <= H < 25 ft.	1/2 Probable Maximum Flood

where:

Berm/Dam height is the vertical distance from the lowest point along the downstream slope to the crest of the emergency spillway.

100-year inflow is the unattenuated peak discharge from the pre- or post-development 100-year 6-hour or 24-hour storm, whichever is larger.

Refer to Section 2.4 for information regarding dams regulated by ADWR.

Emergency spillways shall be designed to convey the design peak discharge and erosion protection shall be provided in accordance with the Hydraulics Manual.

Down-gradient properties are to be protected from flow depths and velocities in excess of pre-development conditions.

A 1 foot minimum freeboard is required between the berm crest and the water surface elevation of the 100-year peak discharge in the emergency spillway (without attenuation from basin storage), except where the berm crest is designed to function as the emergency spillway.

The finished floor elevation of adjacent structures must be at least 1.0 feet above the 100-year peak water surface elevation of the flow passing through the emergency spillway.

15.4.3.8 Landscaping

Landscaping components should not adversely affect the basin hydrologic and hydraulics functions.

15.4.3.9 Ownership and Maintenance Requirements

Regional: Publicly-owned COUNTY/DISTRICT Maintained.

Commercial: Drainage easement attached to the deed for single parcels. Privately maintained.

Commercial or Residential Subdivision: Parcel recorded on the Final Plat. Privately maintained.

Single Family Residential (>1 acre): Drainage easement attached to the deed. Privately maintained.

15.4.3.10 NPDES Requirement

Discharges from stormwater facilities must be in compliance with 40 CFR 122, the NPDES, and the AZPDES.

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16 EROSION CONTROL DURING CONSTRUCTION

16.1 INTRODUCTION

Construction activity disturbs the land surface, thereby exposing native soils to increased rates of erosion by wind and rain. Airborne soil poses detrimental health risks and reduces visibility. Erosion of soil from construction sites by stormwater increases the rate of siltation of drainageways, which can exacerbate flooding and increase the cost of on-going maintenance. Appropriate erosion control measures are required at construction sites.

16.2 TECHNICAL DESIGN CRITERIA

Technical guidance for erosion control during construction shall be in accordance with the Flood Control District of Maricopa County Erosion Control Manual (FCDMC, 2012).

16.3 EROSION CONTROL DURING CONSTRUCTION POLICIES

16.3.1 STORMWATER CONVEYANCE DURING CONSTRUCTION

Stormwater conveyance is to be provided at all times during construction in a manner that does not increase flood depths, sedimentation, or erosive velocities above pre-construction levels for the areas adjacent to, and downstream of, construction projects.

16.3.2 STORMWATER POLLUTION PREVENTION PLANS

Stormwater Pollution Prevention Plans (SWPPP) or Stormwater Management Plans (SWMP) that incorporate best management practices are required of new development/construction. See NPDES Stormwater construction requirements for full details.

16.3.3 PERMITTING

There is a myriad of federal and state permits that may be required prior to the start of construction of a project (see Chapter 2). It is the applicant's responsibility to ensure and document that the plans for a proposed project satisfy state and federal permit requirements, including a requirement for a small MS4.

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17 SEDIMENTATION

17.1 INTRODUCTION

Sedimentation and the fluvial processes associated with sediment transport play an important role in the long-term conveyance capacity of a drainage system as well as the on-going cost of maintenance. Sedimentation is a very complex subject and not all drainage designs need to consider it as a primary design criteria. The policies and standards in this chapter define the conditions where sedimentation should be considered as an important design parameter.

17.2 SEDIMENTATION TECHNICAL CRITERIA

Technical guidance for defining and addressing erosion/sedimentation hazards shall be in accordance with the sedimentation chapter of the Hydraulics Manual. Specific design policies and standards for Mohave County needed for application of the technical information contained in the Hydraulics Manual are defined herein.

17.3 SEDIMENTATION POLICIES

The designer of drainage facilities should undertake the appropriate level of erosion and sedimentation analysis commensurate with the risk of undesirable consequences expected to the health, safety, and welfare of the general public. Erosion zones consistent with ADWR (1996b) may be required for all development meeting the criteria defined in Section 17.4 in which the watercourses are to be left in an undisturbed state. ADWR (1996b) specifies a three level approach. Each level must be performed by a registered civil engineer licensed to practice in Arizona. Level I is a simplified approach, requires the watershed area, is only applicable to watersheds with an area less than 30 square miles, and in general provides a conservative estimate for the erosion setback. Engineering analysis is minimal for the Level I approach. Depending on the geomorphic conditions of the area, if the erosion limits are estimated by the COUNTY/DISTRICT to exceed those estimated using a Level I analysis, a more detailed engineered analysis may be required as defined in ADWR (1996b), using a Level II or Level III approach.

A Level II approach is only applicable for watersheds less than 30 square miles in area, and is normally applied if the developer believes the Level I setback is overly conservative, or the COUNTY/DISTRICT suspects the Level I setback is insufficient.

A Level III approach is required if:

1. the watershed area is greater than 30 square miles, or
2. significant shifting of the river channel has been observed in the past, or
3. the area is undergoing channel filling (aggradation) to a significant degree, or
4. local river mining, channelization, or other modifications could result in flow redirection unanticipated in the development of the Level I or Level II setback.

Level III erosion hazard analysis shall be done in conformance with the guidelines set forth in ADWR (1996b) and Hydraulics Manual Chapter 11 Sedimentation.

If erosion hazard guidelines (ADWR, 1996b) are determined to apply, and the developer/homeowner elects to not use the erosion setback approach, structural mitigation measures are required in conformance with Section 17.4.

17.4 SEDIMENTATION STANDARDS

17.4.1 CRITERIA DEFINING NEED FOR SEDIMENTATION ANALYSES

Recognizing that sedimentation and sediment transport is either supply or transport control and that stormwater runoff may produce sedimentation or erosion, the following standards shall be applied to:

1. Watercourses with drainage areas equal to or greater than 0.25 sm or a 100-year peak discharge estimate of more than 500 cfs, as estimated using the procedures in Chapter 7 Hydrology.
2. Structures that could fail or incur significant damage as a result of erosion or deposition.
3. Proposed structures that, if built, could result in adverse impacts to adjacent properties.

17.4.2 TECHNICAL REFERENCES

Erosion control improvements shall be designed and constructed in accordance with guidance provided in ADWR (1998) and Hydraulics Manual Chapters 5, 8 and 11. Chapter 11 of the Hydraulics Manual lists and summarizes numerous technical references that are appropriate for

use in Mohave County for erosion and sediment transport modeling and design of erosion/sedimentation facilities.

17.4.3 SEDIMENTATION BASIN REQUIREMENTS

Where sediment transport analysis is required, sedimentation basins and/or structures shall be designed and constructed as an integral part of stormwater storage and/or conveyance facilities unless a sediment transport analysis of the system demonstrates that sediment is conveyed through the system during frequent events including the 2-year storm event.

Sedimentation basins and/or structures shall be designed to hold a minimum of two years of watershed sediment yield using an annual sediment yield of 0.25 ac-ft/sq. mi./year or the site-specific sediment yield based upon in-situ geomorphic and engineering analyses meeting or exceeding those methods identified in the Hydraulics Manual Chapter 11.

Sediment basins and/or structures shall be designed with minimum 6:1 side slopes and 16-foot wide access ways on opposing sides. Sediment basins and/or structures shall be designed to slow the passage of runoff but not prevent the passage of runoff.

Sediment check structures shall have low flow outlets with inverts set equal to the invert of the drainageway and shall be no higher than 18 inches. All outlets shall be designed for protection from scour per the Hydraulics Manual.

17.4.4 ROADWAY CROSSING REQUIREMENTS

For County Highways, arterial roads, and all-weather access roads crossing a distributary flow area or alluvial fan, the following minimum standards shall apply for the design of culverts or bridges, where a low water crossing approach is not taken:

1. The natural wash bottom width should be completely spanned where possible.
2. A minimum height of 4 feet should be provided (5 feet high is preferred), and the structure flowline set to equilibrium grade (inverts may be buried a maximum of 6-inches for sediment continuity, but the minimum clear opening above the channel invert shall be a minimum of 4 feet) .
3. Culverts shall be sized so that the sediment transport capacity of flow does not vary more than 5% from the existing condition.

For adjacent watercourses, separated by less than 100 feet, where the natural grade of the watercourses at the culvert inlets are within 12 inches vertically, an equalizer ditch should be

placed on the upgradient side of the road, between culverts. The bottom width shall be no narrower than 5 feet with side slopes no steeper than 25% (4:1).

17.4.5 CHANNEL CONSIDERATIONS

Encroachment and/or erosion control on one bank of a channel may result in increased erosion potential on the opposite bank. Such adverse effects shall be evaluated and mitigated as a part of the design.

18 NUMERICAL MODELING

18.1 INTRODUCTION

The purpose of this chapter is to provide general modeling guidelines for the use of one- and two-dimensional (1D, 2D) hydrologic and hydraulic models for floodplain management and drainage design purposes within Mohave County. Detailed technical guidance is not provided since this depends on the model being applied and the needs and specific topographic characteristics of the project being modeled. Instead, general modeling guidance is provided including which models are preferred, or may be accepted, for use within Mohave County, when a 1D and/or 2D model should be applied, and for what aspects (hydrology, hydraulics, or both).

18.2 MODELING GUIDELINES

18.2.1 1D AND 2D MODELS ACCEPTED FOR USE IN MOHAVE COUNTY

The numerical models meeting the minimum requirement of the NFIP, as approved by FEMA, are also accepted for use for the same purposes within Mohave County. The lists of approved models can be found at:

Hydrology:

FEMA Hydrologic Numerical Models Meeting the Minimum Requirements of the NFIP

Hydraulics:

FEMA Hydraulic Numerical Models Meeting the Minimum Requirements of the NFIP

List of preferred numerical models for use within Mohave County:

1D Hydrology.	HEC-1 version 4.1 with DDMSW for Mohave County, most recent version.
1D Hydraulics:	HEC-RAS (most recent version) HY-8 (most recent version) EPA-SWMM (most recent version)
2D Hydrology	FLO-2D (most recent version, or as approved by FEMA for an FIS study)
2D Hydraulics	FLO-2D (most recent version, or as approved by FEMA for an FIS study) XP Storm (most recent version, or as approved by FEMA for an FIS study)
2D Hydraulics	HEC-RAS 2D

Written approval from Mohave County shall be obtained before using any model other than the preferred for a floodplain delineation or drainage design project within Mohave County. The engineer/hydrologist shall also obtain written approval before use of any 2D model for such projects. The engineer/hydrologist shall submit a technical justification report for the use of other than a preferred 1D model, and any 2D model, as a part of the request for approval. The report shall describe the need and technical basis for the use of an accepted, but not preferred model.

Use of the HEC-HMS model instead of HEC-1 is one of the accepted, but not preferred, models requiring a technical justification report. HEC-HMS does not currently have an equivalent capability equal to the HEC-1 JD record option for design rainfall – depth-area reduction. Nor does the HEC-HMS Clark Unit Hydrograph implementation allow user defined time-area curves. In the technical justification report, the engineer/hydrologist shall present sound reasoning and a valid technical approach for developing a HEC-HMS model that will produce similar results to a HEC-1 model developed using Mohave County hydrologic methodology.

18.2.2 DETERMINING WHERE TO USE 1D OR 2D MODELS

1D models should be applied wherever the basic assumptions for such models can be met. 1D hydrologic models should only be applied to dendritic drainage systems. If diverging flow splits exist, there should be a minimal number and most should be able to be neglected by delineating around them, or modeled using flow diversions based on the results from 1D or 2D hydraulic models. A 1D model is generally not an appropriate choice where:

1. There are large areas of sheet flow within the watershed that provide significant attenuation and/or result in significant transmission losses.
2. There are distributary flow areas that cannot be readily modeled as flow diversions using hydraulic rating curves.
3. Flow is dominantly unconfined.
4. Urban and suburban areas where flow patterns can change significantly dependent upon the magnitude of the storm, and where street and drainage system flow patterns are distributary. A 1D model may also not be appropriate when peak discharges are needed at most intersections and/or at mid-block locations and it is not practical to subdivide the watershed to that level of detail.

2D models should be applied in areas where flow is dominantly unconfined and the following characteristics are present and the effects need to be accounted for:

1. There are large areas of sheet flow that cause significant flow attenuation and transmission losses.
2. There are significant obstructions to flow, the local effects of which need to be simulated.
3. There are distributary flow areas that cannot be readily modeled as flow diversions using 1D hydraulic rating curves.
4. There are channels that can be modeled using 1D methods but overbank flow is unconfined.
5. Unconfined flow hydrology and hydraulics are interdependent and cannot be modeled separately with an acceptable degree of accuracy.

18.2.3 1D HYDROLOGIC AND HYDRAULIC MODELING

Any non-preferred, but accepted, 1D hydrologic or hydraulic model that is proposed for use on a project within Mohave County must have a special capability that is needed for the specific application. The model must produce results favorably comparable to the equivalent preferred model prepared using the Mohave County methodology as set forth in this DDM.

18.2.4 2D INTEGRATED HYDROLOGIC AND HYDRAULIC MODELING

Any 2D model that is proposed for integrated 2D hydrologic and hydraulic modeling on a project within Mohave County shall be applied using the following guidelines:

1. Grid Size. No minimum or maximum grid size for a uniform square grid model typically used for 2D hydrology is specified. Instead, the engineer/hydrologist shall evaluate the terrain, project objectives, available topography, and the conveyance system doing the majority of the hydrologic work, and determine an optimal grid size that also considers model run time.
2. Rainfall. Point rainfall values from NOAA Atlas 14 shall be spatially-varied and applied directly to the 2D model surface without depth-area reduction. A single hypothetical rainfall distribution shall be used for the entire study area. The hypothetical distribution should be generated using HEC-1, with a precision of 4 decimal places. Alternatively, the hypothetical distribution may be generated by hand using a spreadsheet using the approach implemented by HEC-1.
3. Rainfall Losses. Rainfall losses shall be modeled using the Green and Ampt equation and the procedures outlined in this DDM. If the 2D model does not have this capability, it shall not be used for hydrologic modeling. If there is insufficient information available to perform model verification, as described in Item 5 below, total infiltration for the model shall be limited to the total infiltration that would be computed from a HEC-1 model for the study area. This has the conservative effect of eliminating most transmission losses, which are a significant unknown. The rainfall loss volume without transmission losses can be estimated by creating a HEC-1 model of the study area with actual infiltration loss records and dummy unit hydrograph records. A single basin model can be used if the infiltration characteristics do not vary significantly. If they do, a multiple sub-basin model should be constructed. The depth of total rainfall loss for each sub-basin can then be

used to compute an equivalent infiltration depth by dividing by the DTHETA parameter. This infiltrated depth can then be used to set a limiting allowable infiltration depth that is either globally applied for the study area or spatially-varied by sub-basin. The 2D model must have a limiting infiltration depth option, such as the FLO-2D model. Another acceptable approach is to perform a site-specific rainfall loss analysis of the watershed using rainfall simulators and tension infiltrometers to determine more accurate Green and Ampt parameters. This approach shall be implemented using the procedures established by the Desert Research Institute. Consult with Mohave County staff before undertaking this level of investigation. It should be reserved for when critical facilities such as flood control dams are involved. The Mohave County standard Green and Ampt parameters are appropriate for 1D modeling methods, but may overestimate infiltration in 2D models when transmission losses are significant.

The adjustment of XKSAT for vegetative canopy cover specified in Section 7.4.2.3 shall not be applied for 2D hydrologic models.

4. Land Surface Characterization. See Section 18.2.5, Item 2.
5. Cross Sections. The engineer/hydrologist shall define cross sections as required to provide hydrographs at key locations such as street crossings and wash confluences, to meet the project goals, and to aid with model verification and/or calibration. Cross sections shall be defined perpendicular to the flow direction. Each cross section shall only cover an area of concentrated flow with a single dominate flow direction. Additional cross sections are required for concentrated flow with a different dominate flow direction.
6. Model Verification/Calibration. Every 2D model shall be verified and calibrated to the extent possible. Historical storm events shall be used whenever possible. The NEXRAD radar data for each storm shall be obtained in 5-minute time intervals, if available, and locally adjusted using any available ground-based rain gage information. The rainfall data should be applied to the model surface as spatially and temporally varied rainfall. The model results should then be compared against any available stream flow gage data available. Any physical evidence of storm flow or ponding depths at specific locations should be collected from roadway maintenance records, field personnel interviews, newspaper records, residents of the area, law enforcement or other government agency personnel who may have been on duty during the event, and television news videos or photographs. This information should then be evaluated, compared with the model results, and the model parameters adjusted if necessary to match the observed results. This effort shall be fully documented. In the event that verification/calibration information is not available, the infiltration depth limit approach shall be taken as described in Item 3 above.

There currently is not a 2D model approved for grid-based hydrology on the FEMA web site. Therefore, flood insurance studies that are to be submitted to FEMA for a new or revised floodplain delineation should not be based on 2D hydrology unless there is a strong case for approval by FEMA and it is not possible to accurately represent the hydrology with a 1D model. These cases should be discussed with FEMA prior to beginning the study.

18.2.5 2D HYDRAULIC MODELING

The following are guidelines for various aspects of 2D hydraulic modeling:

1. Grid/cell Size. The maximum grid size for a hydraulics 2D model in Mohave County is 10 meters on a side. Grid size for uniform size square grid models should be based on an evaluation of the topographic mapping available, the size of the drainage conveyance channels present in the 2D study area, the features being modeled such as streets and flow blockages, and model run time considerations. The selection of grid size process shall be fully documented in the study technical documentation notebook.
2. Land Surface Characterization. A land surface characterization shall be prepared for reach 2D model. The characterization shall be polygon based in GIS, with each polygon representing a surface feature such as:
    a. Building Obstructions
    b. Asphalt
    c. Concrete
    d. Unpaved Roads
    e. Urban Bare Ground
    f. Undeveloped Desert Rangeland
    g. Undeveloped Hillslope
    h. Undeveloped Mountain
    i. Natural vegetation (low, medium and high density)
    j. Urban vegetation (low, medium and high density)

    The level of detail and number of classifications used will depend on the project objectives. Each surface feature should have an assigned n-value at 3 feet of flow depth (in the case of FLO-2D; may be different for other 2D models), initial abstraction (IA), percent impervious (RTIMP), and initial soil moisture condition for assigning DTHETA. These polygons and their associated characteristics are then used to spatially vary surface roughness and model building obstructions. For an integrated 2D hydrologic and hydraulic model, the land surface characterization polygons are used to assign spatially-varied values of IA, RTIMP, and to assign a dry, normal or saturated DTHETA value based on XKSAT.
3. Surface Roughness. Surface roughness at 3 feet of flow depth should be spatially varied based on the land surface characterization from Item 2 above. If the model supports it, a depth variable n-value approach should be used.
4. 1D Channels. The modeling of inset 1D channels may be necessary, depending on whether or not the selected grid size can accurately model any significant channels within the study area. If the channels present can be modeled using 1D techniques within the channel banks, that may be the most efficient approach. Use of 1D channels will often allow use of a larger grid size for the overbank areas than is necessary to model the study area without 1D channels. It becomes a balance between model run times for smaller grid

models, and the use of inset 1D channels with a larger grid. The level of effort to code any 1D channels may outweigh the benefits.

5. Obstructions to Flow. A key component of any 2D model is the ability to model flow obstructions at a high level of detail, especially in an urban environment. Building obstructions should be modeled when necessary to produce accurate results and/or meet the project goals. If the model is performing integrated hydrology and hydraulics, the model must be able to simulate runoff from the building as well as act as an obstruction to flow.
6. Hydraulic Structures. Hydraulic structures such as culverts, bridges and storm drains should be included in the 2D model if they have a significant impact on flow distribution on the surface, and/or if necessary to meet the goals of the project.
7. Walls and Levees. Masonry and concrete walls and levees can have a significant impact on distribution of flow within the study area. Modeling of these structures should be carefully considered as preparation of input data files can be a significant effort. The 2D model should be run first without such obstructions to determine flow patterns. Then the walls and levees that are hydraulically significant can be determined and the level of effort for data collection and data input file coding can by more accurately estimated. This is often a trial and error process.
8. Model Verification/Calibration. The same basic approach described in Section 18.2.4, Item 5, should be followed for verification and calibration of the 2D hydraulic model. For 2D hydraulics only models, the verification/calibration effort should be based on known high water marks and comparison with measured hydrographs and is subject to the accuracy of inflow hydrographs and inflow locations used.

19 DOCUMENTATION REQUIREMENTS

19.1 INTRODUCTION

An important part of any drainage design is complete and accurate documentation. This helps review of the design proceed more quickly, and provides information that will be needed in the future when maintaining, modifying, or extending the improvements. Following an orderly report format also helps ensure that critical items are not missed and make it easier to locate needed information. The following sections identify the required outline for preparation of hydrology and hydraulics reports for projects in Mohave County. Flood Control District Engineer may determine specific sections to be optional or approve formatting changes.

19.2 HYDROLOGY AND HYDRAULICS REPORTS

19.2.1 FLOOD INSURANCE STUDIES

Hydrology and hydraulics reports documenting floodplain delineation studies for approval by the DISTRICT and/or FEMA shall be prepared in accordance with ADWR State Standard 1-97 (ADWR, 1997). Checklist E.5 should be used and a completed copy of both provided with the submittal.

19.2.2 DESIGN CONCEPT REPORT

Design Concept Reports for subdivisions, preliminary design of roadway drainage, or preliminary design of flood control facilities shall, as a minimum, include the following information:

1. Documentation for new and revised hydrology and hydraulic models.
2. Assumptions and parameters that are to be used for design of each drainage system component.
3. Identification of all areas where flooding may affect proposed building pads and other structures. These are the areas where minimum building pad and finished floor elevations for areas within floodplains and backwater ponding from structures or roadway embankments must be specified in the Final Drainage Design Report.
4. Parameters proposed for design of retention basins and location and approximate sizes of proposed retention structures.
5. If a variance from stormwater retention criteria is being requested, a Stormwater Quality Plan identifying proposed permanent stormwater quality features including First Flush provisions shall be provided.

6. Narrative, summary tables and exhibits shall be provided for each section. Supporting calculations shall be referenced in a specific exhibit for each section of the main report.

The Table of Contents must be sealed by a Civil Engineer licensed to practice in the State of Arizona. The Design Concept Report should be organized to include sections as follows (as a minimum):

TABLE OF CONTENTS

1.0 Completed Hydrology and Hydraulics Report General Checklist
2.0 Introduction/Purpose
3.0 Location
4.0 Site Description and Proposed Development
5.0 FEMA Floodplain Classification
6.0 Survey and Mapping
7.0 Off-site Drainage Description
- 7.1 Background
  Describe drainage studies that are of record for the off-site watershed, methods being used to handle drainage, and the anticipated future development conditions. Identify where off-site flow enters and exits the subject project, including multiple frequency discharges, depth, velocity, and extent of floodplain on the subject project and a minimum of 200 feet upstream and downstream of the subject project.
- 7.2 Proposed Offsite Flow Management Plan
  Describe how off-site flows will be addressed for the subject project. The description shall include guidelines to be used for design of the project drainage facilities to ensure that drainage is handled in accordance with the DDM and that there are no adverse impacts on adjacent, upstream, or downstream properties.

8.0 Proposed On-site Drainage Plan Description
Describe the proposed methods for handling on-site drainage. Provide the criteria and guidelines that will be used for design of the project drainage facilities. Provide the preliminary proposed location, size, type and configuration of retention facilities, culverts, channels, storm drains, erosion protection, sedimentation basins and other facilities. Identify proposed flow directions for streets, channels and site grading and drainage. Identify existing floodplain and/or floodway limits, and delineate new floodplain and floodway limits for previously unstudied washes, in accordance with the DDM. Describe how the proposed project will impact the floodplain and/or floodway, and mitigation measures to be taken for those impacts. If a CLOMR or LOMR is proposed, or required by COUNTY/DISTRICT, provide the time table for preparation of the design plans, TDN, and submittals to COUNTY/DISTRICT and FEMA.

9.0 Hydrology

This section shall document all hydrology calculations made for both the on-site and off-site watersheds and set forth in Sections 7.0 and 8.0.

9.1 Methodology

Describe the hydrologic methodology used and any numerical modeling approaches applied, including software used and software versions.

9.2 Parameters

Document all hydrologic modeling parameters including:

9.2.1 Rainfall
9.2.2 Rational Method Parameters
9.2.3 Rainfall Losses
9.2.4 Unit Hydrograph Parameters
9.2.5 Channel Routing
9.2.6 Storage Routing
9.2.7 Transmission Losses

9.3 Results

Present and discuss the hydrologic modeling results.

9.4 Confidence Checks, Calibration and Sensitivity Analyses

Document confidence checks made in conformance with DDM Section 7.11, any calibration efforts, and any sensitivity analyses conducted for critical parameters.

9.5 Unique Conditions and Problems

Document any unique watershed conditions and modeling problems encountered and describe how each was addressed. This includes documenting all modeling warning and error messages in the computer model output and describing the significance of the messages and, if necessary, what has been done to address them.

10.0 Hydraulics

This section shall document all preliminary hydraulic calculations made for both the on-site and off-site watersheds and set forth in Sections 7.0 and 8.0.

10.1 Methodology

10.1.1 Floodplain Delineations

Describe the hydraulic methods used for floodplain/floodway delineations, including the numerical modeling approaches applied, software used and software versions. Describe the methods used to delineate floodplain boundaries and the compute floodway limits. Describe the cross section placement, orientation, and how cross sections were obtained.

10.1.2 Project Drainage Conveyance Facilities

Describe the methods used for preliminary sizing of proposed culverts, channels, storm drains, flow transition facilities, and

other stormwater conveyance facilities. List software used including software versions.

10.2 Parameters and Modeling Considerations

Document all hydraulic modeling parameters including:

10.2.1 Floodplain Delineations

10.2.1.1 Flow Regime
10.2.1.2 Frequencies for which Profiles were Computed
10.2.1.3 Roughness Coefficients
10.2.1.4 Expansion and Contraction Coefficients
10.2.1.5 Hydraulic Jump and Drop Analysis
10.2.1.6 Bridges and Culverts
10.2.1.7 Levees and Dikes
10.2.1.8 Islands and Flow Splits
10.2.1.9 Ineffective Flow Areas
10.2.1.10 Supercritical Flow
10.2.1.11 Floodway Modeling

10.2.2 Project Drainage Conveyance Facilities

10.2.2.1 Roadway Drainage
10.2.2.2 Storm Drains
10.2.2.3 Culverts and Bridges
10.2.2.4 Open Channels
10.2.2.5 Hydraulic Structures

10.3 Results

Present and discuss the hydraulic modeling results.

10.3.1 Floodplain Delineations
10.3.2 Project Drainage Conveyance Facilities

10.4 Calibration and Sensitivity Analyses

Document any calibration efforts made, and any sensitivity analyses conducted for critical parameters.

10.4.1 Floodplain Delineations
10.4.2 Project Drainage Conveyance Facilities

10.5 Unique Conditions and Problems

Document any unique hydraulic conditions and modeling problems encountered and describe how each was addressed. This includes documenting all modeling warning and error messages in the computer model output and describing the significance of the messages and, if necessary, what has been done to address them.

10.5.1 Floodplain Delineations
10.5.2 Project Drainage Conveyance Facilities

11.0 Stormwater Retention and First Flush Requirements

Document the proposed location, size and design criteria and guidelines for proposed retention facilities. Identify if first flush facilities will be necessary and if so, where they are to be located.

12.0 Minimum Finished Floor Elevation Requirements

Identify where minimum finished floor elevations are anticipated to be necessary and specified in the final construction documents and on the Final Plat.

13.0 Sedimentation and Erosion Hazards Discussion
Discuss sedimentation issues and erosion hazards that must be addressed during the design phase. Provide design criteria and guidelines for use by the design engineer.

15.0 Stormwater Permits Requirements (401/404, Floodplain, Right-of-Way, Stormwater Quality, and other permit requirements)
Identify stormwater, drainage, and floodplain permits that will be necessary for the project.

16.0 Conclusions and Recommendations

17.0 References

FIGURES

Figure 1 Area Location Map
Figure 2 Site Aerial Photo Map
Figure 3 FIRM Map
Figure 4 Off-site Watershed Map
Figure 5 On-site Watershed Map
Figure 6 On-Site Drainage and Grading Plan
Figure 7 Floodplain/Floodway Delineation Work Study Maps
Figure 8 Floodplain Profiles

APPENDICES

Appendix A Offsite Hydrology Documentation
Appendix B On-Site Hydrology Documentation
Appendix C Channel Design and Floodplain Hydraulics Documentation
Appendix D Street Capacities & Storm Drain Analysis Documentation
Appendix E Stormwater Storage and First Flush Documentation
Appendix F Stormwater Quality Documentation
Appendix G Sediment and Erosion Hazard Documentation
Appendix H Digital Data/Model Input and Output Files

If a report section does not apply, the section should still be included and identified as not applicable. The outline numbering scheme should be maintained. Add subsections as necessary to describe methodologies used and results. Include supporting calculations and computer printouts in the appropriate appendix.

19.2.3 FINAL DRAINAGE DESIGN REPORT

The Final Drainage Design Report should, as a minimum, include the following information:

1. Documentation for new and revised hydrology and hydraulic models that have changed since the Design Concept Report.
2. Design assumptions and parameters for each drainage system component.
3. Minimum building pad and finished floor elevations for areas within floodplains and backwater ponding from structures or roadway embankments.
4. Retention basin design parameters and rating curves.
5. If a variance from stormwater retention criteria is being requested, a Stormwater Quality Plan documenting permanent stormwater quality features including First Flush provisions shall be provided.
6. It is also recommended that a Stormwater Pollution Prevention Plan (SWPPP), as filed with ADEQ, documenting recommended BMP's and recommended BMP locations for the various phases of the construction process, be included as an appendix of the Final Drainage Design Report.

The Table of Contents must be sealed by a Civil Engineer licensed to practice in the State of Arizona. The Final Drainage Design Report should be organized to include the same sections and sub-sections as the Design Concept Report. The report shall document all changes made since the Design Concept Report and all design computations and results for the project drainage facilities under the appropriate report section.

If a report section does not apply, the section should still be included and identified as not applicable. The outline numbering scheme should be maintained. Various designed components should be included under the appropriate section. Add subsections as necessary to describe methodologies used and results. Include supporting calculations and computer printouts in the appropriate appendix.

19.2.4 DRAINAGE DESIGN REPORT CHECKLISTS

Each report should contain the applicable hydrologic and hydraulic analysis checklists shown in Appendix E, completed as appropriate for the proposed project.

19.2.5 ADDITIONAL REPORT REQUIREMENTS

1. Drainage Design Reports shall include, but not be limited to, the following items:
    a. Professional engineer seal, signed and dated, on the Title page and Table of Contents.

b. A drainage map that shows the discharges at points of concentration and clearly identifies the existing drainage system. Minimum scale will be 1 inch equals 500 feet. Where drainage areas are large, a smaller scale may be approved.

c. Detailed street hydraulic analysis and storm drain analysis (where required).

d. Calculations for the proposed stormwater retention facilities showing storage volume required and retention volume provided, and First Flush calculations. If more than one facility is proposed, calculations must be separated for each area, and each tributary area referenced to its respective stormwater storage facility. Analysis confirming that each basin will drain within 36 hours of the end of the design precipitation event is required.

e. If adjacent land drains into or is diverted around the development, the adjacent contributory drainage area must be shown and quantified. Size of the adjacent drainage area and slope of the land information shall be shown.

f. A schematic line drawing of the proposed drainage system in plan view showing design flow and capacity.

g. Sufficient information to determine the path of the water entering and leaving the project property under pre-development and post-development conditions. Sufficient information to show that proposed conditions do not pond water on adjacent properties or change the historical flow path and pre-development hydrologic and hydraulic characteristics of stormwater leaving the property.

h. Typical cross sections of all street classifications.

i. FEMA floodplains in and adjacent to the project area as an exhibit or figure.

j. Summary of previously prepared drainage reports pertinent to the subject area.

19.3 GENERAL CONSTRUCTION DRAWING REQUIREMENTS

19.3.1 CONSTRUCTION DOCUMENTS

Construction documents shall comply with requirements in the Mohave County Engineering Design Standards, Specifications and Details for items to be installed or constructed in public rights-of-way or easements.

19.3.2 PREPARATION BY LICENSED PROFESSIONAL

All plans for engineered drainage improvements shall be prepared under the direction of a Civil Engineer licensed to practice in the State of Arizona, and sealed, dated and signed by that engineer.

19.3.3 PLAN REQUIREMENTS FOR Q_{100}<50 CFS

Engineered drainage improvements designed for flows less than 50 cfs may be shown in plan view with spot elevations, flow direction arrows, and typical sections. The plan shall show the horizontal alignment and dimensions as well as the type and extent of the proposed work. Other elements from Section 19.3.5 may be required.

19.3.4 PLAN REQUIREMENTS FOR 50 CFS≤Q_{100}<500 CFS

All drainage improvement plans may be required to contain a plan and profile as well as adequate cross sections to describe geometry.

The profile, if required, shall show the following: proposed invert, estimated water surface profile, energy grade line, hydraulic jump location and length, original ground at channel center line, top of slope, all utilities and structure crossings, and if necessary, top of proposed embankment and fill including freeboard as required. Other elements from Section 19.3.5 may be required.

19.3.5 PLAN REQUIREMENTS FOR Q_{100}≥500 CFS.

The following are general requirements for drainage improvement plans:

1. Information to determine drainage patterns, including direction of flow for ditches, channels, natural drainageways, etc.
2. The type of work on existing facilities shall be clearly indicated.
3. Temporary construction and permanent easements and rights-of-way lines shall be clearly shown and labeled.
4. Inlet and outlet elevations for all drainage facilities.
5. Type and thickness of drainage facility linings.
6. Type, dimensions, and details of elements providing scour and erosion protection, including aprons, cut-off walls, and bank protection, shall be clearly shown and identified.
7. Existing ground line profile shown as a dashed line and finished grade line as a solid line.
8. Profile line of drainage facilities such as ditches and drainage channels with the slope labeled as a decimal in ft/ft.
9. Information to determine that an adjacent property drainage pattern will not be adversely affected.
10. A HEC-RAS analysis for designed channels and existing washes shall be provided. The model characteristics and results shall be submitted in plan and profile at a scale not to exceed 1"=100'. The plan view shall show existing and proposed ground contours, depict the exact location of the beginning and end point locations of each cross section, the left

and right bank station alignments, the limits of defined reaches, and 100-year floodplain limits. Profiles shall include the existing ground, design water surface, and the energy grade line. This information is to be provided with the design data sheet(s) from the hydrology/hydraulics report. The following data shall also be included in addition to the HEC-RAS standard output tables:

a. Delta water surface elevation change between cross sections.

b. Left bank freeboard.

c. Right bank freeboard.

d. Velocity distribution for each cross section.

11. Profiles of storm drains, culverts, box culverts, and catch basins and connector pipes shall be provided. These profiles shall show gutter elevation, top of curb elevation, catch basin type, depth, size and cross-section, connector pipe invert at the catch basin and at the inlet to the main line storm drain (as well as any grade breaks), connector pipe size and slope in ft/ft, and the location and size of existing and proposed utilities along the profile and in the vicinity of the catch basin. Each catch basin profile shall be labeled by road centerline station or main storm drain stationing if different. Profiles shall also include:

    a. Pipe material and dimensions labels.

    b. Inlet and outlet structures and wingwalls, if any, clearly identified and labeled.

    c. The finished street elevation over the storm drain pipe.

    d. The pipe profile and size.

    e. The design peak discharge (cfs) in each storm drain pipe segment.

    f. The velocity (fps) in each storm drain pipe segment.

    g. Appropriate stationing.

12. On the storm drain plan sheets, the engineer shall show the rim and invert elevations at all existing sanitary sewer manholes.

13. In plan and profile, existing and proposed underground utilities shall be labeled according to size and type. Corresponding alphanumeric labels shall be shown for each utility and depicted in the legend. If the utility is an underground conduit, give all the details such as number of ducts and whether or not the conduit is encased in concrete. Any utilities to be constructed prior to the project shall be shown and so indicated. Conflicts between existing utilities and proposed construction are to be identified. Utilities that are abandoned or to be abandoned shall be indicated as well as those designated to be relocated or removed. The engineer shall contact the appropriate utility if any questions arise about types or locations of underground facilities. Existing and proposed underground tanks shall also be shown.

14. The minimum vertical clearance between a proposed storm drain and all existing utilities shall be 1 foot unless otherwise required by the given utility.

15. Below ground utilities shall be dimensioned from the road center or monument line.

16. Above ground utilities such as power poles, light poles, guys and anchors, irrigation structures, utility pedestals, transformers, switching cabinets, gas regulators, waterline back-flow prevention units, and other features shall be called out including size and pad

elevation, shown in plan view, and stationed relative to the adjacent road monument line or centerline from the street side face of the utility (e.g. 12+33 R 32').

17. When below ground appurtenances (utilities, monuments, tanks, valve boxes, and other features) depicted on As-Built or "Record" drawings cannot be field located, they shall be shown and labeled as "not found".
18. The following items shall be shown on storm drain plan and profile sheets:
    a. New storm drain pipe
    b. Manholes/Junction structures
    c. Catch basins
    d. Connector pipe
    e. Pipe collars
    f. Prefabricated pipe fittings
    g. Other drainage appurtenances (headwalls, trash racks, drop inlets, hand rails, pipe supports, etc.).
19. Where new street paving work joins existing side streets, pavement crown and gutter elevations are required to be displayed and shall be shown in plan view for a minimum of 100 feet beyond the curb return on the side street intersections. Where new street paving work joins an existing street linearly, the existing pavement crown and gutter elevation shall be a minimum of 300 feet beyond the new work to ensure proper drainage and a smooth ride for vehicular traffic.
20. All storm drain plans shall have the following format:
    a. Storm drain designs shall be depicted on single plan/profile sheets.
    b. Main line storm drain plans shall be 1 inch=20 feet horizontal and 1 inch=2 feet vertical, unless otherwise approved.
    c. Scales for connector pipe/catch basin profiles shall be 1 inch=5 feet horizontal and 1 inch=5 feet vertical, unless otherwise approved.
    d. Profile slopes shall be shown in feet per foot dimensions to four significant figures.
    e. Grade breaks shall be stationed with elevations shown. Station and elevations shall also be shown at sheet match lines and at the beginning/end of the storm drain.
    f. Centerline stationing shall be shown on plan and profile. Stationing shall run from the low point, or outfall, and increase toward the high point or inflow. Where the storm drain is being installed in conjunction with a paving project (i.e. depicted on corresponding paving plans), the stationing shall be correlated with the paving project stationing.
    g. Final plan sheets shall be 24 inch x 36 inch. As-built plans shall be 24 inch x 36 inch ink on mylar.
    h. Letter size on full size drawings shall be 14 point minimum.
    i. Title blocks shall be located in the lower right-hand corner of the plans and shall include the title "Grading and Drainage Plans".

j. Storm drain diameters shall be shown in plan and profile without reference to material type.

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20 REVISION PROCESS

The revision process includes a 2-tier approach, as follows:

Tier 1 Revisions. Tier 1 revisions are all changes that are minor in nature. Minor revisions only require approval of the MOHAVE COUNTY ENGINEER. Such revisions do not require a public approval process or approval by the Flood Control District Board of Directors or the Mohave County Board of Supervisors. Minor Revisions are defined as errata, typographical errors and any non-substantive changes that do not affect policy or technical standards.

Tier 2 Revisions. Tier 2 revisions are all other changes to the Drainage Design Manual. Tier 2 revisions require a public notification and review process, and approval by the MOHAVE COUNTY ENGINEER, the Flood Control District Board of Directors and the Mohave County Board of Supervisors.

Those seeking changes to policies or standards contained in this manual must make a formal submittal to the MOHAVE COUNTY ENGINEER stating the present policy/standard, identifying the proposed change(s), and providing comprehensive justification for the change. A review committee, appointed by the MOHAVE COUNTY ENGINEER, will convene periodically to review requested changes. If proposed changes are found appropriate by the review committee, the manual will be revised in draft form, posted on the Mohave County Flood Control Drainage Design Manual web page at:

Drainage Design Manual for Mohave County

and notices send out to holders of the manual soliciting review and comments. A notice regarding the availability of the new draft document for review and comment and the review period will be posted on the Mohave County Flood Control web page. Public review comments received will be carefully considered and changes made if appropriate. The revised manual will be forwarded to the Flood Control District Board of Directors and the County Board of Supervisors for approval.

Amendment application forms are available from Mohave County Flood Control District. Six copies of the completed application and supporting documents should be delivered to Mohave County Public Works. Upon review and certification of a complete submittal, a date will be assigned at which time the committee will review requested amendments.

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22 GLOSSARY

100-year Storm/Flood

A storm or flood with a one (1) percent chance of occurring or being exceeded within any given year.

Adverse Impacts

Any physical action performed in a floodplain that adversely impacts the property and rights of others. An adverse impact can be measured by an increase in flood stages, flood velocity, flows, the potential for erosion and sedimentation, degradation of water quality, or increased cost of public services.

All Weather Access

Each lot within a subdivision shall have at least one vehicular access route which, regardless of street width design classification, provides access to and from the lot for private and emergency vehicles during flood events. Such routes are referred to as "All Weather Access" routes.

Base Flood Elevation

The water surface elevation of a flood having a one percent (1%) chance of being equaled or exceeded in any given year.

Best Management Practices (BMPs)

Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants to stormwater discharges. BMPs also include treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from outdoor storage areas.

Bridge

Structures designed to span a watercourse, including bridges for vehicular roadways and pedestrian-only uses.

Conditional Letter of Map Amendment (CLOMA)

A letter from FEMA stating that a proposed structure that is not to be elevated by fill would not be inundated by the 100-year flood if built to the proposed finished floor elevation.

Conditional Letter of Map Revision (CLOMR)

A letter from FEMA commenting on whether a proposed project, if built as proposed, would justify a map revision.

Conditional Letter of Map Revision Based on Fill (CLOMR-F)

A letter from FEMA stating that a parcel of land or proposed structure that is to be elevated by fill would not be inundated by the 100-year flood if fill is placed on the parcel as proposed or the structure is built as proposed.

Culvert

Buried pipe or box hydraulic conveyance structure designed to convey stormwater from one side of a roadway, embankment, or service area to the other side.

Erosion

The wearing away of the earth's surface by running water.

Design Storm

The storm frequency and duration that a drainage facility is designed for, as a minimum.

FEMA 100-year Floodplain

An area of ground described by a FEMA/FIRM map as a potential flood hazard, or the delineation of a potential flood hazard.

FEMA Regulatory Floodway

A "Regulatory Floodway" means the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. In Arizona, that height is one (1) foot.

Lowest Floor Elevation

The elevation of the lowest floor of the lowest enclosed area of a structure, including the basement.

First Flush

The initial or early stages of stormwater runoff from a storm event which commonly delivers a disproportionately large amount of previously accumulated pollutants due to the rapid rate of runoff. The first flush is defined as the first one-half (1/2) inch of direct runoff from the contributing drainage basin.

Letter of Map Amendment (LOMA).

A letter from FEMA stating that an existing structure or parcel of land that has not been elevated by fill would not be inundated by the 100-year flood.

Letter of Map Revision (LOMR)

A letter from FEMA officially revising the current FIRM to show changes to floodplains, floodways, or flood elevation. Physical changes include watershed development, flood control structures, etc.

Letter of Map Revision Based on Fill (LOMR-F)

A letter from FEMA stating that an existing structure or parcel of land that has been elevated by fill would not be inundated by the 100-year flood.

MS4

Municipal separate storm sewer systems (MS4s) that often transport polluted stormwater runoff to, and ultimately discharge into, local rivers and streams without treatment. EPA's Stormwater Phase II Rule establishes an MS4 stormwater management program that is intended to improve the Nation's waterways by reducing the quantity of pollutants that stormwater picks up and carries into storm sewer systems during storm events.

A "Small MS4" is any MS4 not already covered by the EPA Phase I program as a medium or large MS4.

Pollutant

Fluids, contaminants, toxic wastes, toxic pollutants, dredged spoil, solid waste, substances and chemicals, pesticides, herbicides, fertilizers and other agricultural chemicals, incinerator residue, sewage, garbage, sewage sludge, munitions, petroleum products,

chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and mining, industrial, municipal and agricultural wastes or any other liquid, solid, gaseous or hazardous substances.

Physical Map Revision (PMR)

A reprinted FIRM incorporating changes to floodplains, floodways, or flood elevations. Because of the time and cost involved to change, reprint, and redistribute a FIRM, a PMR is usually processed when a revision reflects increased flood hazards or large-scope changes.

Regulatory Flood Elevation

Regulatory Flood Elevation means an elevation one foot (1') above the Base Flood Elevation for a Watercourse for which the Base Flood Elevation has been or shall be as determined by the criteria developed by the Director of ADWR (ADEM or other designated agency) for any other and/or all other Watercourses.

Regulatory Floodway (or Floodway)

Regulatory Floodway (or Floodway): channel of a river or other Watercourse and the adjacent land areas that must be reserved in order to discharge the Base Flood without cumulatively increasing the Water Surface Elevation more than one (1) foot.

Scour

Localized erosion in a channel resulting from a physical obstruction to flow.

Sedimentation

The depositing of sediment by fluvial processes.

Subdivision

The definition from the current version of the Mohave County Land Division Regulations is used for the purposes of this document.

SWPPP

A "stormwater pollution prevention plan." A SWPPP may also be called a "construction best practices plan," "sediment and stormwater plan," "erosion, sedimentation, and pollution prevention plan," or similar term. The SWPPP (or similarly named plan) is

generally required to comply with EPA's or the state's stormwater construction general permit.

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DRAINAGE DESIGN MANUAL FOR MOHAVE COUNTY

APPENDICES

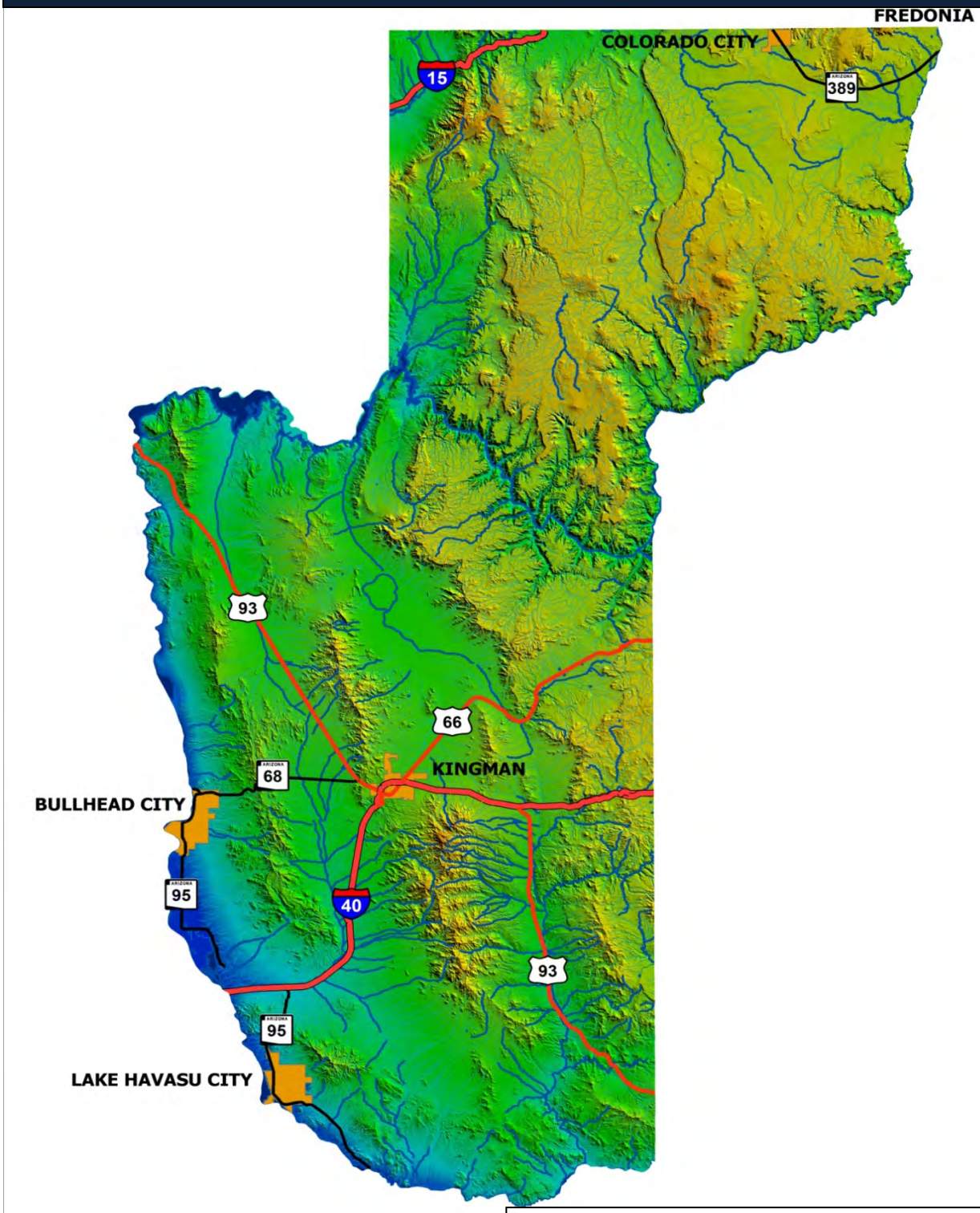

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Table D.10 AZ629 Coconino County Area North Kaibab Part D-91
Table D.11 AZ631 Coconino County Central Part D-95
Table D.12 AZ637 Yavapai County Western Part D-99

Table D.13 AZ657 Kofa Area, Arizona, Parts Of La Paz And Yuma Counties..... D-105
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A. HYDROLOGY EXAMPLES

A.1 RAINFALL EXAMPLES

A.1.1 D-D-F AND I-D-F DATA FOR USE WITH THE RATIONAL METHOD

The Depth-Duration-Frequency (D-D-F) and Intensity-Duration-Frequency (I-D-F) data for use with the Rational Method can be generated in three ways.

Manually using Figure B.1 through Figure B.60.
Using the manual method within the DDMSW computer program.
Using ESRI ArcMap Shape files within the DDMSW computer program.
The use of each method will be demonstrated for the following problem:
Problem: A D-D-F and an I-D-F are needed for a small project in Kingman, AZ. The site is located in the west half of Section 9, T21N, R16W, G and SRM, and overlaps into Section 8.

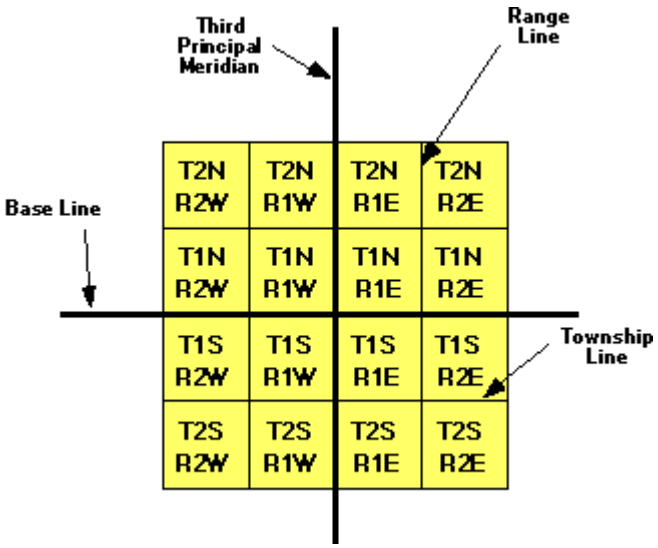
A.1.1.1 Example Using the Manual Method

Solution: The first step is to assemble copies of Figure B.1 through Figure B.60. Then the site must be located on each figure. Sites are located on the figures by use of world coordinates or by use of the Federal Township and Range System. A world coordinate graticule grid (latitude and longitude) with a 30-second resolution is shown on each figure. Also shown are the grid of township and range lines from the Federal Township and Range System. As a refresher, a basic graphical representation of the Federal Township and Range System is shown on Figure A.1. Using this information, a site can be located within the level of positional accuracy of the NOAA Atlas 14 point rainfall data depicted on the figure.

The T21N and R16W grid cell can be easily located on each figure. Then the location of Section 9 can be estimated visually by understanding where Section 9 is located using the standard system shown on Figure A.1. The example site location is identified on the Figure B.2 2-year 10-minute isopluvial map as shown on Figure A.2. Interpolating the isopluvial lines at the site location, the 2-year 10-minute point precipitation is estimated at 0.39 inches. This value is then entered in the appropriate cell in Table A.1. This same process was duplicated for the fifty-nine (59) other isopluvial maps and the estimated point precipitation values tabulated in Table A.1.

Figure A.1 Federal Township and Range System

The largest grouping is the township which is named in reference to a Principal Meridian (P.M.) and a Baseline. T2N, R1E refers to Township 2 North (of the Baseline), Range 1 East (of the Principal Meridian). Surveys in Arizona are governed by the Gila and Salt River Base Line and Meridian. The Initial Point is at the intersection of these two lines. The Base Line runs east and west though this point and the Meridian runs north and south through the point. Land descriptions and property boundaries are governed by and identified by this point.



Within each township are 36 sections, each one mile square. Each section contains approximately 640 acres. The sections are numbered from 1 to 36 in the following order.

35	36	31	32	33	34	35	36	31	32
2	1	6	5	4	3	2	1	6	5
11	12	7	8	9	10	11	12	7	8
14	13	18	17	16	15	14	13	18	17
23	24	19	20	21	22	23	24	19	20
26	25	30	29	28	27	26	25	30	29
35	36	31	32	33	34	35	36	31	32
2	1	6	5	4	3	2	1	6	5

Figure A.2 I-D-F example site location for 2-year 10-minute precipitation

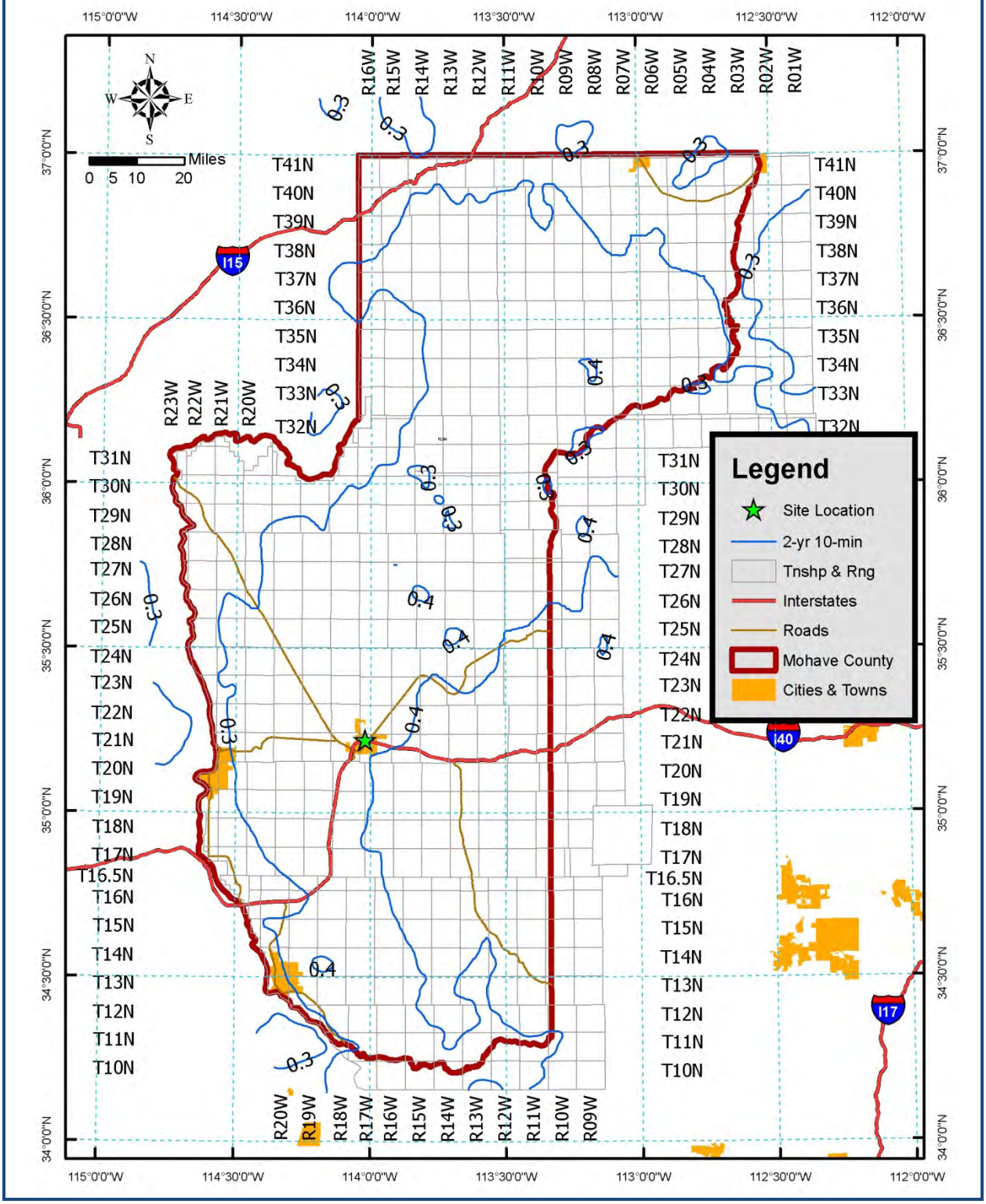


Table A.1 Rainfall Depth-Duration-Frequency for Kingman, AZ (manual)

(estimated using Figure B.1 through Figure B.60)

Duration	Rainfall Depth, in inches Storm Frequency, in years					
	2	5	10	25	50	100
5-min	0.23	0.37	0.44	0.56	0.60	0.69
10-min	0.39	0.56	0.66	0.79	0.90	1.05
15-min	0.48	0.68	0.80	0.99	1.18	1.29
30-min	0.64	0.90	1.09	1.38	1.58	1.70
1-hour	0.79	1.10	1.37	1.68	1.96	2.18
2-hour	0.88	1.26	1.50	1.90	2.20	2.49
3-hour	0.95	1.29	1.59	2.00	2.41	2.80
6-hour	1.09	1.49	1.86	2.36	2.76	3.30
12-hour	1.29	1.77	2.17	2.76	3.10	3.50
24-hour	1.58	2.17	2.75	3.40	3.90	4.40

The next step is to use the point precipitation data from Table A.1 to compute the rainfall intensity for each storm duration and frequency combination. This is done as follows:

$$I_{F,D} = \frac{P_{F,D}}{D} \qquad \text{A.1}$$

where:

$I_{F,D}$ = rainfall intensity in inches per hour for frequency F and duration D.
$P_{F,D}$ = point precipitation in inches for frequency F and duration D.
D = storm duration D in hours.

Applying Equation A.1 for the 5-minute 2-year storm:

$$I_{2-\text{yr},5-\text{min}} = \frac{0.23}{\frac{5}{60}}$$

= 2.76 inches/hour.

Insert the computed value in Table A.2 in the 2-year 5-minute cell. Apply Equation A.1 to all values from Table A.1 and place the results in Table A.2.

Table A.2 Rainfall Intensity-Duration-Frequency for Kingman, AZ (manual)

(computed using the data in Table A.1)

Duration	Rainfall Intensity, in inches/hour					
	Storm Frequency, in years					
	2	5	10	25	50	100
5-min	2.76	4.44	5.28	6.72	7.20	8.28
10-min	2.34	3.36	3.96	4.74	5.40	6.30
15-min	1.92	2.72	3.20	3.96	4.72	5.16
30-min	1.28	1.80	2.18	2.76	3.16	3.40
1-hour	0.79	1.10	1.37	1.68	1.96	2.18
2-hour	0.44	0.63	0.75	0.95	1.10	1.25
3-hour	0.32	0.43	0.53	0.67	0.80	0.93
6-hour	0.18	0.25	0.31	0.39	0.46	0.55
12-hour	0.11	0.15	0.18	0.23	0.26	0.29
24-hour	0.07	0.09	0.11	0.14	0.16	0.18

A.1.1.2 Example using the DDMSW Manual Method

NOTE: *To apply this method, the Mohave County-specific version of the DDMSW computer program must be installed on your computer as well as Adobe Acrobat Reader. Both are free programs. DSMSW can be downloaded from the Mohave County web site at* DDMSW Download *and Adobe Acrobat Reader can be downloaded at* http://www.adobe.com*.*

Solution: The NOAA Atlas 14-point precipitation data is supplied by NOAA in a GIS grid format with a cell size of about 2,500 feet square. This method is applied by determining the average point precipitation value of the cell or cells that cover the subject watershed. In DDMSW, the user selects the cell or cells that cover the project site. DDMSW then "looks up" the point precipitation values for each storm frequency and duration for each cell or cells specified and compute an average value for every storm frequency-duration combination. To select the project cells, the general project site location is identified by the user from an index map contained within DDMSW in Adobe PDF format. The index map is on page 1 of the PDF (100 pages). The user locates the map covering the project watershed (Figure A.3) and then moves to the page where the more detailed map is located (Figure A.4).

Figure A.3 DDMSW NOAA Atlas 14 index map

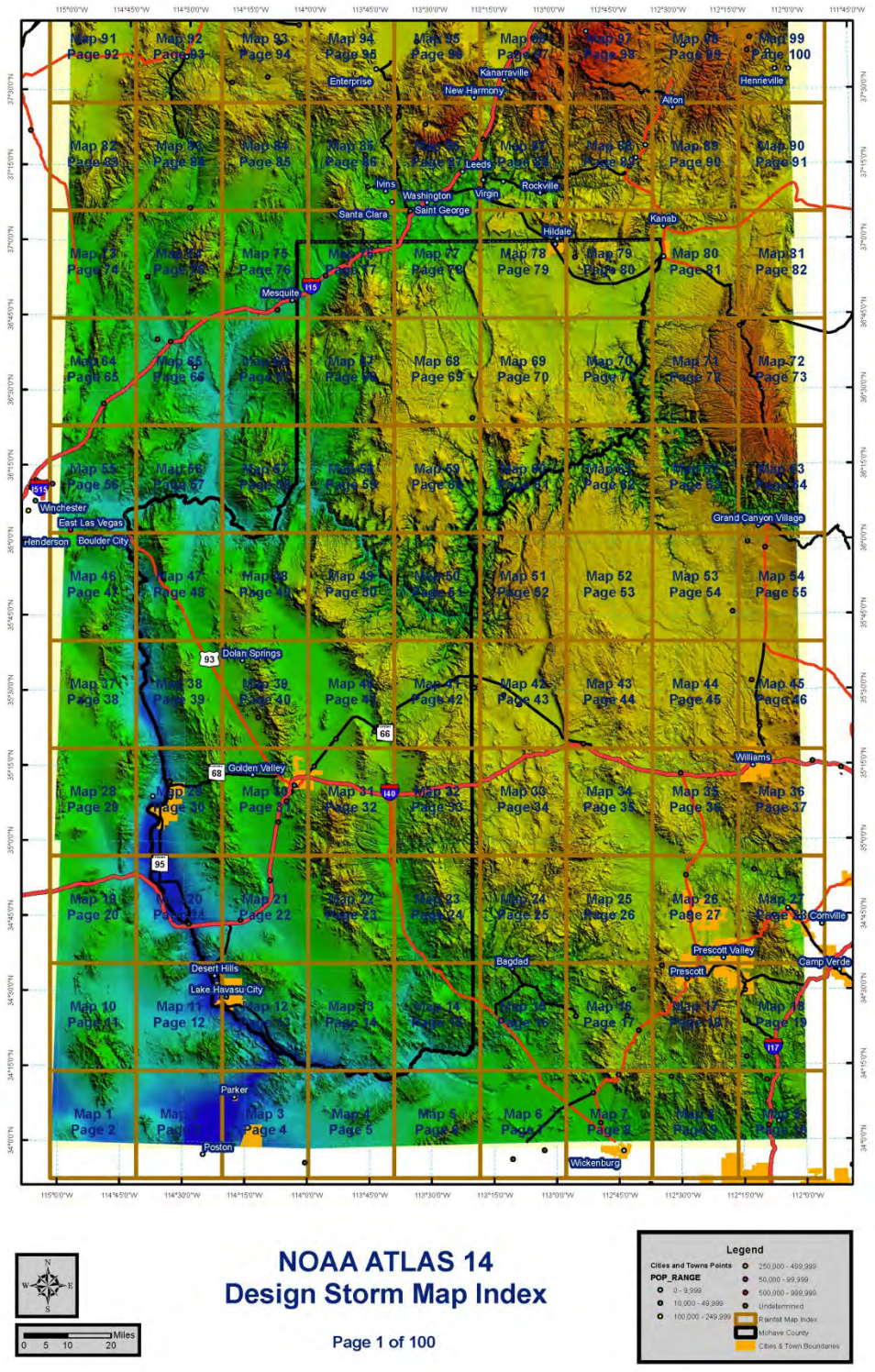
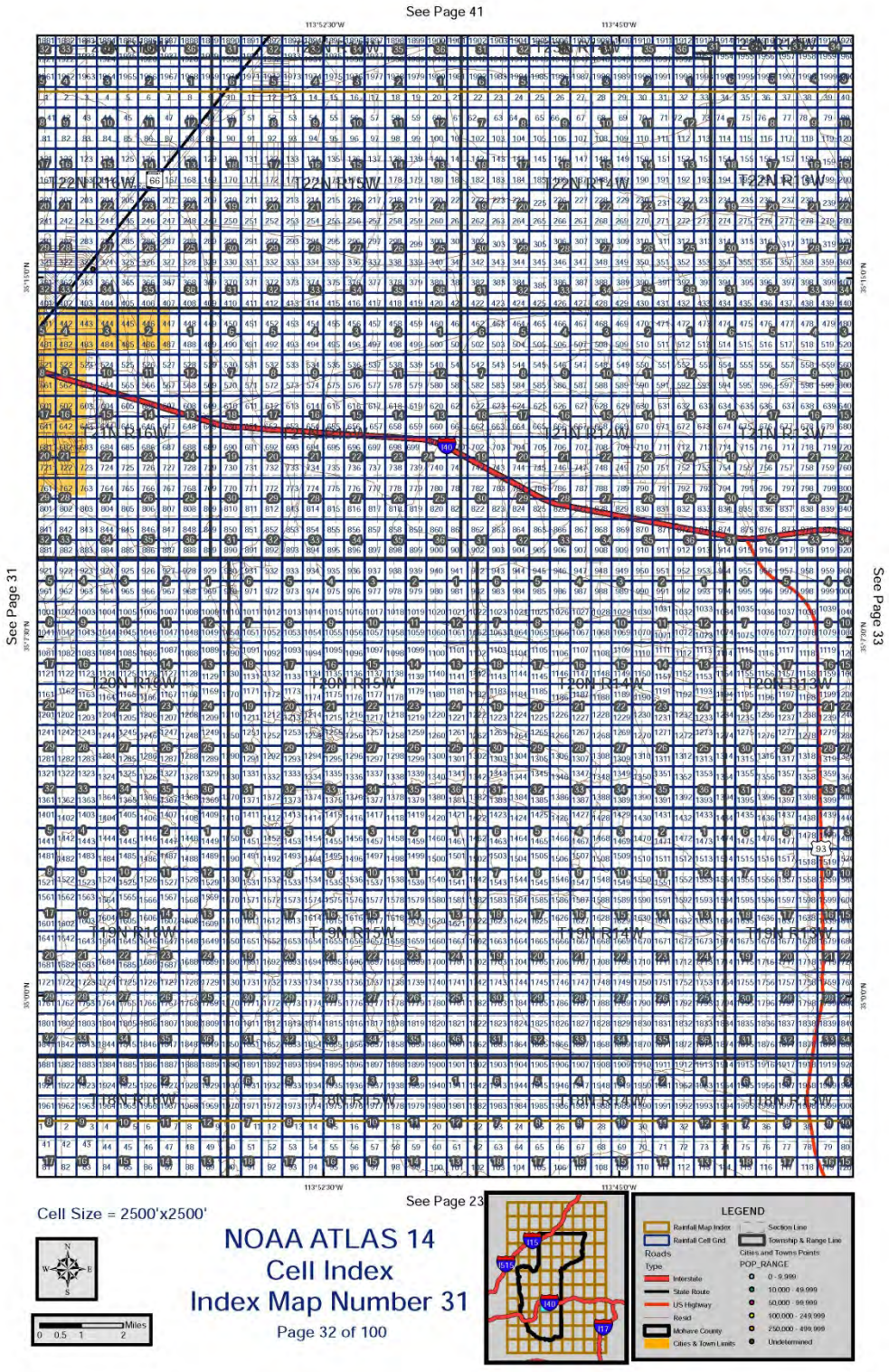


Figure A.4 DDMSW NOAA Atlas 14 detailed location map



Using Figure A.3, it can be seen that the project site, in T21N, R16W, is located on Map 31 (page 32). Moving to Map 31, as shown on Figure A.4, the Sections 8 and 9 must be located. The sections are labeled in white with a brown background. The NOAA Atlas 14 cells are labeled blue. Grid cells 521, 522, 561 and 562 approximate the location of the watershed in the west half of Section 9 and overlapping into Section 8.

In DDMSW, establish a new project then perform the following steps:

1. Open menu item *Hydrology*|*Rainfall*.
2. Set the *Data Source* to Manual.
3. Click on the *Maps* button to load the PDF of the NOAA Atlas 14 Index Maps.
4. Locate the project site on the overview index page and see that detailed Map Number 31 is needed.
5. Move to PDF page 32 to find Map Number 31.
6. Verify that Map Number 31 depicts Township 21N, Range 16W. Estimate the location of Section 9 on the map and write down the numbers of the grid cells covering the project watershed (521, 522, 562 and 562).
7. Close the PDF file and return to DDMSW.
8. Use the *Multiple Map Selection Menu*. The table on the left side of the window with the headings *Map*, *From*, and *To*, should be empty.
9. Click on *Add*.
10. Click on the *Magnifying Glass* icon to the right of *Map Index* and select Map 31.
11. Enter 521 in the *From* field and 522 in the *To* field. Click Save.
12. Click on *Add*.
13. Enter 561 in the *From* field and 562 in the *To* field. Click Save.
14. Click on *Update*. The *Average Rainfall Data for Project* table should be updated and match the values listed in Table A.3.

Table A.3 Rainfall Depth-Duration-Frequency for Kingman, AZ (DDMSW mm)

(estimated using the DDMSW Manual Method)

Duration	Rainfall Depth, in inches Storm Frequency, in years					
	2	5	10	25	50	100
5-min	0.254	0.357	0.429	0.526	0.597	0.671
10-min	0.387	0.543	0.653	0.801	0.907	1.022
15-min	0.480	0.673	0.810	0.992	1.127	1.267
30-min	0.646	0.907	1.091	1.336	1.518	1.706
1-hour	0.800	1.122	1.350	1.654	1.878	2.111
2-hour	0.874	1.234	1.512	1.891	2.203	2.529
3-hour	0.936	1.302	1.599	2.021	2.375	2.757
6-hour	1.101	1.509	1.833	2.302	2.686	3.107
12-hour	1.284	1.754	2.134	2.653	3.076	3.531
24-hour	1.597	2.189	2.650	3.299	3.819	4.368

A.1.1.3 Example using the DDMSW GIS Method

Solution: Create an ESRI shape file containing a polygon of the total study watershed area. The fields required for the various ESRI shape files used within DDMSW are listed in Table A.4. Note that the rainfall shape file for the overall watershed boundary polygon only requires one field, the Major Basin ID. For this example, a polygon of the Kingman corporate boundary is used to obtain an average D-D-F for the entire city (Figure A.5). DDMSW overlays the polygon on the NOAA Atlas 14 rain cell grid, which is a GIS version of the grids shown in the PDF file used for the DDMSW manual method (see Figure A.4). The grid cells that touch and are contained within the polygon are selected and an average point precipitation depth computed for each frequency-duration combination. To implement the GIS approach using DDMSW, the following steps should be followed. For this example, the results are shown in Table A.5.

1. Open menu item *Hydrology*|*Rainfall*.
2. Set the *Data Source* to GIS.

   3. Click on the *Select a* file button and point DDMSW to the desired polygon of the entire watershed under consideration.

4. Click on *Update*.

Table A.4 DDMSW required fields for GIS shape files

Map	Field Name	Type and Length	Description
Rainfall	BASINID	Character 2	Major Basin ID
Sub Basin	AREAID	Character 6	Unique ID
	BASINID	Character 2	Major Basin ID
	AREASF	Numeric 12.0	Area in square feet
Land Use	LUCODE	Character 15	Land use code
Soils	SOIL_LID	Numeric 15.0	Soils code
L_{ca}	AREAID	Character 6	Unique ID (same as sub basin)
	BASINID	Character 2	Major Basin ID
	LENGTH	Numeric 12.0	Length in feet
	USGE	Numeric 9.2	Upstream ground elevation
	DSGE	Numeric 9.2	Downstream ground elevation
T_c	AREAID	Character 6	Unique ID (same as sub basin)
	BASINID	Character 2	Major Basin ID
	LENGTH	Numeric 12.0	Length in feet
	USGE	Numeric 9.2	Upstream ground elevation
	DSGE	Numeric 9.2	Downstream ground elevation

Figure A.5 DDMSW NOAA Atlas 14 Kingman-area polygon

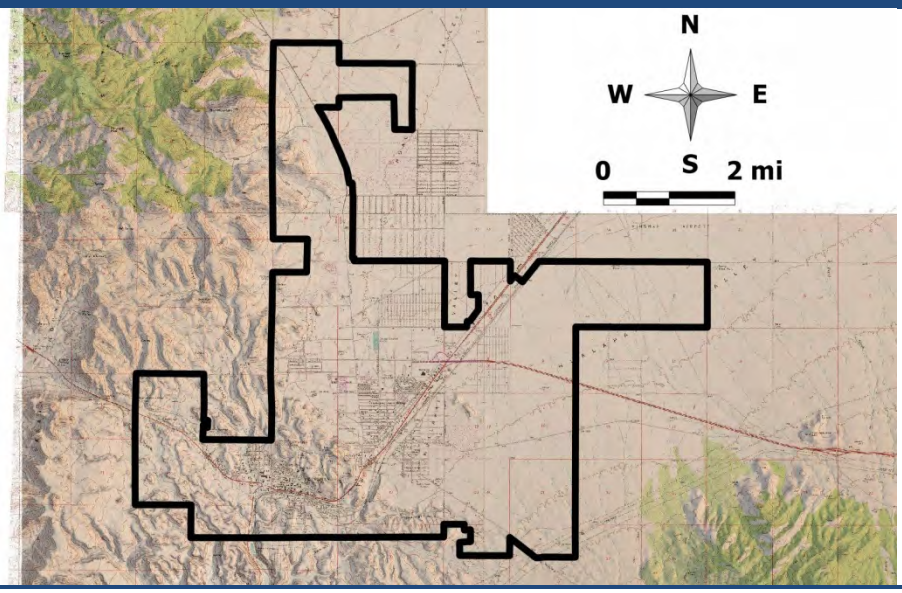


Table A.5 Rainfall Depth-Duration-Frequency for Kingman, AZ (DDMSW GIS)

(estimated using the DDMSW GIS Method)

Duration	Rainfall Depth, in inches Storm Frequency, in years					
	2	5	10	25	50	100
5-min	0.252	0.354	0.427	0.526	0.599	0.676
10-min	0.383	0.539	0.651	0.800	0.912	1.029
15-min	0.475	0.669	0.807	0.992	1.131	1.276
30-min	0.640	0.901	1.087	1.336	1.523	1.719
1-hour	0.792	1.115	1.345	1.654	1.886	2.127
2-hour	0.870	1.230	1.509	1.894	2.211	2.545
3-hour	0.932	1.300	1.598	2.022	2.379	2.766
6-hour	1.097	1.506	1.832	2.304	2.691	3.114
12-hour	1.280	1.752	2.133	2.656	3.086	3.540
24-hour	1.580	2.168	2.625	3.272	3.789	4.340

An important consideration when applying the DDMSW GIS method is to be sure the following projection and coordinate system is used when preparing all shape files for use with the Mohave County-specific version of DDMSW:

State Plane Coordinate System, NAD 83, Arizona West, International feet.

The Mohave County DDMSW NOAA Atlas 14 GIS rainfall data is in the above projection. To obtain meaningful results, all shape files must be in the Mohave County standard projection and coordinate system.

An ESRI ArcView license is NOT required to apply the DDMSW GIS method. Shape files can, of course, be created using ArcView (ESRI). Other options include Global Mapper (Global Mapper) AutoCAD Civil 3D and Bentley Map , Map Info (MapInfo Pro), and Manifold Project (MANIFOLD).

A.1.1.4 Comparison of Methods

The first comparison is between the Manual Method and the DDMSW Manual Method. Closely examine the results in Table A.1 and Table A.3. The differences in point precipitation vary from hundredths of an inch to as much as 0.19 inches for the 100-year 6-hour storm. The differences are minimal and will not have a significant effect on hydrologic modeling results for small watersheds based on either method when applying the Rational Method.

The second comparison is between the DDMSW Manual Method and the DDMSW GIS method. Keep in mind that the DDMSW Manual Method example is for a site-specific location within Kingman in Section 9, T21N, R16W. The DDMSW GIS Method example is for the City of Kingman corporate area. Closely examine the results displayed in Table A.3 and Table A.5. The differences are minor, with variances measured in hundredths of an inch. This means that the NOAA Atlas 14-point precipitation data only has slight variations for all considered durations and frequencies across the entire Kingman metropolitan area. The data in Table A.5 can be used with confidence for rainfall-runoff modeling for watersheds within the Kingman corporate boundary.

A.1.2 RAINFALL DATA FOR USE WITH THE UNIT HYDROGRAPH METHOD

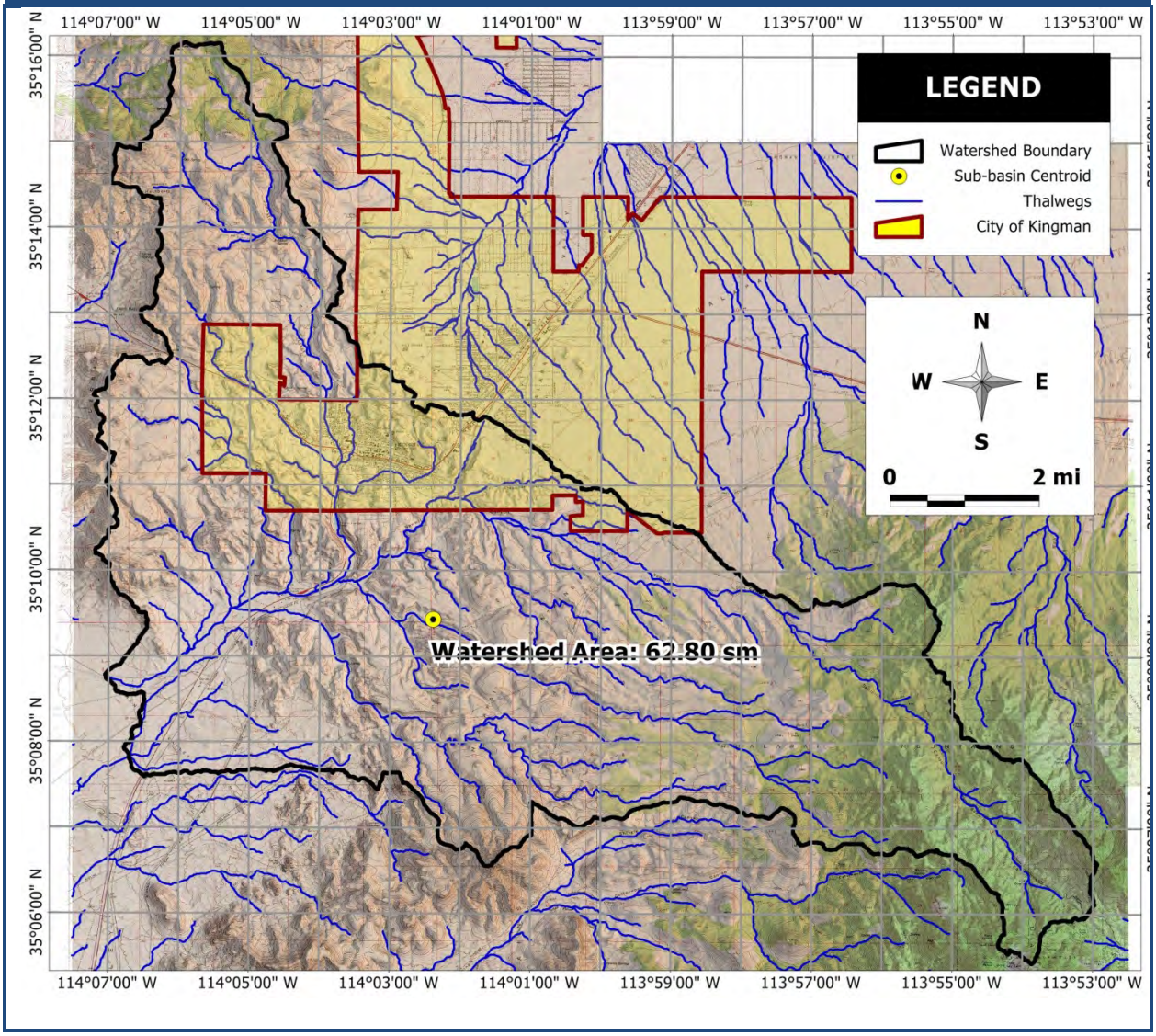
The data necessary for use with the unit hydrograph method is as follows:

1. The following point precipitation values for the storm to be modeled (ie. 100-yr, 10-yr, etc.). Items g and h are only necessary for storms longer than 6-hours.
    a. 5-min, b. 15- min, c. 1-hr, d. 2- hr, e. 3- hr, f. 6- hr, g. 12- hr, h. 24- hr.

The depth area curve for the storm to be modeled.

Problem: Point precipitation data are needed for a HEC-1 model of a large watershed partially within, and south of, Kingman, AZ. The site is located as shown on Figure A.6. Prepare the HEC-1 precipitation records for a 100-year 24-hour storm.

Figure A.6 Unit Hydrograph Method watershed limits map



A.1.2.2 Example Using the Manual Method

Solution: Prepare a watershed location map as shown on Figure A.6. Next, assemble copies of Figure B.51, Figure B.53, and Figure B.55 through Figure B.60. There is a significant elevation difference from the top to the bottom of the watershed; 8,054 to 2,814. Therefore, orographic effects could significantly affect precipitation. Due to the scale and lack of resolution of the isopluvial maps, it is not reasonable to attempt to determine multiple precipitation values for representative portions of the watershed. Therefore, accounting for orographic effects is not a viable option for this watershed when using this method. The centroid of the overall

watershed is used to estimate the average point precipitation values. The same basic procedure applied in Appendix A.1.1.1 should be followed here. However, instead of using the Section, Township, and Range information, the world coordinates for the watershed centroid will be used to location the position on the NOAA Atlas 14 isopluvial maps from Appendix B. The coordinates of the watershed centroid are: 35°09'26" North by -114°02'23" West.

A world coordinate graticule grid (latitude and longitude) with a 30-second resolution is shown on each isopluvial figure. Using this information, the point precipitation values were interpolated from Figure B.51, Figure B.53, and Figure B.55 through Figure B.60 and are shown in Table A.6.

Table A.6 Unit Hydrograph Method point precipitation estimate (manual)

ID	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Watershed	0.70	1.31	2.20	2.65	2.83	3.40	3.70	4.50

Depth-area reduction factors for the 100-year 24-hour storm are determined using the data in Table 7.3. The results are shown in Table A.7.

Table A.7 Unit Hydrograph Method depth-area reduction (manual)

Watershed Area	Depth-Area Factor	Areally Reduced Precipitation
0	1.000	4.50
10	0.950	4.28
20	0.919	4.14
30	0.900	4.05
40	0.887	3.99
50	0.877	3.95
60	0.870	3.92
70	0.863	3.88

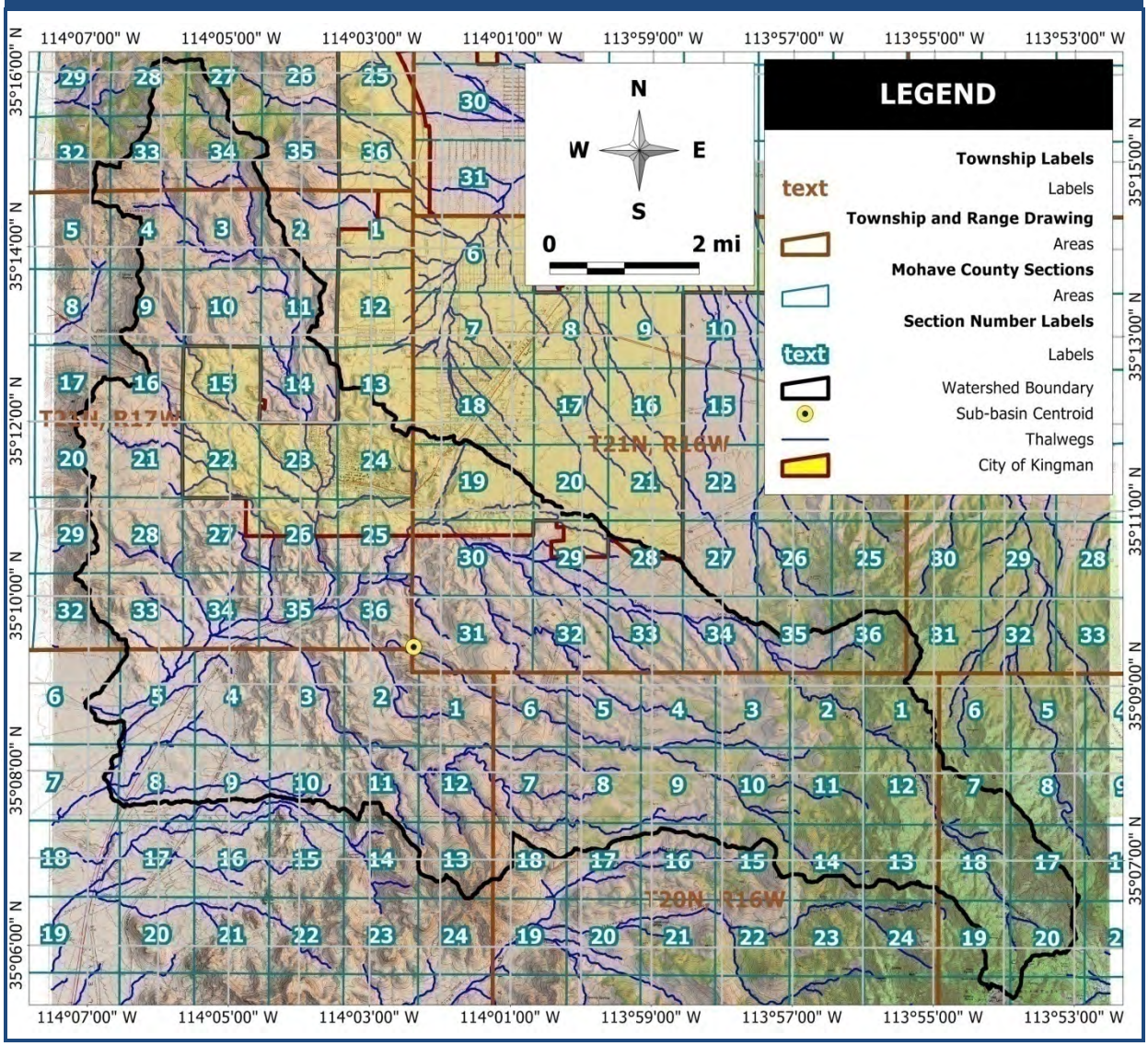
A.1.2.3 Example using the DDMSW Manual Method

NOTE: *To apply this method, the Mohave County-specific version of the DDMSW computer program must be installed on your computer as well as Adobe Acrobat Reader. Both are free programs. DSMSW can be downloaded from the Mohave County web site at* DDMSW Download *and Adobe Acrobat Reader can be downloaded at* http://www.adobe.com*.*

page not found

Solution: Follow the same approach as outlined in Appendix A.1.1.2. The Section, Township and Range lines are shown on Figure A.7. Use this information with the PDF map file in DDMSW to locate the project cells. Inspection of the DDMSW PDF Index Map shows that the subject watershed lies on Maps 30 and 31 as shown on Figure A.8. Inspection of these four maps with the section, township and range data yields the following cell numbers listed by Map Number and shown graphically on Figure A.9 and Figure A.10:

Figure A.7 Unit Hydrograph Method watershed limits map



Map 30: 269-270, 308-311, 348-352, 387-392, 427-432, 468-473, 508-513, 548-553, 588-594, 626-635, 666-678, 707-719, 747-760, 787-800, 826-840, 867-880, 907-920, 947-960, 987-1000, 1027-1040, 1067-1080, 1115-1120, and 1156-1158.

Map 31: 721, 761-763, 801-804, 841-849, 881-889, 921-930, 961-970, 1001-1012, 1041-1052, 1081-1093, 1125-1134, 1170-1174, 1211-1214, and 1251-1252.

In DDMSW, establish a new project then perform the following steps:

1. Open menu item *Hydrology*|*Rainfall*.
2. Set the *Data Source* to Manual.
3. Click on the *Maps* button to load the PDF of the NOAA Atlas 14 Index Maps.
4. Locate the project site on the overview index page and see that detailed Map Numbers 30 and 31 are needed.
5. Examine PDF pages 31 and 32 to find Map Numbers 30 and 31, respectively. Determine the cell numbers listed above for each map.
6. Close the PDF file and return to DDMSW.
7. Use the *Multiple Map Selection Menu*. The table on the left side of the wind with the headings *Map*, *From*, and *To*, should be empty.
8. Click on *Add*.
9. Click on the *Magnifying Glass* icon to the right of *Map Index* and select Map 30.
10. Enter 269 in the *From* field and 270 in the *To* field. Click Save.
11. Click on *Add*.
12. Enter 308 in the *From* field and 311 in the *To* field. Click Save.
13. Repeat Steps 11 and 12 for the remaining cells on Map 30.
14. Follow Steps 8 through 13 for cells on Map 31.
15. Click on *Update*. The *Average Rainfall Data for Project* table should be updated and match the values listed in Table A.8.

Figure A.8 DDMSW NOAA Atlas 14 Index Map

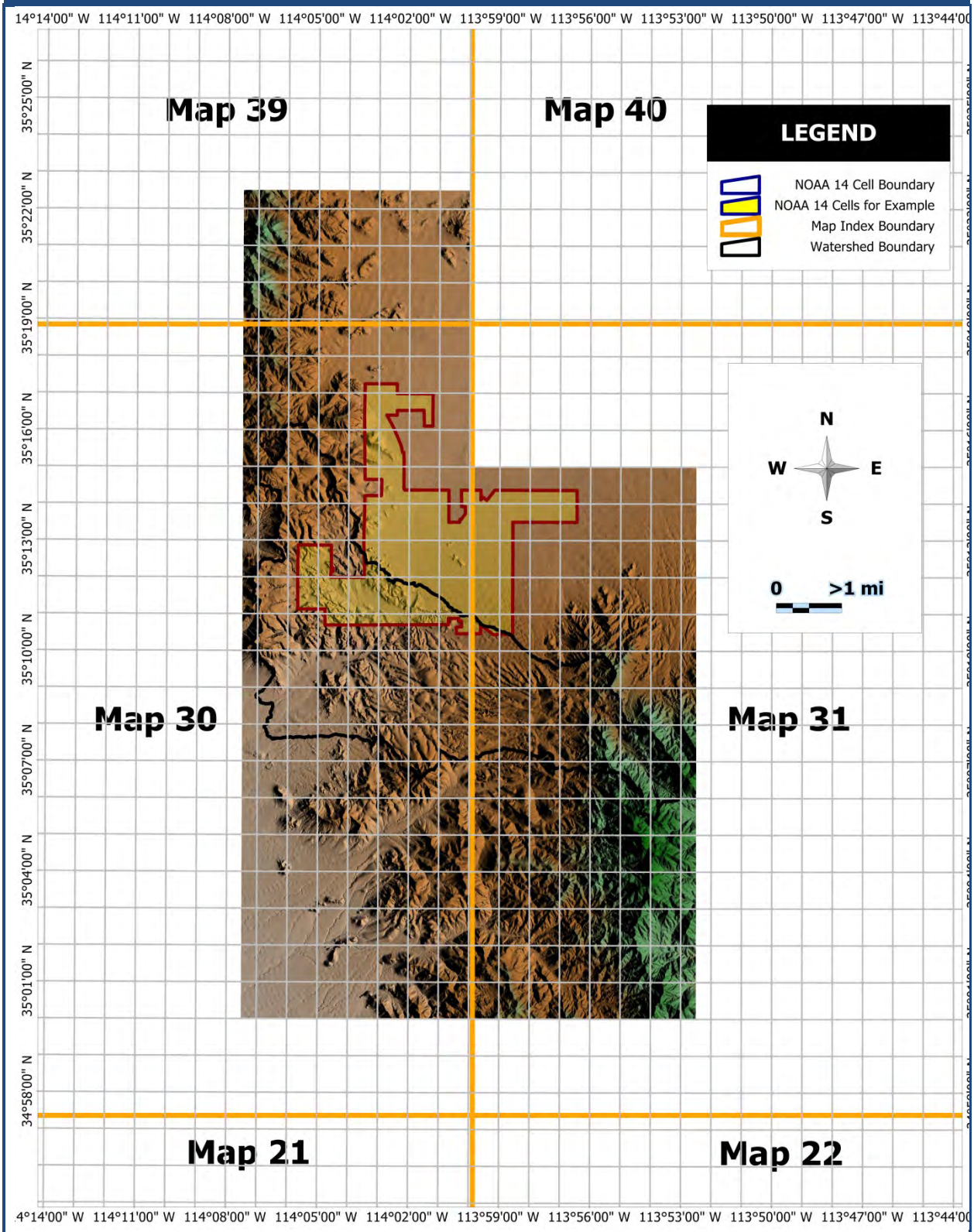


Figure A.9 DDMSW NOAA Atlas 14 Map 30

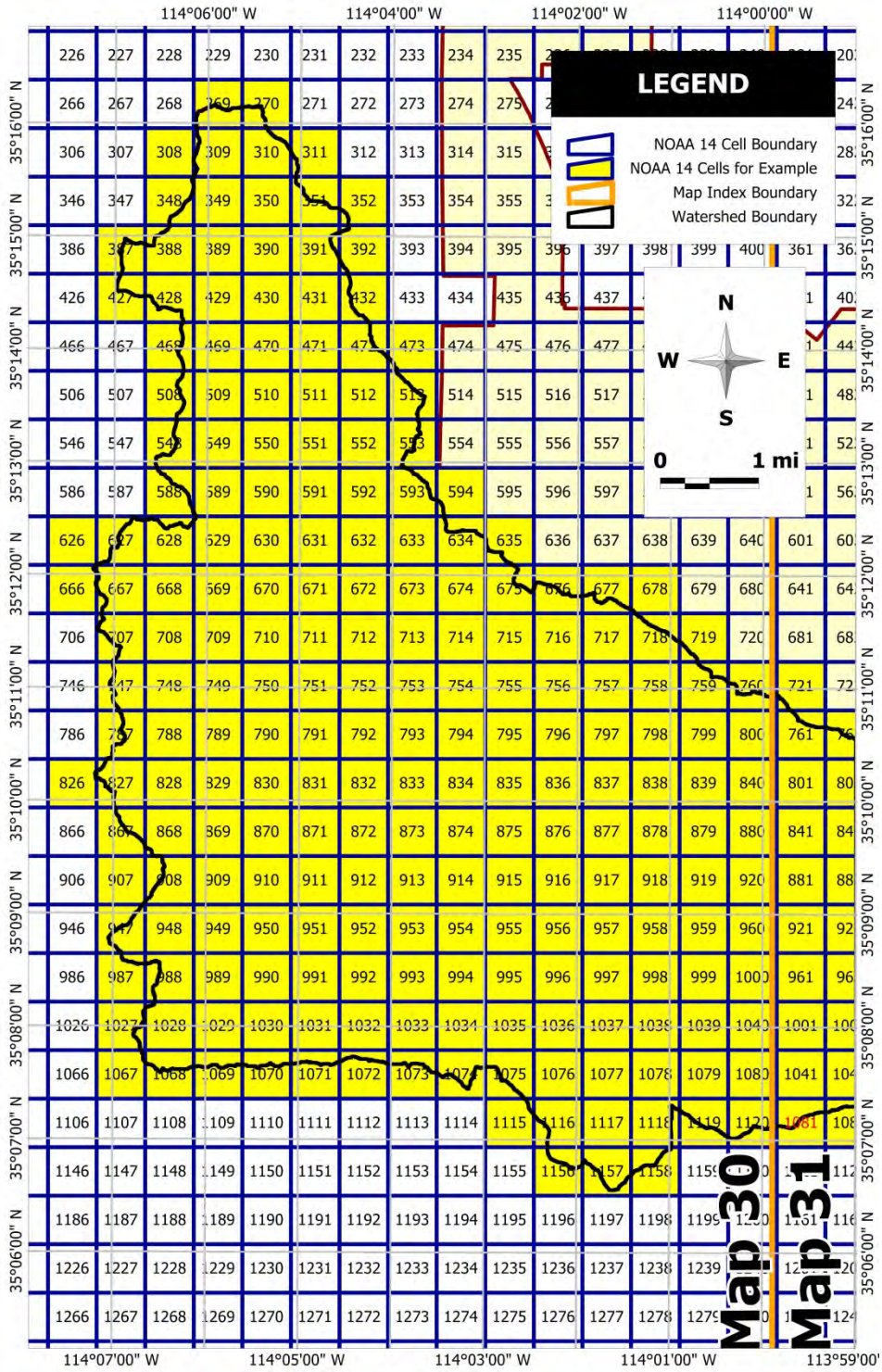


Figure A.10 DDMSW NOAA Atlas 14 Map 31

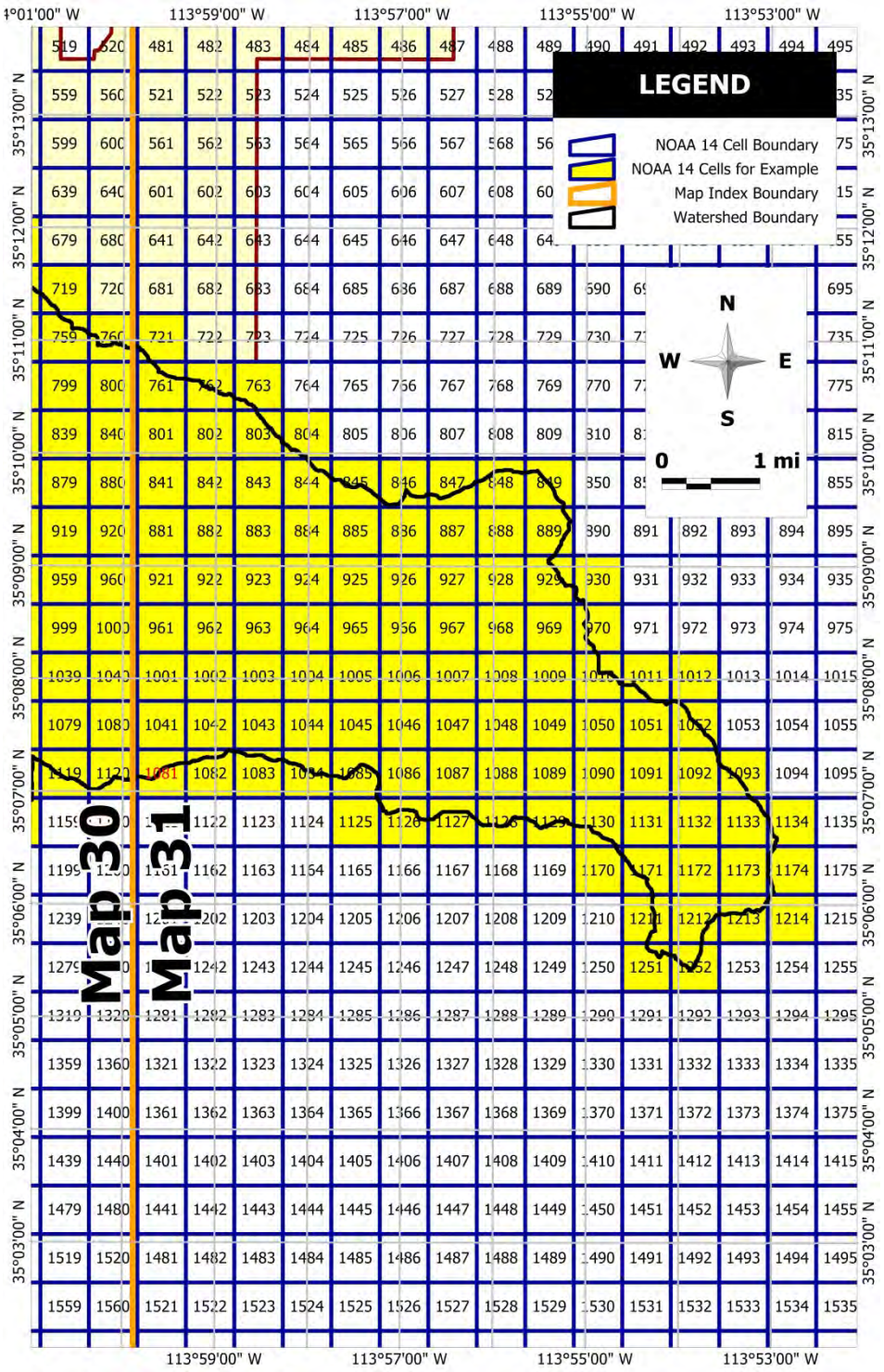


Table A.8 Rainfall D-D-F for Unit Hydrograph Example (DDMSW mm)

(estimated using the DDMSW Manual Method)

Duration	Rainfall Depth, in inches Storm Frequency, in years					
	2	5	10	25	50	100
5-min	0.257	0.363	0.439	0.543	0.622	0.705
10-min	0.391	0.552	0.669	0.826	0.946	1.073
15-min	0.485	0.685	0.829	1.025	1.174	1.331
30-min	0.653	0.922	1.117	1.380	1.581	1.792
1-hour	0.808	1.142	1.382	1.708	1.957	2.218
2-hour	0.894	1.267	1.558	1.963	2.299	2.656
3-hour	0.958	1.338	1.648	2.091	2.464	2.872
6-hour	1.128	1.549	1.888	2.378	2.781	3.222
12-hour	1.320	1.808	2.202	2.746	3.191	3.667
24-hour	1.615	2.219	2.690	3.359	3.894	4.464

The data in Table A.8 can then be used to prepare the needed input data for the HEC-1 PH and JD records as shown in Table A.9 and Table A.10.

Table A.9 Unit Hydrograph Method point precipitation estimate(DDMSW mm)

(results using the DDMSW Manual Method)

ID	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Watershed	0.705	1.331	2.218	2.656	2.872	3.222	3.667	4.464

Depth-area reduction factors for the 100-year 24-hour storm are determined using the data in Table 7.3. The results are shown in Table A.10.

Table A.10 Unit Hydrograph Method depth-area reduction (DDMSW manual)		
Watershed Area	**Depth-Area Factor**	**Areally Reduced Precipitation**
0	1.000	4.464
10	0.950	4.241
20	0.919	4.102
30	0.900	4.018
40	0.887	3.960
50	0.877	3.915
60	0.870	3.884
70	0.863	3.852

A.1.2.4 Example using the DDMSW GIS Method

Solution: Create an ESRI shape file containing a polygon of the total study watershed area. The fields required for the various ESRI shape files used within DDMSW are listed in Table A.4. Note that the rainfall shape file for the overall watershed boundary polygon only requires one field, the Major Basin ID. For this example, a polygon of the entire watershed is used to obtain a watershed-specific D-D-F for the study area (Figure A.6). DDMSW overlays the polygon on the NOAA Atlas 14 rain cell grid, which is a GIS version of the grids shown in the PDF file used for the DDMSW manual method (see Figure A.8 through Figure A.10). The grid cells that touch and are contained within the polygon are selected and an average point precipitation depth computed for each frequency-duration combination. To implement the GIS approach using DDMSW, the following steps should be followed. For this example, the results are shown in Table A.11.

1. Open menu item *Hydrology*|*Rainfall*.
2. Set the *Data Source* to GIS.
3. Click on the *Select* button and point DDMSW to the desired polygon of the entire watershed under consideration.

Click on *Update*.

Be sure to verify that the correct projection and coordinate system is assigned to the GIS shape file used for the watershed limits, as described in Appendix A.1.1.3.

Table A.11 Rainfall D-D-F for unit hydrograph example (DDMSW GIS)

(estimated using the DDMSW GIS Method)

Duration	Rainfall Depth, in inches Storm Frequency, in years					
	2	5	10	25	50	100
5-min	0.257	0.363	0.439	0.543	0.622	0.705
10-min	0.391	0.552	0.669	0.826	0.946	1.073
15-min	0.485	0.685	0.829	1.025	1.174	1.331
30-min	0.653	0.922	1.117	1.380	1.581	1.792
1-hour	0.808	1.142	1.382	1.708	1.957	2.218
2-hour	0.894	1.267	1.558	1.963	2.299	2.656
3-hour	0.958	1.338	1.648	2.091	2.464	2.872
6-hour	1.128	1.549	1.888	2.378	2.781	3.222
12-hour	1.320	1.808	2.202	2.746	3.191	3.667
24-hour	1.615	2.219	2.690	3.359	3.894	4.464

The data in Table A.11 can then be used to prepare the needed input data for the HEC-1 PH and JD records as shown in Table A.12 and Table A.13.

Table A.12 Unit Hydrograph Method point precipitation estimate(DDMSW GIS)

(results using the DDMSW GIS Method)

ID	5-min	15-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Watershed	0.705	1.331	2.218	2.656	2.872	3.222	3.667	4.464

Depth-area reduction factors for the 100-year 24-hour storm are determined using the data in Table 7.3. The results are shown in Table A.13.

Table A.13 Unit Hydrograph Method depth-area reduction (DDMSW GIS)		
Watershed Area	**Depth-Area Factor**	**Areally Reduced Precipitation**
0	1.000	4.464
10	0.950	4.241
20	0.919	4.102
30	0.900	4.018
40	0.887	3.960
50	0.877	3.915
60	0.870	3.884
70	0.863	3.852

A.1.2.5 Comparison of Methods

The results from the three methods for use with the HEC-1 PH and JD records are compared in Table A.14.

Table A.14 Unit Hydrograph Method point precipitation estimate(DDMSW GIS) (results using the DDMSW GIS Method)								
Method	**5-min**	**15-min**	**1-hr**	**2-hr**	**3-hr**	**6-hr**	**12-hr**	**24-hr**
Manual	0.70	1.31	2.20	2.65	2.83	3.40	3.70	4.50
DDMSW Manual	0.705	1.331	2.218	2.656	2.872	3.222	3.667	4.464
DDMSW GIS	0.705	1.331	2.218	2.656	2.872	3.222	3.667	4.464

The most accurate results are expected from the DDMSW GIS Method, so the other two methods are compared with it. Note that the Manual Method has the highest error, especially for the 100-year 24-hour point precipitation. The DDMSW Manual Method and the DDMSW GIS Method are identical. The Manual Method is most acceptable for small watersheds where the difference in point precipitation values are small across the watershed. The DDMSW methods should be used for larger watersheds.

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A.2 RATIONAL METHOD EXAMPLE

A.2.1 PROBLEM STATEMENT

A 212.3 acre mixed-use residential and commercial development is planned in Kingman, AZ for the tract of land shown on Figure A.11. One of the watersheds (71.38 acres) that is contained entirely within the site has been delineated into three (3) sub-basins using available topographic mapping and the proposed street drainage patterns. A storm drain is to be constructed to convey runoff from the residential areas through the commercial tract.

Determine the 10-year, post-development peak discharge at concentration points CP 1 (storm drain inlet) and CP 2 (storm drain outlet). Use both the combined watershed and triangular hydrograph method approaches as defined in Section 7.3.3.2. Compare the results.

A.2.2 GIVEN PARAMETERS

Rainfall depth-duration-frequency statistics were prepared as described in Appendix A.1 and the results listed in Table A.15 and Table A.16.

Time of concentration and land use area data are listed in Table A.17.

The resistance coefficient for all three sub-basins is 0.025 per Table 7.4.

The maximum permissible velocity in the storm drain is 6 fps, and the storm drain length is 918 feet, as shown on Figure A.11.

The land use zoning classifications proposed are:

R-1, 2 acre minimum = LDR Land Use Code
R-1, 0.5 acre minimum = LDR Land Use Code
R-MH, 7,000 sf lots = MDR Land Use Code
C-1, Neighborhood Commercial = C1 Land Use Code

Table A.15 Rainfall Depth-Duration-Frequency for Kingman, AZ (DDMSW GIS)

(estimated using the DDMSW GIS Method)

Duration	Rainfall Depth, in inches Storm Frequency, in years					
	2	5	10	25	50	100
5-min	0.252	0.354	0.427	0.526	0.599	0.676
10-min	0.383	0.539	0.651	0.800	0.912	1.029
15-min	0.475	0.669	0.807	0.992	1.131	1.276
30-min	0.640	0.901	1.087	1.336	1.523	1.719
1-hour	0.792	1.115	1.345	1.654	1.886	2.127
2-hour	0.870	1.230	1.509	1.894	2.211	2.545
3-hour	0.932	1.300	1.598	2.022	2.379	2.766
6-hour	1.097	1.506	1.832	2.304	2.691	3.114
12-hour	1.280	1.752	2.133	2.656	3.086	3.540
24-hour	1.580	2.168	2.625	3.272	3.789	4.340

Table A.16 Rainfall Intensity-Duration-Frequency for Kingman, AZ (DDMSW GIS)

(computed using the data in Table A.15)

Duration	Rainfall Intensity, in inches/hour Storm Frequency, in years					
	2	5	10	25	50	100
5-min	3.024	4.248	5.124	6.312	7.188	8.112
10-min	2.298	3.234	3.906	4.800	5.472	6.174
15-min	1.900	2.676	3.228	3.968	4.524	5.104
30-min	1.280	1.802	2.174	2.672	3.046	3.438
1-hour	0.792	1.115	1.345	1.654	1.886	2.127
2-hour	0.435	0.615	0.755	0.947	1.106	1.273
3-hour	0.311	0.433	0.533	0.674	0.793	0.922
6-hour	0.183	0.251	0.305	0.384	0.449	0.519
12-hour	0.107	0.146	0.178	0.221	0.257	0.295
24-hour	0.066	0.090	0.109	0.136	0.158	0.181

Figure A.11 Rational Method watershed and land use map

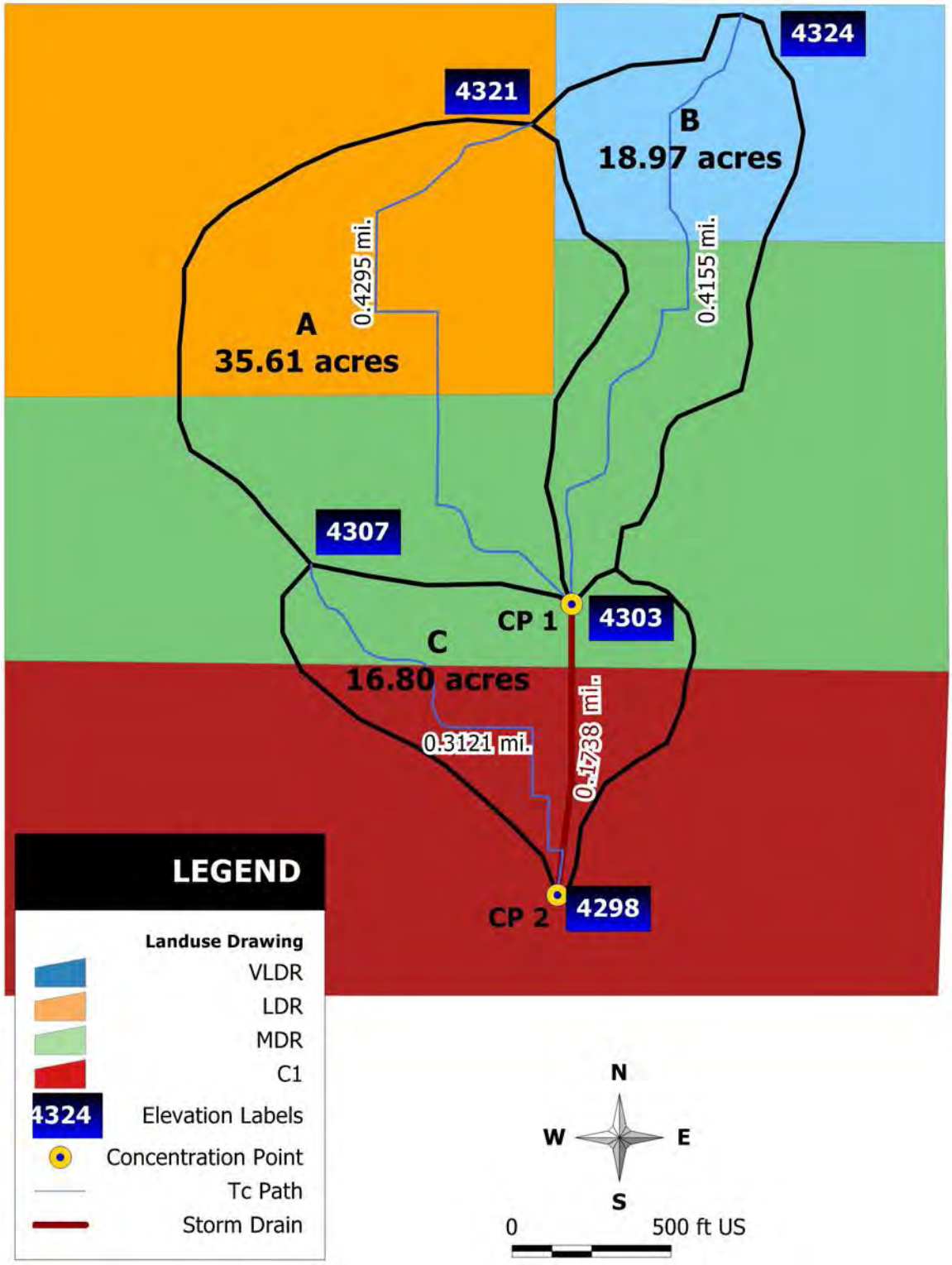


Table A.17 T_c and land use data								
Sub-basin ID	T_c Computation Data			Land Use Area, acres				Total Drainage Area, acres
	Length, miles	Slope, ft./mi.	K_b	VLDR (114)	LDR (140)	MDR (160)	C1 (220)	
A	0.4295	41.9	0.025	0.36	20.25	15.00	0.00	35.61
B	0.4155	50.5	0.025	9.44	0.11	9.42	0.00	18.97
C	0.3121	28.8	0.025	0.00	0.00	7.61	9.19	16.80
			TOTALS:	**9.80**	**20.36**	**32.03**	**9.19**	**71.38**

A.2.3 SOLUTION USING MANUAL METHODS

1. Area: The areas for each sub-basin, and each land use within each sub-basin, were determined using available topographic mapping and are provided in Table A.17.

C: The C values for each land use were selected from Table 7.19 and are shown in Table A.18.

Table A.18 Rational Method example, land use C coefficients					
DDMSW ID	Zoning Classification	Hydrologic Classification	Land Use Code	C	K_b
114	R-1, 2 acre	Very Low Density Residential	VLDR	0.42	0.04
140	R-1, 0.5 acre	Low Density Residential	LDR	0.48	0.04
160	R-MH, 7,000 sf	Medium Density Residential	MDR	0.60	0.025
220	C-1, Neighborhood Commercial	Commercial	C1	0.83	0.025

Compute the arithmetically area-weighted C value for sub-basins A, B, and C; A+B; and A+B+C, using the areas from Table A.17 and the C values from Table A.18:

NOTE: Composite C values are normally rounded to the nearest hundredth.

Sub-basin A:

$$C_w = \frac{(0.42)(0.36)+(0.48)(20.25)+(0.60)(15.00)}{35.61} = 0.53$$

Sub-basin B:

$$C_w = \frac{(0.42)(9.44)+(0.48)(0.11)+(0.60)(9.42)}{18.97} = 0.51$$

Sub-basin C:

$$C_w = \frac{(0.60)(7.61)+(0.83)(9.19)}{16.80} = 0.73$$

Sub-basins A + B:

$$C_w = \frac{(0.53)(35.61)+(0.51)(18.97)}{54.58} = 0.52$$

Sub-basins A + B + C:

$$C_w = \frac{(0.53)(35.61)+(0.51)(18.97)+(0.73)(16.80)}{71.38} = 0.57$$

The computed runoff coefficients (C) are:

Sub-basin A: 0.53

Sub-basin B: 0.51

Sub-basin C: 0.73

Sub-basin A + B: 0.52

Sub-basin A + B + C: 0.57

T_c Parameters:

L: The T_c flow paths were defined on the topographic mapping and measured. The lengths are tabulated in Table A.17.

S: The T_c paths were inspected and found to have a reasonably constant slope. The slopes were calculated in feet/mile using the lengths and elevations shown on Figure A.11 and tabulated in Table A.17.

K_b: Compute the arithmetically area-weighted K_b value for sub-basins A, B, and C; A+B; and A+B+C, using the areas from Table A.17 and the K_b values from Table A.18:

Sub-basin A:

$$K_{b_w} = \frac{(0.04)(0.36)+(0.04)(20.25)+(0..025)(15.00)}{35.61} = 0.034$$

Sub-basin B:

$$K_{b_w} = \frac{(0.04)(9.44)+(0.04)(0.11)+(0..025)(9.42)}{18.97} = 0.033$$

Sub-basin C:

$$K_{b_w} = 0.025$$

Sub-basins A + B:

$$K_{b_w} = \frac{(0.034)(35.61)+(0.033)(18.97)}{54.58} = 0.034$$

Sub-basins A + B + C:

$$K_{b_w} = \frac{(0.034)(35.76)+(0033)(18.97)+(0.025)(16.80)}{71.38} = 0.032$$

NOTE: K_b estimates are normally rounded to the nearest hundredth.

The computed K_b estimates are:

Sub-basin A: 0.03

Sub-basin B: 0.03

Sub-basin C: 0.03

Sub-basin A + B: 0.03

Sub-basin A + B + C: 0.03

Compile the rainfall data (already complete, see Table A.15 and Table A.16).

T_c: Compute T_c for sub-basins A, B, C, A + B, and A + B + C:

Sub-basin A:

$$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38}$$

$$T_c = 11.4(0.4295)^{0.5}(0.03)^{0.52}(41.9)^{-0.31}i^{-0.38}$$

$$T_c = 0.379i^{-0.38}$$

Estimate an initial T_c. Assume 5 fps velocity.

T_c = L/V = 2,268/5*60 = 8 min

From Table A.16:

$$i = \big((8-5)/(10-5)\big) * (3.91-5.14) + 5.14 = 4.4\ inches/hour$$

NOTE: Estimates of *i* are normally rounded to the nearest tenth of an inch per hour.

$$T_c = 0.379(4.4)^{-0.38} = 0.216\ hours = 13.0\ minutes$$

Recompute i for T_c = 13.0 minutes

$$i = \big((13.0-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.5\ inches/hour$$

$$T_c = 0.379(3.5)^{-0.38} = 0.235\ hours = 14.1\ minutes$$

Recompute i for T_c = 14.1 minutes

$$i = \big((14.1-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.4\ inches/hour$$

$$T_c = 0.379(3.4)^{-0.38} = 0.238\ hours = 14.3\ minutes$$

Difference is less than 2%. Use T_c = 14 min, i = 3.4 inches/hour

Sub-basin B:

$$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38}$$

$$T_c = 11.4(0.4155)^{0.5}(0.03)^{0.52}(50.5)^{-0.31}i^{-0.38}$$

$$T_c = 0.352i^{-0.38}$$

Estimate an initial T_c. Assume 4 fps velocity.

T_c = L/V = 2193/4*60 = 9 min

From Table A.16:

$$i = \big((9-5)/(10-5)\big) * (3.91-5.14) + 5.14 = 4.2\ inches/hour$$

$$T_c = 0.352(4.2)^{-0.38} = 0.204\ hours = 12.2\ minutes$$

Recompute i for T_c = 12.2 minutes

$$i = \big((12.2-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.6\ inches/hour$$

$$T_c = 0.352(3.6)^{-0.38} = 0.216\ hours = 13.0\ minutes$$

Recompute i for T_c = 13.0 minutes

$$i = \big((13.0-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.5\ inches/hour$$

$$T_c = 0.352(3.5)^{-0.38} = 0.219\ hours = 13.1\ minutes$$

Difference is less than 2%. Use T_c = 13 min, i = 3.5 inches/hour

Sub-basin C:

$$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38}$$

$$T_c = 11.4(0.3121)^{0.5}(0.03)^{0.52}(28.8)^{-0.31}i^{-0.38}$$

$$T_c = 0.363i^{-0.38}$$

Estimate an initial T_c. Assume 4 fps velocity.

T_c = L/V = 1648/4*60 = 6.9 min

From Table A.16:

$$i = \big((6.9-5)/(10-5)\big) * (3.91-5.14) + 5.14 = 4.7\ inches/hour$$

$$T_c = 0.363(4.7)^{-0.38} = 0.202\ hours = 12.1\ minutes$$

Recompute i for T_c = 12.1 minutes

$$i = \big((12.1-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.6\ inches/hour$$

$$T_c = 0.363(3.6)^{-0.38} = 0.223\ hours = 13.4\ minutes$$

Recompute i for T_c = 13.4 minutes

$$i = \big((13.4-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.4\ inches/hour$$

$$T_c = 0.363(3.4)^{-0.38} = 0.228\ hours = 13.7\ minutes$$

Recompute i for T_c = 13.7 minutes

$$i = \big((13.7-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.4\ inches/hour$$

$$T_c = 0.363(3.4)^{-0.38} = 0.228\ hours = 13.7\ minutes$$

Difference is less than 2%. Use T_c = 14 min, i = 3.4 inches/hour

Sub-basin A + B:

$$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38}$$

Use the longest L, which is sub-basin A, and the T_c from sub-basin A, assuming that a K_b of 0.034 will have negligible effect on T_c.

Use T_c = 14 min, i = 3.4 inches/hour

Sub-basin A + B + C:

$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38}$

L = 2268 + 918 = 3186 ft

S = (4321-4298)/3186/5280 = 38.1 feet/mile

$T_c = 11.4(0.6034)^{0.5}(0.03)^{0.52}(38.1)^{-0.31}i^{-0.38}$

$T_c = 0.462i^{-0.38}$

Estimate an initial T_c. Assume 4 fps velocity.

T_c = L/V = 3186/4*60 = 13.3 min

From Table A.16:

$i = \big((13.3-10)/(15-10)\big) * (3.23-3.91) + 3.91 = 3.5\ inches/hour$

$T_c = 0.462(3.5)^{-0.38} = 0.287\ hours = 17.2\ minutes$

Recompute i for T_c = 17.2 minutes

$i = \big((17.2-15)/(30-15)\big) * (2.18-3.23) + 3.23 = 3.1\ inches/hour$

$T_c = 0.462(3.1)^{-0.38} = 0.301\ hours = 18.1\ minutes$

Recompute i for T_c = 18.1 minutes

$i = \big((18.1-15)/(30-15)\big) * (2.18-3.23) + 3.23 = 3.0\ inches/hour$

$T_c = 0.462(3.0)^{-0.38} = 0.304\ hours = 18.3\ minutes$

Difference is less than 2%. Use T_c = 18.0 min, i = 3.0 inches/hour

To summarize:

Sub-basin A: T_c = 14 min, i = 3.4 inches/hour

Sub-basin B: Use T_c = 13 min, i = 3.5 inches/hour

Sub-basin C: Use T_c = 14 min, i = 3.4 inches/hour

Sub-basin A + B: Use T_c = 14 min, i = 3.4 inches/hour

Sub-basin A + B + C: Use T_c = 18.0 min, i = 3.0 inches/hour

Compute Q for each Sub-basin using the Combined Watershed Approach:

Sub-basin A: $Q_{10} = CiA = (0.53)(3.4)(35.61) = 64\ cfs$

Sub-basin B: $Q_{10} = CiA = (0.51)(3.5)(18.97) = 34\ cfs$

Sub-basin C: $Q_{10} = CiA = (0.73)(3.4)(16.80) = 42\ cfs$

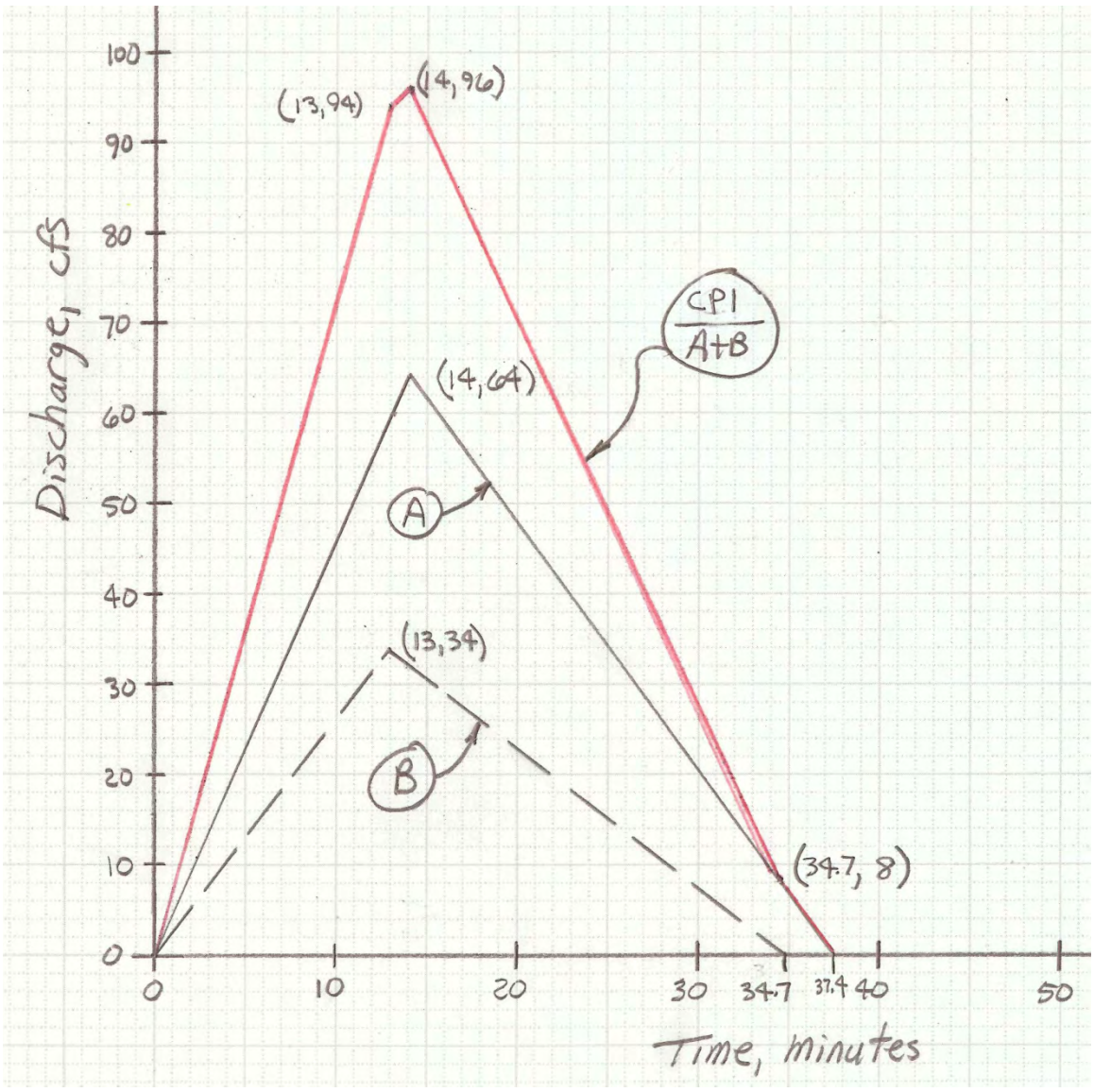
Sub-basin A + B: $Q_{10} = CiA = (0.52)(3.4)(54.58) = 97\ cfs$

Sub-basin A + B + C: $Q_{10} = CiA = (0.57)(3.0)(71.38) = 122\ cfs$

Compute Q for each sub-basin using the manual Triangular Hydrograph Approach:

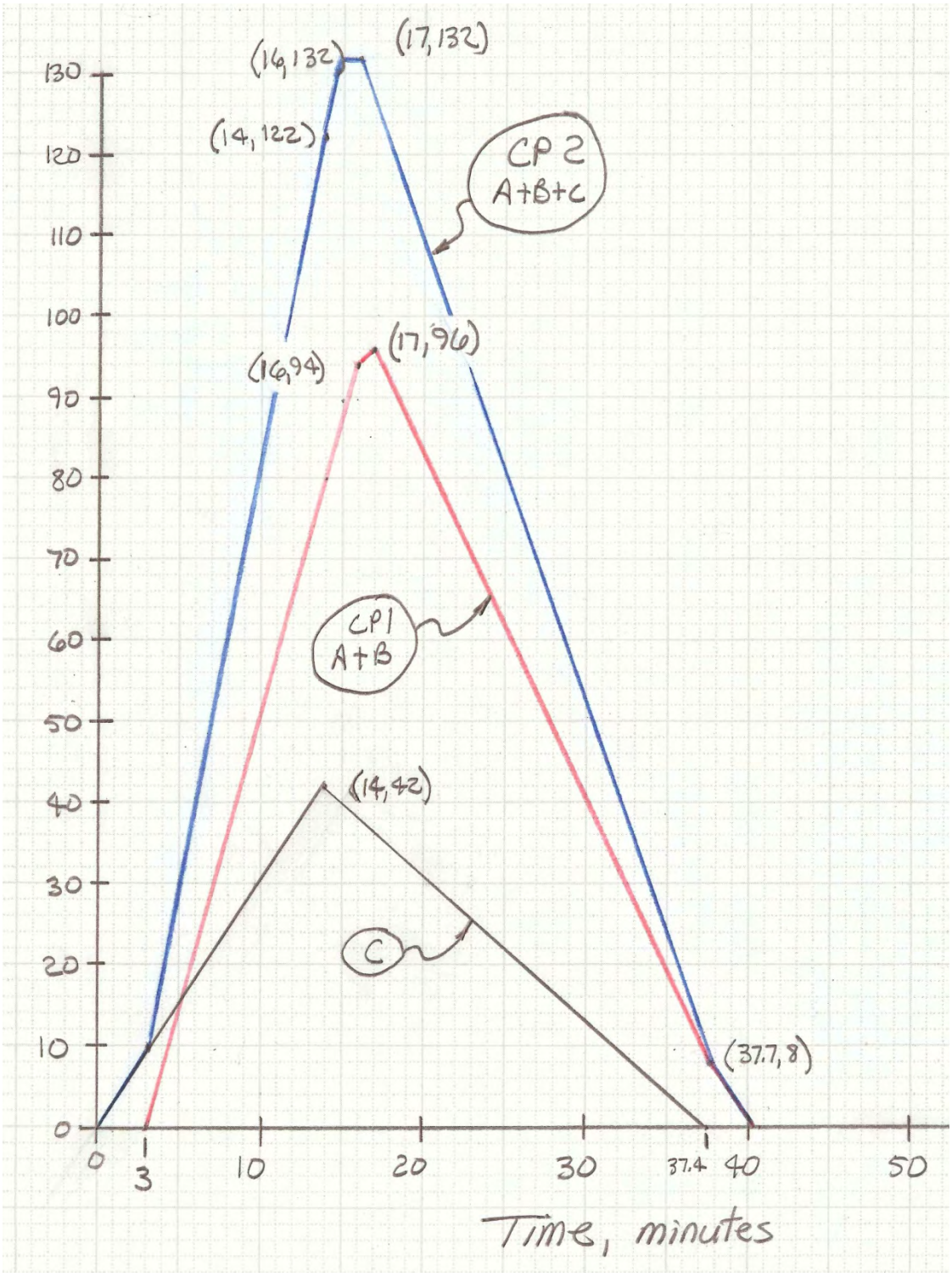
Use Figure 7.9 to construct a triangular hydrograph for both sub-basin A and sub-basin B. Then add the ordinates of the two hydrographs to estimate the total flow at CP 1 as shown on Figure A.12.

Figure A.12 10-year Rational Method hydrographs at CP 1



Lag the hydrograph for CP 1 in relation to the hydrograph for sub-basin C and plot as shown on Figure A.13. Assume that the travel time for flow from CP 1 to CP 2 is the length of the storm drain divided by 6 fps. The length of the storm drain is 918 ft. At 6 fps, the estimated travel time is about 3 minutes. Therefore, lag the hydrograph from CP 1 (sub-basin A + sub-basin B) by 3 minutes in relation to the hydrograph from sub-basin C. Then add the ordinates of the two hydrographs to estimate the total flow at CP 2.

Figure A.13 10-year Rational Method hydrographs at CP 2



The total peak discharge at the two concentration points is estimated to be:

CP 1: Q_{10} = 96 cfs at 14 minutes.

CP 2: Q_{10} = 132 cfs at 17 minutes.

The results of the two multiple basin approaches are summarized in Table A.19. Note that the results compare favorably with the exception of the peak discharge at CP 2. There is a 1-minute difference in time-to-peak between the two methods, contributing to the difference in peak discharge of 10 cfs.

The Triangular Hydrograph results should be revised using the actual velocity in the storm drain for a peak discharge of 96 cfs. Assuming a 54-inch diameter CMP storm drain, it is determined that the full flow capacity is only about 79 cfs. Therefore, the design is revised to use two 54-inch CMP's with a full flow capacity of about 157 cfs and a velocity of about 4.9 fps, which provides factor of safety. The design could be refined to use smaller pipes, and of course other physical constraints may affect the final pipe size selection. For a storm drain length of 918 feet, the travel time is approximately 3.1 minutes. The lag of 3 minutes is still a valid assumption.

In general, the accepted approach is to use the Triangular Hydrograph Method when applying the Rational Method in Mohave County; however, the Combined Watershed Method may be used when performing the hydrology computations manually.

A.2.4 SOLUTION USING DDMSW

The DDMSW computer program applies only the Triangular Hydrograph Method. The general steps for using the Rational Method under DDMSW are as follows:

1. *File|Select Project*. Create a new project and set the model project default to Rational.
2. *Hydrology|Rainfall*. Establish the rainfall criteria as described in Appendix A.1.1.
3. Sub-Basin and Land Use Data, GIS Method:
    a. Create shape files for the sub-basins, land use and Tc paths, making sure the required fields exist and are populated. Make sure the projection and coordinate system are the Mohave County standard.
    b. *Maps|Update Hydrology*. Set the pointers to the path and file name for the sub-basins, land use and T_c GIS shape files. Click *Save*, then click *Update*.
    c. *Hydrology|Sub Basins*. Check data to be sure it was imported properly. Click *Update*.
    d. *Hydrology|Land Use*. Check data to be sure it was imported properly. Click *Update*.

Sub-Basin and Land Use Data, Manual Method.

a. *Hydrology|Sub Basins*. Enter the sub-basin data manually and click *Update*.

b. *Hydrology|Land Use*. Enter land use data manually and click *Update*.

Hydrology|Rational Method|Network. Click Add and select *Type* sub-basin. Select the *ID* for the first sub-basin. Click Save. Repeat for all sub-basins.

Hydrology|Rational Method|Model. Select desired return periods and click *Run Model*. Click *Results,* then click *View* and select the return period you want to review first. Check for reasonableness. Click *Graph* and review hydrographs for reasonableness. Click *View* and select another return period (assuming you ran the model with multiple return periods selected). Repeat for all storm return periods modeled.

Hydraulics|Conveyance Facilities. If conveyance facilities such as storm drains are to be modeled, add them in.

Hydrology|Rational Method|Network. Add in the Conveyance Facilities defined and add in any hydrograph combines. Place in the proper order to simulate the flow progression.

Repeat Step 6.

The DDMSW 10-year results for the example problem are shown on Figure A.14, Figure A.15, and Figure A.16. One of the many advantages of using DDMSW is that the results can easily be obtained for multiple return periods (not shown for this example).

Figure A.14 DDMSW 10-year Rational Method results

			County of Mohave								
			Drainage Design Management System								
			RATIONAL METHOD FLOW SUMMARY								
			Project Reference: MOHAVE EXAMPLE2								
Page	1		Return Period: 10 Years								8/21/2012
Type	Model ID		Size	Area (acres)	CA (acres)	I (in/hr)	Q (cfs)	elocity (ft/sec)	Length (feet)	Tp (min)	Tc (min)	
Major Basin: 01												
Sub Basin	A			35.6	18.87	3.30	62.3				14	
Sub Basin	B			19.0	9.67	3.50	33.8				13	
Combine	C1			54.6	28.54		94.5					
Convey	P1	*	2-54" Dia Pipe	54.6	28.54		94.5	4.9	918	3.1		
Sub Basin	C			16.8	12.26	3.40	41.7				14	
Combine	C2			71.4	40.80		130.8					

A.2.5 COMPARISON OF RESULTS

The results prepared using DDMSW are compared with the Manual Method results in Table A.19. Rainfall is for the City of Kingman corporate area. Note that the DDMSW method produces more accurate computations, but when rounded are nearly identical to the Manual Method results.

Figure A.15 DDMSW 10-year Rational Method hydrographs at CP 1

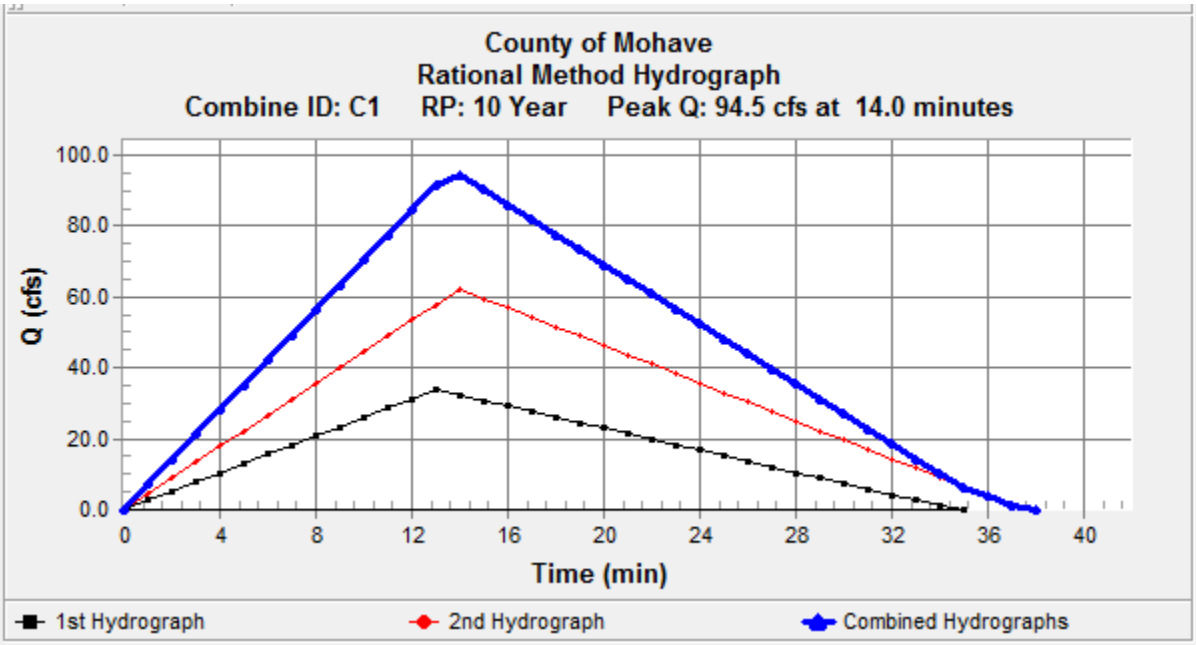


Figure A.16 DDMSW 10-year Rational Method hydrographs at CP 2

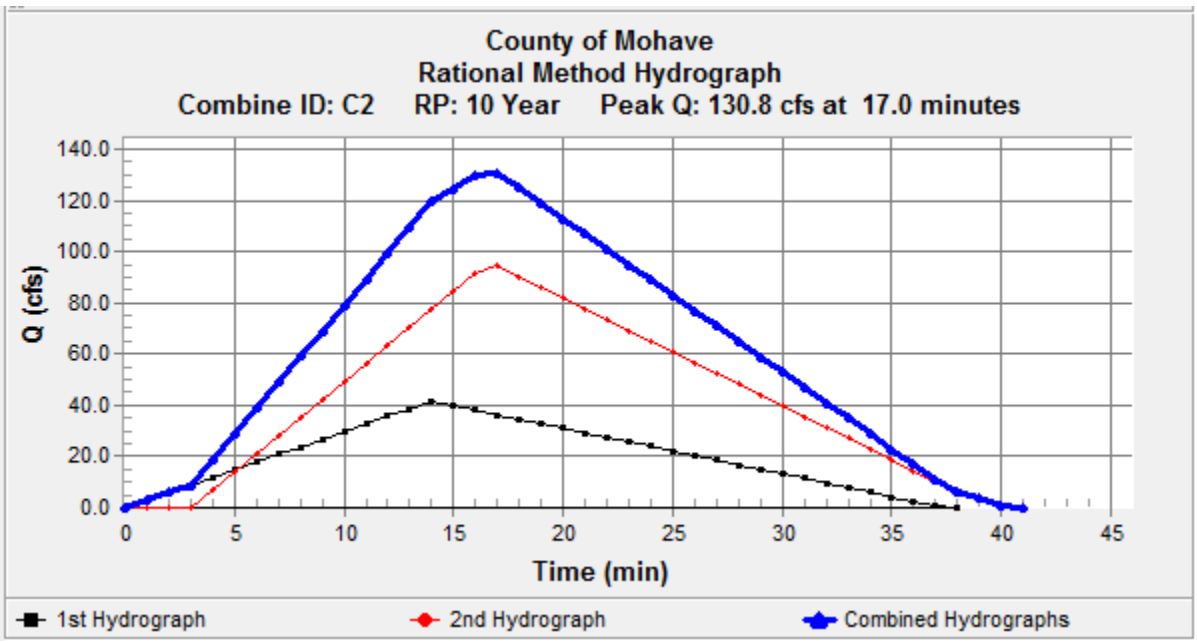


Table A.19 Summary of results for the various methods

Location	Manual Method		Triangular Hydrograph Method			
			Manual Method		DDMSW	
	Q_{10}, cfs	T_p, min.	T_p, min.	Q_{10}, cfs	T_p, min	Q_{10}, cfs
Sub-basin A	64	14	14	64	14.4	62.3
Sub-basin B	34	13	13	34	13.1	33.8
CP 1	97	14	14	96	14.0	94.5
Sub-basin C	42	14	14	42	13.6	41.7
CP 2	122	18	17	132	17.0	130.8

A.3 RAINFALL LOSSES EXAMPLE

This section pertains to estimating rainfall loss parameters for use with the unit hydrograph method. Refer to Section 7.4 for a description of the methodology used. Refer to Appendix D for a complete description of the Green and Ampt parameters used in Mohave County and derived from NCRS databases and GIS coverages.

A.3.1 EXAMPLE FOR GREEN AND AMPT METHOD

A.3.1.1 Problem Statement

Rainfall loss parameters for use with the Green and Ampt method are needed for a HEC-1 model of a large watershed within, and south of, Kingman, AZ. The site is located as shown on Figure A.6. Derive the parameters and prepare the HEC-1 rainfall loss records for the model using the instructions set forth in Section 7.4.4. There are three methods that can be used:

1. Manual Computations. Computations are performed by hand or with a calculator.
2. DDMSW Manual Input. Areas and other parameters are determined by the most expedient means available and then manually input to DDMSW. DDMSW then computes rainfall loss parameters for each sub-basin.
3. DDMSW GIS Method. Sub-basin boundaries, soil map unit boundaries and land use boundaries are created in ERSI GIS shape file format external to DDMSW, read into DDMSW, and then DDMSW performs the rainfall loss parameter computations for each sub-basin using the GIS information.

A.3.1.2 Problem Solution

The solution consists of several steps, which are common to all methods.

1. Watershed delineation.
2. Watershed slope evaluation.
3. Land use definition.
4. Soil Map Unit definition.
5. Concentration point definition and Sub-basin delineation.
6. Computation of sub-basin composite initial abstraction.
7. Computation of sub-basin composite bare ground XKSAT.
8. Assignment of PSIF and DTHETA.
9. Computation of sub-basin composite vegetation cover density (VCD).
10. Computation of XKSAT adjusted for vegetation canopy cover.

11. Estimation of sub-basin composite RTIMP.
12. Preparation of the HEC-1 rainfall loss input records.

Step 1. Watershed Delineation.

The bottom end of the study watershed is normally a known point that is the focus of the study. The upstream watershed should first be delineated using the best available topographic information. USGS quadrangle maps covering the watershed, in combination with the 10-meter resolution USGS digital elevation maps (DEM), were used for delineation of the watershed boundaries shown on Figure A.6.

Step 2. Watershed Slope Evaluation.

It is very helpful to assess the range of slopes present on the watershed. This information is useful when deciding how the watershed should be delineated into sub-basins, and for the assignment natural land use classifications (undeveloped desert, hillslopes, or mountain terrain), which are slope dependant. The USGS DEM's of the watershed were used to prepare Figure A.17. Slope ranges defined were less than 5%, greater than 5%, and greater than 20%. This information was used to define simplified natural terrain polygons for the three classifications, as shown on Figure A.18, which is the natural land use map. The land use codes (LUCODE) shown on Figure A.18 are related to terrain classification in Table A.20.

Table A.20 Natural land use codes

LUCODE	Description
500	Undeveloped Desert Rangeland. Little topographic relief, slopes <5%.
510	Hillslopes, Sonoran Desert. Moderate topographic relief, slopes >5%.
520	Mountain Terrain. High topographic relief, slopes >20%.

Step 3. Land Use Definition.

Definition of land use spatial limits is necessary to estimate the impervious area (RTIMP), developed vegetation canopy cover (VCD), Initial Abstraction (IA), and the areas where the soil moisture deficit at start of rainfall (DTHETA) are assumed to be have a normal value. The standard Mohave County land use/zoning map in GIS shape file format was used to define the land uses for the areas in the unincorporated County. Land use polygons for the area within Kingman were drawn in GIS using the USGS quadrangle maps and knowledge of the area. These land use types and limits are for the purposes of this example only and are not an

accurate representation of actual land uses in the area. The urban land use map was combined with the natural land use map to produce a comprehensive land use GIS shape file coverage of the entire watershed. Refer to Figure A.19.

Figure A.17 Unit Hydrograph Method watershed slope variation map

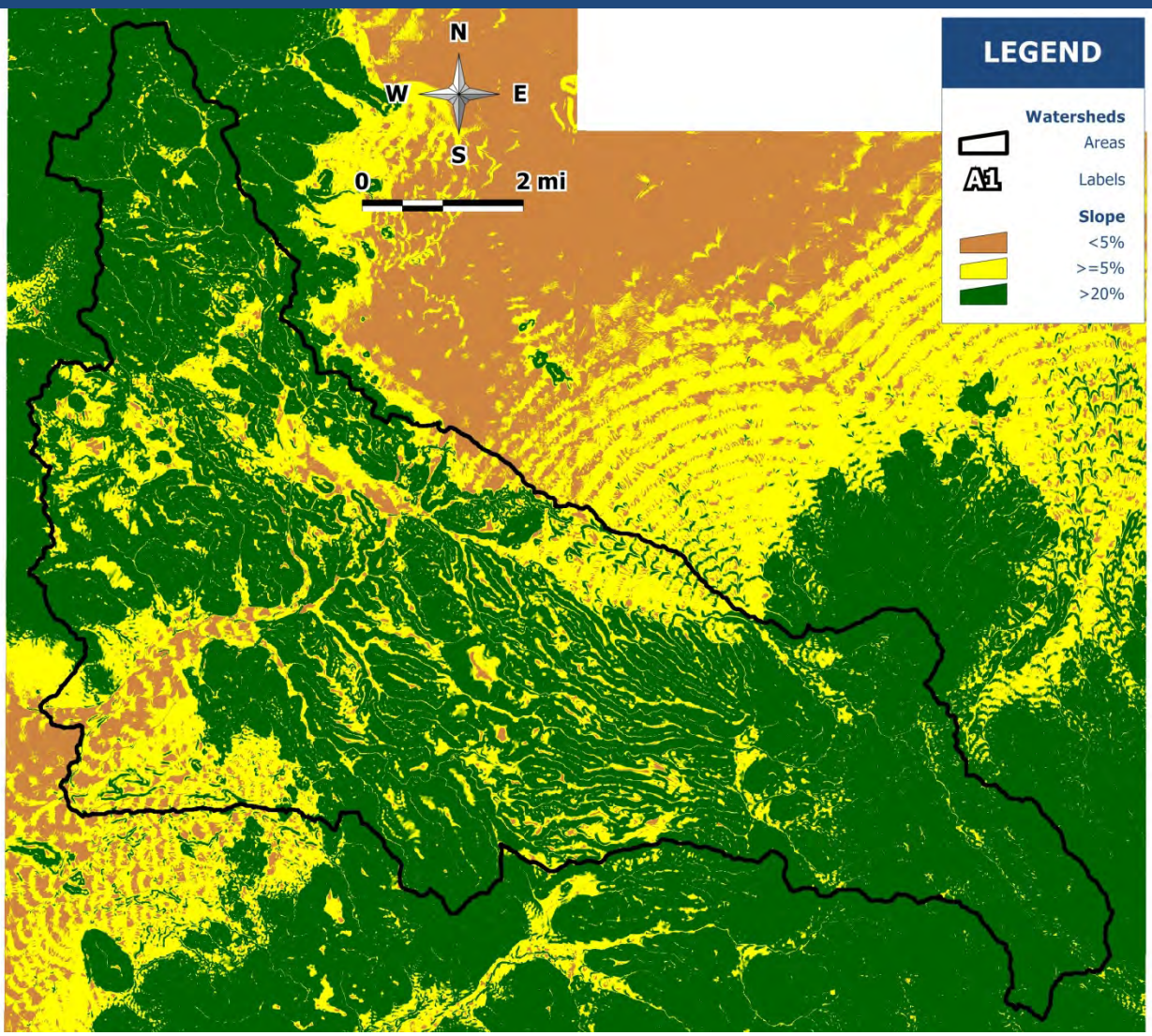


Figure A.18 Unit Hydrograph Method natural terrain classification map

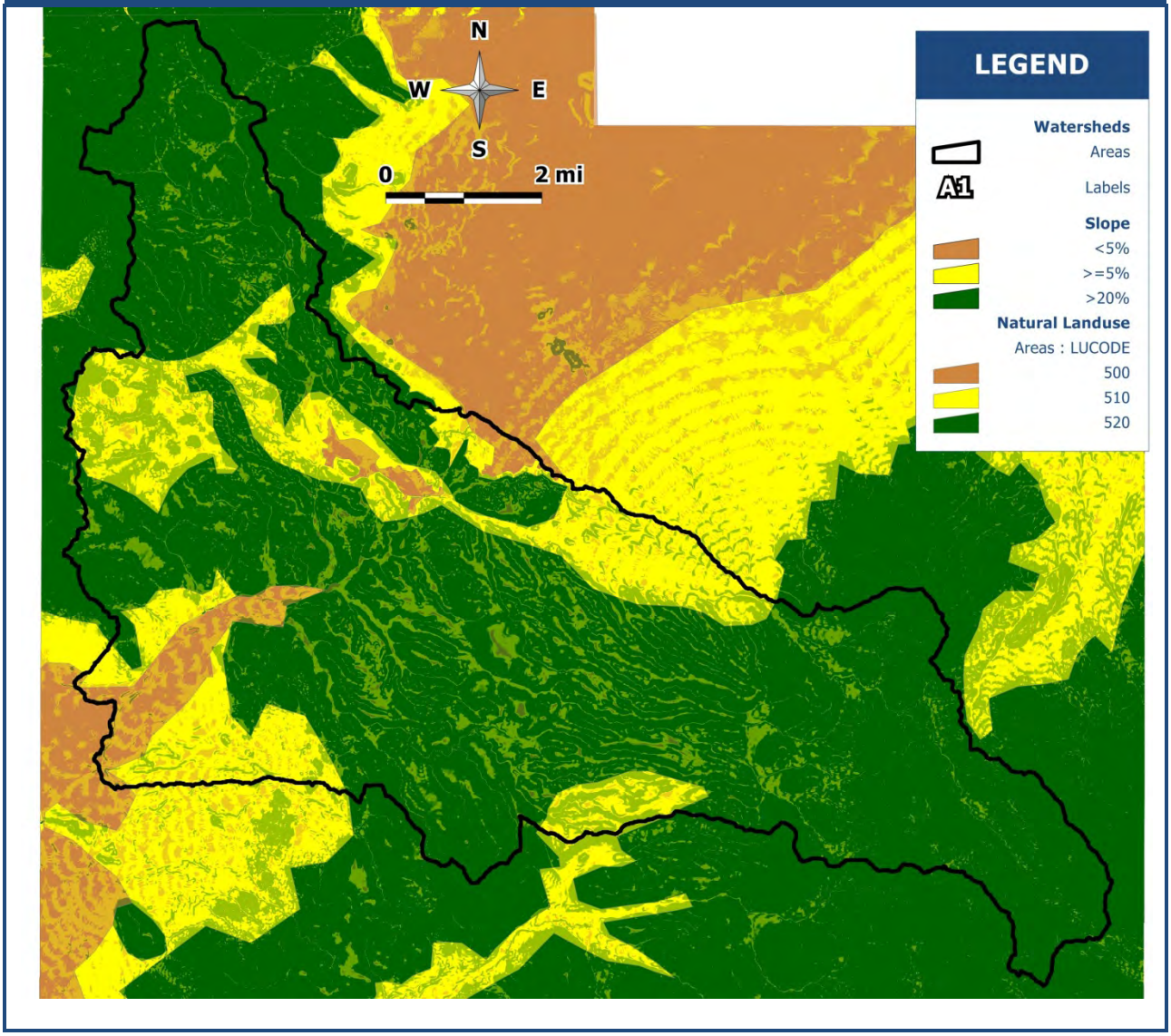
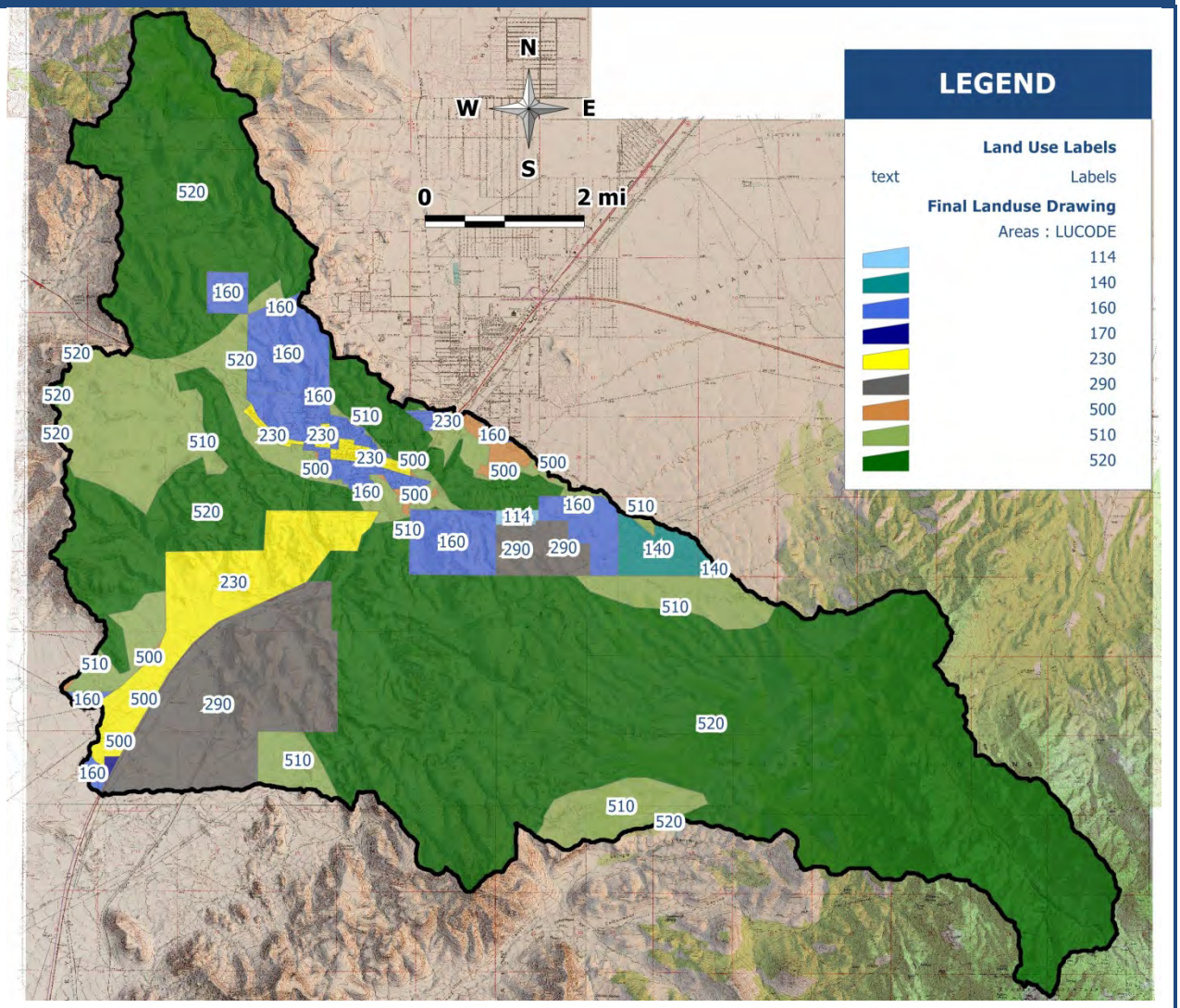


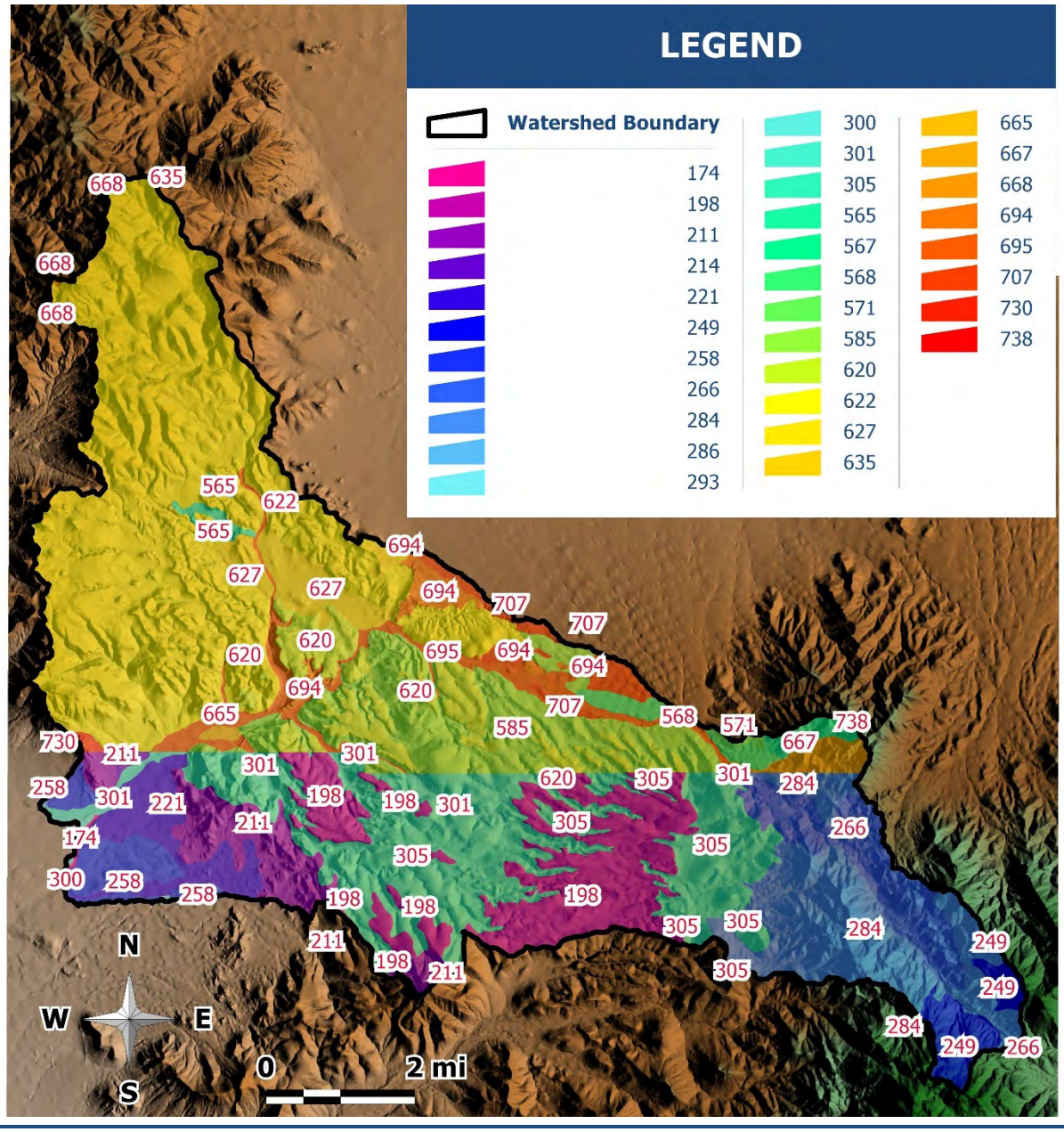
Figure A.19 Unit Hydrograph Method combined land use map



Step 4. Soil Map Unit Definition.

The NRCS soil map units (SMU) present in each sub-basin are needed for estimation of saturated hydraulic conductivity (XKSAT), the wetting front capillary suction (PSIF), and DTHETA. The NRCS soil map units for all Mohave County watersheds are available in GIS shape file format. The soil map unit boundaries for the watershed are shown on Figure A.20. The NRCS soils data for the watershed were used to define sub-areas for this example. Each sub-area polygon defines the limits of an NRCS soil map unit (SMU). These sub-area polygons are used to define natural impervious area and to estimate the Green and Ampt rainfall loss parameters.

Figure A.20 Unit Hydrograph Method soil map units map



Step 5. Concentration Point Definition and Sub-Basin Delineation.

The watershed should be broken into sub-basins if hydrologic parameters such as topography, land use, soil characteristics, vegetation, or percent impervious area vary significantly. The sub-basins should be as homogeneous as possible in terms of those parameters. For this example, significant changes in slope and differences in land ownership occur between the upper and lower watersheds; therefore, the watershed is divided into nine (9) sub-basins as

shown on Figure A.21 and Figure A.22. The land use types with the delineated sub-basins superimposed are shown on Figure A.23. The soil map units with the delineated sub-basins superimposed are shown on Figure A.24. Method 2006 natural XKSAT values are shown on Figure A.25. Further delineation of sub-basins A2 and A3 would be warranted for an actual study because of the change in land use from natural to urban and the need for concentration points where off-site watersheds impact the developed area. Sub-basin A5 could also be split again because of slope change. Further sub-basin delineation would make this example more complex and harder to follow and therefore was not done.

Computation of the rainfall loss parameters using manual methods will be done for sub-basin A3. Computation of the rainfall loss parameters for the other sub-basins will be done using DDMSW.

Figure A.21 Unit Hydrograph Method sub-basin delineation map (quads)

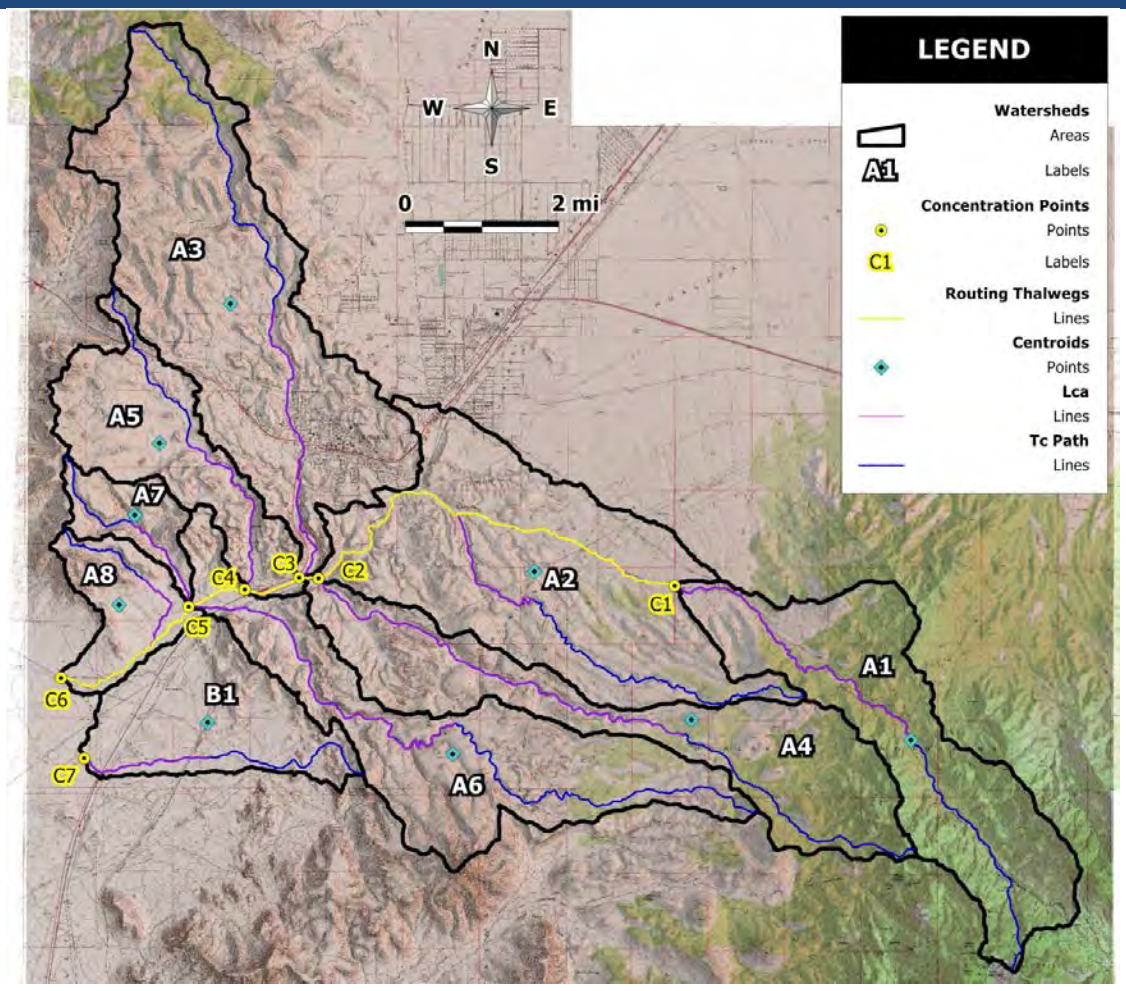


Figure A.22 Unit Hydrograph Method sub-basin delineation map (photo)

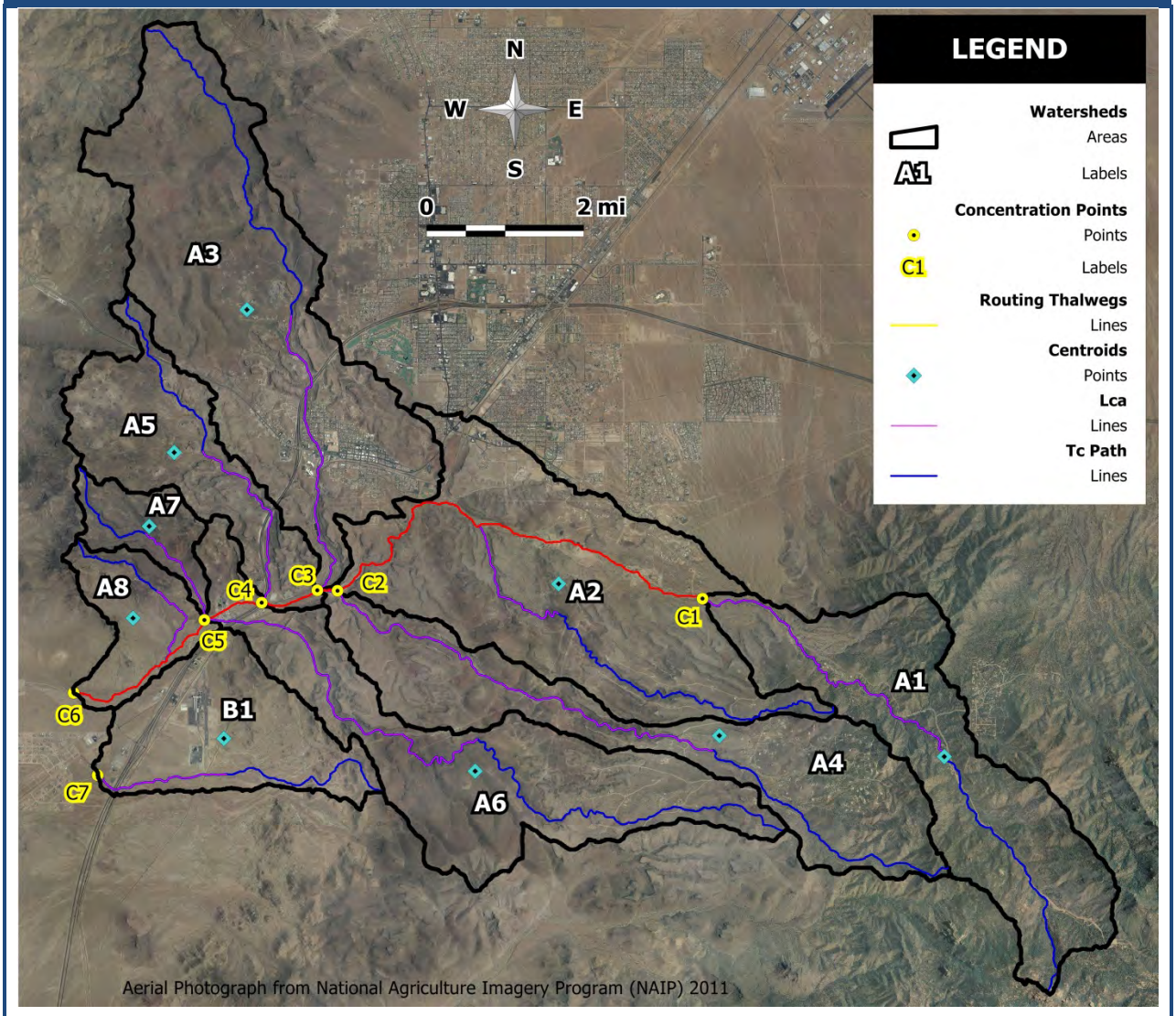
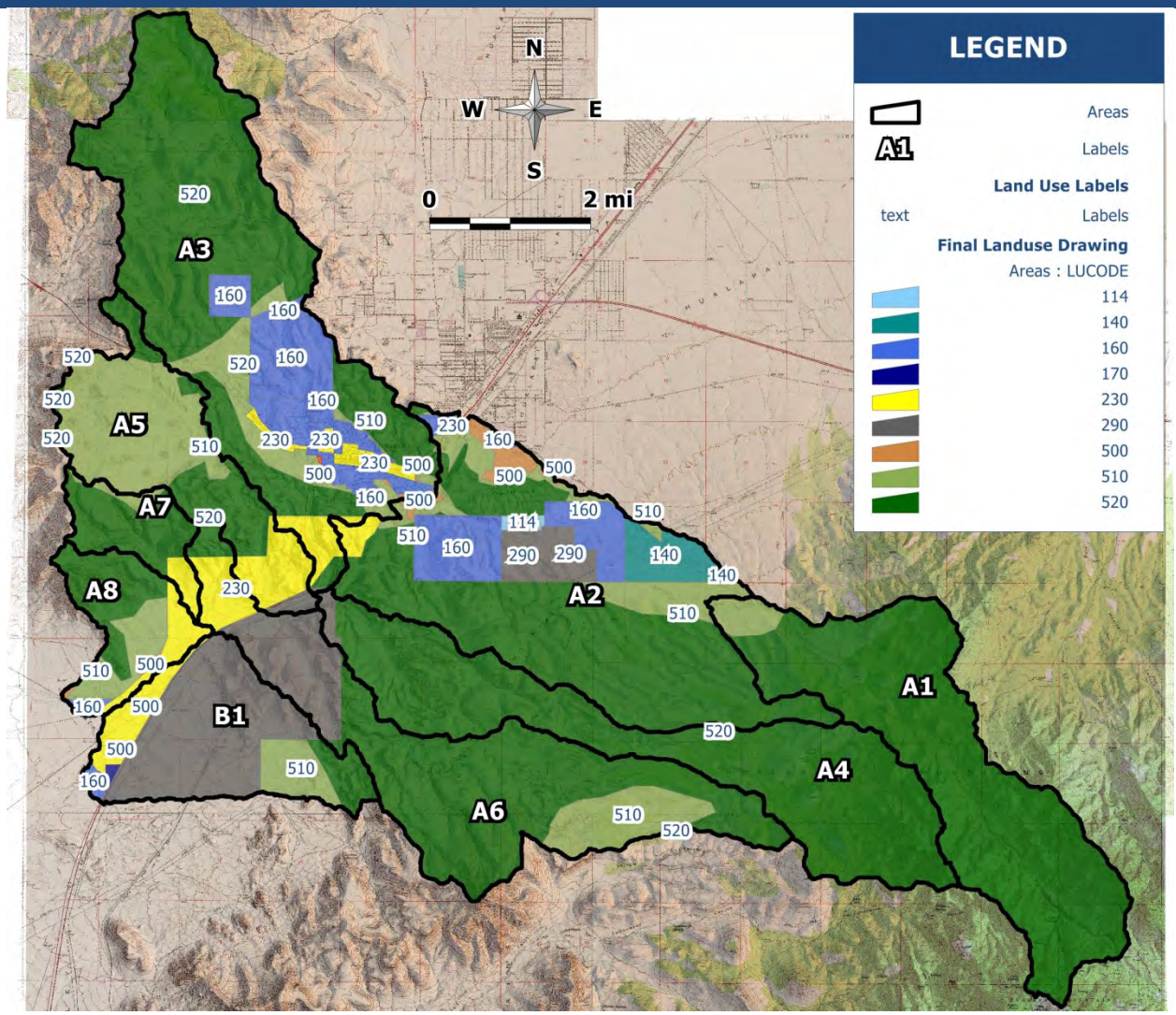


Figure A.23 Unit Hydrograph Method land use map



Step 6. Computation of sub-basin composite initial abstraction.

IA is estimated by calculating an area-weighted value for each sub-basin using standard values assigned for the land use sub-areas. The areas of the land use sub-areas can be determined by hand using a hard copy of the watershed land use map or digitally using CADD or GIS software. For this example, the areas were calculated using GIS. The sub-basin and land use sub-areas are summarized in Table A.22.

Figure A.24 Unit Hydrograph Method soils ID map

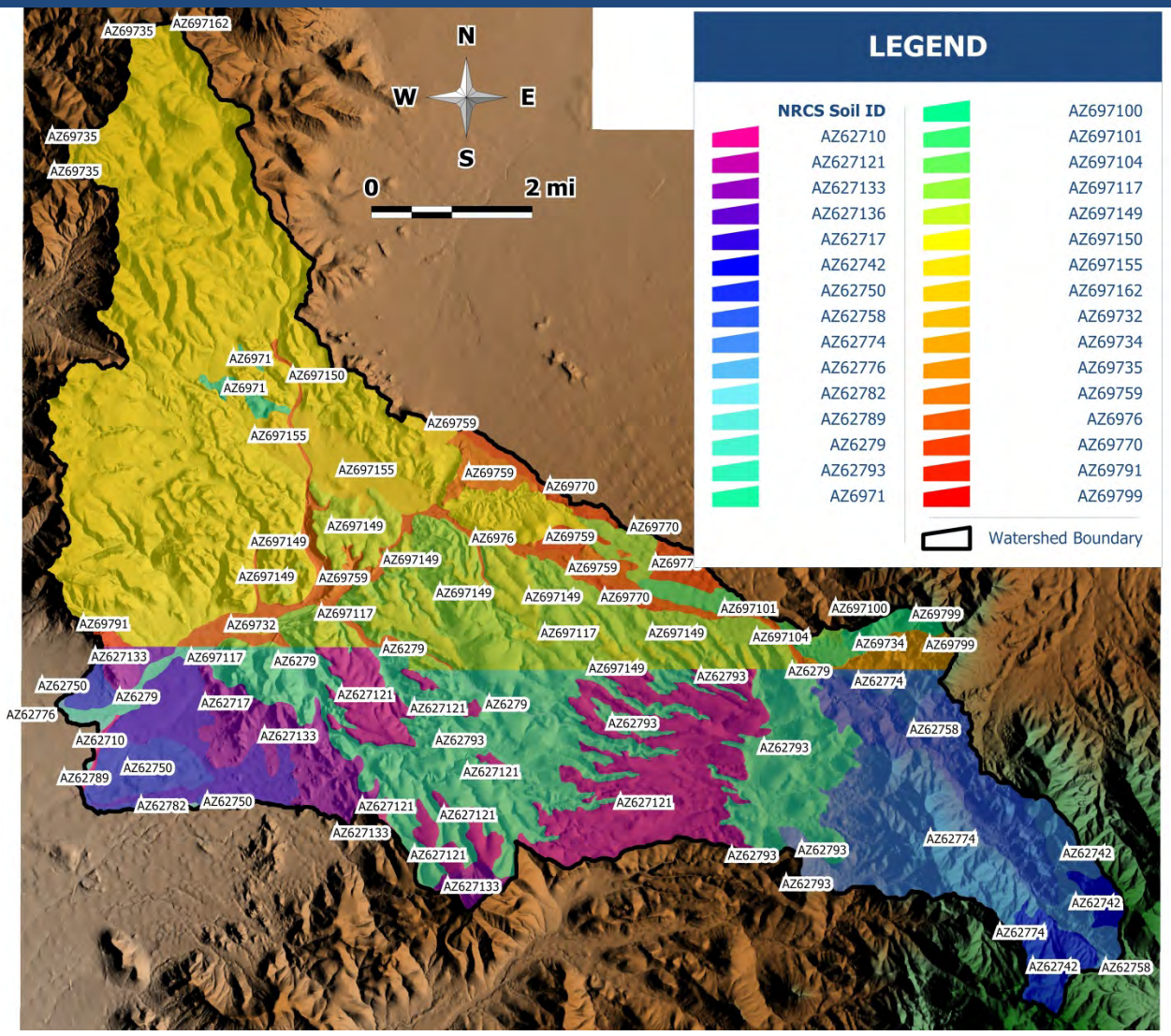


Figure A.25 Unit Hydrograph Method soils XKSAT map

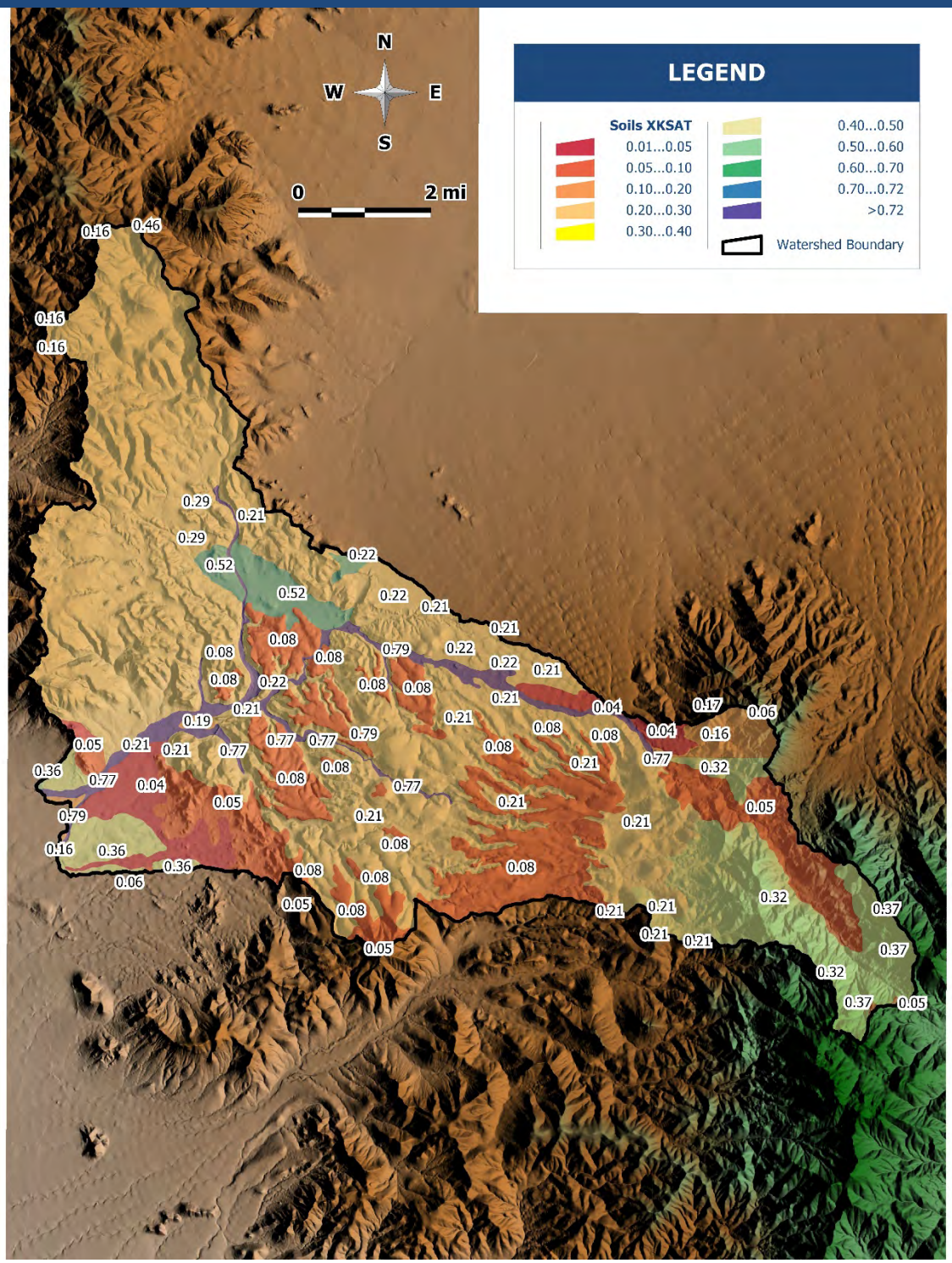


Table A.21 Unit hydrograph example soils and land use parameters

ID	Soil ID	Land Use		XKSAT, in/hr				Area (A)		[8]*[10]	VCD	VCD * A [12]*[10]	IA	IA * A [14]*[10]
		CODE	Cond.	Nat	Dev	Assign	Log10	sm	%					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A1	AZ697101	510	N	0.04	0.01	0.04	-1.40	0.050	0.6	-0.840	10	6.0	0.15	0.09
A1	AZ697117	510	N	0.21	0.10	0.21	-0.68	0.228	2.7	-1.836	10	27.0	0.15	0.41
A1	AZ697149	510	N	0.08	0.03	0.08	-1.10	0.002	0.0	0.000	10	0.0	0.15	0.00
A1	AZ6976	510	N	0.79	0.46	0.79	-0.10	0.072	0.9	-0.090	10	9.0	0.15	0.14
A1	AZ627121	520	N	0.08	0.03	0.08	-1.10	0.040	0.5	-0.550	20	10.0	0.25	0.13
A1	AZ62742	520	N	0.37	0.20	0.37	-0.43	1.074	12.8	-5.504	20	256.0	0.25	3.20
A1	AZ62758	520	N	0.05	0.02	0.05	-1.30	2.376	28.4	-36.920	20	568.0	0.25	7.10
A1	AZ62774	520	N	0.32	0.16	0.32	-0.49	2.635	31.5	-15.435	20	630.0	0.25	7.88
A1	AZ6279	520	N	0.77	0.45	0.77	-0.11	0.008	0.1	-0.011	20	2.0	0.25	0.03
A1	AZ62793	520	N	0.21	0.10	0.21	-0.68	0.356	4.3	-2.924	20	86.0	0.25	1.08
A1	AZ697100	520	N	0.17	0.07	0.17	-0.77	0.359	4.3	-3.311	20	86.0	0.25	1.08
A1	AZ697101	520	N	0.04	0.01	0.04	-1.40	0.195	2.3	-3.220	20	46.0	0.25	0.58
A1	AZ697104	520	N	0.04	0.01	0.04	-1.40	0.102	1.2	-1.680	20	24.0	0.25	0.30
A1	AZ697117	520	N	0.21	0.10	0.21	-0.68	0.234	2.8	-1.904	20	56.0	0.25	0.70
A1	AZ697149	520	N	0.08	0.03	0.08	-1.10	0.037	0.4	-0.440	20	8.0	0.25	0.10
A1	AZ69734	520	N	0.16	0.07	0.16	-0.80	0.544	6.5	-5.200	20	130.0	0.25	1.63
A1	AZ6976	520	N	0.79	0.46	0.79	-0.10	0.048	0.6	-0.060	20	12.0	0.25	0.15
A1	AZ69799	520	N	0.06	0.02	0.06	-1.22	0.003	0.0	0.000	20	0.0	0.25	0.00
			Area				**Totals:**	**8.363**	**99.9**	**-79.930**		**1956.0**		**24.56**
	Natural Area:		**99.9**	**%**		**Bare Ground XKSAT$_{Comp}$:**		**0.158**		**VC$_{Avg}$:**		**19.6**		
	Developed Area:		**0.0**	**%**		**PSIF:**		**8.68**		**DTHETA$_{Avg}$:**		**0.29**		**A1**
	Total:		**99.9**	**%**		**DTHETA$_{Dry}$:**		**0.29**		**XKSAT$_{Adj}$:**		**0.18**		
						DTHETA$_{Normal}$:		**0.18**		**IA$_{Avg}$:**		**0.25**		
A2	AZ697150	114	N	0.21	0.09	0.21	-0.68	0.091	0.8	-0.544	50	40.0	0.30	0.24
A2	AZ6976	114	N	0.79	0.46	0.79	-0.10	0.005	0.0	0.000	50	0.0	0.30	0.00
A2	AZ697101	140	D	0.04	0.01	0.01	-2.00	0.092	0.8	-1.600	50	40.0	0.25	0.20
A2	AZ697117	140	D	0.21	0.10	0.10	-1.00	0.182	1.6	-1.600	50	80.0	0.25	0.40
A2	AZ69759	140	D	0.22	0.09	0.09	-1.05	0.010	0.1	-0.105	50	5.0	0.25	0.03
A2	AZ6976	140	D	0.79	0.46	0.46	-0.34	0.067	0.6	-0.204	50	30.0	0.25	0.15
A2	AZ69770	140	D	0.21	0.08	0.08	-1.10	0.335	2.9	-3.190	50	145.0	0.25	0.73
A2	AZ697117	160	D	0.21	0.10	0.10	-1.00	0.744	6.4	-6.400	50	320.0	0.25	1.60
A2	AZ697149	160	D	0.08	0.03	0.03	-1.52	0.196	1.7	-2.584	50	85.0	0.25	0.43
A2	AZ697150	160	D	0.21	0.09	0.09	-1.05	0.164	1.4	-1.470	50	70.0	0.25	0.35
A2	AZ697155	160	D	0.52	0.28	0.28	-0.55	0.068	0.6	-0.330	50	30.0	0.25	0.15
A2	AZ69759	160	D	0.22	0.09	0.09	-1.05	0.054	0.5	-0.525	50	25.0	0.25	0.13
A2	AZ6976	160	D	0.79	0.46	0.46	-0.34	0.163	1.4	-0.476	50	70.0	0.25	0.35
A2	AZ69770	160	D	0.21	0.08	0.08	-1.10	0.237	2.0	-2.200	50	100.0	0.25	0.50
A2	AZ697149	230	D	0.08	0.03	0.03	-1.52	0.148	1.3	-1.976	75	97.5	0.10	0.13
A2	AZ697155	230	D	0.52	0.28	0.28	-0.55	0.033	0.3	-0.165	75	22.5	0.10	0.03
A2	AZ69759	230	D	0.22	0.09	0.09	-1.05	0.032	0.3	-0.315	75	22.5	0.10	0.03
A2	AZ69770	230	D	0.21	0.08	0.08	-1.10	0.000	0.0	0.000	75	0.0	0.10	0.00
A2	AZ697117	290	D	0.21	0.10	0.10	-1.00	0.218	1.9	-1.900	60	114.0	0.15	0.29
A2	AZ697149	290	D	0.08	0.03	0.03	-1.52	0.206	1.8	-2.736	60	108.0	0.15	0.27
A2	AZ697150	290	D	0.21	0.09	0.09	-1.05	0.017	0.1	-0.105	60	6.0	0.15	0.02

Table A.21 Unit hydrograph example soils and land use parameters

ID	Soil ID	Land Use		XKSAT, in/hr				Area (A)		[8]*[10]	VCD	VCD * A [12]*[10]	IA	IA * A [14]*[10]
		CODE	Cond.	Nat	Dev	Assign	Log10	sm	%					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A2	AZ69759	290	D	0.22	0.09	0.09	-1.05	0.022	0.2	-0.210	60	12.0	0.15	0.03
A2	AZ6976	290	D	0.79	0.46	0.46	-0.34	0.178	1.5	-0.510	60	90.0	0.15	0.23
A2	AZ69770	290	D	0.21	0.08	0.08	-1.10	0.071	0.6	-0.660	60	36.0	0.15	0.09
A2	AZ697149	500	N	0.08	0.03	0.08	-1.10	0.003	0.0	0.000	10	0.0	0.35	0.00
A2	AZ697150	500	N	0.21	0.09	0.21	-0.68	0.000	0.0	0.000	10	0.0	0.35	0.00
A2	AZ697155	500	N	0.52	0.28	0.52	-0.28	0.007	0.1	-0.028	10	1.0	0.35	0.04
A2	AZ69759	500	N	0.22	0.09	0.22	-0.66	0.166	1.4	-0.924	10	14.0	0.35	0.49
A2	AZ6976	500	N	0.79	0.46	0.79	-0.10	0.025	0.2	-0.020	10	2.0	0.35	0.07
A2	AZ69770	500	N	0.21	0.08	0.21	-0.68	0.117	1.0	-0.680	10	10.0	0.35	0.35
A2	AZ697101	510	N	0.04	0.01	0.04	-1.40	0.188	1.6	-2.240	10	16.0	0.15	0.24
A2	AZ697117	510	N	0.21	0.10	0.21	-0.68	0.359	3.1	-2.108	10	31.0	0.15	0.47
A2	AZ697149	510	N	0.08	0.03	0.08	-1.10	0.069	0.6	-0.660	10	6.0	0.15	0.09
A2	AZ697150	510	N	0.21	0.09	0.21	-0.68	0.123	1.1	-0.748	10	11.0	0.15	0.17
A2	AZ697155	510	N	0.52	0.28	0.52	-0.28	0.024	0.2	-0.056	10	2.0	0.15	0.03
A2	AZ69759	510	N	0.22	0.09	0.22	-0.66	0.182	1.6	-1.056	10	16.0	0.15	0.24
A2	AZ6976	510	N	0.79	0.46	0.79	-0.10	0.131	1.1	-0.110	10	11.0	0.15	0.17
A2	AZ69770	510	N	0.21	0.08	0.21	-0.68	0.176	1.5	-1.020	10	15.0	0.15	0.23
A2	AZ627121	520	N	0.08	0.03	0.08	-1.10	1.184	10.2	-11.220	20	204.0	0.25	2.55
A2	AZ62758	520	N	0.05	0.02	0.05	-1.30	0.000	0.0	0.000	20	0.0	0.25	0.00
A2	AZ62793	520	N	0.21	0.10	0.21	-0.68	1.078	9.3	-6.324	20	186.0	0.25	2.33
A2	AZ697117	520	N	0.21	0.10	0.21	-0.68	2.397	20.7	-14.076	20	414.0	0.25	5.18
A2	AZ697149	520	N	0.08	0.03	0.08	-1.10	1.165	10.0	-11.000	20	200.0	0.25	2.50
A2	AZ697150	520	N	0.21	0.09	0.21	-0.68	0.608	5.2	-3.536	20	104.0	0.25	1.30
A2	AZ697155	520	N	0.52	0.28	0.52	-0.28	0.013	0.1	-0.028	20	2.0	0.25	0.03
A2	AZ69759	520	N	0.22	0.09	0.22	-0.66	0.150	1.3	-0.858	20	26.0	0.25	0.33
A2	AZ6976	520	N	0.79	0.46	0.79	-0.10	0.088	0.8	-0.080	20	16.0	0.25	0.20
A2	AZ69770	520	N	0.21	0.08	0.21	-0.68	0.013	0.1	-0.068	20	2.0	0.25	0.03
			Area				**Totals:**	**11.599**	**100.0**	**-86.645**		**2837.5**		**23.34**
	Natural Area:		**72.0**	**%**			**Bare Ground XKSAT$_{Comp}$:**		**0.136**		**VC$_{Avg}$:**	**28.4**		
	Developed Area:		**28.0**	**%**			**PSIF:**		**9.05**		**DTHETA$_{Avg}$:**	**0.25**		**A2**
	Total:		**100.0**	**%**			**DTHETA$_{Dry}$:**		**0.28**		**XKSAT$_{Adj}$:**	**0.17**		
							DTHETA$_{Normal}$:		**0.17**		**IA$_{Avg}$:**	**0.23**		
A3	AZ6971	160	D	0.29	0.13	0.13	-0.89	0.137	1.0	-0.890	50	50.0	0.25	0.25
A3	AZ697149	160	D	0.08	0.03	0.03	-1.52	0.020	0.2	-0.304	50	10.0	0.25	0.05
A3	AZ697150	160	D	0.21	0.09	0.09	-1.05	1.309	9.9	-10.395	50	495.0	0.25	2.48
A3	AZ697155	160	D	0.52	0.28	0.28	-0.55	0.818	6.2	-3.410	50	310.0	0.25	1.55
A3	AZ6976	160	D	0.79	0.46	0.46	-0.34	0.081	0.6	-0.204	50	30.0	0.25	0.15
A3	AZ697149	230	D	0.08	0.03	0.03	-1.52	0.113	0.9	-1.368	75	67.5	0.10	0.09
A3	AZ697150	230	D	0.21	0.09	0.09	-1.05	0.163	1.2	-1.260	75	90.0	0.10	0.12
A3	AZ697155	230	D	0.52	0.28	0.28	-0.55	0.289	2.2	-1.210	75	165.0	0.10	0.22
A3	AZ69759	230	D	0.22	0.09	0.09	-1.05	0.053	0.4	-0.420	75	30.0	0.10	0.04
A3	AZ6976	230	D	0.79	0.46	0.46	-0.34	0.058	0.4	-0.136	75	30.0	0.10	0.04
A3	AZ697150	290	D	0.21	0.09	0.09	-1.05	0.000	0.0	0.000	60	0.0	0.15	0.00
A3	AZ69759	290	D	0.22	0.09	0.09	-1.05	0.003	0.0	0.000	60	0.0	0.15	0.00

Table A.21 Unit hydrograph example soils and land use parameters

ID	Soil ID	Land Use CODE	Land Use Cond.	XKSAT, in/hr Nat	XKSAT, in/hr Dev	XKSAT, in/hr Assign	XKSAT, in/hr Log10	Area (A) sm	Area (A) %	[8]*[10]	VCD	VCD * A [12]*[10]	IA	IA * A [14]*[10]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A3	AZ6976	290	D	0.79	0.46	0.46	-0.34	0.008	0.1	-0.034	60	6.0	0.15	0.02
A3	AZ697149	500	N	0.08	0.03	0.08	-1.10	0.000	0.0	0.000	10	0.0	0.35	0.00
A3	AZ697155	500	N	0.52	0.28	0.52	-0.28	0.041	0.3	-0.084	10	3.0	0.35	0.11
A3	AZ6971	510	N	0.29	0.13	0.29	-0.54	0.087	0.7	-0.378	10	7.0	0.15	0.11
A3	AZ697149	510	N	0.08	0.03	0.08	-1.10	0.150	1.1	-1.210	10	11.0	0.15	0.17
A3	AZ697150	510	N	0.21	0.09	0.21	-0.68	0.813	6.2	-4.216	10	62.0	0.15	0.93
A3	AZ697155	510	N	0.52	0.28	0.52	-0.28	0.119	0.9	-0.252	10	9.0	0.15	0.14
A3	AZ69759	510	N	0.22	0.09	0.22	-0.66	0.002	0.0	0.000	10	0.0	0.15	0.00
A3	AZ6976	510	N	0.79	0.46	0.79	-0.10	0.014	0.1	-0.010	10	1.0	0.15	0.02
A3	AZ6971	520	N	0.29	0.13	0.29	-0.54	0.005	0.0	0.000	20	0.0	0.25	0.00
A3	AZ697149	520	N	0.08	0.03	0.08	-1.10	0.166	1.3	-1.430	20	26.0	0.25	0.33
A3	AZ697150	520	N	0.21	0.09	0.21	-0.68	8.510	64.6	-43.928	20	1292.0	0.25	16.15
A3	AZ697155	520	N	0.52	0.28	0.52	-0.28	0.022	0.2	-0.056	20	4.0	0.25	0.05
A3	AZ697162	520	N	0.46	0.24	0.46	-0.34	0.007	0.1	-0.034	20	2.0	0.25	0.03
A3	AZ69735	520	N	0.16	0.07	0.16	-0.80	0.040	0.3	-0.240	20	6.0	0.25	0.08
A3	AZ69759	520	N	0.22	0.09	0.22	-0.66	0.064	0.5	-0.330	20	10.0	0.25	0.13
A3	AZ6976	520	N	0.79	0.46	0.79	-0.10	0.075	0.6	-0.060	20	12.0	0.25	0.15
			Area				**Totals:**	**13.167**	**100.0**	**-71.859**		**2728.5**		**23.36**
	Natural Area:		**76.9**	**%**			**Bare Ground $XKSAT_{Comp}$:**	**0.191**			**VC_{Avg}:**	**27.3**		
	Developed Area:		**23.1**	**%**			**PSIF:**	**8.18**			**$DTHETA_{Avg}$:**	**0.28**		**A3**
	Total:		**100.0**	**%**			**$DTHETA_{Dry}$:**	**0.30**			**$XKSAT_{Adj}$:**	**0.23**		
							$DTHETA_{Normal}$:	**0.19**			**IA_{Avg}:**	**0.23**		
A4	AZ627121	290	D	0.08	0.03	0.03	-1.52	0.017	0.2	-0.30	60	12.0	0.15	0.03
A4	AZ697117	290	D	0.21	0.10	0.10	-1.00	0.021	0.3	-0.30	60	18.0	0.15	0.05
A4	AZ697149	290	D	0.08	0.03	0.03	-1.52	0.057	0.7	-1.06	60	42.0	0.15	0.11
A4	AZ69759	290	D	0.22	0.09	0.09	-1.05	0.004	0.1	-0.11	60	6.0	0.15	0.02
A4	AZ6976	290	D	0.79	0.46	0.46	-0.34	0.023	0.3	-0.10	60	18.0	0.15	0.05
A4	AZ627121	520	N	0.08	0.03	0.08	-1.10	1.372	17.2	-18.92	20	344.0	0.25	4.30
A4	AZ62758	520	N	0.05	0.02	0.05	-1.30	0.013	0.2	-0.26	20	4.0	0.25	0.05
A4	AZ62774	520	N	0.32	0.16	0.32	-0.49	2.189	27.5	-13.48	20	550.0	0.25	6.88
A4	AZ6279	520	N	0.77	0.45	0.77	-0.11	0.082	1.0	-0.11	20	20.0	0.25	0.25
A4	AZ62793	520	N	0.21	0.10	0.21	-0.68	3.559	44.7	-30.40	20	894.0	0.25	11.18
A4	AZ697117	520	N	0.21	0.10	0.21	-0.68	0.338	4.2	-2.86	20	84.0	0.25	1.05
A4	AZ697149	520	N	0.08	0.03	0.08	-1.10	0.186	2.3	-2.53	20	46.0	0.25	0.58
A4	AZ6976	520	N	0.79	0.46	0.79	-0.10	0.096	1.2	-0.12	20	24.0	0.25	0.30
			Area				**Totals:**	**7.957**	**99.9**	**-70.54**		**2062.0**		**24.82**
	Natural Area:		**98.3**	**%**			**Bare Ground $XKSAT_{Comp}$:**	**0.197**			**VC_{Avg}:**	**20.6**		
	Developed Area:		**1.6**	**%**			**PSIF:**	**8.09**			**$DTHETA_{Avg}$:**	**0.30**		**A4**
	Total:		**99.9**	**%**			**$DTHETA_{Dry}$:**	**0.30**			**$XKSAT_{Adj}$:**	**0.22**		
							$DTHETA_{Normal}$:	**0.19**			**IA_{Avg}:**	**0.25**		
A5	AZ697149	230	D	0.08	0.03	0.03	-1.52	0.087	1.9	-2.89	75	142.5	0.10	0.19
A5	AZ697150	230	D	0.21	0.09	0.09	-1.05	0.486	10.4	-10.92	75	780.0	0.10	1.04
A5	AZ69732	230	D	0.19	0.07	0.07	-1.15	0.001	0.0	0.00	75	0.0	0.10	0.00

Table A.21 Unit hydrograph example soils and land use parameters

ID	Soil ID	Land Use CODE	Land Use Cond.	XKSAT, in/hr Nat	XKSAT, in/hr Dev	XKSAT, in/hr Assign	XKSAT, in/hr Log10	Area (A) sm	Area (A) %	[8]*[10]	VCD	VCD * A [12]*[10]	IA	IA * A [14]*[10]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A5	AZ6976	230	D	0.79	0.46	0.46	-0.34	0.069	1.5	-0.51	75	112.5	0.10	0.15
A5	AZ697117	290	D	0.21	0.10	0.10	-1.00	0.064	1.4	-1.40	60	84.0	0.15	0.21
A5	AZ697150	290	D	0.21	0.09	0.09	-1.05	0.004	0.1	-0.11	60	6.0	0.15	0.02
A5	AZ69732	290	D	0.19	0.07	0.07	-1.15	0.007	0.1	-0.12	60	6.0	0.15	0.02
A5	AZ6976	290	D	0.79	0.46	0.46	-0.34	0.048	1.0	-0.34	60	60.0	0.15	0.15
A5	AZ697150	510	N	0.21	0.09	0.21	-0.68	2.607	55.8	-37.94	10	558.0	0.15	8.37
A5	AZ697150	520	N	0.21	0.09	0.21	-0.68	1.289	27.6	-18.77	20	552.0	0.25	6.90
A5	AZ6976	520	N	0.79	0.46	0.79	-0.10	0.007	0.1	-0.01	20	2.0	0.25	0.03
			Area				**Totals:**	**4.669**	**99.9**	**-73.00**		**2303.0**		**17.07**
	Natural Area:		**83.5**	**%**		**Bare Ground XKSAT$_{Comp}$:**		**0.186**			**VC$_{Avg}$:**	**23.1**		**A5**
	Developed Area:		**16.4**	**%**			**PSIF:**	**8.25**			**DTHETA$_{Avg}$:**	**0.28**		
	Total:		**99.9**	**%**			**DTHETA$_{Dry}$:**	**0.30**			**XKSAT$_{Adj}$:**	**0.22**		
							DTHETA$_{Normal}$:	**0.18**			**IA$_{Avg}$:**	**0.17**		
A6	AZ697150	230	D	0.21	0.09	0.09	-1.05	0.363	4.2	-4.41	75	315.0	0.10	0.42
A6	AZ69732	230	D	0.19	0.07	0.07	-1.15	0.018	0.2	-0.23	75	15.0	0.10	0.02
A6	AZ6976	230	D	0.79	0.46	0.46	-0.34	0.114	1.3	-0.44	75	97.5	0.10	0.13
A6	AZ627121	290	D	0.08	0.03	0.03	-1.52	0.055	0.6	-0.91	60	36.0	0.15	0.09
A6	AZ627133	290	D	0.05	0.03	0.03	-1.52	0.129	1.5	-2.28	60	90.0	0.15	0.23
A6	AZ6279	290	D	0.77	0.45	0.45	-0.35	0.033	0.4	-0.14	60	24.0	0.15	0.06
A6	AZ62793	290	D	0.21	0.10	0.10	-1.00	0.775	8.9	-8.90	60	534.0	0.15	1.34
A6	AZ697117	290	D	0.21	0.10	0.10	-1.00	0.178	2.0	-2.00	60	120.0	0.15	0.30
A6	AZ697149	290	D	0.08	0.03	0.03	-1.52	0.011	0.1	-0.15	60	6.0	0.15	0.02
A6	AZ69732	290	D	0.19	0.07	0.07	-1.15	0.061	0.7	-0.81	60	42.0	0.15	0.11
A6	AZ6976	290	D	0.79	0.46	0.46	-0.34	0.100	1.2	-0.41	60	72.0	0.15	0.18
A6	AZ627121	510	N	0.08	0.03	0.08	-1.10	1.113	12.8	-14.08	10	128.0	0.15	1.92
A6	AZ62793	510	N	0.21	0.10	0.21	-0.68	0.023	0.3	-0.20	10	3.0	0.15	0.05
A6	AZ627121	520	N	0.08	0.03	0.08	-1.10	1.717	19.8	-21.78	20	396.0	0.25	4.95
A6	AZ627133	520	N	0.05	0.03	0.05	-1.30	0.362	4.2	-5.46	20	84.0	0.25	1.05
A6	AZ62774	520	N	0.32	0.16	0.32	-0.49	0.000	0.0	0.00	20	0.0	0.25	0.00
A6	AZ62793	520	N	0.21	0.10	0.21	-0.68	3.441	39.6	-26.93	20	792.0	0.25	9.90
A6	AZ697150	520	N	0.21	0.09	0.21	-0.68	0.197	2.3	-1.56	20	46.0	0.25	0.58
			Area				**Totals:**	**8.690**	**100.1**	**-90.70**		**2800.5**		**21.32**
	Natural Area:		**79.0**	**%**		**Bare Ground XKSAT$_{Comp}$:**		**0.124**			**VC$_{Avg}$:**	**28.0**		**A6**
	Developed Area:		**21.1**	**%**			**PSIF:**	**9.25**			**DTHETA$_{Avg}$:**	**0.25**		
	Total:		**100.1**	**%**			**DTHETA$_{Dry}$:**	**0.28**			**XKSAT$_{Adj}$:**	**0.15**		
							DTHETA$_{Normal}$:	**0.16**			**IA$_{Avg}$:**	**0.21**		
A7	AZ697150	230	D	0.21	0.09	0.09	-1.05	0.195	13.3	-13.97	75	997.5	0.10	1.33
A7	AZ6976	230	D	0.79	0.46	0.46	-0.34	0.000	0.0	0.00	75	0.0	0.10	0.00
A7	AZ697150	510	N	0.21	0.09	0.21	-0.68	0.158	10.8	-7.34	10	108.0	0.15	1.62
A7	AZ697150	520	N	0.21	0.09	0.21	-0.68	1.111	75.9	-51.61	20	1518.0	0.25	18.98
			Area				**Totals:**	**1.464**	**100.0**	**-72.92**		**2623.5**		**21.93**

Table A.21 Unit hydrograph example soils and land use parameters

ID	Soil ID	Land Use CODE	Land Use Cond.	XKSAT, in/hr Nat	XKSAT, in/hr Dev	XKSAT, in/hr Assign	XKSAT, in/hr Log10	Area (A) sm	Area (A) %	[8]*[10]	VCD	VCD * A [12]*[10]	IA	IA * A [14]*[10]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Natural Area:	86.7	%		Bare Ground $XKSAT_{Comp}$:			0.187		VC_{Avg}:	26.2		
		Developed Area:	13.3	%		PSIF:			8.24		$DTHETA_{Avg}$:	0.29		
		Total:	100.0	%		$DTHETA_{Dry}$:			0.30		$XKSAT_{Adj}$:	0.22		
						$DTHETA_{Normal}$:			0.18		IA_{Avg}:	0.22		
A8	AZ62750	160	D	0.36	0.16	0.16	-0.80	0.003	0.1	-0.08	50	5.0	0.25	0.03
A8	AZ62789	160	D	0.16	0.06	0.06	-1.22	0.024	1.1	-1.34	50	55.0	0.25	0.28
A8	AZ6279	160	D	0.77	0.45	0.45	-0.35	0.049	2.2	-0.77	50	110.0	0.25	0.55
A8	AZ627133	230	D	0.05	0.03	0.03	-1.52	0.001	0.0	0.00	75	0.0	0.10	0.00
A8	AZ627136	230	D	0.21	0.09	0.09	-1.05	0.024	1.1	-1.16	75	82.5	0.10	0.11
A8	AZ62717	230	D	0.04	0.01	0.01	-2.00	0.040	1.8	-3.60	75	135.0	0.10	0.18
A8	AZ62750	230	D	0.36	0.16	0.16	-0.80	0.001	0.0	0.00	75	0.0	0.10	0.00
A8	AZ62789	230	D	0.16	0.06	0.06	-1.22	0.014	0.6	-0.73	75	45.0	0.10	0.06
A8	AZ6279	230	D	0.77	0.45	0.45	-0.35	0.138	6.2	-2.17	75	465.0	0.10	0.62
A8	AZ697150	230	D	0.21	0.09	0.09	-1.05	0.155	7.0	-7.35	75	525.0	0.10	0.70
A8	AZ6976	230	D	0.79	0.46	0.46	-0.34	0.045	2.0	-0.68	75	150.0	0.10	0.20
A8	AZ627133	500	N	0.05	0.03	0.05	-1.30	0.002	0.1	-0.13	10	1.0	0.35	0.04
A8	AZ627136	500	N	0.21	0.09	0.21	-0.68	0.002	0.1	-0.07	10	1.0	0.35	0.04
A8	AZ62750	500	N	0.36	0.16	0.36	-0.44	0.003	0.1	-0.04	10	1.0	0.35	0.04
A8	AZ62776	500	N	0.45	0.23	0.45	-0.35	0.011	0.5	-0.18	10	5.0	0.35	0.18
A8	AZ6279	500	N	0.77	0.45	0.77	-0.11	0.013	0.6	-0.07	10	6.0	0.35	0.21
A8	AZ627133	510	N	0.05	0.03	0.05	-1.30	0.108	4.9	-6.37	10	49.0	0.15	0.74
A8	AZ627136	510	N	0.21	0.09	0.21	-0.68	0.068	3.1	-2.11	10	31.0	0.15	0.47
A8	AZ62750	510	N	0.36	0.16	0.36	-0.44	0.220	9.9	-4.36	10	99.0	0.15	1.49
A8	AZ62776	510	N	0.45	0.23	0.45	-0.35	0.001	0.0	0.00	10	0.0	0.15	0.00
A8	AZ6279	510	N	0.77	0.45	0.77	-0.11	0.009	0.4	-0.04	10	4.0	0.15	0.06
A8	AZ697150	510	N	0.21	0.09	0.21	-0.68	0.205	9.2	-6.26	10	92.0	0.15	1.38
A8	AZ69791	510	N	0.04	0.02	0.04	-1.40	0.027	1.2	-1.68	10	12.0	0.15	0.18
A8	AZ627133	520	N	0.05	0.03	0.05	-1.30	0.117	5.3	-6.89	20	106.0	0.25	1.33
A8	AZ62750	520	N	0.36	0.16	0.36	-0.44	0.017	0.8	-0.35	20	16.0	0.25	0.20
A8	AZ697150	520	N	0.21	0.09	0.21	-0.68	0.860	38.8	-26.38	20	776.0	0.25	9.70
A8	AZ69791	520	N	0.04	0.02	0.04	-1.40	0.061	2.8	-3.92	20	56.0	0.25	0.70
			Area				Totals:	2.218	99.9	-76.72		2827.5		19.44
		Natural Area:	77.8	%	28.3				0.171		VC_{Avg}:	28.3		
		Developed Area:	22.1	%	0.27				8.49		$DTHETA_{Avg}$:	0.27		
		Total:	99.9	%	0.21				0.29		$XKSAT_{Adj}$:	0.21		
							$DTHETA_{Normal}$:		0.18		IA_{Avg}:	0.19		
B1	AZ62710	160	D	0.79	0.46	0.46	-0.34	0.010	0.2	-0.07	50	10.0	0.25	0.05
B1	AZ62717	160	D	0.04	0.01	0.01	-2.00	0.004	0.1	-0.20	50	5.0	0.25	0.03
B1	AZ62750	160	D	0.36	0.16	0.16	-0.80	0.060	1.3	-1.04	50	65.0	0.25	0.33
B1	AZ62789	160	D	0.16	0.06	0.06	-1.22	0.010	0.2	-0.24	50	10.0	0.25	0.05
B1	AZ62750	170	D	0.36	0.16	0.16	-0.80	0.034	0.7	-0.56	50	35.0	0.25	0.18
B1	AZ62710	230	D	0.79	0.46	0.46	-0.34	0.041	0.9	-0.31	75	67.5	0.10	0.09
B1	AZ62717	230	D	0.04	0.01	0.01	-2.00	0.287	6.1	-12.20	75	457.5	0.10	0.61

A7

A8

Table A.21 Unit hydrograph example soils and land use parameters

ID	Soil ID	Land Use		XKSAT, in/hr				Area (A)		[8]*[10]	VCD	VCD * A [12]*[10]	IA	IA * A [14]*[10]
		CODE	Cond.	Nat	Dev	Assign	Log10	sm	%					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B1	AZ62750	230	D	0.36	0.16	0.16	-0.80	0.129	2.8	-2.24	75	210.0	0.10	0.28
B1	AZ62789	230	D	0.16	0.06	0.06	-1.22	0.040	0.9	-1.10	75	67.5	0.10	0.09
B1	AZ6279	230	D	0.77	0.45	0.45	-0.35	0.041	0.9	-0.32	75	67.5	0.10	0.09
B1	AZ6976	230	D	0.79	0.46	0.46	-0.34	0.002	0.0	0.00	75	0.0	0.10	0.00
B1	AZ627133	290	D	0.05	0.03	0.03	-1.52	0.900	19.3	-29.34	60	1158.0	0.15	2.90
B1	AZ62717	290	D	0.04	0.01	0.01	-2.00	1.081	23.1	-46.20	60	1386.0	0.15	3.47
B1	AZ62750	290	D	0.36	0.16	0.16	-0.80	0.840	18.0	-14.40	60	1080.0	0.15	2.70
B1	AZ62782	290	D	0.06	0.03	0.03	-1.52	0.008	0.2	-0.30	60	12.0	0.15	0.03
B1	AZ6279	290	D	0.77	0.45	0.45	-0.35	0.006	0.1	-0.04	60	6.0	0.15	0.02
B1	AZ62793	290	D	0.21	0.10	0.10	-1.00	0.188	4.0	-4.00	60	240.0	0.15	0.60
B1	AZ697117	290	D	0.21	0.10	0.10	-1.00	0.001	0.0	0.00	60	0.0	0.15	0.00
B1	AZ6976	290	D	0.79	0.46	0.46	-0.34	0.007	0.1	-0.03	60	6.0	0.15	0.02
B1	AZ62717	500	N	0.04	0.01	0.04	-1.40	0.000	0.0	0.00	10	0.0	0.35	0.00
B1	AZ62750	500	N	0.36	0.16	0.36	-0.44	0.000	0.0	0.00	10	0.0	0.35	0.00
B1	AZ627133	510	N	0.05	0.03	0.05	-1.30	0.283	6.1	-7.93	10	61.0	0.15	0.92
B1	AZ62717	510	N	0.04	0.01	0.04	-1.40	0.289	6.2	-8.68	10	62.0	0.15	0.93
B1	AZ62750	510	N	0.36	0.16	0.36	-0.44	0.001	0.0	0.00	10	0.0	0.15	0.00
B1	AZ627133	520	N	0.05	0.03	0.05	-1.30	0.381	8.2	-10.66	20	164.0	0.25	2.05
B1	AZ62793	520	N	0.21	0.10	0.21	-0.68	0.028	0.6	-0.41	20	12.0	0.25	0.15
			Area				Totals:	4.671	100.0	-140.26		5182.0		15.55
	Natural Area:		21.1	%		Bare Ground $XKSAT_{Comp}$:		0.040		VC_{Avg}:		51.8	B1	
	Developed Area:		78.9	%		PSIF:		10.81		$DTHETA_{Avg}$:		0.13		
	Total:		100.0	%		$DTHETA_{Dry}$:		0.23		$XKSAT_{Adj}$:		0.06		
	$DTHETA_{Normal}$:							0.10		IA_{Avg}:		0.16		

Table A.22 Sub-basin and land use areas

Sub-basin ID	Land Use Area, in sq. mi.									Totals
	114	140	160	170	230	290	500	510	520	
A1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.352	8.012	8.363
A2	0.096	0.686	1.625	0.000	0.214	0.712	0.318	1.252	6.696	11.599
A3	0.000	0.000	2.365	0.000	0.676	0.012	0.042	1.184	8.888	13.167
A4	0.000	0.000	0.000	0.000	0.000	0.122	0.000	0.000	7.834	7.957
A5	0.000	0.000	0.000	0.000	0.643	0.123	0.000	2.607	1.296	4.669
A6	0.000	0.000	0.000	0.000	0.495	1.341	0.000	1.136	5.717	8.689
A7	0.000	0.000	0.000	0.000	0.196	0.000	0.000	0.158	1.111	1.464
A8	0.000	0.000	0.076	0.000	0.417	0.000	0.030	0.638	1.055	2.215
B1	0.000	0.000	0.084	0.034	0.539	3.033	0.001	0.573	0.409	4.672
Totals	0.096	0.686	4.150	0.034	3.179	5.347	0.391	7.901	41.017	62.800

Per Table 7.20, the unit hydrograph land use parameters are listed in Table A.23 for each land use type present in the watershed:

Table A.23 Unit hydrograph land use parameters

DDMS ID	Mohave County Zoning Classification	Vegetation Cover Density	RTIMP	IA	DTHETA Condition
Commercial					
230	C-2: General Commercial (6,000 sf minimum, C2)	75	80	0.10	NORMAL
290	M-X: Heavy Manufacturing (1 acre minimum, I2)	60	60	0.15	NORMAL
Natural					
500	Undeveloped Desert Rangeland. Little topographic relief, slopes <5%	10 (varies)	varies	0.35	DRY
510	Hillslopes, Sonoran Desert. Moderate topographic relief, slopes >5%	10 (varies)	varies	0.15	DRY
520	Mountain Terrain. High topographic relief, slopes >20%	20 (varies)	varies	0.25	DRY
Residential					
114	A-R, R-E, R-1, R-MH, R-TT, R-M, R-O, R-O/A (2-5 acre minimum, VLDR)	50	15	0.30	NORMAL
140	R-E, R-1, R-MH, R-TT, R-M, R-O (20,000 sf – 1 acre minimum, LDR)	50	25	0.25	NORMAL
160	R-1, R-MH, R-TT, R-M, R-O (7,000-10,000 sf minimum, MDR)	50	50	0.25	NORMAL
170	R-1, R-MH, R-TT, R-M, R-O (6,000-7,000 sf minimum, MDR)	50	60	0.25	NORMAL

Using sub-basin A7 as an example and the data in Table A.21, the area-weighted, or composite, value of IA is computed as follows, using Equation 7.12 in Section 7.4.4.3:

$$\overline{IA} = \left(\frac{\sum A_i IA_i}{A_T} \right)$$

where:

$\overline{IA}$ = composite value of IA, inches

IA_i = IA of each sub-area, inches

A_i = size of IA sub-area

A_T = size of the watershed or sub-basin

$$\overline{IA} = \left(\frac{0.000 * 0.10 + 0.195 * 0.10 + 0.158 * 0.15 + 1.111 * 0.25}{1.464} \right) = 0.22 \, inches$$

Using the same procedure, IA for the other sub-basins was computed. Refer to Table A.21. The results are summarized as follows:

	A1	A2	A3	A4	A5	A6	A7	A8	B1
IA	0.25	0.23	0.23	0.25	0.17	0.21	0.22	0.19	0.16

Step 7. Computation of sub-basin composite bare ground XKSAT.

The first step is to obtain the needed soil properties data. The most difficult part has already been completed on a countywide basis for Mohave County. This is the estimate for an average value of bare ground XKSAT for natural and developed conditions each NRCS soil map unit (SMU). The procedures used to accomplish this are described in Appendix D. The values of XKSAT for each SMU in each NRCS Soil Survey are tabulated in Appendix D.3.

To estimate an average value of bare ground XKSAT for each sub-basin, the area of each SMU within the sub-basin is needed. These areas can be measured by hand using a scaled map of the watershed overlaid on the NRCS soil map, in CAD software by importing the available GIS databases, using GIS software, or using the GIS Method within the DDMSW computer program. For this example, the GIS Method within DDMSW was used. The computed soils sub-areas for sub-basin A7 are listed in Table A.21. The value of XKSAT used in the computation of sub-basin average XKSAT is dependant on the land use condition. Therefore, the land use polygons must be overlaid on the soil map unit polygons to define the land use condition overlaying each soil map unit individual area. The values in Table A.21 reflect this double “cookie-cutter” approach for each sub-basin. For example, in Sub-basin A7, the 1st polygon listed in Table A.21 is for Soil_ID AZ697150 (NRCS Soil Survey AZ697, SMU 150) and Land Use Code 230. Since the land use condition is developed, the developed condition XKSAT (0.09 in/hr) is used in the

computation. For the 3rd polygon, Soil_ID AZ697150 and Land Use Code 510, the natural condition XKSAT value (0.21 in/hr) is used.

The sub-basin log-area-averaged value of bare ground XKSAT for sub-basin A7 is computed using Equation 7.13 in Section 7.4.4.4 and data from Table A.21 as follows:

$$\overline{XKSAT} = anti\log\left(\frac{\sum A_i \log_{10} XKSAT_i}{A_T}\right)$$

where:

$\overline{XKSAT}$ = composite bare ground hydraulic conductivity for the watershed sub-basin, inches/hour

$XKSAT_i$ = bare ground hydraulic conductivity of the soil map unit within a sub-basin, inches/hour

A_i = area of soil map unit subarea within a sub-basin

A_T = total area of the watershed or sub-basin

$$\overline{XKSAT} = a\log\left[\frac{0.195\log_{10}(0.09) + 0.000\log_{10}(0.46) + 0.158\log_{10}(0.21) + 1.111\log_{10}(0.21)}{1.464}\right]$$

$$\overline{XKSAT} = 0.19\ inches/hour$$

Using the same procedure, composite bare ground XKSAT for the other sub-basins was computed. The results are summarized as follows:

Bare Ground	A1	A2	A3	A4	A5	A6	A7	A8	B1
XKSAT	0.16	0.14	0.19	0.20	0.19	0.12	0.19	0.17	0.04

Step 8. Assignment of PSIF and DTHETA.

The values of PSIF and DTHETA for each sub-basin are estimated using the bare ground XKSAT computed in Step 7. Refer to Figure 7.14 and Figure 7.15, and Equation 7.9, Equation 7.10, and Equation 7.11 in Section 7.4.2.3. The bare ground XKSAT for sub-basin A7 is 0.19 in/hr. From Figure 7.14, the PSIF value corresponding to an XKSAT of 0.19 is approximately 8 in. Applying Equation 7.9, PSIF is:

$$PSIF = 11.63103 * 0.15801^{0.19}$$

$PSIF = 8.19\ inches$ (Note:Table A.21 shows a value of 8.24, based on XKSAT carried to 3 decimal place accuracy)

From Figure 7.15, $DTHETA_{dry}$ and $DTHETA_{normal}$ are about 0.30 and 0.19, respectively. Applying Equation 7.10 and Equation 7.11, $DTHETA_{dry}$ and $DTHETA_{normal}$ are:

$$DTHETA_{dry} = 0.36180 + 0.03953 * \log_e 0.19$$

$$DTHETA_{dry} = 0.30$$

$$DTHETA_{norm} = 0.28536 + 0.060058 * LOG_e(0.19) - 0.001009 * LOG_e(0.19)^2 - 0.000615 * LOG_e(0.19)^3$$

$DTHETA_{norm} = 0.19$ (Note: Table A.21 shows a value of 0.18, based on XKSAT carried to 3 decimal place accuracy)

When a sub-basin contains a mix of natural and urban land uses, an area-weighted value of DTHETA should be computed. The total area of natural land use from Table A.22 (Types 510 and 520) for sub-basin A7 is 1.268 square miles, or 86.7%. The total area of developed land use from Table A.22 (Type 230) for sub-basin A7 is 0.196 square miles, or 13.3%. The area-weighted, or composite, value of DTHETA is computed as follows, using Equation 7.14 in Section 7.4.4.5:

$$\overline{DTHETA} = \left(\frac{\sum A_i DTHETA_i}{A_T} \right)$$

where:

$\overline{DTHETA}$ = composite value of DTHETA

$DTHETA_i$ = DTHETA of each subarea

A_i = size of DTHETA subarea

A_T = size of the watershed or sub-basin

$$\overline{DTHETA} = \left(\frac{86.7 * 0.30 + 13.3 * 0.19}{100.0} \right) = 0.29$$

The percent of natural and developed area, rather than the area in square miles or acres, is used for this example because that is how DDMSW does its calculations. Using the same procedure, area-weighted DTHETA for the other sub-basins was computed. The results, taken from Table A.21, are summarized as follows:

	A1	A2	A3	A4	A5	A6	A7	A8	B1
PSIF	8.68	9.05	8.18	8.09	8.25	9.25	8.24	8.49	10.81
PSIF DDMSW Ex 1	8.67	9.03	8.15	8.07	8.22	9.24	8.22	8.47	10.80
DTHETA	0.29	0.25	0.28	0.30	0.28	0.25	0.29	0.27	0.13

The values of PSIF computed by DDMSW are included above to show there are slight differences between DDMSW and the hand calculations shown herein. These slight differences are due to roundoff within DDMSW.

Step 9. Computation of sub-basin composite vegetation cover density (VCD).

VCD is estimated by calculating an area-weighted value for each sub-basin using standard values assigned for the land use sub-areas. The areas of the land use sub-areas can be determined by hand using a hard copy of the watershed land use map or digitally using CADD or GIS software. For this example, the areas were calculated using GIS. The sub-basin and land use sub-areas are summarized in Table A.22, the default values of VCD for each land use are listed in Table A.23.

Using sub-basin A7 as an example, the area-weighted, or composite, value of VCD is computed as follows, using Equation 7.15 in Section 7.4.4.6:

$$\overline{VCD} = \left(\frac{\sum A_i VCD_i}{A_T} \right)$$

where:

$\overline{VCD}$ = composite value of VCD, inches

VCD_i = VCD of each subarea, inches

A_i = size of VCD subarea

A_T = size of the watershed or sub-basin

$$\overline{VCD} = \left(\frac{0.196 * 75 + 0.000 * 75 + 0.158 * 10 + 1.111 * 20}{1.464} \right) = 26\%$$

Using the same procedure, VCD for the other sub-basins was computed. The results are summarized as follows, rounded to the nearest percent:

	A1	A2	A3	A4	A5	A6	A7	A8	B1
VCD	20	28	27	21	23	28	26	28	52

Note that the sub-basin VCD values are affected by having a significant percentage of both developed and undeveloped land uses within most of the sub-basins. The sub-basin VCD is significantly higher than the estimates for the undeveloped areas and significantly lower than the estimates for the developed areas. This is an example of why it is a preferred approach to breakout developed and undeveloped areas into separate sub-basins. The same effect can be seen in IA, DTHETA and RTIMP.

Step 10. Computation of XKSAT adjusted for vegetation canopy cover.

The sub-basin composite bare ground XKSAT values from Step 7 area adjusted for the effects of vegetation canopy cover using Figure 7.16 or Equation 7.16 in Section 7.4.4.6. The adjusted XKSAT for sub-basin A7 is computed using Equation 7.16 as follows:

$$XKSAT_{adj} = \overline{XKSAT}_{BG}\left(\frac{\overline{VCD} - 10}{90} + 1\right)$$

where:

$XKSAT_{adj}$ = $\overline{XKSAT}_{BG}$ adjusted for the effects of vegetation canopy cover, inches/hour

$\overline{XKSAT}_{BG}$ = sub-basin composite bare ground XKSAT, inches/hour

$\overline{VCD}$ = sub-basin composite value of vegetation canopy cover, percent

$$XKSAT_{adj} = 0.187\left(\frac{26 - 10}{90} + 1\right) = 0.22\ inches/hour$$

Using the same procedure, $XKSAT_{adj}$ for the other sub-basins was computed. The results are summarized as follows:

	A1	A2	A3	A4	A5	A6	A7	A8	B1
$XKSAT_{adj}$	0.18	0.17	0.23	0.22	0.22	0.15	0.22	0.21	0.06

Step 11. Estimation of sub-basin composite RTIMP.

RTIMP is estimated by calculating an area-weighted value for each sub-basin for the natural areas and the developed areas separately, and then area weighting the natural and developed average values. The RTIMP computations for each sub-basin are listed in Table A.24.

Table A.24 Unit hydrograph example RTIMP calculations

Basin ID	Soil LID	Land Use		RTIMP	RTIMP, %			Area	Area x $RTIMP_N$	Area x $RTIMP_D$
		CODE	Cond.	Nat % Eff	Nat.	Adj	Dev.	sm		
1	2	3	4	5	6	7	8	9	10	11
A1	AZ697101	510	N	100	0	0	0	0.050	0.000	0.000
A1	AZ697117	510	N	100	20	20	0	0.228	4.560	0.000
A1	AZ697149	510	N	100	0	0	0	0.002	0.000	0.000
A1	AZ6976	510	N	100	0	0	0	0.072	0.000	0.000
A1	AZ627121	520	N	100	0	0	0	0.040	0.000	0.000
A1	AZ62742	520	N	100	20	20	0	1.074	21.480	0.000
A1	AZ62758	520	N	100	20	20	0	2.376	47.520	0.000
A1	AZ62774	520	N	100	20	20	0	2.635	52.700	0.000
A1	AZ6279	520	N	100	0	0	0	0.008	0.000	0.000
A1	AZ62793	520	N	100	20	20	0	0.356	7.120	0.000
A1	AZ697100	520	N	100	0	0	0	0.359	0.000	0.000
A1	AZ697101	520	N	100	0	0	0	0.195	0.000	0.000
A1	AZ697104	520	N	100	0	0	0	0.102	0.000	0.000
A1	AZ697117	520	N	100	20	20	0	0.234	4.680	0.000
A1	AZ697149	520	N	100	0	0	0	0.037	0.000	0.000
A1	AZ69734	520	N	100	20	20	0	0.544	10.880	0.000
A1	AZ6976	520	N	100	0	0	0	0.048	0.000	0.000
A1	AZ69799	520	N	100	20	20	0	0.003	0.060	0.000
							Totals:	**8.363**	**149.000**	**0.000**
							$RTIMP_{Avg}$:		**17.82**	**0.00**
							Total RTIMP:		**18**	**A1**
A2	AZ697150	114	N	100	0	0	15	0.091	0.000	1.365
A2	AZ6976	114	N	100	0	0	15	0.005	0.000	0.075
A2	AZ697101	140	D	100	0	0	25	0.092	0.000	2.300
A2	AZ697117	140	D	100	20	20	25	0.182	3.640	4.550
A2	AZ69759	140	D	100	20	20	25	0.010	0.200	0.250
A2	AZ6976	140	D	100	0	0	25	0.067	0.000	1.675
A2	AZ69770	140	D	100	0	0	25	0.335	0.000	8.375
A2	AZ697117	160	D	100	20	20	50	0.744	14.880	37.200
A2	AZ697149	160	D	100	0	0	50	0.196	0.000	9.800
A2	AZ697150	160	D	100	0	0	50	0.164	0.000	8.200
A2	AZ697155	160	D	100	0	0	50	0.068	0.000	3.400
A2	AZ69759	160	D	100	20	20	50	0.054	1.080	2.700
A2	AZ6976	160	D	100	0	0	50	0.163	0.000	8.150
A2	AZ69770	160	D	100	0	0	50	0.237	0.000	11.850
A2	AZ697149	230	D	100	0	0	80	0.148	0.000	11.840
A2	AZ697155	230	D	100	0	0	80	0.033	0.000	2.640

Table A.24 Unit hydrograph example RTIMP calculations

Basin ID	Soil LID	Land Use		RTIMP	RTIMP, %			Area	Area x $RTIMP_N$	Area x $RTIMP_D$
		CODE	Cond.	Nat % Eff	Nat.	Adj	Dev.	sm		
1	2	3	4	5	6	7	8	9	10	11
A2	AZ69759	230	D	100	20	20	80	0.032	0.640	2.560
A2	AZ69770	230	D	100	0	0	80	0.000	0.000	0.000
A2	AZ697117	290	D	100	20	20	60	0.218	4.360	13.080
A2	AZ697149	290	D	100	0	0	60	0.206	0.000	12.360
A2	AZ697150	290	D	100	0	0	60	0.017	0.000	1.020
A2	AZ69759	290	D	100	20	20	60	0.022	0.440	1.320
A2	AZ6976	290	D	100	0	0	60	0.178	0.000	10.680
A2	AZ69770	290	D	100	0	0	60	0.071	0.000	4.260
A2	AZ697149	500	N	100	0	0	0	0.003	0.000	0.000
A2	AZ697150	500	N	100	0	0	0	0.000	0.000	0.000
A2	AZ697155	500	N	100	0	0	0	0.007	0.000	0.000
A2	AZ69759	500	N	50	20	10	0	0.166	1.660	0.000
A2	AZ6976	500	N	100	0	0	0	0.025	0.000	0.000
A2	AZ69770	500	N	100	0	0	0	0.117	0.000	0.000
A2	AZ697101	510	N	100	0	0	0	0.188	0.000	0.000
A2	AZ697117	510	N	50	20	10	0	0.359	3.590	0.000
A2	AZ697149	510	N	100	0	0	0	0.069	0.000	0.000
A2	AZ697150	510	N	100	0	0	0	0.123	0.000	0.000
A2	AZ697155	510	N	100	0	0	0	0.024	0.000	0.000
A2	AZ69759	510	N	50	20	10	0	0.182	1.820	0.000
A2	AZ6976	510	N	100	0	0	0	0.131	0.000	0.000
A2	AZ69770	510	N	100	0	0	0	0.176	0.000	0.000
A2	AZ627121	520	N	100	0	0	0	1.184	0.000	0.000
A2	AZ62758	520	N	50	20	10	0	0.000	0.000	0.000
A2	AZ62793	520	N	50	20	10	0	1.078	10.780	0.000
A2	AZ697117	520	N	50	20	10	0	2.397	23.970	0.000
A2	AZ697149	520	N	100	0	0	0	1.165	0.000	0.000
A2	AZ697150	520	N	100	0	0	0	0.608	0.000	0.000
A2	AZ697155	520	N	100	0	0	0	0.013	0.000	0.000
A2	AZ69759	520	N	50	20	10	0	0.150	1.500	0.000
A2	AZ6976	520	N	100	0	0	0	0.088	0.000	0.000
A2	AZ69770	520	N	100	0	0	0	0.013	0.000	0.000
							Totals:	**11.599**	**68.560**	**159.650**
							$RTIMP_{Avg}$:		**5.91**	**13.76**
							Total RTIMP:		**20**	**A2**
A3	AZ6971	160	D	100	0	0	50	0.137	0.000	6.850
A3	AZ697149	160	D	100	0	0	50	0.020	0.000	1.000
A3	AZ697150	160	D	100	0	0	50	1.309	0.000	65.450
A3	AZ697155	160	D	100	0	0	50	0.818	0.000	40.900
A3	AZ6976	160	D	100	0	0	50	0.081	0.000	4.050
A3	AZ697149	230	D	100	0	0	80	0.113	0.000	9.040
A3	AZ697150	230	D	100	0	0	80	0.163	0.000	13.040
A3	AZ697155	230	D	100	0	0	80	0.289	0.000	23.120
A3	AZ69759	230	D	100	20	20	80	0.053	1.060	4.240

Table A.24 Unit hydrograph example RTIMP calculations

Basin	Soil	Land Use		RTIMP	RTIMP, %			Area	Area x	Area x
ID	LID	CODE	Cond.	Nat % Eff	Nat.	Adj	Dev.	sm	$RTIMP_N$	$RTIMP_D$
1	2	3	4	5	6	7	8	9	10	11
A3	AZ6976	230	D	100	0	0	80	0.058	0.000	4.640
A3	AZ697150	290	D	100	0	0	60	0.000	0.000	0.000
A3	AZ69759	290	D	100	20	20	60	0.003	0.060	0.180
A3	AZ6976	290	D	100	0	0	60	0.008	0.000	0.480
A3	AZ697149	500	N	100	0	0	0	0.000	0.000	0.000
A3	AZ697155	500	N	100	0	0	0	0.041	0.000	0.000
A3	AZ6971	510	N	100	0	0	0	0.087	0.000	0.000
A3	AZ697149	510	N	100	0	0	0	0.150	0.000	0.000
A3	AZ697150	510	N	100	0	0	0	0.813	0.000	0.000
A3	AZ697155	510	N	100	0	0	0	0.119	0.000	0.000
A3	AZ69759	510	N	100	20	20	0	0.002	0.040	0.000
A3	AZ6976	510	N	100	0	0	0	0.014	0.000	0.000
A3	AZ6971	520	N	100	0	0	0	0.005	0.000	0.000
A3	AZ697149	520	N	100	0	0	0	0.166	0.000	0.000
A3	AZ697150	520	N	100	0	0	0	8.510	0.000	0.000
A3	AZ697155	520	N	100	0	0	0	0.022	0.000	0.000
A3	AZ697162	520	N	100	10	10	0	0.007	0.070	0.000
A3	AZ69735	520	N	100	0	0	0	0.040	0.000	0.000
A3	AZ69759	520	N	100	20	20	0	0.064	1.280	0.000
A3	AZ6976	520	N	100	0	0	0	0.075	0.000	0.000
							Totals:	**13.167**	**2.510**	**172.990**
							$RTIMP_{Avg}$:		**0.19**	**13.14**
							Total RTIMP:		**13**	**A3**
A4	AZ627121	290	D	100	0	0	60	0.017	0.000	1.020
A4	AZ697117	290	D	100	20	20	60	0.021	0.420	1.260
A4	AZ697149	290	D	100	0	0	60	0.057	0.000	3.420
A4	AZ69759	290	D	100	20	20	60	0.004	0.080	0.240
A4	AZ6976	290	D	100	0	0	60	0.023	0.000	1.380
A4	AZ627121	520	N	100	0	0	0	1.372	0.000	0.000
A4	AZ62758	520	N	100	20	20	0	0.013	0.260	0.000
A4	AZ62774	520	N	100	20	20	0	2.189	43.780	0.000
A4	AZ6279	520	N	100	0	0	0	0.082	0.000	0.000
A4	AZ62793	520	N	100	20	20	0	3.559	71.180	0.000
A4	AZ697117	520	N	100	20	20	0	0.338	6.760	0.000
A4	AZ697149	520	N	100	0	0	0	0.186	0.000	0.000
A4	AZ6976	520	N	100	0	0	0	0.096	0.000	0.000
							Totals:	**7.957**	**122.480**	**7.320**
							$RTIMP_{Avg}$:		**15.39**	**0.92**
							Total RTIMP:		**16**	**A4**
A5	AZ697149	230	D	100	0	0	80	0.087	0.000	6.960
A5	AZ697150	230	D	100	0	0	80	0.486	0.000	38.880
A5	AZ69732	230	D	100	0	0	80	0.001	0.000	0.080
A5	AZ6976	230	D	100	0	0	80	0.069	0.000	5.520

Table A.24 Unit hydrograph example RTIMP calculations

Basin ID	Soil LID	Land Use		RTIMP	RTIMP, %			Area	Area x $RTIMP_N$	Area x $RTIMP_D$
		CODE	Cond.	Nat % Eff	Nat.	Adj	Dev.	sm		
1	2	3	4	5	6	7	8	9	10	11
A5	AZ697117	290	D	100	20	20	60	0.064	1.280	3.840
A5	AZ697150	290	D	100	0	0	60	0.004	0.000	0.240
A5	AZ69732	290	D	100	0	0	60	0.007	0.000	0.420
A5	AZ6976	290	D	100	0	0	60	0.048	0.000	2.880
A5	AZ697150	510	N	100	0	0	0	2.607	0.000	0.000
A5	AZ697150	520	N	100	0	0	0	1.289	0.000	0.000
A5	AZ6976	520	N	100	0	0	0	0.007	0.000	0.000
							Totals:	**4.669**	**1.280**	**58.820**
							$RTIMP_{Avg}$:		**0.27**	**12.60**
							Total RTIMP:		**13**	**A5**
A6	AZ697150	230	D	100	0	0	80	0.363	0.000	29.040
A6	AZ69732	230	D	100	0	0	80	0.018	0.000	1.440
A6	AZ6976	230	D	100	0	0	80	0.114	0.000	9.120
A6	AZ627121	290	D	100	0	0	60	0.055	0.000	3.300
A6	AZ627133	290	D	100	15	15	60	0.129	1.935	7.740
A6	AZ6279	290	D	100	0	0	60	0.033	0.000	1.980
A6	AZ62793	290	D	100	20	20	60	0.775	15.500	46.500
A6	AZ697117	290	D	100	20	20	60	0.178	3.560	10.680
A6	AZ697149	290	D	100	0	0	60	0.011	0.000	0.660
A6	AZ69732	290	D	100	0	0	60	0.061	0.000	3.660
A6	AZ6976	290	D	100	0	0	60	0.100	0.000	6.000
A6	AZ627121	510	N	100	0	0	0	1.113	0.000	0.000
A6	AZ62793	510	N	100	20	20	0	0.023	0.460	0.000
A6	AZ627121	520	N	100	0	0	0	1.717	0.000	0.000
A6	AZ627133	520	N	100	15	15	0	0.362	5.430	0.000
A6	AZ62774	520	N	100	20	20	0	0.000	0.000	0.000
A6	AZ62793	520	N	100	20	20	0	3.441	68.820	0.000
A6	AZ697150	520	N	100	0	0	0	0.197	0.000	0.000
							Totals:	**8.690**	**95.705**	**120.120**
							$RTIMP_{Avg}$:		**11.01**	**13.82**
							Total RTIMP:		**25**	**A6**
A7	AZ697150	230	D	100	0	0	80	0.195	0.000	15.600
A7	AZ6976	230	D	100	0	0	80	0.000	0.000	0.000
A7	AZ697150	510	N	100	0	0	0	0.158	0.000	0.000
A7	AZ697150	520	N	100	0	0	0	1.111	0.000	0.000
							Totals:	**1.464**	**0.000**	**15.600**
							$RTIMP_{Avg}$:		**0.00**	**10.66**
							Total RTIMP:		**11**	**A7**
A8	AZ62750	160	D	100	0	0	50	0.003	0.000	0.150
A8	AZ62789	160	D	100	0	0	50	0.024	0.000	1.200
A8	AZ6279	160	D	100	0	0	50	0.049	0.000	2.450
A8	AZ627133	230	D	100	15	15	80	0.001	0.015	0.080
A8	AZ627136	230	D	100	0	0	80	0.024	0.000	1.920

Table A.24 Unit hydrograph example RTIMP calculations

Basin	Soil	Land Use		RTIMP	RTIMP, %			Area	Area x	Area x
ID	LID	CODE	Cond.	Nat % Eff	Nat.	Adj	Dev.	sm	$RTIMP_N$	$RTIMP_D$
1	2	3	4	5	6	7	8	9	10	11
A8	AZ62717	230	D	100	0	0	80	0.040	0.000	3.200
A8	AZ62750	230	D	100	0	0	80	0.001	0.000	0.080
A8	AZ62789	230	D	100	0	0	80	0.014	0.000	1.120
A8	AZ6279	230	D	100	0	0	80	0.138	0.000	11.040
A8	AZ697150	230	D	100	0	0	80	0.155	0.000	12.400
A8	AZ6976	230	D	100	0	0	80	0.045	0.000	3.600
A8	AZ627133	500	N	100	15	15	0	0.002	0.030	0.000
A8	AZ627136	500	N	100	0	0	0	0.002	0.000	0.000
A8	AZ62750	500	N	100	0	0	0	0.003	0.000	0.000
A8	AZ62776	500	N	100	0	0	0	0.011	0.000	0.000
A8	AZ6279	500	N	100	0	0	0	0.013	0.000	0.000
A8	AZ627133	510	N	100	15	15	0	0.108	1.620	0.000
A8	AZ627136	510	N	100	0	0	0	0.068	0.000	0.000
A8	AZ62750	510	N	100	0	0	0	0.220	0.000	0.000
A8	AZ62776	510	N	100	0	0	0	0.001	0.000	0.000
A8	AZ6279	510	N	100	0	0	0	0.009	0.000	0.000
A8	AZ697150	510	N	100	0	0	0	0.205	0.000	0.000
A8	AZ69791	510	N	100	15	15	0	0.027	0.405	0.000
A8	AZ627133	520	N	100	15	15	0	0.117	1.755	0.000
A8	AZ62750	520	N	100	0	0	0	0.017	0.000	0.000
A8	AZ697150	520	N	100	0	0	0	0.860	0.000	0.000
A8	AZ69791	520	N	100	15	15	0	0.061	0.915	0.000
							Totals:	**2.218**	**4.740**	**37.240**
							$RTIMP_{Avg}$:		**2.14**	**16.79**
							Total RTIMP:		**19**	**A8**
B1	AZ62710	160	D	100	0	0	50	0.010	0.000	0.500
B1	AZ62717	160	D	100	0	0	50	0.004	0.000	0.200
B1	AZ62750	160	D	100	0	0	50	0.060	0.000	3.000
B1	AZ62789	160	D	100	0	0	50	0.010	0.000	0.500
B1	AZ62750	170	D	100	0	0	60	0.034	0.000	2.040
B1	AZ62710	230	D	100	0	0	80	0.041	0.000	3.280
B1	AZ62717	230	D	100	0	0	80	0.287	0.000	22.960
B1	AZ62750	230	D	100	0	0	80	0.129	0.000	10.320
B1	AZ62789	230	D	100	0	0	80	0.040	0.000	3.200
B1	AZ6279	230	D	100	0	0	80	0.041	0.000	3.280
B1	AZ6976	230	D	100	0	0	80	0.002	0.000	0.160
B1	AZ627133	290	D	100	15	15	60	0.900	13.500	54.000
B1	AZ62717	290	D	100	0	0	60	1.081	0.000	64.860
B1	AZ62750	290	D	100	0	0	60	0.840	0.000	50.400
B1	AZ62782	290	D	100	0	0	60	0.008	0.000	0.480
B1	AZ6279	290	D	100	0	0	60	0.006	0.000	0.360
B1	AZ62793	290	D	100	20	20	60	0.188	3.760	11.280
B1	AZ697117	290	D	100	20	20	60	0.001	0.020	0.060
B1	AZ6976	290	D	100	0	0	60	0.007	0.000	0.420

Table A.24 Unit hydrograph example RTIMP calculations

Basin ID	Soil LID	Land Use		RTIMP	RTIMP, %			Area	Area x $RTIMP_N$	Area x $RTIMP_D$
		CODE	Cond.	Nat % Eff	Nat.	Adj	Dev.	sm		
1	2	3	4	5	6	7	8	9	10	11
B1	AZ62717	500	N	100	0	0	0	0.000	0.000	0.000
B1	AZ62750	500	N	100	0	0	0	0.000	0.000	0.000
B1	AZ627133	510	N	100	15	15	0	0.283	4.245	0.000
B1	AZ62717	510	N	100	0	0	0	0.289	0.000	0.000
B1	AZ62750	510	N	100	0	0	0	0.001	0.000	0.000
B1	AZ627133	520	N	100	15	15	0	0.381	5.715	0.000
B1	AZ62793	520	N	100	20	20	0	0.028	0.560	0.000
							Totals:	**4.671**	**27.800**	**231.300**
							$RTIMP_{Avg}$:		**5.95**	**49.52**
							Total RTIMP:		**55**	**B1**

Using Equation 7.17 in Section 7.4.4.7, the developed RTIMP for sub-basin A5 is computed as follows:

$$\overline{RTIMP}_{N,D} = \left(\frac{\sum A_i RTIMP_i}{A_T} \right)$$

where:

$\overline{RTIMP}_{N,D}$ = natural or developed condition composite value of RTIMP, inches

$RTIMP_i$ = RTIMP of each subarea, inches

A_i = area of RTIMP subarea

A_T = area of the watershed or sub-basin

$$\overline{RTIMP}_N = \left(\frac{0.064 * 20}{4.669} \right)$$

$$\overline{RTIMP_N} = 0.27\%$$

$$\overline{RTIMP}_D = \left(\frac{(0.087 + 0.486 + 0.001 + 0.069) * 80 + (0.064 + 0.004 + 0.007 + 0.048) * 60 + (2.607 + 1.289 + 0.007) * 0}{4.669} \right)$$

$$\overline{RTIMP_D} = 12.59\%$$

$$\overline{RTIMP} = \overline{RTIMP}_N + \overline{RTIMP}_D$$

$$\overline{RTIMP} = 0.27 + 12.59 = 13\%$$

The impervious areas for Sub-basin A-5 are assumed to be hydraulically connected and 100% effective for the purposes of this example. Refer to Table A.24, column 5. If the impervious area cannot be assumed hydraulically connected, as with some sub-areas within sub-basin A-2, then the impervious area is reduced based on engineering judgment, in this case using a 50%

reduction. Using the same procedure, composite RTIMP for the other sub-basins was computed. The results, rounded to the nearest percent, are summarized as follows:

	A1	A2	A3	A4	A5	A6	A7	A8	B1
RTIMP	18	20	13	16	13	25	11	19	55

Note that the DDMSW Example 1 uses an RTIMP of 23% for sub-basin A-2. This is because that example does not apply the 50% effective factor done for illustrative purposes here.

Step 12. Preparation of the HEC-1 rainfall loss input records.

Code the HEC-1 LG record for sub-basin A3 as follows:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
LG  0.23    0.28    7.94    0.25    13.0
```

Where Field 1 is IA, Field 2 is DTHETA, Field 3 is PSIF, Field 4 is adjusted XKSAT and Field 5 is RTIMP.

The other sub-basin LG records are coded similarly.

A.3.2 EXAMPLE FOR INITIAL LOSS AND UNIFORM LOSS RATE METHOD

The Initial Loss and Uniform Loss Rate Method is not normally applied in Mohave County. This method may be applicable when the soils for a watershed are predominately sands with a bare ground XKSAT greater than 2 inches hour. Sub-basin A3 from Appendix A.3.1 is used to illustrate application of this method. Refer to Section 7.4.5 for the procedures for the Initial Loss and Uniform Loss Rate Method.

Steps 1 through 7, 9, 10 and 11 from Appendix A.3.1 should be followed to obtain sub-basin composite values of IA, adjusted bare ground XKSAT, and RTIMP. The adjusted bare ground XKSAT is assigned as CNSTL. For sub-basin A3, this is 0.19 inches/hour.

Estimate STRTL. STRTL is the sum of IA and the initial infiltration, II. IA for sub-basin A3 is computed to be 0.23 inches. Using Table 7.10, and a CNSTL of 0.19 inches/hour, II_{dry} is 0.5 inches and II_{normal} is 0.3 inches. II_{dry} is applicable for the natural portion of sub-basin A3, and II_{normal} is applicable to the developed areas. An area-weighted value of II is computed as follows, using a similar method to that applied in Green and Ampt Step 8 above for computing composite DTHETA:

$$\overline{II} = \left(\frac{\sum A_i II_i}{A_T} \right)$$

where:

$\overline{II}$ = composite value of II, inches

II_i = II of each subarea, inches

A_i = size of II subarea

A_T = size of the watershed or sub-basin

$$\overline{II} = \left(\frac{10.114 * 0.5 + 3.053 * 0.3}{13.167} \right) = 0.45 inches$$

$$STRL = \overline{IA} + \overline{II}$$

$$STRTL = 0.23 + 0.45 = \ 0.68 \ inches$$

Preparation of the HEC-1 rainfall loss input records.

Code the HEC-1 LU record for sub-basin A3 as follows:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
LU  0.68     0.25     13.0
```

where: Field 1 is STRTL, Field 2 is CNSTL, and Field 3 is RTIMP.

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A.4 UNIT HYDROGRAPH EXAMPLE

A.4.1 PROBLEM STATEMENT

Clark unit hydrograph parameters are needed for a HEC-1 model of a large watershed within, and south of, Kingman, AZ. The site is located as shown on Figure A.6, and is the same watershed used for the Appendix A.3 example. Derive the parameters and prepare the HEC-1 unit hydrograph records for the model using the instructions set forth in Section 7.5.3. There are two methods that can be used:

1. Manual Computations. Computations are performed by hand or with a calculator.
2. DDMSW Manual Input. Lengths and other parameters are determined by the most expedient means available and then manually input to DDMSW. DDMSW then computes the Clark unit hydrograph parameters for each sub-basin.
3. DDMSW GIS Method. Sub-basin boundaries, land use boundaries, Tc paths, and Lca paths are created in ERSI GIS shape file format external to DDMSW, read into DDMSW, and then DDMSW computes Clark unit hydrograph parameters for each sub-basin using the GIS information.

A.4.2 PROBLEM SOLUTION

The manual solution consists of the following steps.

1. Watershed delineation.
2. Definition of the T_c and L_{ca} paths for each sub-basin.
3. Definition of the L_{ca} path for each sub-basin.
4. Calculation of T_c.
5. Calculation of R.
6. Determination of the time-area relationship for each sub-basin.
7. Preparation of the HEC-1 UC record for each sub-basin.\

Determine the NMIN and NQ Parameters for the HEC-1 Model.

Step 1. Watershed Delineation.

Refer to Appendix A.3.1.2, Step 1.

Step 2. Definition of the T_c and L_{ca} paths for each sub-basin.

The T_c and L_{ca} paths were delineated using the USGS 7.5-minute Quadrangle Maps and 10-meter Digital Elevation Maps (DEM) of the area. The results are shown on Figure A.21. The parameters derived from the USGS Quadrangle Maps and DEMs are listed in Table A.25.

Table A.25 Unit hydrograph T_c and L_{ca} parameters						
		T_c Path				L_{ca}
Sub-basin ID	Area, sm	Length, mi	Top Elevation	Bottom Elevation	Slope, ft/mi	Length, mi
A1	8.363	8.66	8054.4	4068.0	460.4	4.77
A2	11.599	9.98	5009.5	3162.2	185.1	5.06
A3	13.167	9.29	5161.0	3131.1	218.4	4.19
A4	7.957	10.60	6274.5	3131.1	296.4	6.54
A5	4.669	5.35	4311.9	3055.8	235.0	2.70
A6	8.690	11.03	4896.3	3001.6	171.8	5.44
A7	1.464	3.12	4110.7	3001.6	355.5	1.54
A8	2.215	4.25	3925.8	2840.1	255.7	2.78
B1	4.672	4.58	3827.5	2813.6	221.3	1.92

Step 3. Determination of sub-basin land uses.

The land uses present on the watershed are shown on Figure A.23. Based on an evaluation of the land uses for each sub-basin, the Tc equation appropriate to the dominate land use in each sub-basin was assigned as listed in Table A.26. Refer to Section 7.5.2.1.

Table A.26 Unit hydrograph T_c equation type assignment	
Sub-basin ID	T_c Equation Type
A1	Desert/Mountain
A2	Desert/Mountain
A3	Desert/Mountain
A4	Desert/Mountain
A5	Desert/Mountain
A6	Desert/Mountain
A7	Desert/Mountain
A8	Desert/Mountain
B1	Urban

Step 4. Calculation of T_c.

The time of concentration, T_c, for sub-basins A3 and B1 are computed using the appropriate T_c equation (Equation 7.17 or 7.19) and data from Appendix A.3.1.2 and Table A.25 as follows:

desert/mountain:

$$T_c = 2.4A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.2}$$

urban

$$T_c = 3.2A^{0.1}L^{0.25}{L_{ca}}^{0.25}S^{-0.14}RTIMP^{-0.36} \quad \text{A.1}$$

where:

T_c	=	time of concentration, in hours,
A	=	area, in square miles,
S	=	watercourse slope, in feet/mile,
L	=	length of watercourse to the hydraulically most distant point, in miles,
L_{ca}	=	length measured from the concentration point along L to a point on L that is perpendicular to the watershed centroid, in miles, and
RTIMP	=	effective impervious area, in percent.

Sub-basin A3:

$$T_c = 2.4(13.167)^{0.1}(9.29)^{0.25}(4.19)^{0.25}(218.4)^{-0.2}$$

$$T_c = 2.64\ hours$$

Sub-basin B1:

$$T_c = 3.2(4.672)^{0.1}(4.58)^{0.25}(1.92)^{0.25}(221.3)^{-0.14}(55)^{-0.36}$$

$$T_c = 0.71\ hours$$

Step 5. Calculation of R.

The storage coefficient, R, for sub-basins A3 and B1 are computed using Equation 7.20 and data from Appendix A.3.1.2 and Table A.25 as follows:

$$R = 0.37{T_c}^{1.11}L^{0.80}A^{-0.57}$$

where: R is in hours and the variables are as defined for the T_c equations.

Sub-basin A3:

$$R = 0.37(2.64)^{1.11}(9.29)^{0.80}(13.167)^{-0.57}$$

$$R = 1.49\ hours$$

Sub-basin B1:

$$R = 0.37(0.71)^{1.11}(4.58)^{0.80}(4.672)^{-0.57}$$

$$R = 0.36\ hours$$

Using the same procedures, T_c and R for the other sub-basins were computed. The results are summarized as follows:

	A1	A2	A3	A4	A5	A6	A7	A8	B1
T_c	2.21	2.88	2.64	2.73	1.83	2.96	1.14	1.59	0.71
R	1.49	1.86	1.49	2.29	1.15	2.46	0.86	1.25	0.36

Step 6. Determination of the time-area relationship for each sub-basin.

A time-area relationship must be either computed or assigned using one of the three synthetic relationships defined in Section 7.5.2.3. For the majority of cases in Mohave County, use of the synthetic relationships is appropriate. In general, the land use codes assigned in Appendix A.3.1.2 can be used as guidance for assigning the synthetic time-area relationship. The dominate land use and the assigned time-area relationship for each sub-basin are listed in Table A.27.

Table A.27 Assignment of the time-area relationship to each sub-basin

Sub-basin ID	Dominate Land Use	Assigned Time-Area Relationship
A1	520	Mountain, HEC-1 Default Curve B
A2	520	Mountain, HEC-1 Default Curve B
A3	520	Mountain, HEC-1 Default Curve B
A4	520	Mountain, HEC-1 Default Curve B
A5	510	Desert Rangeland, Curve C
A6	520	Mountain, HEC-1 Default Curve B
A7	520	Mountain, HEC-1 Default Curve B
A8	520	Mountain, HEC-1 Default Curve B
B1	290	Urban, Curve A

Land use codes 500 and 510, undeveloped desert rangeland and hillslope areas, are assigned curve C. Land use code 520, Mountain, areas are assigned curve B. Predominately urban areas are assigned curve A. Note that this is another instance where proper sub-basin delineation based on land use is very important. For instance, sub-basins A2 and A3 have a significant percentage of urban area. The urban areas should be delineated into separate sub-basins whenever possible so that an appropriate time-area relationship can be assigned.

Step 7. Preparation of the HEC-1 UC record for each sub-basin.

Code the HEC-1 UC record for the Clark unit hydrograph parameters for sub-basin A3 as follows:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
UC  2.64    1.49
```

Where Field 1 is T_c, and Field 2 is R.

Code the HEC-1 UA record for the time-area relationship for sub-basin A3 as follows. The UA records follow the UC record in the HEC-1 input file.

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10

UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
```

Where Field 1 is percent of watershed area at time interval 0, Field 2 is percent of watershed area at time interval 2, etc. UC and UA records for the other sub-basins should be coded in a similar manner.

Step 8. Determine the NMIN and NQ Parameters for the HEC-1 Model.

As described in Section 7.9.2.4, NMIN is the integer number of minutes for the computation interval, which will usually be either 2 minutes or 5 minutes. To determine NMIN, estimate the time of concentration (T_c) for the smallest sub-basin. Using this value, estimate the number of hydrograph ordinates (NQ) required to provide an adequate time base for the HEC-1 model.

Per Step 6 above, the shortest T_c is 0.71 hours for sub-basin B1. NMIN should be between $0.1T_c$ and $0.25T_c$, or between 4 and 11 minutes. Select a T_c of 5-minutes.

The total length of channel reach routes for the model is 56,701 feet (refer to Appendix A.5). Assuming an average velocity of 5 fps, the total reach travel time is 3.15 hours. The storm duration for this example is 24-hours. Use a model duration of 24+4 hours = 28 hours. NQ is

therefore 28*60/NMIN or 336. Use NQ = 400. NQ should be checked after the HEC-1 model is completed.

A.4.3 UNIT HYDROGRAPH METHOD HEC-1 MODEL RESULTS

DDMSW was used to model the unit hydrograph method example discussed in Appendixs A.3, A.4, A.5, and A.6. The resultant HEC-1 input file is listed in Figure A.26.

Figure A.26 Unit Hydrograph Method example HEC-1 input file

```
ID      County of Mohave
ID      MOHAVE EXAMPLE1 - Mohave County Unit Hydrograph Method Example
ID      100 YEAR
ID      24 Hour Storm
ID      Unit Hydrograph: Clark
ID      09/11/2017
IT     5       0       0     400
IN    15
IO     3
*DIAGRAM
*
JD 4.464    0.01
PH              0.705   1.331   2.218   2.656   2.872   3.222   3.667   4.464
JD 4.241      10
JD 4.098      20
JD 4.018      30
JD 3.915      50
JD 3.785     100
JD 3.714     150
JD 3.598     300
JD 3.495     500
KK    A1   BASIN
BA 8.363
LG  0.25    0.29    8.67    0.18      18
UC 2.207   1.493
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
*
KK001002   ROUTE
RS     8    FLOW
RC 0.055   0.045   0.055   33573  0.0270 3575.00
RX  0.00  100.00  614.00  629.00  739.00  748.60  765.80  950.40
RY3624.2 3570.00 3569.00 3566.00 3566.00 3570.90 3573.10 3618.00
*
KK    A2   BASIN
BA11.599
```

Figure A.26 Unit Hydrograph Method example HEC-1 input file

```
LG  0.23    0.25    9.03    0.16      23
UC 2.877   1.863
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
*
KK    C2 COMBINE
KO     1
HC     2
*
KK002003   ROUTE
RS     1    FLOW
RC 0.055   0.045   0.055    1586  0.0196 3170.00
RX  0.00    0.10  253.00  274.00  336.20  359.40  380.70  394.80
RY3173.5 3166.40 3164.50 3162.20 3162.40 3164.90 3164.90 3173.50
*
KK    A3   BASIN
BA13.167
LG  0.23    0.27    8.15    0.23      13
UC 2.642   1.489
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
*
KK    A4   BASIN
BA 7.957
LG  0.25    0.30    8.07    0.22      16
UC 2.730   2.287
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
*
KK    C3 COMBINE
KO     1
HC     3
*
KK003004   ROUTE
RS     1    FLOW
RC 0.055   0.045   0.055    4417  0.0170 3123.00
RX  0.00   31.20   77.70  124.50  164.60  231.90  316.30  363.50
RY3123.3 3122.90 3116.10 3112.80 3114.20 3118.40 3121.00 3123.30
*
KK    A5   BASIN
BA 4.669
LG  0.17    0.28    8.22    0.22      13
UC 1.831   1.150
UA     0     3.0     5.0     8.0    12.0    20.0    43.0    75.0    90.0    96.0
UA   100
```

Figure A.26 Unit Hydrograph Method example HEC-1 input file

```
*
KK    C4 COMBINE
KO     1
HC     2
*
KK004005   ROUTE
RS     1    FLOW
RC 0.055   0.045   0.055    4644  0.0117 3039.00
RX  0.00  256.30  462.90  620.20  673.90  826.70  936.90 1045.80
RY3044.2 3042.70 3035.70 3030.80 3030.40 3035.60 3041.50 3049.90
*
KK    A6   BASIN
BA 8.690
LG  0.21    0.26    9.24    0.15      25
UC 2.962   2.457
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
*
KK   C5L COMBINE
KO     1
HC     2
*
KK    A7   BASIN
BA 1.464
LG  0.22    0.28    8.22    0.22      11
UC 1.140   0.856
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
*
KK    C5 COMBINE
KO     1
HC     2
*
KK005006   ROUTE
RS     4    FLOW
RC 0.055   0.045   0.055   12481  0.0129 2925.00
RX  0.00  102.40  200.20  285.30  391.40  478.90  530.80  619.50
RY2928.0 2922.70 2916.90 2918.30 2918.10 2916.00 2917.60 2928.00
*
KK    A8   BASIN
BA 2.215
LG  0.19    0.27    8.47    0.21      19
UC 1.589   1.250
UA     0     4.5    12.6    23.2    35.8    50.0    64.2    76.8    87.4    95.5
UA   100
```

Figure A.26 Unit Hydrograph Method example HEC-1 input file

```
*
KK    C6 COMBINE
KO     1
HC     2
*
KK    B1   BASIN
KO     1
BA 4.672
LG  0.16    0.13   10.80    0.06      55
UC 0.713   0.357
UA     0     5.0    16.0    30.0    65.0    77.0    84.0    90.0    94.0    97.0
UA   100
*
KK  B1DS  DIVERT
KO     1
DT B1DIV  400.00     0.0
DI   0.0   100.0   250.0   500.0   750.0  1000.0  2000.0  4000.0  6000.0 10000.0
DQ   0.0   100.0   250.0   500.0   750.0  1000.0  2000.0  4000.0  6000.0 10000.0
*
ZZ
```

The output results are listed in Table A.28. There are several areas of interest in the results.

1. The Time-to-Peak (T_p) in column 4 for the last combine operation (C6) is 14.75 hours. Therefore, the total time base is 24 hours + 2.75 hours = 26.75 hours. The NQ value for the model could be reduced to: NQ = 26.75*60/5 = 321 minutes. The value used, 400, is a good estimate and does not need to be adjusted.
2. Check the Channel Route operations. In all cases the peak discharge is reduced because of attenuation in the reach. If any peak discharges had increased because of the route, the operation would need to be checked in detail as this is an indication of improper coding of parameters. The cross section should be plotted to make sure there are no input errors and all other parameters should be verified.

   Evaluate the combine operations. At C2 note that the combined peak discharge is less than the sum of the upstream peaks. The same is true for the combined runoff volume. All the combine operations show this result. This is due to the use of the HEC-1 JD record option. The combine operation increases the total watershed area at the concentration point. The increased watershed area results in a greater areal reduction factor applied to the rainfall value.

   The JD record option causes HEC-1 to compute what are called index hydrographs, one for each JD record used. Each JD record specifies a watershed area and corresponding areally-reduced point precipitation value. The index hydrographs represent the runoff hydrograph for that specific watershed area and precipitation value. When a sub-basin operation is performed, HEC-1 computes all the index hydrographs and then computes a log-based

interpolated hydrograph using the actual sub-basin area. The interpolated hydrograph results are what are reported.

The index hydrographs are carried forward. When a hydrograph operation such as a combine is performed, the index hydrographs from the upstream hydrograph operations are added and then the log-based interpolation is performed using the total watershed area at the combine operation concentration point. This process results in the areally-reduced peak discharge at the combine being lower than the total of the peak discharges being added.

The unit peak discharges in column 6 represent the peak discharge in column 5 divided by the watershed area in column 3. The unit peak discharges are very useful for checking the reasonableness of the model results by indirect methods, as described in Section 7.11.

Table A.28 Unit hydrograph method example HEC-1 results

HEC-1 Operation	ID	Area, sm	Time to Peak, hrs	Peak Discharge, cfs	Unit Discharge, cfs/sq mi	Rainfall Excess, in	Runoff Volume, ac-ft
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HYDROGRAPH_AT	A1	8.36	13.92	3,183	381	1.952	871
ROUTED_TO	001002	8.30	14.50	3,105	374	1.952	870
HYDROGRAPH_AT	A2	11.60	14.42	3,754	324	2.139	1324
2_COMBINED_AT	C2	19.96	14.50	6,366	319	1.939	2064
ROUTED_TO	002003	19.90	14.50	6,357	319	1.939	2064
HYDROGRAPH_AT	A3	13.17	14.17	4,126	313	1.686	1184
HYDROGRAPH_AT	A4	7.96	14.42	2,092	263	1.818	772
3_COMBINED_AT	C3	41.09	14.42	10,634	259	1.917	4200
ROUTED_TO	003004	41.00	14.50	10,606	259	1.614	3536
HYDROGRAPH_AT	A5	4.67	13.58	2,426	519	1.782	444
2_COMBINED_AT	C4	45.75	14.42	11,455	250	1.571	3833
ROUTED_TO	004005	45.70	14.50	11,413	250	1.57	3832
HYDROGRAPH_AT	A6	8.69	14.67	2,505	288	2.239	1038
2_COMBINED_AT	C5L	54.44	14.50	12,987	239	1.582	4593
HYDROGRAPH_AT	A7	1.46	13.00	921	631	1.746	136
2_COMBINED_AT	C5	55.91	14.50	13,075	234	1.568	4677
ROUTED_TO	005006	55.90	14.83	12,986	232	1.567	4672
HYDROGRAPH_AT	A8	2.21	13.42	1,065	482	1.992	235
2_COMBINED_AT	C6	58.12	14.75	13,224	228	1.557	4828
HYDROGRAPH_AT	B1	4.67	12.42	6,874	1,472	3.333	831

A.5 CHANNEL ROUTING EXAMPLE

A.5.1 PROBLEM STATEMENT

Channel hydrograph routing parameters are needed for a HEC-1 model of a large watershed within, and south of, Kingman, AZ. The site is located as shown on Figure A.6, and is the same watershed used for the Appendixs A.3 and A.4 examples. Derive the parameters and prepare the HEC-1 channel route records for the model using the instructions set forth in Section 7.6.4. An excellent resource for guidance when performing hydrologic routing using HEC-1 is Hoggan (1997).

A.5.2 PROBLEM SOLUTION

The procedure consists of the following steps:

1. Watershed delineation.
2. Definition of the routing paths for each routing reach.
3. Evaluation the physical characteristics of each reach.
4. Determinations of the reach or sub-reach cross section.
5. Assignment of Manning's n-values.
6. Preparation of the HEC-1 channel route input records.
7. Estimation and optimization of routing computation steps.

Step 1. Watershed Delineation.

Refer to Appendix A.3.1.2, Step 1.

Step 2. Definition of the routing paths for each routing reach.

There are five (5) routing reaches for this example. They have been defined using the "blue" thalweg lines on the 7.5-minute USGS Quadrangle Maps and are shown on Figure A.21 and Figure A.22. Concentration points at the outlet of each sub-basin and at confluences have been defined and are also shown on Figure A.21 and Figure A.22. The routing reaches for this example are named by combining the concentration point identifiers for the upstream and downstream end of the reach. For example, the reach that routes the hydrograph from sub-basin A1 through sub-basin A2 is named '001002' because it connects concentration points C1 and C2. In HEC-1, the maximum length of a named for a hydrograph operation such as a reach route operation or a sub-basin designation is characters. Using this naming convention, a total

of 999 concentration points could be defined for a given HEC-1 model. The reach names for this example are 001002, 002003, 003004, 004005, and 005006.

Step 3. Evaluation the physical characteristics of each reach.

The first characteristic to evaluate is slope. If there are significant changes in slope within the reach, it should be subdivided into sub-reaches. Reach 001002 is very long (33,573 feet) and does have significant change in slope. Before dividing up the reach, evaluate the second characteristic, which is the average cross section. Does it significantly change in configuration (ie. significant changes in the width, or the depth to width ratio)? Can the reach be subdivided to account for both characteristics? Other characteristics to consider are changes in roughness, soils, natural conditions versus constructed, and vegetation. All these characteristics affect travel time in the reach and potential storage, which are the effects being modeled with the normal depth channel route method. A detailed examination of reaches 001002 and 005006, including field reconnaissance, would likely result in subdivision of both reaches. For the purposes of this example, no further subdivision will be made, but the hydrologist/engineer is expected to break routing reaches into sub-reaches where appropriate.

Table A.29 Reach route physical characteristics

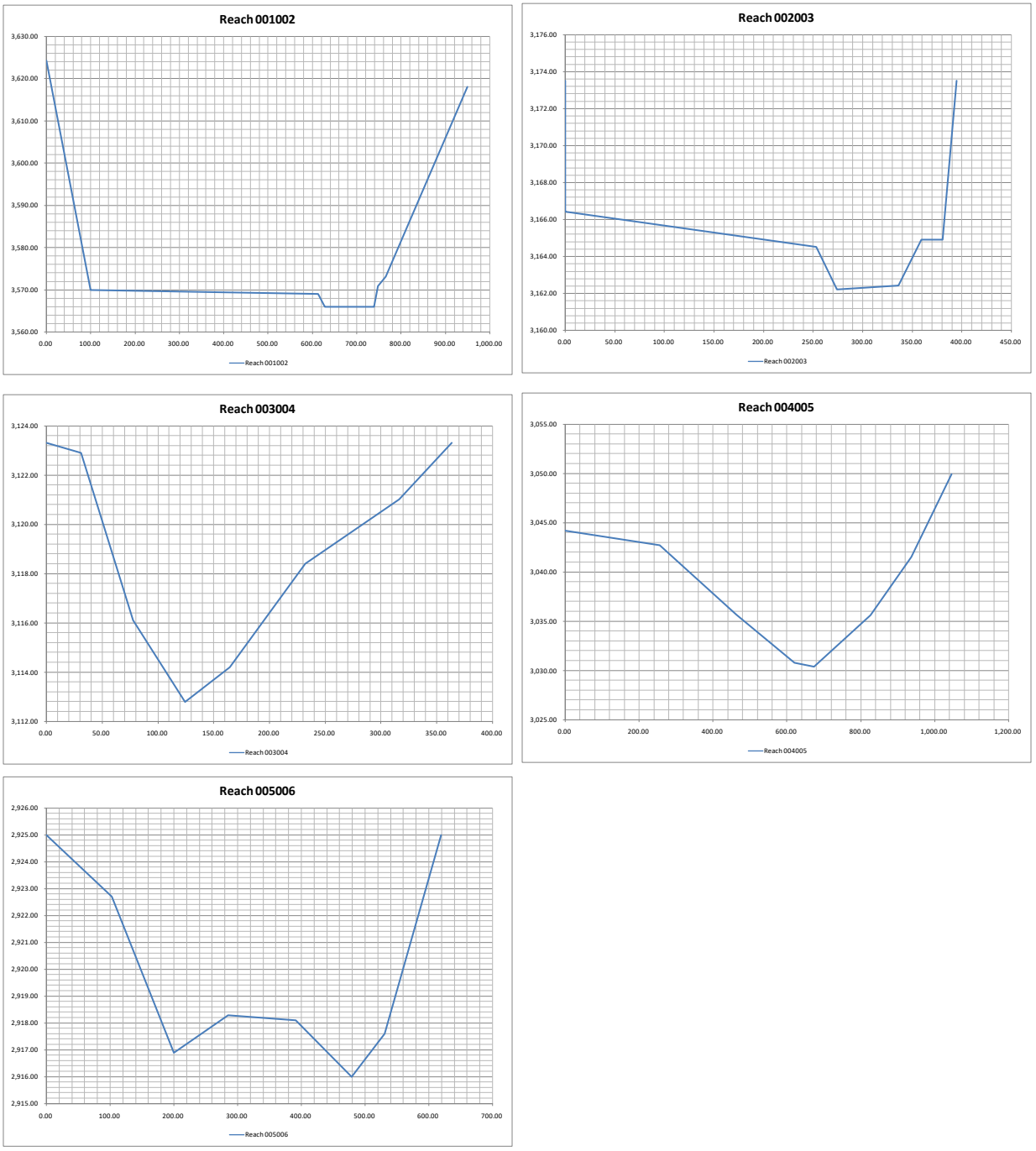
Reach ID	In Sub-basin	Elevation		Length, ft	Slope, ft/ft
		Top	Bottom		
001002	A2	4068.0	3162.2	33,572.5	0.0270
002003	A4	3162.2	3131.1	1,585.7	0.0196
003004	A5	3131.1	3055.8	4,416.60	0.0170
004005	A6	3055.8	3001.6	4,644.1	0.0117
005006	A8	3001.6	2840.1	12,481.1	0.0129

Step 4. Determinations of the reach or sub-reach cross section.

The next step is to establish a cross section for each reach that is a reasonable approximation of the various cross section configurations present within the reach. This can be done by examining the available contour mapping covering each reach and by field reconnaissance. The cross sections for this example were defined using the USGS 7.5-minute Quadrangle Maps. In actual application, if the quad maps are the best available topography, the hydrologist/engineer should conduct a field reconnaissance and survey field cross sections at representative

locations. Then a composite eight (8) point cross section that is representative of the reach can be prepared. HEC-1 normal depth routing reach cross sections are limited to eight (8) points to define cross section. The cross sections used for this example are shown in Figure A.27.

Figure A.27 Reach route cross sections



In general, use cross section points 1-3 and 6-8 to define the left and right overbank areas, respectively, and cross section points 3-6 should be used to define the main channel. As with HEC-2 and HEC-RAS, routing cross sections should be stationed from left to right looking downstream.

Step 5. Assignment of Manning's n-values.

Manning's n for the main channel and left and right overbanks should be determined using the procedures set forth in Chapter 13. For the purposes of this example, a value of 0.045 was used for the main channel for all five routing reaches. An n-value of 0.055 was assigned for the left and right overbank areas for all five reaches.

Step 6. Preparation of the HEC-1 channel route input records.

Using the data from Steps 1-5, the HEC-1 input data file records for reach route 001002 are coded as follows:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
KK001002  ROUTE
RS    16    FLOW      -1
RC 0.055   0.045   0.055   33573  0.0270 3575.00
RX  0.00  100.00  614.00  629.00  739.00  748.60  765.80  950.40
RY3624.2 3570.00 3569.00 3566.00 3566.00 3570.90 3573.10 3618.00
```

The KK record defines the hydrograph operation name.

The RS record establishes that this is a storage route. The type of storage route is not yet specified. The Normal Depth channel route is actually a form of storage route based on the Modified Puls method (refer to Hoggan, 1997). Field 1, NSTPS, is set equal to eight (8), which is the number of steps to be used in the route operation. This value should be computed through an optimization process as described in Step 7. "FLOW" is entered in Field 2, which specifies that the discharge rate for the beginning of the first time period will be in the next field. The next field (Field 3) is set to -1, which specifies the initial outflow rate is set equal to the initial inflow rate.

The RC record establishes that this is a Normal Depth Channel Routing operation. The fields are:

1. ANL, Left overbank Manning's n-value.
2. ANCH, Channel Manning's n-value.
3. ANR, Right overbank Manning's n-value.

4. RLNTH, Reach length, in feet.
5. SEL, Energy gradeline slope in ft/ft. Can be computed from a HEC-RAS model. If unknown, estimate using the average channel slope for the reach.
6. ELMAX, Maximum elevation for which storage and outflow values are to be computed.

The RX record is used to define the ground stations for each point on the cross section, increasing from left to right looking downstream. Note that the left and right bank are assumed to be located at points 3 and 6, respectively, on the cross section. A maximum of eight (8) points are allowed per cross section.

The RY record is used to define the ground elevation of each point on the cross section, corresponding to the stations defined on the RX record.

Step 7. Estimation and optimization of routing computation steps.

The NSTPS parameter, entered in Field 1 of the RS record, should be optimized as described in Section 7.9.2.9. The DDMSW computer program will perform the optimization but it is important to understand how the program accomplishes the optimization and there may be times when the hydrologist/engineer needs to perform the optimization manually. The process for accomplishing the optimization of NSTPS manually for reach 001002 is presented here.

1. Initial Estimation of NSTEPS. Determine an initial estimate of NSTPS by assuming an average velocity for the reach and using Equation 7.23. Assume an average velocity of 7 fps and use the reach data from Table A.29. Assume an NMIN of 5-minutes is used for the HEC-1 model.

$$\text{NSTPS} = \frac{L}{(V_{avg})(60)(NMIN)}$$

where:

L = the minimum reach length, in feet.
NSTPS = an integer with a minimum value of 1, but preferably more than 1.
V_{avg} = an estimate of the average velocity, in feet/second.
NMIN = the integer number of minutes for the computation interval.

$$\text{NSTPS} = \frac{33{,}572.5}{(7)(60)(5)} = 16$$

Iteration 1. After an initial estimate of NSTPS has been made for all routing reaches, the NSTPS values should be coded on the RS record and the HEC-1 model run. Then open the HEC-1 Output file with a text editor such as Notepad or TextPAD (TextPad) and evaluate the RUNOFF SUMMARY table at the end of the file. Refer to Figure A.28 for an excerpt from the

the Runoff Summary table from the 100-year 24-hour HEC-1 model for this example using NSTPS = 16 for reach 001002.

Figure A.28 HEC-1 output Runoff Summary table excerpt, NSTPS=16

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA
HYDROGRAPH AT							
	A1	3183.	13.92	1499.	437.	317.	8.36
ROUTED TO							
	001002	3144.	14.50	1478.	436.	317.	8.36

Using the data in Figure A.28, compute the reach travel time by subtracting the Time-to-Peak at the beginning of the route from the Time-to-Peak at the end of the route:

Travel Time = 14.50-13.92 = 0.58 hours.

Compute the new estimate of NSTPS:

NSTPS Iteration 2 = (0.58)(60)/5 = 7

Iteration 2. Revise the RS record for reach 001002 by changing the NSTPS value from 16 to 7. Rerun the HEC-1 model and determine NSTPS from the Runoff Summary table. The results are shown in Figure A.29. Note that the travel time of 0.58 hours remains unchanged, but that the routed peak discharge is reduced from 3183 cfs to 3093 cfs. The value of NSTPS = 7 is accepted for use in the model. NSTPS normally converges to no change within three (3) iterations. This technique is only accurate to +/- 1 time step. Sometimes the computed NSTPS value will oscillate by a value of +/- 1 between iterations. In this case, use engineering judgment to select which of the two values to use.

The current version of DDMSW uses the 100-year storm frequency to perform the NSTPS optimization. The optimized NSTPS values from 100-year HEC-1 model are then used for any other frequencies run. The hydrologist/engineer should keep this in mind when checking the results for frequencies other than the 100-year. The Runoff Summary table results for other frequencies should be checked to be sure the NSTPS values computed by HEC-1 are not significantly different than input. Manual adjustment may be necessary.

Figure A.29 HEC-1 output Runoff Summary table excerpt, NSTPS=7

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA
	HYDROGRAPH AT							
+		A1	3183.	13.92	1499.	437.	317.	8.36
	ROUTED TO							
+		001002	3093.	14.50	1469.	436.	317.	8.36

Other items to check when evaluating the HEC-1 results of reach route operations are:

a. The routed peak discharge should not increase because of the routing operation. If it does, the cross section and other routing parameters should be carefully reviewed for errors.

The peak discharge entering the routing reach should not exceed the normal depth flow capacity of the cross section. If it does, the cross section should be extended.

If the reach travel time is less than 1, consider using the HEC-1 lag operation instead of a Normal Depth Channel route or no routing operation at all.

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A.6 STORAGE ROUTING EXAMPLES

A.6.1 MODIFIED PULS METHOD

The Modified Puls Method HEC-1 option can be used to model the effects of stormwater storage facilities used as detention basins or flood retarding structures. The steps for application are as follows:

1. Determine the Stage-Storage characteristics of the basin.
2. Determine the Stage-Discharge characteristics of the outlet(s).
3. Code the HEC-1 input records.

Step 1. Determine the Stage-Storage characteristics of the basin.

A rating curve of the available storage for storm water within the basin should be developed. This can be accomplished using the design topography for the basin and computing the storage for the basin in depth increments appropriate for physical characteristics affecting storage such as changes side slope ratios and horizontal shape changes. An example of data computed for a storage basin is shown in Table A.30 and graphically on Figure A.30.

Table A.30 Example stage-storage curve data

Depth, ft	Stage, ft	Surface Area, acres	Volume, ac-ft	
			Incremental	Cumulative
0.0	3570.0	1.00	0.00	0.00
0.5	3570.5	1.05	0.51	0.51
1.0	3571.0	1.25	0.57	1.09
1.5	3571.5	1.50	0.69	1.77
2.0	3572.0	2.00	0.87	2.65
2.5	3572.5	3.00	1.24	3.89
3.0	3573.0	3.50	1.62	5.51
4.0	3574.0	4.00	3.75	9.26
5.0	3575.0	5.00	4.49	13.75

The volume data can be calculated using Equation A.2 (USACE, 1998).

$$\Delta V_{1,2} = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad \text{A.2}$$

where:

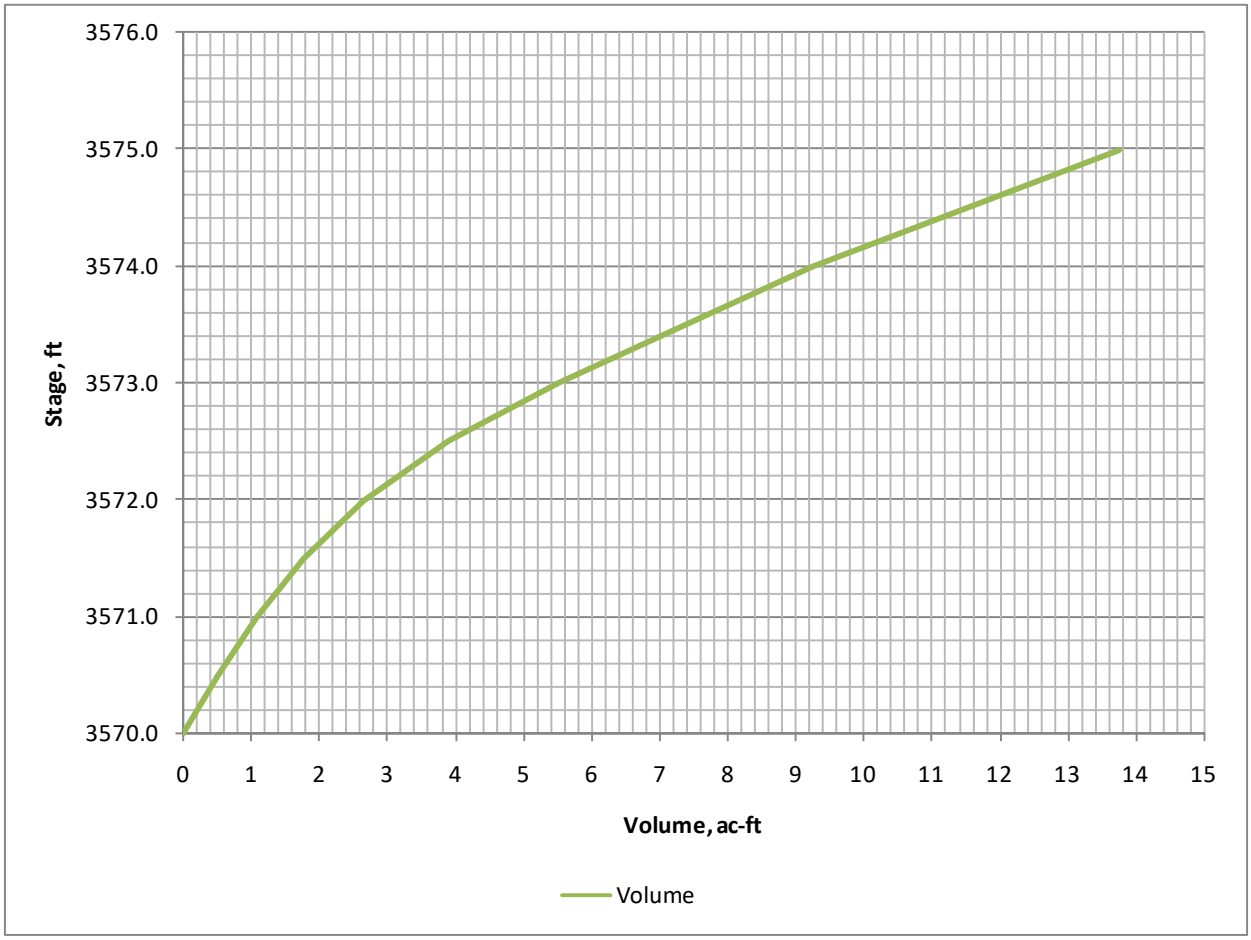
$\Delta A_{1,2}$ = volume between stage areas 1 and 2,

h = vertical distance (depth) between stage areas A1 and A2,

A_1 = surface area of stage 1, and

A_2 = surface area of stage 2.

Figure A.30 Example stage-storage rating curve



Step 2. Determine the Stage-Discharge characteristics of the outlet(s).

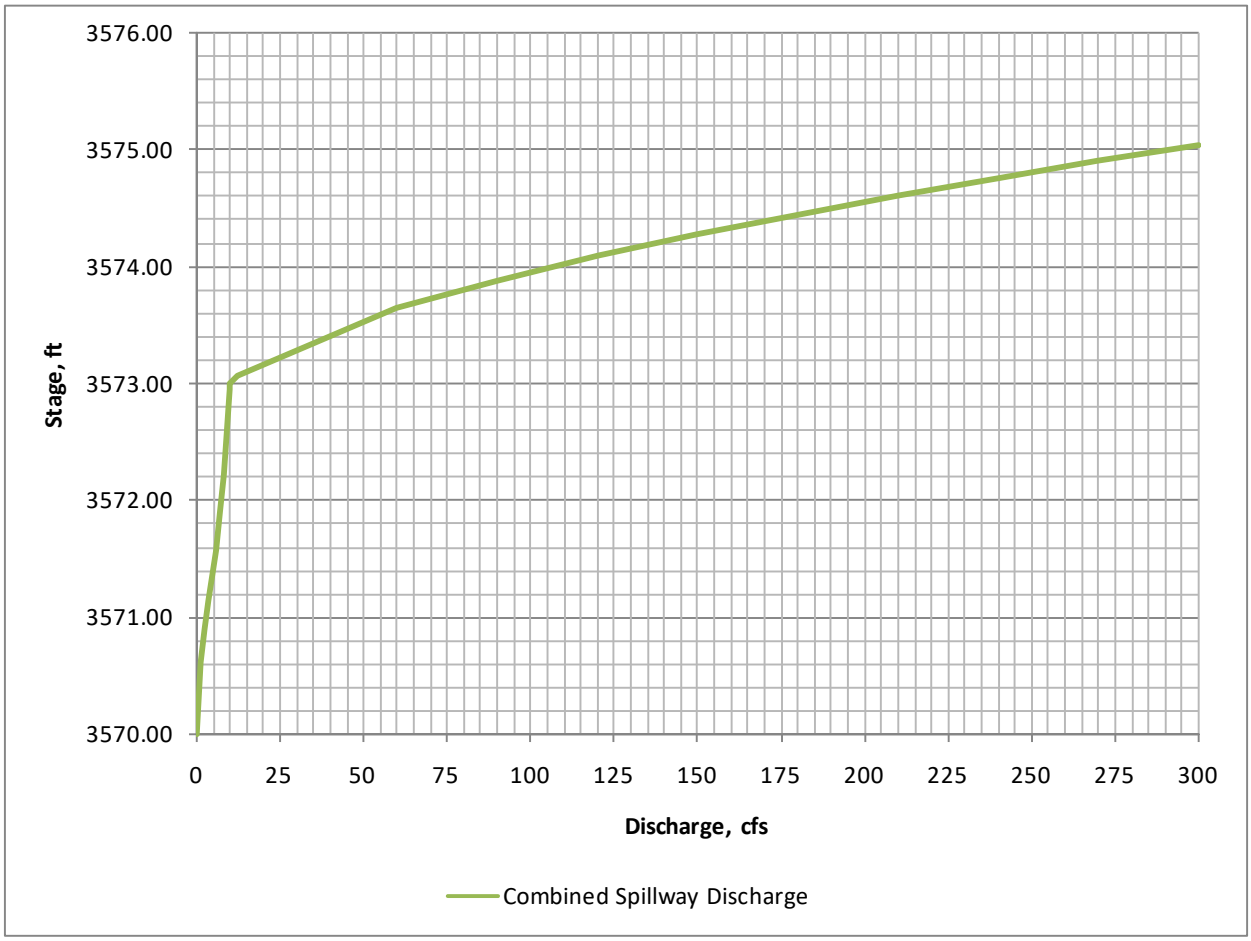
HEC-1 can model the effects of both principal spillways (culverts) and emergency spillways (overflow weirs or channels) through a combined hydraulic rating curve. The rating curves for both types of outlets should be developed using appropriate hydraulic modeling software such

as HEC-RAS or HY-8 and then combined into a single rating table. For the above example, the principal spillway is an 18-inch CMP with headwalls on a slope of 1 percent. The culvert discharges into a riprap lined trapezoidal channel with 2:1 side slopes, a bottom width of 15 feet, and a slope of 0.8 percent. The emergency spillway is a broad-crested weir with a crest length of 25 feet, a crest width of 10 feet, and the flowline set at elevation 3573.0. HY-8 (USDOT, 2005b and 2007) was used to model the spillway hydraulics and the results are shown in Table A.31. The design criteria require that a total 100-year peak discharge of 100 cfs be passed through the spillways with a freeboard of 1 foot (ie. water surface cannot exceed elevation 3574.0). Also, the total spillway capacity is to be determined and the basin must drain completely within 36 hours.

Table A.31 Example stage-discharge curve data

Outlet Control Depth, ft	Stage, ft	Spillway Discharge, cfs		
		Principal	Emergency	Combined
0.00	3570.00	0.0	0.0	0.0
0.62	3570.62	1.2	0.0	1.2
0.90	3570.90	2.4	0.0	2.4
1.14	3571.14	3.6	0.0	3.6
1.36	3571.36	4.8	0.0	4.8
1.58	3571.58	6.0	0.0	6.0
1.91	3571.91	7.2	0.0	7.2
2.23	3572.23	8.0	0.0	8.0
2.95	3572.95	9.6	0.0	9.6
3.00	3573.00	9.7	0.0	9.7
3.08	3573.08	9.9	2.1	12.0
3.65	3573.65	11.0	49.0	60.0
3.89	3573.89	11.4	78.5	90.0
4.10	3574.10	11.7	108.2	120.0
4.29	3574.29	11.6	138.2	150.0
4.46	3574.46	11.6	168.3	180.0
4.62	3574.62	11.6	198.2	210.0
4.77	3574.77	11.5	228.3	240.0
4.91	3574.91	11.5	258.4	270.0
5.05	3575.05	11.5	288.5	300.0

Figure A.31 Example stage-discharge rating curve



Note from examination of Table A.31 that the principal spillway is functioning under outlet control for the entire rating. Also note from examination of Figure A.31 that at stage 3574 the combined spillway discharge is about 105 cfs and the total combined spillway capacity at the crest of the basin is about 300 cfs. The average discharge for the principal spillway can be assumed to be 5 cfs. At that flow rate, the time to drain the basin, assuming it is filled to the crest of the emergency spillway at elevation 3573, is estimated as follows:

Drain Time = (5.51 ac-ft)(43,560 sf/ac-ft)/(5 ft^3/s)(3600s/hr) = 13.3 hours. Therefore, OK.

If the estimated drain time were close to 36 hours, a more detailed computation of drain time would be necessary. This can be accomplished using HEC-1 as described in Chapter 9 of the Hydraulics Manual.

Step 3. Code the HEC-1 input records.

Using the data from Steps 1 and 2, the HEC-1 input data file records for a storage route through the basin are coded as follows:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
KK BASIN STORAGE
RS     1    ELEV  3570.0
SV  0.00    0.51    1.09    1.77    2.65    3.89    5.51    9.26   13.75
SE3570.0  3570.5  3571.0  3571.5  3572.0  3572.5  3573.0  3574.0  3575.0
SQ   0.0     1.2     2.4     3.6     4.8     6.0     7.2     8.0     9.6     9.7
SQ  12.0    60.0    90.0   120.0   150.0   180.0   210.0   240.0   270.0   300.0
SE3570.0 3570.62 3570.90 3571.14 3571.36 3571.58 3571.91 3572.23 3572.95 3573.00
SE3573.1 3573.65 3573.89 3574.10 3574.29 3574.46 3574.62 3574.77 3574.91 3575.05
```

The KK record defines the hydrograph operation name.

The RS record establishes that this is a storage route. The type of storage route is not yet specified. Field 1, NSTPS, is set equal to one (1), which is the number of steps to be used in the route operation. "ELEV" is entered in Field 2, which specifies that the elevation for the beginning of the first-time period will be in the next field. The next field (Field 3) is set to 3570.0, which is the bottom elevation of the storage basin.

The SV record establishes that this is a Modified Puls storage operation. The values are the storage in acre-feet from column five (5) of Table A.30. A total of 20 values may be entered on two SV records.

The first SE record contains the stage elevation values corresponding to the storage values in the same field on the SV record. The values are from column two (2) of Table A.30.

The SQ record contains the peak discharge values in cfs from column five (5) of Table A.31. A total of 20 values may be entered on two SQ records.

The second SE record contains the stage elevation values corresponding to the peak discharge values in the same field on the SQ record. The values are from column two (2) of Table A.31.

A.6.2 RETENTION BASIN STORAGE DIVERSIONS

When stormwater storage is in place for developments in a watershed it is usually appropriate to account for it in a HEC-1 model of the watershed. Normally, stormwater storage basins have relatively small watersheds and, in Mohave County, are sized to retain the 100-year 2-hour storm runoff volume. Due to the small scale of such watersheds in comparison with the sub-basin size of most HEC-1 models, it is not practical to model the retention basins using the

procedure described in Appendix A.6.1. The preferred approach is to make an estimate of the total design storage capacity of the retention basins in each HEC-1 sub-basin and then divert that volume from the rising limb of the sub-basin runoff hydrograph. This is accomplished in HEC-1 using the diversion operation records.

Consider the B1 HEC-1 sub-basin from the example in Appendix A.4 that is 79 percent developed and has retention basins in place designed to retain all runoff from the 100-year 2-hour storm. The hydrologist has reviewed the as-built drawings for all the developments in the area and totaled the as-built retention basin design volumes. The hydrologist has also performed a field reconnaissance of the sub-basin to verify the retention basins are in place and sized per the as-built drawings. It was noted that on average the basins have 25 percent less capacity than the as-built drawings indicate due to sedimentation and changes made during landscaping. The total as-built storage volume is 533 ac-ft. Reduce this storage capacity by 25 percent and use 400 ac-ft.

The HEC-1 runoff computation records for sub-basin B1 are:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
KK     B1    BASIN
BA  4.672
LG   0.16     0.16    10.30     0.10       55
UC  0.713    0.357
UA      0      5.0     16.0     30.0     65.0     77.0     84.0     90.0     94.0     97.0
UA    100
```

This HEC-1 operation generates the runoff hydrograph for sub-basin B1. Next, the retention volume is diverted from the B1 runoff hydrograph, which has the effect of removing it from the rising limb. The following KK record set is used to accomplish the diversion:

```
_______1_______2_______3_______4_______5_______6_______7_______8_______9______10
KK   B1DS   DIVERT
KO      1
DT B1DIV    400.0      0.0
DI    0.0    100.0    250.0    500.0    750.0   1000.0   2000.0   4000.0   6000.0 10000.0
DQ    0.0    100.0    250.0    500.0    750.0   1000.0   2000.0   4000.0   6000.0 10000.0
```

The KK record defines the name of the hydrograph that will continue downstream in the HEC-1 model after the diversion.

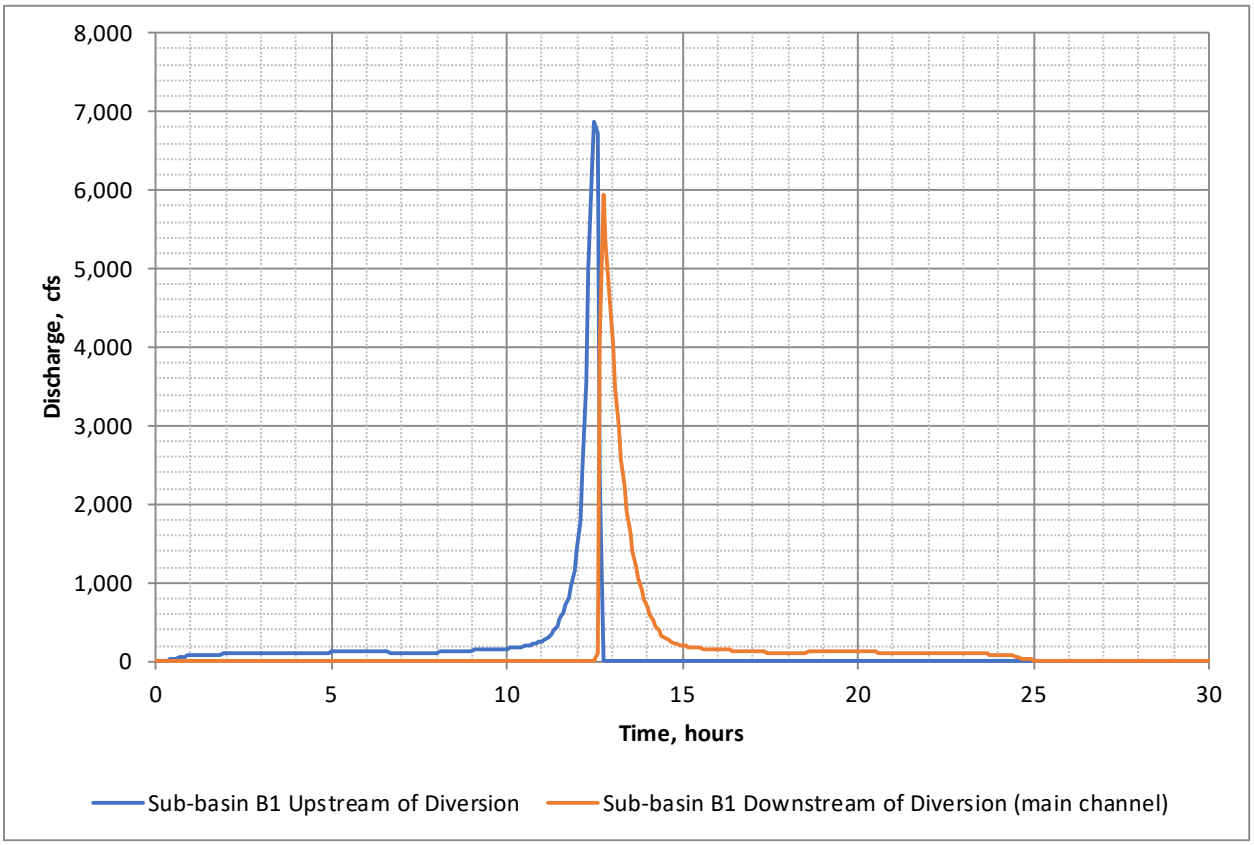
The DT record defines the name of the diverted flow hydrograph in Field 1 so it could be retrieved later in the model. However, for this example no retrieval is desired. Field 2 contains the total volume to be diverted in acre-feet.

The DI record contains a list of inflow values to the diversion operation.

The DQ record contains the list of flow rates to be diverted corresponding to the field values on the DI record. Note that for this example the flow rates are the same for both the DI and DQ records. This has the effect of diverting all flow up to 10,000 cfs until a total volume of 400 acre-feet have been diverted. Then no more flow is diverted.

The results are shown on Figure A.32. Note that the 100-year 24-hour peak discharge from sub-basin B1 is reduced from 6,874 cfs to 5,934 cfs because of the on-site retention.

Figure A.32 Example of retention basin diversion hydrographs



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A.7 INDIRECT METHODS EXAMPLE

The unit hydrograph method example results can be checked for reasonableness using indirect methods, as described in Section 7.11. The following is a discussion of the check made with each of the three methods. This approach is an example of what is expected by Mohave County for inclusion in drainage design reports when the unit hydrograph method is applied.

A.7.1 INDIRECT METHOD 1

The Method 1 check, shown on Figure A.33, is a comparison of the HEC-1 model results with unit peak discharge envelope curves of maximum observed floods of record from natural watersheds for differing hydrologic regions in the southwestern United States. As expected, note that all the model results except for sub-basin B1 fall below the envelope curves. Sub-basin B1 is predominately an urban watershed and is expected to have a higher unit discharge than the other sub-basins. This check yields no reason to suspect the model results are unreasonable.

A.7.2 INDIRECT METHOD 2

Indirect Method 2, shown on Figure A.34, is a comparison with 100-year peak discharges for Arizona analyzed by the USGS from streamflow data. The example peak discharges check very well against the data fit line and lie within the 90% confidence limits. Sub-basin B1 lies on the upper 90 percent confidence limit, which is treasonable as these data are from predominately natural watersheds. This check yields no reason to suspect the model results are unreasonable.

A.7.3 INDIRECT METHOD 3

Checks of the applicability of the Indirect Method 3 regression equations independent variable *PRECIP* and *ELEV* are shown on Figure A.35 and Figure A.36, respectively. The Indirect Method 3 peak discharge check is shown on Figure A.37. This is a check against the data used to generate the USGS regional regression equation for Region 3, which covers the example watershed. The example results compare favorably with the regression equation data points. The example results plot within the regression equation data points scatter. Sub-basin B1 again plots high but is within the scatter of LP3 data points. This check yields no reason to suspect the model results are unreasonable.

Figure A.33 Indirect Method 1 check of Unit Hydrograph Method example

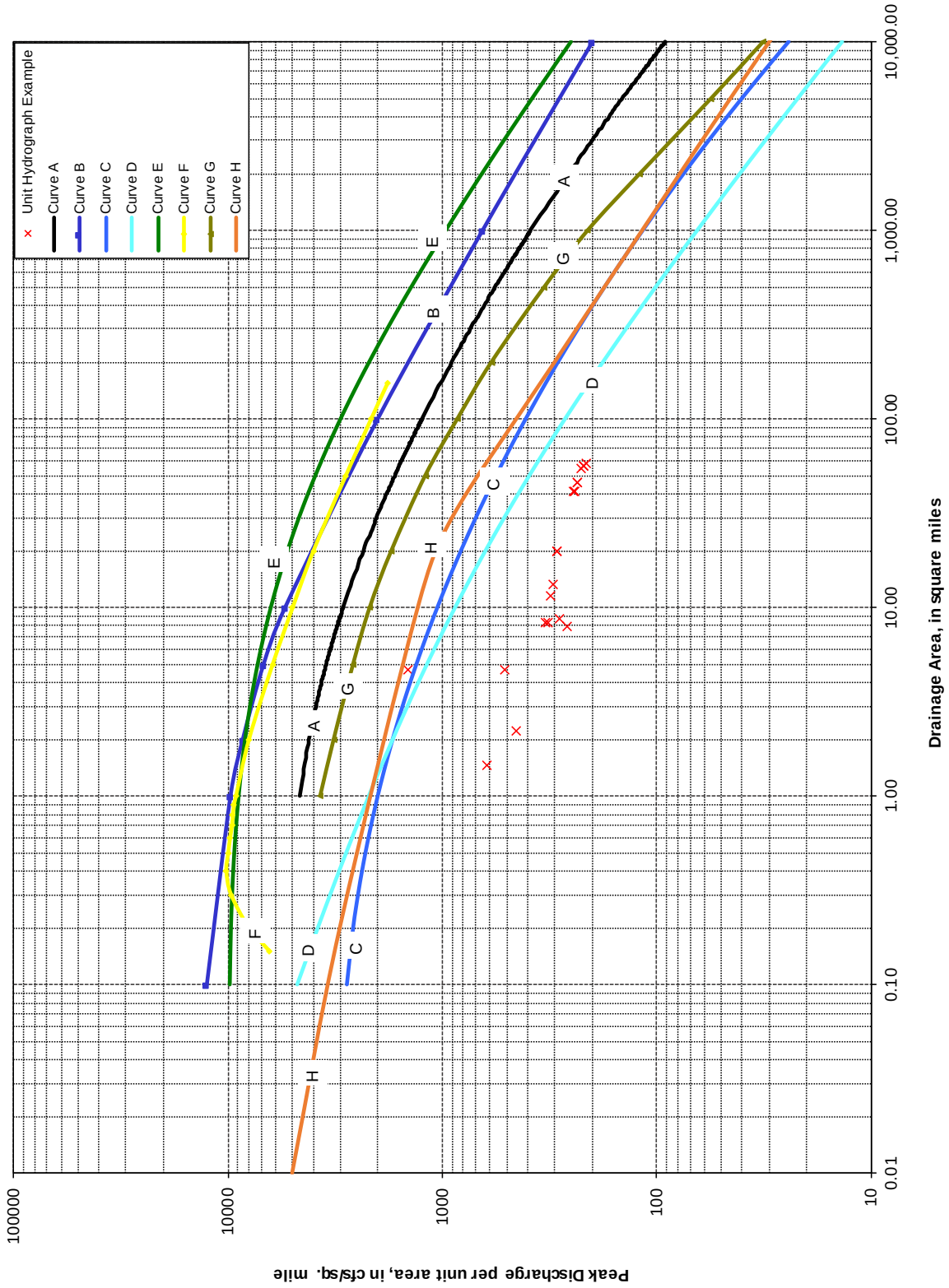


Figure A.34 Indirect Method 2 check of Unit Hydrograph Method example

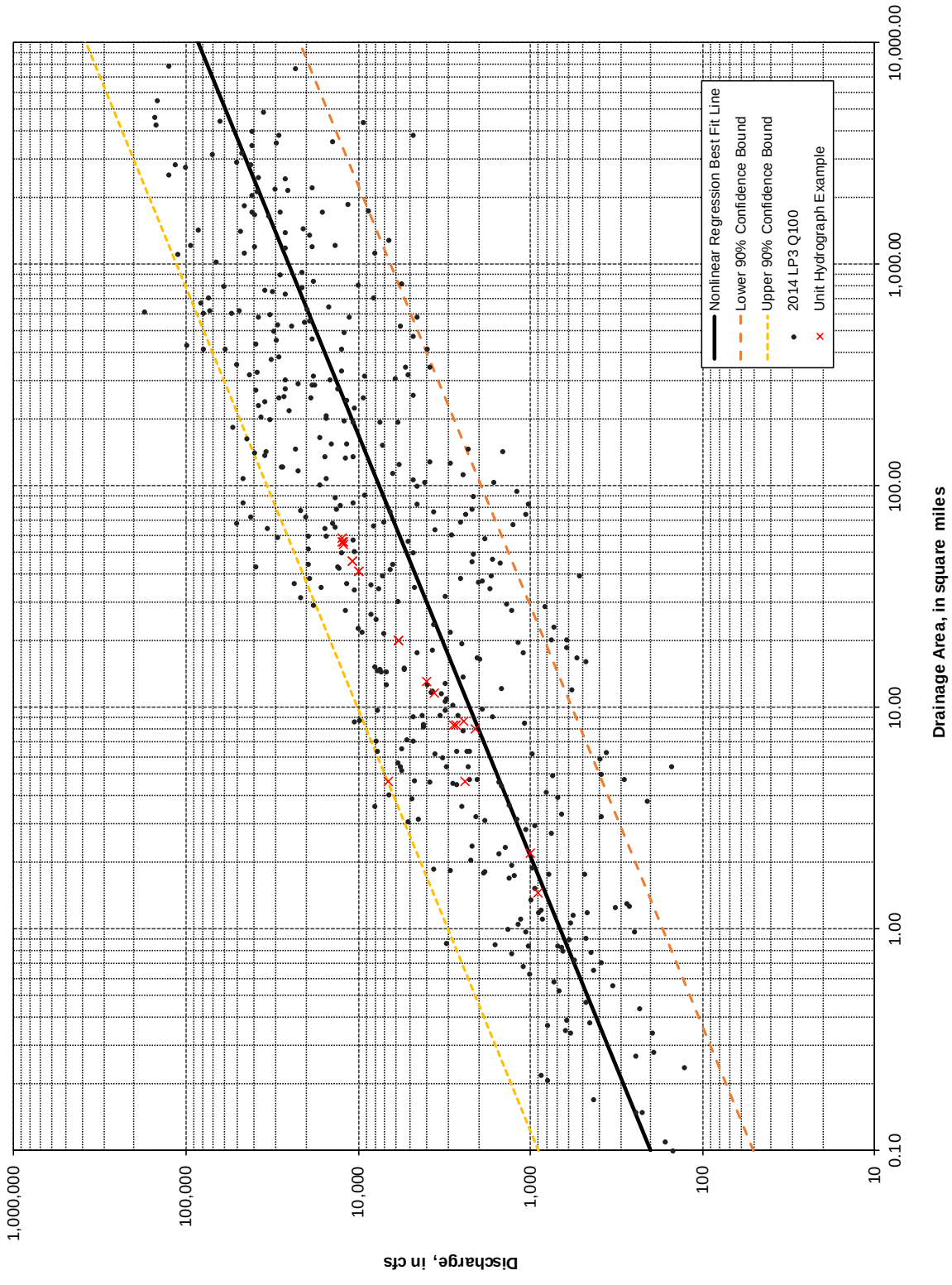


Figure A.35 Indirect Method 3 check of independent variable *PRECIP*

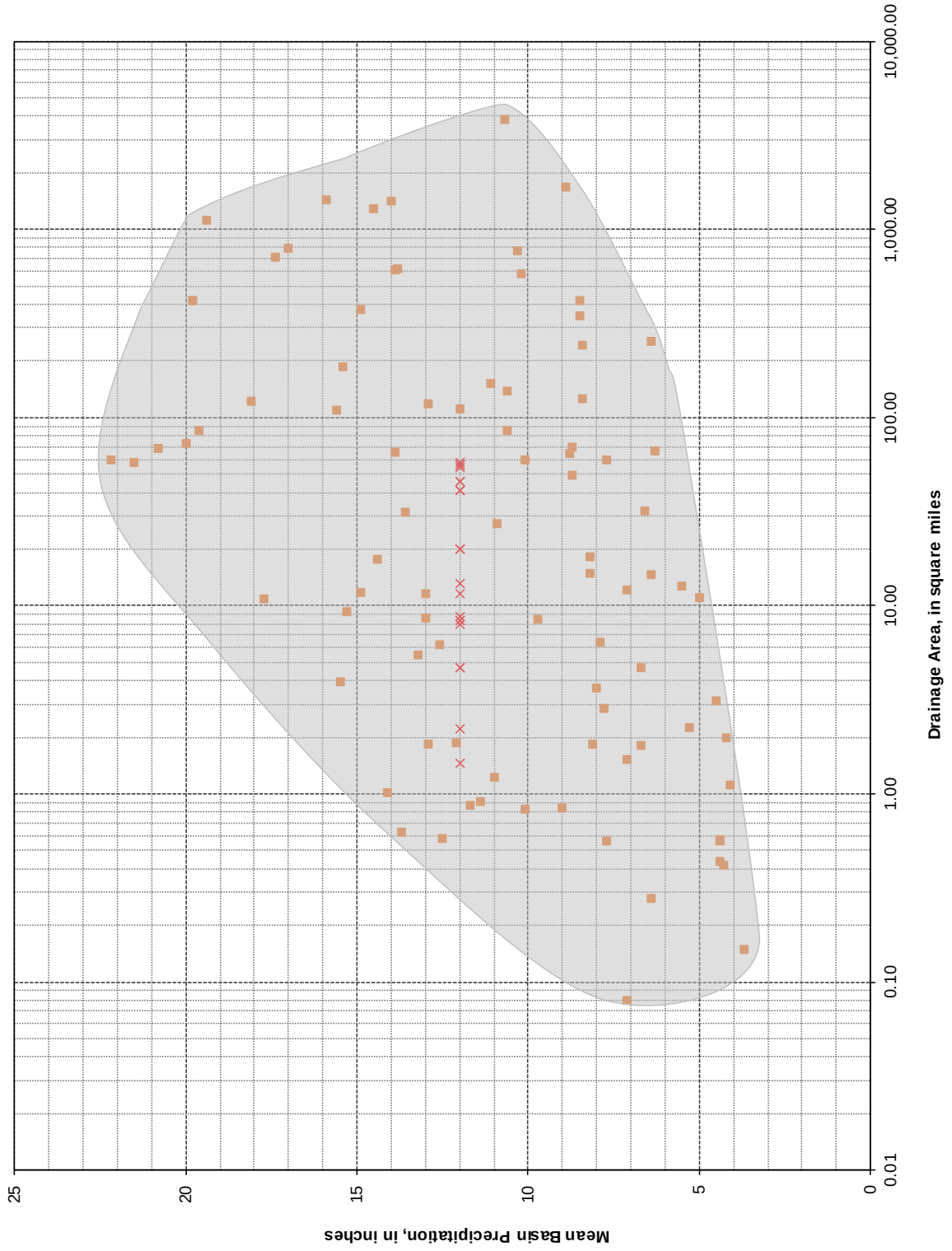


Figure A.36 Indirect Method 3 check of independent variable *ELEV*

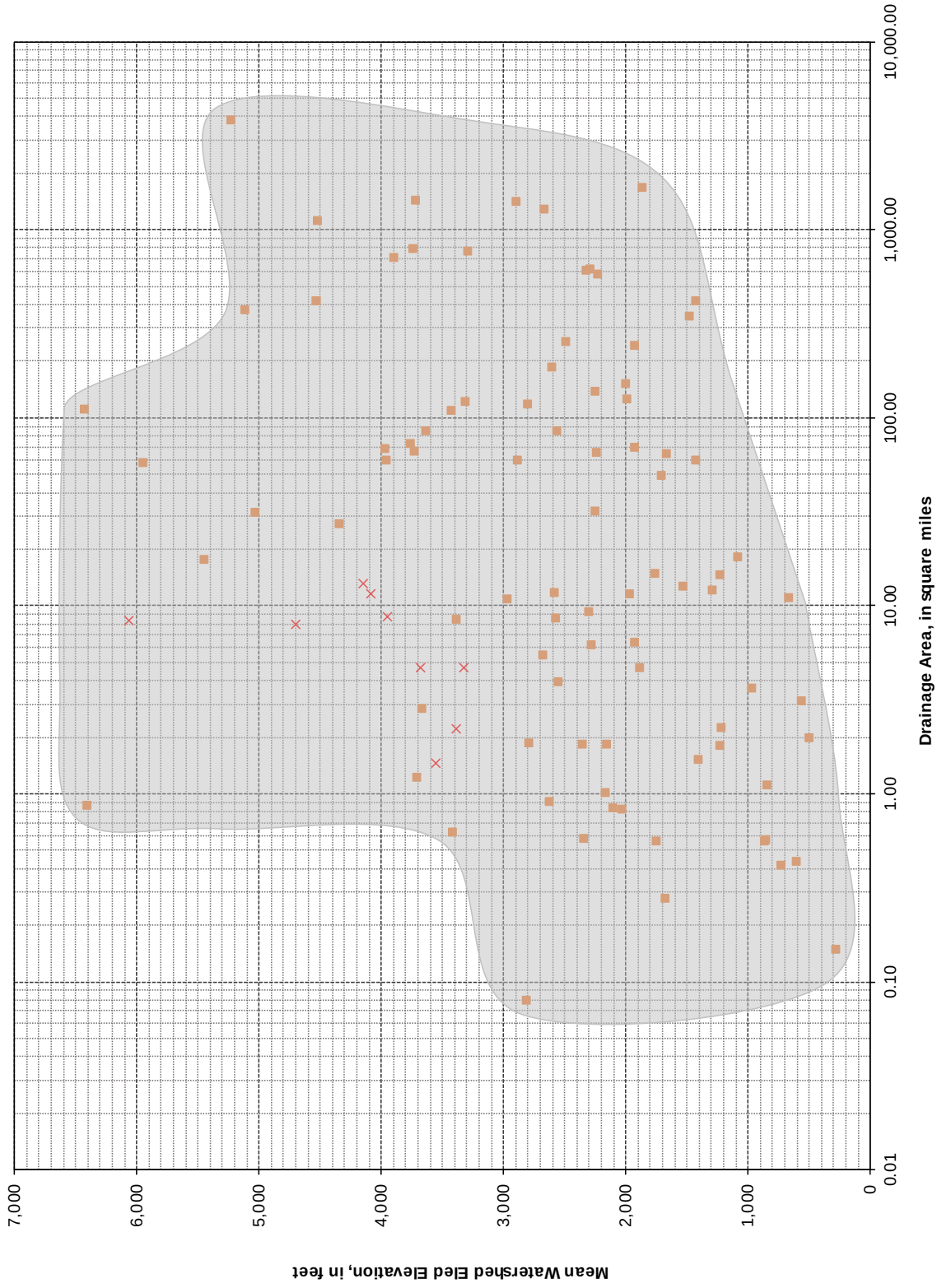
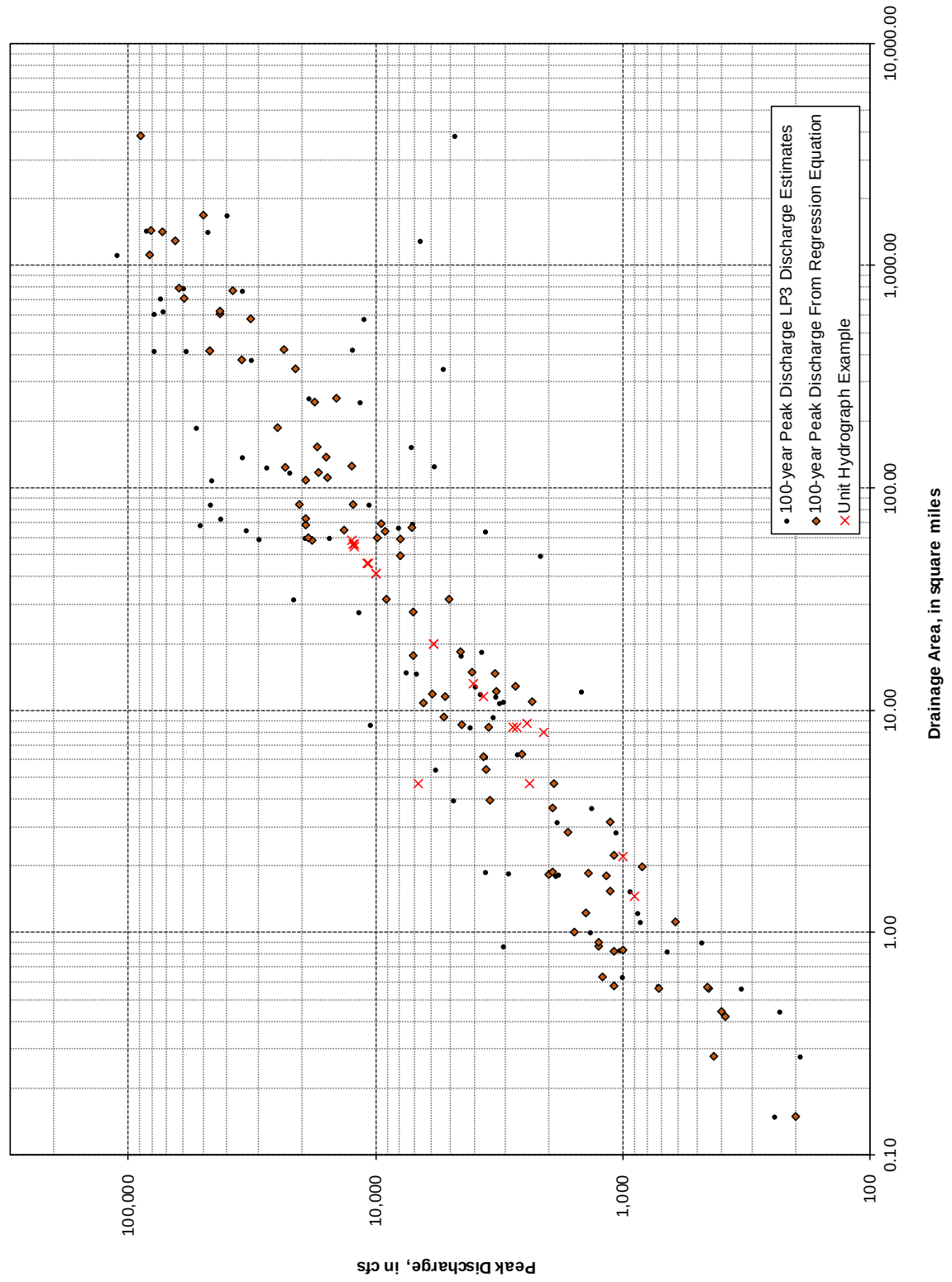


Figure A.37 Indirect Method 3 check of Unit Hydrograph Method example



A.8 STORMWATER STORAGE EXAMPLE

A.8.1 PROBLEM STATEMENT

A stormwater storage basin is needed for the commercial parcel within sub-basin C from the Rational Method example in Appendix A.2. Refer to Figure A.11. The design storage volume is to be determined and basin characteristics recommended based on drain time and Mohave County minimum requirements for inclusion in a Preliminary Design Report for the project.

A.8.2 PROBLEM SOLUTION

A.8.2.1 Given Information

The physical information for the solution is derived from Table A.15, Table A.17 and Table A.18 as follows:

1. 100-year 2-hour Storm Point Precipitation: 2.546 inches
2. Area of Commercial Site: 9.19 acres
3. Rational C coefficient for C1 zoning: 0.83

A.8.2.2 Basin Sizing

The retention basin must be designed to contain the entire runoff volume from the site from a 100-year 2-hour storm. The required minimum design storage volume is determined using Equation 7.7:

$$V = C\left(\frac{P}{12}\right)A$$

where: V = runoff volume, in acre-feet,
C = runoff coefficient (or C_{comp}),
P = rainfall depth, in inches, and
A = drainage area, in acres.

$$V = 0.83\left(\frac{2.546}{12}\right)9.19 = 1.62\ acre-feet$$

Prior to scheduling geotechnical testing for the proposed site, approximate basin dimensions are needed. The basin should have the following characteristics:

1. Depth: 4 feet total, 3-feet of depth at the crest of the emergency spillway.
2. Side slopes: 3:1

Approximate land area required is estimated as follows, assuming a square basin and applying Equation A.2:

Bottom area = x^2

Top area = $(x+2*3*3)^2$

$$\Delta V_{B,T} = \frac{d}{3}\left(A_B + A_T + \sqrt{A_B A_T}\right)$$

where:

$\Delta A_{1,2}$ = volume between the top and bottom of the basin,

d = vertical distance (depth) between top and bottom,

A_B = surface area of bottom of basin, and

A_T = surface area of top of basin.

$$(1.62)(43560) = \frac{3}{3}\left(x^2 + (x+18)^2 + \sqrt{x^2(x+18)^2}\right)$$

Solving for x:

$x^2 + (x^2 + 36x + 324) + \sqrt{x^2(x+18)^2} = 70{,}567.2$

$2x^2 + 54x + 324 = 70{,}567.2$

$3x^2 + 36x + 324 + x(x+18) = 70{,}567.2$

$x^2 + 18x - 23{,}414.4 = 0$

Solving the quadratic, X=144.28. Use X=150 feet

The basin bottom area is therefore = 150*150 = 22,500 sq ft

Per Table 15.2, the minimum number of soil log hole/percolation tests required for a basin bottom area of 22,500 feet is four.

A geotechnical firm was retained to perform testing in conformance with Section 15.4.1.4. The following are the results of the geotechnical investigation:

Test Location 1:

14-foot deep soil log hole (10 feet below bottom of basin).

0 to 5 inches	Gravelly sandy loam
5-inches to 9-feet	Gravelly loam
9-feet to 13-feet	Caliche
13-feet to 14-feet	Gravelly Clay loam

Measured percolation rate: 1.2 inches/hour

Test Location 2:

14-foot deep soil log hole (10 feet below bottom of basin).

0 to 5 inches Gravelly sandy loam

5-inches to 10-feet Gravelly loam

10-feet to 12-feet Caliche

12-feet to 14-feet Gravelly Clay loam

Measured percolation rate: 1.5 inches/hour

Test Location 3:

14-foot deep soil log hole (10 feet below bottom of basin).

0 to 8 inches Gravelly sandy loam

8-inches to 10-feet Gravelly loam

10-feet to 13-feet Caliche

13-feet to 14-feet Gravelly Clay loam

Measured percolation rate: 1.2 inches/hour

Test Location 4:

14-foot deep soil log hole (10 feet below bottom of basin).

0 to 5 inches Gravelly sandy loam

5-inches to 9-feet Gravelly loam

9-feet to 12-feet Caliche

12-feet to 14-feet Gravelly Clay loam

Measured percolation rate: 1.2 inches/hour

The lowest percolation rate of 1.2 inches/hour is selected for use in the design. An impermeable layer was found in the soil log hole at a depth of 6- to 9-feet below the basin bottom.

From Table 15.3, a Design Factor, D_r, of 4.0 is selected.

Applying Equation 15.1 to determine the design percolation rate:

$$P_d = \frac{P}{D_r}$$

where:

P_d = Design percolation rate, in inches/hour,
P = Lowest measured percolation rate, in inches/hour, and
D_r = Design Factor from Table 15.3.

$$P_d = \frac{1.2}{4} = 0.3\ inches/hour$$

Next, applying Equation 15.2 to estimate the minimum required basin bottom area:

$$T_d = \frac{V}{A_p \frac{P_d}{12}}$$

where:

T_d	=	Retention basin drain time in hours,
A_p	=	Percolation area (basin bottom), in acres
P_d	=	Design percolation rate, in inches/hour, and
V	=	Retention basin design storage volume, in acre-feet.

$$A_p = \frac{V}{T_d \frac{P_d}{12}}$$

$$A_p = \frac{1.62}{(36)\left(\frac{0.3}{12}\right)} = 1.80\ acres$$

The required basin bottom area is significantly greater than the minimum area of 2,500 sf. The new approximate basin dimensions are:

Design Ponding Depth = 36(0.3/12) = 0.9 feet

Design Freeboard = 1 foot.

Total Basin Design Depth = 1.9 feet

Side Slope = 3:1

Top Area = $((2)(1.9)(3)+280)^2$ = 84,914 sf or 1.95 acres

If a basin with a smaller land requirement is desired, the design will need to be supplemented with dry wells.

A.8.2.3 Emergency Spillway Design

In accordance with Section 15.4.3.7, all stormwater storage basins shall have an emergency spillway. The spillway must be designed to safely pass the 100-year peak discharge, which is 42 cfs for sub-basin C. In this case, the spillway discharges into a trapezoidal channel with the following characteristics:

Slope (S): 0.006 ft/ft

Base width (w): 10 feet

Available depth (d): 2 feet

Side slopes = 2:1

Lining: rock rip rap with a d_{50} of 6-inches

The spillway cannot have a flow depth greater than 1 foot without exceeding the maximum design basin depth of 4 feet. Assuming normal depth in the channel and no constrictions downstream that result in backwater effects that could impact the spillway area, the Manning equation may be used to determine the spillway characteristics. Assuming a flow depth of 1 foot:

$$Q = \left(\frac{1.486R^{0.67}S^{0.5}}{n}\right)A$$

A = (12)(1) = 12 sf

P = 2(2.24)+10 = 14.5 ft

R = A/P = 12/14.5 = 0.83 ft

n = 0.040 (from Table 13.4)

$$Q = \left(\frac{1.486\left(0.83^{0.67}\right)\left(0.006^{0.5}\right)}{0.040}\right)12 = 30.5\ cfs$$

30.5 cfs<42 cfs therefore no good.

Try w = 15 feet

A = 17 sf

P = 19.5 ft

R = 17/19.5 = 0.87 ft

$$Q = \left(\frac{1.486\left(0.87^{0.67}\right)\left(0.006^{0.5}\right)}{0.040}\right)17 = 44.6\ cfs$$

44.6 cfs>42 cfs, therefore OK

The velocity is 2.6 fps. By inspection use of 6-inch riprap is acceptable.

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B. RAINFALL

B.1 2-YEAR STORM ISOPLUVIALS

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Figure B.1 NOAA Atlas 14 2-year 5-minute isopluvial map

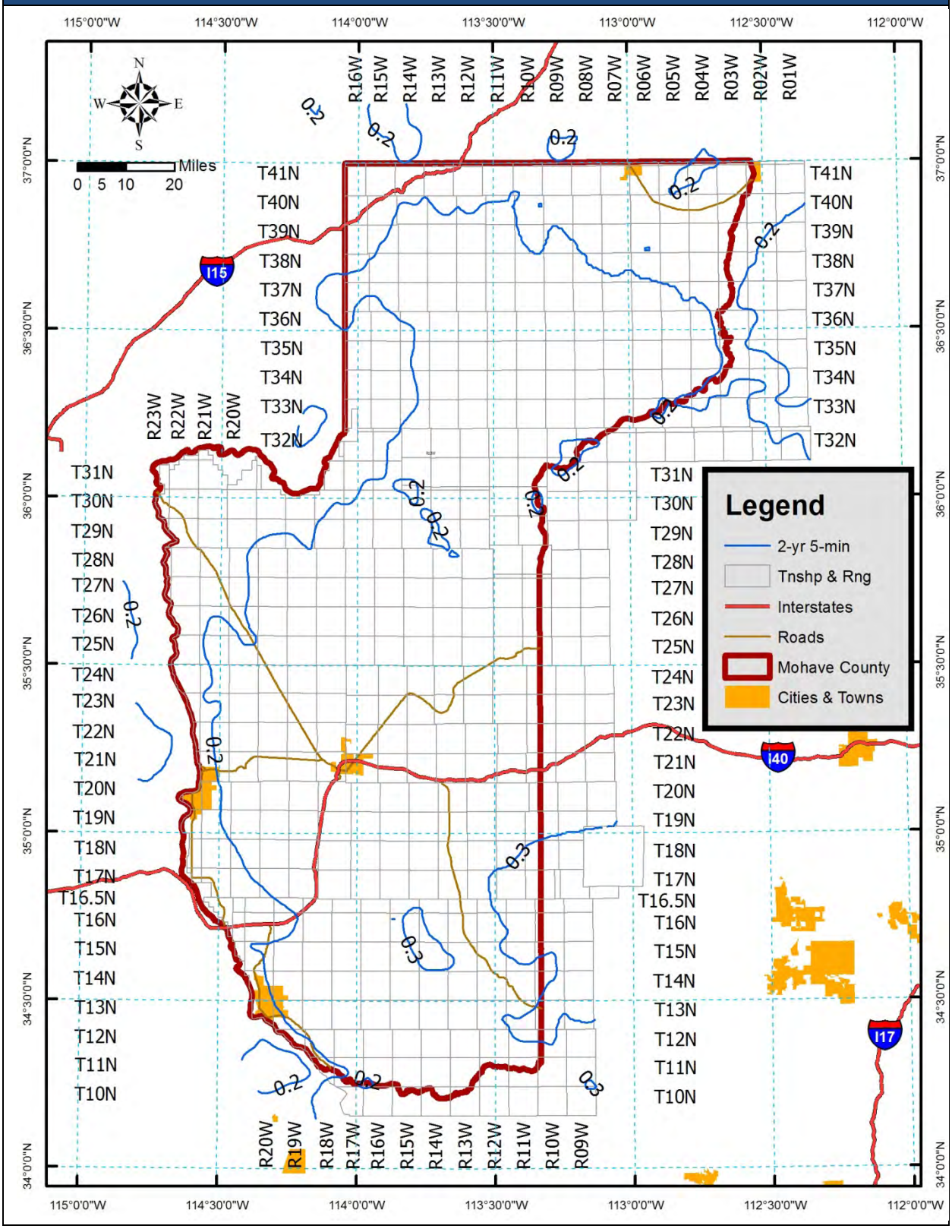


Figure B.2 NOAA Atlas 14 2-year 10-minute isopluvial map

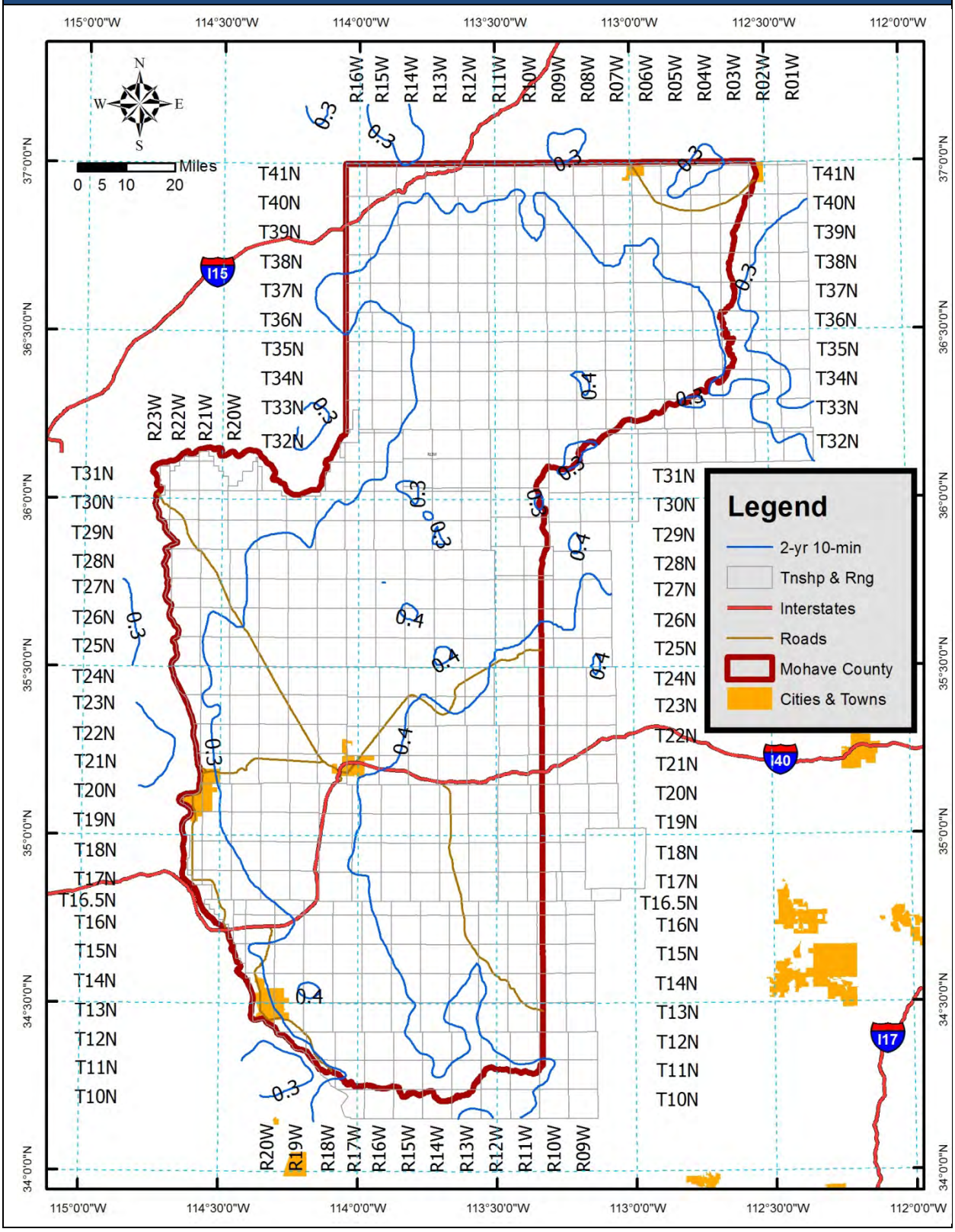


Figure B.3 NOAA Atlas 14 2-year 15-minute isopluvial map

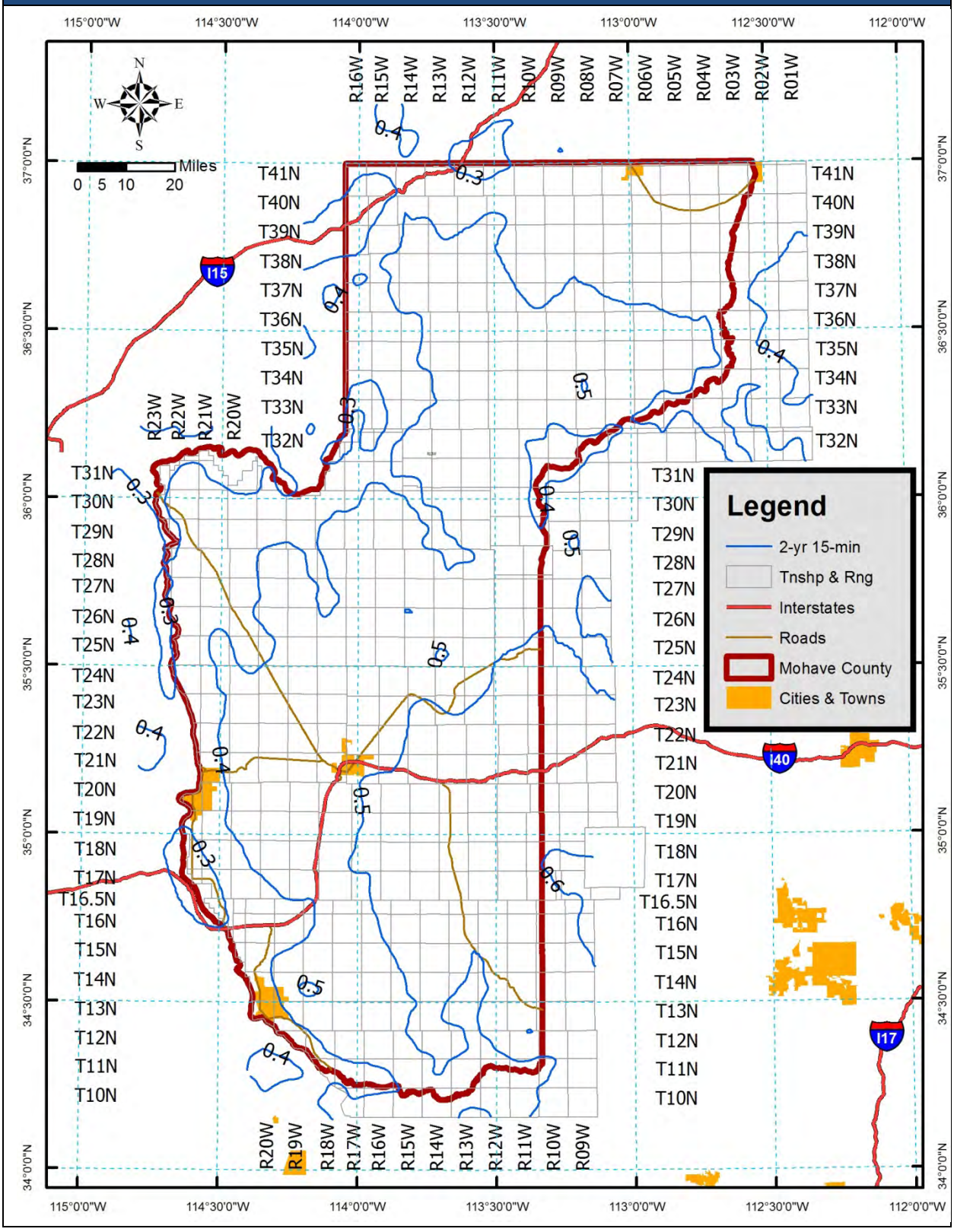


Figure B.4 NOAA Atlas 14 2-year 30-minute isopluvial map

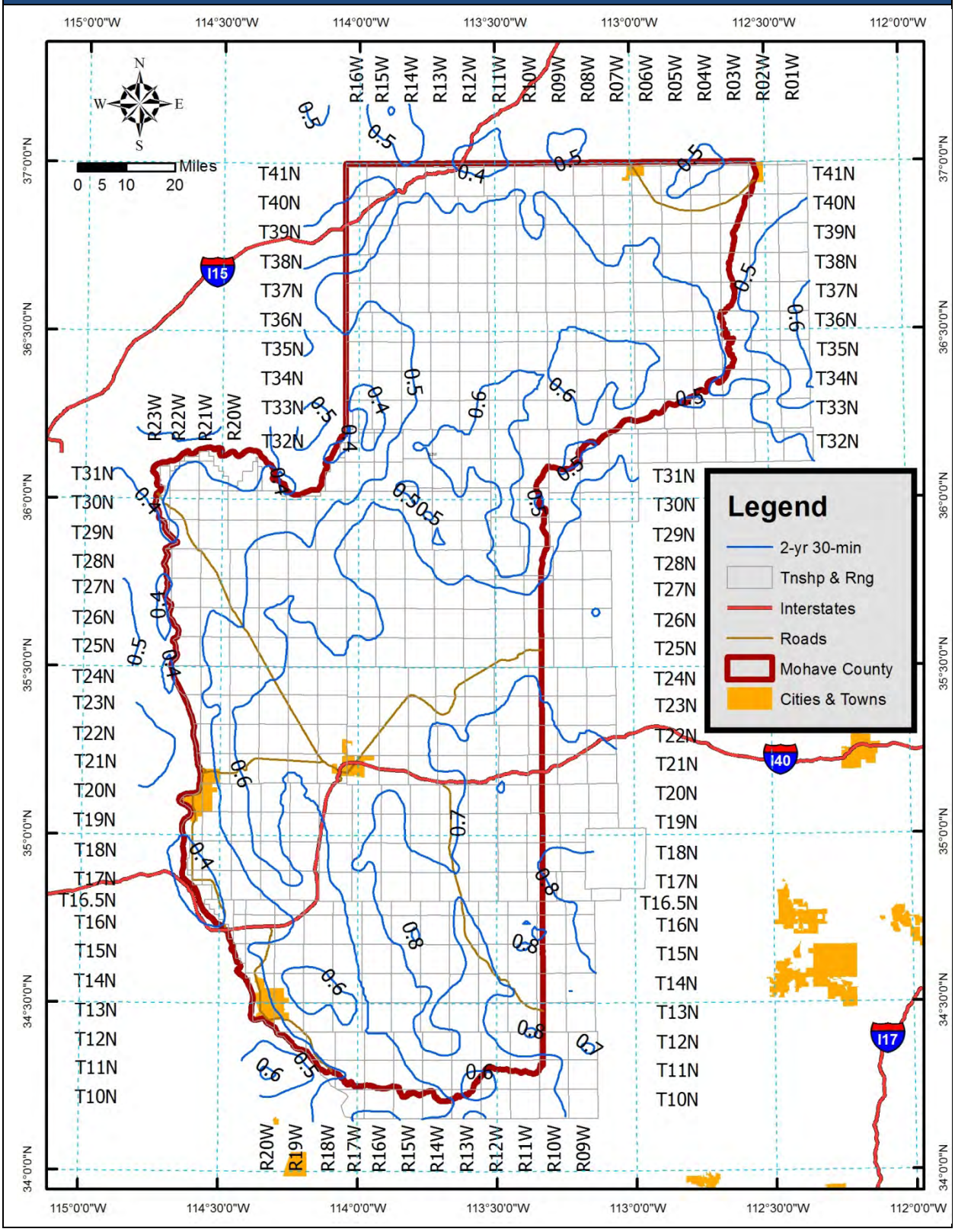


Figure B.5 NOAA Atlas 14 2-year 1-hour isopluvial map

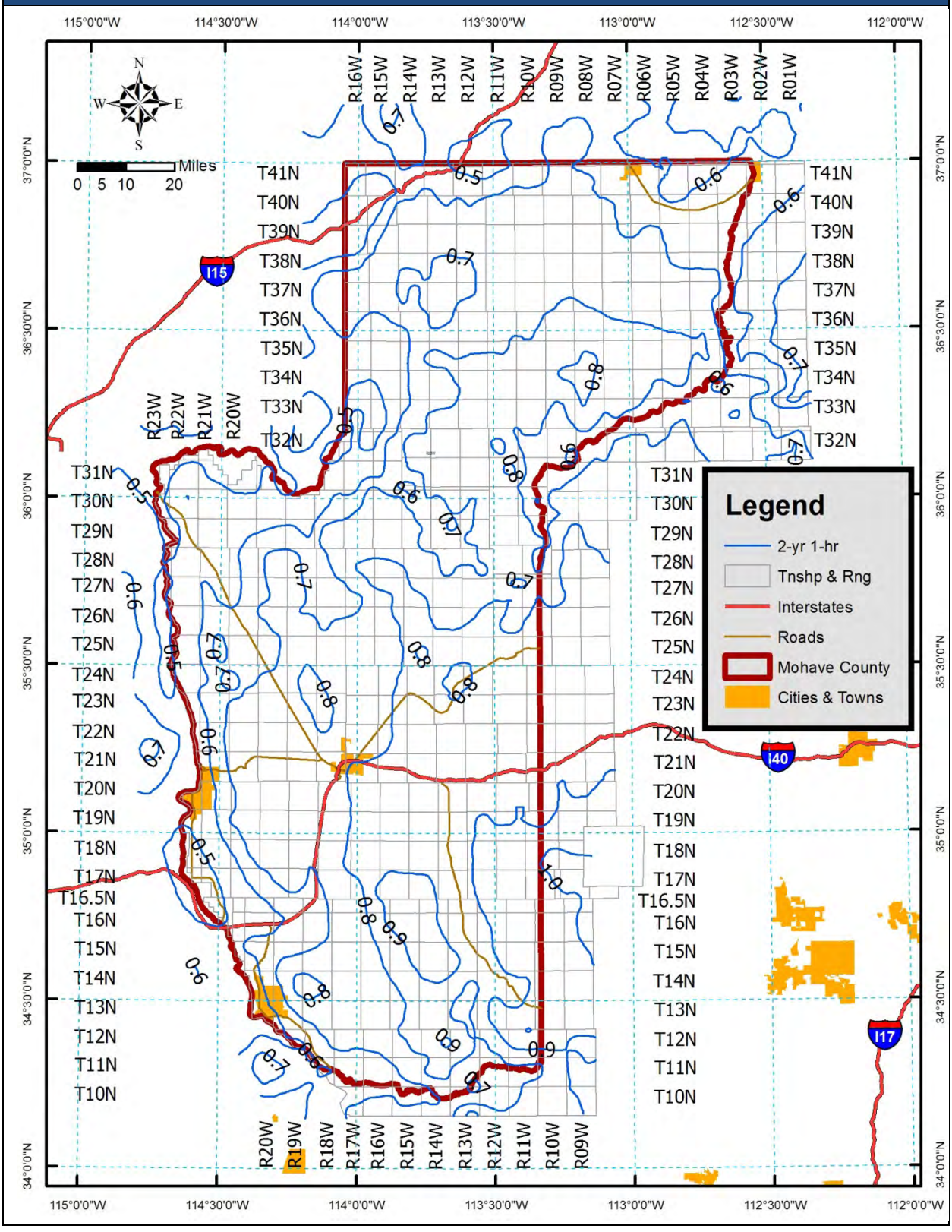


Figure B.6 NOAA Atlas 14 2-year 2-hour isopluvial map

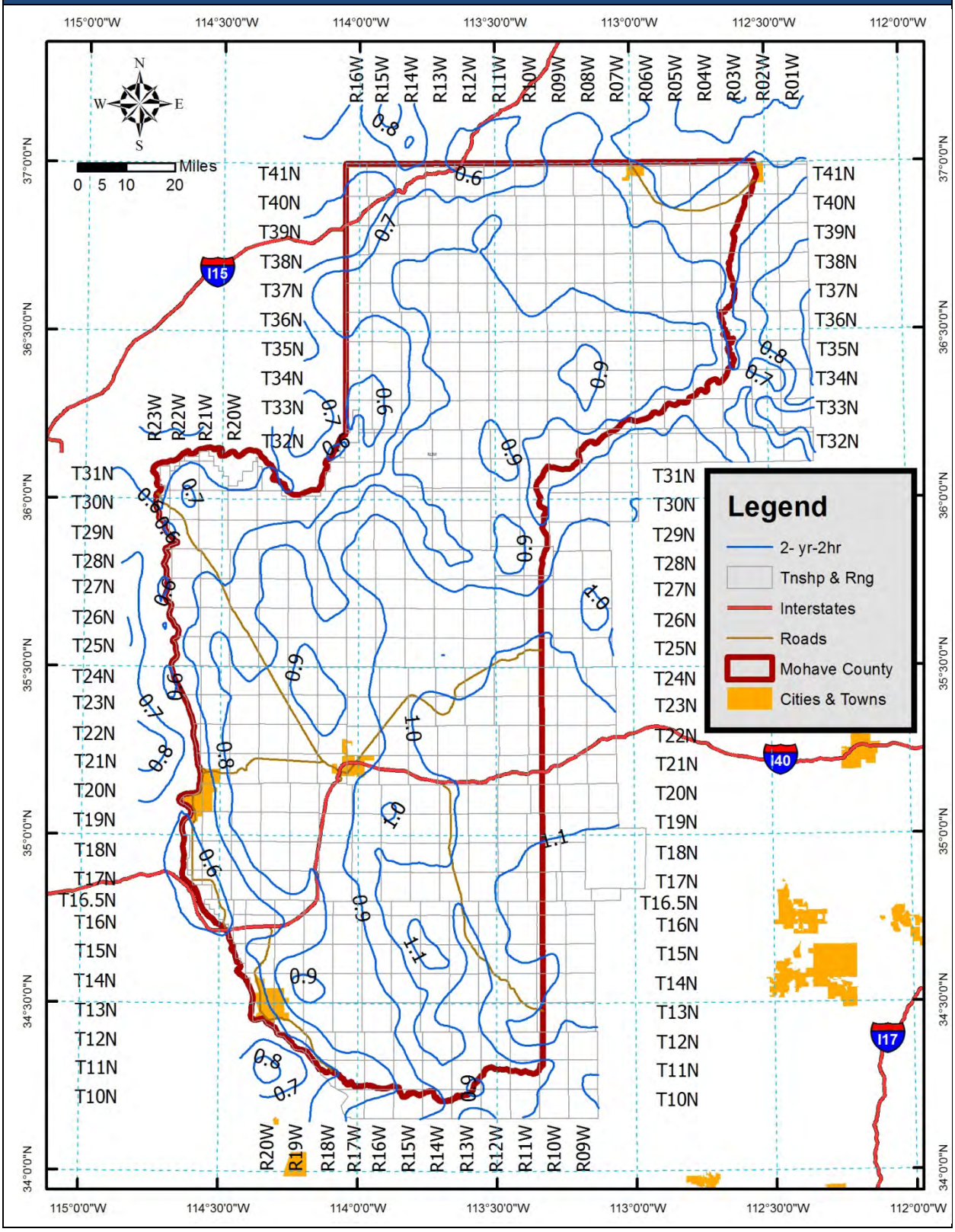


Figure B.7 NOAA Atlas 14 2-year 3-hour isopluvial map

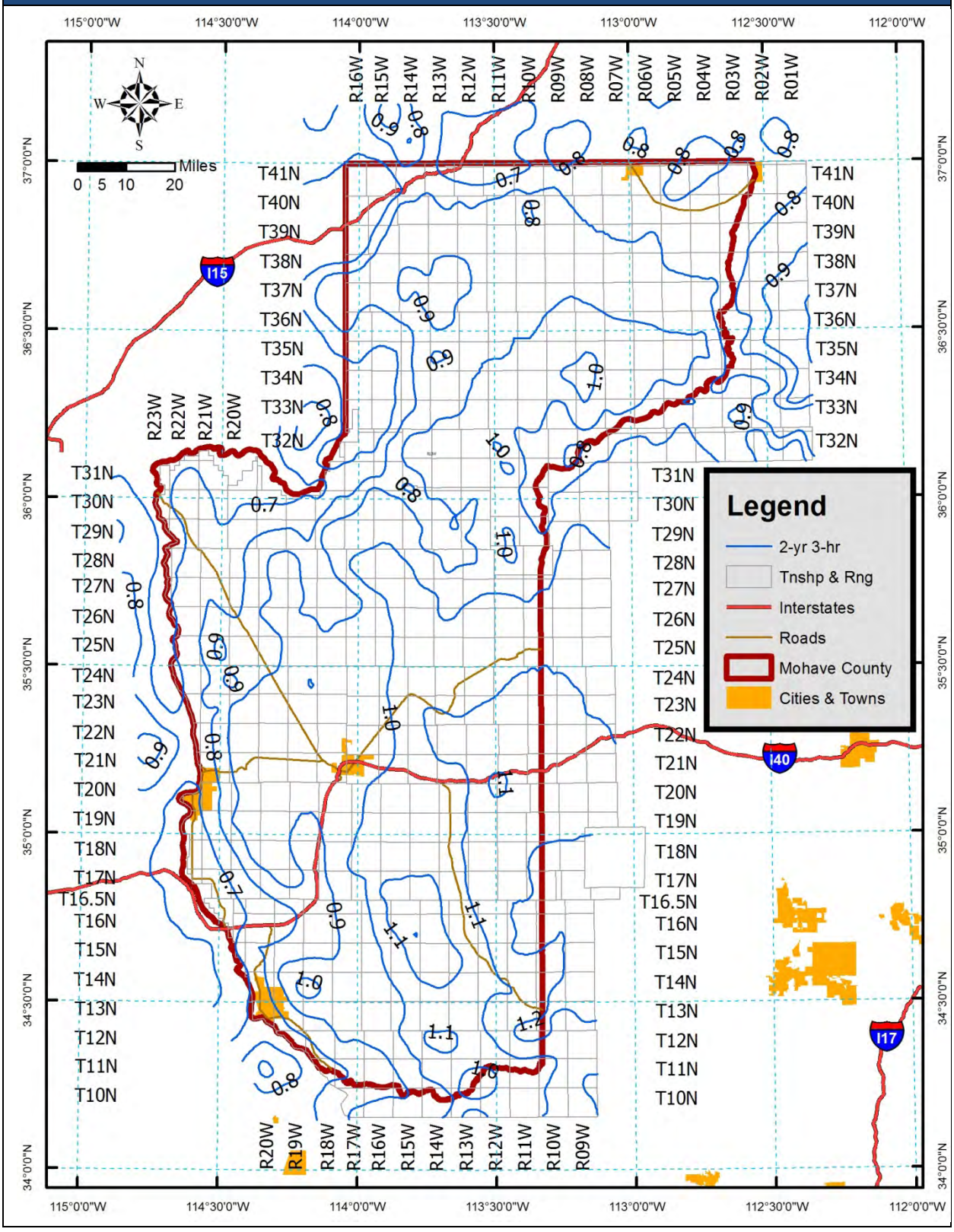


Figure B.8 NOAA Atlas 14 2-year 6-hour isopluvial map

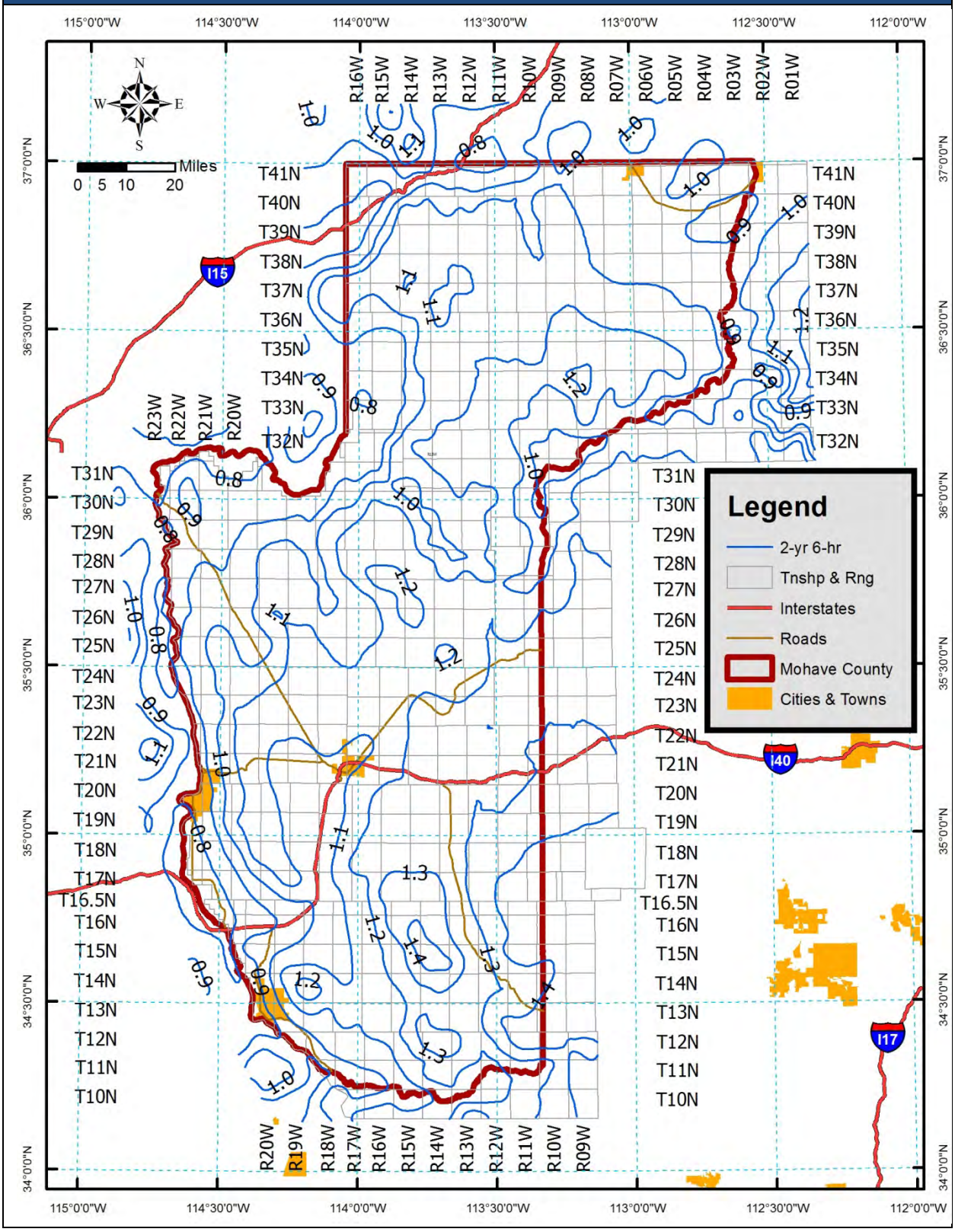


Figure B.9 NOAA Atlas 14 2-year 12-hour isopluvial map

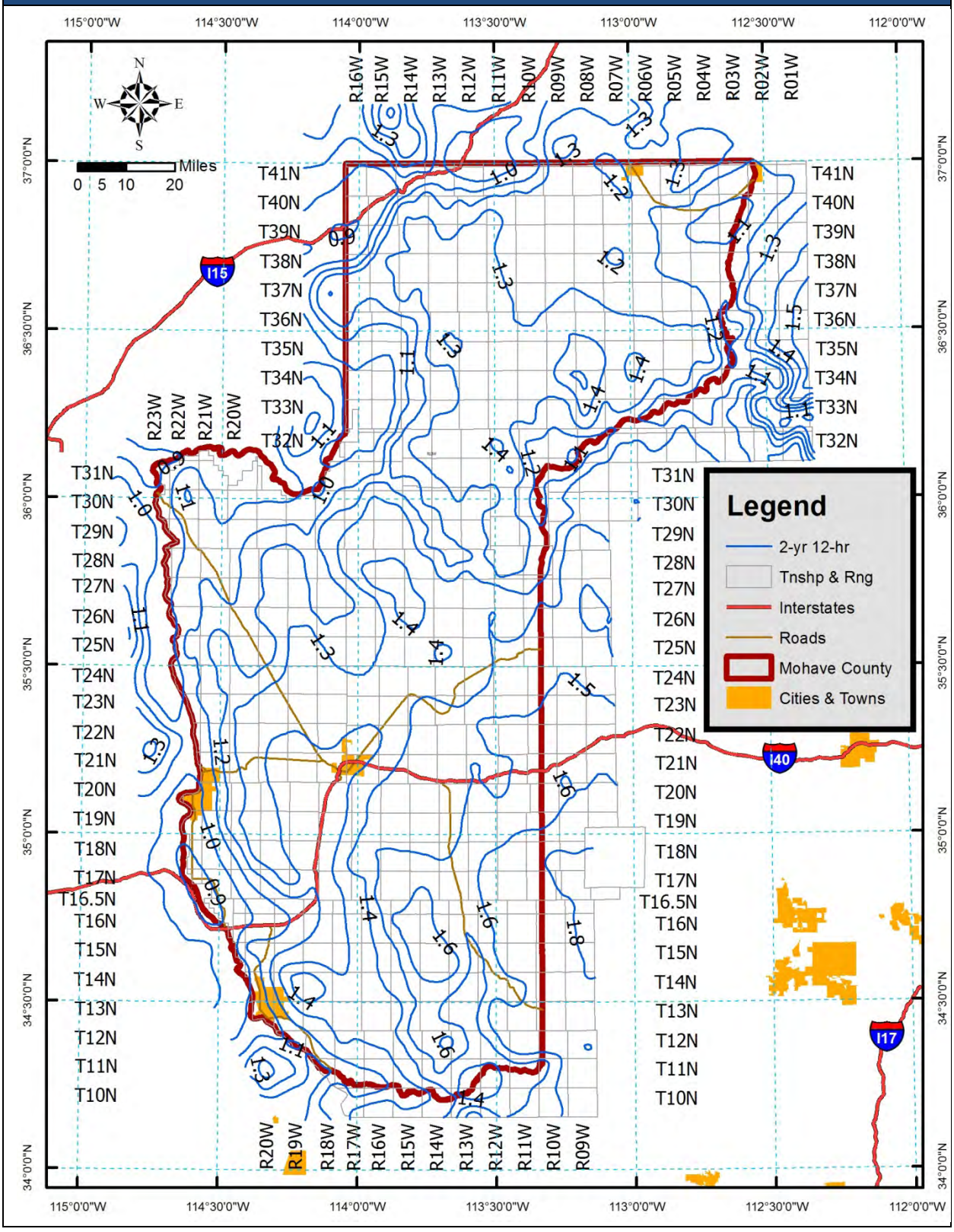
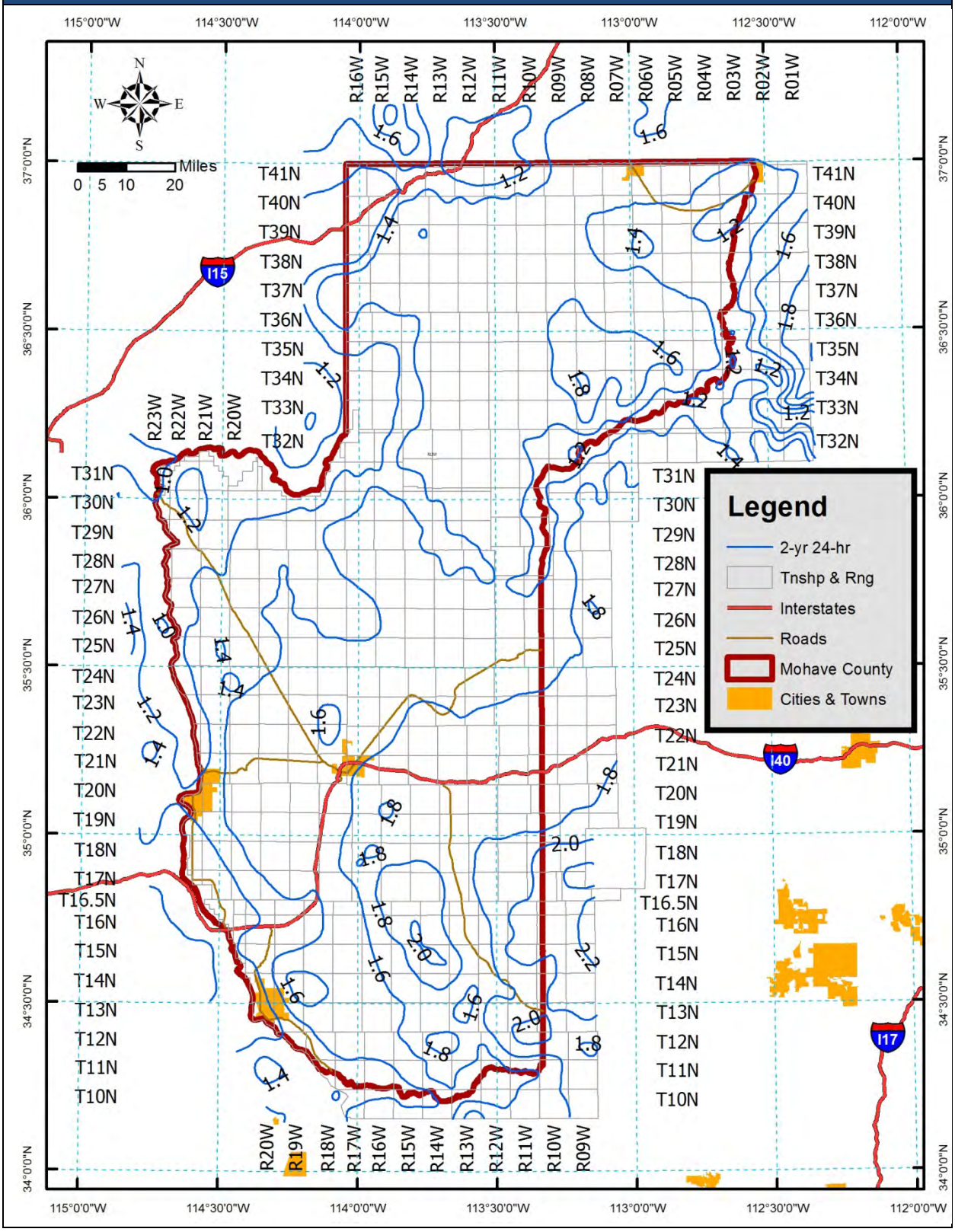


Figure B.10 NOAA Atlas 14 2-year 24-hour isopluvial map



B.2 5-YEAR STORM ISOPLUVIALS

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Figure B.11 NOAA Atlas 14 5-year 5-minute isopluvial map

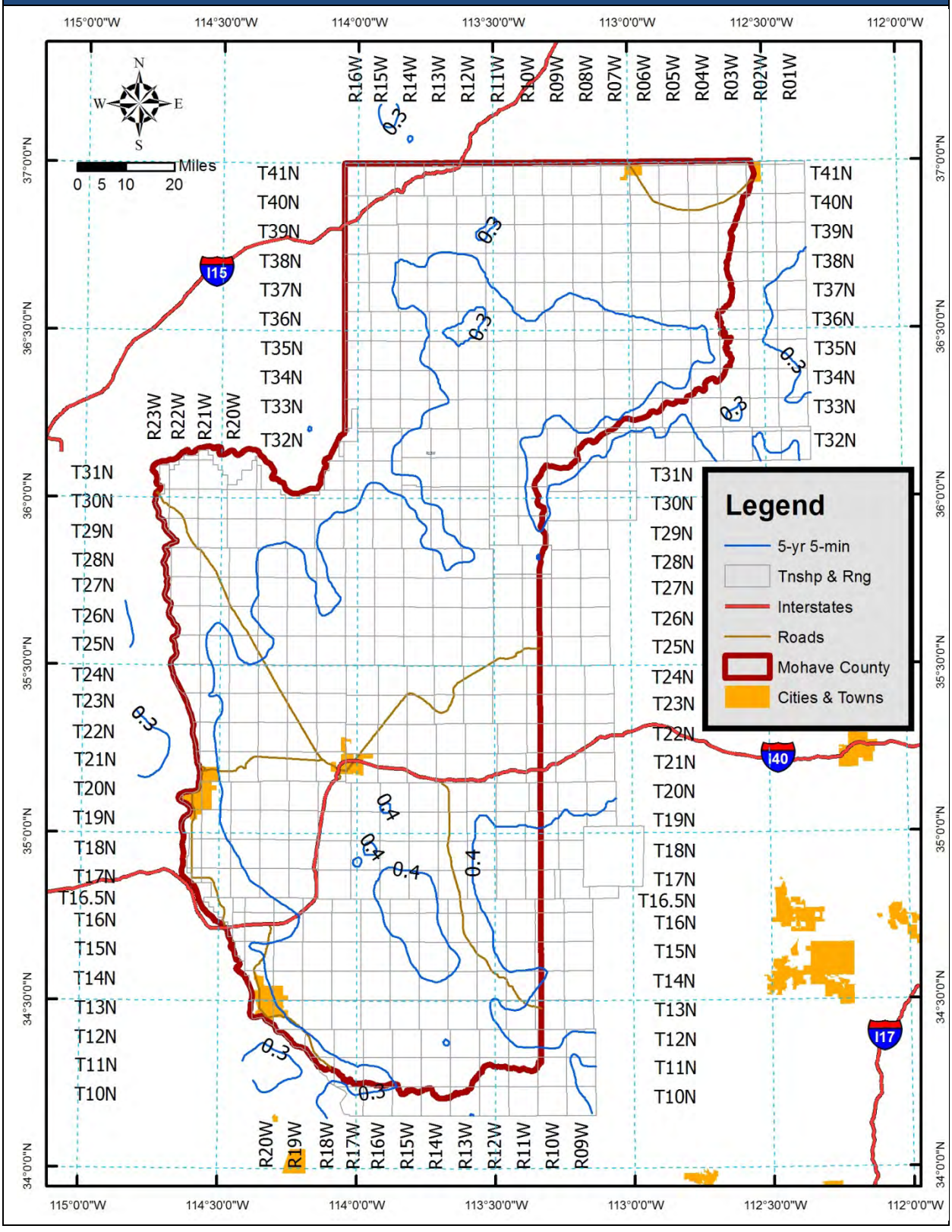


Figure B.12 NOAA Atlas 14 5-year 10-minute isopluvial map

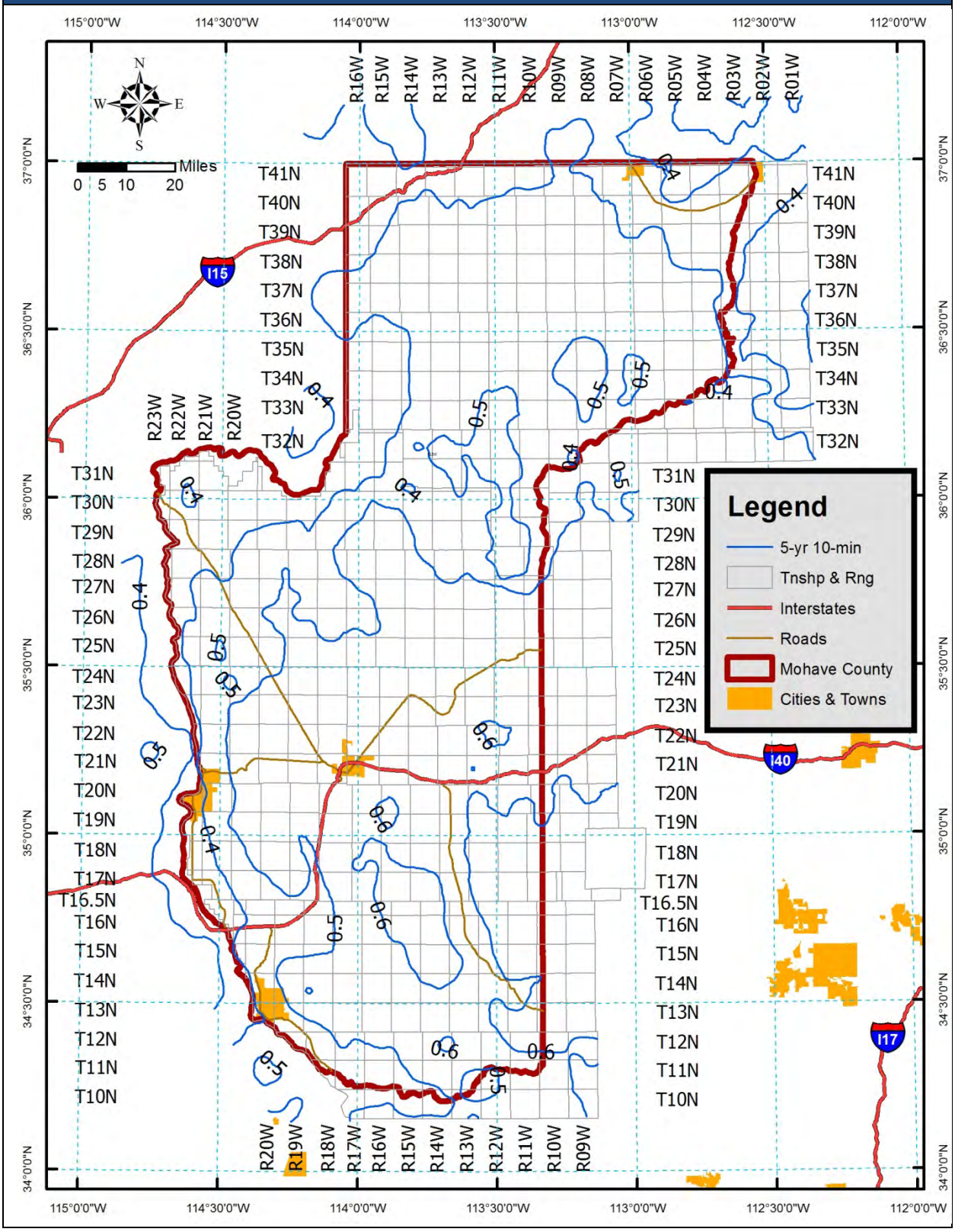


Figure B.13 NOAA Atlas 14 5-year 15-minute isopluvial map

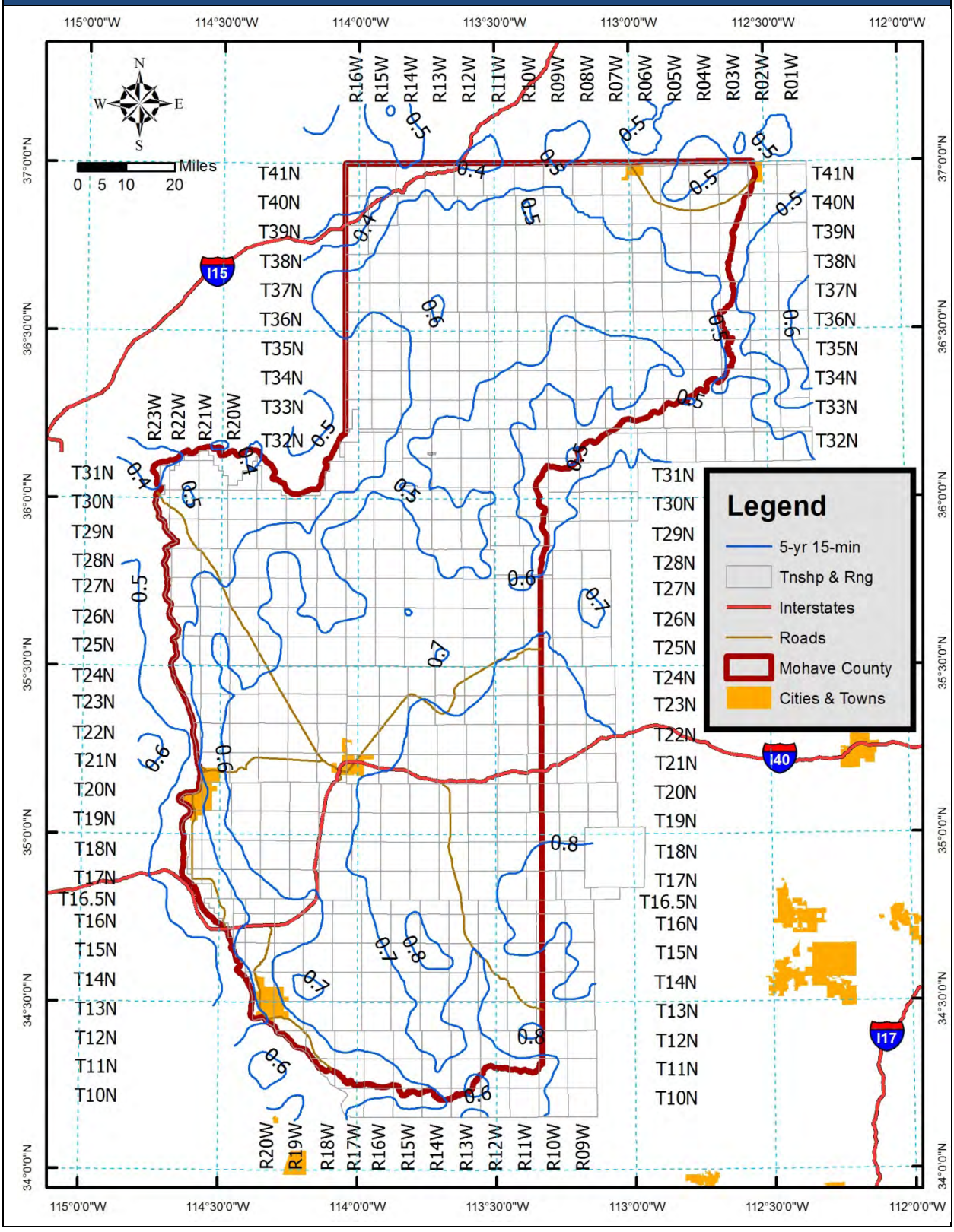


Figure B.14 NOAA Atlas 14 5-year 30-minute isopluvial map

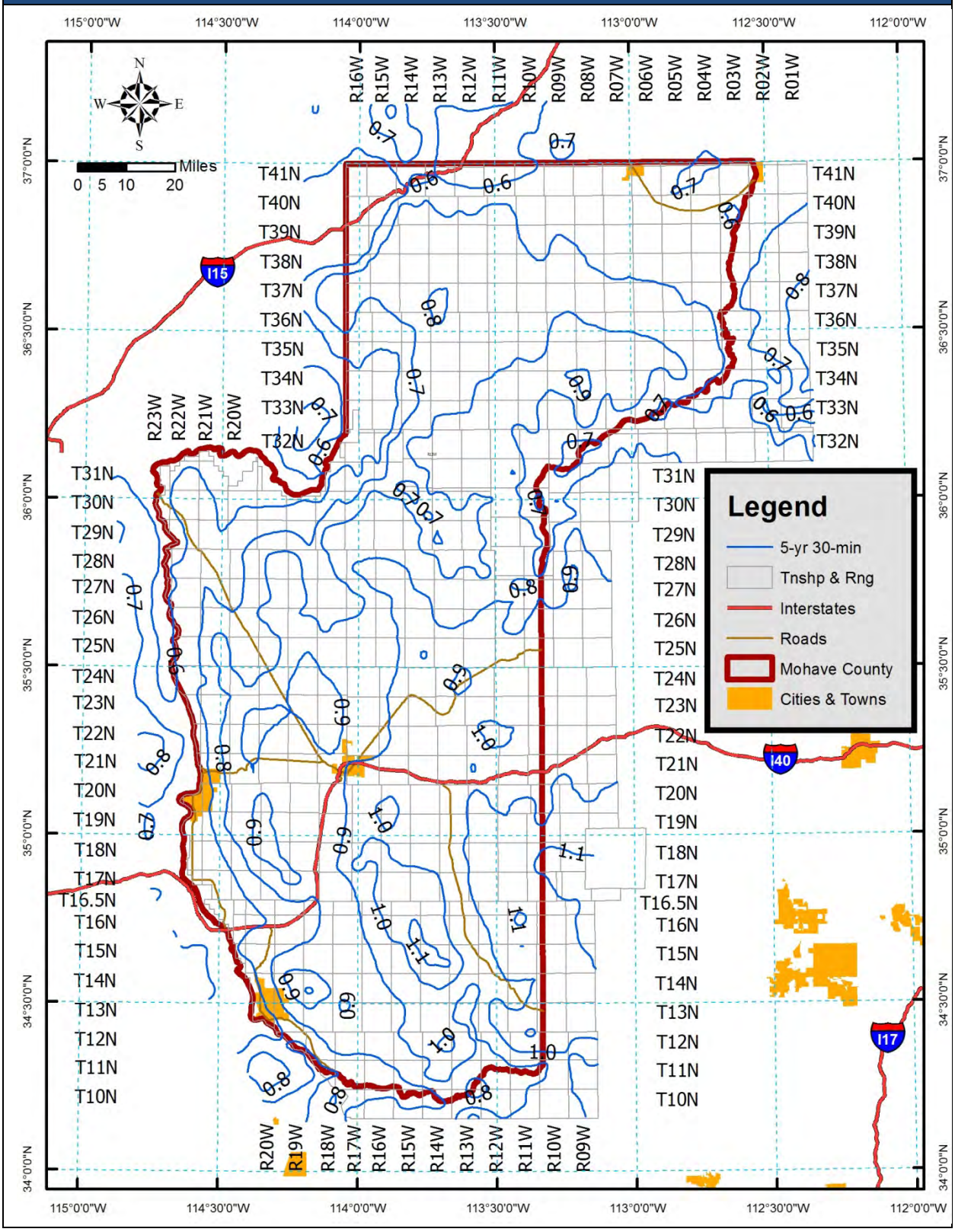


Figure B.15 NOAA Atlas 14 5-year 1-hour isopluvial map

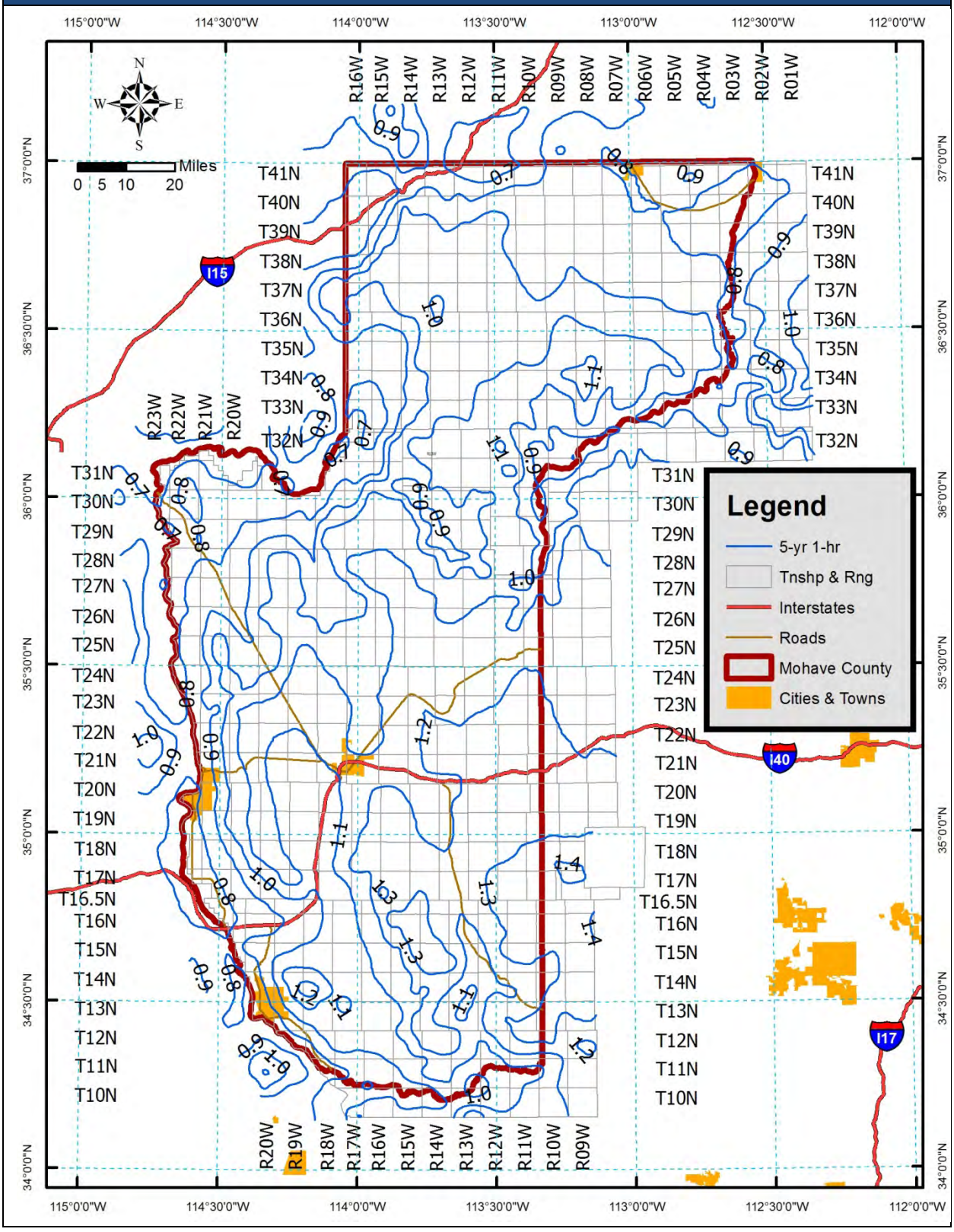


Figure B.16 NOAA Atlas 14 5-year 2-hour isopluvial map

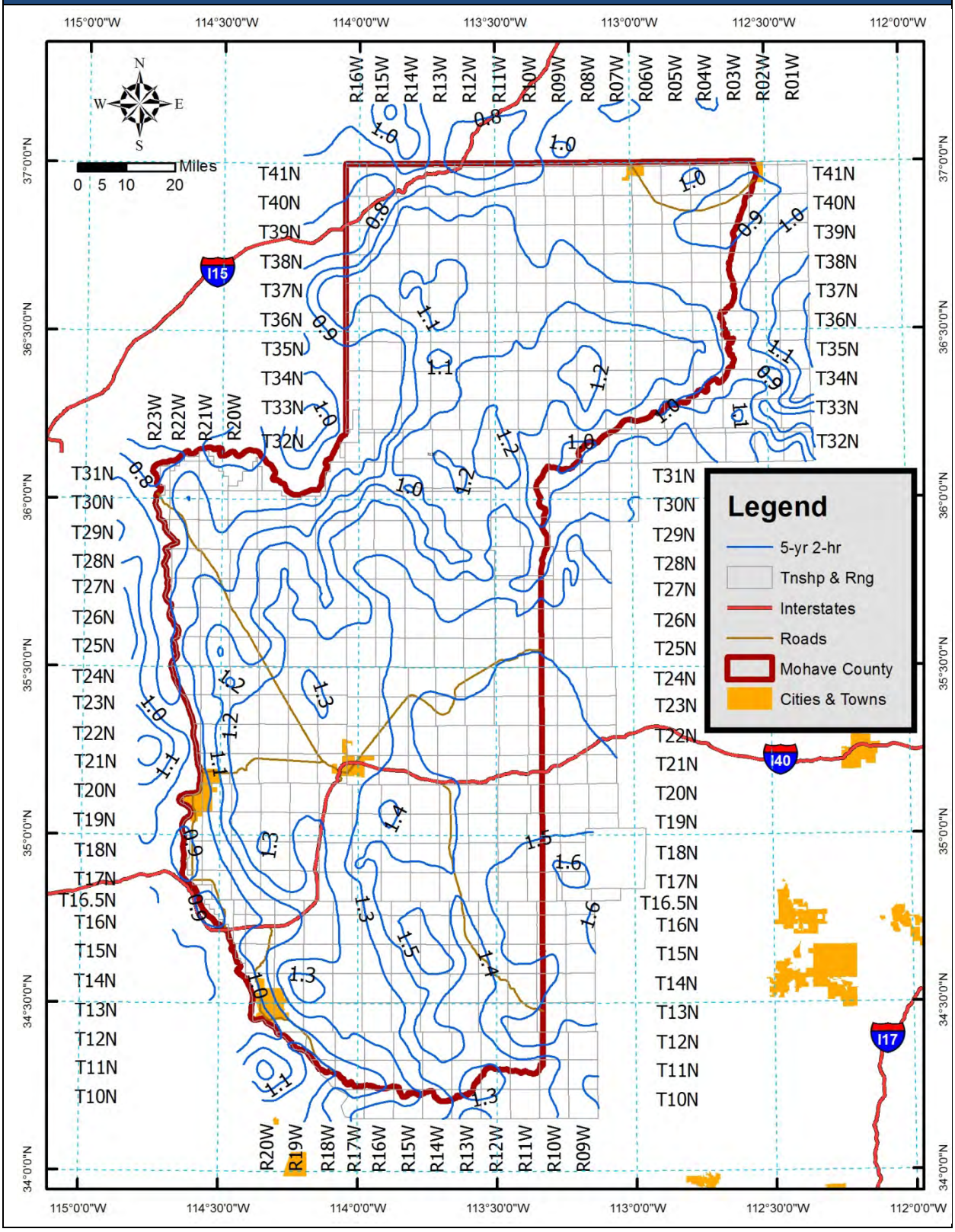


Figure B.17 NOAA Atlas 14 5-year 3-hour isopluvial map

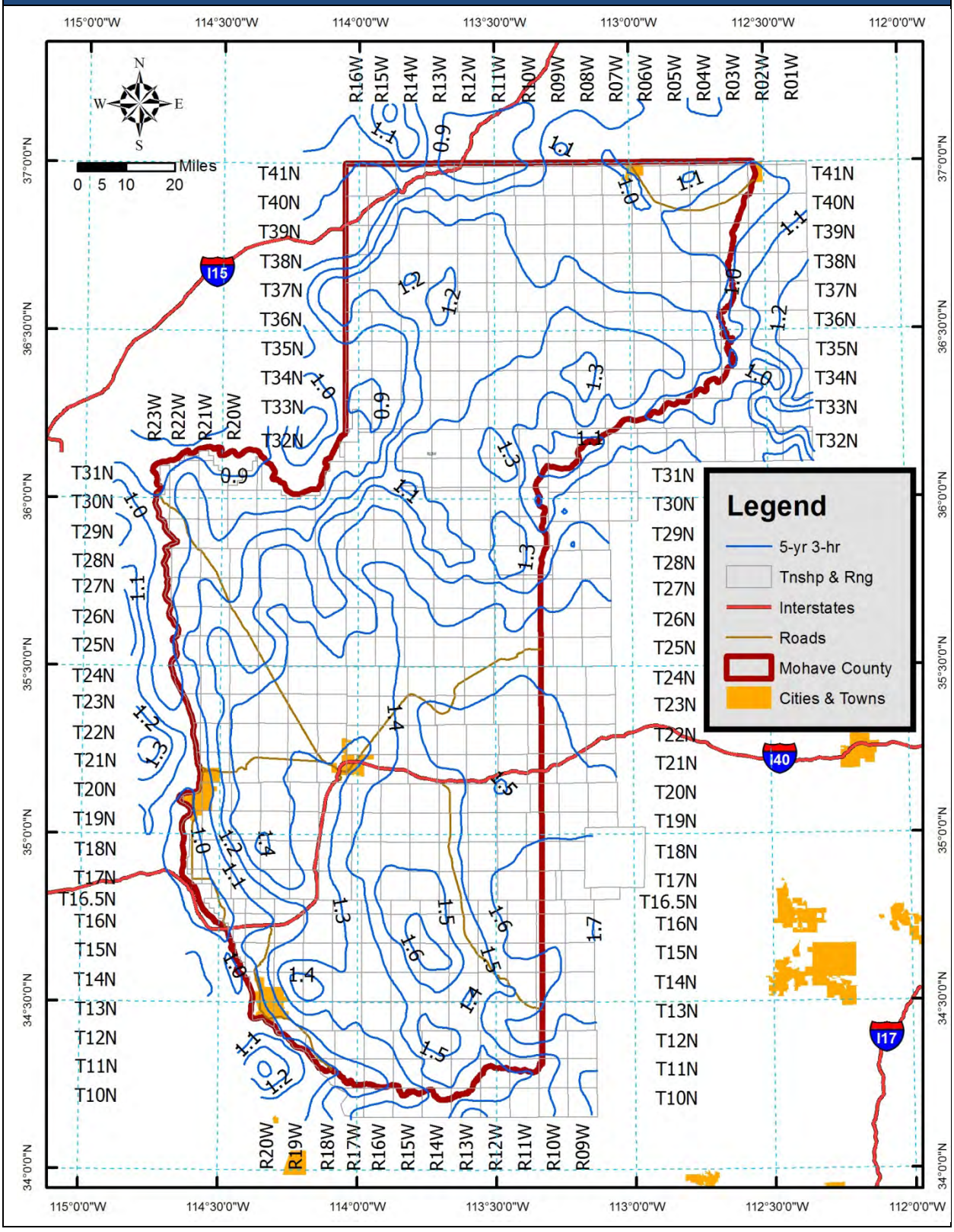


Figure B.18 NOAA Atlas 14 5-year 6-hour isopluvial map

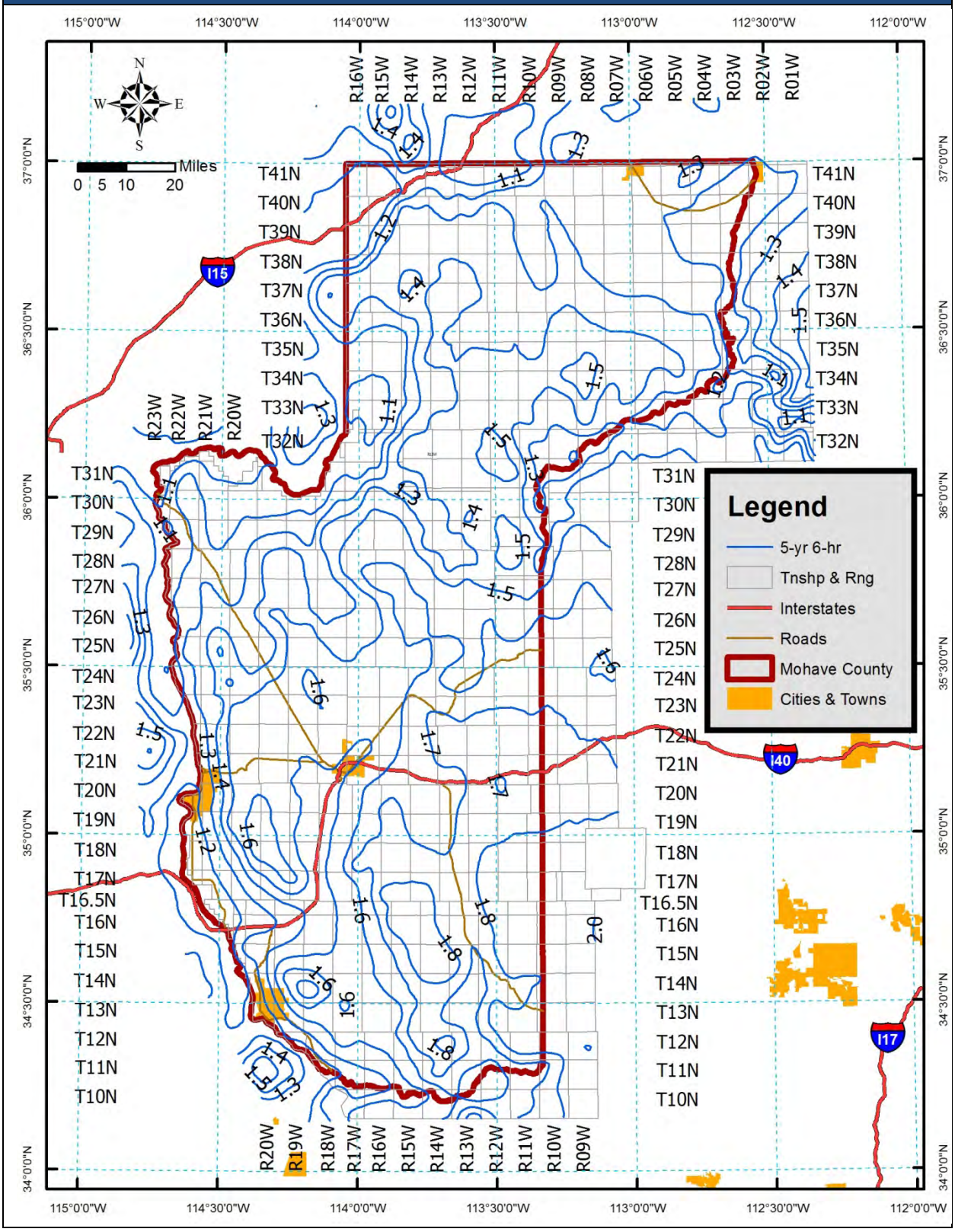


Figure B.19 NOAA Atlas 14 5-year 12-hour isopluvial map

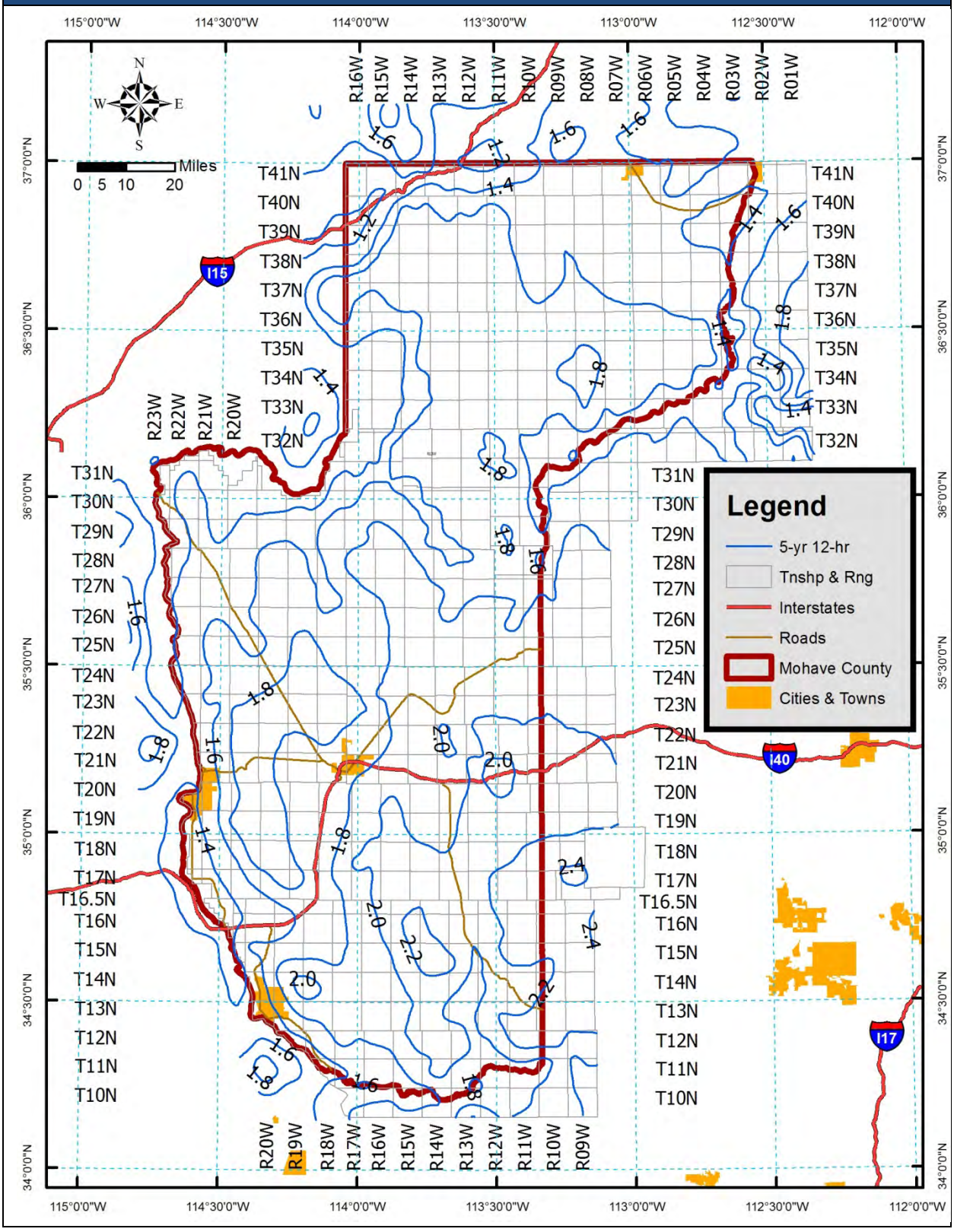
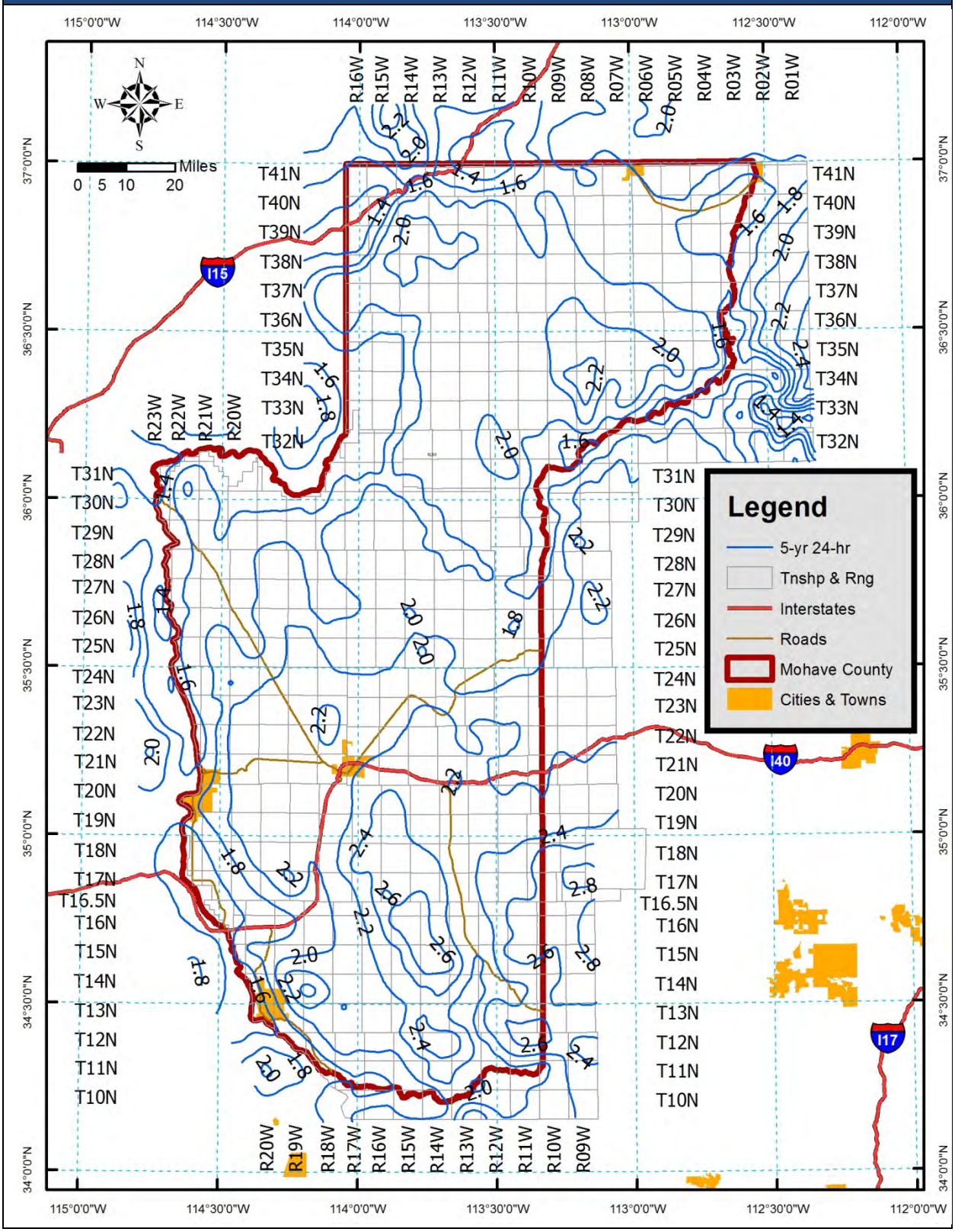


Figure B.20 NOAA Atlas 14 5-year 24-hour isopluvial map



B.3 10-YEAR STORM ISOPLUVIALS

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Figure B.21 NOAA Atlas 14 10-year 5-minute isopluvial map

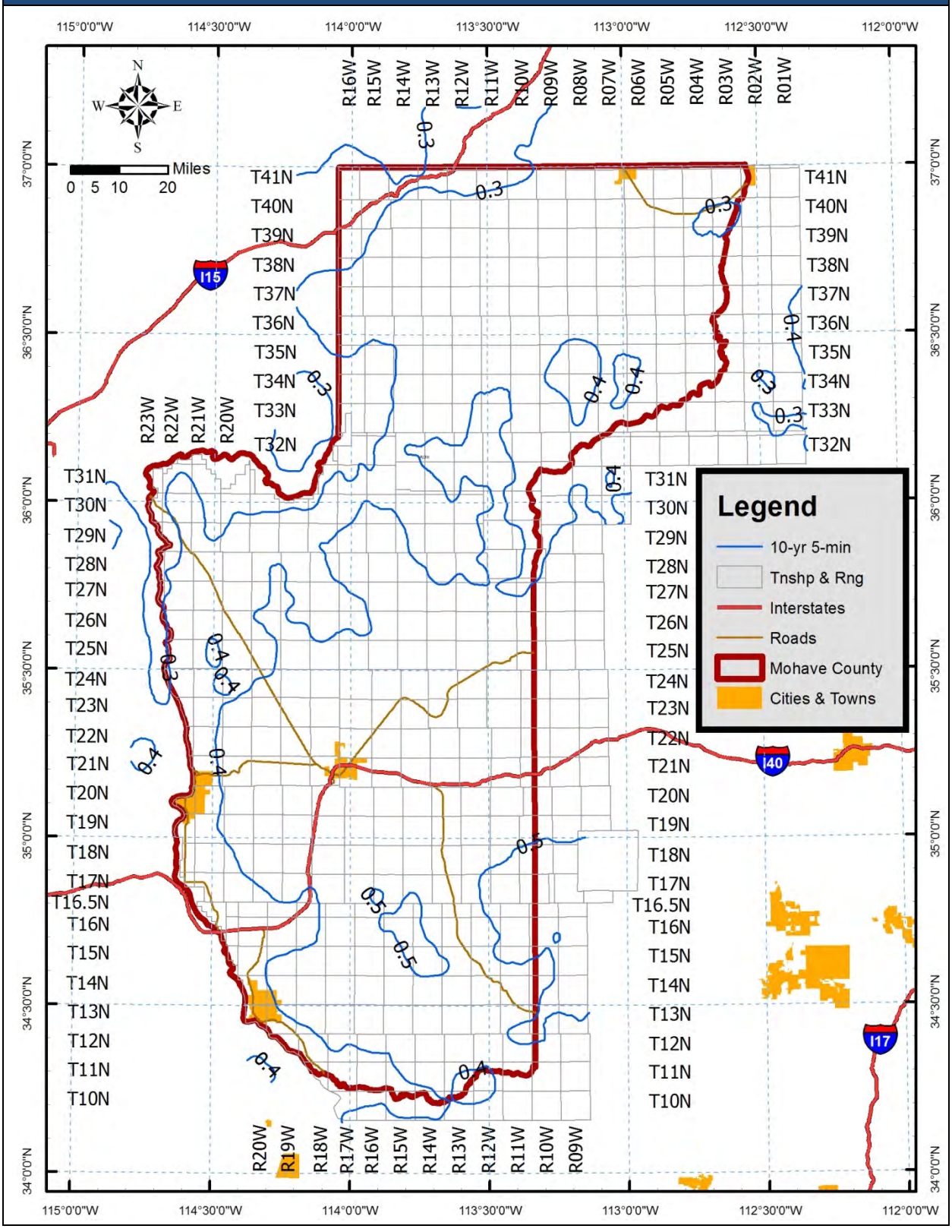


Figure B.22 NOAA Atlas 14 10-year 10-minute isopluvial map

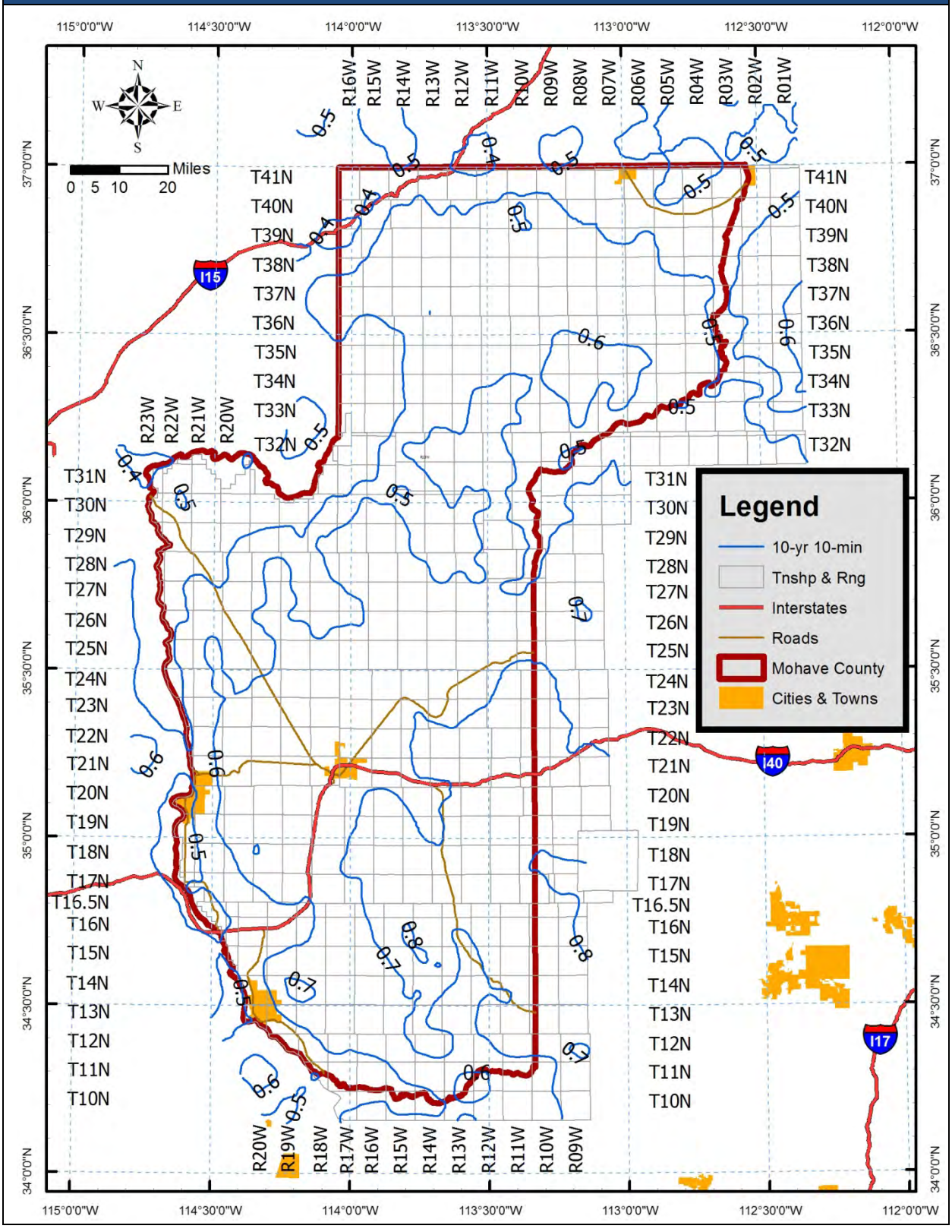


Figure B.23 NOAA Atlas 14 10-year 15-minute isopluvial map

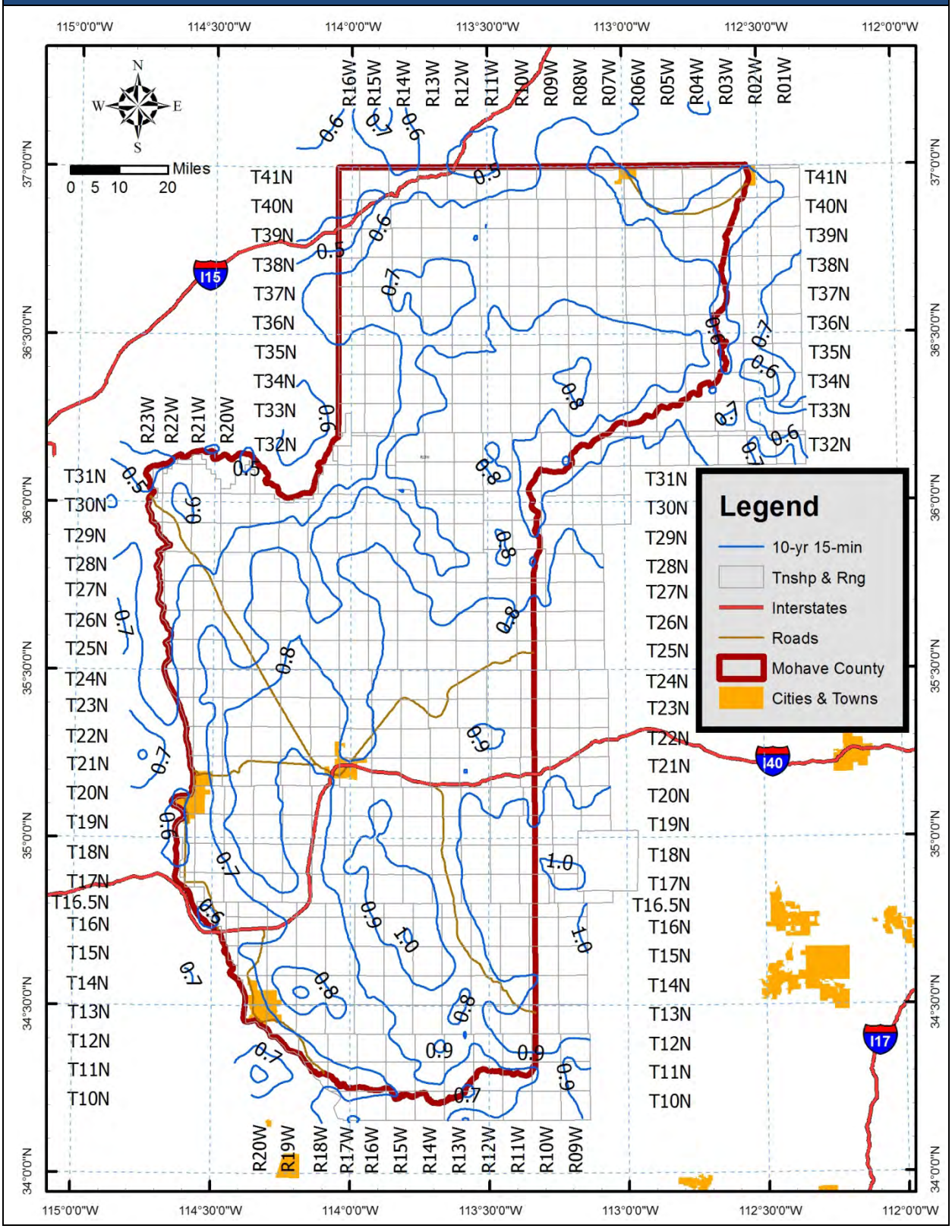


Figure B.24 NOAA Atlas 14 10-year 30-minute isopluvial map

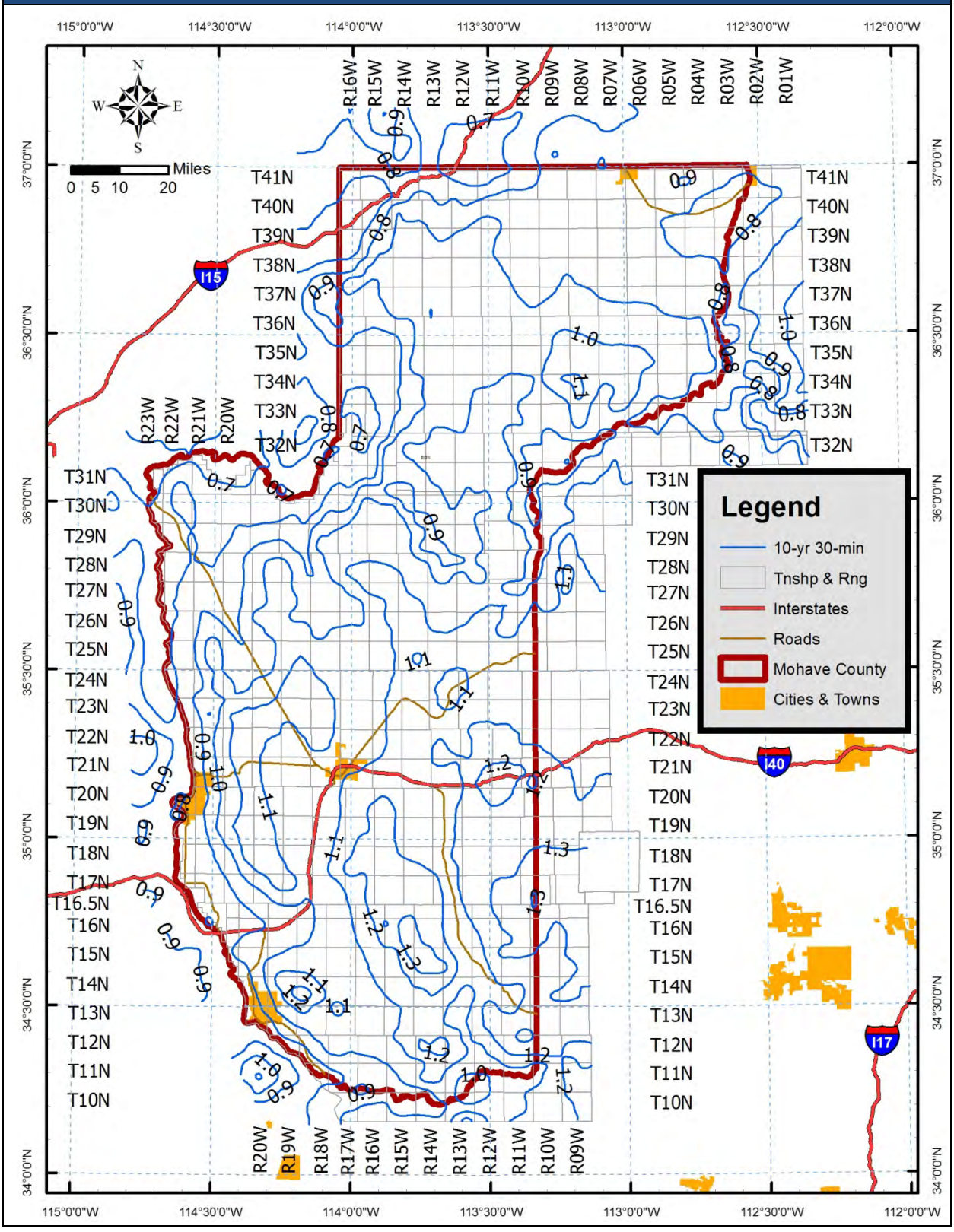


Figure B.25 NOAA Atlas 14 10-year 1-hour isopluvial map

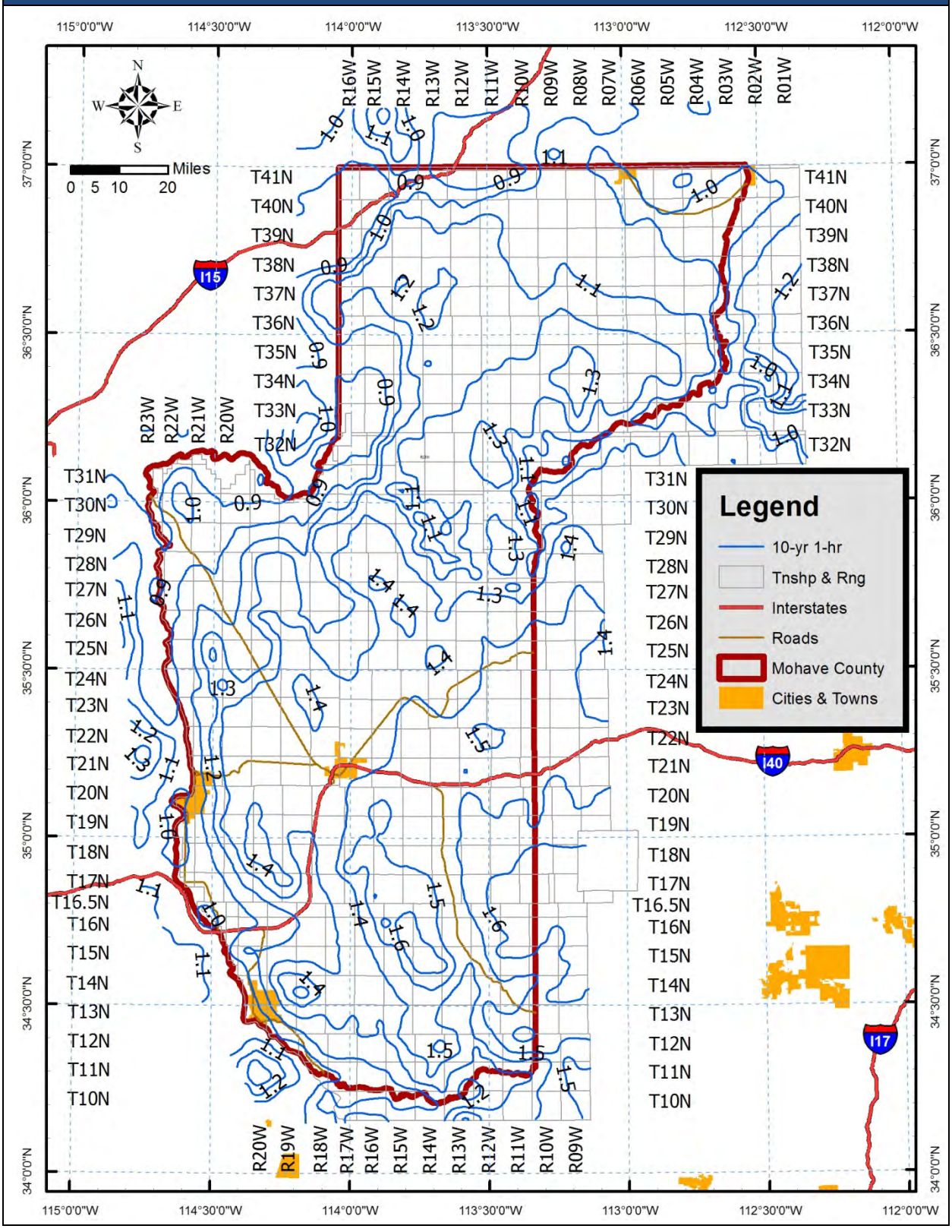


Figure B.26 NOAA Atlas 14 10-year 2-hour isopluvial map

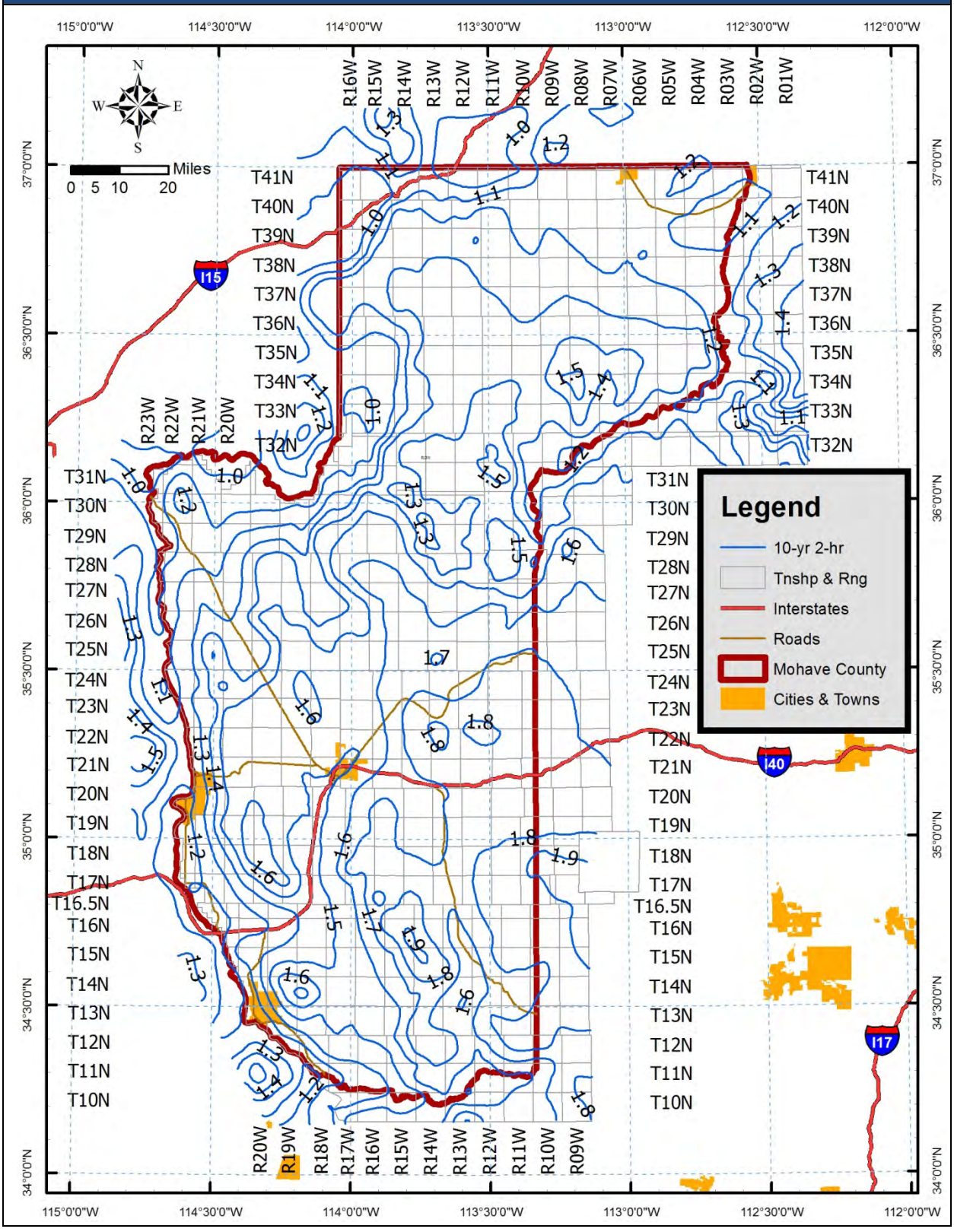


Figure B.27 NOAA Atlas 14 10-year 3-hour isopluvial map

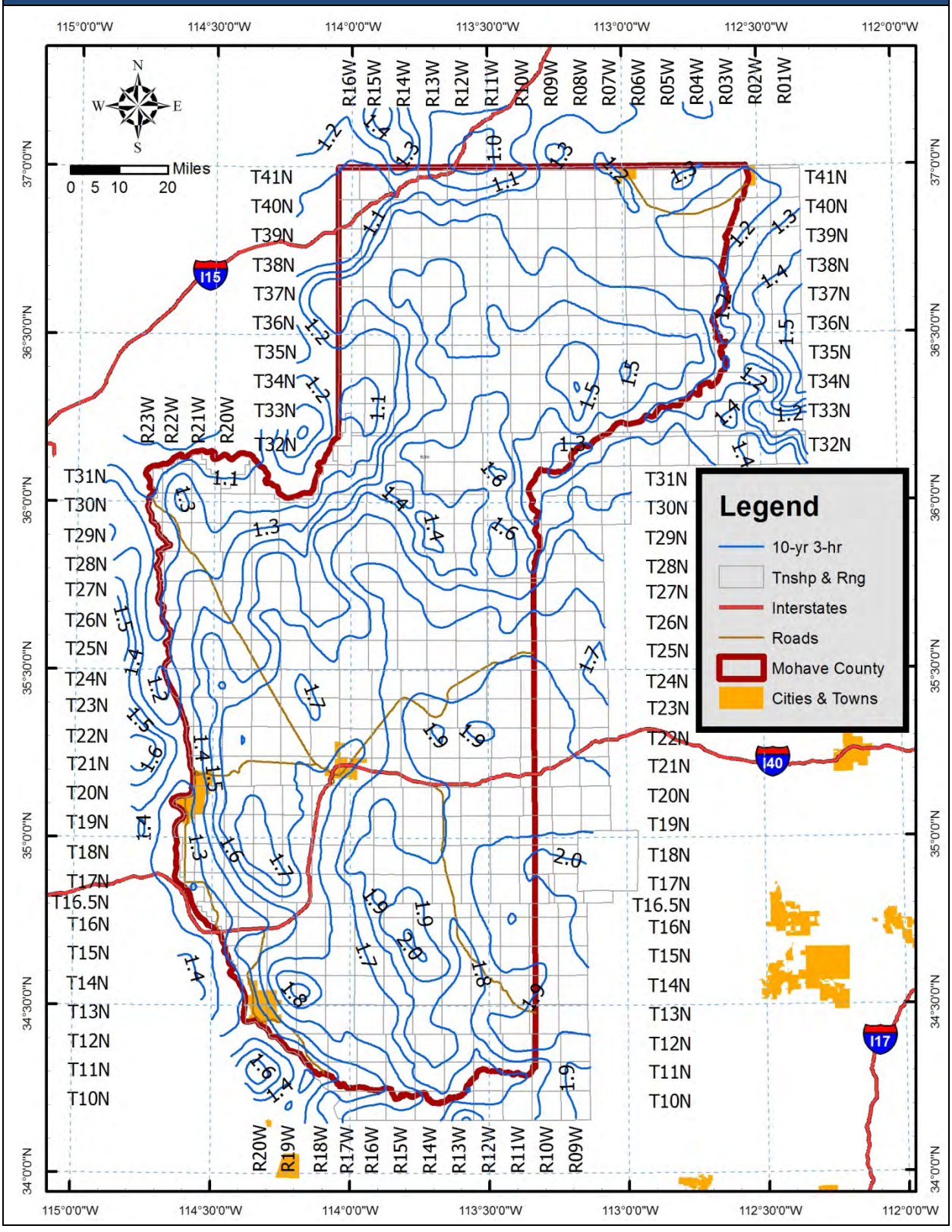


Figure B.28 NOAA Atlas 14 10-year 6-hour isopluvial map

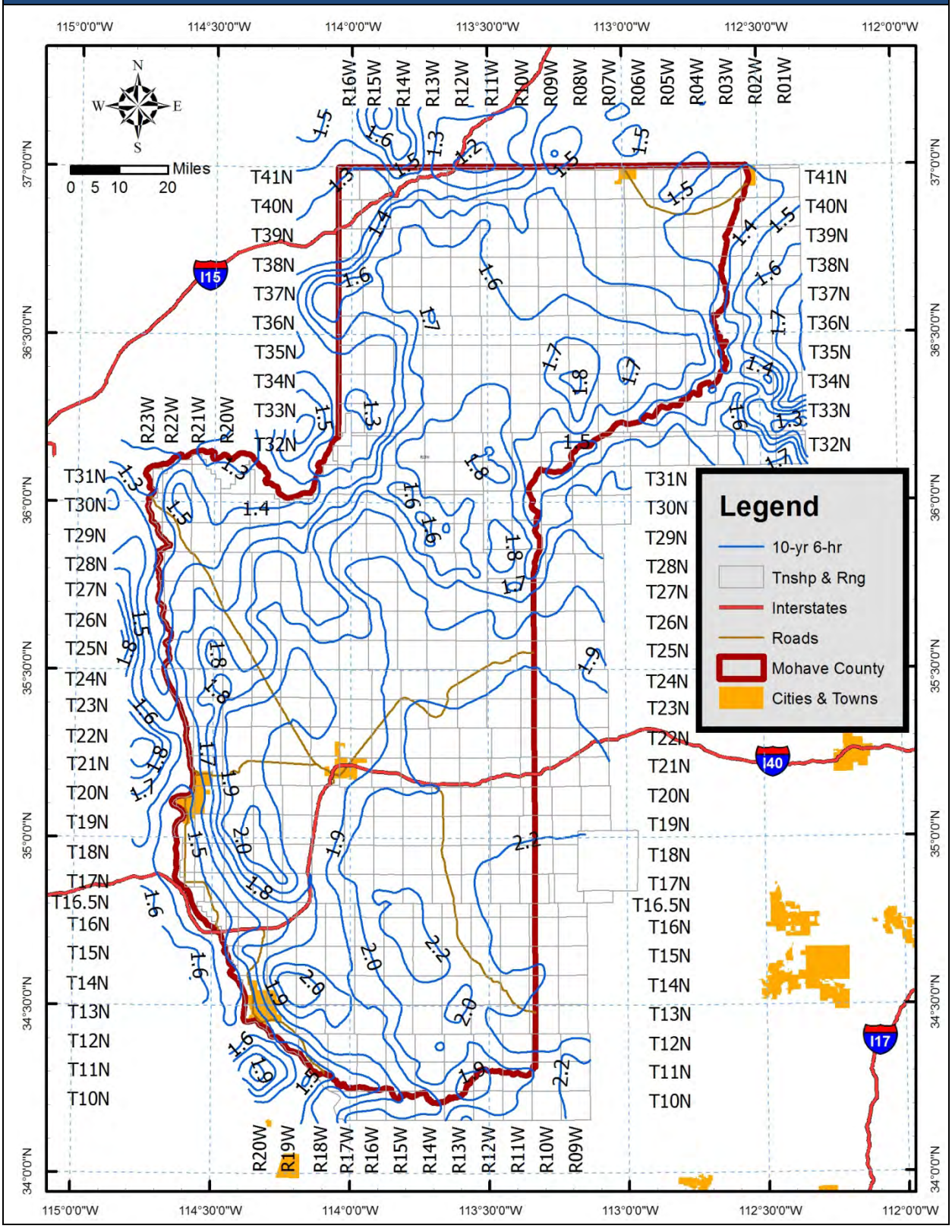


Figure B.29 NOAA Atlas 14 10-year 12-hour isopluvial map

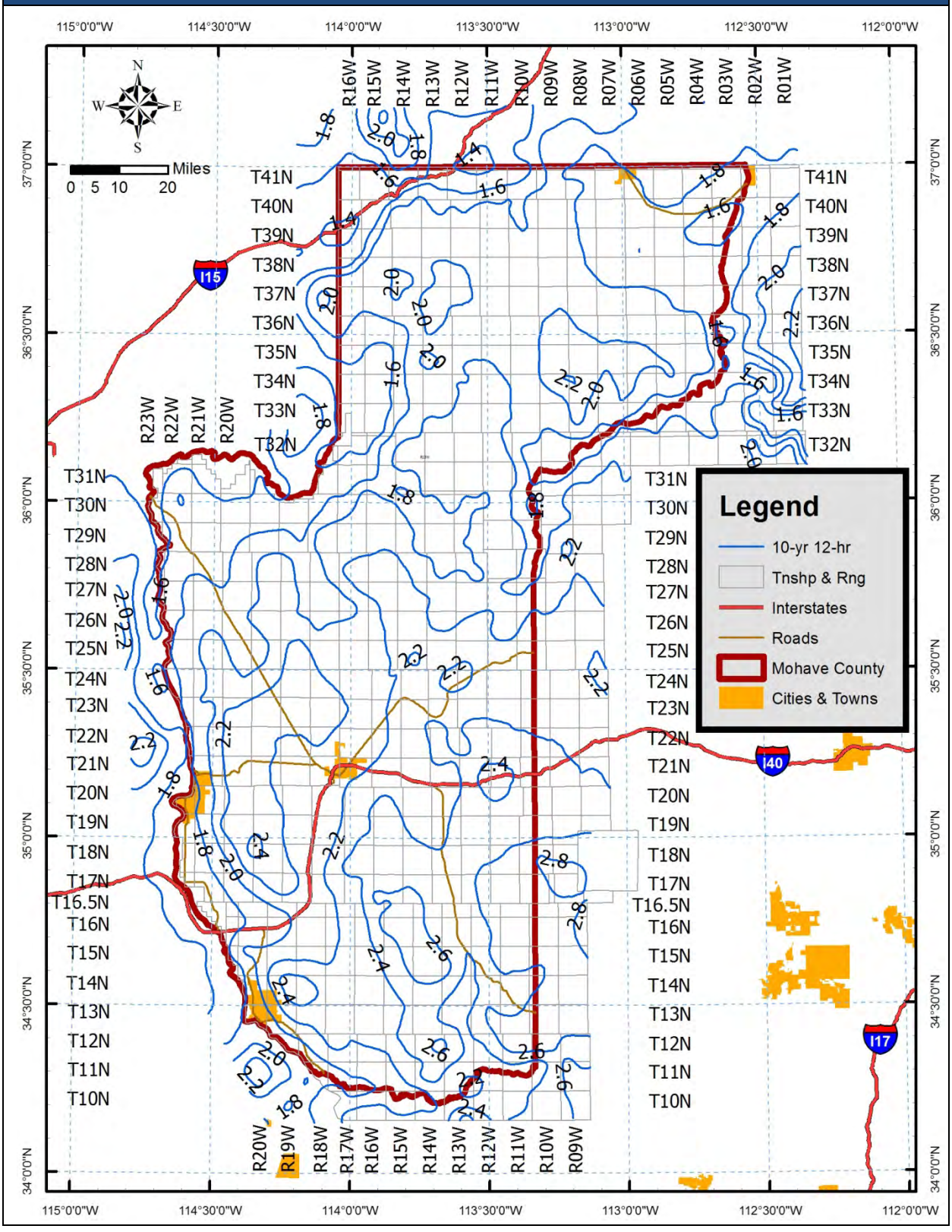
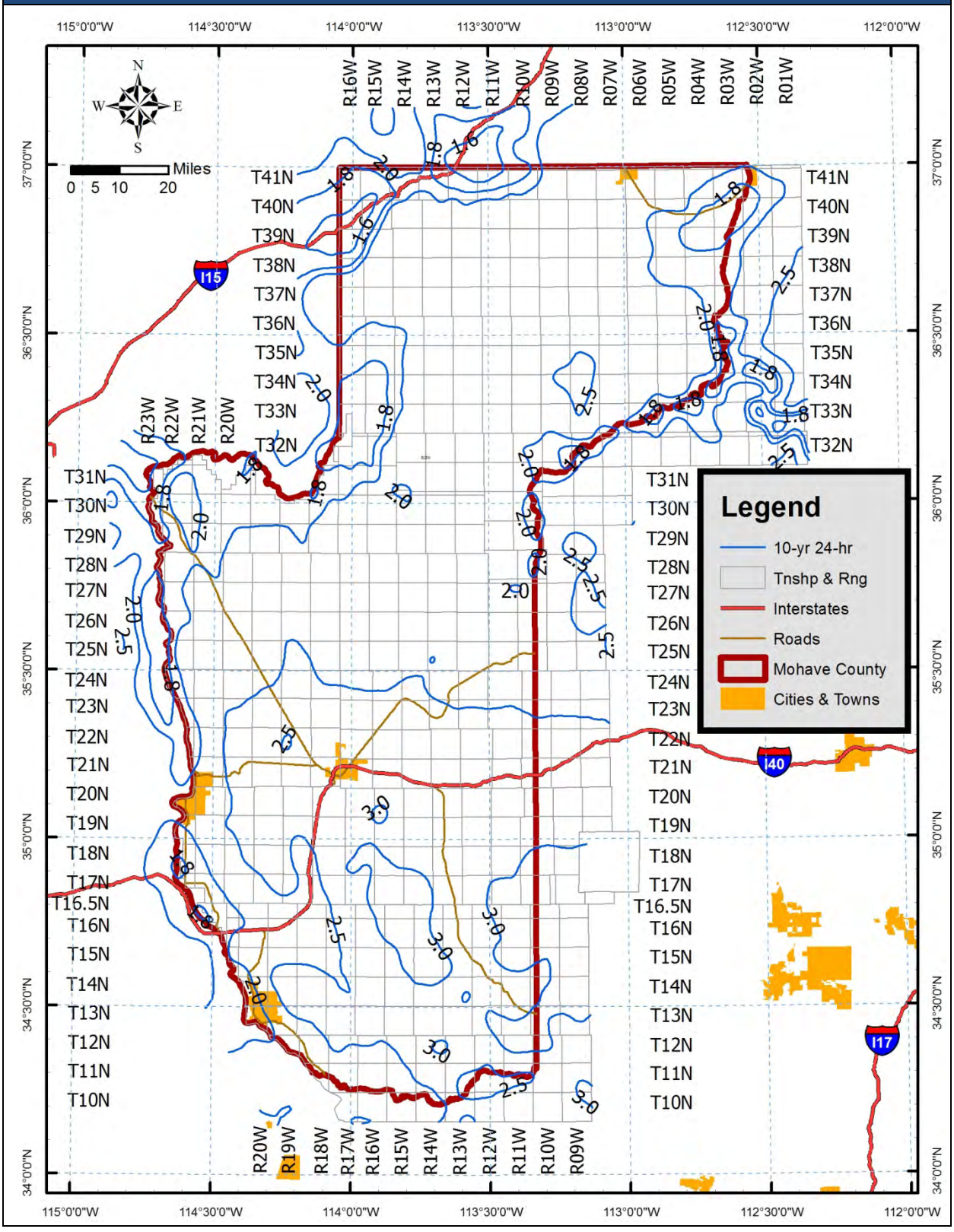


Figure B.30 NOAA Atlas 14 10-year 24-hour isopluvial map



B.4 25-YEAR STORM ISOPLUVIALS

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Figure B.31 NOAA Atlas 14 25-year 5-minute isopluvial map

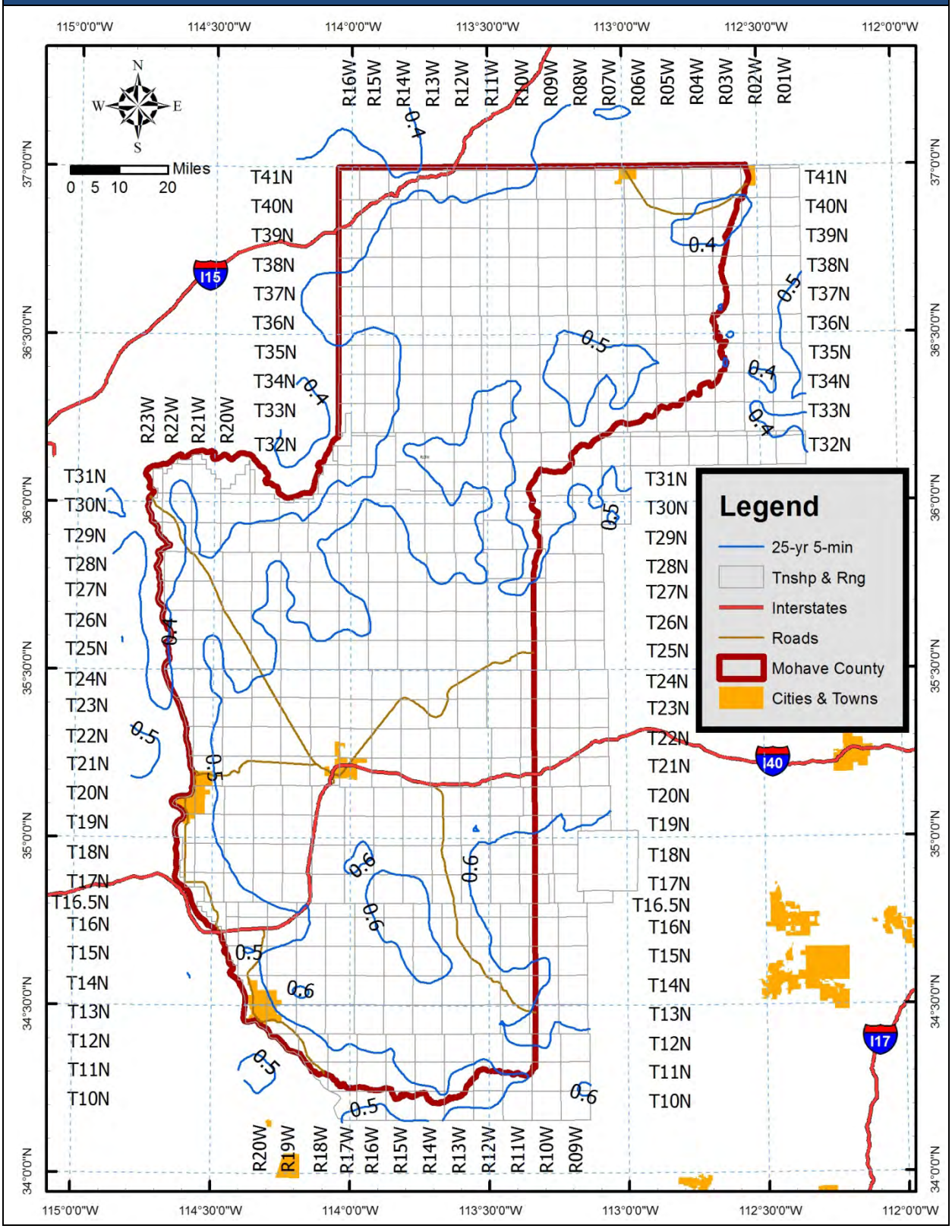


Figure B.32 NOAA Atlas 14 25-year 10-minute isopluvial map

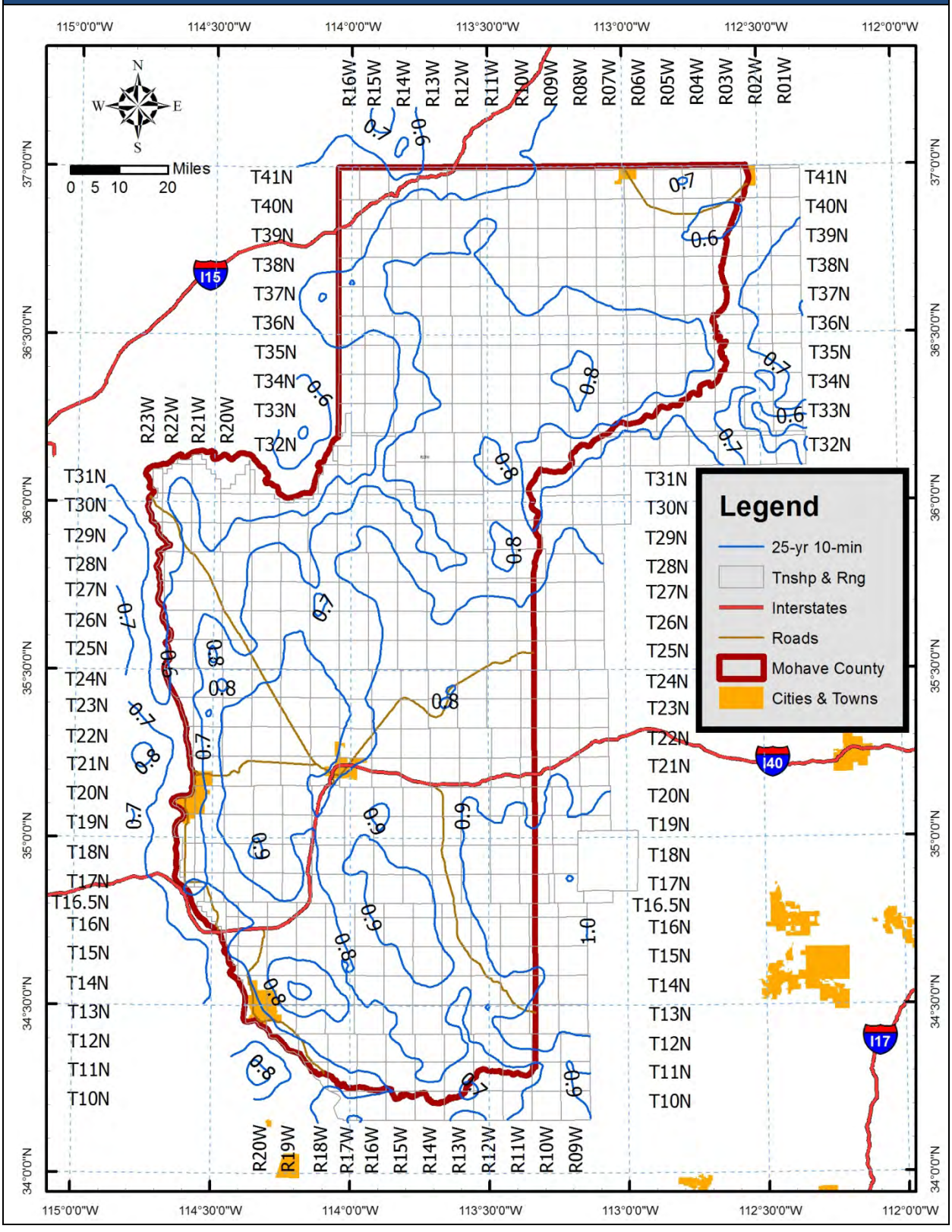


Figure B.33 NOAA Atlas 14 25-year 15-minute isopluvial map

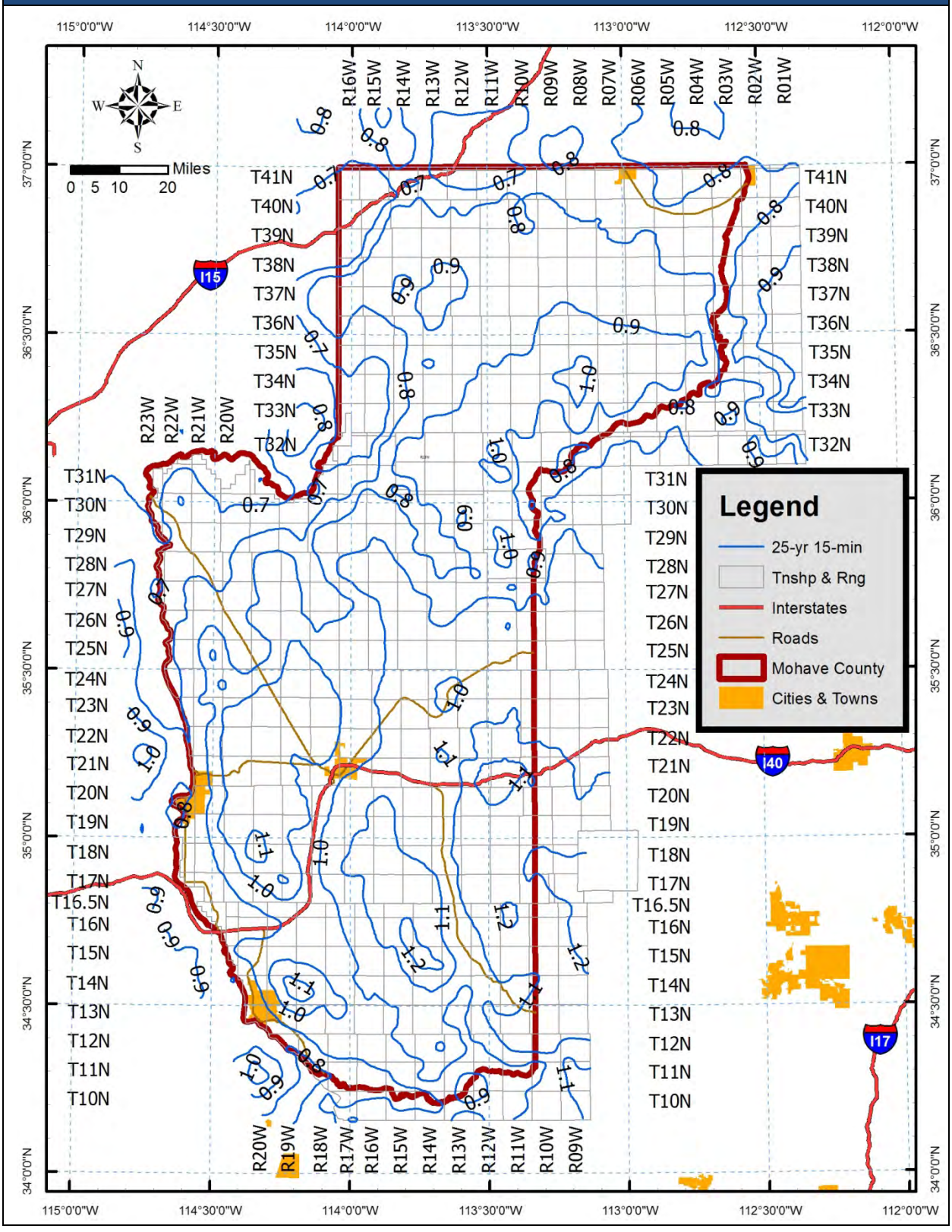


Figure B.34 NOAA Atlas 14 25-year 30-minute isopluvial map

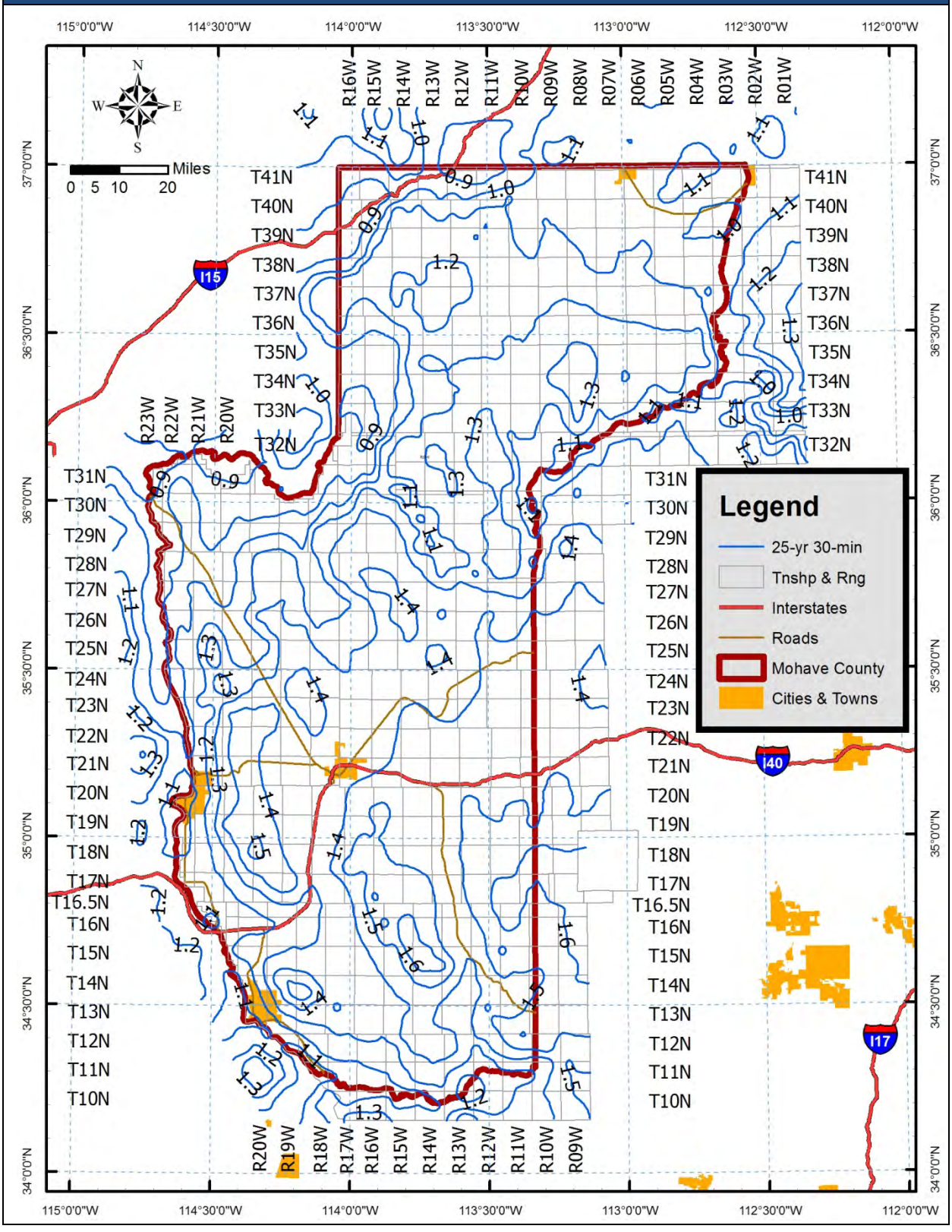


Figure B.35 NOAA Atlas 14 25-year 1-hour isopluvial map

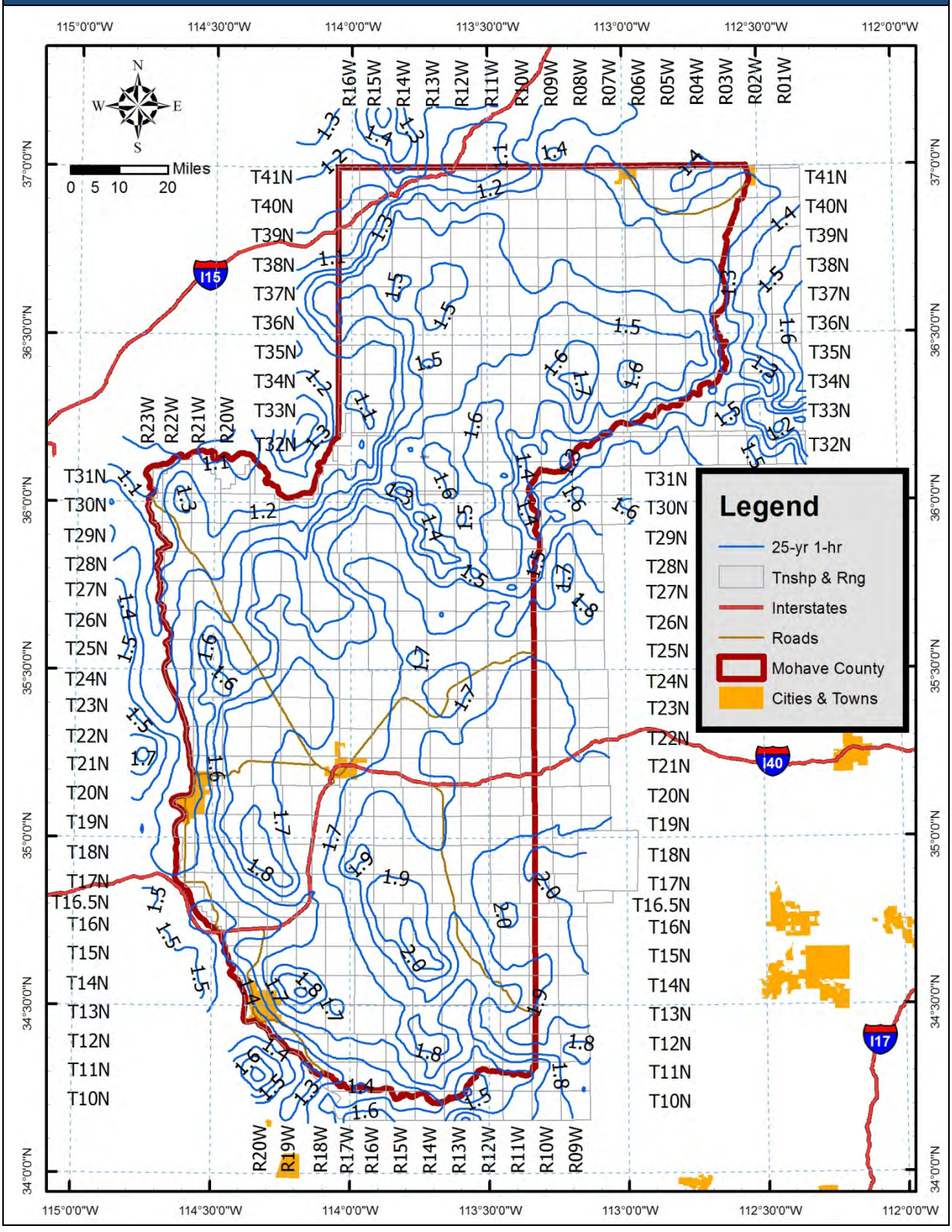


Figure B.36 NOAA Atlas 14 25-year 2-hour isopluvial map

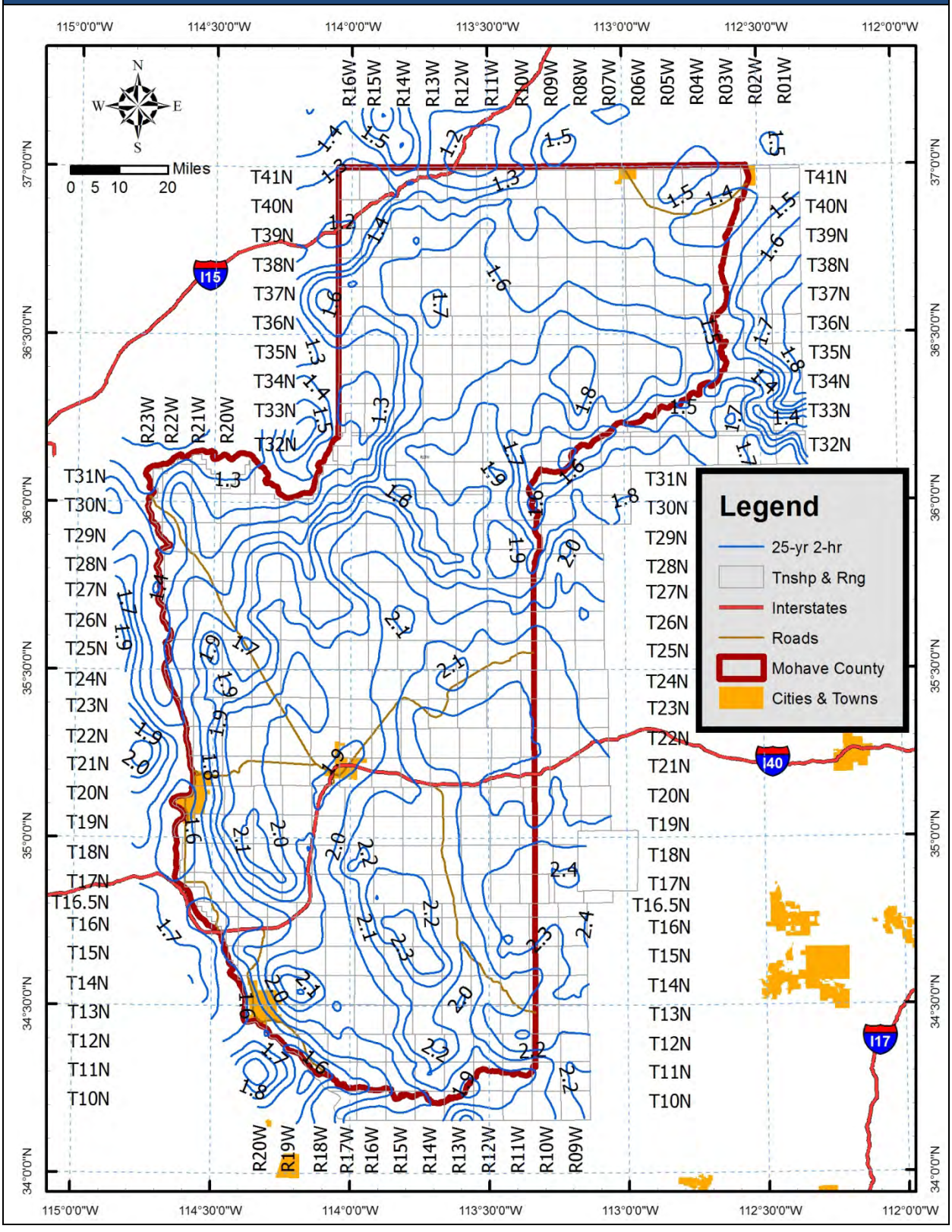


Figure B.37 NOAA Atlas 14 25-year 3-hour isopluvial map

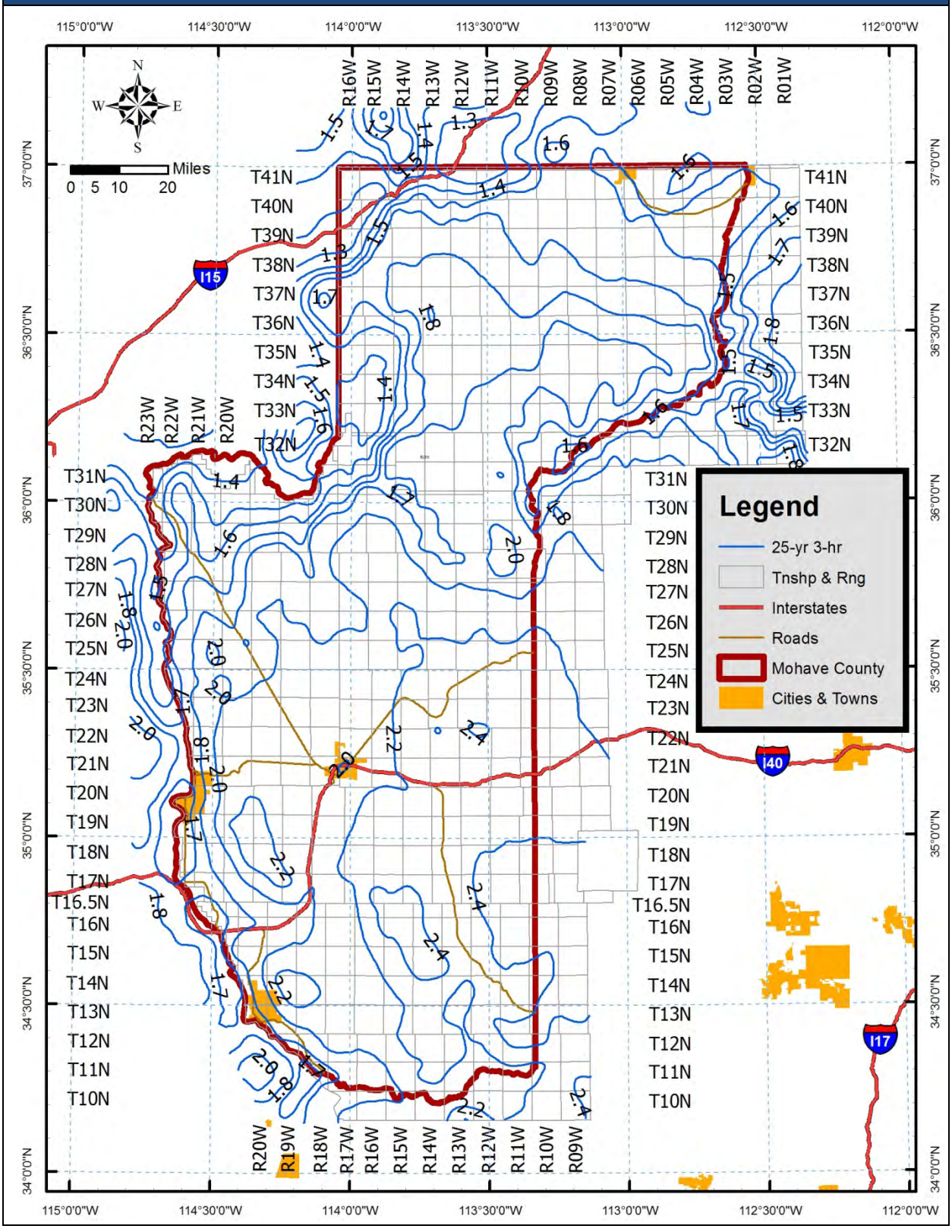


Figure B.38 NOAA Atlas 14 25-year 6-hour isopluvial map

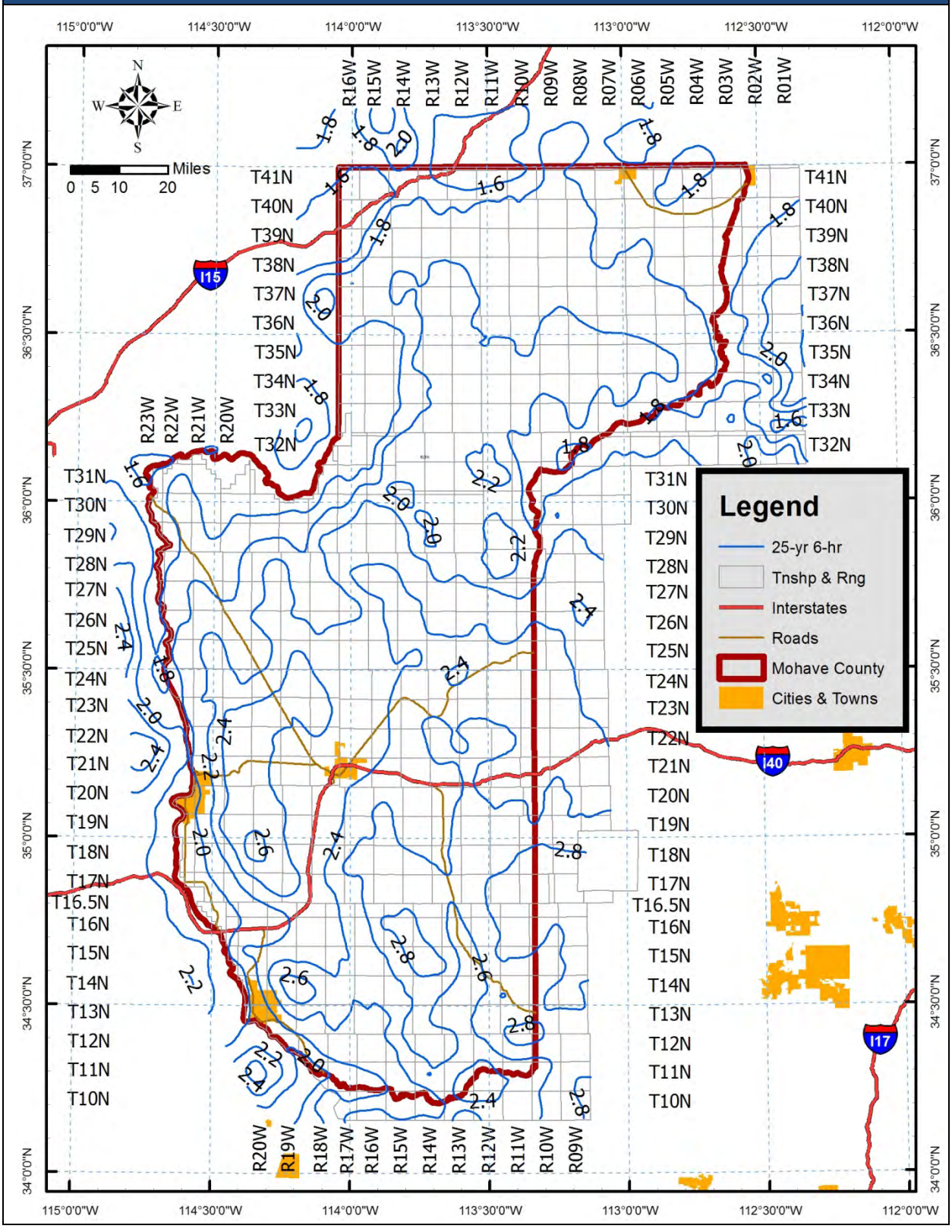


Figure B.39 NOAA Atlas 14 25-year 12-hour isopluvial map

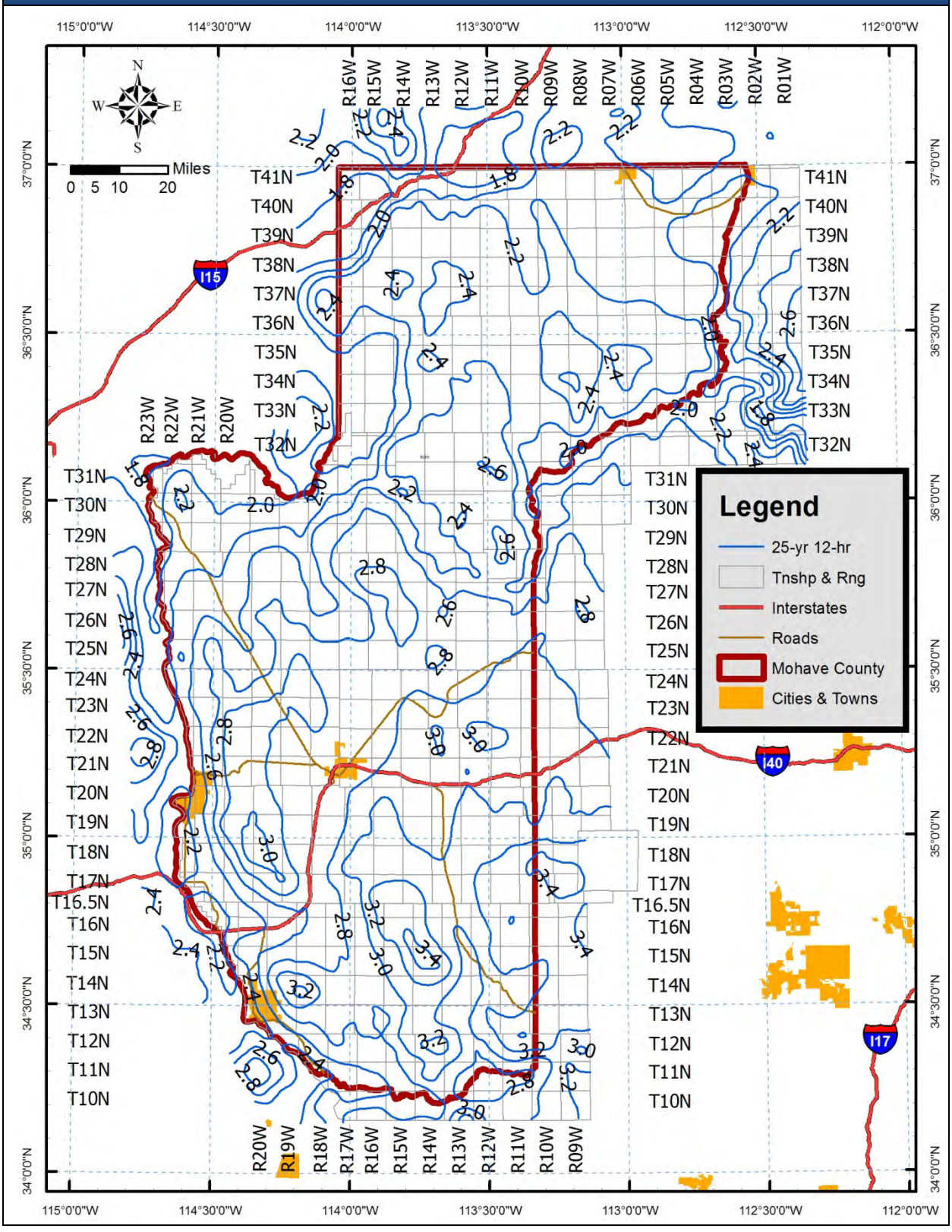
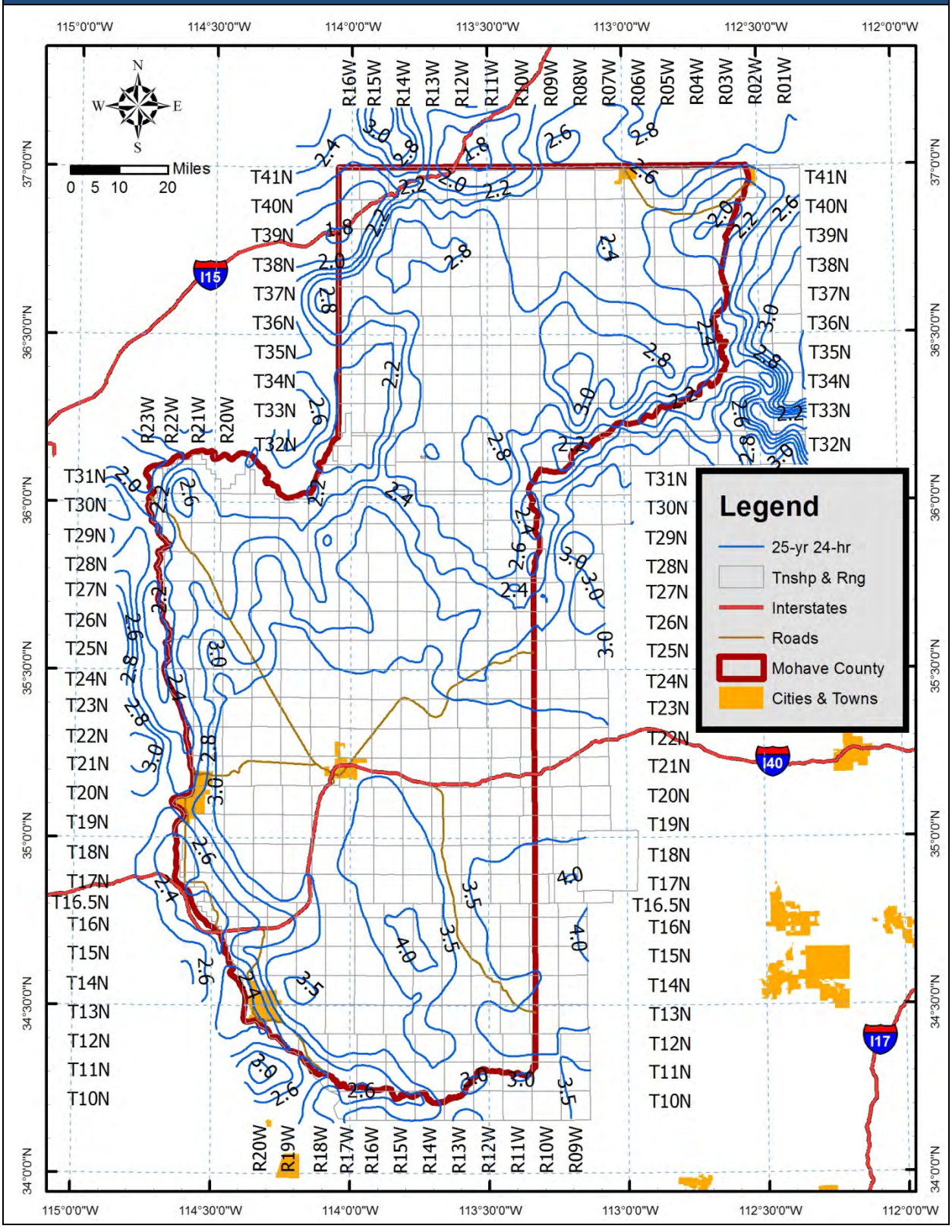


Figure B.40 NOAA Atlas 14 25-year 24-hour isopluvial map



B.5 50-YEAR STORM ISOPLUVIALS

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Figure B.41 NOAA Atlas 14 50-year 5-minute isopluvial map

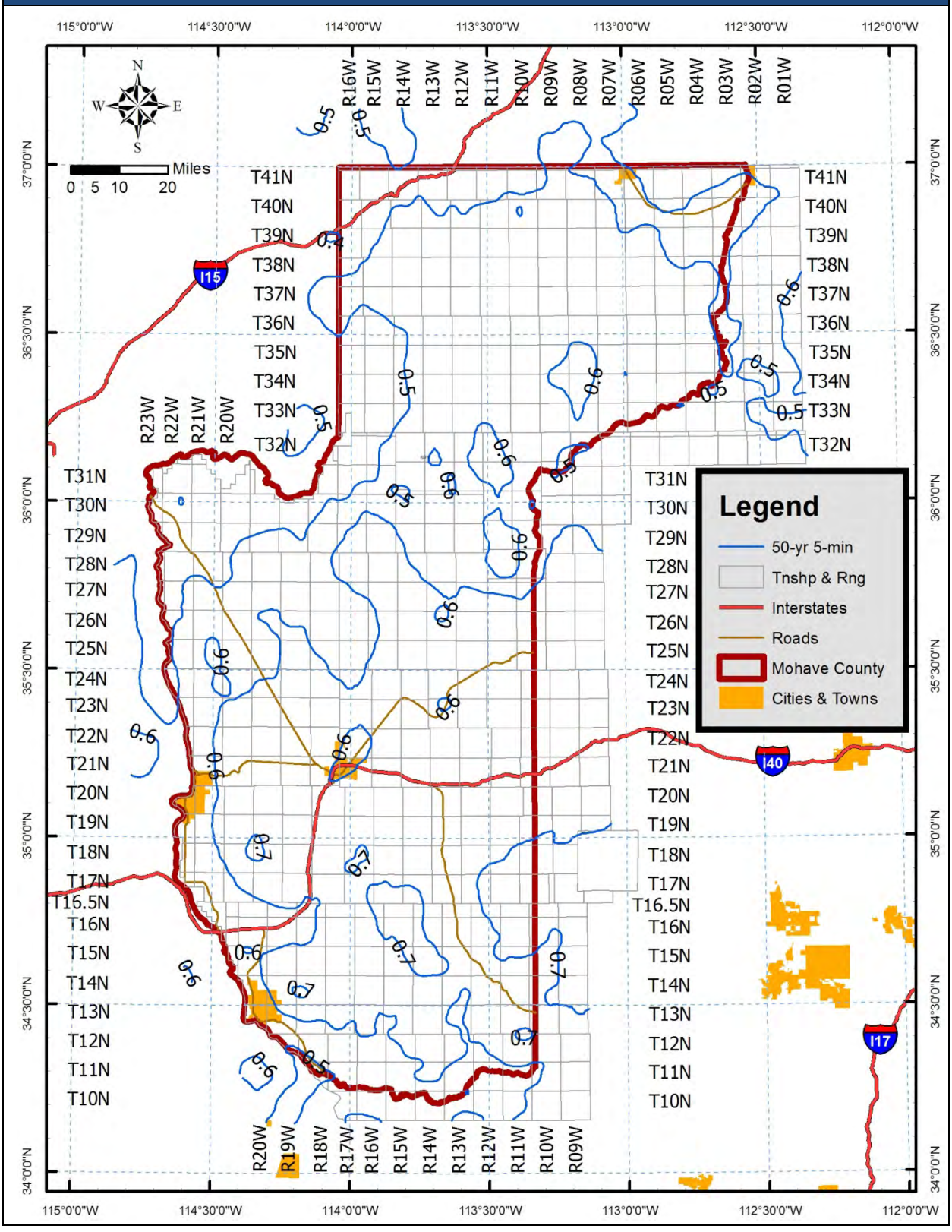


Figure B.42 NOAA Atlas 14 50-year 10-minute isopluvial map

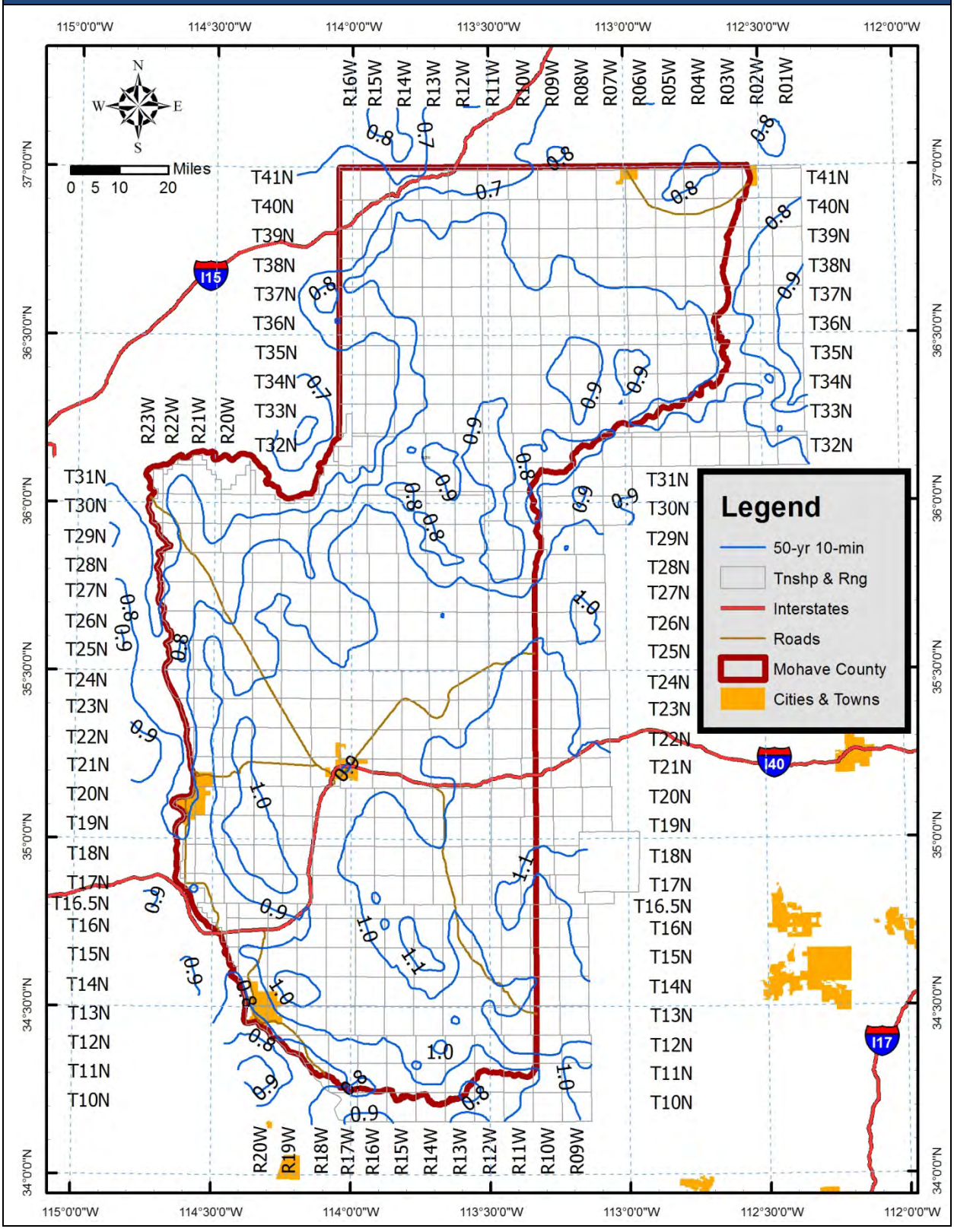


Figure B.43 NOAA Atlas 14 50-year 15-minute isopluvial map

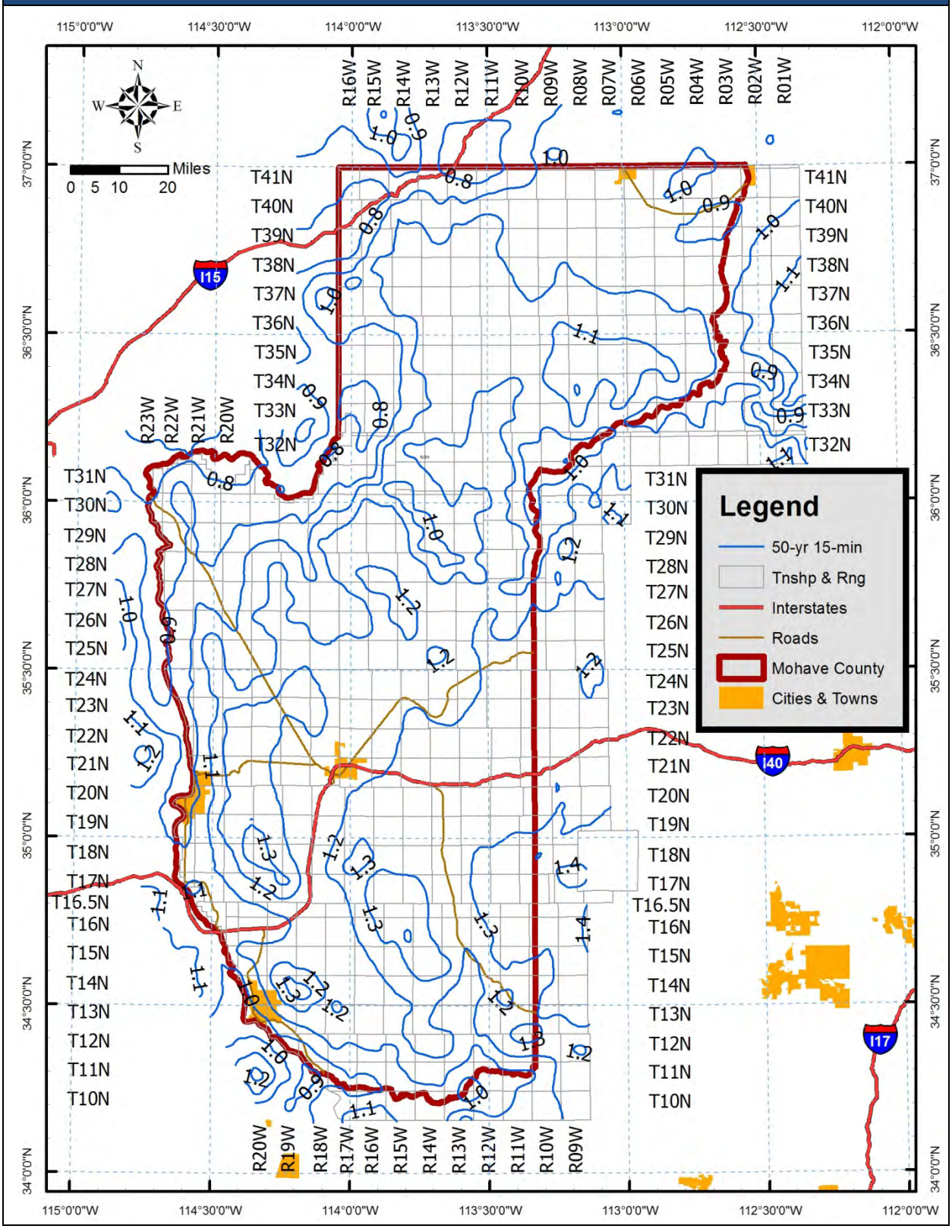


Figure B.44 NOAA Atlas 14 50-year 30-minute isopluvial map

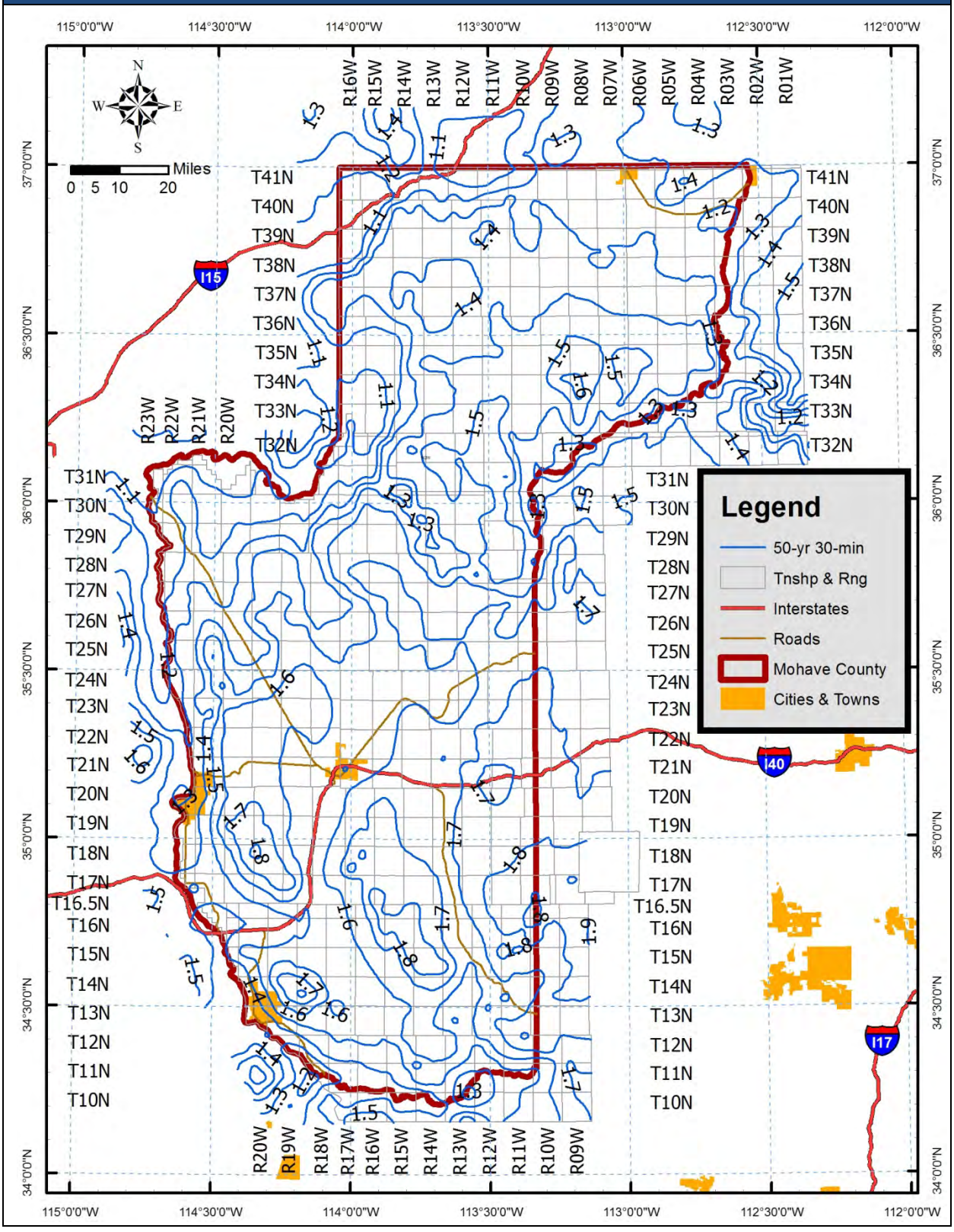


Figure B.45 NOAA Atlas 14 50-year 1-hour isopluvial map

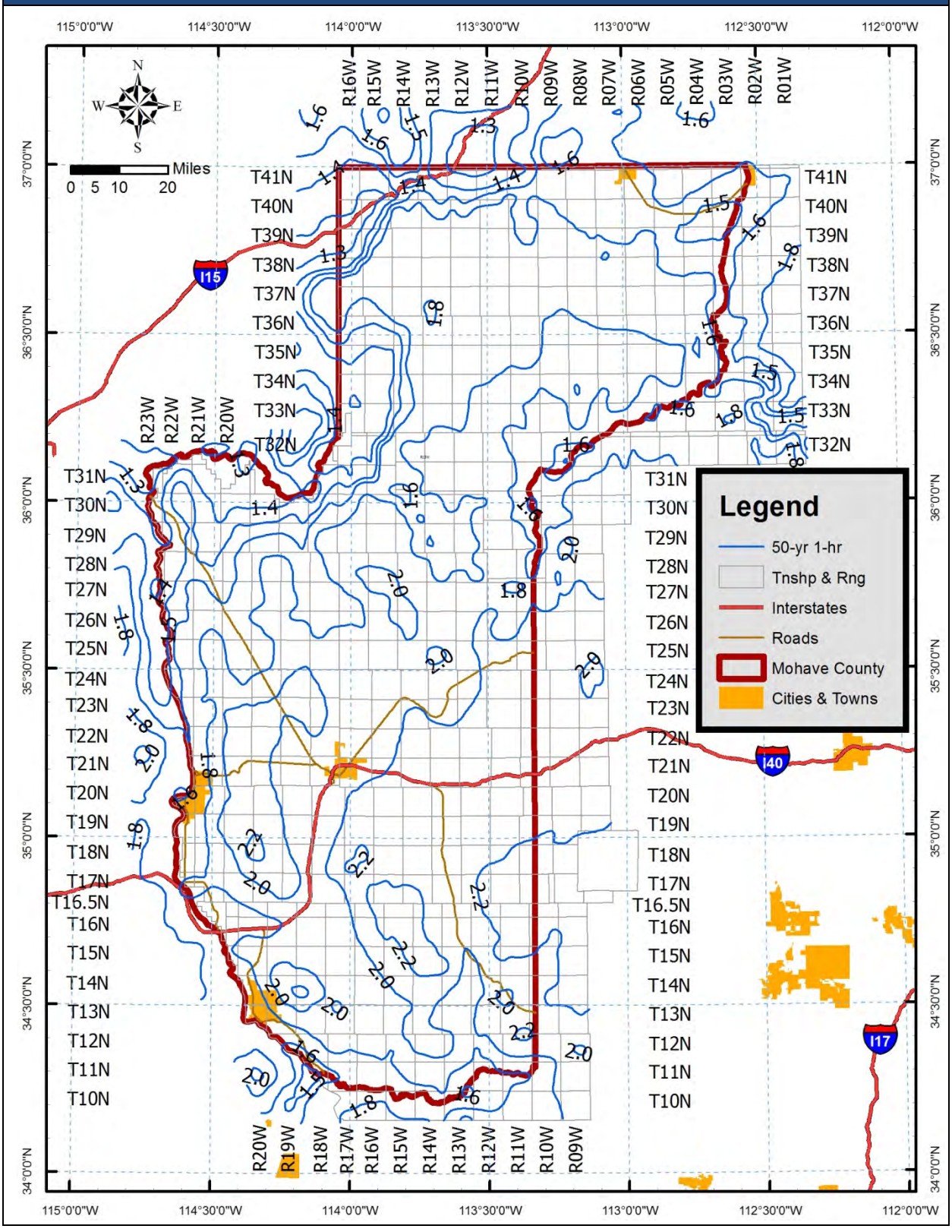


Figure B.46 NOAA Atlas 14 50-year 2-hour isopluvial map

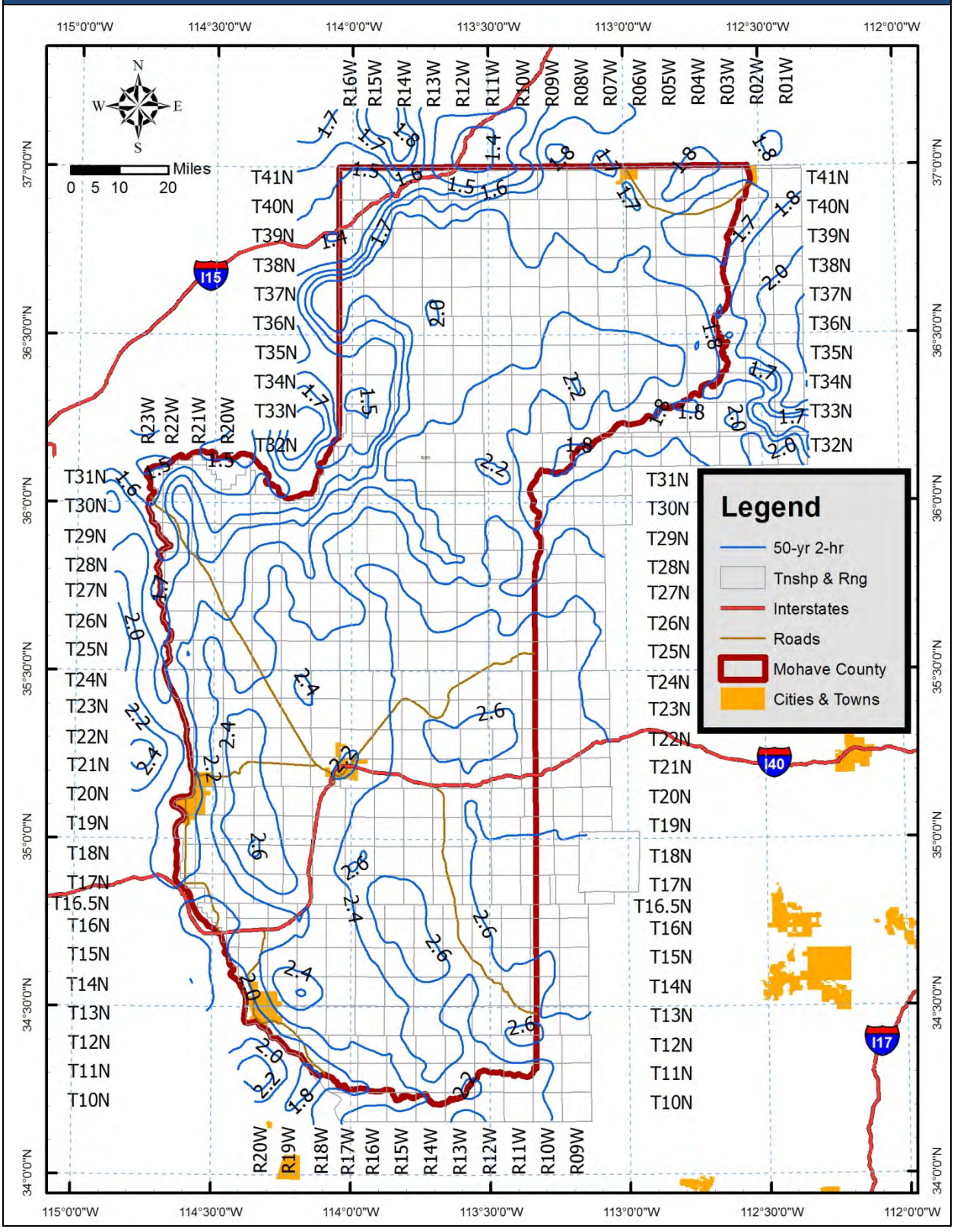


Figure B.47 NOAA Atlas 14 50-year 3-hour isopluvial map

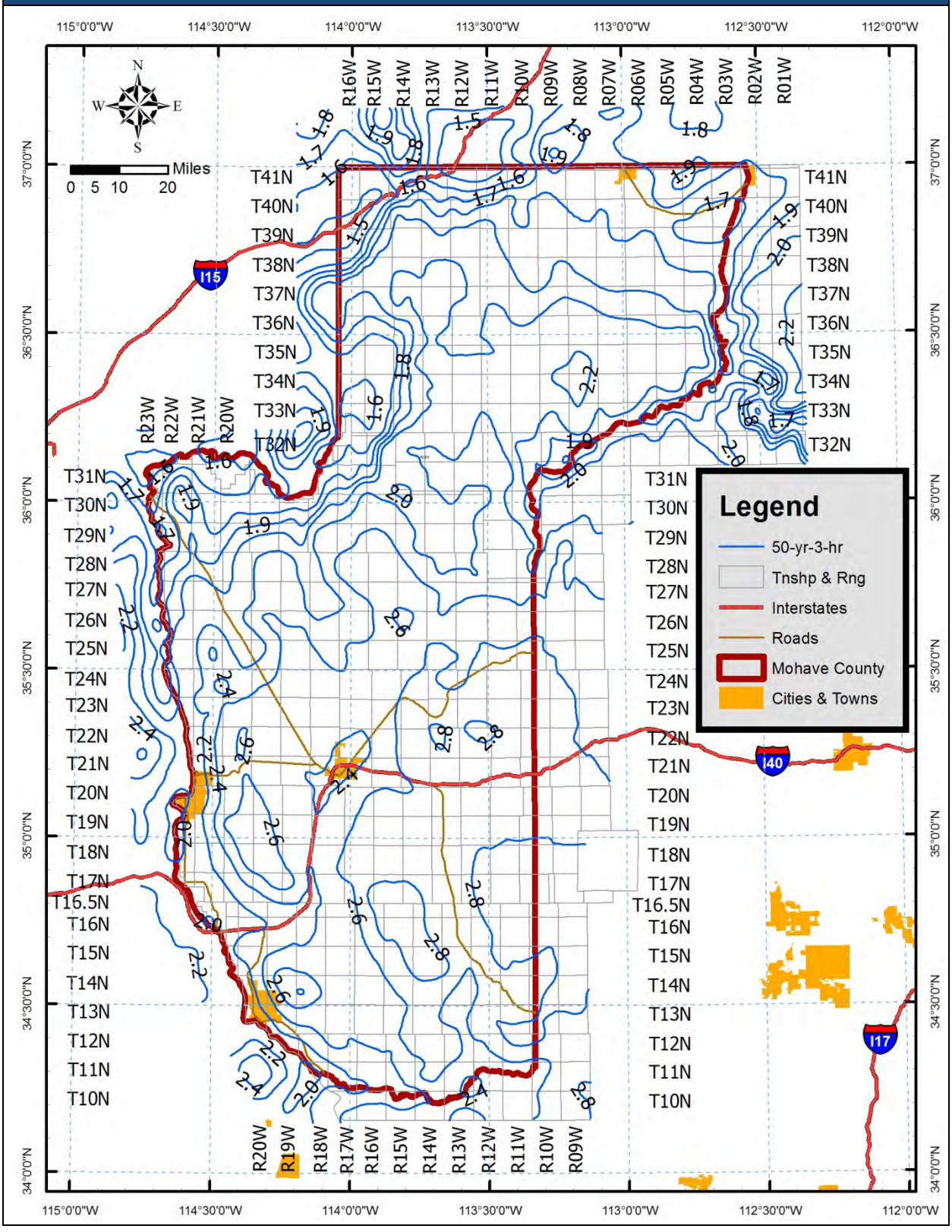


Figure B.48 NOAA Atlas 14 50-year 6-hour isopluvial map

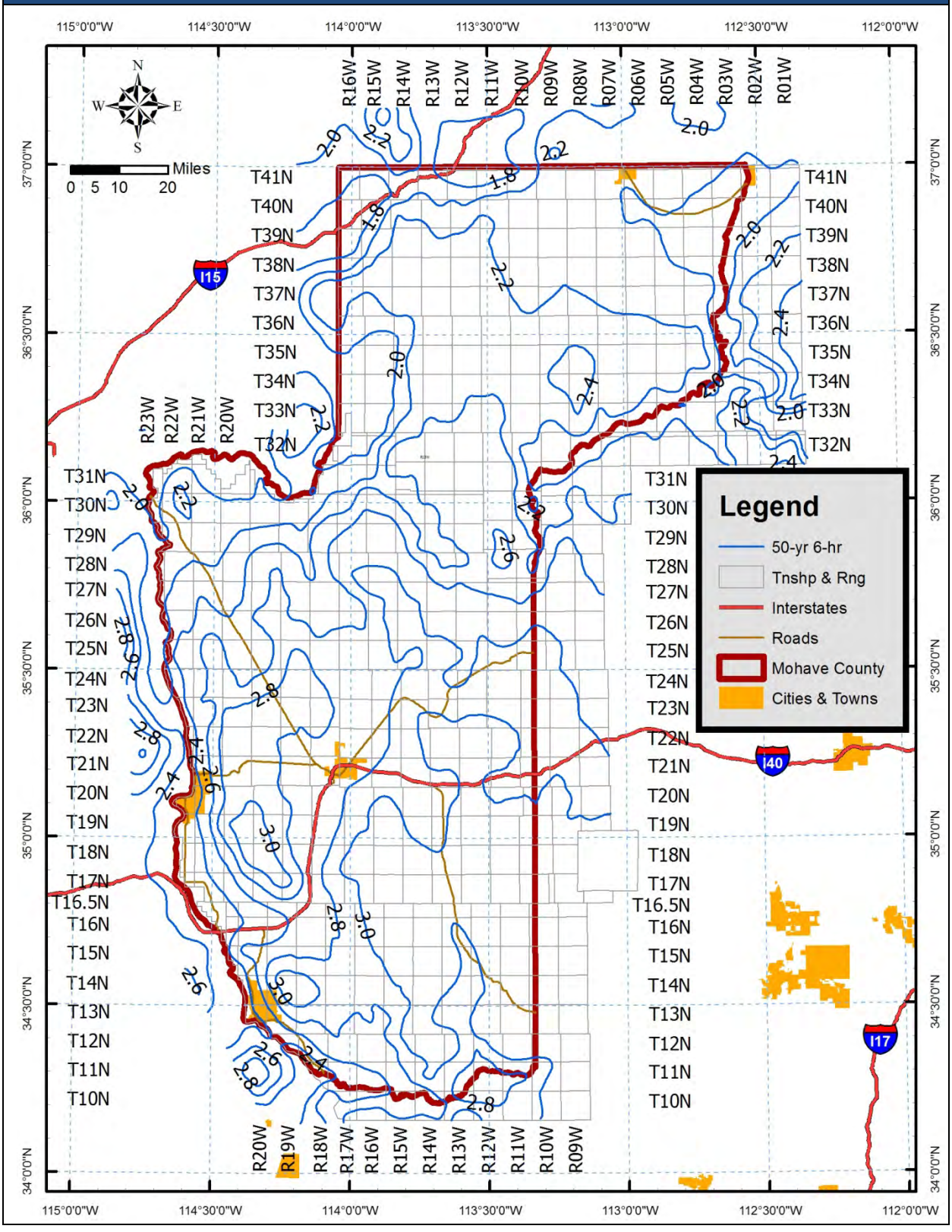


Figure B.49 NOAA Atlas 14 50-year 12-hour isopluvial map

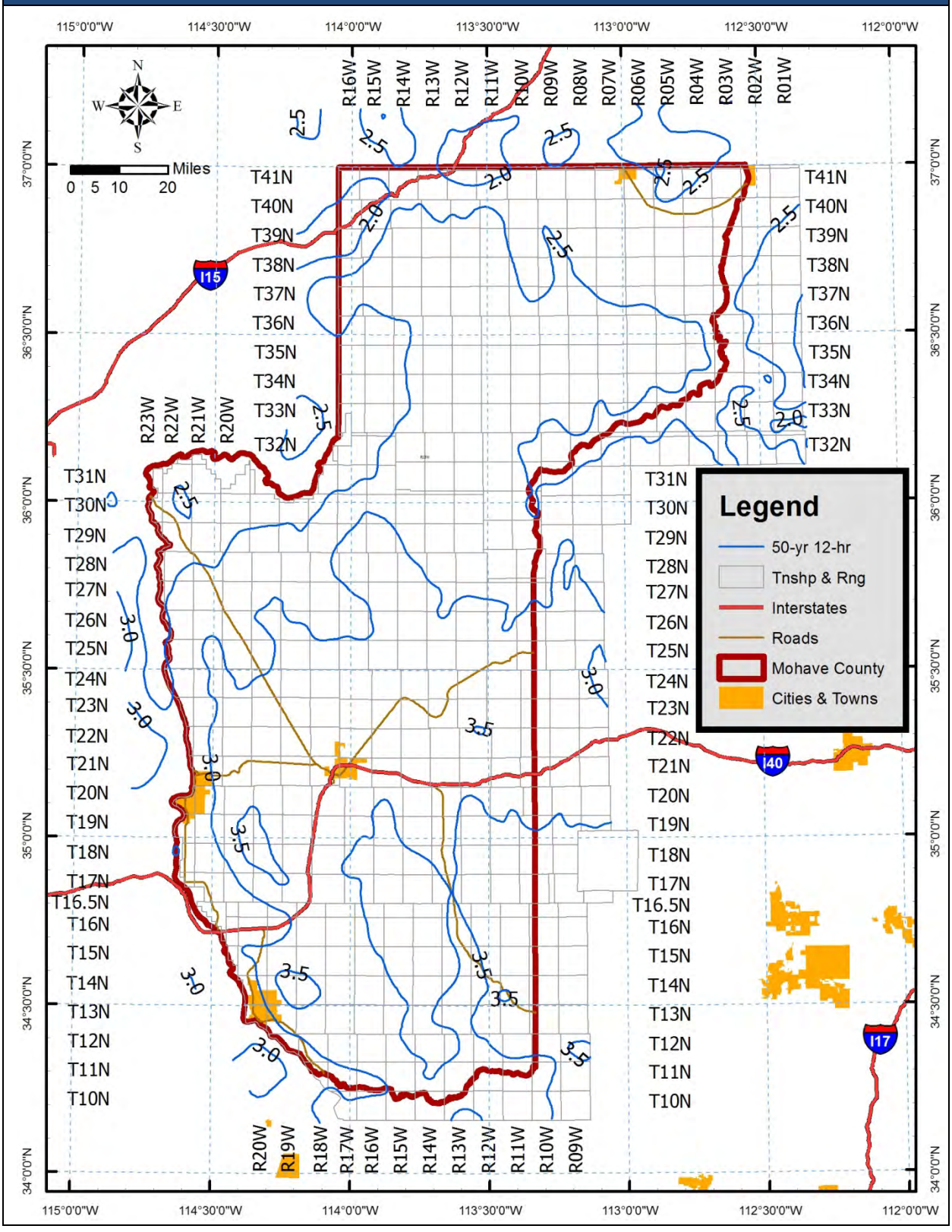
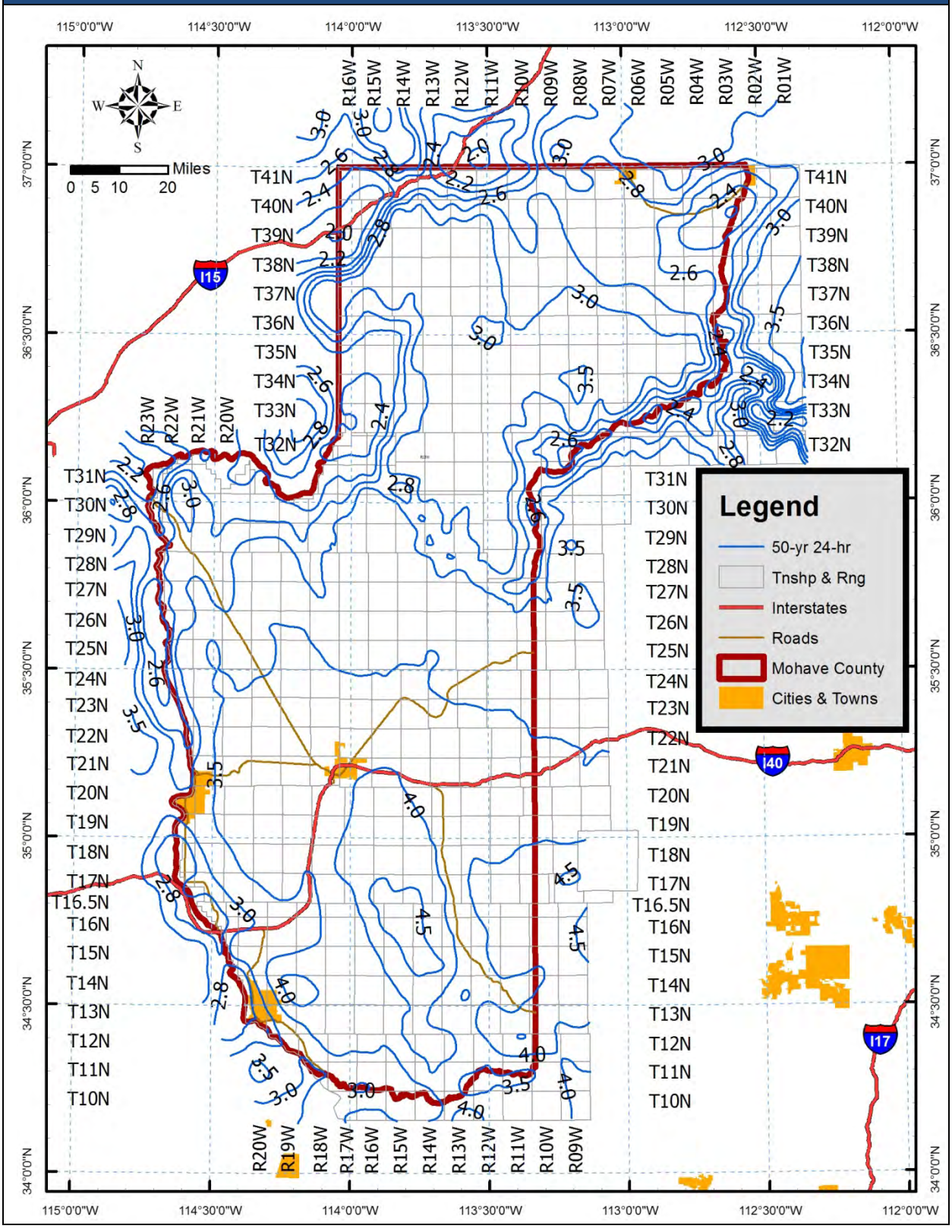


Figure B.50 NOAA Atlas 14 50-year 24-hour isopluvial map



B.6 100-YEAR STORM ISOPLUVIALS

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Figure B.51 NOAA Atlas 14 100-year 5-minute isopluvial map

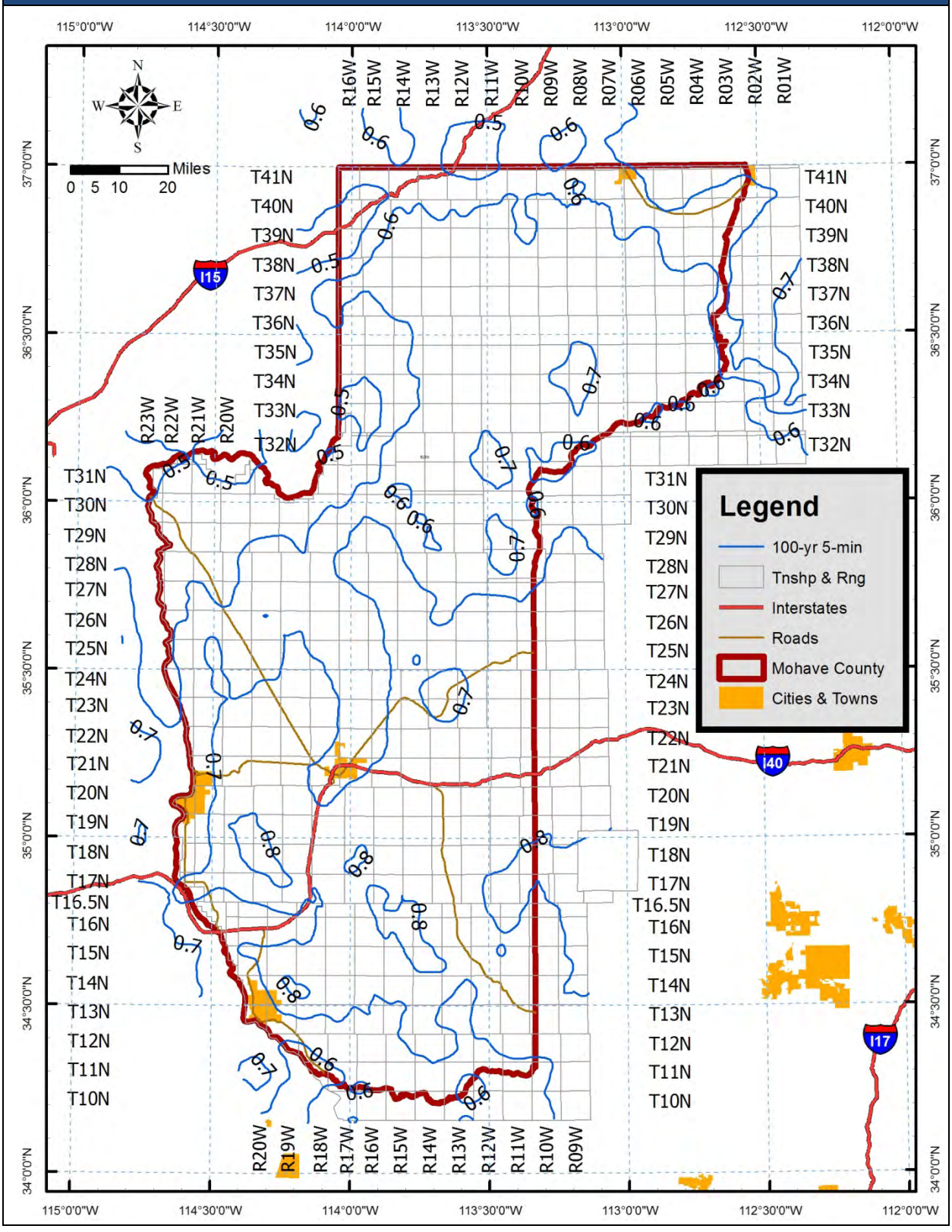


Figure B.52 NOAA Atlas 14 100-year 10-minute isopluvial map

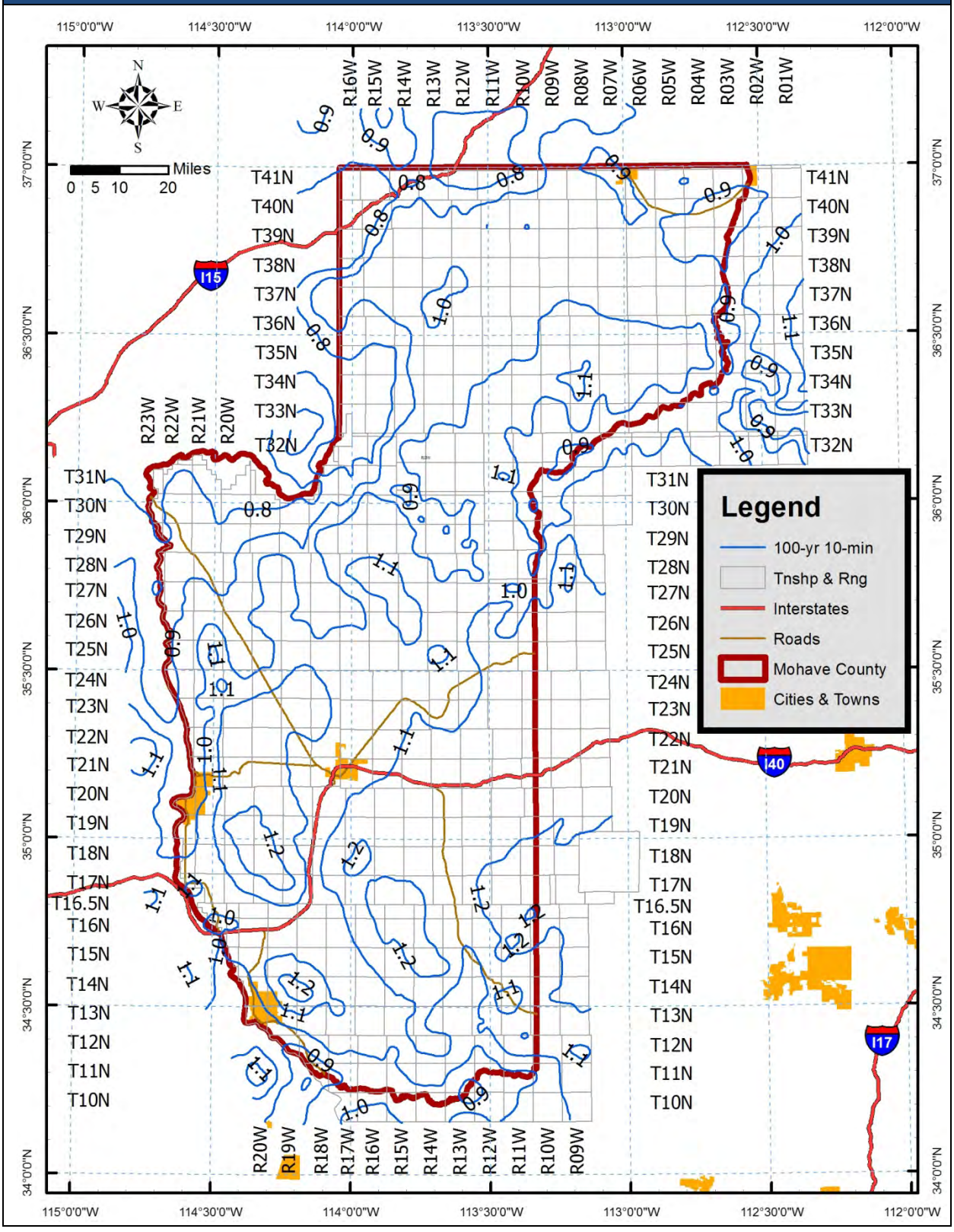


Figure B.53 NOAA Atlas 14 100-year 15-minute isopluvial map

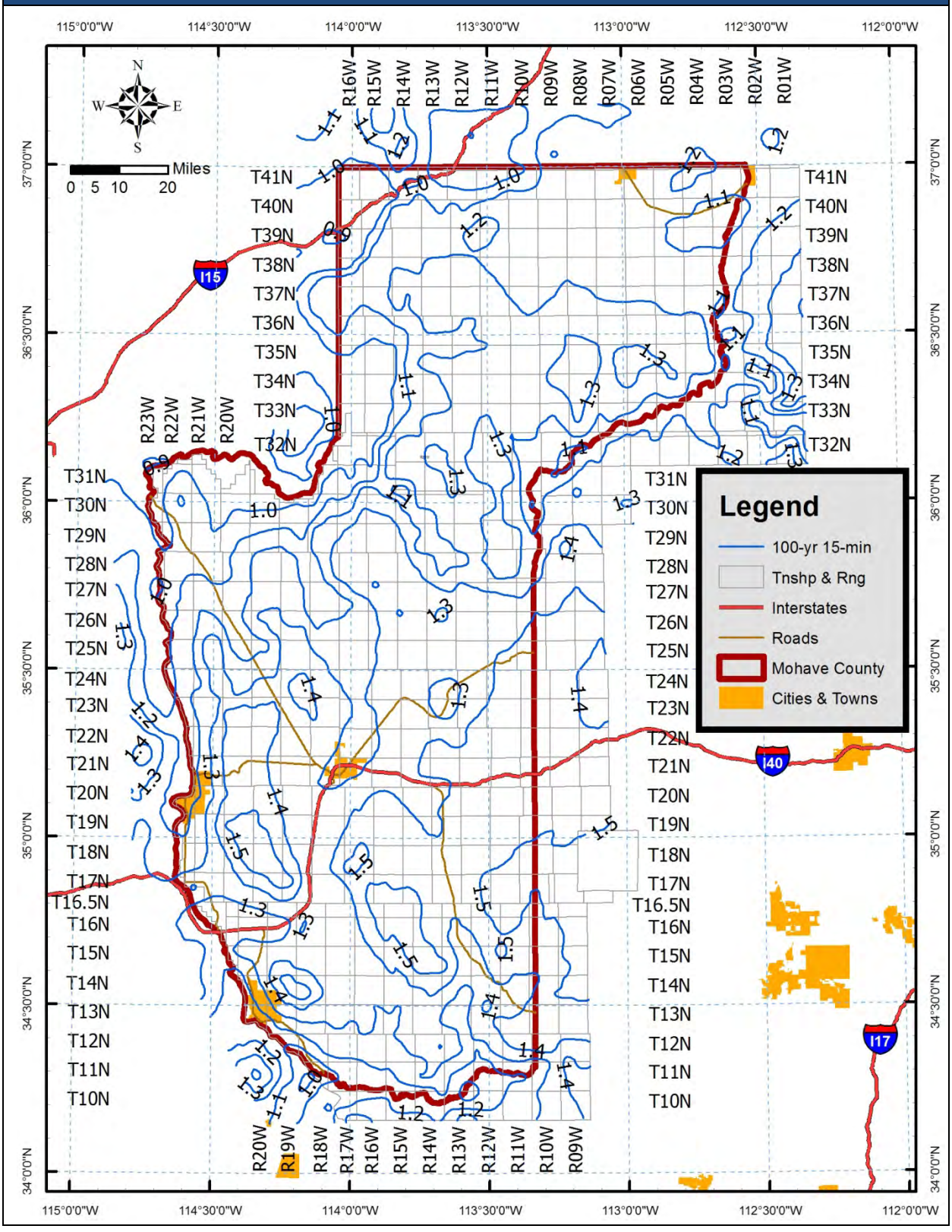


Figure B.54 NOAA Atlas 14 100-year 30-minute isopluvial map

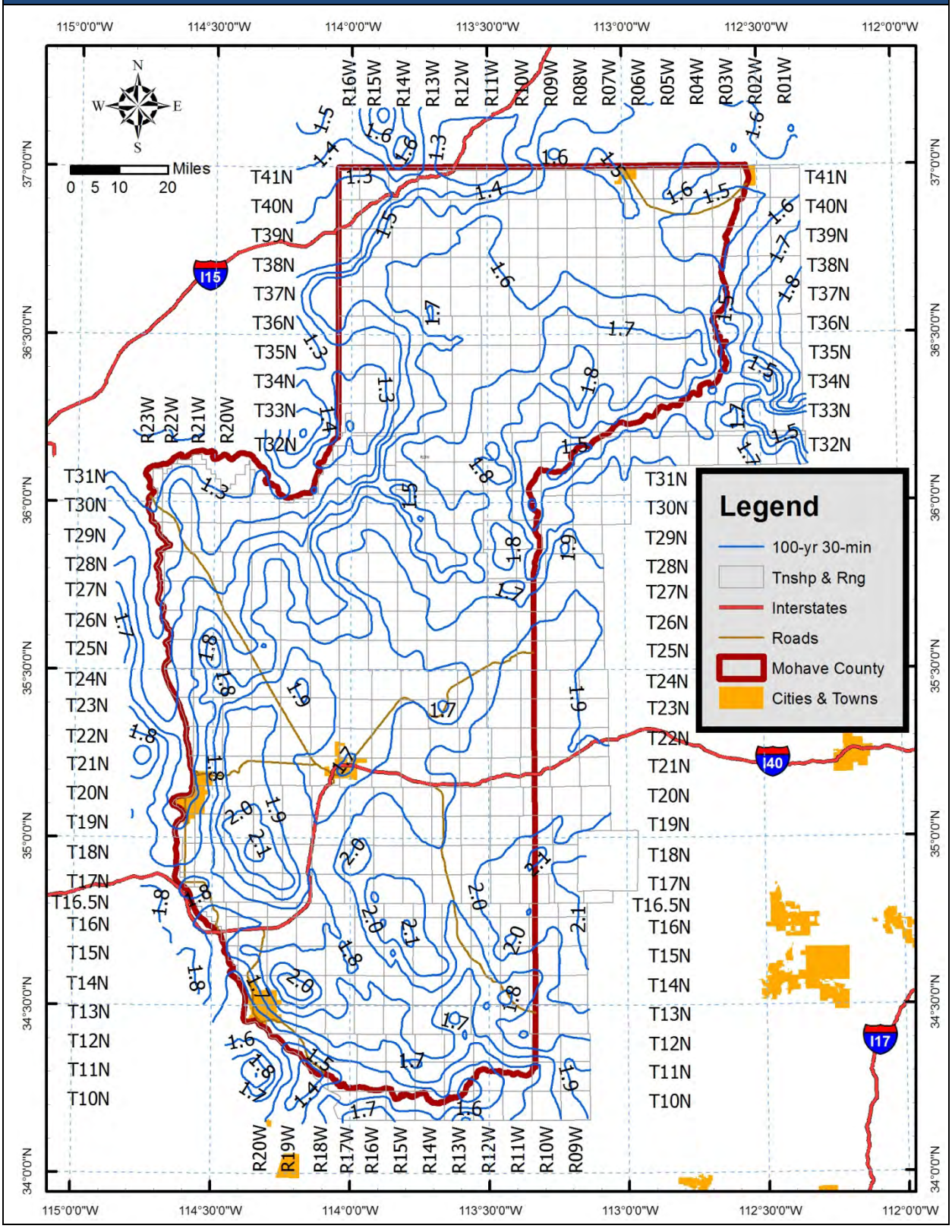


Figure B.55 NOAA Atlas 14 100-year 1-hour isopluvial map

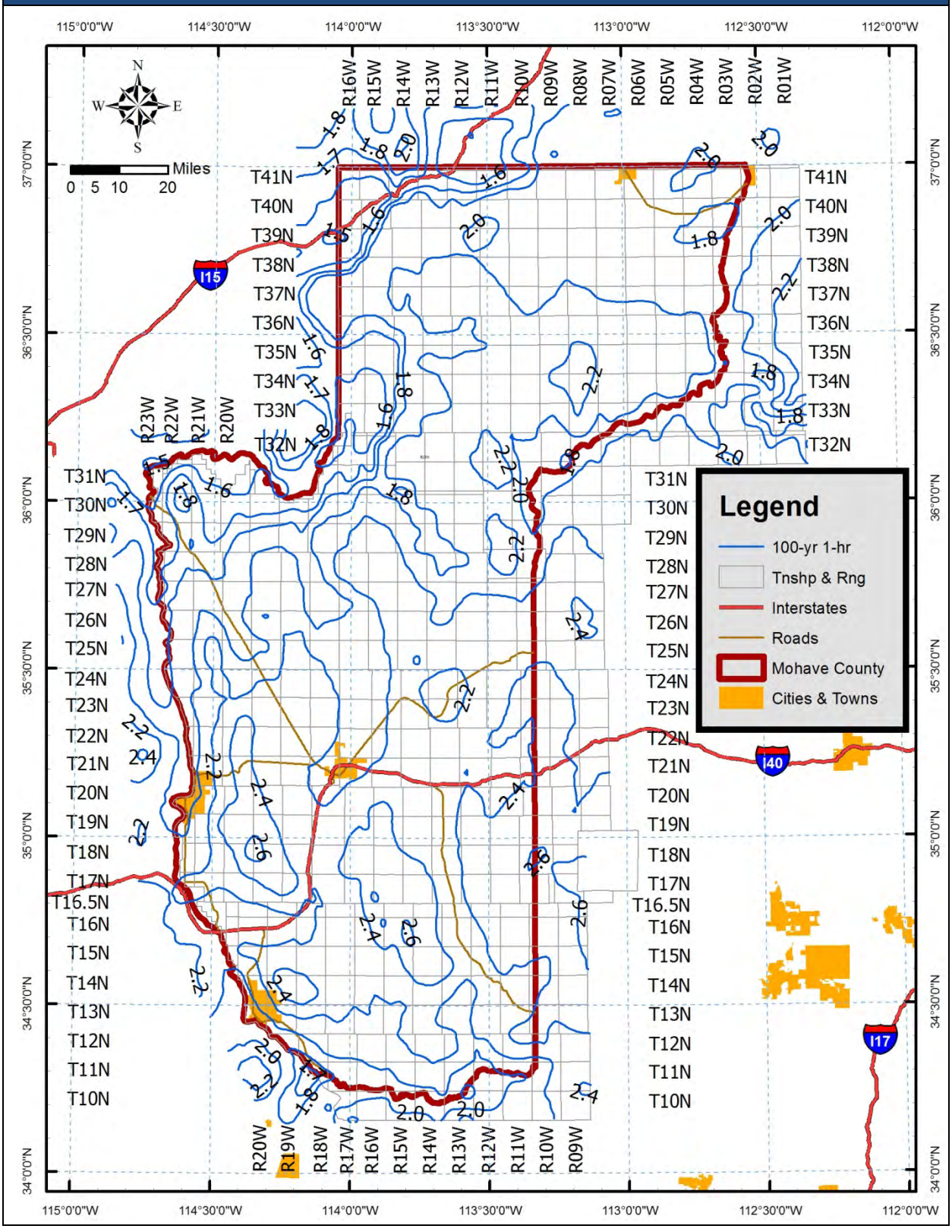


Figure B.56 NOAA Atlas 14 100-year 2-hour isopluvial map

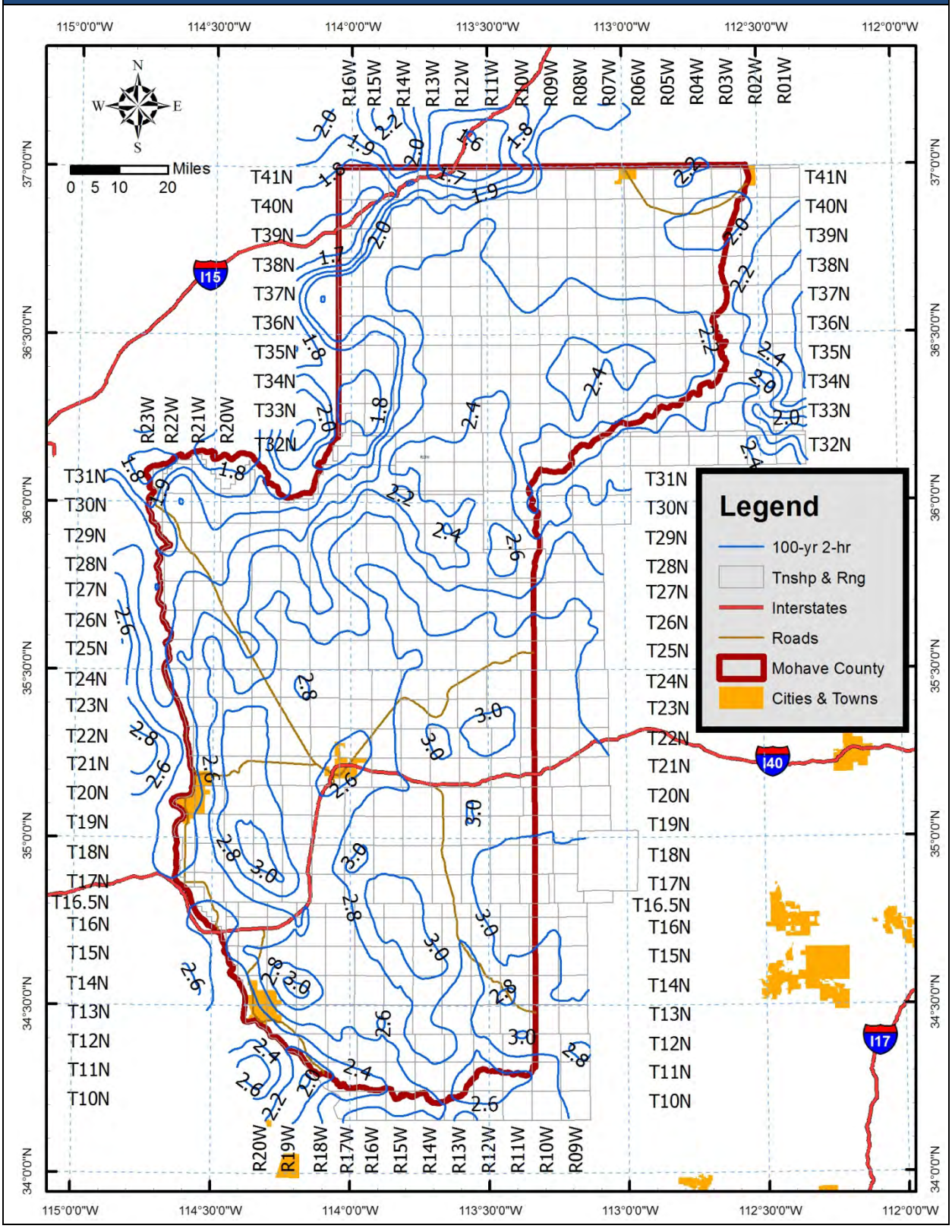


Figure B.57 NOAA Atlas 14 100-year 3-hour isopluvial map

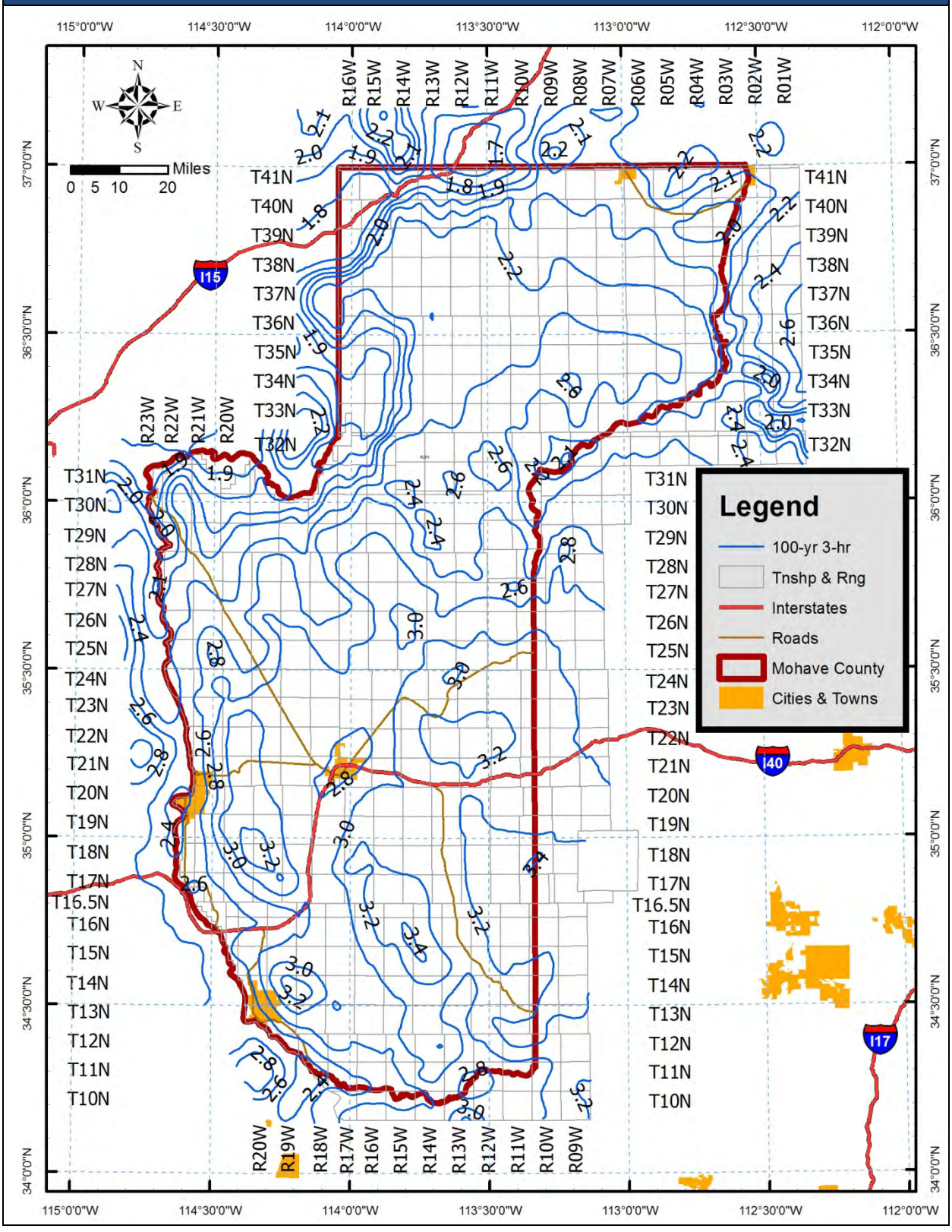


Figure B.58 NOAA Atlas 14 100-year 6-hour isopluvial map

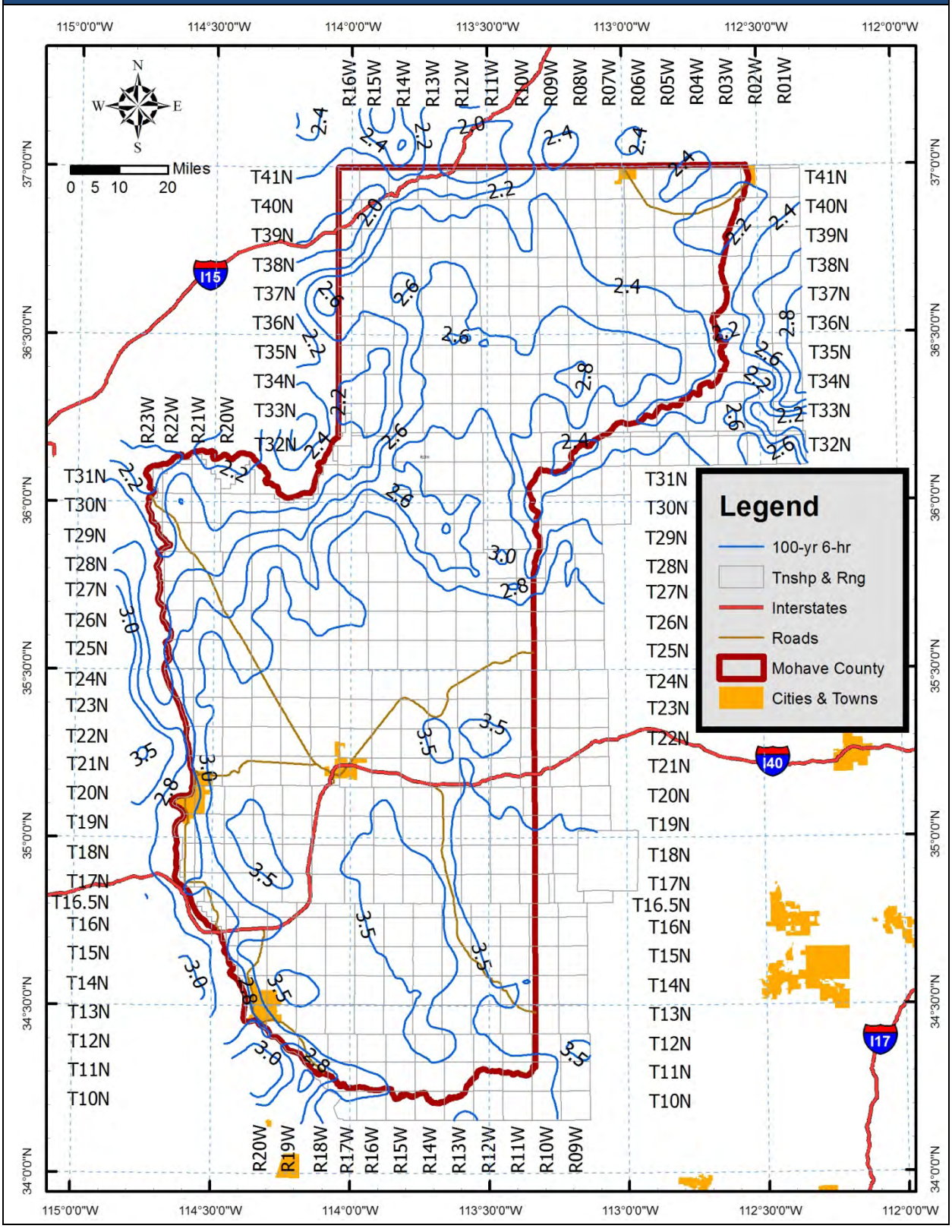


Figure B.59 NOAA Atlas 14 100-year 12-hour isopluvial map

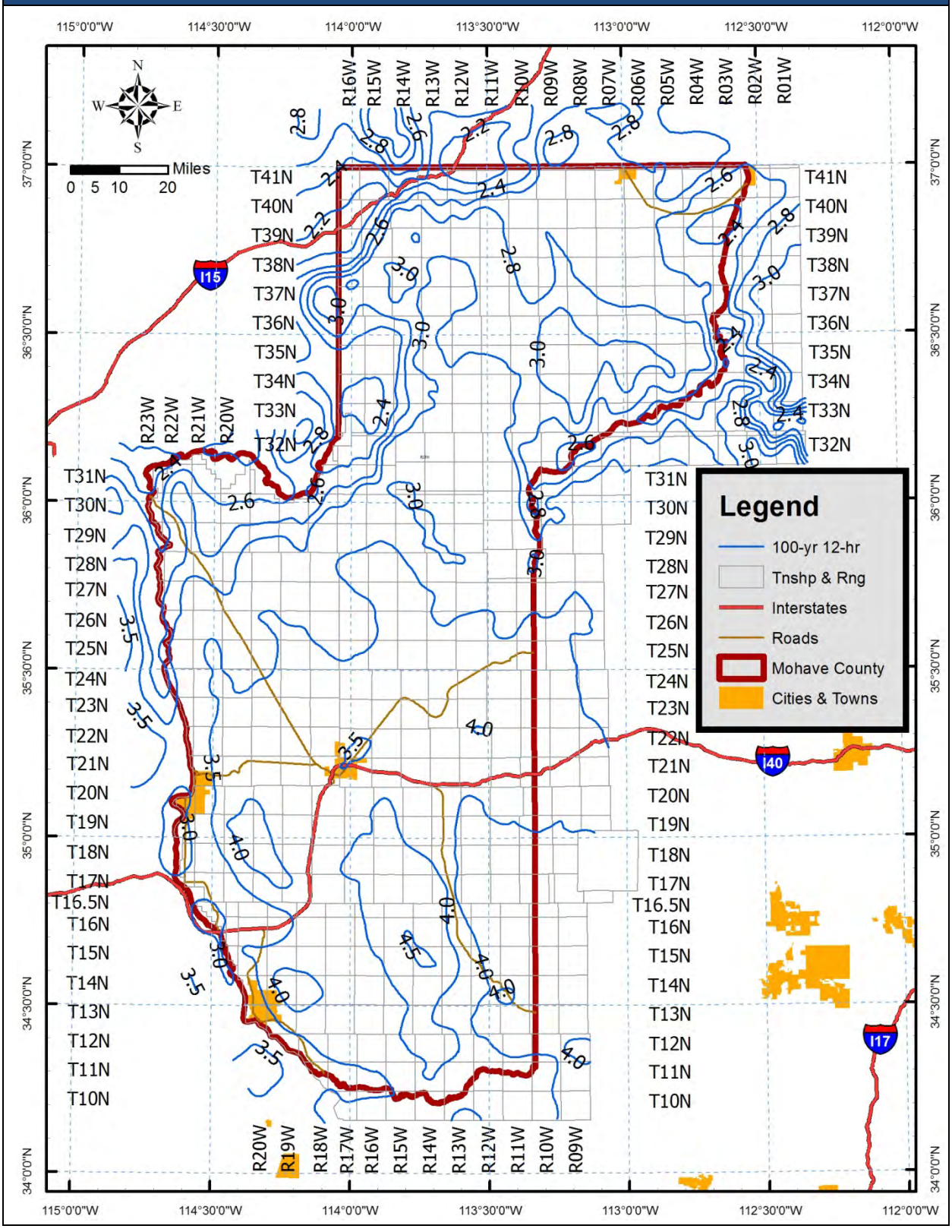
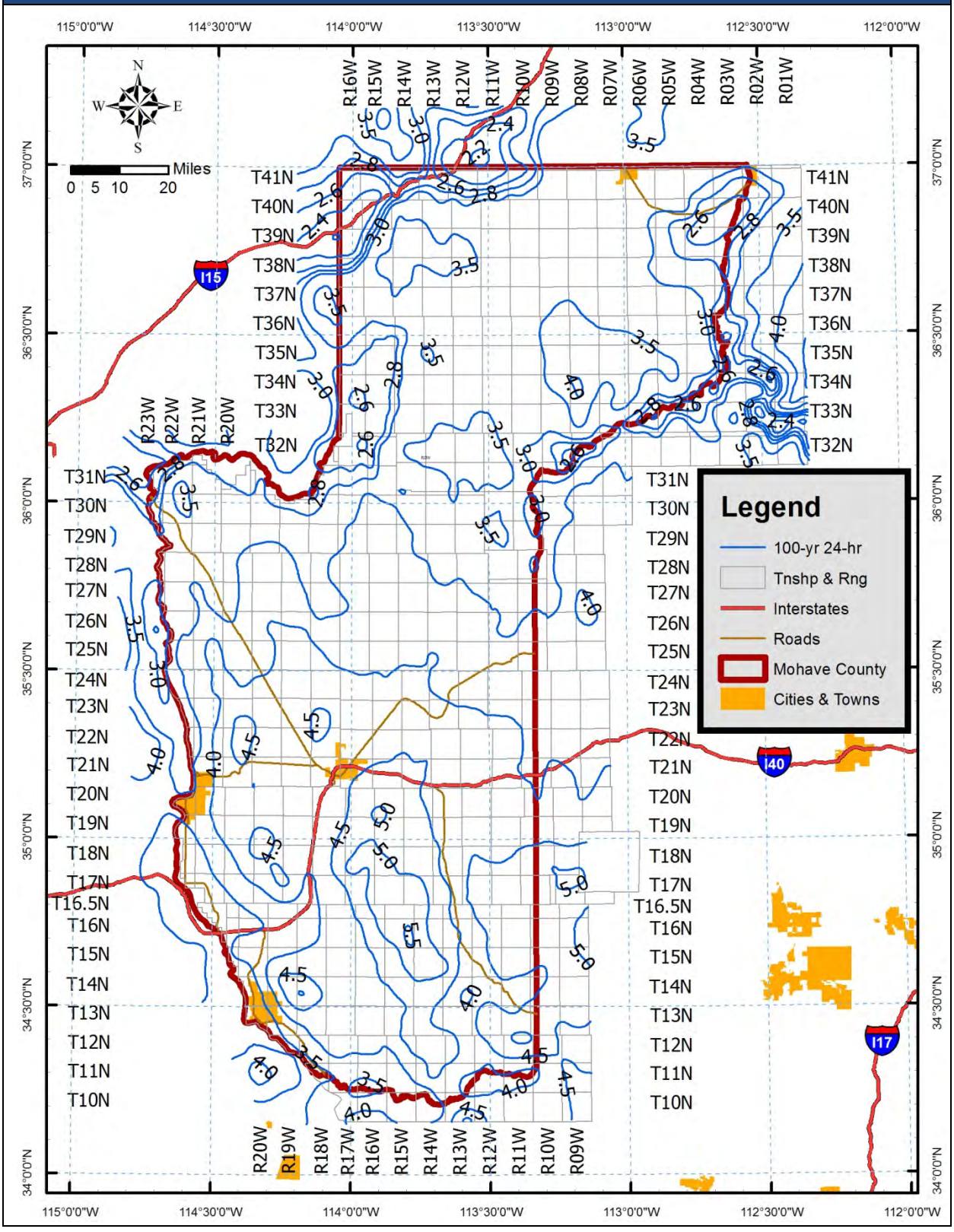


Figure B.60 NOAA Atlas 14 100-year 24-hour isopluvial map



B.7 RAINFALL FORMS AND GRAPH PAPER

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Rainfall Depth-Duration-Frequency Table						
Project No:				Date:		
Project Name:						
Location/Watershed:						
Designer:				Checked by:		
	Rainfall Depth$_{(i,j)}$, in inches					
	Storm Frequency$_{(j)}$, in years					
Duration$_{(i)}$	**2**	**5**	**10**	**25**	**50**	**100**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
5-min						
10-min						
15-min						
30-min						
1-hour						
2-hour						
3-hour						
6-hour						
12-hour						
24-hour						

Rainfall Intensity-Duration-Frequency Table						
Project No:				Date:		
Project Name:						
Location/Watershed:						
Designer:				Checked by:		
	Rainfall Intensity$_{(i,j)}$, in inches/hour					
	Storm Frequency$_{(j)}$, in years					
Duration$_{(i)}$	2	5	10	25	50	100
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5-min						
10-min						
15-min						
30-min						
1-hour						
2-hour						
3-hour						
6-hour						
12-hour						
24-hour						

The rainfall intensity is computed as follows: $$Intensity_{(i,j)} = \frac{Depth_{(i,j)}}{(Duration_{(i)})(60)}$$

where:

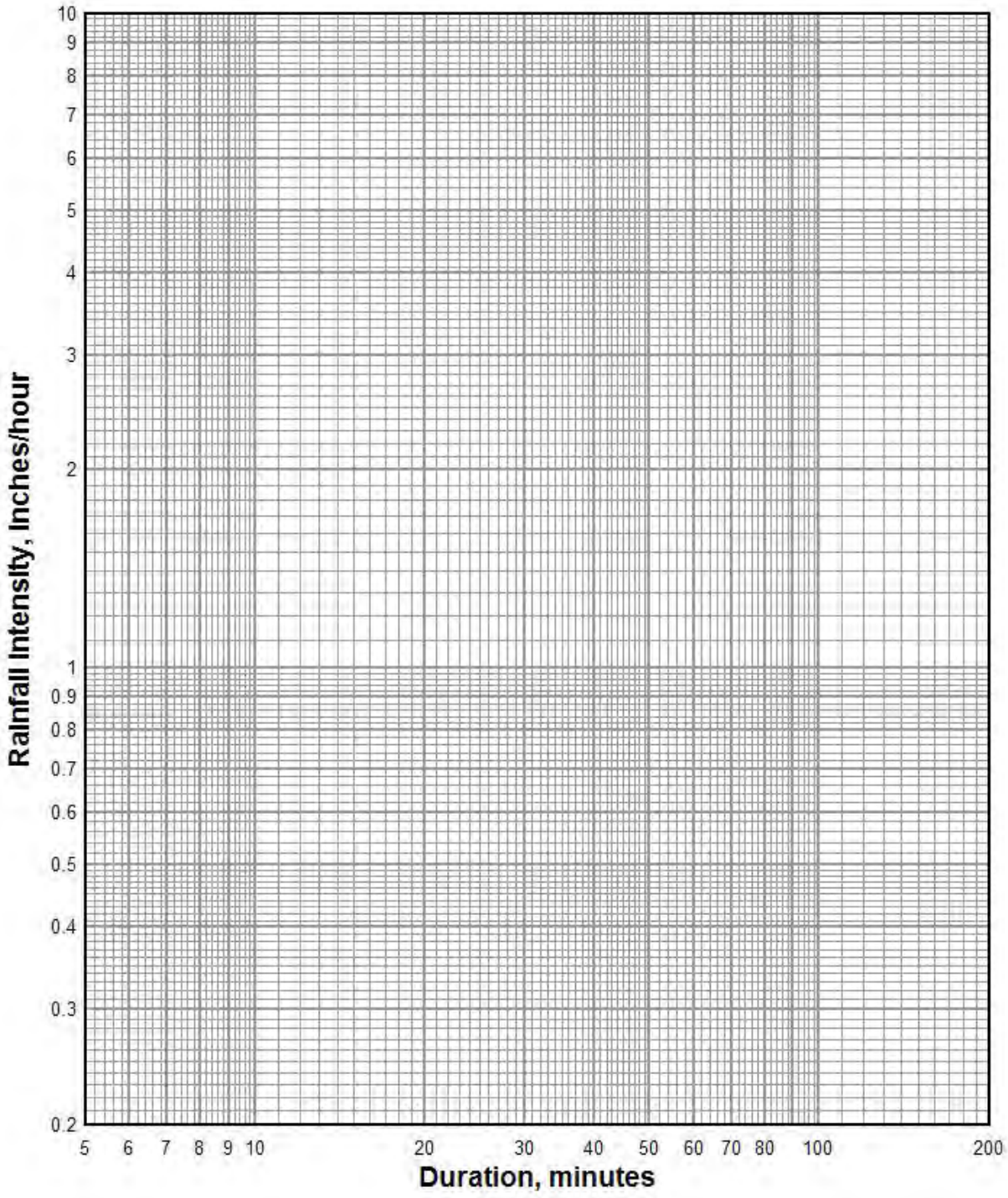
Depth$_{(i,j)}$ = Point rainfall corresponding to Duration$_{(i)}$ and Frequency$_{(j)}$ in inches.

Duration$_{(i)}$ = Duration of point rainfall for Frequency$_{(j)}$ in minutes.

Intensity$_{(i,j)}$ = Rainfall intensity corresponding to Duration$_{(i)}$ and Frequency$_{(j)}$ in inches/hour.

Figure B.61 Intensity-Duration-Frequency Graph

Location/Watershed:



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C. PROCEDURE FOR ESTIMATION OF VEGETATIVE COVER

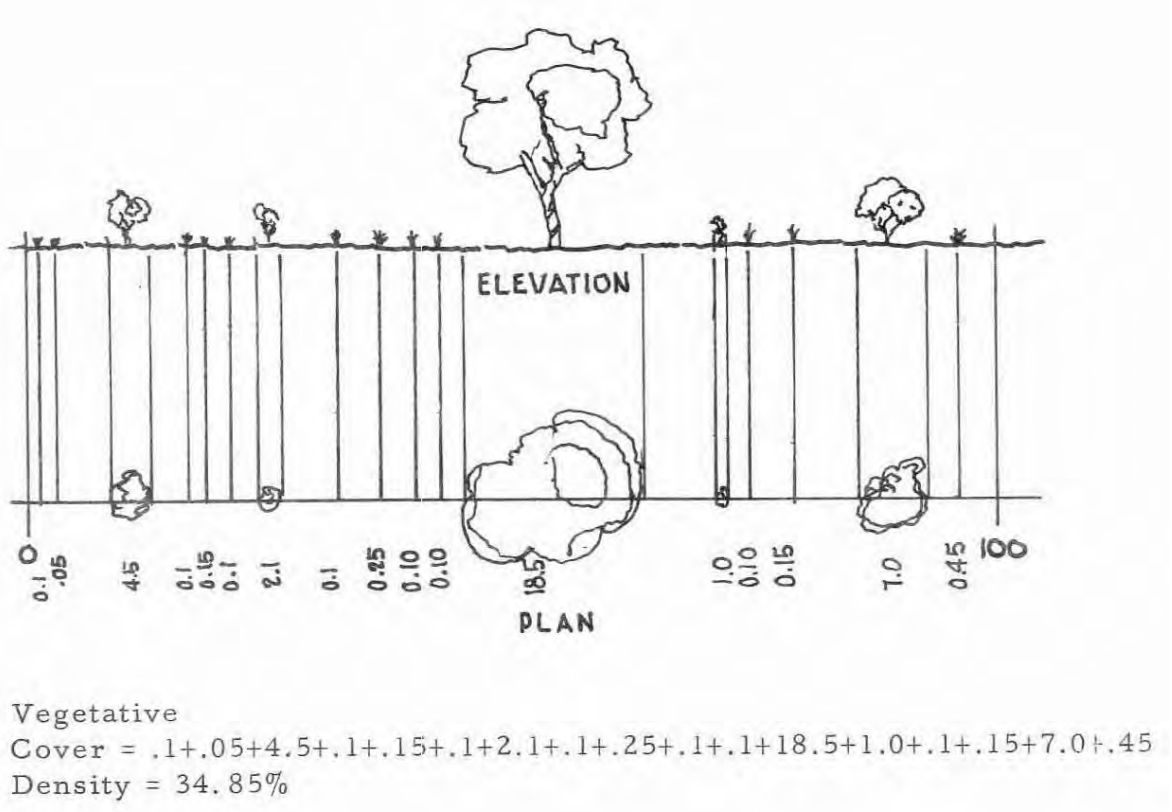
Vegetative cover densities are determined using one or both of the two following methods:

C.1 METHOD 1: PHYSICAL MEASUREMENT

1. An area representing the typical vegetative cover density for the drainage sub-basin or sub-area is selected.
2. A 100-foot chain is stretched out on the ground in a straight line in the area selected.
3. The intercepts of the vegetative canopy along the 100-foot length are noted.
4. The total distances covered by vegetation canopy along the 100-foot length are summed up and repre sent the percent of vegetative cover for the selected area.
5. Several determinations mayhave to be made to compute the average percent of cover for the drainage sub-basin or sub-area.

The following sketch (Jencsok, 1969) illustrates the field procedure:

Figure C.1 Physical measurement of vegetative canopy cover schematic



C.2 METHOD 2: AERIAL PHOTOGRAPH GIS/CAD POLYGONS

Fully rectified and scaled digital aerial photographs of the sub-basins or sub-areas can be used to estimate vegetative canopy cover. The photographs are used to define polygons covering the various areas of visible vegetation using CAD or GIS software. Then the percent coverage area of each sub-basin or sub-area is computed using CAD or GIS tools. This method should be verified and/or calibrated using Method 1 above.

D. RAINFALL LOSSES

D.1 PROCEDURES USED TO ASSIGN G&A PARAMETERS

D.1.1 BASE SOILS DATA

D.1.1.1 Source

The data used for estimation of Green and Ampt parameters was the SSURGO detailed soil survey data obtained from the NRCS. The web site the data was downloaded from is:

NRCS Web Soil Survey.

The information consisted of GIS polygon files in ESRI shape file format, and Microsoft Access format databases for the following soil surveys:

Table D.1 List of soil surveys

ID	Soil Survey Title
AZ623	SHIVWITS AREA, ARIZONA, PART OF MOHAVE COUNTY
AZ625	MOHAVE COUNTY AREA, AZ, NORTHEASTERN PART, AND PART OF COCONINO COUNTY
AZ627	MOHAVE COUNTY, AZ, SOUTHERN PART
AZ629	COCONINO COUNTY AREA, ARIZONA, NORTH KAIBAB PART
AZ631	COCONINO COUNTY AREA, ARIZONA, CENTRAL PART
AZ637	YAVAPAI COUNTY, ARIZONA, WESTERN PART
AZ639	Black Hills-Sedona Area, Arizona, Parts of Coconino and Yavapai Counties. Database not available yet. The AZ STATSGO feature class was used and clipped to AZ639 boundary.
AZ657	KOFA AREA, ARIZONA, PARTS OF LA PAZ AND YUMA COUNTIES: Databaseis only partially available. Where data is not provided, the AZ STATSGO feature class was used to fill in the missing areas.
AZ695	KAIBAB NATIONAL FORESTS, ARIZONA, PARTS OF COCONINO, MOHAVE AND YAVAPAI COUNTIES. Database not available yet. The AZ STATSGO feature class was used and clipped to AZ695 boundary.
AZ697	MOHAVE COUNTY, AZ. CENTRAL PART
AZ699	HUALAPAI-HAVASUPAI AREA, PARTS OF COCONINO, MOHAVE, AND YAVAPAI COUNTIES

Table D.1 List of soil surveys	
ID	**Soil Survey Title**
AZ701	GRAND CANYON AREA, ARIZONA, PARTS OF COCONINO AND MOHAVE COUNTIES
NV608	VIRGIN RIVER AREA, NEVADA AND ARIZONA
NV713	MEADOW VALLEY AREA, NEVADA AND UTAH
NV754	LINCOLN COUNTY, NEVADA, SOUTH PART
NV755	CLARK COUNTY AREA, NEVADA
UT634	IRON-WASHINGTON AREA, UTAH, PARTS OF IRON, KANE, AND WASHINGTON COUNTIES
UT636	PANGUITCH AREA, PARTS OF GARFIELD, IRON, KANE AND PIUTE COUNTIES, UTAH
UT641	WASHINGTON COUNTY AREA, UTAH
UT642	KANE COUNTY, UTAH: : The UT STATSGO feature class was used and clipped to UT642 boundary
UT646	DIXIE NATL.FOREST-PARTS OF GARFIELD, WASHINGTON, IRON, KANE & WAYNE COUNTIES. Database not available yet. The UT STATSGO feature class was used and clipped to UT646 boundary.
UT686	GRAND STAIRCASE - ESCALANTE NATIONAL MONUMENT, PARTS OF KANE AND GARFIELD COUNTIES, UTAH
AZ	ARIZONA GENERAL SOIL SURVEY
UT	UTAH GENERAL SOIL SURVEY

D.1.2 DATA EXTRACTION

The NRCS databases are very complex and contain a large amount of data in numerous tables. The data necessary for computation of Green and Ampt parameters was extracted from each soils database and stored in a new separate database file containing two tables. The procedures used to accomplish this are as follows. Familiarity with Microsoft Access 2003 is required, and these instructions are specific to MS Access 2003. MS Access 2007 can also be used but the location of the commands is often slightly different.

1. Populate the NRCS template database with data using the procedures provided by the NRCS.
2. Extract the physical soil properties data needed to compute XKSAT, PSIF, and DTHETA.

   Create a new empty database named "?????_XKSAT.mdb". Use the NRCS soil survey ID number from Table D.1 in place of the question marks.

Make a copy of the NRCS database and name it: soil?????db_US_2002.mdb. Again, use the NRCS soil survey ID number from Table D.1 in place of the question marks. Open the copy of the NRCS database.

Create a new Query using the “Simple Wizard” and adding the fields listed below. Name it "Query - XKSAT Computation Data."

	1	2	3	4	5	6	7
Source Table:	mapunit		component		chtexturegrp	chtexture	
Source Field:	musym	muname	cokey	compname	texdesc	texcl	lieutex
Description:	SMU	Map Unit Name	Component Key	Component Name	Texture Description	Texture Class	in lieu Texture

	8	9	10	11	12	13	14
Source Table:	chorizon						chfrags
Source Field:	ksat_r	hzdept_r	hzdepb_r	sandtotal_r	silttotal_r	claytotal_r	fragsize_r
Description:	KSAT micrometers/s	Horizon, inches		Total Percentage by weight < 2mm			Gravel Size, mm
		Top	Bottom	Sand	Silt	Clay	

	15	16	17	18	19	20	21
Source Table:	chfrags	chorizon			Component	chtexture	Chorizon
Source Field:	fragvol_r	om_r	dbthirdbar_r	dbovendry_r	mukey	chtgkey	chkey
Description:	Gravel percent of total volume	Organic Matter percent of total volume	Oven dried weight of < 2mm material at a water tension of 1/3 Bar	exclusive of desication cracks, measured on a coated clod	Map unit key	Horizon texture key	Horizon key

	22
Source Table:	Chfrags
Source Field:	chfragskey
Description:	Horizon fragments key

In "Design View", sort ascending on the fields “musym”, “cokey”, “hzdept_r”, and “fragsize_r”.

In "Design View", set criteria for “hzdept_r”: <=6.

In "Design View", select the link between the “chorizon” and “chfrags” tables, right-click on the link, and select “Join Properties”. Set radio button 2, “Include ALL records from ‘chorizon’...”

Save Query.

Go to "Datasheet View". Copy and Paste Query. Rename copy to "Make-Table Query XKSAT Computation Data."

Open the Make-Table Query and enter "Design View".

Click on the "Query Type" icon and select "Make-Table Query." (in Access 2007, click on "Make Table")

Use the "Another Database" option and use table name ="XKSAT". Point to the "????_XKSAT" database file from Step 1.

Save the Query and hit the "Run" icon.

Save the work and open the new "????_XKSAT" database. Explore the database to verify the data was processed correctly.

3. Extract the percentage of each component soil within each soil map unit.

   Re-open the NRCS database.

   Create a new Query using the “Simple Wizard” and adding the fields listed below. Name it "Query – SMU Component Percentages."

	1	2	3	4	5	6	7
Source Table:	mapunit		component				mapunit
Source Field:	musym	muname	compname	comppct_r	slope_r	cokey	mukey
Description	SMU	Map Unit Name	Component Name	Component Percentage	Average Slope	Keys: Component	Keys: Map Unit

   In "Design View", sort ascending on the fields “musym” and “compname”.

   Save Query and go to "Datasheet View".

   Copy and Paste Query. Rename copy to "Make-Table Query SMU Component Percentages."

   Open the Make-Table Query and enter Design mode.

   Click on the "Query Type" icon and select "Make-Table Query SMU Component Percentages." (in Access 2007, click on "Make Table")

   Use the "Another Database" option and use table name ="SMU_Comp". Point to the "????_XKSAT" database file from Step 1.

   Save the Query and hit the "Run" icon.

   Save the work and open the new "????_XKSAT" database. Explore the database to verify the data was processed correctly.

4. Create queries in the XKSAT database.

   Create a query named “Query_XKSAT” in the "????_XKSAT" database and populate it with all the fields in the XKSAT table. In "Design View", sort ascending on the fields “musym”, “cokey”, “hzdept_r”, and “fragsize_r”. Save and return to "Datasheet View."

Create a query named “Query_SMU” in the "????_XKSAT" database and populate it with all the fields in the SMU_Comp table. In "Design View", sort ascending on the fields “musym” and “compname”. Save and return to "Datasheet View."

Check for records in the XKSAT table (not the Query) for blank “texcl” fields. Assign a texture if possible and appropriate. Use Saxton’s equations or program to determine the texture class based on the percent sand and clay if either the sand OR clay fields are populated. If both sand and clay are not populated, the component must become a Miscellaneous Component Soil or sand and clay percentages must be estimated based on texture and ksat_r. If the component is a Miscellaneous Component Soil, then delete the record from the database unless perhaps a value for clay has been assigned. Make sure the value assigned corresponds with the texture class. Check for XKSAT2006 values of “NaN.” Manually assign values for these SMU’s.

This data was used as described in Appendix D.2.2 below. Note that not all SMU’s and Component soils listed in the SMU_Comp database are included in the XKSAT database. There are a large number of miscellaneous soils for which no laboratory data is available. These are addressed in Appendix D.2.5.

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D.2 COMPUTATION OF GREEN AND AMPT PARAMETERS

D.2.1 METHOD

D.2.1.1 General

The Green and Ampt parameters were computed using a computer program called XKSAT that uses data from the NRCS soil survey databases. A summary of the procedures used to compute Green and Ampt parameters follows:

1. Data necessary to implement the Saxton and Rawls (2006) pedotransfer function is extracted from NRCS soils databases and saved in MS Access format. The NRCS data used is structured as follows:
    a. Soil Map Units (SMU). This is the identifier for a soil type and the name comes from the "musys" field. An SMU is composed of one or more major and minor soil types. The minor soils are neglected for these procedures, unless included within the NRCS soils database. The newer NRCS soil surveys do not distinguish between major and minor component soils. Each major soil is called a Component soil with the name coming from the "compname" field. The physical data needed for computation of Green and Ampt parameters, and specific to each Component of an SMU, are contained within multiple tables. The required data extracted from the various NRCS tables and stored in a separate Access database in a table named *XKSAT*. The percentages of the area of each Component within each SMU are also extracted from the NRCS database tables and stored in the same separate Access database in a table named *SMU_Comp*. Each component soil is made up of vertical soil layers called Horizons. The thickness of each Horizon is measured in inches and the depth to the top and bottom of each Horizon comes from the "hzdept_r" and "hzdepb_r" fields, respectively. The top 6-inches of each Component is evaluated to determine which Horizon is the limiting soil layer for infiltration. The XKSAT value for that layer is used to represent the infiltration ability of that Component.
    b. Sand, Silt and Clay. The percentage of sand, silt, and clay provided by the NRCS is the percentage by weight of the matric soil (all particles <2mm). This data is provided in fields "sandtotal_r", "silttotal_r", and "claytotal_r".
    c. Gravel. The gravel size in mm is provided in the field "fragsize_r" and the percentage by volume of the bulk soil in field "fragvol_r". Each Horizon soil contains either none, or one or more gravel size fractions.
2. Total the gravel for each Horizon. The total gravel volume for each Horizon must be computed by totaling the volumes for the size fractions. There are often multiple duplicate records for each size fraction in the NRCS database table. Multiple duplicate records of a given size fraction are ignored.
3. Compute XKSAT, PSIF and DTHETA for each horizon.
4. Determine the control horizon for each component.
5. Total RTIMP for each Horizon where multiple records exist.

6. Compute an area log-averaged value of XKSAT for each SMU.
7. Assign PSIF and DTHETA values to each SMU based on the relationship to XKSAT using equations developed by regression analysis.

D.2.1.2 XKSAT by the 1983 Method

Sabol (1993) refers to the *Drainage Design Manual for Maricopa County – Hydrology*, by George V. Sabol, first published in 1993. The relationships between soil texture and saturated hydraulic conductivity, XKSAT, from that publication are used to assign XKSAT to each Component Horizon based on texture only. In the GIS soils files and spreadsheets for Mohave County, XKSAT values assigned using this method are referred to as "XKSAT 1983". These values are not approved for use within Mohave County. Instead, they are provided for reference and comparison with the current ADOT and Maricopa values. The basis for Sabols' work is a paper by Walter J. Rawls, Donald L. Brakensiek, and Norman Miller titled *Green-Ampt Infiltration Parameters From Soils Data* published in the ASCE Journal of Hydraulic Engineering, Volume 109, Number 1, January 1983 (Rawls, Brakiensiek and Miller, 1983).

D.2.1.3 XKSAT by Saxton and Rawls (2006)

The Mohave County Green and Ampt parameters are based on a paper titled *Soil Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions* by K.E. Saxton and W.J. Rawls (Saxton and Rawls (2006). This is a continuation of the 1983 work by Rawls, Brakensiek and Miller. XKSAT may now be computed based on the percent volume by weight of sand and clay for a given matric soil and corrected based on the percentage of gravel and organic matter in the bulk soil, and the relative level of compaction of the bulk soil. The new procedures are based on extensive research using 2,000 A-Horizon and 2,000 B-Horizon samples from the NRCS. The A Horizon is the top soil layer, and the B Horizon the second layer below the surface. These two Horizons cover the top 6-inches of the surface soils, which is the area of concern for this analysis. The new procedure also provides the necessary information to directly compute PSIF and DTHETA for each Horizon using the equations included in Rawls, Brakensiek and Miller (1983). Refer to Appendix D.2.7. The equations used for computation of XKSAT, PSIF and DTHETA and the corrections for gravel content, organic matter and compaction are listed below:

D.2.1.4 Green and Ampt Parameters Equations

The equations from Saxton and Rawls (2006), as applied for the Mohave County Method and implemented using the XKSAT computer program, are summarized as follows:

Wilting Point

```
Predict = -0.024 * Sand + 0.487 * Clay + 0.006 * OrgMat + 0.005 * Sand
* OrgMat - 0.013 * Clay * OrgMat + 0.068 * Sand * Clay + 0.031
WPoint = Predict + (0.14 * Predict - 0.02)
```

Field Capacity

```
Predict = -0.251 * Sand + 0.195 * Clay + 0.011 * OrgMat + 0.006 * Sand
* OrgMat - 0.027 * Clay * OrgMat + 0.452 * Sand * Clay + 0.299
FCapac = Predict + (1.283 * Predict ^ 2 - 0.374 * Predict - 0.015)
```

Saturation

```
Predict = 0.278 * Sand + 0.034 * Clay + 0.022 * OrgMat - 0.018 * Sand *
OrgMat - 0.027 * Clay * OrgMat - 0.584 * Sand * Clay + 0.078
S33 = Predict + (0.636 * Predict - 0.107)
Sat = FCapac + S33 - 0.097 * Sand + 0.043
```

Adjustment for organic matter and compaction

```
DensityO = (1 - Sat) * 2.65
DensityC = DensityO * DensityFactor
PorO = 1 - (DensityC / 2.65)
PorC = PorO - (1 - DensityO / 2.65)
M33C = FCapac + 0.25 * PorC
PM33C = PorO - M33C
If PM33C < 0 Then PM33C = 0
```

XKSAT CALCULATION

```
Gadj = (1 - Gravel) / (1 - Gravel * (1 - 1.5 * ((DensityC) / 2.65)))
B = (Math.Log(1500) - Math.Log(33)) / (Math.Log(M33C) -
Math.Log(WPoint))
A = Math.Exp(Math.Log(33) + (B * Math.Log(M33C)))
Lamda = 1 / B
XKSAT = 1930 * (PM33C ^ (3 - Lamda)) * 0.0393700787 * Gadj
sngKsCF = CSng(frmOptions.txtKsCF.Text)
XKSAT = XKSAT * sngKsCF
If XKSAT < 0.01 Then
    XKSAT = 0.01
End If
```

DTHETA(dry And normal)CALCULATION

```
DTHETAdry = Sat - WPoint
DTHETAnormal = Sat - FCapac
```

PSIF CALCULATIONS

```
BubblingPressure = -21.674 * Sand - 27.932 * Clay - 81.975 * PM33C +
71.121 * Sand * PM33C + 8.294 * Clay * PM33C + 14.05 * Sand * Clay +
27.161
BPadj = BubblingPressure + (0.02 * BubblingPressure ^ 2 - 0.113 *
BubblingPressure - 0.7)
If BubblingPressure >= 0 Then
    PSIF = (2 * Lamda + 3) / (2 * Lamda + 2) * BubblingPressure / 2 *
4.014630787
Else
    PSIF = -999
End If
If BPadj >= 0 Then
    PSIFadj = (2 * Lamda + 3) / (2 * Lamda + 2) * BPadj / 2 *
4.014630787
Else
    PSIFadj = -999
End If
PSIFscp = Math.Exp(6.53 - 7.326 * PorO + 0.00158 * (Clay * 100) ^ 2 +
3.809 * PorO ^ 2 + 0.000344 * Sand * 100 * Clay * 100 - 0.04989 * Sand
* 100 * PorO + 0.0016 * (Sand * 100) ^ 2 * PorO ^ 2 + 0.0016 * (Clay *
100) ^ 2 * PorO ^ 2 - 0.0000136 * (Sand * 100) ^ 2 * Clay - 0.00348 *
(Clay * 100) ^ 2 * PorO - 0.000799 * (Sand * 100) ^ 2 * PorO) *
0.393700787
```

The documentation for Saxton and Rawls (2006) is found at: Saxton and Rawls SPAW Download Page. ← site cannot be reached

The documentation is included as a part of the SPAW computer program available on that web page. A spreadsheet available as a part of the "Soil Water Characteristics" portion of the SPAW download from this website can be used to check the computations made using these equations.

D.2.2 COMPUTATION OF PARAMETERS FOR EACH HORIZON

An Adobe PDF file for each soil survey area has been prepared that contains the data used for computation of the Green and Ampt parameters and lists the assigned XKSAT parameters. These files are available upon request to Mohave County Flood Control District. The PDF files contain groups of data for each NRCS Soil Survey as listed in Table D.2. The PDF files were created from corresponding Excel spreadsheets that are written by the XKSAT computer program. The Excel spreadsheets contain the raw XKSAT program output and formatted worksheets that are printed to create the PDF files. The Excel spreadsheets are also available upon request to the Mohave County Flood Control District.

Table D.2 List of summary results files

Data Group Number	Data Group Name	Description
1	List of All NRCS Soil Map Unit XKSAT Computation Data	Contains the data from the NRCS Soil Survey database tables used for computation of XKSAT, DTHETA, and PSIF.
2	List of All NRCS Soil Map Unit Components	Contains the Component percentages from the NRCS component database table for each SMU.
3	Table of All Horizons Covering the Top 6-inches, Processed Total Gravel Volumes and Computed Green and Ampt Parameters (DF 1.0)	Contains a list of all Horizons with the gravel volumes totaled, including the computed XKSAT, PSIF and DTHETA values from both the 1983 and 2006 methods using Density Factor 1.0.
4	Table of All Horizons Covering the Top 6-inches, Processed Total Gravel Volumes and Computed Green and Ampt Parameters (DF 1.1)	Contains a list of all Horizons with the gravel volumes totaled, including the computed XKSAT, PSIF and DTHETA values from both the 1983 and 2006 methods using Density Factor 1.1.
5	Table of Control Horizons Using Rawls et al 1983 (DF 1.0)	Contains a listing of the results of the determination of the control Horizon for each Component based on 1983 method for Density Factor 1.0.
6	Table of Control Horizons Using Rawls et al 1983 (DF 1.1). This is a place holder only. Currently only contains a copy of the Density Factor 1.0 results.	Contains a listing of the results of the determination of the control Horizon for each Component based on 1983 method for Density Factor 1.1.
7	Table of Control Horizons Using Saxton and Rawls 2006 (DF 1.0)	Contains a listing of the results of the determination of the control Horizon for each Component based on the Saxton and Rawls (2006) method for Density Factor 1.0.
8	Table of Control Horizons Using Saxton and Rawls 2006 (DF 1.1)	Contains a listing of the results of the determination of the control Horizon for each Component based on the Saxton and Rawls (2006) method for Density Factor 1.1.
9	Table of Composite XKSAT & RTIMP Values Using Rawls 1983 & Saxton and Rawls 2006	Contains the computed area log-averaged values of XKSAT for each SMU for the 1983 method, and Saxton and Rawls (2006) method for both Density Factor 1.0 and 1.1.

D.2.3 COMPUTING GREEN AND AMPT PARAMETERS FOR EACH COMPONENT HORIZON

The data in Group Number 1 was used to create the data in Group Number 3. The gravel volumes for each horizon were totaled, and XKSAT, PSIF and DTHETA computed. The following are key assumptions made when implementing the Saxton and Rawls (2006) method using the XKSAT computer program:

1. The maximum percentage of gravel used is 50%. The Saxton and Rawls (2006) equations are not valid for gravel percentages greater than 50%. When the NRCS data contained a soil horizon with greater than 50% gravel content, the value was set to 50%.
2. The maximum percentage of organic matter used is 8%. The Saxton and Rawls (2006) equations are not valid for organic matter percentages greater than 8%. When the NRCS data contained a soil horizon with greater than 8% organic matter, the value was set to 8%.
3. The Saxton and Rawls (2006) equations have a correction for salinity. This correction was not used in the Mohave County method.
4. The Saxton and Rawls (2006) equations contain a correction for relative soil density, varying from 0.9 to 1.3, where a value of 1.0 represents a normal condition. For the Mohave County Method, a density factor of 1.0 was used to compute XKSAT for natural soils. A density factor of 1.1 was used to compute XKSAT for developed land uses where the soil has been disturbed and recompacted and various activities.
5. The Saxton and Rawls (2006) equations yield K_s, not XKSAT. The correction of of 0.5 was multiplited times K_s to obtain XKSAT.
6. The XKSAT value for very sandy soils is often a large value, which could result in unrealistic values of total infiltration. As a conservative assumption for hydrogic modeling purposes, XKSAT values greater than 2.0 in/hr were set to 2.0 in/hr for the 2006 method. The 1983 method implemented by ADOT and Maricopa County use a limit of 1.2 in/hr, so this limit was used for the 1983 values assigned by the XKSAT computer program.

7. XKSAT assigned using the 1983 method was done using the values in Table D.3. No adjustments were made based on adjectives to the soil texture classification, such as “fine”, “very fine”, “gravelly” or “very gravelly”.

8. The XKSAT program relies on the physical soil properties data being available to apply the Saxton and Rawls (2006) equations. In some cases, the needed data was not present in the NRCS databases. The following is a summary of how these situations were addressed:

    a. Sand and clay percentage not supplied, but texture class was. The texture class was used to assign XKSAT from the data in Table D.6.

    b. Sand and clay percentage, and texture class, not supplied. The component soil was classified as a Miscellaneous Component soil and default XKSAT values for Density Factor 1.0 were assigned based on research and engineering judgment. Refer to Section D.2.5 for documentation. Values for Density Factor 1.1 were computed using a regression equation developed from all the computed values of Ks for both Density Factors 1.0 and 1.1. The equations used are:

        For XKSAT1.0 >= 0.05:

        *XKSAT1.1 = (a + b*LN(XKSAT1.0)^2 + c/(XKSAT1.0)^0.5) * XKSAT1.0*

        For XKSAT1.0 < 0.05:

        *XKSAT1.1 = d * XKSAT1.0*

        For XKSAT1.0 <= 0.01:

        XKSAT10 = XKSAT1.1 = 0.01

        where:

        a = 0.790158322734567
        b = 0.0515810075083139
        c = -0.23269790642807
        d = 0.212411

    c. Sand and clay percentage not supplied for a component soil in a particular soil map unit, but data was supplied for that component soil in a different soil map unit in the same NRCS soil survey. For this case, there was usually no physical data record, but a component percentage was supplied. New physical data

records were added based on the physical data available from another soil map unit. That data was used to compute XKSAT for the missing component.

Table D.3 Green and Ampt parameters as a function of soil texture

(Source: Sabol, 1993)

Soil Texture Classification (1)	XKSAT inches/hour (2)	PSIF inches (3)	DTHETA[1] Dry (4)	Normal (5)	Saturated (6)
loamy sand & sand	1.20	2.4	0.35	0.30	0
sandy loam	0.40	4.3	0.35	0.25	0
loam	0.25	3.5	0.35	0.25	0
silty loam	0.15	6.6	0.40	0.25	0
silt	0.10	7.5	0.35	0.15	0
sandy clay loam	0.06	8.6	0.25	0.15	0
clay loam	0.04	8.2	0.25	0.15	0
silty clay loam	0.04	10.8	0.30	0.15	0
sandy clay	0.02	9.4	0.20	0.10	0
silty clay	0.02	11.5	0.20	0.10	0
clay	0.01	12.4	0.15	0.05	0

otes:

Selection of DTHETA

Dry	=	Nonirrigated lands, such as desert and rangeland;
Normal	=	Irrigated lawn, turf, and permanent pasture;
Saturated	=	Irrigated agricultural land.

D.2.4 DETERMINING THE CONTROL HORIZON FOR EACH COMPONENT SOIL

The control horizon for each Component is listed in Group Number 5, 7 and 8, for the 1983 method and Saxton and Rawls (2006) methods, respectively. The assignments were made using the data in Group Numbers 3 and 4. The Horizon with the lowest value of XKSAT was selected as the control Horizon.

D.2.5 MISCELLANEOUS COMPONENT SOILS

The miscellaneous component soils were addressed before computing the composite values of XKSAT. A list of missing component soil types from the soil surveys evaluated is shown in Table D.4. Only the missing component soil types for SMU's within the stady area are listed. A texture class was assigned for each missing Component using one of three approaches:

1. If the Component was listed in another soil survey, the texture was assigned based on that survey.
8. The NRCS Soil Taxonomy Handbook was consulted and the assignment made based on the typical texture for the soil order corresponding to that Component.
9. If methods 1 or 2 above could not be used, then the texture was assigned based on a Google rearch and/or engineering judgment.

Assignment of XKSAT for both the 1983 method and Saxton and Rawls (2006) methods was made using the assigned texture and the values of K_s in Table D.5 after correction to K_e. All the miscellaneous component soils for each NRCS soil survey are included; therefore, there are many more listings than shown in Table D.4.

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ	s1126	rock outcrop
AZ	s1129	badland
AZ	s289	rock outcrop
AZ	s293	rock outcrop
AZ	s316	rock outcrop
AZ	s318	rock outcrop
AZ	s351	rock outcrop
AZ	s362	cinder land
AZ	s403	rock outcrop
AZ	s404	rock outcrop
AZ	s407	rock outcrop
AZ	s411	rock outcrop
AZ	s412	rock outcrop
AZ	s415	rock outcrop
AZ	s455	lithic ustorthents family
AZ	s461	rock outcrop
AZ	s8196	rock outcrop
AZ	s8197	rock outcrop
AZ	s8198	rock outcrop
AZ	s8369	water
AZ623	6	badland
AZ623	10	rock outcrop
AZ623	17	rock outcrop
AZ623	20	rock outcrop
AZ623	28	badland

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ623	32	gypsiorthids
AZ623	34	rock outcrop
AZ623	42	rock outcrop
AZ623	45	rock outcrop
AZ623	51	rock outcrop
AZ623	52	rock outcrop
AZ623	55	rock outcrop
AZ623	56	rock outcrop
AZ623	57	rock outcrop
AZ623	64	riverwash
AZ623	65	rock outcrop
AZ623	74	rock outcrop
AZ623	78	calciorthids
AZ623	80	rock outcrop
AZ623	84	rock outcrop
AZ623	86	rock outcrop
AZ623	87	rock outcrop
AZ623	93	rock outcrop
AZ623	94	rock outcrop
AZ625	1	badland
AZ625	6	rock outcrop
AZ625	15	gypsiorthids
AZ625	26	lava flows
AZ625	51	riverwash
AZ625	63	rock outcrop
AZ625	64	rock outcrop
AZ625	65	rock outcrop
AZ625	70	rock outcrop
AZ627	1	rock outcrop
AZ627	2	rock outcrop
AZ627	8	rock outcrop
AZ627	9	riverwash
AZ627	10	riverwash
AZ627	20	riverwash
AZ627	21	riverwash
AZ627	22	riverwash
AZ627	25	rock outcrop
AZ627	26	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ627	27	rock outcrop
AZ627	40	rock outcrop
AZ627	41	rock outcrop
AZ627	42	rock outcrop
AZ627	48	rock outcrop
AZ627	49	rock outcrop
AZ627	55	rock outcrop
AZ627	58	rock outcrop
AZ627	62	rock outcrop
AZ627	63	rock outcrop
AZ627	69	riverwash
AZ627	70	riverwash
AZ627	73	rock outcrop
AZ627	74	rock outcrop
AZ627	75	rock outcrop
AZ627	79	marshes
AZ627	90	rock outcrop
AZ627	92	rock outcrop
AZ627	93	rock outcrop
AZ627	94	rock outcrop
AZ627	95	rock outcrop
AZ627	96	rock outcrop
AZ627	102	fluvaquents
AZ627	103	rock outcrop
AZ627	104	rock outcrop
AZ627	105	rock outcrop
AZ627	106	rock outcrop
AZ627	107	rock outcrop
AZ627	108	torriorthents
AZ627	109	torriorthents
AZ627	117	rock outcrop
AZ627	119	torriorthents
AZ627	120	torriorthents
AZ627	127	water
AZ627	132	rock outcrop
AZ627	133	rock outcrop
AZ627	134	rock outcrop
AZ627	137	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ627	138	rock outcrop
AZ629	6	rock outcrop
AZ629	9	torriorthents
AZ629	40	pits borrow
AZ629	41	rock outcrop
AZ629	43	rock outcrop
AZ629	47	torriorthents
AZ629	48	rock outcrop
AZ631	12	rock outcrop
AZ631	20	rock outcrop
AZ631	48	rock outcrop
AZ631	64	rock outcrop
AZ631	65	rock outcrop
AZ631	73	water
AZ637	AwE	rock outcrop
AZ637	Ba	badland
AZ637	BoF	rock outcrop
AZ637	CnC	rock outcrop
AZ637	CnF	rock outcrop
AZ637	CvB	loamy alluvial land
AZ637	DrC	rock outcrop
AZ637	FaC	rock outcrop
AZ637	JaC	rock outcrop
AZ637	JaD	rock outcrop
AZ637	Lh	rock outcrop
AZ637	LvE	rock land
AZ637	LxD	rock outcrop
AZ637	MkF	rock outcrop
AZ637	MoD	rock outcrop
AZ637	Ro	rock land
AZ637	Rr	rock land
AZ637	Rs	rough broken land
AZ637	Sa	gravelly alluvial land
AZ637	TmD	rock outcrop
AZ637	TnF	rock outcrop
AZ637	W	water
AZ657	210	riverwash
AZ657	245	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ657	390	riverwash
AZ657	425	rock outcrop
AZ697	4	aridic argiustolls
AZ697	6	riverwash
AZ697	7	riverwash
AZ697	8	riverwash
AZ697	9	riverwash
AZ697	10	riverwash
AZ697	16	riverwash
AZ697	17	riverwash
AZ697	22	riverwash
AZ697	23	rock outcrop
AZ697	33	rock outcrop
AZ697	34	rock outcrop
AZ697	40	rock outcrop
AZ697	41	rock outcrop
AZ697	42	rock outcrop
AZ697	46	rock outcrop
AZ697	53	gypsids
AZ697	54	haplogypsids
AZ697	55	rock outcrop
AZ697	56	rock outcrop
AZ697	59	rock outcrop
AZ697	65	rock outcrop
AZ697	67	rock outcrop
AZ697	68	rock outcrop
AZ697	75	rock outcrop
AZ697	82	riverwash
AZ697	83	rock outcrop
AZ697	86	rock outcrop
AZ697	91	rock outcrop
AZ697	99	rock outcrop
AZ697	108	rock outcrop
AZ697	109	rock outcrop
AZ697	112	pits-dumps mine
AZ697	113	playa
AZ697	114	rock outcrop
AZ697	117	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ697	118	rock outcrop
AZ697	122	rock outcrop
AZ697	123	rock outcrop
AZ697	124	rock outcrop
AZ697	125	rock outcrop
AZ697	126	rock outcrop
AZ697	127	rock outcrop
AZ697	129	rock outcrop
AZ697	130	rock outcrop
AZ697	139	rock outcrop
AZ697	142	rock outcrop
AZ697	144	torriorthents
AZ697	145	haplocambids
AZ697	146	rock outcrop
AZ697	155	urban land
AZ697	156	rock outcrop
AZ697	158	rock outcrop
AZ697	162	rock outcrop
AZ697	163	rock outcrop
AZ697	164	water
AZ697	169	rock outcrop
AZ697	170	rock outcrop
AZ699	10	rock outcrop
AZ699	18	rock outcrop
AZ699	23	rock outcrop
AZ699	33	rock outcrop
AZ699	36	rock outcrop
AZ699	38	rock outcrop
AZ699	39	rock outcrop
AZ699	43	rock outcrop
AZ699	47	rock outcrop
AZ699	52	rock outcrop
AZ699	54	rock outcrop
AZ699	55	rock outcrop
AZ699	57	rock outcrop
AZ699	59	rock outcrop
AZ699	60	water
AZ701	3	argic petrocalcids

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ701	4	aridic haplustalfs
AZ701	5	aridic haplustepts
AZ701	6	aridic lithic ustorthents
AZ701	10	rock outcrop
AZ701	14	calcic petrocalcids
AZ701	15	calcic petrocalcids
AZ701	16	calcic petrocalcids
AZ701	17	calcic petrocalcids
AZ701	20	lava flows
AZ701	33	rock outcrop
AZ701	39	rock outcrop
AZ701	40	fluvaquents
AZ701	41	fluvaquents
AZ701	46	rock outcrop
AZ701	48	rock outcrop
AZ701	56	rock outcrop
AZ701	57	lava flows
AZ701	58	lithic haplargids
AZ701	59	lithic haplargids
AZ701	60	lava flows
AZ701	61	lithic haplocalcids
AZ701	62	lithic haplocalcids
AZ701	63	lithic haplargids
AZ701	64	lava flows
AZ701	65	lithic haplustolls
AZ701	66	lithic calciargids
AZ701	67	lithic calciargids
AZ701	68	lithic torriorthents
AZ701	69	lithic torriorthents
AZ701	70	lithic torriorthents
AZ701	71	lithic torriorthents
AZ701	72	lithic ustic torriorthents
AZ701	73	lithic ustic torriorthents
AZ701	74	lithic ustic torriorthents
AZ701	80	rock outcrop
AZ701	82	rock outcrop
AZ701	88	orthents
AZ701	90	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ701	101	rock outcrop
AZ701	102	rock outcrop
AZ701	103	lithic torriorthents
AZ701	105	lithic torriorthents
AZ701	106	lithic torriorthents
AZ701	110	lithic torriorthents
AZ701	111	lithic ustic torriorthents
AZ701	112	lithic ustic torriorthents
AZ701	113	rock outcrop
AZ701	114	rock outcrop
AZ701	115	lithic torriorthents
AZ701	119	rock outcrop
AZ701	120	rock outcrop
AZ701	126	lava flows
AZ701	127	haplogypsids
AZ701	128	lithic haplargids
AZ701	129	rock outcrop
AZ701	134	lava flows
AZ701	135	typic haplocalcids
AZ701	136	typic haplocalcids
AZ701	138	typic haplocalcids
AZ701	139	typic haplocalcids
AZ701	140	typic haplogypsids
AZ701	141	haplogypsids
AZ701	142	rock outcrop
AZ701	143	typic torrifluvents
AZ701	144	typic torrifluvents
AZ701	145	typic torrifluvents
AZ701	147	typic torriorthents
AZ701	148	typic haplogypsids
AZ701	149	lava flows
AZ701	150	ustic haplocalcids
AZ701	151	rock outcrop
AZ701	152	ustic haplocambids
AZ701	153	ustic haplocambids
AZ701	154	badlands
AZ701	155	ustic torriorthents
AZ701	156	ustic torriorthents

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
AZ701	157	ustic torriorthents
AZ701	158	lithic ustic haplargids
AZ701	160	vitrandic haplocalcids
AZ701	161	vitrandic haplocalcids
AZ701	162	water
AZ701	165	rock outcrop
AZ701	166	rock outcrop
AZ701	171	rock outcrop
AZ701	172	rock outcrop
AZ701	173	rock outcrop
AZ701	174	rock outcrop
AZ701	175	rock outcrop
AZ701	176	rock outcrop
NV608	BD	badland
NV608	BHC	badland
NV608	BLB	badland
NV608	BP	pits
NV608	BSG	rock outcrop
NV608	BZF	rock outcrop
NV608	GHF	rock outcrop
NV608	GP	pits
NV608	HHD	rock outcrop
NV608	HUF	badland
NV608	MAE	rock outcrop
NV608	MBG	badland
NV608	PME	rock outcrop
NV608	RBG	rock outcrop
NV608	RHF	rock outcrop
NV608	Ri	water
NV608	RME	rock land
NV608	RTF	rock land
NV608	SEG	rock outcrop
NV608	STE	rock outcrop
NV608	Ty	badland
NV608	USE	badland
NV608	UWD	badland
NV608	VFG	rock outcrop
NV608	W	water

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
NV608	WHE	badland
NV608	ZAG	rock outcrop
NV713	1173	rock outcrop
NV713	1182	rock outcrop
NV713	1364	rock outcrop
NV713	1460	rock outcrop
NV713	1464	rock outcrop
NV713	1539	badlands
NV713	1542	badlands
NV713	1544	badlands
NV713	1704	rock outcrop
NV713	1706	rock outcrop
NV713	1825	rock outcrop
NV713	1828	rock outcrop
NV713	1829	rock outcrop
NV713	1898	rock outcrop
NV713	1922	rock outcrop
NV713	1924	rock outcrop
NV713	1994	rock outcrop
NV713	1998	rock outcrop
NV713	2010	rock outcrop
NV713	2011	rock outcrop
NV713	2129	rock outcrop
NV713	2130	rock outcrop
NV713	2132	rock outcrop
NV713	3674	rock outcrop
NV754	1040	rock outcrop
NV754	1060	rock outcrop
NV754	1061	rock outcrop
NV754	1063	rock outcrop
NV754	1065	rock outcrop
NV754	1066	rock outcrop
NV754	1110	rock outcrop
NV754	1270	rock outcrop
NV754	1420	rock outcrop
NV754	1430	badland
NV754	1570	rock outcrop
NV754	1810	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
NV754	1833	rock outcrop
NV754	1890	rock outcrop
NV754	1920	rock outcrop
NV754	1990	rock outcrop
NV754	1992	rock outcrop
NV754	1993	rock outcrop
NV754	1994	rock outcrop
NV754	1998	rock outcrop
NV754	2011	rock outcrop
NV754	2129	rock outcrop
NV755	100	rock outcrop
NV755	105	rock outcrop
NV755	106	rock outcrop
NV755	115	badland
NV755	134	rock outcrop
NV755	140	rock outcrop
NV755	141	rock outcrop
NV755	144	rock outcrop
NV755	165	badland
NV755	167	badland
NV755	175	rock outcrop
NV755	176	rock outcrop
NV755	178	rock outcrop
NV755	205	badland
NV755	207	badland
NV755	225	badland
NV755	226	badland
NV755	228	badland
NV755	232	badland
NV755	235	badland
NV755	241	rock outcrop
NV755	255	rock outcrop
NV755	270	rock outcrop
NV755	271	rock outcrop
NV755	272	rock outcrop
NV755	288	badland
NV755	289	badland
NV755	290	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
NV755	298	rock outcrop
NV755	320	rock outcrop
NV755	321	rock outcrop
NV755	330	badland
NV755	335	rock outcrop
NV755	340	rock outcrop
NV755	341	rock outcrop
NV755	343	rock outcrop
NV755	351	rock outcrop
NV755	360	badland
NV755	365	badland
NV755	375	rock outcrop
NV755	376	rock outcrop
NV755	405	water
NV755	415	rock outcrop
NV755	460	badland
NV755	475	badland
NV755	477	badland
NV755	478	badland
NV755	501	dams
NV755	504	pits
NV755	506	dumps
NV755	508	dumps
NV755	520	rock outcrop
NV755	521	rock outcrop
NV755	522	rock outcrop
NV755	530	rock outcrop
NV755	531	rock outcrop
NV755	532	rock outcrop
NV755	535	rock outcrop
NV755	540	rock outcrop
NV755	541	rock outcrop
NV755	542	badland
NV755	552	rock outcrop
NV755	560	rock outcrop
NV755	565	badland
NV755	603	rock outcrop
NV755	604	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
NV755	605	badland
NV755	606	rock outcrop
NV755	610	rock outcrop
NV755	612	rock outcrop
NV755	613	rock outcrop
NV755	640	rock outcrop
NV755	645	rock outcrop
NV755	646	rock outcrop
NV755	670	rock outcrop
NV755	673	rock outcrop
NV755	750	rock outcrop
NV755	751	rock outcrop
NV755	753	rock outcrop
NV755	810	rock outcrop
NV755	820	rock outcrop
NV755	821	rock outcrop
NV755	833	rock outcrop
NV755	900	urban land
NV755	911	badland
NV755	930	badland
NV755	940	rock outcrop
NV755	951	badland
NV755	952	badland
NV755	955	badland
NV755	965	badland
NV755	981	rock outcrop
NV755	982	rock outcrop
NV755	998	miscellaneous water
NV755	999	water
UT	s351	rock outcrop
UT	s362	cinder land
UT	s5563	rock outcrop
UT	s5598	rock outcrop
UT	s8173	rock outcrop
UT	s8175	rock outcrop
UT	s8176	rock outcrop
UT	s8179	rock outcrop
UT	s8185	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
UT	s8186	rock outcrop
UT	s8187	cinder land
UT	s8194	rock outcrop
UT	s8195	rock outcrop
UT	s8196	rock outcrop
UT	s8197	rock outcrop
UT	s8198	rock outcrop
UT	s8201	rock outcrop
UT	s8209	rock outcrop
UT	s8217	rock outcrop
UT	s8218	rock outcrop
UT	s8219	rock outcrop
UT	s8232	rock outcrop
UT	s8233	badland
UT	s8234	badland
UT	s8235	badland
UT634	313	badland
UT634	314	badland
UT634	319	rock outcrop
UT634	330	blown out land
UT634	332	blown out land
UT634	347	rock outcrop
UT634	348	rock outcrop
UT634	350	cinder land
UT634	377	poorly drained soils
UT634	403	lava flows
UT634	426	rock outcrop
UT634	429	rock outcrop
UT634	442	rock outcrop
UT634	448	dumps
UT634	459	rock outcrop
UT634	467	badland
UT634	493	rock outcrop
UT634	495	rock outcrop
UT634	496	rock outcrop
UT634	497	rock outcrop
UT634	502	rock outcrop
UT634	510	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
UT634	518	water
UT634	1364	rock outcrop
UT636	8	badland
UT636	9	badland
UT636	16	rock outcrop
UT636	34	rock outcrop
UT636	37	alldown clay
UT636	39	rock outcrop
UT636	43	alldown clay
UT636	53	rock outcrop
UT636	54	alldown clay
UT636	55	alldown clay
UT636	72	alldown clay
UT636	75	lava flows
UT636	76	badland
UT636	77	ahlstrom silt
UT636	78	ahlstrom silt
UT636	79	rock outcrop
UT636	80	alldown clay
UT636	105	rock outcrop
UT636	107	limestone rock outcrop
UT636	110	limestone rock outcrop
UT636	111	limestone rock outcrop
UT636	115	rock outcrop
UT636	116	rock outcrop
UT636	122	rock outcrop
UT636	124	rubble land
UT636	126	rock outcrop
UT636	129	rock outcrop
UT636	130	limestone rock outcrop
UT636	135	rock outcrop
UT636	138	rock outcrop
UT636	140	rock outcrop
UT636	144	lava flows
UT636	145	rock outcrop
UT636	149	rock outcrop
UT636	157	rock outcrop
UT636	158	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
UT636	159	rock outcrop
UT636	162	badland
UT636	163	badland
UT636	173	rock outcrop
UT636	174	water
UT636	175	pits gravel
UT636	177	miscellaneous water
UT641	1922	rock outcrop
UT641	BA	badland
UT641	BB	badland
UT641	BF	rock land
UT641	BP	borrow pits
UT641	CI	cinder land
UT641	CUF	rock outcrop
UT641	DU	dune land
UT641	EA	eroded land
UT641	EB	eroded land
UT641	GA	gullied land
UT641	GP	gravel pit
UT641	HD	rock land
UT641	HG	rock land
UT641	LA	lava flows
UT641	MBG	rock outcrop
UT641	MEG	rock outcrop
UT641	MOG	rock outcrop
UT641	PKE	rock outcrop
UT641	RE	rock land
UT641	RO	rock land
UT641	RP	rock land
UT641	RR	rock land
UT641	RT	rock outcrop
UT641	RU	rough broken land
UT641	SY	stony colluvial land
UT641	TG	rock land
UT641	W	water
UT641	WCF	rock outcrop
UT686	5004	rock outcrop
UT686	5007	rock outcrop

Table D.4 List of miscellaneous component soils within the study area

NRCS Soil Survey	SMU	Miscellaneous Component Soil
(1)	(2)	(3)
UT686	5011	badland
UT686	5020	rock outcrop
UT686	5026	rock outcrop
UT686	5027	badland
UT686	5029	rock outcrop
UT686	5038	rock outcrop
UT686	5087	rock outcrop
UT686	5095	rock outcrop
UT686	5096	rock outcrop
UT686	5102	badland
UT686	5105	rock outcrop
UT686	5106	badland
UT686	5117	badland
UT686	5118	rock outcrop
UT686	5121	riverwash
UT686	5137	rock outcrop
UT686	5149	rock outcrop
UT686	5150	badland
UT686	5158	rock outcrop
UT686	5164	badland
UT686	5169	rock outcrop
UT686	5180	rock outcrop
UT686	5182	rock outcrop
UT686	5183	rock outcrop
UT686	5190	rock outcrop
UT686	5191	rock outcrop
UT686	5192	rock outcrop
UT686	5207	riverwash
UT686	5210	hetz

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10 t0 20 inches deep over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
10 to 20 inches deep over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
20 t0 40 inches deep over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
20 to 40 inches deep	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
20 to 40 inches deep over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
20 to 60 inches deep over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
40 to 60 inches deep over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
40 to 60 inches deep over hardpan soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
40 to 60 inches over bedrock soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes
abela	UT634		sandy loam	No	0.8	1.92	1.24	Yes
acord	UT634		loam	No	0.5	0.61	0.31	Yes
ahlstrom silt	Description		Silt	No	0.20	0.80	0.43	Yes
alhstrom	Ahlstrom		silt	No	0.2	0.8	0.43	Yes
alldowm clay	Description		Clay	No	0.02	0.04	0.01	Yes
alldown	UT636		clay loam	No	0.08	0.17	0.07	Yes
alldown alkali loam	Description		Clay	No	0.02	0.04	0.01	Yes
alldown clay	Description		Clay	No	0.02	0.04	0.01	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
alluvial land	Engineering judgement		Silt	No	0.20	0.80	0.43	Yes
anabella	UT634		loam	No	0.5	0.61	0.31	Yes
andys	UT636		loam	No	0.5	0.61	0.31	Yes
andys loam	Description		loam	No	0.5	0.61	0.31	Yes
aned	UT634		sandy loam	No	0.8	1.92	1.24	Yes
annabella	UT634		loam	No	0.5	0.61	0.31	Yes
antelope	UT634		loam	No	0.5	0.61	0.31	Yes
antelope springs	UT634		silt loam	No	0.3	0.63	0.32	Yes
aquents	NRCS Soil Taxonomy Handbook	Entisols, pg 138	Sand	No	4.60	4.03	3.12	Yes
aquic argiustolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 174	Silt loam	No	0.30	0.63	0.32	Yes
aquic haplustolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 147	Silt loam	No	0.30	0.63	0.32	Yes
aquic ustipsamments	NRCS Soil Taxonomy Handbook	Entisols, pg 139	Sand	No	4.60	4.03	3.12	Yes
aquolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 144	Silt loam	No	0.30	0.63	0.32	Yes
arabrab	UT686		loamy sand	No	2.4	3.6	2.71	Yes
arches	UT686		sandy loam	No	0.8	1.92	1.24	Yes
arches family	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
ardnas	UT634		loam	No	0.5	0.61	0.31	Yes
arents earthen dam	Engineering judgement	Entisols	Sand	No	4.60	4.03	3.12	Yes
argic petrocalcids	NV755		Loam	No	0.50	0.61	0.31	Yes
argillic horizon soils	Google		clay	No	0.02	0.04	0.01	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
aridic argiustolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 174	Silt loam	No	0.30	0.63	0.32	Yes
aridic haplustalfs	AZ		Loam	No	0.50	0.61	0.31	Yes
aridic haplustepts	NRCS Soil Taxonomy Handbook	Inceptisols, pg 143	Sandy clay loam	No	0.12	0.44	0.21	Yes
aridic lithic ustorthents	NRCS Soil Taxonomy Handbook	Entisols, pg 140	Sand	No	4.60	4.03	3.12	Yes
aridic ustorthents	Engineering judgment		loamy sand	No	2.4	3.6	2.71	Yes
arnas	UT634		loam	No	0.5	0.61	0.31	Yes
ashdown	UT634		silt loam	No	0.3	0.63	0.32	Yes
atrac	UT686		sandy loam	No	0.8	1.92	1.24	Yes
badland	AZ, UT, NV713		loam	No	0.50	0.61	0.31	Yes
badland very steep	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
badlands	AZ, UT, AZ701		loam	No	0.50	0.61	0.31	Yes
baird hollow	UT634		loam	No	0.5	0.61	0.31	Yes
baldfield	UT636		clay	No	0.02	0.04	0.01	Yes
baldfield clay	Description		clay	No	0.02	0.04	0.01	Yes
baldfield family	UT686		clay	No	0.02	0.04	0.01	Yes
bamos	UT634		loam	No	0.5	0.61	0.31	Yes
bandag	UT634		loam	No	0.5	0.61	0.31	Yes
bannion	UT634		sandy loam	No	0.8	1.92	1.24	Yes
barx	UT636		sandy clay loam	No	0.12	0.44	0.21	Yes
bayfield	UT636		clay	No	0.02	0.04	0.01	Yes
befar	UT636		clay	No	0.02	0.04	0.01	Yes
befar	UT636		clay	No	0.02	0.04	0.01	Yes
behanim	Behanin		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
behanin	UT636		loam	No	0.5	0.61	0.31	Yes
berent	UT634		loamy sand	No	2.4	3.6	2.71	Yes
bermesa	UT641		loamy sand	No	2.4	3.6	2.71	Yes
beron	UT634		sandy loam	No	0.8	1.92	1.24	Yes
beryl	UT634		sandy loam	No	0.8	1.92	1.24	Yes
bess	UT634		sandy loam	No	0.8	1.92	1.24	Yes
bibleqprings	UT634		sandy loam	No	0.8	1.92	1.24	Yes
biblesprings	UT634		loam	No	0.5	0.61	0.31	Yes
bigpack	UT686		clay loam	No	0.08	0.17	0.07	Yes
billings	UT686		clay loam	No	0.08	0.17	0.07	Yes
birdow	UT634		loam	No	0.5	0.61	0.31	Yes
bispen	UT686		sand	No	4.6	4.03	3.12	Yes
blown out land	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
blown-out land	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
bluegyp	Engineering judgement	Aridisols, pg 137	Silt loam	No	0.30	0.63	0.32	Yes
bodacious	UT634		loam	No	0.5	0.61	0.31	Yes
bodot	UT686		silty clay	No	0.04	0.15	0.06	Yes
bodot family	UT686		silty clay	No	0.04	0.15	0.06	Yes
bond	UT641		sandy loam	No	0.8	1.92	1.24	Yes
borohemists ponded	NRCS Soil Taxonomy Handbook	Histosols, pg 142	Loam	No	0.50	0.61	0.31	Yes
borolic natrargids	ADOT		clay	No	0.02	0.04	0.01	Yes
borollic natragrids	ADOT		clay	No	0.02	0.04	0.01	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
borrow pit	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
borrow pits	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
bowdish family	UT686		loam	No	0.5	0.61	0.31	Yes
bracken	NRCS ksat		Sandy loam	No	0.80	1.92	1.24	Yes
braffits	UT634		loam	No	0.5	0.61	0.31	Yes
briefly flooded soils	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
broncho	UT636		sandy loam	No	0.8	1.92	1.24	Yes
bruman	UT636		loam	No	0.5	0.61	0.31	Yes
brumley	UT686		sandy loam	No	0.8	1.92	1.24	Yes
brycan	UT636		sandy loam	No	0.8	1.92	1.24	Yes
budland	UT641		sandy loam	No	0.8	1.92	1.24	Yes
bullion	UT634		silt loam	No	0.3	0.63	0.32	Yes
bushvalley	UT634		loam	No	0.5	0.61	0.31	Yes
cabinpine	Google		sand	No	4.6	4.03	3.12	Yes
calcic petrocalcids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
calciorthids	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
calcross	UT634		silty clay loam	No	0.08	0.23	0.10	Yes
callings	UT636		loam	No	0.5	0.61	0.31	Yes
cannonville	UT636		clay	No	0.02	0.04	0.01	Yes
cannonville clay	Description		clay	No	0.02	0.04	0.01	Yes
cannonville family	UT686		clay	No	0.02	0.04	0.01	Yes
cannonville member entrada formation badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
cannonville very stony clay	Description		clay	No	0.02	0.04	0.01	Yes
carbonate subsoils	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
carmel and entrada formation badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
carmel formation badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
carmel formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
castino	UT636		silt loam	No	0.3	0.63	0.32	Yes
castino extremely cobbly loam	Description		Loam	No	0.5	0.61	0.31	Yes
castino gravelly silt loam	Description		silt loam	No	0.3	0.63	0.32	Yes
catahoula	UT686		loam	No	0.5	0.61	0.31	Yes
catahoula family	UT686		loam	No	0.5	0.61	0.31	Yes
caval	UT641		sandy loam	No	0.8	1.92	1.24	Yes
cave	AZ637		Sandy loam	No	0.80	1.92	1.24	Yes
cavel	UT641		sandy loam	No	0.8	1.92	1.24	Yes
charkiln	NV755		sandy loam	No	0.8	1.92	1.24	Yes
check canyon	UT634		loam	No	0.5	0.61	0.31	Yes
checkett	UT634		loam	No	0.5	0.61	0.31	Yes
chilton	UT641		loam	No	0.5	0.61	0.31	Yes
chinle formation badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
chipeta	UT686		silty clay loam	No	0.08	0.23	0.10	Yes
cinder land	AZ, UT		Sand	No	4.60	4.03	3.12	Yes
circleville	UT636		clay loam	No	0.08	0.17	0.07	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
clapper	UT686		loam	No	0.5	0.61	0.31	Yes
clapper cobbly loam	Description		Loam	No	0.5	0.61	0.31	Yes
clay subsoils	UT634		loam	No	0.5	0.61	0.31	Yes
clayey aridic ustorthents	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
clayey lithic haplustalfs	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
clayey lithic ustic haplargids	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
clayey shallow aridic ustorthents	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
clovis	UT641		sandy loam	No	0.8	1.92	1.24	Yes
coarse textured soils	ADOT		Sandy loam	No	0.8	1.92	1.24	Yes
coarse-loamy torrifluvents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
coarse-loamy typic haplustalfs	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
coarse-loamy ustic calciargids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
coarse-loamy ustic haplargids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
coarse-loamy ustic haplocalcids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
coarse-loamy ustic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
cobbly clay loam soils	Engineering judgment		clay loam	No	0.08	0.17	0.07	Yes
codely silt	Description		Silt	No	0.2	0.8	0.43	Yes
codley	UT636		silt loam	No	0.3	0.63	0.32	Yes
collbran	UT641		clay loam	No	0.08	0.17	0.07	Yes
colskel family	UT686		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
comodore	UT636		clay loam	No	0.08	0.17	0.07	Yes
crestline	UT636		sandy loam	No	0.8	1.92	1.24	Yes
cryaquents	NRCS Soil Taxonomy Handbook	Entisols, pg 138	Sand	No	4.60	4.03	3.12	Yes
cryaquolls loamy-skeletal	NRCS Soil Taxonomy Handbook	Mollisols, pg 144	Silt loam	No	0.30	0.63	0.32	Yes
cryofibrists	NRCS Soil Taxonomy Handbook	Histosols, pg 141	Loam	No	0.50	0.61	0.31	Yes
cryohemists	NRCS Soil Taxonomy Handbook	Histosols, pg 142	Loam	No	0.50	0.61	0.31	Yes
cumulic haplaquolls	Engineering judgement	Mollisols, aquolls	Silt loam	No	0.30	0.63	0.32	Yes
curecanti	UT686		loam	No	0.5	0.61	0.31	Yes
curecanti family	UT686		loam	No	0.5	0.61	0.31	Yes
curhollow	UT641		sandy loam	No	0.8	1.92	1.24	Yes
dag flat	UT641		sandy loam	No	0.8	1.92	1.24	Yes
daklos	UT686		loam	No	0.5	0.61	0.31	Yes
dakota and morrison formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
dakota formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
dalcan	UT636		clay loam	No	0.08	0.17	0.07	Yes
dam	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
dams	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
decca	UT634		sandy loam	No	0.8	1.92	1.24	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
deep clay in dperssional areas	Description		Clay	No	0.02	0.04	0.01	Yes
deep grayish brown very stony loam	Description		Loam	No	0.5	0.61	0.31	Yes
deep sandy soils that have a subsoil of calcareous loam	ADOT		Sandy loam	No	0.8	1.92	1.24	Yes
deep soils	UT641		loam	No	0.5	0.61	0.31	Yes
deep soils similar to andys	Andys		Loam	No	0.5	0.61	0.31	Yes
deep very gravelly loam soils	UT641		loam	No	0.5	0.61	0.31	Yes
deerlodge	UT634		loam	No	0.5	0.61	0.31	Yes
denied access	Engineering judgement		Loam	No	0.50	0.61	0.31	Yes
denmard	UT634		loam	No	0.5	0.61	0.31	Yes
denmark	UT634		loam	No	0.5	0.61	0.31	Yes
dennot	UT634		loam	No	0.5	0.61	0.31	Yes
denpark	UT634		loam	No	0.5	0.61	0.31	Yes
descot	UT636		sandy loam	No	0.8	1.92	1.24	Yes
detra	UT634		loam	No	0.5	0.61	0.31	Yes
detra	UT641		sandy loam	No	0.8	1.92	1.24	Yes
dient	UT686		sandy clay loam	No	0.12	0.44	0.21	Yes
dient family	UT686		sandy clay loam	No	0.12	0.44	0.21	Yes
dimyaw family soil	ADOT		Silty clay	No	0.04	0.15	0.06	Yes
dixie	UT634		loam	No	0.5	0.61	0.31	Yes
doyce	UT634		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
dumps	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
dune land	AZ, UT		Sand	No	4.60	4.03	3.12	Yes
earlweed	UT686		loamy sand	No	2.4	3.6	2.71	Yes
earlweed family	UT686		loamy sand	No	2.4	3.6	2.71	Yes
elenore	UT634		loam	No	0.5	0.61	0.31	Yes
elias	UT686		sandy loam	No	0.8	1.92	1.24	Yes
elledge family	AZ701		sandy loam	No	0.8	1.92	1.24	Yes
emlin	UT686		loam	No	0.5	0.61	0.25	Yes
endoaquolls	Engineering judgement	Inceptisols, Xerepts, pgs 142, 491	Silt loam	No	0.30	0.63	0.32	Yes
entrada and carmel formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
entrada sandstone rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
eroded land	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
escalante	UT634		sandy loam	No	0.8	1.92	1.24	Yes
esplin	UT641		loam	No	0.5	0.61	0.31	Yes
ess	UT636		sandy loam	No	0.8	1.92	1.24	Yes
evanston	UT636		loam	No	0.5	0.61	0.31	Yes
evpark	UT686		sandy loam	No	0.8	1.92	1.24	Yes
evpark family	UT686		sandy loam	No	0.8	1.92	1.24	Yes
excalante	UT634		loam	No	0.5	0.61	0.31	Yes
faim	UT634		clay loam	No	0.08	0.17	0.07	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
festus	UT634		sandy loam	No	0.8	1.92	1.24	Yes
fewtus	UT634		sandy loam	No	0.8	1.92	1.24	Yes
filoa	UT636		loam	No	0.5	0.61	0.31	Yes
fine textured soils	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
fine-loamy aridic ustorthents	Engineering judgment	Google	loam	No	0.5	0.61	0.31	Yes
fine-loamy typic torriorthents	Engineering judgment	Google	loam	No	0.5	0.61	0.31	Yes
fine-loamy ustic haplocalcids	Engineering judgment	Structure and Function of a Chihuahuan Desert Ecosystem	loam	No	0.5	0.61	0.31	Yes
fine-loamy ustic torriorthents	Engineering judgment	NV755, UT, AZ701	loam	No	0.5	0.61	0.31	Yes
fluvaquentic haplaquoll	Engineering judgement	Mollisols, aquolls, pgs 147, 557	Silt loam	No	0.30	0.63	0.32	Yes
fluvaquentic haplaquolls	Engineering judgement	Mollisols, aquolls, pgs 147, 557	Silt loam	No	0.30	0.63	0.32	Yes
fluvaquentic haplustoll	NRCS Soil Taxonomy Handbook	Mollisols, pgs 147, 557	Silt loam	No	0.30	0.63	0.32	Yes
fluvaquentic haplustolls	NRCS Soil Taxonomy Handbook	Mollisols, pgs 147, 557	Silt loam	No	0.30	0.63	0.32	Yes
fluvaquents	UT641		Sand	No	4.60	4.03	3.12	Yes
fluvaquents frequently flooded	UT641		Sand	No	4.60	4.03	3.12	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
fluvents	Engineering judgment	Google	silt	No	0.2	0.8	0.43	Yes
frandsen	UT636		clay loam	No	0.08	0.17	0.07	Yes
frigid soils	UT634		loam	No	0.5	0.61	0.31	Yes
fughes	UT634		loam	No	0.5	0.61	0.31	Yes
garbo	UT634		sandy loam	No	0.8	1.92	1.24	Yes
gerst family	UT686		loam	No	0.5	0.61	0.31	Yes
gomine	UT634		loam	No	0.5	0.61	0.31	Yes
gravel piet	UT634		loam	No	0.5	0.61	0.31	Yes
gravel pit	Engineering judgement		Sand	No	4.60	4.03	3.12	Yes
gravelly alluvial land	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
gravelly fine textured soil	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
gravelly sandy loam soils	UT634		sandy loam	No	0.8	1.92	1.24	Yes
gravelly soils	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
gravelly throughout soils	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
green river	UT686		sandy loam	No	0.8	1.92	1.24	Yes
greengrove	OSDs		sandy loam	No	0.8	1.92	1.24	Yes
greenhalgh	UT636		silt loam	No	0.3	0.63	0.32	Yes
greenhalgh silt	Description		Silt	No	0.2	0.8	0.43	Yes
grimm	UT636		sandy loam	No	0.8	1.92	1.24	Yes
guben	UT636		loam	No	0.5	0.61	0.31	Yes
guben gravelly loam	Description		Loam	No	0.5	0.61	0.31	Yes
gullied land	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
gypsids	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes
gypsids shallow	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes
gypsiorthids	Engineering judgement		Sandy clay loam	No	0.12	0.44	0.21	Yes
gypsum land	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes
hanksville	UT686		silty clay loam	No	0.08	0.23	0.10	Yes
hanksville family	UT686		silty clay loam	No	0.08	0.23	0.10	Yes
hantz	UT641		silty clay loam	No	0.08	0.23	0.10	Yes
haplaquolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 144	Silt loam	No	0.30	0.63	0.32	Yes
haplocalcids	NV755, AZ701		Loam	No	0.50	0.61	0.31	Yes
haplocambids	NRCS Soil Taxonomy Handbook	Aridisols, pg 138	Sandy clay loam	No	0.12	0.44	0.21	Yes
haplofibrists	NRCS Soil Taxonomy Handbook	Histosols, pg 141	Loam	No	0.50	0.61	0.31	Yes
haplogypsids	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes
hardpan soils	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
hardpan soils	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
harol	UT636		clay loam	No	0.08	0.17	0.07	Yes
harrisburg	UT641		sandy loam	No	0.8	1.92	1.24	Yes
hatch	UT636		clay loam	No	0.08	0.17	0.07	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
hatu	UT634		silty clay	No	0.04	0.15	0.06	Yes
haulings	Engineering judgement		loam	No	0.50	0.61	0.31	Yes
henreville	henreville		Loam	No	0.5	0.61	0.31	Yes
henrieville	UT636		loam	No	0.5	0.61	0.31	Yes
henriville sandy loam	Description		Sandy loam	No	0.8	1.92	1.24	Yes
hetz	UT686		Sandy loam	No	0.80	1.92	1.24	Yes
hiko peak	UT634		sandy loam	No	0.8	1.92	1.24	Yes
hiko springs	OSDs		Sandy loam	No	0.8	1.92	1.24	Yes
hillburn family	UT686		sandy loam	No	0.8	1.92	1.24	Yes
hobog	UT641		loam	No	0.5	0.61	0.31	Yes
hogg	UT641		sandy loam	No	0.8	1.92	1.24	Yes
honlu	OSDs		Loam	No	0.5	0.61	0.31	Yes
hoodle	UT636		loam	No	0.5	0.61	0.31	Yes
horsemountain family	UT686		sandy loam	No	0.8	1.92	1.24	Yes
hoye	UT634		sandy loam	No	0.8	1.92	1.24	Yes
humbug	UT686		sandy loam	No	0.8	1.92	1.24	Yes
ikit	UT634		loam	No	0.5	0.61	0.31	Yes
intermittent water	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
ipson	UT636		loam	No	0.5	0.61	0.31	Yes
ironco	UT634		loam	No	0.5	0.61	0.31	Yes
isom	UT641		sandy loam	No	0.8	1.92	1.24	Yes
ivins	UT641		loamy sand	No	2.4	3.6	2.71	Yes
jigsaw	UT634		silty clay loam	No	0.08	0.23	0.10	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
jodero	UT636		loam	No	0.5	0.61	0.31	Yes
jodero loam	Description		Loam	No	0.5	0.61	0.31	Yes
junction	UT641		sandy loam	No	0.8	1.92	1.24	Yes
junkett	UT634		sandy loam	No	0.8	1.92	1.24	Yes
kaiparowits	AZ701		loam	No	0.5	0.61	0.31	Yes
kanabownits	AZ701		sandy loam	No	0.8	1.92	1.24	Yes
kanarra	UT634		sandy clay loam	No	0.12	0.44	0.21	Yes
kayenta formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
kenzo family	UT686		loam	No	0.5	0.61	0.31	Yes
kinesava	UT641		sandy loam	No	0.8	1.92	1.24	Yes
kinghorn	UT634		loam	No	0.5	0.61	0.31	Yes
kippers	AZ701		loam	No	0.5	0.61	0.31	Yes
kjar	Engineering judgement		Silty clay loam	No	0.08	0.23	0.10	Yes
kolob	UT634		loam	No	0.5	0.61	0.31	Yes
kolob	UT641		sandy loam	No	0.8	1.92	1.24	Yes
krudger	UT634		loam	No	0.5	0.61	0.31	Yes
kruegar	UT634		loam	No	0.5	0.61	0.31	Yes
krueger	UT634		loam	No	0.5	0.61	0.31	Yes
kruger	UT634		loam	No	0.5	0.61	0.31	Yes
kunz	UT634		sandy loam	No	0.8	1.92	1.24	Yes
ladyofsnow	NV755		siltloam	No	0.3	0.63	0.32	Yes
lagnaf	UT634		loam	No	0.5	0.61	0.31	Yes
las	muname		Loamy sand	No	2.40	3.60	2.71	Yes
lava	UT634		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
lava flows	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
lavate	UT641		sandy loam	No	0.8	1.92	1.24	Yes
laverkin	UT641		silty clay loam	No	0.08	0.23	0.10	Yes
lazear	UT636		loam	No	0.5	0.61	0.31	Yes
leeds	UT641		silty clay loam	No	0.08	0.23	0.10	Yes
lemrac	UT686		silt loam	No	0.3	0.63	0.32	Yes
less steep soils	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
levee	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
limestone rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
lithic calciargids	NRCS Soil Taxonomy Handbook		Loam	No	0.50	0.61	0.31	Yes
lithic haplargids	NV755		Loam	No	0.50	0.61	0.31	Yes
lithic haplocalcids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
lithic haplocambids	NRCS Soil Taxonomy Handbook	Aridisols, pg 138	Sandy clay loam	No	0.12	0.44	0.21	Yes
lithic haplustalfs	AZ		Clay loam	No	0.08	0.17	0.07	Yes
lithic haplustolls	AZ		Loam	No	0.50	0.61	0.31	Yes
lithic hapustalfs	lithic haplustalfs	Google	clay loam	No	0.08	0.17	0.07	Yes
lithic torriorthents	AZ, UT		Sandy loam	No	0.80	1.92	1.24	Yes
lithic torripsamments	Engineering judgment	Google	sandy loam	No	0.8	1.92	1.24	Yes
lithic ustic haplargids	NV755		Loam	No	0.50	0.61	0.31	Yes
lithic ustic haplocalcids	Engineering judgment	Google	silt	No	0.2	0.8	0.43	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
lithic ustic torriorthents	NV755		Loam	No	0.50	0.61	0.31	Yes
lithic ustorthents	lithic ustic torriorthents	NV755, UT, AZ701	loam	No	0.5	0.61	0.31	Yes
lithic ustorthents family	NRCS Soil Taxonomy Handbook	Entisols,140	Sand	No	4.60	4.03	3.12	Yes
loam	Description		Loam	No	0.5	0.61	0.31	Yes
loam or silt loam soils	UT634		loam	No	0.5	0.61	0.31	Yes
loamy alluvial land	Engineering judgement		Loam	No	0.50	0.61	0.31	Yes
loamy lithic calciargids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy lithic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy lithic ustic haplargids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy lithic ustic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy shallow typic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy typic torrifluvents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal calcidic haplustalfs	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal lithic ustic haplargids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal lithic ustic haplocalcids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal lithic ustic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
loamy-skeletal shallow ustic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal torrifluvents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal ustic haplocalcids	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletal ustic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
loamy-skeletel lithic torriorthents	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
lorhunt	UT634		loam	No	0.5	0.61	0.31	Yes
losee	UT636		clay loam	No	0.08	0.17	0.07	Yes
losee gravelly	OSDs		Loam	No	0.5	0.61	0.31	Yes
losee gravelly loam	Description		Loam	No	0.5	0.61	0.31	Yes
losee gravelly sandy loam	Description		sandy loam	No	0.8	1.92	1.24	Yes
lucero	UT634		loam	No	0.5	0.61	0.31	Yes
luhon	UT636		loam	No	0.5	0.61	0.31	Yes
mack	UT686		loamy sand	No	2.4	3.6	2.71	Yes
magotsu	UT641		loam	No	0.5	0.61	0.31	Yes
manderfield	UT634		sandy loam	No	0.8	1.92	1.24	Yes
manderfiels	UT634		sandy loam	No	0.8	1.92	1.24	Yes
manselo	UT634		loam	No	0.5	0.61	0.31	Yes
marshes	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
maryjane	NV755		loam	No	0.5	0.61	0.31	Yes
mathis	UT641		loamy sand	No	2.4	3.6	2.71	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
medburn	UT634		sandy loam	No	0.8	1.92	1.24	Yes
medium textured gravelly soils	Engineering judgement		Loam	No	0.5	0.61	0.31	Yes
medium textured soils taht have a loam surface	Description		Loam	No	0.5	0.61	0.31	Yes
medium textured soils that have a loam surface	UT636		loam	No	0.5	0.61	0.31	Yes
mellenthin	UT686		loam	No	0.5	0.61	0.31	Yes
melling	UT634		loam	No	0.5	0.61	0.31	Yes
menefee	UT634		clay loam	No	0.08	0.17	0.07	Yes
menefee	UT686		loam	No	0.5	0.61	0.31	Yes
menefee family	UT686		loam	No	0.5	0.61	0.31	Yes
mespun	UT641		sand	No	4.6	4.03	3.12	Yes
mespun	UT686		sand	No	4.6	4.03	3.12	Yes
mident	UT686		sand	No	4.6	4.03	3.12	Yes
mido	UT686		sand	No	4.6	4.03	3.12	Yes
mido family	UT686		sand	No	4.6	4.03	3.12	Yes
mikim	UT636		clay loam	No	0.08	0.17	0.07	Yes
mikim clay	Description		Clay	No	0.02	0.04	0.01	Yes
milok	UT686		loamy sand	No	2.4	3.6	2.71	Yes
mined land	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
minu	UT634		sandy loam	No	0.8	1.92	1.24	Yes
miscellaneous water	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
mitch	UT636		silt loam	No	0.3	0.63	0.32	Yes
mitch silt	Description		Silt	No	0.2	0.8	0.43	Yes
mivida	UT636		sandy loam	No	0.8	1.92	1.24	Yes
moderately deep soils	Engineering judgement		Loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
moderately deep soils similar to lazear	OSDs		Loam	No	0.5	0.61	0.31	Yes
moderately deep soils similar to zyme	UT636		Loam	No	0.5	0.61	0.31	Yes
moderately well drained soils	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
moderatly deep soils	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
moenkopi formation badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
moenkopi formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
moenkopie	UT686		loam	No	0.5	0.61	0.31	Yes
moepitz	UT686		sandy loam	No	0.8	1.92	1.24	Yes
moffat	UT686		loamy sand	No	2.4	3.6	2.71	Yes
mollic fluvaquents	NRCS Soil Taxonomy Handbook	Entisols, pg 138	Sand	No	4.60	4.03	3.12	Yes
mollic halaquepts	NRCS Soil Taxonomy Handbook	Inceptisols, pg 142	Sandy clay loam	No	0.12	0.44	0.21	Yes
monox	UT634		sandy loam	No	0.8	1.92	1.24	Yes
monroe	UT634		silt loam	No	0.3	0.63	0.32	Yes
montoqua	UT641		sandy loam	No	0.8	1.92	1.24	Yes
mord	UT634		loam	No	0.5	0.61	0.31	Yes
morrison and entrada formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
morrison formation and romano mesa sandstone rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
morrison formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
mosida	UT634		sandy loam	No	0.8	1.92	1.24	Yes
motoqua	UT634		loam	No	0.5	0.61	0.31	Yes
motoqua	UT641		sandy loam	No	0.8	1.92	1.24	Yes
muleypoint	UT634		loam	No	0.5	0.61	0.31	Yes
musina	UT634		loam	No	0.5	0.61	0.31	Yes
musinia	UT634		silty clay loam	No	0.08	0.23	0.10	Yes
nakai	UT686		sand	No	4.6	4.03	3.12	Yes
nalcase	UT686		sand	No	4.6	4.03	3.12	Yes
naplene	UT641		silt loam	No	0.3	0.63	0.32	Yes
navajo sandstone and carmel formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
navajo sandstone rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
needle	UT686		loamy sand	No	2.4	3.6	2.71	Yes
nehar	UT641		sandy loam	No	0.8	1.92	1.24	Yes
nepalto	UT686		loamy sand	No	2.4	3.6	2.71	Yes
neto	UT636		sandy loam	No	0.8	1.92	1.24	Yes
nickey	UT641		sandy loam	No	0.8	1.92	1.24	Yes
nihelen	NV754		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
nikey	UT641		sandy loam	No	0.8	1.92	1.24	Yes
not complete	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
notcom	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
notcomm	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
notter	UT636		Clay loam	No	0.08	0.17	0.07	Yes
notter	UT636		sandy clay loam	No	0.12	0.44	0.21	Yes
notter gravelly loam	Description		Loam	No	0.5	0.61	0.31	Yes
notter variant	UT636		loam	No	0.5	0.61	0.31	Yes
nuhelen	NV754		loam	No	0.5	0.61	0.31	Yes
ocambee	UT634		loam	No	0.5	0.61	0.31	Yes
onaqui	UT634		loam	No	0.5	0.61	0.31	Yes
orcap	UT634		clay loam	No	0.08	0.17	0.07	Yes
orthents	NRCS Soil Taxonomy Handbook	Entisols,139	Sand	No	4.60	4.03	3.12	Yes
osote	UT636		silty clay loam	No	0.08	0.23	0.10	Yes
pachic argiustolls	Description	https://casoilresource.lawr.ucdavis.edu/	loam	No	0.5	0.58	0.29	Yes
pachic haplustolls	NV755		silt loam	No	0.3	0.63	0.32	Yes
page sandstone carmel formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
pagina	UT686		loamy sand	No	2.4	3.6	2.71	Yes
pagina family	UT686		loamy sand	No	2.4	3.6	2.71	Yes
pahreah	UT636		loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
pahreah gravelly loam	Description		Loam	No	0.5	0.61	0.31	Yes
palma	UT641		sandy loam	No	0.8	1.92	1.24	Yes
panguitch	UT636		clay loam	No	0.08	0.17	0.07	Yes
panguitch gravelly loam	Description		Loam	No	0.5	0.61	0.31	Yes
paragonah	UT634		silty clay loam	No	0.08	0.23	0.10	Yes
parkwash	UT686		loamy sand	No	2.4	3.6	2.71	Yes
parowan	UT634		silt loam	No	0.3	0.63	0.32	Yes
pass canyon	UT634		loam	No	0.5	0.61	0.31	Yes
pastura	UT641		loam	No	0.5	0.61	0.31	Yes
paunsaugunt	UT636		sandy loam	No	0.8	1.92	1.24	Yes
pausaugunt	UT641		silt loam	No	0.3	0.63	0.32	Yes
pavan	UT634		loam	No	0.5	0.61	0.31	Yes
pavant	UT634		loam	No	0.5	0.61	0.31	Yes
peekaboo	UT686		loamy sand	No	2.4	3.6	2.71	Yes
peteetneet	Engineering judgement		Silty clay loam	No	0.08	0.23	0.10	Yes
petrocalcic paleustalfs	Engineering judgment	Google	loam	No	0.5	0.61	0.31	Yes
pinntank	AZ701		loam	No	0.5	0.61	0.31	Yes
pintura	UT641		loamy sand	No	2.4	3.6	2.71	Yes
pits	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
pits borrow	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
pits gravel	Engineering judgement		Sand	No	4.60	4.03	3.12	Yes
pits quarry	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
pits-dumps complex	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
pits-dumps mine	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
playa	NV754, UT634		Silty clay loam	No	0.08	0.23	0.10	Yes
playas	NV754, UT634		Silty clay loam	No	0.08	0.23	0.10	Yes
plite	UT634		sandy loam	No	0.8	1.92	1.24	Yes
plite sandy loam	UT636		Sandy loam	No	0.80	1.92	1.24	Yes
plumasano	UT686		loamy sand	No	2.4	3.6	2.71	Yes
podo	UT636		loam	No	0.5	0.61	0.31	Yes
podo family	UT686		sandy loam	No	0.8	1.92	1.24	Yes
polychrome family	UT686		sand	No	4.6	4.03	3.12	Yes
poorly drained soils	UT636		Loam	No	0.50	0.61	0.31	Yes
poorly drained textured soils	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
progresso family	UT686		loam	No	0.5	0.61	0.31	Yes
psamments	NRCS Soil Taxonomy Handbook	Entisols,138	Sand	No	4.60	4.03	3.12	Yes
pyrat	UT634		loam	No	0.5	0.61	0.31	Yes
quazo	UT641		sandy loam	No	0.8	1.92	1.24	Yes
quichipa	UT634		silty clay loam	No	0.08	0.23	0.10	Yes
quilt	UT636		clay loam	No	0.08	0.17	0.07	Yes
radec	UT634		loam	No	0.5	0.61	0.31	Yes
radnik	UT686		sandy loam	No	0.8	1.92	1.24	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
ramps	UT634		sandy loam	No	0.8	1.92	1.24	Yes
ranion	UT686		loamy sand	No	2.4	3.6	2.71	Yes
red butte	UT634		loam	No	0.5	0.61	0.31	Yes
redbank	UT641		silty clay loam	No	0.08	0.23	0.10	Yes
redcreek	UT636		loam	No	0.5	0.61	0.31	Yes
redcreek cobbly loam	Description		Loam	No	0.5	0.61	0.31	Yes
remorris	UT686		loam	No	0.5	0.61	0.31	Yes
renbac	UT641		clay loam	No	0.08	0.17	0.07	Yes
repmis	UT634		loam	No	0.5	0.61	0.31	Yes
retsabal	UT686		sandy loam	No	0.8	1.92	1.24	Yes
ripgut	UT634		loam	No	0.5	0.61	0.31	Yes
riverwash	All surveys		Sand	No	4.60	4.03	3.12	Yes
riverwash and water	All surveys		Sand	No	4.60	4.03	3.12	Yes
rizno	UT686		loam	No	0.5	0.61	0.31	Yes
rob roy	UT634		loam	No	0.5	0.61	0.31	Yes
rock land	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
rock land stony	Engineering judgment		clay	No	0.02	0.04	0.01	Yes
rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
rock outcrop with shale and sandstone	Description		Clay	Yes	0.02	0.04	0.01	Yes
rock outcrot	UT634		loam	No	0.5	0.61	0.31	Yes
rockland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
rough broken land	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
rubble land	Engineering judgement		Loam	Yes	0.50	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
rubbleland	Engineering judgement		Loam	Yes	0.50	0.61	0.31	Yes
ruko	UT636		clay	No	0.02	0.04	0.01	Yes
ruko clay	Description		Clay	No	0.02	0.04	0.01	Yes
ruko family	UT686		clay loam	No	0.08	0.17	0.07	Yes
rustico	UT634		silty clay loam	No	0.08	0.23	0.10	Yes
ruvaquents	NRCS Soil Taxonomy Handbook	Entisols,138	Sand	No	4.60	4.03	3.12	Yes
rypod	UT634		loam	No	0.5	0.61	0.31	Yes
sackett	UT634		loam	No	0.5	0.61	0.31	Yes
sandy alluvial land	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
sandy and gravelly alluvial land	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
sandy aridic ustorthents	aridic lithic ustorthents	NRCS Soil Taxonomy Handbook, Entisols, pg 140	sand	No	4.6	4.03	3.12	Yes
sandy clay loams and clay loam soils	UT634		clay loam	No	0.08	0.17	0.07	Yes
sandy lithic ustic torriorthent	lithic ustic torriorthents	NV755, UT, AZ701	sandy loam	No	0.8	1.92	1.24	Yes
sandy loam surface texture soils	UT634		sandy loam	No	0.8	1.92	1.24	Yes
sandy soils	Description		Sandy loam	No	0.8	1.92	1.24	Yes
sandy ustic torriorthents	ustic torriorthents	NV755, UT, AZ701	sandy loam	No	0.8	1.92	1.24	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
sandy-skeletal lithic ustic torriorthents	lithic ustic torriorthents	NV755, UT, AZ701	sandy loam	No	0.8	1.92	1.24	Yes
sandy-skeletal shallow ustic torriorthents	ustic torriorthents	NV755, UT, AZ701	sandy loam	No	0.8	1.92	1.24	Yes
sandy-skeletal typic torrifluvents	typic torriorthents	NV754, AZ, AZ701, UT	sandy loam	No	0.8	1.92	1.24	Yes
sanostee	UT686		sandy loam	No	0.8	1.92	1.24	Yes
sanpete	UT634		loam	No	0.5	0.61	0.31	Yes
santrick	UT686		sand	No	4.6	4.03	3.12	Yes
saxby	UT634		loam	No	0.5	0.61	0.31	Yes
sazi	UT686		sandy loam	No	0.8	1.92	1.24	Yes
schauson	UT636		Loam	No	0.5	0.61	0.31	Yes
schmutz	UT641		loam	No	0.5	0.61	0.31	Yes
seeg	UT686		loamy sand	No	2.4	3.6	2.71	Yes
seth	UT634		loam	No	0.5	0.61	0.31	Yes
sevier	UT636		clay loam	No	0.08	0.17	0.07	Yes
sevy	UT634		loam	No	0.5	0.61	0.31	Yes
shalcar family	Engineering judgement		Silty clay	No	0.04	0.15	0.06	Yes
shalet	UT641		clay loam	No	0.08	0.17	0.07	Yes
shallow gravelly soils	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
shallow sandy loam soils	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
shallow sandy soils	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
shallow soils	Engineering judgment		clay loam	No	0.08	0.17	0.07	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
shallow soils that have less than 35 percent rock fragments	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
shalona family	UT686		sandy loam	No	0.8	1.92	1.24	Yes
sheckle	UT634		loam	No	0.5	0.61	0.31	Yes
sheege	UT636		loam	No	0.5	0.61	0.31	Yes
sheppard	UT686		sand	No	4.6	4.03	3.12	Yes
shinarump member chinle formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
showalter cobbly loam	Description		Loam	No	0.5	0.61	0.31	Yes
sielo	UT636		sandy loam	No	0.8	1.92	1.24	Yes
sielo fine sandy loam	Description		Sandy loam	No	0.8	1.92	1.24	Yes
sili	UT686		silty clay loam	No	0.08	0.23	0.10	Yes
simel	UT686		loam	No	0.5	0.61	0.31	Yes
simper	UT634		loam	No	0.5	0.61	0.31	Yes
siroco	UT634		loam	No	0.5	0.61	0.31	Yes
skumpah	UT634		silt loam	No	0.3	0.63	0.32	Yes
skutum	UT636		Sandy loam	No	0.80	1.92	1.24	Yes
slickspot	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
slickspots	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
small depressions	UT636		Sand	No	4.60	4.03	3.12	Yes
sodic haplocalcids	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
soils similar to jodero soil near panguitch	Jodero		Loam	No	0.5	0.61	0.31	Yes
soils similar to lazear soil	Lazear		Loam	No	0.5	0.61	0.31	Yes
soils similar to the gerst family soils	Gerst		Loam	No	0.5	0.61	0.31	Yes
soils similar to the podo soil	Podo		Loam	No	0.5	0.61	0.31	Yes
soils similar to these dimyaw soils	Dimyaw		Loam	No	0.5	0.61	0.31	Yes
soils that are shallow to moderately deep to a lime-cemented	Engineering judgement		Clay	No	0.02	0.04	0.01	Yes
soils that are similar to clapper soil	Clapper		Loam	No	0.5	0.61	0.31	Yes
soils that are similar to mikim soil	Mikim		Loam	No	0.5	0.61	0.31	Yes
soils that are similar to mitch soil	Mitch		Silt loam	No	0.3	0.63	0.32	Yes
soils that are similar to panguitch soil	Panguitch		Loam	No	0.5	0.61	0.31	Yes
soils that are similar to schauson soil	Schauson		Loam	No	0.5	0.61	0.31	Yes
soils that are similar to schauson soil but with lime	Schauson		Loam	No	0.5	0.61	0.31	Yes
soils with bedrock at 40-60 inches	Engineering judgement		Loam	No	0.5	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
soils with less than 35 percent rock fragments	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
soils with more than 35 percent rock fragments	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
soils with more than 35 percent rock fragments throughout	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
soils with more than 40 percent calcium carbonate	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
soils with very cobbly surface	Engineering judgement		Loam	No	0.5	0.61	0.31	Yes
sojourn family	UT686		loamy sand	No	2.4	3.6	2.71	Yes
somewhat poorly drained sils	Engineering judgment		clay loam	No	0.08	0.17	0.07	Yes
somewhat poorly drained soils	Engineering judgement		Silty clay	No	0.04	0.15	0.06	Yes
soutin	UT634		loam	No	0.5	0.61	0.31	Yes
sponiker	AZ701	Report	silty clay loam	No	0.08	0.23	0.10	Yes
spooky	UT686		loamy sand	No	2.4	3.6	2.71	Yes
springmeadow	NV713		silty clay loam	No	0.08	0.23	0.10	Yes
squawcave	UT634		silt loam	No	0.3	0.63	0.32	Yes
st george	UT641		clay	No	0.02	0.04	0.01	Yes
st. george	UT641		silty clay loam	No	0.08	0.23	0.10	Yes
steeper soils	UT634		sandy loam	No	0.8	1.92	1.24	Yes
stony colluvial land	Engineering judgement		Silt	No	0.20	0.80	0.43	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
straight cliffs and dakota formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
straight cliffs and wahweap formation badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
straight cliffs and wahweap formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
straight cliffs formation burnt sandstone rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
straight cliffs formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
straight cliffs formation sandstone rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
streuling	UT634		loam	No	0.5	0.61	0.31	Yes
strych	UT686		sandy loam	No	0.8	1.92	1.24	Yes
studhorse	UT634		loam	No	0.5	0.61	0.31	Yes
suwanee	UT686		loam	No	0.5	0.61	0.31	Yes
swapps	UT636		loam	No	0.5	0.61	0.31	Yes
syrett	UT636		loam	No	0.5	0.61	0.31	Yes
tacan	UT641		sandy loam	No	0.8	1.92	1.24	Yes
taylorsflat	UT634		sandy loam	No	0.8	1.92	1.24	Yes
tebbs	UT636		loam	No	0.5	0.61	0.31	Yes
tepete	Engineering judgement		Silty clay loam	No	0.08	0.23	0.10	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
terric cryosaprists		Histosols, saprists, pgs 141, 485	Loam	No	0.50	0.61	0.31	Yes
timpoweap member moenkopi formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
tobish	UT641		clay loam	No	0.08	0.17	0.07	Yes
tobler	UT641		silty clay loam	No	0.08	0.23	0.10	Yes
tolman	UT636		clay loam	No	0.08	0.17	0.07	Yes
tombar	UT634		loam	No	0.5	0.61	0.31	Yes
toquerville	UT641		sand	No	4.6	4.03	3.12	Yes
torrifluvents	AZ, UT		Sand	No	4.60	4.03	3.12	Yes
torriorthents	NV755, AZ		Sandy loam	No	0.80	1.92	1.24	Yes
torripsamments	NRCS Soil Taxonomy Handbook	Entisols,139	Sand	No	4.60	4.03	3.12	Yes
trag	UT634		loam	No	0.5	0.61	0.31	Yes
tridell	UT636		loam	No	0.5	0.61	0.31	Yes
tropic formation shale badland	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
troughspring	NV755		loam	No	0.5	0.61	0.31	Yes
tryon	muname		Loamy sand	No	2.40	3.60	2.71	Yes
tsaya	UT686		loam	No	0.5	0.61	0.31	Yes
typic calciargids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
typic cryaquents	NRCS Soil Taxonomy Handbook	Entisols, pg 138	Sand	No	4.60	4.03	3.12	Yes
typic haplaquolls	NV754, NV613		Silt loam	No	0.30	0.63	0.32	Yes
typic haplargids	NV755		Loam	No	0.50	0.61	0.31	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
typic haplocalcids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
typic haplocambids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
typic haplogypsids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
typic natraquolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 144	Silt loam	No	0.30	0.63	0.32	Yes
typic petrocalcids	NV755		Loam	No	0.50	0.61	0.31	Yes
typic psammaquents	NRCS Soil Taxonomy Handbook	Entisols,138	Sand	No	4.60	4.03	3.12	Yes
typic torrifluvents	NRCS Soil Taxonomy Handbook	Entisols,139	Sand	No	4.60	4.03	3.12	Yes
typic torrifolists	NRCS Soil Taxonomy Handbook	Histosols, pg 141	Loam	No	0.50	0.61	0.31	Yes
typic torriorthents	NV754, AZ, AZ701, UT		Sandy loam	No	0.80	1.92	1.24	Yes
typic torripsamments	NRCS Soil Taxonomy Handbook	Entisols,139	Sand	No	4.60	4.03	3.12	Yes
udic haplustolls	NRCS Soil Taxonomy Handbook	Mollisols, pg 174	Silt loam	No	0.30	0.63	0.32	Yes
urban land	Engineering judgement		Sandy loam	No	0.80	1.92	1.24	Yes
ustic calciargids	Engineering judgment	Google	loam	No	0.5	0.61	0.31	Yes
ustic haplargids	NV755		Loam	No	0.50	0.61	0.31	Yes
ustic haplocalcids	NV755		Sandy loam	No	0.80	1.92	1.24	Yes
ustic haplocambids	NRCS Soil Taxonomy Handbook	Entisols,138	Sand	No	4.60	4.03	3.12	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
ustic petrocalcids	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes
ustic torrifluvents	Engineering judgment	Google	sand	No	4.6	4.03	3.12	Yes
ustic torriorthents	NV755, UT, AZ701		Loam	No	0.50	0.61	0.31	Yes
ustic torripsamments	Engineering judgment	Google	sand	No	4.6	4.03	3.12	Yes
ustifluvents	Engineering judgment	Google	sand	No	4.6	4.03	3.12	Yes
ustipsamments	Engineering judgment	Google	sand	No	4.6	4.03	3.12	Yes
ustorthents	NRCS Soil Taxonomy Handbook	Entisols,140	Sand	No	4.60	4.03	3.12	Yes
utaline	ADOT		Loam	No	0.5	0.61	0.31	Yes
vanet	UT636		clay loam	No	0.08	0.17	0.07	Yes
vennob	UT634		loam	No	0.5	0.61	0.31	Yes
venture	UT636		clay loam	No	0.08	0.17	0.07	Yes
vertic natrargids	Engineering judgment	Google	clay	No	0.02	0.04	0.01	Yes
very cobbly soils tat are 40 to 60 inches deep to bedrock	Engineering judgement		Loam	No	0.5	0.61	0.31	Yes
very deep and very gravelly clay soils	UT634		clay	No	0.02	0.04	0.01	Yes
very deep sand loam	UT634		sandy loam	No	0.8	1.92	1.24	Yes
very deep very gravelly soils	Engineering judgment		loam	No	0.5	0.61	0.31	Yes
very gravelly loamy coarse sand soils	UT634		loamy sand	No	2.4	3.6	2.71	Yes
very saline soils	Engineering judgement		Silt	No	0.20	0.80	0.43	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
very shallow sandy soils	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
very shallow soils	Engineering judgement		clay loam	No	0.08	0.17	0.07	Yes
very shallow to hardpan soils	UT634		clay	No	0.02	0.04	0.01	Yes
veyo	UT641		sandy loam	No	0.8	1.92	1.24	Yes
villy family soils	Villy		Silty clay loam	No	0.08	0.23	0.10	Yes
vitrandic haplocalcids	NRCS Soil Taxonomy Handbook	Aridisols, pg 137	Sandy clay loam	No	0.12	0.44	0.21	Yes
vitrandic haplocambids	NRCS Soil Taxonomy Handbook	Aridisols, pg 138	Sandy clay loam	No	0.12	0.44	0.21	Yes
wahweap formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
wales	UT634		sandy loam	No	0.8	1.92	1.24	Yes
walring	UT641		sandy loam	No	0.8	1.92	1.24	Yes
waltershow	UT634		loam	No	0.5	0.61	0.31	Yes
water	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
wayneco	UT686		sandy loam	No	0.8	1.92	1.24	Yes
well drained soils	Engineering judgment		sandy loam	No	0.8	1.92	1.24	Yes
wenzel	UT634		loam	No	0.5	0.61	0.31	Yes
whiteman	UT636		clay loam	No	0.08	0.17	0.07	Yes
widtsoe	UT636		sandy loam	No	0.8	1.92	1.24	Yes
widtsoe family	UT686		loam	No	0.5	0.61	0.31	Yes
wiggler	UT636		clay loam	No	0.08	0.17	0.07	Yes
wind deposited soils	Engineering judgment		silt loam	No	0.3	0.63	0.32	Yes

Table D.5 Assignment of XKSAT to miscellaneous component soils

Component Name	Source of Texture	Soil Order	Assumed Texture	Impervious	K_s, in/hr			Include
						2006		
					1983	DF =1.0	DF =1.1	
winetti	UT636		loamy sand	No	2.4	3.6	2.71	Yes
wingate formation rock outcrop	Engineering judgement		Clay	Yes	0.02	0.04	0.01	Yes
winkel	UT641		sandy loam	No	0.8	1.92	1.24	Yes
winnemucca	UT636		loam	No	0.5	0.61	0.31	Yes
winnemucca soils	UT634		loam	No	0.5	0.61	0.31	Yes
woodrow	UT634		silty clay loam	No	0.08	0.23	0.10	Yes
wye	UT634		loam	No	0.5	0.61	0.31	Yes
xeric torriorthents	NRCS Soil Taxonomy Handbook	Entisols, Orthents, pgs 138, 391	Sand	No	4.60	4.03	3.12	Yes
yaki	UT641		loam	No	0.5	0.61	0.31	Yes
yarts	UT636		sandy loam	No	0.8	1.92	1.24	Yes
yarts sandy loam	Description		sandy loam	No	0.8	1.92	1.24	Yes
yenlo	UT636		clay loam	No	0.08	0.17	0.07	Yes
zigzag	UT686		clay loam	No	0.08	0.17	0.07	Yes
zillion	UT636		clay loam	No	0.08	0.17	0.07	Yes
zinzer	UT636		loam	No	0.5	0.61	0.31	Yes
zukan	UT641		sandy loam	No	0.8	1.92	1.24	Yes
zyme clay	Description		clay loam	No	0.08	0.17	0.07	Yes

Table D.6 Average XKSAT values for bare ground			
	XKSAT		
	Rawls, et al (1983)	Saxton and Rawls (2006)	
Texture	in/hr	in/hr	mm/hr
1	2	3	4
Sand	4.60	2.02	51.18
Loamy sand	1.20	1.80	45.72
Sandy loam	0.40	0.96	24.38
Silt	0.10	0.40	10.16
Silt loam	0.15	0.32	8.00
Loam	0.25	0.31	7.75
Sandy clay loam	0.06	0.22	5.59
Silty clay Loam	0.04	0.12	2.92
Clay loam	0.04	0.09	2.16
Silty clay	0.02	0.08	1.91
Sandy clay	0.02	0.03	0.76
Clay	0.01	0.02	0.51

D.2.6 COMPUTATION OF COMPOSITE XKSAT FOR EACH SOIL MAP UNIT

The computed composite value of XKSAT for each SMU for both the 1983 and 2006 methods are listed in Group Number 9. The data in Numbers 3 and 4 in combination with the data in Group Numbers 5, 7 and 8 was used for the computation. The computations were done using equation 1.

$$\overline{XKSAT} = a\log\left(\frac{\sum A_i \log XKSAT_i}{A_T}\right) \qquad \text{Eqn 1}$$

where:

$\overline{XKSAT}$ = composite bare ground hydraulic conductivity for the SMU (or watershed sub-basin), inches/hour

$XKSAT_i$ = bare ground hydraulic conductivity of the SMU component soil, inches/hour

A_i = component area in % of SMU from File 2

A_T = Total % of the SMU components

When the SMU component percentages do not total 100%, the percentages were normalized to total 100%.

D.2.7 COMPUTATION OF PSIF AND DTHETA

PSIF is the Green and Ampt wetting front capillary pressure term. Per Rawls, Brakensiek and Miller (1983) equation 5, PSIF can be calculated from the estimated Brooks and Corey constants using equation D.1:

$$PSIF = \frac{2\lambda + 3}{2\lambda + 2}\left(\frac{\psi_b}{2}\right) \quad \text{D.1}$$

where:

PSIF = wetting front capillary pressure, in inches,

λ = the pore-size distribution index (defined as the slope of the logarithmic tension-moisture curve in Saxton and Rawls, 2006), and

ψ_b = bubbling pressure (defined as the tension at air entry, ψ_e, in Saxton and Rawls, 2006), in inches of water. The value used for Mohave County is adjusted as shown in the Excel spreadsheet provided by Saxton and Rawls (2006).

DTHETA is the Green and Ampt volumetric soil moisture deficit at start of rainfall term (defined as effective porosity, θ_e, in Rawls, Brakensiek and Miller, 1983), in cubic inches per cubic inch. Per Rawls, Brakensiek and Miller (1983) equation 6, DTHETA can be calculated using equation D.2:

$$DTHETA = \phi - \phi_r \quad \text{D.2}$$

where:

DTHETA = volumetric soil moisture deficit, in cubic inches per cubic inch,

ϕ = total porosity (defined as the slope of the logarithmic tension-moisture curve in Saxton and Rawls, 2006), and

ϕ_r = bubbling pressure (defined as the tension at air entry, ψ_e, in Saxton and Rawls, 2006), in inches of water. The value used for Mohave County is adjusted as shown in the Excel spreadsheet provided by Saxton and Rawls (2006).

The PSIF and DTHETA values for Saxton and Rawls (2006) listed in Group Numbers 3 and 4 for each horizon were used to prepare a relationship with XKSAT as an independent variable and PSIF and DTHETA as dependant variables. A nonlinear regression analysis was performed for each dependant variable. The results are shown on Figure D.1 and Figure D.2 in comparison with the curves from the 1983 method.

The regression equations recommended for computing PSIF and DTHETA are:

$$PSIF = 11.63103 * 0.15801^{XKSAT}$$

$$DTHETA_{dry} = 0.36180 + 0.03953 * \mathrm{LOG}_e(\mathrm{XKSAT})$$

$$DTHETA_{normal} = 0.28536 + 0.060058 * \mathrm{LOG}_e(\mathrm{XKSAT}) - 0.001009 * \mathrm{LOG}_e(\mathrm{XKSAT})^2 - 0.000615 * \mathrm{LOG}_e(\mathrm{XKSAT})^3$$

D.2.8 PROPOSED XKSAT METHOD

The Saxton and Rawls (2006) Green and Ampt parameter method is accepted for use in surface water hydrology in Mohave County. The values of bare ground XKSAT for each SMU are listed Appendix D.3, organized by NRCS soil survey.

Figure D.1 PSIF as a function of XKSAT

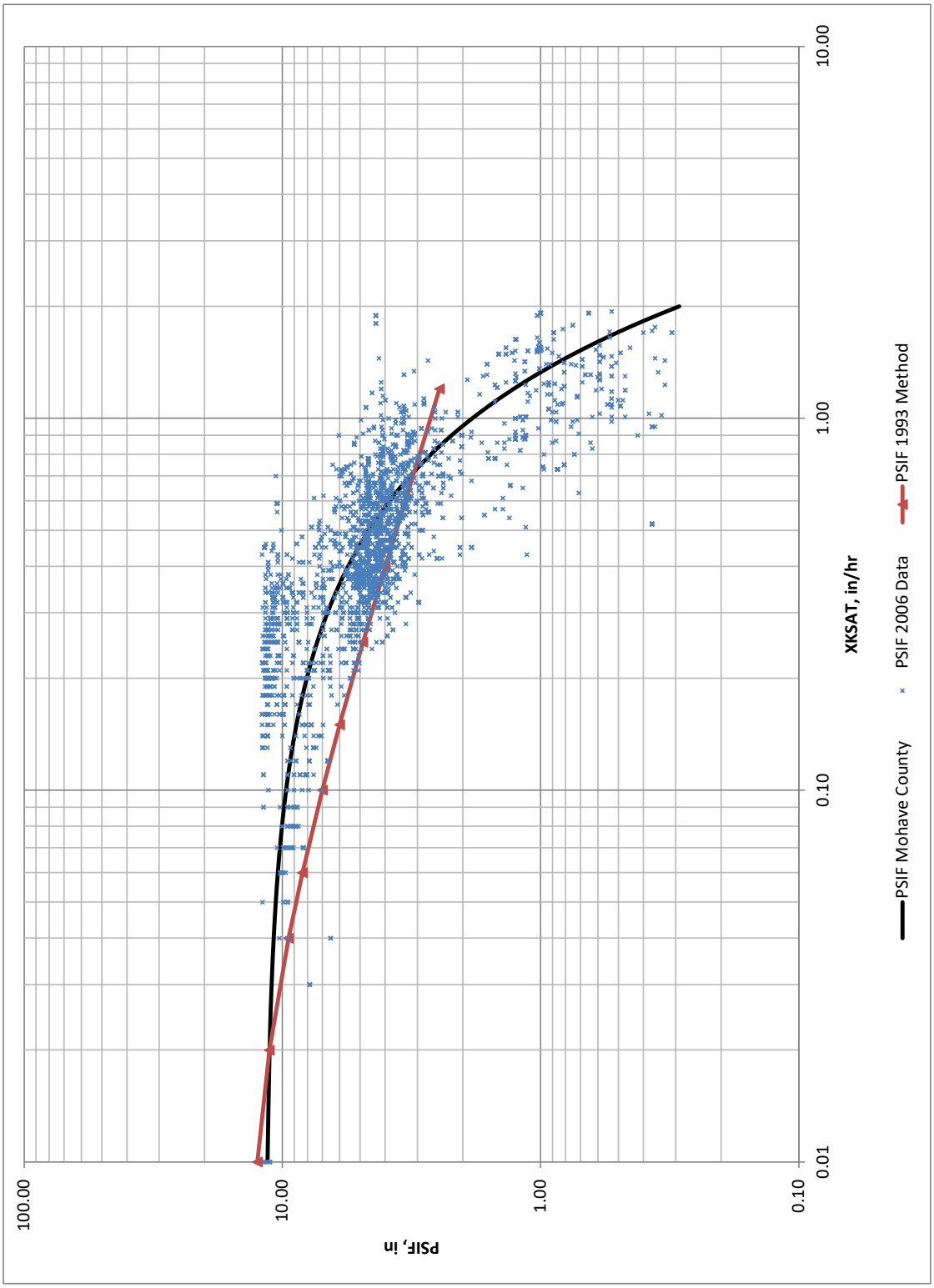
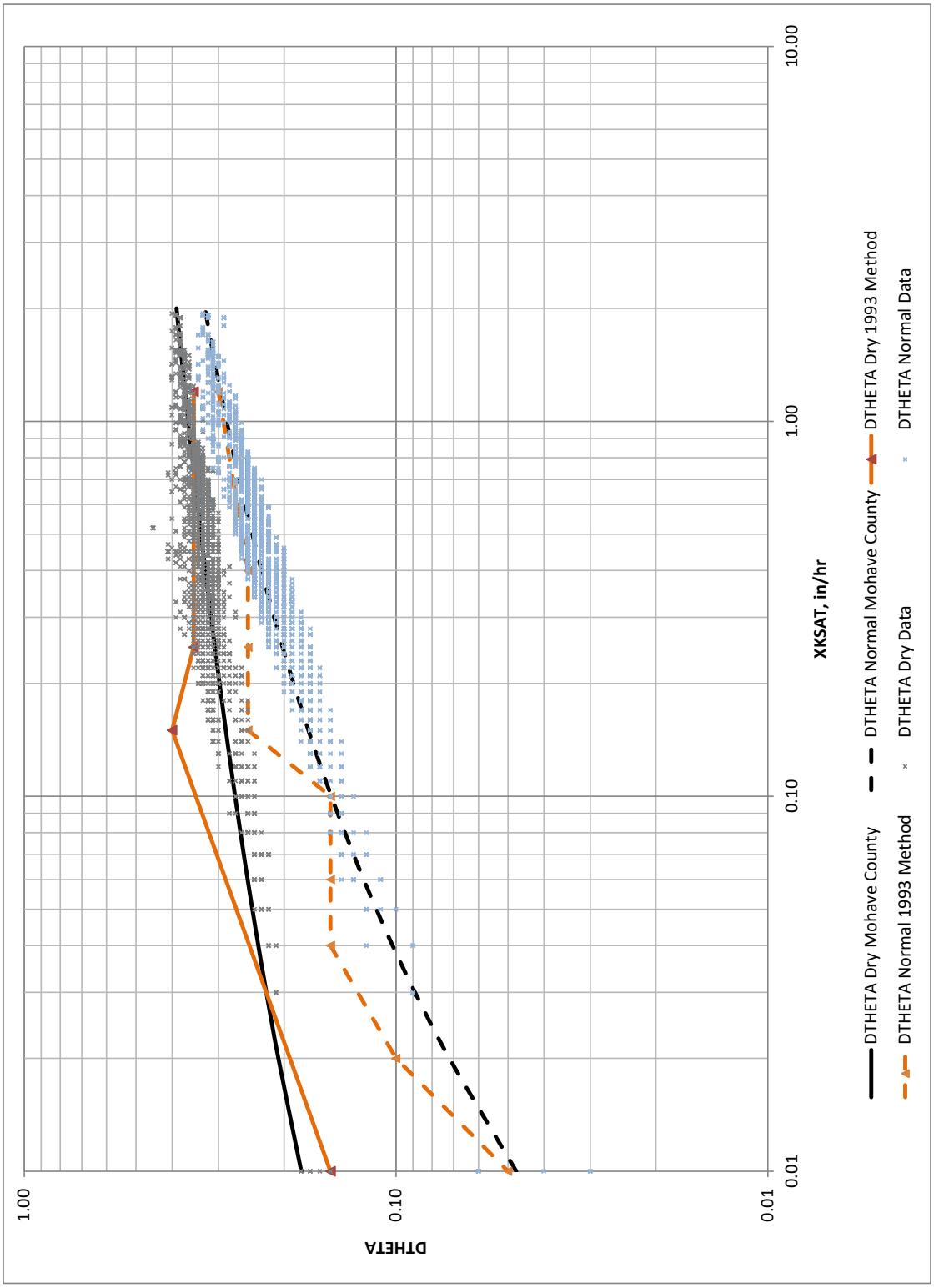


Figure D.2 DTHETA as a function of XKSAT



D.3 XKSAT VALUES BY NRCS SOIL SURVEY

D.3.1 AZ623

Table D.7 AZ623 Shivwits Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Akinville-Mokaac association 2 to 20 percent slopes	0.45	0.22	0
2	Albers silty clay 0 to 1 percent slopes	0.02	0.01	0
3	Arada family loamy fine sand 1 to 10 percent slopes	1.63	1.01	0
4	Arizo gravelly sandy loam 1 to 5 percent slopes nonflooded	0.61	0.32	0
5	Arizo very gravelly sandy loam 1 to 5 percent slopes flooded	0.52	0.27	0
6	Badland	0.31	0.16	0
7	Bard family-Tonopah-Arada family association 1 to 10 percent slopes	1.22	0.73	0
8	Barx fine sandy loam 1 to 5 percent slopes	0.07	0.02	0
9	Barx-Strych complex 1 to 10 percent slopes	0.11	0.04	0
10	Berzatic family-Rock outcrop-Goblin complex 35 to 70 percent slopes	0.23	0.10	30
11	Bisoodi-Anasazi family complex 1 to 8 percent slopes	0.30	0.13	0
12	Blind family-Shelley complex 5 to 15 percent slopes moist	0.36	0.17	0
13	Blind family-Shelley complex 5 to 15 percent slopes stony	0.23	0.10	0
14	Boquillas family-Showlow complex 25 to 50 percent slopes	0.02	0.01	0
15	Carrizo complex 1 to 5 percent slopes	0.96	0.57	0
16	Cave-Harrisburg-Grapevine complex 1 to 15 percent slopes	0.60	0.32	0
17	Chic-Teesto-Rock outcrop complex 1 to 30 percent slopes	0.15	0.05	15
18	Childers-Rizno association 4 to 15 percent slopes	0.30	0.14	0
19	Dera very gravelly fine sandy loam 1 to 10 percent slopes	0.28	0.12	0
20	Dermala family-Guy family-Rock outcrop complex 10 to 40 percent slopes	0.06	0.01	20

Table D.7 AZ623 Shivwits Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
21	Disterheff-Natank-Yumtheska complex 2 to 15 percent slopes	0.04	0.02	0
22	Dutchman-McCullan complex 1 to 10 percent slopes	0.38	0.18	0
23	Goblin gravelly fine sandy loam 15 to 50 percent slopes	0.55	0.29	0
24	Goblin-Gyppocket complex 2 to 10 percent slopes	0.36	0.17	0
25	Goesling loam 1 to 5 percent slopes	0.41	0.21	0
26	Grapevine-Hobcan complex 1 to 5 percent slopes	0.61	0.32	0
27	Grapevine-Shelley complex 1 to 5 percent slopes	0.54	0.28	0
28	Gypill-Badland association 10 to 70 percent slopes	0.39	0.20	0
29	Gypill fine sandy loam 15 to 40 percent slopes	0.50	0.24	0
30	Gypill-Hobog complex 6 to 35 percent slopes	0.45	0.22	0
31	Gypill very cobbly sandy loam 15 to 40 percent slopes	0.46	0.25	0
32	Gypsiorthids-Gypsiorthids shallow complex 1 to 50 percent slopes	0.22	0.10	0
33	Havasupai very gravelly loam 1 to 5 percent slopes	0.20	0.08	0
34	Hindu-Rock outcrop-Gypill complex 35 to 70 percent slopes	0.22	0.09	30
35	Hobcan fine sandy loam 1 to 5 percent slopes	0.58	0.30	0
36	Hobog-Grapevine complex 2 to 35 percent slopes	0.43	0.23	0
37	Hobog-Grapevine complex 2 to 35 percent slopes moist	0.43	0.23	0
38	Hobog-Tidwell family complex 8 to 35 percent slopes	0.32	0.16	0
39	Hobog very gravelly sandy loam 5 to 30 percent slopes	0.35	0.18	0
40	Ivanpatch fine sandy loam 1 to 5 percent slopes	0.38	0.18	0
41	Ives loam 1 to 3 percent slopes	0.24	0.09	0

Table D.7 AZ623 Shivwits Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
42	Katzine-Rock outcrop-Yumtheska complex 35 to 70 percent slopes	0.26	0.12	25
43	Meadview-Cave complex 2 to 30 percent slopes stony	0.39	0.19	0
44	Meadview very gravelly sandy loam 2 to 18 percent slopes	0.53	0.28	0
45	Mellenthin-Rock outcrop-Torriorthents complex 10 to 70 percent slopes	0.35	0.17	20
46	Mellenthin-Strych complex 4 to 25 percent slopes cool	0.21	0.09	0
47	Mellenthin-Strych complex 4 to 25 percent slopes warm	0.21	0.09	0
48	Mellenthin-Tanbark complex 5 to 50 percent slopes cool	0.31	0.14	0
49	Mellenthin-Tanbark complex 5 to 50 percent slopes dry	0.32	0.14	0
50	Mellenthin-Tanbark complex 5 to 50 percent slopes warm	0.31	0.14	0
51	Meriwhitica-Rock outcrop-Strych complex 35 to 70 percent slopes	0.23	0.10	30
52	Meriwhitica-Rock outcrop-Strych complex 35 to 70 percent slopes warm	0.23	0.10	30
53	Mespun complex 2 to 10 percent slopes	1.76	1.43	0
54	Moenkopie-Goblin complex 5 to 50 percent slopes	0.41	0.19	0
55	Moenkopie-Pennell-Rock outcrop complex 10 to 50 percent slopes	0.27	0.11	20
56	Nikey family-Ruesh family-Rock outcrop complex 10 to 40 percent slopes	0.28	0.12	25
57	Nipton-Rock outcrop-Nickel family complex 10 to 50 percent slopes	0.34	0.16	20
58	Nutter-Gyppocket complex 2 to 20 percent slopes	0.30	0.13	0
59	Padilla silt loam 1 to 5 percent slopes	0.02	0.01	0
60	Pocum-Childers-Ubank complex 1 to 10 percent slopes	0.29	0.13	0
61	Pocum-Spenlo complex 1 to 10 percent slopes	0.20	0.08	0

Table D.7 AZ623 Shivwits Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
62	Pompeii family-Huevi complex 2 to 15 percent slopes	0.09	0.04	0
63	Radnik loam 1 to 5 percent slopes	0.37	0.17	0
64	Riverwash-Torrifluvents complex 1 to 3 percent slopes	2.00	1.56	0
65	Rizno-Bond-Rock outcrop complex 4 to 25 percent slopes	0.26	0.12	15
66	Robroost fine sandy loam 1 to 3 percent slopes	0.28	0.12	0
67	Ruesh very gravelly fine sandy loam 3 to 20 percent slopes	0.37	0.16	0
68	Sedillo very cobbly loam 1 to 8 percent slopes	0.04	0.01	0
69	Showlow-Thunderbird complex 2 to 25 percent slopes	0.03	0.01	0
70	Showlow very cobbly clay loam 1 to 15 percent slopes	0.06	0.02	0
71	Sponiker loam 1 to 10 percent slopes	0.12	0.04	0
72	Springerville-Delenbaw complex 3 to 25 percent slopes	0.05	0.01	0
73	Strych very gravelly loam 2 to 10 percent slopes	0.20	0.08	0
74	Tanbark family-Strych family-Rock outcrop complex 10 to 40 percent slopes	0.31	0.15	25
75	Tanbark loam 15 to 75 percent slopes	0.52	0.25	0
76	Tassi-Rizno complex 5 to 35 percent slopes	0.29	0.13	0
77	Tonopah gravelly loamy fine sand 1 to 10 percent slopes	1.78	1.12	0
78	Torriorthents-Calciorthids-Rock outcrop complex 10 to 40 percent slopes	0.96	0.62	15
79	Tours silt loam 1 to 3 percent slopes	0.07	0.01	0
80	Tsezhin family-Ashfork family-Rock outcrop complex 10 to 70 percent slopes	0.07	0.02	20
81	Tsezhin very cobbly sandy loam 5 to 15 percent slopes	0.04	0.01	0
82	Twist sandy loam 2 to 10 percent slopes	0.09	0.02	0
83	Twist very cobbly loam 1 to 8 percent slopes	0.05	0.01	0

Table D.7 AZ623 Shivwits Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
84	Virgin Peak-Rock outcrop complex 10 to 70 percent slopes	0.27	0.13	30
85	Whiskey silt loam 1 to 4 percent slopes MLRA 35	0.23	0.10	0
86	Winkel-Rock outcrop complex 2 to 35 percent slopes	0.16	0.06	15
87	Winkel-Rock outcrop complex 2 to 35 percent slopes moist	0.16	0.06	15
88	Winkel very gravelly loam 2 to 25 percent slopes	0.16	0.06	0
89	Winkel very gravelly loam 2 to 25 percent slopes moist	0.16	0.06	0
90	Wutoma-Lozinta complex 15 to 50 percent slopes	0.21	0.09	0
91	Yellowhorse family silty clay o to 3 percent slopes	0.05	0.02	0
92	Yellowhorse-Luzena family complex 1 to 10 percent slopes	0.04	0.01	0
93	Yumtheska-Katzine-Rock outcrop complex 2 to 30 percent slopes	0.30	0.15	20
94	Yumtheska-Katzine-Rock outcrop complex 5 to 50 percent slopes moist	0.29	0.14	15
95	Yumtheska-Natank complex 10 to 45 percent slopes	0.19	0.10	0
96	Yurm family-Meadview association 15 to 40 percent slopes	0.27	0.12	0
97	Yurm family-Meadview association 15 to 40 percent slopes moist	0.27	0.12	0
98	Yurm family very gravelly loam 15 to 35 percent slopes	0.23	0.10	0
99	Yurm family very gravelly loam 15 to 35 percent slopes moist	0.23	0.10	0

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D.3.2 AZ625

Table D.8 AZ625 Mohave County Area, Northeastern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Badland	0.31	0.16	0
2	Barx fine sandy loam 1 to 5 percent slopes	0.19	0.07	0
3	Barx loam 1 to 4 percent slopes	0.22	0.08	0
4	Begay fine sandy loam 1 to 3 percent slopes	0.81	0.47	0
5	Begay fine sandy loam 3 to 12 percent slopes	0.81	0.47	0
6	Bidonia-Bond-Rock outcrop complex 1 to 25 percent slopes	0.04	0.02	15
7	Bond-Bidonia complex 1 to 7 percent slopes	0.08	0.02	0
8	Brinkerhoff-Grieta complex 0 to 5 percent slopes	0.46	0.22	0
9	Campanile clay 1 to 6 percent slopes	0.02	0.01	0
10	Clayhole loam 1 to 3 percent slopes	0.15	0.05	0
11	Curhollow-Prieta complex 4 to 20 percent slopes	0.05	0.02	0
12	Godding gravelly loam 3 to 40 percent slopes	0.10	0.04	0
13	Grieta fine sandy loam 1 to 5 percent slopes	0.12	0.04	0
14	Grieta loam 1 to 5 percent slopes	0.12	0.04	0
15	Gypsiorthids-Gypsiorthids shallow complex 1 to 50 percent slopes	0.22	0.10	0
16	Hatknoll-Kinan complex 1 to 10 percent slopes	0.09	0.03	0
17	Havasupai-Mellenthin complex 2 to 12 percent slopes	0.13	0.05	0
18	Jocity loamy fine sand saline-sodic 1 to 3 percent slopes	0.10	0.03	0
19	Jocity-Clayhole complex 1 to 4 percent slopes	0.05	0.01	0
20	Jocity silty clay loam 1 to 4 percent slopes	0.02	0.01	0
21	Jocity silty clay loam 1 to 2 percent slopes flooded	0.05	0.01	0
22	Kinan gravelly loam 1 to 15 percent slopes	0.26	0.11	0
23	Kinan-Hatknoll-Grieta complex 1 to 5 percent slopes	0.15	0.05	0
24	Kinan-Pennell complex 1 to 20 percent slopes	0.25	0.11	0

Table D.8 AZ625 Mohave County Area, Northeastern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
25	Klondike sandy clay loam 2 to 15 percent slopes MLRA 35	0.11	0.04	0
26	Lava flows	0.01	0.01	100
27	Lozinta extremely gravelly loam 1 to 15 percent slopes	0.14	0.06	0
28	Lozinta extremely gravelly loam 15 to 45 percent slopes	0.14	0.06	0
29	Manikan silty clay loam 1 to 4 percent slopes	0.07	0.02	0
30	Mellenthin-Anasazi complex 1 to 15 percent slopes	0.48	0.25	0
31	Mellenthin-Barx complex 1 to 15 percent slopes	0.23	0.10	0
32	Mellenthin-Progresso complex 1 to 7 percent slopes	0.18	0.07	0
33	Mellenthin very gravelly loam 1 to 25 percent slopes	0.19	0.08	0
34	Mellenthin very gravelly loam 30 to 50 percent slopes	0.17	0.08	0
35	Mellenthin very gravelly loam cool 1 to 25 percent slopes	0.17	0.08	0
36	Mellenthin very gravelly loam warm 1 to 25 percent slopes	0.17	0.08	0
37	Mido fine sand 1 to 10 percent slopes	2.00	1.36	0
38	Mido loamy fine sand 1 to 4 percent slopes gullied	1.52	0.95	0
39	Milok gravelly loam 1 to 15 percent slopes	0.26	0.12	0
40	Moab loam 1 to 5 percent slopes	0.16	0.07	0
41	Moab-Mellenthin complex 1 to 20 percent slopes	0.16	0.07	0
42	Monue fine sandy loam 1 to 5 percent slopes	0.60	0.31	0
43	Padilla-Penistaja-Campanile complex 1 to 6 percent slopes	0.04	0.02	0
44	Palma loamy fine sand 1 to 5 percent slopes	1.44	0.88	0
45	Penistaja fine sandy loam 1 to 5 percent slopes	0.16	0.05	0
46	Pennell-Bacobi complex 1 to 7 percent slopes	0.35	0.16	0
47	Pennell gravelly loam 1 to 12 percent slopes	0.24	0.10	0
48	Poley cobbly silty clay loam 1 to 5 percent slopes	0.04	0.01	0

Table D.8 AZ625 Mohave County Area, Northeastern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
49	Poley-Moab complex 1 to 10 percent slopes	0.08	0.03	0
50	Radnik fine sandy loam 1 to 5 percent slopes	0.76	0.43	0
51	Riverwash	2.00	1.56	0
52	Royosa fine sand 2 to 10 percent slopes	1.43	0.88	0
53	Royosa-Tonalea complex 1 to 15 percent slopes	1.91	1.38	0
54	Saido-Brinkerhoff complex 1 to 5 percent slopes	0.13	0.04	0
55	Sheppard fine sand 1 to 7 percent slopes	1.55	0.95	0
56	Sheppard loamy fine sand 1 to 4 percent slopes gullied	1.55	0.95	0
57	Showlow-Section complex 1 to 15 percent slopes	0.11	0.04	0
58	Showlow-Thimble complex 1 to 15 percent slopes	0.03	0.02	0
59	Showlow very cobbly clay loam 1 to 15 percent slopes	0.06	0.02	0
60	Showlow very cobbly silty clay loam 15 to 35 percent slopes	0.06	0.02	0
61	Sponiker gravelly loam 1 to 15 percent slopes	0.11	0.04	0
62	Sponiker gravelly loam 15 to 40 percent slopes	0.11	0.04	0
63	Torriorthents-Rock outcrop complex 30 to 70 percent slopes	0.96	0.62	45
64	Torriorthents-Rock outcrop complex dry 30 to 70 percent slopes	0.96	0.62	45
65	Torriorthents-Rock outcrop complex warm 30 to 70 percent slopes	0.96	0.62	45
66	Whiskey silt loam 1 to 4 percent slopes MLRA 35	0.23	0.10	0
67	Wukoki-Lomaki complex 15 to 50 percent slopes	0.11	0.04	0
68	Wutoma-Lozinta complex 1 to 15 percent slopes	0.15	0.06	0
69	Wutoma-Lozinta complex 15 to 50 percent slopes	0.15	0.07	0
70	Wutoma-Rock outcrop complex 1 to 15 percent slopes	0.22	0.09	30

Table D.8 AZ625 Mohave County Area, Northeastern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
71	Yumtheska-Goesling complex 1 to 15 percent slopes	0.24	0.11	0
72	Yumtheska very gravelly loam 4 to 20 percent slopes	0.20	0.09	0
73	Yumtheska very gravelly loam 30 to 50 percent slopes	0.20	0.09	0

D.3.3 AZ627

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Akela-Rock outcrop-Rubble land complex 40 to 70 percent slopes	0.21	0.10	40
2	Akela-Rock outcrop-Rubble land complex dry 40 to 70 percent slopes	0.21	0.10	40
3	Alko family cobbly loam 2 to 15 percent slopes	0.28	0.13	0
4	Alko family cobbly loam dry 2 to 15 percent slopes	0.28	0.13	0
5	Amole sandy loam 1 to 3 percent slopes	0.61	0.32	0
6	Amole sandy loam dry 1 to 3 percent slopes	0.60	0.32	0
7	Anthony-Dudleyville complex 1 to 3 percent slopes	0.68	0.38	0
8	Aquarius-Akela-Rock outcrop complex 1 to 25 percent slopes	0.12	0.05	20
9	Arizo-Franconia-Riverwash complex 1 to 3 percent slopes	0.77	0.45	0
10	Arizo-Franconia-Riverwash complex dry 1 to 3 percent slopes	0.79	0.46	0
11	Bartmus very gravelly sandy loam 2 to 15 percent slopes	0.13	0.05	0
12	Bonita family very cobbly silty clay loam 2 to 10 percent slopes	0.02	0.01	0
13	Bonita family-Gonzales complex 10 to 35 percent slopes	0.02	0.01	0
14	Brazito family sand 0 to 3 percent slopes	2.00	1.45	0
15	Bucklebar sandy loam 1 to 3 percent slopes	0.19	0.07	0
16	Cacique family extremely gravelly loam 1 to 7 percent slopes	0.09	0.03	0
17	Castaneda extremely gravelly loam 1 to 7 percent slopes	0.04	0.01	0
18	Castaneda extremely gravelly loam dry 1 to 7 percent slopes	0.04	0.01	0
19	Carrizo family very gravelly loamy sand 1 to 3 percent slopes	0.88	0.53	0
20	Carrizo family-Riverwash complex 1 to 3 percent slopes	1.07	0.68	0
21	Carrizo-Riverwash complex 3 to 8 percent slopes MLRA 30	0.91	0.55	0

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
22	Carrizo-Riverwash complex 1 to 3 percent slopes	1.09	0.69	0
23	Cave gravelly sandy loam 10 to 35 percent slopes	0.52	0.27	0
24	Cave gravelly sandy loam dry 10 to 35 percent slopes	0.52	0.27	0
25	Cellar-Rock outcrop complex 20 to 60 percent slopes	0.39	0.20	25
26	Cellar-Rock outcrop complex dry 20 to 60 percent slopes	0.39	0.20	25
27	Cellar-Topock-Rock outcrop complex 5 to 35 percent slopes	0.09	0.06	20
28	Cherioni very cobbly loam 2 to 15 percent slopes	0.04	0.01	0
29	Chuckawalla-Riverbend complex 2 to 15 percent slopes	0.13	0.05	0
30	Chuckawalla-Riverbend families complex 2 to 15 percent slopes	0.16	0.06	0
31	Cipriano very stony loam 2 to 10 percent slopes	0.23	0.10	0
32	Cline very stony loam 2 to 15 percent slopes	0.08	0.03	0
33	Cline very stony loam dry 2 to 15 percent slopes	0.08	0.03	0
34	Continental-Tres Hermanos complex 2 to 15 percent slopes	0.08	0.02	0
35	Continental-Tres Hermanos complex dry 2 to 15 percent slopes	0.08	0.02	0
36	Continental-Rillino complex 2 to 15 percent slopes	0.10	0.03	0
37	Continental-Rillino complex dry 2 to 15 percent slopes	0.10	0.03	0
38	Coolidge-Denure complex 1 to 7 percent slopes	0.79	0.45	0
39	Coolidge-Denure families complex 1 to 7 percent slopes	0.51	0.26	0
40	Courthouse family-Rock outcrop-Rubble land complex 40 to 70 percent slopes	0.26	0.12	40
41	Courthouse family-Rock outcrop-Wagonbow complex 15 to 70 percent slopes	0.15	0.05	30

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
42	Far-Rock outcrop complex 10 to 45 percent slopes	0.37	0.20	20
43	Dutchflat sandy loam 0 to 2 percent slopes	0.19	0.07	0
44	Dutchflat fine sandy loam dry 1 to 3 percent slopes	0.09	0.03	0
45	Gadsden silty clay 0 to 1 percent slopes	0.02	0.01	0
46	Gila-Glendale complex 1 to 3 percent slopes	0.12	0.03	0
47	Gila-Glendale complex dry 1 to 3 percent slopes	0.12	0.03	0
48	Goldroad-Rock outcrop complex 20 to 60 percent slopes	0.38	0.20	20
49	Gonzales-Rock outcrop complex 15 to 35 percent slopes	0.02	0.01	25
50	Goodsprings family gravelly sandy loam 1 to 15 percent slopes	0.36	0.16	0
51	Goodsprings family gravelly sandy loam dry 1 to 15 percent slopes	0.36	0.16	0
52	Goodsprings family gravelly sandy loam 10 to 35 percent slopes	0.36	0.16	0
53	Goodsprings family gravelly sandy loam dry 10 to 35 percent slopes	0.36	0.16	0
54	Graham-Arivaca complex 2 to 15 percent slopes	0.06	0.02	0
55	Graham-Rock outcrop complex 10 to 40 percent slopes	0.09	0.03	20
56	Gunsight very gravelly loam 2 to 15 percent slopes	0.17	0.07	0
57	Gunsight very gravelly sandy loam 10 to 40 percent slopes	0.38	0.20	0
58	Hassell family-Lampshire-Rock outcrop complex 10 to 30 percent slopes	0.05	0.02	20
59	Holtville silty clay 0 to 1 percent slopes	0.02	0.01	0
60	Huevi very gravelly loam 2 to 15 percent slopes	0.23	0.10	0
61	Huevi very gravelly loam 10 to 40 percent slopes	0.24	0.11	0
62	Akela-Rock outcrop complex 20 to 60 percent slopes	0.38	0.20	20
63	Hyder-Rock outcrop-Rubble land complex 40 to 70 percent slopes	0.21	0.10	40

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
64	Indio silt loam 0 to 1 percent slopes	0.12	0.03	0
65	Ireteba family-Arizo complex 1 to 3 percent slopes	0.55	0.29	0
66	Kinley gravelly loamy sand 15 to 35 percent slopes	0.67	0.36	0
67	Kinley-Poachie complex 2 to 15 percent slopes	0.20	0.07	0
68	Kofa silty clay 0 to 1 percent slopes	0.04	0.01	0
69	Dudleyville-Vinton-Riverwash complex 1 to 3 percent slopes	1.08	0.66	0
70	Dudleyville-Vinton-Riverwash complex dry 1 to 3 percent slopes	1.08	0.66	0
71	Lagunita sand 0 to 1 percent slopes	2.00	1.37	0
72	Lagunita-Ripley complex 0 to 3 percent slopes	0.83	0.45	0
73	Lampshire-Rock outcrop complex 20 to 60 percent slopes	0.51	0.29	20
74	Lampshire-Rock outcrop complex cool 30 to 70 percent slopes	0.32	0.16	20
75	Lampshire-Rock outcrop complex 15 to 60 percent slopes stony	0.30	0.15	40
76	Lostman gravelly sandy loam moist 1 to 5 percent slopes	0.45	0.23	0
77	Lostman sandy loam dry 1 to 3 percent slopes	0.63	0.34	0
78	Lostman-Kinley complex 1 to 7 percent slopes	0.58	0.31	0
79	Marshes	0.01	0.01	100
80	Meloland very fine sandy loam 0 to 1 percent slopes	0.54	0.27	0
81	Mohon-Kinley complex 2 to 15 percent slopes	0.08	0.04	0
82	Mohon-Poachie complex 2 to 15 percent slopes	0.06	0.03	0
83	Mohon-Poachie complex dry 2 to 15 percent slopes	0.06	0.03	0
84	Nickel-Topawa-Eba families complex 10 to 50 percent slopes	0.04	0.02	0
85	Orwash family sandy loam 1 to 3 percent slopes	0.61	0.32	0

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
86	Orwash family sandy loam dry 1 to 3 percent slopes	0.61	0.32	0
87	Penthouse-Gonzales complex 5 to 35 percent slopes	0.06	0.02	0
88	Poachie very gravelly loam 1 to 4 percent slopes	0.16	0.06	0
89	Poachie very gravelly loam dry 1 to 4 percent slopes	0.16	0.06	0
90	Quilotosa-Rock outcrop complex 20 to 60 percent slopes	0.38	0.20	20
91	Razorback extremely gravelly sandy loam 15 to 35 percent slopes	0.38	0.20	0
92	Razorback-Rock outcrop complex 1 to 25 percent slopes	0.21	0.10	20
93	Razorback-Rock outcrop complex 15 to 70 percent slopes	0.21	0.10	20
94	Razorback-Rock outcrop complex dry 15 to 70 percent slopes	0.21	0.10	20
95	Razorback-Rock outcrop-Rubble land complex 40 to 70 percent slopes	0.21	0.10	40
96	Razorback-Rock outcrop-Rubble land complex dry 40 to 70 percent slopes	0.21	0.10	40
97	Rillino gravelly loamy sand 15 to 35 percent slopes	0.15	0.06	0
98	Rillino-Tres Hermanos complex 2 to 15 percent slopes	0.10	0.03	0
99	Ripley silt loam 0 to 1 percent slopes	0.13	0.04	0
100	Riverbend family very cobbly sandy loam 2 to 15 percent slopes	0.42	0.22	0
101	Riverbend very cobbly sandy loam 2 to 15 percent slopes	0.38	0.19	0
102	Riverwash-Fluvaquents association 0 to 3 percent slopes	2.00	1.56	0
103	Rock outcrop-Hyder complex 35 to 65 percent slopes	0.21	0.10	45
104	Rock outcrop-Razorback complex 20 to 70 percent slopes	0.21	0.10	65
105	Rock outcrop-Sunrock complex 35 to 65 percent slopes	0.37	0.19	45

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
106	Romero-Chiricahua-Rock outcrop complex 5 to 35 percent slopes	0.03	0.02	20
107	Romero-Lampshire-Rock outcrop complex 35 to 70 percent slopes	0.13	0.05	15
108	Rositas family superstition and torriorthents soils 1 to 60 percent slopes	1.55	1.21	0
109	Rositas superstition family and torriorthents soils 1 to 60 percent slopes	1.68	1.15	0
110	Stagecoach very gravelly loam 2 to 15 percent slopes	0.24	0.11	0
111	Stagecoach very gravelly loam 10 to 40 percent slopes	0.24	0.11	0
112	Stagecoach very gravelly sandy loam 5 to 35 percent slopes	0.30	0.14	0
113	Stagecoach very gravelly sandy loam dry 5 to 35 percent slopes	0.30	0.14	0
114	Stagecoach-Topawa family-Eba complex 10 to 50 percent slopes	0.07	0.04	0
115	Stagecoach-Topawa family-Eba complex dry 10 to 50 percent slopes	0.07	0.04	0
116	Sunrock extremely gravelly sandy loam 15 to 35 percent slopes	0.35	0.18	0
117	Sunrock-Rock outcrop complex 30 to 65 percent slopes	0.35	0.18	20
118	Tombstone-Caralampi-Eloma complex 10 to 50 percent slopes	0.09	0.04	0
119	Torriorthents 35 to 65 percent slopes	0.96	0.62	0
120	Torriorthents dry 35 to 65 percent slopes	0.96	0.62	0
121	Tumarion very cobbly loam 2 to 15 percent slopes	0.08	0.03	0
122	Tumarion very cobbly loam dry 2 to 15 percent slopes	0.10	0.03	0
123	Tyro extremely stony sandy loam 3 to 35 percent slopes	0.36	0.19	0
124	Tyro very stony loam 2 to 10 percent slopes	0.21	0.10	0
125	Vekol family gravelly loamy sand 2 to 7 percent slopes	0.50	0.26	0
126	Vekol family gravelly loamy sand dry 2 to 7 percent slopes	0.50	0.26	0
127	Water	0.01	0.01	100

Table D.9 AZ627 Mohave County Southern Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
128	Whitehills very gravelly loam 1 to 5 percent slopes	0.15	0.06	0
129	Whitehills very gravelly loam dry 2 to 15 percent slopes	0.15	0.06	0
130	White House family very gravelly loamy sand 2 to 15 percent slopes	0.08	0.03	0
131	White House gravelly loamy sand 2 to 15 percent slopes	0.01	0.01	0
132	Wikieup-Mutang-Rock outcrop complex 5 to 35 percent slopes	0.12	0.06	20
133	Mutang-Wikieup-Rock outcrop complex 3 to 30 percent slopes	0.05	0.03	15
134	Wikieup-Rock outcrop complex dry 20 to 60 percent slopes	0.41	0.21	25
135	Yahana family silty clay loam 1 to 3 percent slopes	0.04	0.01	0
136	Tumarion-Nickel family complex 8 to 35 percent slopes	0.21	0.09	0
137	Valena-Rock outcrop-Carri family complex 1 to 25 percent slopes	0.39	0.18	20
138	Nodman-Rock outcrop complex 15 to 65 percent slopes	0.06	0.02	20
139	Nodman-Romero family complex 15 to 65 percent slopes	0.17	0.07	0

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D.3.4 AZ629

Table D.10 AZ629 Coconino County Area North Kaibab Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Aneth fine sand 2 to 16 percent slopes	1.31	0.78	0
2	Arches-Pensom complex 4 to 12 percent slopes	2.00	1.61	0
3	Arches-Pensom complex cool 4 to 12 percent slopes	2.00	1.52	0
4	Barx gravelly loam 1 to 6 percent slopes	0.11	0.04	0
5	Barx-Pensom complex 1 to 6 percent slopes	0.15	0.05	0
6	Bidonia-Rock outcrop complex 1 to 15 percent slopes	0.01	0.01	15
7	Bison-Curob complex 2 to 6 percent slopes	0.19	0.08	0
8	Clayhole silty clay loam 1 to 5 percent slopes	0.06	0.01	0
9	Clayhole-Torriorthents complex 2 to 25 percent slopes	0.20	0.08	0
10	Curhollow-Mellenthin complex 2 to 12 percent slopes	0.17	0.08	0
11	Curob loamy sand 2 to 10 percent slopes	1.56	0.98	0
12	Curob very gravelly loam 2 to 12 percent slopes	0.15	0.06	0
13	Disterheff very gravelly loam 2 to 15 percent slopes	0.09	0.03	0
14	Disterheff-Houserock complex 3 to 15 percent slopes	0.07	0.02	0
15	Doak fine sandy loam 1 to 6 percent slopes	0.08	0.02	0
16	Glenyon silty clay loam 0 to 2 percent slopes	0.04	0.01	0
17	Houserock-Disterheff complex 3 to 15 percent slopes	0.05	0.01	0
18	Jocity clay loam 1 to 3 percent slopes	0.05	0.01	0
19	Jocity silty clay loam 1 to 3 percent slopes	0.05	0.01	0
20	Keeseha loam 1 to 6 percent slopes	0.02	0.01	0
21	Kinan-Pennell complex 4 to 15 percent slopes	0.41	0.20	0
22	Kinan-Pennell complex dry 4 to 15 percent slopes	0.41	0.20	0
23	Klondike sandy clay loam 2 to 15 percent slopes MLRA 35	0.11	0.04	0
24	Manikan silty clay loam 1 to 3 percent slopes	0.07	0.02	0
25	Mellenthin very gravelly loam 1 to 25 percent slopes	0.19	0.08	0

Table D.10 AZ629 Coconino County Area North Kaibab Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
26	Mellenthin very gravelly loam 30 to 60 percent slopes	0.17	0.08	0
27	Monierco clay loam 2 to 15 percent slopes	0.04	0.01	0
28	Monue sandy loam 1 to 6 percent slopes	0.61	0.32	0
29	Monue-Seeg complex 1 to 6 percent slopes	0.55	0.28	0
30	Needle-Rock outcrop complex 4 to 15 percent slopes	1.62	1.02	15
31	Needle-Sheppard complex 2 to 12 percent slopes	1.71	1.08	0
32	Pagina loamy sand 1 to 3 percent slopes	1.33	0.80	0
33	Pagina-Wahweap complex 3 to 16 percent slopes	1.30	0.78	0
34	Pennell cobbly loam 3 to 10 percent slopes	0.20	0.08	0
35	Pennell gravelly sandy loam 20 to 45 percent slopes	0.38	0.18	0
36	Pennell sandy loam 20 to 45 percent slopes	0.60	0.31	0
37	Pensom fine sand 2 to 16 percent slopes	2.00	1.35	0
38	Pensom-Arches complex 4 to 12 percent slopes	1.54	0.95	0
39	Pensom-Arches complex moist 4 to 16 percent slopes	1.54	0.95	0
40	Pits borrow	0.02	0.01	0
41	Rock outcrop	0.01	0.01	85
42	Rock outcrop-Needle complex 4 to 50 percent slopes	1.62	1.02	55
43	Rock outcrop-Torriorthents complex warm 25 to 65 percent slopes	0.96	0.62	65
44	Sheppard loamy fine sand 1 to 5 percent slopes	2.00	1.30	0
45	Sheppard loamy fine sand 5 to 15 percent slopes	2.00	1.30	0
46	Strych loam 1 to 4 percent slopes	0.17	0.08	0
47	Torriorthents 3 to 50 percent slopes	0.96	0.62	0
48	Torriorthents-Rock outcrop complex 25 to 65 percent slopes	0.96	0.62	30
49	Wahweap loamy sand 0 to 5 percent slopes	1.22	0.73	0
50	Wahweap-Rock outcrop complex 1 to 15 percent slopes	0.54	0.28	35
51	Yumtheska very gravelly loam 4 to 30 percent slopes	0.20	0.09	0

Table D.10 AZ629 Coconino County Area North Kaibab Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
52	Yumtheska-Houserock association 4 to 20 percent slopes	0.11	0.04	0
1	Aneth fine sand 2 to 16 percent slopes	1.31	0.78	0

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D.3.5 AZ631

Table D.11 AZ631 Coconino County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Ashfork gravelly clay loam 1 to 15 percent slopes	0.05	0.01	0
2	Aut gravelly loam 0 to 8 percent slopes	0.20	0.08	0
3	Aut-Cross association moderately sloping	0.13	0.04	0
4	Aut-Lynx association gently sloping	0.15	0.06	0
5	Badland-Torriorthents complex moderately steep	0.44	0.24	0
6	Boquillas-Seligman complex 1 to 15 percent slopes	0.03	0.01	0
7	Clovis loamy sand 1 to 8 percent slopes	0.10	0.03	0
8	Cross-Apache complex 2 to 15 percent slopes	0.04	0.01	0
9	Daze-Deama association moderately steep	0.25	0.11	0
10	Deama gravelly loam 2 to 15 percent slopes	0.18	0.07	0
11	Deama stony loam 1 to 15 percent slopes	0.14	0.06	0
12	Deama-Rock outcrop complex 8 to 30 percent slopes	0.15	0.06	30
13	Deama-Toqui complex 0 to 8 percent slopes	0.06	0.03	0
14	Deama-Tovar association steep	0.09	0.03	0
15	Disterheff very gravelly sandy clay loam 1 to 15 percent slopes	0.02	0.01	0
16	Disterheff-Kopie association moderately sloping	0.06	0.02	0
17	Epikom very cindery loamy sand 0 to 5 percent slopes	0.83	0.49	0
18	Epikom complex 0 to 15 percent slopes	0.21	0.08	0
19	Epikom-Rock outcrop complex 8 to 60 percent slopes	0.20	0.08	20
20	Faraway-Rock outcrop complex 20 to 80 percent slopes	0.26	0.13	30
21	Keeseha-Poley gravelly sandy loams 0 to 8 percent slopes	0.03	0.01	0
22	Kopie-Servilleta association moderately sloping	0.10	0.04	0
23	Lava flows	0.01	0.01	100
24	Lomaki-Nalaki very cindery loams 0 to 8 percent slopes	0.09	0.03	0

Table D.11 AZ631 Coconino County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
25	Mespun-Palma complex 1 to 8 percent slopes	0.99	0.56	0
26	Navajo clay 0 to 5 percent slopes	0.02	0.01	0
27	Palma sandy loam 0 to 5 percent slopes	0.51	0.25	0
28	Pastura gravelly loam 0 to 8 percent slopes	0.14	0.05	0
29	Paymaster-Lynx association gently sloping	0.21	0.09	0
30	Poley sandy loam 0 to 5 percent slopes	0.08	0.02	0
31	Poley gravelly loam 0 to 8 percent slopes	0.08	0.02	0
32	Poley-Lynx association gently sloping	0.09	0.02	0
33	Poley-Tusayan association gently sloping	0.08	0.02	0
34	Purgatory gravelly fine sandy loam 0 to 8 percent slopes	0.50	0.26	0
35	Quivera very gravelly loam 0 to 8 percent slopes	0.03	0.01	0
36	Riverwash	2.00	1.56	0
37	Rune silty clay loam 0 to 8 percent slopes	0.05	0.02	0
38	Rune-Disterheff association gently sloping	0.04	0.01	0
39	Servilleta fine sandy loam 1 to 8 percent slopes	0.03	0.01	0
40	Servilleta-Tusayan complex 1 to 8 percent slopes	0.04	0.01	0
41	Showlow gravelly fine sandy loam 0 to 8 percent slopes	0.03	0.01	0
42	Showlow gravelly fine sandy loam 8 to 30 percent slopes	0.03	0.01	0
43	Springerville cobbly clay 0 to 8 percent slopes	0.02	0.01	0
44	Springerville very stony clay 0 to 8 percent slopes	0.01	0.01	0
45	Tajo-Springerville complex 0 to 15 percent slopes	0.05	0.02	0
46	Tenorio very gravelly sandy loam 0 to 8 percent slopes	0.07	0.02	0
47	Thunderbird-Cabezon complex 2 to 30 percent slopes	0.02	0.01	0
48	Thunderbird-Rock outcrop complex 30 to 60 percent slopes	0.03	0.01	30
49	Thunderbird-Springerville association strongly sloping	0.03	0.01	0
50	Torrifluvents saline	2.00	1.56	0

Table D.11 AZ631 Coconino County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
51	Tours silty clay loam 0 to 8 percent slopes	0.05	0.01	0
52	Tours-Ives association gently sloping	0.61	0.32	0
53	Tovar complex 2 to 25 percent slopes	0.07	0.02	0
54	Tovar complex 25 to 60 percent slopes	0.07	0.02	0
55	Tusayan-Lynx association gently sloping	0.14	0.05	0
56	Tuweep very gravelly loam 0 to 15 percent slopes	0.07	0.02	0
57	Valle gravelly silt loam 0 to 8 percent slopes	0.08	0.03	0
58	Wilaha cindery loam 2 to 30 percent slopes	0.08	0.03	0
59	Wilaha-Wukoki association steep	0.10	0.04	0
60	Winona gravelly loam 0 to 8 percent slopes	0.11	0.04	0
61	Winona stony loam 0 to 8 percent slopes	0.11	0.04	0
62	Winona-Boysag gravelly loams 0 to 8 percent slopes	0.07	0.02	0
63	Winona-Epikom association gently sloping	0.14	0.05	0
64	Winona-Rock outcrop complex 15 to 30 percent slopes	0.11	0.04	30
65	Winona-Rock outcrop complex 30 to 70 percent slopes	0.11	0.04	30
66	Winona-Tusayan association gently sloping	0.11	0.04	0
67	Wukoki-Rock outcrop complex 5 to 25 percent slopes	0.12	0.05	25
68	Wukoki-Wupatki very cindery loams 15 to 60 percent slopes	0.12	0.05	0
69	Wupatki-Wukoki very cindery loams 0 to 15 percent slopes	0.12	0.05	0
70	Ziegler gravelly loam 0 to 8 percent slopes	0.02	0.01	0
71	Ziegler-Cross association moderately sloping	0.02	0.01	0
72	Ziegler-Wilaha association strongly sloping	0.03	0.01	0
73	Water	0.01	0.01	100
100	Bighawk gravelly sandy loam 1 to 5 percent slopes	1.64	1.05	0
101	Bighawk family gravelly sand 2 to 11 percent slopes	0.17	0.07	0
102	Chedeski very gravelly sandy loam 0 to 6 percent slopes	0.11	0.03	0
103	Flaco extremely gravelly coarse sand 1 to 3 percent slopes	0.04	0.01	0
104	Flaco-Lava flows complex 1 to 18 percent slopes	0.24	0.10	10

Table D.11 AZ631 Coconino County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
105	Flaco-Pocum complex 1 to 3 percent slopes	0.05	0.02	0
106	Gish very gravelly coarse sand 0 to 0.4 percent slopes	0.03	0.01	0
107	Ives-Riverwash complex 1 to 5 percent slopes rarely flooded	0.30	0.06	0
108	Meriwhitica-Rock outcrop complex 7 to 68 percent slopes	0.55	0.29	25
109	Miburn coarse sand 1 to 10 percent slopes	2.00	1.69	0
110	Miburn-Cambidic Haplodurids complex 1 to 8 percent slopes	2.00	1.92	0
111	Miburn-Heiser-Lava flows complex 4 to 45 percent slopes	2.00	1.35	10
112	Moenkopie-Typic Haplocambids complex 1 to 6 percent slopes	0.24	0.10	0
113	Moenkopie-Rock outcrop complex 1 to 14 percent slopes	1.50	0.92	20
114	Nalakihu loamy sand 0 to 4 percent slopes	0.39	0.18	0
115	Peshlaki-Rock outcrop complex 1 to 11 percent slopes	1.02	0.62	10
116	Rock outcrop-Typic Torriorthents-Heiser association 3 to 40 percent slopes	0.22	0.09	35
117	Sandy Typic Torriorthents 1 to 15 percent slopes	0.27	0.12	0
118	Shinume channery sandy clay loam 2 to 30 percent slopes	0.12	0.04	0
119	Trachute-Lava flows complex 0 to 5 percent slopes very rarely flooded	0.57	0.29	10
120	Tsosie very gravelly coarse sand 1 to 5 percent slopes	0.13	0.04	0
121	Vitrandic Torriorthents 10 to 63 percent slopes	1.76	1.11	0

D.3.6 AZ637

Table D.12 AZ637 Yavapai County Western Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
AaB	Abra gravelly sandy loam 0 to 8 percent slopes	0.16	0.06	0
AbB	Abra-Lonti loams 0 to 5 percent slopes	0.09	0.03	0
AeB	Abra-Poley loams 0 to 5 percent slopes	0.09	0.04	0
AlC	Abra-Balon association rolling	0.11	0.04	0
AlD	Abra-Balon association hilly	0.12	0.04	0
AmC	Abra-Lynx association rolling	0.19	0.07	0
AnC	Abra-Wineg association rolling	0.15	0.06	0
AoC	Anthony gravelly loamy sand 8 to 15 percent slopes	0.33	0.15	0
ApB	Anthony gravelly sandy loam 0 to 8 percent slopes	0.33	0.15	0
ArA	Anthony-Mohave sandy loams 1 to 3 percent slopes	0.41	0.20	0
As	Apache gravelly loam	0.13	0.05	0
At	Apache very stony loam	0.13	0.05	0
AuC	Arp gravelly clay loam 0 to 20 percent slopes	0.02	0.01	0
AvD	Arp cobbly clay loam 10 to 25 percent slopes	0.02	0.01	0
AwE	Arp very rocky clay loam 20 to 40 percent slopes	0.02	0.01	20
AxD	Arp-Moano complex 0 to 30 percent slopes	0.05	0.02	0
AyC	Arp-Lynx association rolling	0.05	0.02	0
Ba	Badland	0.31	0.16	0
BdC	Balon sandy loam 0 to 15 percent slopes	0.07	0.02	0
BgD	Balon gravelly sandy clay loam 5 to 30 percent slopes	0.07	0.02	0
BlC	Balon-Lynx association rolling	0.08	0.02	0
BmF	Barkerville cobbly sandy loam 20 to 60 percent slopes	0.60	0.33	0
BnD	Barkerville very stony sandy loam 5 to 25 percent slopes	0.28	0.14	0
BoF	Barkerville extremely rocky sandy loam 20 to 60 percent slopes	0.60	0.33	20
BrD	Bridge gravelly loam 0 to 25 percent slopes	0.08	0.02	0
BsC	Brolliar very stony silt loam 0 to 15 percent slopes	0.33	0.19	0
BsD	Brolliar very stony silt loam 15 to 30 percent slopes	0.33	0.19	0

Table D.12 AZ637 Yavapai County Western Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
CaD	Cabezon-Springerville complex 5 to 25 percent slopes	0.02	0.01	0
CbC	Cabezon-Springerville cobbly complex 5 to 15 percent slopes	0.02	0.01	0
CdC	Cabezon-Thunderbird complex 5 to 15 percent slopes	0.02	0.01	0
CeE	Cabezon soils 8 to 45 percent slopes	0.02	0.01	0
CgC	Cave gravelly sandy loam 2 to 15 percent slopes	0.59	0.32	0
ClD	Cave-Continental gravelly sandy loams 2 to 30 percent slopes	0.16	0.08	0
CmD	Cellar very gravelly sandy loam 8 to 30 percent slopes	0.12	0.04	0
CnC	Cellar very rocky sandy loam 2 to 15 percent slopes	0.12	0.04	20
CnF	Cellar very rocky sandy loam 15 to 60 percent slopes	0.12	0.04	20
CoD	Cellar-Chiricahua complex 8 to 30 percent slopes	0.07	0.03	0
CrF	Cellar soils 20 to 60 percent slopes	0.12	0.04	0
CsC	Continental gravelly sandy loam 2 to 15 percent slopes	0.02	0.01	0
CtD	Continental-Cave gravelly sandy loams 8 to 30 percent slopes	0.07	0.04	0
CuC	Continental-Whitlock gravelly sandy loams 2 to 15 percent slopes	0.08	0.04	0
CvB	Continental-Loamy alluvial land association sloping	0.05	0.03	0
CwD	Continental soils 3 to 30 percent slopes	0.02	0.01	0
Cx	Cordes sandy loam	0.61	0.35	0
Cy	Cordes fine sandy loam red variant	0.63	0.36	0
CzC	Cross Cabezon and Apache soils 2 to 15 percent slopes	0.04	0.02	0
DaF	Dandrea gravelly loam 20 to 60 percent slopes	0.21	0.09	0
DgC	Dye gravelly loam 2 to 15 percent slopes	0.03	0.01	0
DrC	Dye very rocky loam 2 to 15 percent slopes	0.03	0.01	20
FaC	Faraway very rocky loam 0 to 15 percent slopes	0.17	0.07	25

Table D.12 AZ637 Yavapai County Western Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
FlE	Faraway-Luzena complex 20 to 40 percent slopes	0.10	0.05	0
FlF	Faraway-Luzena complex 40-60 percent slopes	0.10	0.05	0
GdD	Gaddes gravelly sandy loam 3 to 25 percent slopes	0.09	0.03	0
Go	Gila soils	0.23	0.09	0
GrB	Graham-Rimrock complex 0 to 8 percent slopes	0.02	0.01	0
GsE	Graham soils 8 to 45 percent slopes	0.03	0.01	0
HgB	Hogg gravelly loam 0 to 8 percent slopes	0.03	0.01	0
HgD	Hogg gravelly loam 8 to 30 percent slopes	0.03	0.01	0
HmE	House Mountain soils 15-40 percent slopes	0.11	0.04	0
JaC	Jacks very rocky loam 3 to 15 percent slopes	0.02	0.01	20
JaD	Jacks very rocky loam 15 to 30 percent slopes	0.02	0.01	20
La	Latene gravelly sandy loam	0.16	0.06	0
Lc	Latene-Mohave complex	0.27	0.12	0
Le	Lehmans gravelly clay loam 8 to 45 percent slopes	0.01	0.01	0
Lh	Lehmans extremely rocky clay loam 8 to 60 percent slopes	0.01	0.01	40
LkD	Lonti gravelly sandy loam 15 to 30 percent slopes	0.03	0.01	0
LlC	Lonti gravelly sandy loam high rainfall 0 to 15 percent slopes	0.03	0.01	0
LlD	Lonti gravelly sandy loam high rainfall 15 to 30 percent slopes	0.03	0.01	0
LmB	Lonti gravelly loam 0 to 8 percent slopes	0.03	0.01	0
LnC	Lonti cobbly loam 0 to 15 percent slopes	0.03	0.01	0
LnF	Lonti cobbly loam 30 to 60 percent slopes	0.03	0.01	0
LoD	Lonti complex 2 to 30 percent slopes	0.03	0.01	0
LpB	Lonti-Abra gravelly sandy loams 0 to 8 percent slopes	0.06	0.02	0
LrD	Lonti-Abra complex 8 to 30 percent slopes	0.06	0.02	0
LsC	Lonti-Pastura complex 0 to 20 percent slopes	0.05	0.02	0
LtB	Lonti-Cordes association undulating	0.10	0.04	0
LuC	Lonti-Wineg complex 3 to 15 percent slopes	0.06	0.02	0
LvE	Lonti-Rock land association hilly	0.03	0.01	35

Table D.12 AZ637 Yavapai County Western Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
LwD	Luzena cobbly loam 0 to 30 percent slopes	0.02	0.01	0
LxD	Luzena very rocky loam 10 to 30 percent slopes	0.02	0.01	25
Ly	Lynx soils	0.14	0.05	0
Ly2	Lynx soils eroded	0.08	0.02	0
Lz	Lynx soils wet variant	0.15	0.05	0
MbC	Mirabal gravelly sandy loam 8 to 20 percent slopes	0.50	0.26	0
MbF	Mirabal gravelly sandy loam 20 to 60 percent slopes	0.50	0.26	0
MdF	Mirabal-Dandrea complex 20 to 60 percent slopes	0.30	0.14	0
MgD	Moano gravelly loam 0 to 30 percent slopes	0.18	0.08	0
MkF	Moano very rocky loam 15 to 60 percent slopes	0.18	0.08	20
MoD	Moano extremely rocky loam 15 to 30 percent slopes	0.18	0.08	30
MrC	Moano-Lynx association rolling	0.20	0.09	0
MsB	Moenkopie association undulating	0.64	0.35	0
Mt	Mohave sandy loam	0.60	0.32	0
PaB	Palma sandy loam 1 to 8 percent slopes	0.48	0.23	0
PcE	Palos Verdes gravelly sandy loam 8 to 40 percent slopes	0.05	0.01	0
Pd	Partri loam	0.03	0.01	0
Pe	Partri gravelly clay loam	0.03	0.01	0
Pf	Partri-Abra loams	0.06	0.02	0
PgB	Pastura gravelly loam 0 to 8 percent slopes	0.13	0.05	0
PhD	Pastura complex 1 to 30 percent slopes	0.13	0.05	0
PlB	Pastura-Poley complex 2 to 8 percent slopes	0.06	0.03	0
PmB	Pastura-Lynx association undulating	0.16	0.06	0
PnB	Pastura-Rune association undulating	0.18	0.08	0
Po	Poley gravelly sandy loam	0.02	0.01	0
Pp	Poley-Partri loams	0.02	0.01	0
PrC	Purner gravelly loam 2 to 15 percent slopes	0.19	0.08	0
PsC	Purner very stony loam 2 to 15 percent slopes	0.16	0.07	0
PsD	Purner very stony loam 15 to 20 percent slopes	0.16	0.07	0
PuC	Purner-Boysag complex 2 to 15 percent slopes	0.09	0.03	0

Table D.12 AZ637 Yavapai County Western Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
PvD	Purner and Dye soils 2 to 30 percent slopes	0.09	0.04	0
PwD	Purner and Moenkopie soils 8 to 30 percent slopes	0.25	0.12	0
ReD	Retriever gravelly loam 2 to 30 percent slopes	0.14	0.05	0
Rk	Rimrock cobbly clay	0.01	0.01	0
Rm	Rimrock-Cave complex	0.04	0.03	0
Rn	Rimrock-Graham complex 3 to 15 percent slopes	0.01	0.01	0
Ro	Rock land	0.01	0.01	90
Rr	Rock land low rainfall	0.01	0.01	90
Rs	Rough broken land	0.01	0.01	95
Rt	Rune loam	0.35	0.18	0
Sa	Sandy and Gravelly alluvial land	0.96	0.62	0
ShB	Showlow gravelly sandy loam 0 to 8 percent slopes	0.12	0.04	0
SlB	Springerville cobbly clay 0 to 8 percent slopes	0.02	0.01	0
SmB	Springerville very stony clay 0 to 8 percent slopes	0.01	0.01	0
SnD	Springerville-Cabezon complex 3 to 30 percent slopes	0.02	0.01	0
SpB	Springerville-Pastura complex 1 to 5 percent slopes	0.04	0.02	0
StB	Springerville-Thunderbird complex 0 to 8 percent slopes	0.02	0.01	0
SuB	Springerville-Lonti association undulating	0.02	0.01	0
TaB	Tajo gravelly loam 0 to 8 percent slopes	0.08	0.02	0
TcC	Tajo-Springerville complex 0 to 15 percent slopes	0.05	0.02	0
TdC	Thunderbird cobbly clay loam 0 to 15 percent slopes	0.02	0.01	0
TdE	Thunderbird cobbly clay loam 15 to 40 percent slopes	0.02	0.01	0
ThC	Thunderbird-Cabezon complex 0 to 15 percent slopes	0.02	0.01	0
TlB	Tortugas gravelly loam 2 to 8 percent slopes	0.21	0.09	0
TmD	Tortugas very rocky loam 8 to 30 percent slopes	0.15	0.07	20

Table D.12 AZ637 Yavapai County Western Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
TnF	Tortugas extremely rocky loam 15 to 60 percent slopes	0.23	0.11	30
To	Tours loam	0.08	0.02	0
TwC	Tres Hermanos-Whitlock gravelly sandy loams 0 to 15 percent slopes	0.25	0.09	0
Vm	Vekol-Mohave complex	0.10	0.04	0
VnD	Venezia cobbly loam 0 to 30 percent slopes	0.32	0.16	0
VrF	Venezia very stony loam 30 to 60 percent slopes	0.28	0.14	0
VsC	Venezia-Springerville complex 0 to 20 percent slopes	0.11	0.06	0
VtC	Venezia-Thunderbird complex 5 to 15 percent slopes	0.12	0.06	0
VtE	Venezia-Thunderbird complex 15 to 40 percent slopes	0.12	0.06	0
W	Water	0.01	0.01	100
WcC	Waldroup-Cabezon association hilly	0.01	0.01	0
WgC	Whitlock gravelly sandy loam 0 to 15 percent slopes	0.52	0.27	0
WhC	Whitlock-Anthony gravelly sandy loams 0 to 15 percent slopes	0.45	0.22	0
WlF	Wilcoxson gravelly loam 30 to 60 percent slopes	0.03	0.01	0
Wm	Wineg sandy loam	0.14	0.06	0
Wn	Wineg-Abra complex	0.15	0.06	0
Wo	Wineg-Lynx association	0.17	0.07	0
Wp	Wineg and Poley soils	0.05	0.02	0

D.3.7 AZ657

Table D.13 AZ657 Kofa Area, Arizona, Parts Of La Paz And Yuma Counties

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
200	Gunsight family-Pinamt complex 1 to 15 percent slopes	0.11	0.04	0
205	Denure-Pahaka-Growler complex 0 to 3 percent slopes	0.70	0.37	0
206	Denure sandy loam 0 to 1 percent slopes	0.95	0.54	0
207	Denure fine sandy loam 0 to 1 percent slopes	0.83	0.46	0
208	Pahaka fine sandy loam 0 to 1 percent slopes	0.75	0.41	0
209	Pahaka sandy loam 0 to 1 percent slopes	1.00	0.57	0
210	Brios-Riverwash complex 0 to 1 percent slopes	1.59	1.06	0
215	Denure complex 1 to 5 percent slopes	0.66	0.35	0
220	Momoli-Carrizo family complex 1 to 5 percent slopes	0.57	0.31	0
225	Growler sandy loam 1 to 5 percent slopes	0.67	0.35	0
230	Casa Grande family-Rositas family complex 0 to 8 percent slopes	0.42	0.18	0
235	Superstition-Rositas family complex dry 0 to 3 percent slopes	1.97	1.25	0
240	Beeline-Laposa complex 2 to 45 percent slopes	0.57	0.30	0
245	Hyder-Rock outcrop complex 5 to 45 percent slopes	0.07	0.02	35
250	Brios coarse sand 3 to 35 percent slopes	1.55	0.96	0
255	Glendale-Gila complex 0 to 1 percent slopes	0.17	0.05	0
257	Glendale silty clay loam 0 to 1 percent slopes	0.06	0.01	0
258	Gila very fine sandy loam 0 to 1 percent slopes	0.79	0.43	0
265	Hickiwan-Gunsight complex 3 to 30 percent slopes	0.46	0.24	0

Table D.13 AZ657 Kofa Area, Arizona, Parts Of La Paz And Yuma Counties

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
270	Pajarito sandy loam 0 to 1 percent slopes	0.93	0.53	0
271	Whitlock family sandy loam 0 to 1 percent slopes	0.49	0.24	0
272	Sahuarita sandy loam 0 to 1 percent slopes	0.88	0.50	0
275	Pajarito-Whitlock-Sahuarita complex 0 to 1 percent slopes	0.67	0.35	0
280	Delnorte-Whitlock complex 2 to 10 percent slopes	0.24	0.10	0
285	Mohave sandy loam 0 to 1 percent slopes	0.07	0.02	0
290	Dixaleta-Rock outcrop complex 3 to 30 percent slopes	0.09	0.03	15
295	Yturbide sand 0 to 1 percent slopes	2.00	1.83	0
296	Brazito sandy loam 0 to 1 percent slopes	0.78	0.42	0
300	Stagecoach-Pinaleno family complex 3 to 15 percent slopes	0.40	0.20	0
305	Mohave sandy loam 0 to 3 percent slopes	0.07	0.02	0
310	Glenbar silt loam 0 to 1 percent slopes	0.07	0.02	0
311	Gadsden silty clay loam 0 to 1 percent slopes	0.04	0.01	0
312	Gadsden-Glenbar complex 0 to 2 percent slopes	0.03	0.01	0
315	Contine sandy loam 0 to 1 percent slopes	0.70	0.37	0
316	Mohall sandy loam 0 to 1 percent slopes	0.54	0.27	0
317	Mohall loam 0 to 1 percent slopes	0.23	0.09	0
318	Glenbar silt loam loamy substratum 0 to 1 percent slopes	0.11	0.03	0
320	Hantz silty clay loam 0 to 1 percent slopes	0.03	0.01	0
321	Hantz silty clay loam 0 to 2 percent slopes	0.05	0.01	0
325	Dateland-Denure complex 0 to 2 percent slopes	0.71	0.38	0

Table D.13 AZ657 Kofa Area, Arizona, Parts Of La Paz And Yuma Counties

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
330	Gunsight family-Rillito complex 1 to 10 percent slopes	0.45	0.23	0
331	Rillito sandy loam 0 to 1 percent slopes	0.61	0.32	0
332	Gunsight family gravelly sandy loam 0 to 1 percent slopes	0.58	0.30	0
335	Dateland loam 0 to 1 percent slopes	0.39	0.18	0
336	Dateland fine sandy loam 0 to 1 percent slopes	0.83	0.45	0
340	Mohall-Contine complex 1 to 5 percent slopes	0.09	0.06	0
345	Gilman silt loam 0 to 1 percent slopes	0.24	0.09	0
350	Gunsight family-Cristobal complex dry 1 to 10 percent slopes	0.22	0.09	0
355	Wintersburg-Laveen complex 0 to 3 percent slopes	0.44	0.20	0
360	Schenco-Chuichu-Rock outcrop complex 3 to 45 percent slopes	0.15	0.06	20
370	Superstition-Rillito complex dry 2 to 10 percent slopes	0.69	0.35	0
375	Riverbend family-Superstition complex dry 1 to 30 percent slopes	0.68	0.40	0
385	Carrizo family very gravelly sandy loam dry 0 to 3 percent slopes	0.45	0.23	0
390	Carrizo family-Riverwash complex dry 0 to 2 percent slopes	1.28	0.82	0
395	Cristobal family-Gunsight family complex dry 1 to 10 percent slopes	0.08	0.03	0
400	Gilman-Carrizo family complex dry 0 to 3 percent slopes	0.62	0.32	0
405	Harqua-Casa Grande family complex dry 0 to 4 percent slopes	0.13	0.04	0
410	Gunsight family very gravelly sandy loam dry 1 to 15 percent slopes	0.37	0.19	0
415	Rock outcrop-Laposa family-Hyder complex dry 3 to 45 percent slopes	0.37	0.19	35
420	Gilman-Yahana complex dry 0 to 2 percent slopes	0.24	0.09	0

Table D.13 AZ657 Kofa Area, Arizona, Parts Of La Paz And Yuma Counties

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
425	Rock outcrop-Schenco complex dry 5 to 50 percent slopes	0.37	0.19	60
430	Water association	0.01	0.01	100
NOTCOM	No Digital Data Available	0.02	0.01	0

D.3.8 AZ697

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Alko family cobbly loam 0 to 25 percent slopes	0.29	0.13	0
2	Alko family gravelly sandy loam 1 to 15 percent slopes	0.29	0.13	0
3	Appleseed-Huevi association 4 to 30 percent slopes	0.27	0.13	0
4	Aridic Argiustolls-Lithic Haplustolls complex 1 to 40 percent slopes	0.31	0.16	0
5	Arizo-Detrital-Nickel complex 2 to 6 percent slopes	0.53	0.27	0
6	Arizo-Franconia-Riverwash complex 1 to 3 percent slopes	0.79	0.46	0
7	Arizo-Riverwash complex 0 to 1 percent slopes	1.30	0.84	0
8	Arizo-Riverwash complex 1 to 4 percent slopes	1.66	1.11	0
9	Arizo-Riverwash complex dry 0 to 1 percent slopes	1.66	1.11	0
10	Arizo-Riverwash complex moist 1 to 3 percent slopes	1.95	1.34	0
11	Azure-Detrital-Antares complex 5 to 30 percent slopes	0.29	0.14	0
12	Birdsbeak very channery loam 10 to 35 percent slopes	0.02	0.01	0
13	Bluebird-Detrital complex 2 to 15 percent slopes very stony	0.19	0.08	0
14	Bluebird-Lostman complex 1 to 5 percent slopes	0.24	0.10	0
15	Carrizo complex 1 to 5 percent slopes	0.29	0.14	0
16	Carrizo-Riverwash complex 0 to 1 percent slopes	0.78	0.45	0
17	Carrizo-Riverwash complex 3 to 8 percent slopes MLRA 30	0.91	0.55	0
18	Chuckawalla-Riverbend complex 2 to 15 percent slopes	0.13	0.05	0
19	Circular complex 1 to 3 percent slopes	0.47	0.23	0
20	Circular-Dusty complex 0 to 4 percent slopes	0.26	0.10	0

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
21	Cod gravelly sandy loam 2 to 6 percent slopes	0.41	0.20	0
22	Cordes-Manikan-Riverwash complex 1 to 6 percent slopes	0.54	0.27	0
23	Cupel-Rock outcrop complex 35 to 65 percent slopes	0.14	0.06	20
24	Cyclopic very stony loam 3 to 8 percent slopes	0.01	0.01	0
25	Deluge-Gotchell-Sunstroke complex 3 to 7 percent slopes	0.11	0.04	0
26	Detrital-Bluebird complex 2 to 12 percent slopes	0.18	0.07	0
27	Detrital-Nealy complex 1 to 6 percent slopes	0.29	0.13	0
28	Detrital-Nickel complex dry 1 to 6 percent slopes	0.41	0.21	0
29	Detrital-Nickel family complex 1 to 4 percent slopes	0.51	0.26	0
30	Detrital-Skelon family complex 1 to 5 percent slopes	0.29	0.14	0
31	Dusty-Kurstan family complex 1 to 6 percent slopes	0.15	0.04	0
32	Dutchflat sandy loam 0 to 2 percent slopes	0.19	0.07	0
33	Dye-Tovar-Rock outcrop complex 6 to 25 percent slopes	0.04	0.01	15
34	Faraway-Rock outcrop complex 30 to 70 percent slopes	0.16	0.07	20
35	Fig-Blind-Nodman complex 30 to 70 percent slopes	0.16	0.07	0
36	Filaree gravelly sandy loam 2 to 6 percent slopes	0.90	0.52	0
37	Filaree-Dutchflat complex 2 to 6 percent slopes	0.76	0.42	0
38	Garnet-Dutchflat complex 2 to 6 percent slopes	0.50	0.24	0
39	Goesling family silt loam 3 to 8 percent slopes	0.13	0.05	0
40	Goldroad-Rock outcrop complex 15 to 35 percent slopes	0.33	0.17	10
41	Goldroad-Rock outcrop complex 35 to 65 percent slopes	0.33	0.17	20

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
42	Gonzales-Rock outcrop complex 15 to 35 percent slopes	0.02	0.01	25
43	Goodsprings family gravelly sandy loam 10 to 35 percent slopes	0.36	0.16	0
44	Gotchell-Sunstroke complex 6 to 35 percent slopes	0.23	0.11	0
45	Graham-Arivaca complex 2 to 15 percent slopes	0.06	0.02	0
46	Graham-Rock outcrop complex 10 to 40 percent slopes	0.09	0.03	20
47	Grandwash extremely flaggy sandy loam 2 to 25 percent slopes	0.01	0.01	0
48	Greyeagle family extremely gravelly coarse sandy loam 15 to 40 percent slopes	0.19	0.08	0
49	Greyeagle family extremely gravelly sandy loam 35 to 60 percent slopes	0.38	0.20	0
50	Greyeagle family-Cyclopic complex 3 to 12 percent slopes	0.16	0.09	0
51	Greyeagle-Skelon families complex 2 to 12 percent slopes	0.23	0.10	0
52	Greyeagle-Skelon families complex moist 4 to 25 percent slopes	0.26	0.12	0
53	Gypsids 3 to 50 percent slopes	0.22	0.10	0
54	Haplogypsids eroded-Haplogypsids complex 35 to 75 percent slopes	0.22	0.10	0
55	Hassell family-Lampshire-Rock outcrop complex 10 to 30 percent slopes	0.05	0.02	20
56	Hindu-Rock outcrop complex 5 to 45 percent slopes	0.12	0.04	20
57	Hooks-Courtland families complex 1 to 5 percent slopes	0.25	0.10	0
58	Hosta family sandy loam 1 to 8 percent slopes	0.18	0.07	0
59	House Mountain family-Calvista family-Rock outcrop complex 10 to 35 percent slopes	0.22	0.09	20
60	Huevi extremely cobbly sandy loam 2 to 6 percent slopes	0.27	0.13	0
61	Huevi very gravelly loam 10 to 40 percent slopes	0.24	0.11	0

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
62	Huevi very gravelly sandy loam 15 to 35 percent slopes	0.33	0.17	0
63	Huevi-Carrizo complex 1 to 25 percent slopes	0.17	0.07	0
64	Huevi-Carrwash complex 2 to 75 percent slopes	0.49	0.26	0
65	Huevi-Sunrock-Rock outcrop complex 20 to 70 percent slopes	0.24	0.11	10
66	Hulda extremely gravelly sandy loam 20 to 65 percent slopes	0.39	0.20	0
67	Hulda-Rock outcrop complex 20 to 65 percent slopes	0.39	0.20	20
68	Hulda-Rock outcrop complex moist 35 to 70 percent slopes	0.31	0.16	35
69	Ireteba family-Arizo complex 1 to 3 percent slopes	0.55	0.29	0
70	Jagerson very gravelly loam 0 to 4 percent slopes	0.21	0.08	0
71	Jagerson-Nealy complex 1 to 3 percent slopes	0.12	0.04	0
72	Kingtut-Promontory complex 3 to 12 percent slopes	0.03	0.02	0
73	Kinley gravelly loamy sand 15 to 35 percent slopes	0.67	0.36	0
74	Kurstan family-Dusty complex 2 to 6 percent slopes	0.33	0.14	0
75	Lampshire-Rock outcrop complex 20 to 60 percent slopes	0.51	0.29	20
76	Lostman gravelly sandy loam moist 1 to 5 percent slopes	0.45	0.23	0
77	Lostman sandy loam 1 to 4 percent slopes	0.69	0.39	0
78	Luzena-Thunderbird complex 3 to 20 percent slopes	0.03	0.01	0
79	Lykorly gravelly loam 1 to 4 percent slopes	0.08	0.02	0
80	Lykorly silt loam moist 1 to 5 percent slopes	0.36	0.18	0
81	Manikan-Nuffel complex 1 to 3 percent slopes	0.18	0.07	0
82	Mathis family-Riverwash complex 1 to 4 percent slopes	0.72	0.44	0

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
83	Mayswell-Rock outcrop complex 5 to 40 percent slopes	0.02	0.01	15
84	Meadview extremely gravelly sandy loam 5 to 40 percent slopes	0.28	0.13	0
85	Meadview-Yurm family complex 4 to 25 percent slopes	0.28	0.13	0
86	Meriwhitica-Rock outcrop complex 5 to 35 percent slopes	0.49	0.27	15
87	Mextank very gravelly sandy loam 2 to 15 percent slopes	0.17	0.07	0
88	Milkweed-Quartermaster-Buckndoe complex 2 to 20 percent slopes	0.16	0.07	0
89	Milok-Pastern complex 4 to 12 percent slopes	0.35	0.16	0
90	Mutang-Dutchflat complex 0 to 3 percent slopes	0.06	0.02	0
91	Mutang-Wikieup-Rock outcrop complex 3 to 30 percent slopes	0.04	0.02	15
92	Nealy-Shamock family complex 2 to 8 percent slopes	0.20	0.07	0
93	Nealy-Skelon family-Detrital complex 3 to 10 percent slopes	0.38	0.18	0
94	Nickel family-Bluebird complex 15 to 45 percent slopes	0.13	0.06	0
95	Nickel-Skelon family-Detrital complex 3 to 10 percent slopes	0.36	0.18	0
96	Nickel-Topawa-Eba families complex 10 to 50 percent slopes	0.04	0.02	0
97	Nodman-Antares complex 3 to 15 percent slopes	0.12	0.04	0
98	Nodman-Courtland family complex 2 to 20 percent slopes	0.15	0.06	0
99	Nodman-Rock outcrop complex 15 to 65 percent slopes	0.06	0.02	20
100	Nodman-Romero family complex 15 to 65 percent slopes	0.17	0.07	0
101	Nolam family-Ustalfic Petrocalcids-Caralampi family complex 1 to 15 percent slopes	0.04	0.01	0
102	Ohaco family-Bluebird complex 2 to 8 percent slopes	0.04	0.02	0

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
103	Orejano gravelly sandy loam 4 to 35 percent slopes	0.05	0.01	0
104	Pantak family-Taine-Terino family complex 15 to 65 percent slopes	0.04	0.01	0
105	Pastern-Strych complex 4 to 20 percent slopes	0.17	0.07	0
106	Peachsprings-Havasupai complex 2 to 35 percent slopes	0.35	0.17	0
107	Pearce extremely stony loam 4 to 15 percent slopes	0.14	0.06	0
108	Pearce-Detrital-Rock outcrop complex 20 to 75 percent slopes	0.18	0.07	10
109	Pearce-Rock outcrop complex 5 to 65 percent slopes	0.14	0.05	15
110	Pedregosa-Tombstone families complex 1 to 15 percent slopes	0.29	0.14	0
111	Pidineen-Tricon families complex 2 to 10 percent slopes	0.24	0.11	0
112	Pits-Dumps complex	0.02	0.01	0
113	Playa	0.12	0.05	0
114	Prieta-Rock outcrop complex 2 to 35 percent slopes	0.01	0.01	15
115	Quagwa silt loam 1 to 3 percent slopes	0.23	0.09	0
116	Razorback extremely gravelly sandy loam 15 to 35 percent slopes	0.38	0.20	0
117	Razorback-Rock outcrop complex 15 to 70 percent slopes	0.21	0.10	20
118	Razorback-Rock outcrop complex 20 to 70 percent slopes	0.16	0.06	30
119	Rift silt loam 0 to 1 percent slopes frequently flooded	0.07	0.02	0
120	Rift silty clay loam 0 to 1 percent slopes	0.05	0.01	0
121	Rillino family-Shamock family-Dutchflat complex 1 to 4 percent slopes	0.47	0.23	0
122	Rock outcrop-Appleseed complex 35 to 75 percent slopes	0.38	0.20	50
123	Rock outcrop-Pearce complex 35 to 75 percent slopes	0.26	0.12	55
124	Rock outcrop-Razorback complex 20 to 70 percent slopes	0.21	0.10	65

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
125	Rock outcrop-Torriorthents complex 35 to 75 percent slopes	0.96	0.62	50
126	Rock outcrop-Torriorthents cool complex 35 to 75 percent slopes	0.96	0.62	50
127	Rock outcrop-Valena-Kopie family complex 5 to 35 percent slopes	0.45	0.22	50
128	Rolie-Dean complex 2 to 20 percent slopes	0.12	0.04	0
129	Romero-Chiricahua-Rock outcrop complex 5 to 35 percent slopes	0.03	0.02	20
130	Romero-Lampshire-Rock outcrop complex 35 to 70 percent slopes	0.13	0.05	15
131	Rositas sand 4 to 30 percent slopes	2.00	1.79	0
132	Shortbread loamy sand 1 to 4 percent slopes	1.42	0.88	0
133	Shortbread-Kurstan family-Dusty complex 0 to 7 percent slopes	0.58	0.30	0
134	Skelon family-Greyeagle family-Detrital complex 3 to 30 percent slopes	0.38	0.19	0
135	Skelon-Pinaleno families complex 1 to 4 percent slopes	0.27	0.13	0
136	Storybook very gravelly loam 1 to 3 percent slopes	0.31	0.15	0
137	Stronghold-McAllister families complex 2 to 15 percent slopes	0.16	0.06	0
138	Sunrock extremely gravelly sandy loam 15 to 35 percent slopes	0.35	0.18	0
139	Sunrock-Rock outcrop complex 30 to 65 percent slopes	0.37	0.19	20
140	Superstition family-Carrwash complex 35 to 75 percent slopes	0.93	0.56	0
141	Taine extremely cobbly loam 12 to 35 percent slopes	0.02	0.01	0
142	Thimble-Rock outcrop complex 35 to 65 percent slopes	0.02	0.01	10
143	Tombstone-Caralampi-Nolam families complex 2 to 30 percent slopes	0.16	0.06	0
144	Torriorthents 25 to 75 percent slopes	0.96	0.62	0
145	Torriorthents gypsic-Haplocambids gypsic complex 3 to 15 percent slopes	0.52	0.29	0
146	Torriorthents-Rock outcrop complex 25 to 75 percent slopes	0.96	0.62	15

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
147	Tovar-Grandwash complex 6 to 25 percent slopes	0.03	0.01	0
148	Truxton complex 1 to 3 percent slopes	0.18	0.07	0
149	Tumarion very cobbly loam 2 to 15 percent slopes	0.08	0.03	0
150	Tumarion-Nickel family complex 8 to 35 percent slopes	0.21	0.09	0
151	Tumarion-Nickel family complex moist 5 to 40 percent slopes	0.21	0.09	0
152	Tyro extremely stony sandy loam 3 to 35 percent slopes	0.33	0.17	0
153	Tyro very gravelly sandy loam 3 to 30 percent slopes	0.35	0.18	0
154	Tyro-Sunrock complex 3 to 15 percent slopes	0.31	0.15	0
155	Urban land-Calvista family complex 2 to 10 percent slopes	0.52	0.28	0
156	Ustorthents-Rock outcrop complex 35 to 90 percent slopes	2.00	1.56	30
157	Valena-Carri complex 3 to 15 percent slopes	0.37	0.17	0
158	Valena-Rock outcrop-Carri family complex 1 to 25 percent slopes	0.39	0.18	20
159	Vekol family gravelly loamy sand 2 to 7 percent slopes	0.50	0.26	0
160	Vekol family loam 1 to 3 percent slopes	0.02	0.01	0
161	Vekol family-Whitehills complex 2 to 7 percent slopes	0.05	0.02	0
162	Vock-Elements-Rock outcrop complex 30 to 65 percent slopes	0.46	0.24	10
163	Vock-Elements-Rock outcrop complex cool 30 to 65 percent slopes	0.41	0.22	10
164	Water	0.01	0.01	100
165	White House gravelly loamy sand 2 to 15 percent slopes	0.01	0.01	0
166	White House family very gravelly loamy sand 2 to 15 percent slopes	0.08	0.03	0
167	Whitehills very gravelly loam 1 to 5 percent slopes	0.15	0.06	0
168	Wodomont-Kydestea complex 5 to 40 percent slopes	0.19	0.08	0

Table D.14 AZ697 Mohave County Central Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
169	Wodomont-Metuck-Rock outcrop complex 25 to 45 percent slopes	0.39	0.21	15
170	Wodomont-Rock outcrop complex 5 to 40 percent slopes	0.15	0.06	20
171	Yahana family silty clay loam 1 to 3 percent slopes	0.04	0.01	0
172	Zibate family extremely gravelly sandy loam 5 to 35 percent slopes	0.03	0.01	0
173	Zibate family very stony loam 12 to 30 percent slopes	0.06	0.02	0
174	Zibate family-Dutchflat-Tumarion complex 4 to 30 percent slopes	0.08	0.04	0

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Table D.15 AZ699 Hualapai-Havasupai Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Albers silty clay loam 0 to 3 percent slopes	0.02	0.01	0
2	Arizo-Lostman complex 1 to 5 percent slopes	0.63	0.35	0
3	Arizo-Riverwash complex 1 to 3 percent slopes	1.84	1.39	0
4	Barx fine sandy loam 1 to 6 percent slopes	0.12	0.04	0
5	Bleumont-Frazwell association 2 to 20 percent slopes	0.02	0.02	0
6	Cowan family-Tobler complex 0 to 3 percent slopes	1.03	0.60	0
7	Curhollow-Puertecito complex 1 to 12 percent slopes	0.07	0.02	0
8	Curhollow-Rolie-Meriwhitica association 1 to 35 percent slopes	0.10	0.03	0
9	Curhollow-Tenderfoot complex 1 to 8 percent slopes	0.07	0.02	0
10	Deama-Rock outcrop complex 25 to 55 percent slopes	0.12	0.05	20
11	Disterheff gravelly fine sandy loam cool 1 to 8 percent slopes	0.02	0.01	0
12	Disterheff gravelly loam 1 to 4 percent slopes	0.02	0.01	0
13	Frazwell-Jacques complex 1 to 3 percent slopes	0.05	0.01	0
14	Grandwash extremely flaggy sandy loam 2 to 25 percent slopes	0.01	0.01	0
15	Havasupai very gravelly loam 1 to 8 percent slopes	0.13	0.04	0
16	Hermshale extremely flaggy fine sandy loam 15 to 35 percent slopes	0.15	0.06	0
17	Hidvalle very fine sandy loam 1 to 6 percent slopes	0.45	0.23	0
18	Hindu-Rock outcrop complex 5 to 45 percent slopes	0.12	0.04	20
19	Lostman family-Harrisburg complex 1 to 5 percent slopes	0.39	0.19	0
20	Luzena-Thunderbird complex 3 to 20 percent slopes	0.04	0.01	0

Table D.15 AZ699 Hualapai-Havasupai Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
21	Lykorly gravelly loam 1 to 4 percent slopes	0.10	0.03	0
22	Lykorly silt loam moist 1 to 5 percent slopes	0.11	0.04	0
23	Metuck-Rock outcrop complex 15 to 60 percent slopes	0.25	0.12	30
24	Mextank-Lykorly-Disterheff complex 2 to 20 percent slopes	0.15	0.06	0
25	Milkweed-Quartermaster-Buckndoe complex 2 to 20 percent slopes	0.16	0.07	0
26	Milok-Pastern complex 4 to 12 percent slopes	0.34	0.16	0
27	Natank-Disterheff-Yumtheska complex 2 to 35 percent slopes	0.03	0.01	0
28	Nickel family extremely gravelly sandy loam 2 to 35 percent slopes	0.28	0.13	0
29	Peachsprings-Havasupai complex 2 to 35 percent slopes	0.35	0.17	0
30	Pinntank fine sandy loam 1 to 8 percent slopes	0.46	0.24	0
31	Pinntank-Pocomate-Retsover complex 1 to 30 percent slopes	0.07	0.03	0
32	Plaintank-Barx complex 1 to 5 percent slopes	0.11	0.04	0
33	Pocomate-Rock outcrop complex 15 to 55 percent slopes	0.07	0.03	35
34	Poley loam 1 to 5 percent slopes	0.05	0.01	0
35	Poley-Rolie complex 1 to 8 percent slopes	0.07	0.02	0
36	Prieta-Rock outcrop complex 2 to 35 percent slopes	0.03	0.01	15
37	Quagwa silt loam 1 to 3 percent slopes	0.23	0.09	0
38	Rizno-Rock outcrop complex 2 to 15 percent slopes	0.66	0.35	25
39	Rock outcrop-Torriorthents complex 35 to 120 percent slopes	0.96	0.62	60
40	Rolie-Dean complex 2 to 20 percent slopes	0.11	0.04	0
41	Saemo extremely gravelly sandy loam 2 to 45 percent slopes	0.09	0.03	0
42	Sazi family very gravelly fine sandy loam 1 to 5 percent slopes	0.40	0.21	0
43	Splanod-Rock outcrop complex 2 to 15 percent slopes	0.12	0.04	40

Table D.15 AZ699 Hualapai-Havasupai Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
44	Sponiker loam 1 to 4 percent slopes	0.11	0.04	0
45	Theecan-Pinespring association 2 to 35 percent slopes	0.03	0.01	0
46	Topocoba-Wodomont association 2 to 15 percent slopes	0.10	0.04	0
47	Toqui-Tovar-Rock outcrop complex 1 to 15 percent slopes	0.02	0.01	20
48	Toqui-Yumtheska complex 2 to 30 percent slopes	0.05	0.02	0
49	Tovar extremely flaggy fine sandy loam 2 to 25 percent slopes	0.03	0.01	0
50	Tovar very fine sandy loam 1 to 10 percent slopes	0.20	0.08	0
51	Turkeytrack gravelly loam 1 to 6 percent slopes	0.17	0.07	0
52	Ustorthents-Rock outcrop complex 35 to 90 percent slopes	2.00	1.56	30
53	Winona-Curhollow complex 1 to 12 percent slopes	0.07	0.02	0
54	Winona-Rock outcrop complex 15 to 55 percent slopes	0.08	0.02	30
55	Winona-Rock outcrop-Tusayan complex 15 to 55 percent slopes	0.11	0.04	25
56	Wodomont-Coconino complex 2 to 15 percent slopes	0.19	0.08	0
57	Wodomont-Rock outcrop complex 5 to 40 percent slopes	0.12	0.05	20
58	Wukoki-Lomaki complex 15 to 50 percent slopes	0.08	0.02	0
59	Wyva family-Rock outcrop complex 5 to 35 percent slopes	0.04	0.01	25
60	Water	0.01	0.01	100

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Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Albers clay loam 0 to 1 percent slopes	0.10	0.04	0
2	Argic Petrocalcids 8 to 15 percent slopes	0.31	0.16	0
3	Argic Petrocalcids warm 2 to 30 percent slopes	0.31	0.16	0
4	Aridic Haplustalfs-Lithic Haplustalfs complex 2 to 30 percent slopes	0.18	0.09	0
5	Aridic Haplustepts 0 to 8 percent slopes	0.22	0.10	0
6	Aridic Lithic Ustorthents-Rock outcrop complex supai group cool 15 to 55 percent slopes	2.00	1.56	30
7	Arizo very gravelly sandy loam 1 to 5 percent slopes	0.43	0.22	0
8	Bilburc very gravelly loam 2 to 6 percent slopes	0.03	0.01	0
9	Binsin-Bilburc-Yumtheska complex 2 to 15 percent slopes	0.11	0.04	0
10	Bluepoint-Rock outcrop complex 5 to 15 percent slopes	2.00	1.80	25
11	Bobzbulz extremely gravelly sandy loam 2 to 10 percent slopes	0.11	0.04	0
12	Bobzbulz extremely gravelly sandy loam 30 to 55 percent slopes	0.18	0.07	0
13	Bobzbulz-Snapcan association	0.15	0.06	0
14	Calcic Petrocalcids 2 to 15 percent slopes	0.96	0.62	0
15	Calcic Petrocalcids-Calcic Petrocalcids moderately steep-Rock outcrop complex hermit formation 2 to 50 percent slopes	0.96	0.62	30
16	Calcic Petrocalcids-Rock outcrop complex 15 to 55 percent slopes	0.96	0.62	20
17	Calcic Petrocalcids-Typic Haplocambids complex 15 to 30 percent slopes	0.96	0.62	0
18	Carrizo complex 1 to 5 percent slopes	1.09	0.67	0
19	Carrizo-Carrizo-Riverbend association	1.73	1.16	0
20	Childers-Lava flows association 4 to 15 percent slopes	0.13	0.05	35
21	Chilton-Teesto-Puertecito families complex 15 to 55 percent slopes	0.27	0.13	0

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
22	Chunkmonk-Wodomont-Houserock families complex 15 to 40 percent slopes	0.12	0.06	0
23	Chunkmonk-Wodomont-Toqui families complex 2 to 15 percent slopes	0.11	0.04	0
24	Cliffdown moderately steep-Cliffdown families complex 15 to 40 percent slopes	0.19	0.08	0
25	Cliffdown-Izo families complex 2 to 8 percent slopes	0.41	0.21	0
26	Curhollow-Lapoint-Mellenthin families complex 2 to 15 percent slopes	0.11	0.04	0
27	Curhollow-Mellenthin complex 2 to 25 percent slopes	0.13	0.05	0
28	Curhollow-Meriwhitica complex 2 to 25 percent slopes	0.12	0.04	0
29	Curhollow-Puertecito complex 1 to 12 percent slopes	0.07	0.02	0
30	Curhollow-Puertecito-Mellenthin families complex 2 to 25 percent slopes	0.11	0.04	0
31	Curhollow-Tenderfoot complex 1 to 8 percent slopes	0.08	0.02	0
32	Curob-Whirlo families complex 15 to 30 percent slopes	0.19	0.08	0
33	Deama-Rock outcrop complex 25 to 55 percent slopes	0.12	0.05	20
34	Dera family 15 to 55 percent slopes	0.09	0.03	0
35	Disterheff-Albers association 1 to 3 percent slopes	0.03	0.01	0
36	Disterheff-Yumtheska complex 2 to 6 percent slopes	0.03	0.02	0
37	Elledge family 2 to 15 percent slopes	0.64	0.33	0
38	Elledge family 15 to 40 percent slopes	0.34	0.17	0
39	Firo family-Sandia-Rock outcrop complex 15 to 55 percent slopes	0.49	0.28	15
40	Fluvaquents-Psamments complex 2 to 6 percent slopes	2.00	1.56	0
41	Fluvaquents-Psamments complex warm 2 to 6 percent slopes	2.00	1.56	0
42	Garr-Zibate families complex 2 to 15 percent slopes	0.05	0.01	0

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
43	Gypill fine sandy loam 15 to 40 percent slopes	0.88	0.49	0
44	Gypill-Meadview complex 2 to 15 percent slopes	0.45	0.22	0
45	Haplocalcids-Rock outcrop complex 1 to 19 percent slopes	0.31	0.16	15
46	Hindu-Rock outcrop complex 5 to 45 percent slopes	0.15	0.05	20
47	Huevi extremely gravelly fine sandy loam 2 to 4 percent slopes	0.39	0.20	0
48	Iceberg-Rock outcrop-Helkitchen association	0.21	0.09	25
49	Kaiparowits gravelly fine sandy loam 15 to 40 percent slopes	0.37	0.19	0
50	Kaiparowits-Plite family complex 2 to 8 percent slopes	0.35	0.16	0
51	Kanabownits fine sandy loam 15 to 40 percent slopes	0.90	0.52	0
52	Kanabownits-Kippers-Kaiparowits complex 2 to 15 percent slopes	0.11	0.05	0
53	Kanabownits-Kippers-Kaiparowits complex cool 2 to 15 percent slopes	0.36	0.19	0
54	Kanackey family 8 to 15 percent slopes	0.06	0.02	0
55	Kellypoint-Luzena complex 2 to 15 percent slopes	0.02	0.01	0
56	Kellypoint-Rock outcrop complex 15 to 35 percent slopes	0.08	0.03	15
57	Lava flows-Typic Torriorthents complex 30 to 60 percent slopes	0.96	0.62	80
58	Lithic Haplargids shinumo formation 8 to 15 percent slopes	0.31	0.16	0
59	Lithic Haplargids-Rock outcrop complex redwall formation 2 to 30 percent slopes	0.31	0.16	20
60	Lithic Haplargids-Typic Haplargids-Lava flows complex 2 to 35 percent slopes	0.31	0.16	15
61	Lithic Haplocalcids pakoon limestone 2 to 8 percent slopes	0.96	0.62	0
62	Lithic Haplocalcids-Rock outcrop complex esplanade formation 2 to 15 percent slopes	0.96	0.62	30

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
63	Lithic Haplocambids-Lithic Haplargids complex bright angel and tapeats formations 2 to 15 percent slopes	0.25	0.12	0
64	Lithic Haplustalfs-Lava flows complex 30 to 60 percent slopes	0.09	0.04	45
65	Lithic Haplustolls-Udic Haplustolls-Rock outcrop complex kaibab torroweap and coconino formations 15 to 55 percent slopes	0.31	0.16	20
66	Lithic Torriorthents-Lithic Calciargids complex bright angel and tapeats formations hyperthermic 2 to 55 percent slopes	0.77	0.47	0
67	Lithic Torriorthents-Lithic Calciargids complex bright angel and tapeats formations thermic 2 to 55 percent slopes	0.68	0.41	0
68	Lithic Torriorthents-Rock outcrop complex dox formation 15 to 60 percent slopes	0.96	0.62	45
69	Lithic Torriorthents-Rock outcrop complex esplanade formation 2 to 8 percent slopes	0.96	0.62	30
70	Lithic Torriorthents-Rock outcrop complex muav and redwall formations 15 to 70 percent slopes	0.96	0.62	30
71	Lithic Torriorthents-Typic Torriorthents-Rock outcrop complex hermit formation 3 to 85 percent slopes	0.96	0.62	20
72	Lithic Ustic Torriorthents-Rock outcrop complex hermit formation 20 to 50 percent slopes	0.31	0.16	40
73	Lithic Ustic Torriorthents-Rock outcrop complex supai group 15 to 55 percent slopes	0.31	0.16	30
74	Lithic Ustic Torriorthents-Udic Haplustolls-Rock outcrop complex kaibab toroweap and coconino formations 15 to 55 percent slopes	0.31	0.16	15
75	Lostman family-Harrisburg complex 1 to 5 percent slopes	0.40	0.19	0
76	Luzena-Kellypoint complex 2 to 35 percent slopes	0.02	0.01	0

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
77	Lykorly gravelly loam 1 to 4 percent slopes	0.10	0.03	0
78	Lykorly loam 2 to 4 percent slopes	0.20	0.08	0
79	Meadview-Arizo complex 1 to 5 percent slopes	0.43	0.20	0
80	Meriwhitica-Rock outcrop complex 35 to 70 percent slopes	0.28	0.13	30
81	Meriwhitica-Tassi complex 0 to 33 percent slopes	0.67	0.39	0
82	Metuck family-Rock outcrop complex 8 to 50 percent slopes	0.19	0.08	30
83	Natank-Disterheff-Yumtheska complex 2 to 35 percent slopes	0.03	0.01	0
84	Natank-Yumtheska complex 2 to 8 percent slopes	0.05	0.02	0
85	Nutter-Gyppocket complex 2 to 20 percent slopes	0.27	0.12	0
86	Orrubo very gravelly loam 15 to 35 percent slopes	0.16	0.07	0
87	Orrubo-Meadview-Meadview moderately steep complex 2 to 40 percent slopes	0.24	0.11	0
88	Orthents-Rock outcrop complex 2 to 6 percent slopes	2.00	1.56	20
89	Oxyaquic Torriorthents-Typic Endoaquents association 1 to 4 percent slopes	1.14	0.70	0
90	Phizphre-Rock outcrop complex 8 to 15 percent slopes	0.21	0.09	15
91	Pinntank-Retsover complex 2 to 8 percent slopes	0.04	0.02	0
92	Plite-Canburn families complex 2 to 8 percent slopes	0.71	0.43	0
93	Pocomate-Pinntank complex 15 to 30 percent slopes	0.13	0.04	0
94	Pocomate-Pinntank-Toqui complex 15 to 25 percent slopes	0.07	0.02	0
95	Pocomate-Pinntank-Ustifluvents complex 2 to 30 percent slopes	0.14	0.05	0
96	Pompeii family-Huevi-Huevi moderately steep complex 2 to 25 percent slopes	0.24	0.11	0
97	Puertecito family 2 to 8 percent slopes	0.08	0.02	0
98	Puertecito family 15 to 35 percent slopes	0.07	0.02	0

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
99	Puertecito-Meriwhitica-Progresso families complex 2 to 8 percent slopes	0.14	0.06	0
100	Robroost fine sandy loam 1 to 3 percent slopes	0.28	0.11	0
101	Rock outcrop-Akela family complex 15 to 60 percent slopes	0.14	0.05	45
102	Rock outcrop-Cellar family complex 15 to 60 percent slopes	0.75	0.44	75
103	Rock outcrop-Lithic Torriorthents complex 15 to 60 percent slopes	0.96	0.62	70
104	Rock outcrop-Lithic Torriorthents complex cardenas formation 15 to 60 percent slopes	0.96	0.62	70
105	Rock outcrop-Lithic Torriorthents complex hakatai formation 15 to 60 percent slopes	0.96	0.62	80
106	Rock outcrop-Lithic Torriorthents complex kaibab toroweap and coconino formations 15 to 60 percent slopes	0.96	0.62	60
107	Rock outcrop-Lithic Torriorthents complex moenkopi kaibab and toroweap formations 15 to 60 percent slopes	0.96	0.62	70
108	Rock outcrop-Lithic Torriorthents complex nankoweap formation 2 to 8 percent slopes	0.96	0.62	70
109	Rock outcrop-Lithic Torriorthents complex supai group 15 to 60 percent slopes	0.96	0.62	60
110	Rock outcrop-Lithic Torriorthents complex vishnu schist formation 15 to 60 percent slopes	0.96	0.62	60
111	Rock outcrop-Lithic Ustic Torriorthents complex esplanade formation 2 to 8 percent slopes	0.31	0.16	60
112	Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex tonto group and redwall formation 30 to 60 percent slopes	0.47	0.26	45
113	Rock outcrop-Skos-Seis families complex 30 to 60 percent slopes	0.33	0.15	40
114	Rock outcrop-Torriorthents complex kaibab formation 15 to 85 percent slopes	0.96	0.62	70
115	Rock outcrop-Torriorthents-Lithic Torriorthents complex supai group and redwall formation 2 to 60 percent slopes	0.96	0.62	50

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
116	Rock outcrop-Typic Torriorthents complex hermit formation 15 to 60 percent slopes	0.96	0.62	60
117	Rock outcrop-Typic Torriorthents complex tonto group and redwall formation 30 to 60 percent slopes	0.96	0.62	60
118	Rockyroad very cobbly silty clay loam 2 to 10 percent slopes	0.02	0.01	0
119	Skos family-Rock outcrop complex 15 to 55 percent slopes	0.24	0.10	30
120	Skos family-Sandia-Rock outcrop complex 15 to 55 percent slopes	0.47	0.25	15
121	Tassi gravelly loamy very fine sand 0 to 3 percent slopes	0.90	0.50	0
122	Topocoba family 2 to 8 percent slopes	0.03	0.01	0
123	Topocoba-Wodomont association 2 to 15 percent slopes	0.10	0.04	0
124	Toqui gravelly loam 1 to 8 percent slopes	0.02	0.01	0
125	Toqui-Yumtheska complex 2 to 30 percent slops	0.04	0.02	0
126	Torriorthents-Haplocalcids-Lava flows complex 10 to 40 percent slopes	0.33	0.16	20
127	Torriorthents-Haplogypsids complex muddy creek formation 35 to 75 percent slopes	0.62	0.36	0
128	Torriorthents-Lithic Haplargids-Rock outcrop complex tonto group 15 to 60 percent slopes	0.69	0.42	15
129	Torriorthents-Rock outcrop complex hermit formation 2 to 40 percent slopes	0.96	0.62	30
130	Tovar loam 2 to 8 percent slopes	0.03	0.01	0
131	Tovar-Toqui-Yumtheska complex 2 to 8 percent slopes	0.04	0.01	0
132	Tunitcha-Valto family-Plite family complex 2 to 15 percent slopes	0.63	0.35	0
133	Twist very cobbly loam 1 to 8 percent slopes	0.05	0.01	0
134	Typic Calciargids-Lava flows complex 2 to 30 percent slopes	0.96	0.62	30
135	Typic Haplocalcids 2 to 8 percent slopes	0.96	0.62	0
136	Typic Haplocalcids 15 to 55 percent slopes	0.96	0.62	0

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
137	Typic Haplocalcids-Typic Calciargids complex 2 to 15 percent slopes	0.96	0.62	0
138	Typic Haplocalcids-Typic Petrocalcids complex 15 to 25 percent slopes	0.61	0.36	0
139	Typic Haplocalcids-Typic Torriorthents complex 2 to 15 percent slopes	0.96	0.62	0
140	Typic Haplogypsids hermit formation 8 to 15 percent slopes	0.96	0.62	0
141	Typic Petrocalcids-Haplogypsids-Rock outcrop complex hermit formation 8 to 45 percent slopes	0.28	0.14	20
142	Typic Petrocalcids-Rock outcrop complex hermit formation 2 to 50 percent slopes	0.31	0.16	30
143	Typic Torrifluvents 0 to 1 percent slopes	2.00	1.56	0
144	Typic Torrifluvents-Typic Torripsamments complex 0 to 6 percent slopes	2.00	1.56	0
145	Typic Torrifluvents-Typic Torripsamments complex cool 0 to 6 percent slopes	2.00	1.56	0
146	Typic Torriorthents soils and badlands chuar group 15 to 65 percent slopes	0.55	0.31	0
147	Typic Torriorthents 2 to 8 percent slopes	0.96	0.62	0
148	Typic Torriorthents-Typic Haplogypsids complex hermit formation 15 to 40 percent slopes	0.96	0.62	0
149	Ustic Haplargids-Lava flows complex 2 to 20 percent slopes	0.31	0.16	30
150	Ustic Haplocalcids-Ustic Petrocalcids complex 2 to 4 percent slopes	0.71	0.43	0
151	Ustic Haplocalcids-Ustic Petrocalcids-Rock outcrop complex hermit formation 8 to 60 percent slopes	0.62	0.36	15
152	Ustic Haplocambids 1 to 2 percent slopes	2.00	1.56	0
153	Ustic Haplocambids 2 to 15 percent slopes	2.00	1.56	0
154	Ustic Torriorthents soils and badlands chuar group 15 to 65 percent slopes	0.31	0.16	0
155	Ustic Torriorthents 0 to 1 percent slopes	0.31	0.16	0
156	Ustic Torriorthents 2 to 4 percent slopes	0.31	0.16	0
157	Ustic Torriorthents 4 to 15 percent slopes	0.31	0.16	0

Table D.16 AZ701 Grand Canyon Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
158	Ustic Torriorthents-Lithic Ustic Torriorthents-Lithic Ustic Haplargids complex tonto group and redwall formation 8 to 60 percent slopes	0.31	0.16	0
159	Valleycity-Berzatic-Seeg families complex 8 to 60 percent slopes	0.18	0.06	0
160	Vitrandic Haplocalcids 15 to 40 percent slopes	0.22	0.10	0
161	Vitrandic Haplocambids-Vitrandic Haplocalcids complex 15 to 40 percent slopes	0.22	0.10	0
162	Water	0.01	0.01	100
163	Wauquie-Houserock families complex 2 to 65 percent slopes	0.06	0.03	0
164	Winkel family 15 to 55 percent slopes	0.24	0.10	0
165	Winkel-Rock outcrop complex 2 to 12 percent slopes	0.19	0.08	15
166	Winona-Rock outcrop-Tusayan complex 15 to 55 percent slopes	0.09	0.04	25
167	Wodomont-Topocoba-Plumasano families complex 2 to 15 percent slopes	0.25	0.11	0
168	Wutoma-Lozinta complex 15 to 60 percent slopes	0.65	0.37	0
169	Yellowhorse-Luzena-Sponiker association 2 to 15 percent slopes	0.06	0.02	0
170	Yumtheska-Bilburc association 10 to 45 percent slopes	0.07	0.02	0
171	Yumtheska-Katzine-Rock outcrop complex 2 to 30 percent slopes	0.16	0.07	20
172	Yumtheska-Rock outcrop complex 0 to 2 percent slopes	0.14	0.06	40
173	Yumtheska-Rock outcrop complex 2 to 8 percent slopes	0.18	0.08	15
174	Yumtheska-Rock outcrop complex 15 to 45 percent slopes	0.18	0.09	25
175	Yumtheska-Toqui-Rock outcrop complex 2 to 8 percent slopes	0.08	0.03	15
176	Yumtheska-Toqui-Rock outcrop complex 15 to 40 percent slopes	0.08	0.03	15
177	Zibate family 2 to 8 percent slopes	0.02	0.01	0

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D.3.11 ARIZONA GENERAL SOIL SURVEY

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s1126	Tecopa-Rock outcrop-Lithic Torriorthents (s1126)	0.50	0.26	58
s1129	Rositas-Beeline-Badland (s1129)	0.47	0.25	0
s1131	Rock outcrop (s1131)	0.29	0.13	65
s1140	Rillito-Gunsight (s1140)	0.14	0.05	0
s1422	Uzona-Rock outcrop-Myton family-Claysprings (s1422)	0.02	0.01	10
s274	Carrizo-Brios-Antho (s274)	0.58	0.31	0
s275	Rositas-Ripley-Indio-Gilman (s275)	0.26	0.10	0
s276	Denure-Dateland (s276)	0.48	0.24	0
s277	Glenbar-Gadsden-Brios (s277)	0.05	0.02	0
s278	Sasco-Marana-Denure (s278)	0.14	0.04	0
s279	Yahana-Indio-Gadsden (s279)	0.10	0.03	0
s280	Pahaka-Mohall-Laveen-Denure (s280)	0.31	0.13	0
s281	Momoli-Denure-Carrizo (s281)	0.44	0.23	0
s282	Why-Wellton-Gunsight-Growler-Denure (s282)	0.42	0.21	0
s283	Mohall-Denure-Coolidge (s283)	0.33	0.14	0
s284	Mohall-Contine (s284)	0.07	0.02	0
s285	Yahana-Shontik-Casa Grande (s285)	0.16	0.05	0
s286	Tremant-Pinamt-Ebon (s286)	0.04	0.01	0
s287	Suncity-Cipriano-Carefree (s287)	0.05	0.02	0
s288	Rillito-Gunsight-Denure-Chuckawalla (s288)	0.27	0.13	0
s289	Hyder-Coolidge-Cipriano-Cherioni (s289)	0.23	0.10	9
s290	Ligurta-Gunsight-Cristobal (s290)	0.05	0.01	0
s291	Pinamt-Gunsight-Cavelt (s291)	0.11	0.03	0
s292	Pinamt-Momoli-Cipriano (s292)	0.18	0.07	0
s293	Rock outcrop-Quilotosa-Momoli (s293)	0.38	0.20	34
s294	Rock outcrop-Quilotosa-Hyder-Gachado (s294)	0.21	0.08	15
s295	Schenco-Rock outcrop-Laposa (s295)	0.08	0.03	30
s296	Laveen-Kamato-Casa Grande (s296)	0.07	0.01	0
s297	Toltec-La Palma-Casa Grande (s297)	0.28	0.10	0
s298	Mohall-Dateland-Casa Grande (s298)	0.13	0.04	0
s299	Pahaka-Estrella-Antho (s299)	0.71	0.38	0
s300	Valencia-Estrella-Cuerda (s300)	0.63	0.33	0
s301	Superstition-Rositas (s301)	2.00	1.70	0
s302	Guest-Glendale-Gila (s302)	0.06	0.01	0

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s303	Riveroad-Comoro-Arizo (s303)	0.41	0.18	0
s305	Mohave-Guest-Continental (s305)	0.06	0.02	0
s306	Tres Hermanos-Pajarito-Mohave (s306)	0.20	0.08	0
s307	Sonoita-Hayhook-Continental (s307)	0.45	0.22	0
s308	Sahuarita-Mohave-Cave (s308)	0.17	0.06	0
s309	Cacique-Bucklebar-Alko (s309)	0.15	0.05	0
s310	Stagecoach-Nahda-Delnorte-Agustin (s310)	0.13	0.07	0
s311	Pinaleno-Eba (s311)	0.01	0.01	0
s312	Nickel-Greyeagle-Continental (s312)	0.08	0.03	0
s313	Pinaleno-Palos Verdes-Nickel (s313)	0.08	0.03	0
s314	Tumarion-Rock outcrop-Lehmans-House Mountain-Akela (s314)	0.07	0.03	15
s315	Rock outcrop-Luzena-Faraway (s315)	0.04	0.03	25
s316	Rock outcrop-Lehmans-Gran (s316)	0.01	0.01	30
s317	Rock outcrop-Lajitas-Delthorny-Anklam (s317)	0.20	0.10	25
s318	Torriorthents-Rock outcrop (s318)	0.96	0.62	90
s319	Tovar-Toqui-Deama (s319)	0.06	0.02	0
s320	Santo Tomas-Pima-Comoro (s320)	0.32	0.15	0
s321	Hondale-Gothard-Bluepoint (s321)	0.04	0.02	0
s322	Sontag-Bonita (s322)	0.02	0.01	0
s323	Tubac-Forrest-Enzian-Diaspar (s323)	0.13	0.06	0
s324	Winkel-Harrisburg-Cave (s324)	0.59	0.31	0
s325	White House-Hathaway-Bernardino (s325)	0.04	0.01	0
s326	Tombstone-Stronghold-Jerag (s326)	0.19	0.07	0
s327	Torriorthents-Rock outcrop-Gypill (s327)	0.62	0.36	20
s328	White House-Hathaway-Caralampi-Bernardino (s328)	0.05	0.02	0
s329	Romero-Rock outcrop-Lampshire (s329)	0.19	0.09	31
s330	Zukan-Rock outcrop-Goblin (s330)	0.21	0.08	10
s331	Tanbark-Mellenthin-Calciorthids (s331)	0.16	0.06	0
s332	Thunderbird-Collbran-Boquillas (s332)	0.02	0.01	0
s333	Yumtheska-Natank-Disterheff (s333)	0.03	0.01	0
s334	Sponiker-Rock outcrop-Cross (s334)	0.06	0.03	10
s335	Rock outcrop-Mabray-Lemitar (s335)	0.08	0.02	15
s336	Pennell-Bacobi (s336)	0.40	0.19	0
s337	Tours saline-Sodic-Riverwash-Jocity saline-Sodic-Ives saline-Sodic-Burnswick (s337)	0.19	0.07	1
s338	Marcou-Jocity saline-Sodic-Burnswick (s338)	0.16	0.06	1
s339	Wepo-Polacca-Jocity-Jeddito (s339)	0.13	0.05	2

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s340	Sheppard sodic-Sheppard-Joraibi-Jocity (s340)	0.62	0.31	0
s341	Torriorthents-Tewa-Sheppard-Jeddito (s341)	0.50	0.21	6
s342	Rock outcrop-Moenkopie (s342)	0.55	0.28	50
s343	Nakai-Monue-Blackston (s343)	0.85	0.47	0
s344	Purgatory-Epikom-Claysprings-Badland (s344)	0.13	0.05	3
s345	Sheppard-Nakai-Monue (s345)	0.67	0.33	2
s346	Kinan-Hatknoll-Grieta (s346)	0.33	0.15	0
s347	Torriorthents-Sheppard-Pennell-Monue-Jocity-Clayhole (s347)	0.25	0.09	0
s348	Pennell-Pagina-Kinan (s348)	0.47	0.24	0
s349	Mellenthin-Curhollow (s349)	0.19	0.08	0
s350	Yumtheska-Showlow-Lozinta (s350)	0.09	0.04	0
s351	Wayneco-Sazi-Rock outcrop-Rizno-Palma-Mespun (s351)	0.73	0.40	10
s352	Winona-Tenderfoot-Curhollow (s352)	0.08	0.02	0
s353	Rudd-Arches (s353)	0.39	0.18	0
s354	Poley-Palma-Clovis (s354)	0.05	0.02	0
s355	Winona-Tusayan-Boysag (s355)	0.08	0.03	0
s356	Rock outcrop-Needle-Epikom (s356)	0.32	0.13	26
s357	Sheppard-Palma-Hubert-Clovis (s357)	0.29	0.12	0
s358	Strych-Monue-Bison (s358)	0.27	0.12	0
s359	Spenlo-Schmutz-Redbank family-Palma family-Naplene-Lavate-Ildefonso family-Clovis family-Caval (s359)	0.30	0.12	0
s360	Wupatki-Wukoki-Tuweep (s360)	0.08	0.02	0
s361	Stagecoach-Hindu (s361)	0.15	0.06	0
s362	Rock outcrop (s362)	0.25	0.12	83
s363	Sheppard-Grieta (s363)	0.33	0.13	0
s364	Ustic Torriorthents-Penistaja-Mido-Begay (s364)	0.51	0.25	7
s365	Milkweed-Deama-Cabezon (s365)	0.06	0.03	0
s366	Ubank-Cerrillos-Barx (s366)	0.13	0.04	5
s367	Rock outcrop-Mellenthin-Leanto-Kech-Bisoodi (s367)	0.23	0.09	30
s368	Nuffel-Kech-Barx (s368)	0.12	0.03	9
s369	Rock outcrop-Deama (s369)	0.10	0.04	42
s370	Toqui-Topocoba-Deama (s370)	0.04	0.01	0
s371	Ziegler-Wilaha-Showlow (s371)	0.03	0.01	0

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s372	Virgin Peak-Rock outcrop-Hualapai (s372)	0.19	0.10	15
s373	Moano-Barkerville (s373)	0.40	0.20	0
s374	Tortugas-Purner-Jacks (s374)	0.15	0.05	0
s375	Thunderbird-Rock outcrop-Luzena (s375)	0.01	0.01	15
s376	Typic Haplustalfs (s376)	0.11	0.04	0
s377	Thunderbird-Springerville-Rudd-Cabezon (s377)	0.02	0.01	0
s378	Whitlock-Continental-Cave (s378)	0.49	0.25	0
s379	Springerville-Cabezon (s379)	0.01	0.01	0
s380	Venezia-Thunderbird-Cabezon (s380)	0.02	0.01	0
s381	Poley-Pastura-Partri-Lynx-Abra (s381)	0.05	0.02	0
s382	Lynx-Lonti-Balon (s382)	0.03	0.01	0
s383	Zyme-Tonalea-Kydestea (s383)	0.13	0.05	7
s384	Torriorthents-Badland (s384)	0.67	0.40	3
s385	Telephone-Rock outcrop-Overgaard-Elledge (s385)	0.59	0.33	10
s386	Spudrock-Elledge-Docdee (s386)	0.23	0.10	0
s387	Gordo-Baldy (s387)	0.99	0.66	0
s388	Sponseller-Ess (s388)	0.07	0.03	0
s389	Thunderbird-Showlow (s389)	0.02	0.01	0
s390	Typic Haplustalfs-Rock outcrop-Aridic Haplustalfs (s390)	0.14	0.05	20
s391	Typic Haplustalfs-Lithic Haplustalfs (s391)	0.27	0.10	0
s392	Sogzie-Sheppard-Rock outcrop-Aneth (s392)	1.34	0.92	10
s393	Shedado-Rock outcrop-Mespun-Begay-Anasazi (s393)	0.81	0.46	15
s394	Ustollic Haplargids-Rock outcrop-Namon (s394)	0.43	0.22	30
s395	Abreu (s395)	0.47	0.25	0
s396	Typic Eutroboralfs (s396)	0.24	0.10	0
s397	Typic Eutroboralfs (s397)	0.24	0.11	0
s398	Sheppard-Rock outcrop-Monue-Moepitz (s398)	1.46	1.02	10
s399	Pinamt-Momoli-Hickiwan-Gunsight-Denure (s399)	0.22	0.10	0
s400	Retriever-Calciorthids (s400)	0.14	0.05	0
s401	Vertic Haplustalfs-Aridic Ustochrepts (s401)	0.04	0.02	0
s402	Rock outcrop-Lama-Fragua (s402)	0.24	0.10	30
s403	Winona-Spudrock-Rock outcrop (s403)	0.28	0.13	10
s404	Winona-Spudrock-Rock outcrop (s404)	0.28	0.13	30

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s405	Quintana (s405)	0.09	0.02	0
s406	Typic Paleboralfs-Eutric Glossoboralfs (s406)	0.17	0.07	0
s407	Typic Cryoboralfs-Rock outcrop-Eutric Glossoboralfs (s407)	0.14	0.06	20
s408	Rock outcrop-Eutric Glossoboralfs (s408)	0.14	0.06	30
s409	Typic Haplustalfs-Fluventic Ustochrepts (s409)	0.15	0.06	0
s410	Rock outcrop-Aridic Ustochrepts-Aridic Haplustolls (s410)	0.07	0.02	10
s411	Typic Paleboralfs-Typic Cryoboralfs-Rock outcrop (s411)	0.21	0.09	10
s412	Vertic Haplustalfs-Typic Haplustalfs (s412)	0.03	0.01	7
s413	Typic Haplustalfs (s413)	0.56	0.30	0
s414	Typic Haplustalfs (s414)	0.11	0.04	0
s415	Typic Haplustalfs-Rock outcrop-Eutric Glossoboralfs (s415)	0.12	0.04	20
s416	Silkie-Espiritu (s416)	0.03	0.01	0
s417	Wineg-Quintana-Amos (s417)	0.03	0.01	0
s418	Typic Haplustalfs-Lithic Haplustalfs (s418)	0.10	0.03	0
s419	Mollic Eutroboralfs (s419)	0.11	0.03	0
s420	Rock outcrop-Mollic Cryoboralfs-Eutric Glossoboralfs (s420)	0.19	0.08	30
s421	Mirand-Derecho (s421)	0.04	0.02	0
s422	Silkie-Mirand (s422)	0.02	0.01	0
s423	Vibo-Casto (s423)	0.18	0.07	0
s424	Typic Haplustalfs-Mollic Eutroboralfs (s424)	0.11	0.03	0
s425	Mirand-Maes (s425)	0.05	0.03	0
s426	Eutric Glossoboralfs (s426)	0.11	0.04	0
s427	Heflin-Casto (s427)	0.13	0.05	0
s428	Rillino-Gila-Continental (s428)	0.18	0.07	0
s429	Tombstone-Romero-Rock outcrop (s429)	0.28	0.13	30
s430	Tubac-Pajarito-Hayhook-Glendale-Bucklebar (s430)	0.31	0.14	0
s431	Tres Hermanos-Pinamt-Artesia (s431)	0.07	0.02	0
s432	Eicks-Eba-Cloverdale (s432)	0.02	0.02	0
s433	Limpia-Graham-Bonita-Atascosa (s433)	0.04	0.02	0
s434	Mabray-Chiricahua-Atascosa (s434)	0.06	0.02	0
s435	Rock outcrop-Mokiak-Faraway (s435)	0.29	0.14	20
s436	Rock outcrop-Luzena-Fallsam (s436)	0.04	0.03	40
s437	Tapco-Peloncillo-Artesia (s437)	0.02	0.01	0

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s438	Wampoo-Signal-Bonita (s438)	0.02	0.01	0
s439	Selevin-Eloma-Alsco (s439)	0.02	0.01	0
s440	Yumtheska-Virgin Peak-Rock outcrop-Katzine (s440)	0.25	0.11	22
s441	Rock outcrop-Piute-Bluechief (s441)	1.22	0.71	15
s442	Uzona-Shumbegay-Escavada (s442)	0.15	0.08	0
s443	Millett-Farview-Doakum (s443)	0.22	0.07	0
s444	Mido-Blanding-Arches (s444)	0.65	0.32	0
s445	Tunitcha-Klizhin-Akhoni (s445)	0.68	0.39	0
s446	Abreu (s446)	0.24	0.10	0
s447	Altar (s447)	0.14	0.05	0
s448	Altar (s448)	0.14	0.05	0
s449	Rock outcrop-Garr (s449)	0.30	0.15	40
s450	Ustorthents-Rizno-Metuck (s450)	0.72	0.42	0
s451	Vibo-Ustochrepts-Badland (s451)	0.24	0.10	0
s452	Telescope-Royosa-Augustine (s452)	0.29	0.12	0
s453	Badland-Aridic Ustochrepts-Aridic Haplustolls (s453)	0.11	0.03	0
s454	Shoegame-McNeal-Badland (s454)	0.18	0.06	0
s455	Rock outcrop-Lithic Ustorthents family-Hogris (s455)	0.86	0.54	30
s456	Torriorthents-Cellar (s456)	0.26	0.12	0
s457	Spudrock-Rock outcrop-Cellar (s457)	0.46	0.23	30
s458	Yaqui-Werlog (s458)	0.17	0.07	0
s459	Werlog-Santo Tomas-Riverwash (s459)	0.34	0.17	0
s460	Torriorthents (s460)	0.18	0.08	0
s461	Rock outcrop-Moenkopie (s461)	0.46	0.24	30
s462	Typic Ustifluvents-Fluventic Ustochrepts (s462)	0.53	0.27	0
s463	Fluventic Ustochrepts-Aquic Ustifluvents (s463)	0.28	0.11	0
s464	Vessilla-Rock outcrop (s464)	0.39	0.19	35
s465	Teromote-Kopie (s465)	0.11	0.03	0
s466	Quintana-Kopie (s466)	0.12	0.03	0
s467	Typic Ustochrepts-Typic Haplustalfs-Rock outcrop (s467)	0.10	0.03	25
s468	Shoegame-Badland-Aridic Ustochrepts (s468)	0.23	0.11	0
s469	Ransect (s469)	0.06	0.01	0
s470	Typic Ustochrepts-Lithic Ustochrepts (s470)	0.12	0.03	0

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s471	Typic Ustochrepts-Typic Haplustalfs-Rock outcrop (s471)	0.10	0.03	30
s472	Typic Dystrochrepts-Spudrock-Rock outcrop (s472)	0.14	0.06	30
s473	Typic Dystrochrepts-Dystric Cryochrepts (s473)	0.04	0.01	0
s474	Typic Dystrochrepts-Rock outcrop-Dystric Cryochrepts (s474)	0.08	0.03	20
s475	Dystric Cryochrepts (s475)	0.42	0.21	0
s476	Sobega-Quintana-Kopie (s476)	0.23	0.09	0
s477	Dystric Cryochrepts (s477)	0.42	0.21	0
s478	Rock outcrop-Lithic Ustochrepts (s478)	0.11	0.03	30
s479	Typic Dystrochrepts-Rock outcrop-Lithic Ustochrepts (s479)	0.11	0.05	30
s480	Quintana (s480)	0.09	0.02	0
s481	Spudrock-Sobega-Rock outcrop (s481)	0.43	0.22	40
s482	Spudrock-Rombo-Rock outcrop (s482)	0.16	0.06	30
s483	Timhus-Quintana-Flugle (s483)	0.10	0.03	0
s484	Riverwash-Prewitt-Lynx (s484)	0.15	0.06	0
s485	Ess-Cundiyo (s485)	0.30	0.14	0
s486	Hereford (s486)	0.11	0.04	0
s487	Vertic Argiborolls (s487)	0.08	0.02	0
s488	Pachic Udic Argiborolls (s488)	0.15	0.06	0
s489	Rock outcrop-Lithic Haplustolls (s489)	0.21	0.10	30
s490	Nakai-Monue-Blackston (s490)	0.85	0.47	0
s491	Ustochreptic Calciorthids (s491)	0.58	0.32	0
s492	Rock outcrop-Bond-Bidonia (s492)	0.16	0.08	15
s493	Winona-Pastura-Cibeque (s493)	0.08	0.02	0
s494	Sponiker-Godding (s494)	0.12	0.05	0
s495	Torriorthents-Calciorthids-Badland (s495)	0.35	0.18	0
s496	Faraway-Barkerville (s496)	0.51	0.28	0
s497	Tours-Showlow-Cibeque (s497)	0.03	0.01	0
s498	Rond-Jacks-Chevelon (s498)	0.04	0.01	0
s499	Tortugas-Roundtop-Rock outcrop (s499)	0.09	0.05	15
s500	Lemitar-Lampshire-Chiricahua (s500)	0.04	0.02	0
s501	Tuloso-Tinaja (s501)	0.20	0.08	0
s502	Riverwash-Prewitt-Pinetop-Lynx (s502)	0.09	0.04	0
s5061	Vertic Haplustalfs-Typic Haplustalfs (s5061)	0.05	0.02	0
s5065	Typic Eutroboralfs-Lithic Haplustalfs (s5065)	0.16	0.05	0

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s5068	Typic Haplustalfs-Rock outcrop-Eutric Glossoboralfs (s5068)	0.11	0.04	30
s5085	Typic Ustorthents-Typic Ustochrepts-Typic Udorthents-Rock outcrop (s5085)	0.29	0.11	25
s5087	Typic Ustochrepts-Rock outcrop-Aridic Ustochrepts (s5087)	0.39	0.19	30
s5094	Udic Ustochrepts-Typic Ustochrepts (s5094)	0.30	0.14	0
s5108	Fluventic Haploborolls-Aquic Ustifluvents (s5108)	0.28	0.14	0
s5116	Typic Argiborolls (s5116)	0.18	0.07	0
s5168	Rock outcrop-Flugle-Catman (s5168)	0.08	0.03	13
s5169	Rock outcrop-Nogal (s5169)	0.07	0.03	22
s5170	Teco-Rock outcrop-Montecito-Cabezon-Atarque (s5170)	0.02	0.01	11
s5172	Stout-Kiln-Hesperus (s5172)	0.40	0.19	0
s5173	Telescope-Royosa (s5173)	1.42	1.04	0
s5177	Weska-Travessilla-Rock outcrop-Oelop (s5177)	0.07	0.02	30
s5249	Ojocal-Alicia (s5249)	0.07	0.02	0
s5315	Rock outcrop-Lehmans-Chiricahua-Chamberino (s5315)	0.03	0.01	20
s5325	Rock outcrop-Muzzler-Luzena (s5325)	0.01	0.01	20
s5331	Thunderbird-Rudd-Hubbell-Cabezon (s5331)	0.06	0.03	0
s5333	Mion-Jacee-Goesling-Celacy-Augustine (s5333)	0.08	0.03	3
s5396	Loarc-Guy-Dioxice-Datil (s5396)	0.25	0.11	2
s5397	Manzano-Hickman-Catman (s5397)	0.05	0.02	0
s5573	Water-Virgin River-Toquop-Riverwash-Black Butte-Alluvial land (s5573)	0.30	0.14	10
s5575	Naye-Mormon Mesa (s5575)	0.50	0.26	1
s5576	St. Thomas-Rock outcrop-Kyler (s5576)	0.20	0.09	15
s5577	Cave family-Cave-Ajo (s5577)	0.20	0.08	0
s5578	Harrisburg-Cave-Arizo (s5578)	0.69	0.37	0
s5579	Toquop-Black Butte-Arada (s5579)	0.74	0.38	0
s5580	Tonopah-Colorock-Badland (s5580)	0.28	0.13	1
s5581	Yurm family-Winkel-Torriorthents (s5581)	0.29	0.14	9
s5586	Zeheme-St. Thomas-Rock outcrop (s5586)	0.33	0.16	19
s5587	Zeheme-Virgin Peak-Rock outcrop-Hobog (s5587)	0.25	0.12	14
s5588	Nickel-Bitter Spring-Arizo (s5588)	0.48	0.24	2

Table D.17 AZ STATSGO Arizona General Soils Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s5589	Rositas-Pompeii-Gunsight-Carrizo-Ajo (s5589)	0.26	0.12	0
s5590	Rock outcrop-Hindu-Gypill-Badland (s5590)	0.29	0.13	25
s5592	Rock outcrop-Kanackey-Dedas-Calvista-Breko (s5592)	0.10	0.05	20
s5742	Typic Torriorthents-Gypill-Cave-Badland (s5742)	0.36	0.18	5
s7770	Sheppard-Rock outcrop-Oljeto-Neskahi-Mota (s7770)	0.81	0.46	10
s7771	Rock outcrop-Piute-Moenkopie-Hoskinnini (s7771)	0.39	0.18	20
s7774	Rock outcrop-Lithic Torriorthents-Badland (s7774)	0.28	0.13	50
s8181	Tobler-St. George-Nikey-Junction-Harrisburg (s8181)	0.46	0.22	0
s8182	Winkel-Renbac-Hobog-Bermesa (s8182)	0.42	0.24	0
s8184	Shalet-Badland (s8184)	0.25	0.11	5
s8187	Pastura family-Magotsu-Curhollow (s8187)	0.15	0.06	5
s8196	Rock outcrop-Mespun-Arches (s8196)	1.74	1.14	10
s8197	Yarts-Palma-Neville family-Barx-Atchee (s8197)	0.19	0.08	5
s8198	Skos-Rock outcrop (s8198)	0.07	0.02	20
s8369	Water (s8369)	0.01	0.01	100
s9582	Leanto-Bisoodi-Arntz (s9582)	0.12	0.04	4
s9583	Torriorthents-Marcou-Claysprings-Burnswick-Badland (s9583)	0.25	0.12	6
s9584	Strych-Rock outcrop-Monue (s9584)	0.37	0.17	18
s9585	Vecont-Trix-Mohall-Denure-Dateland-Casa Grande (s9585)	0.22	0.09	0
s9586	Selevin-Kimrose-Keysto-Caralampi (s9586)	0.06	0.03	0

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D.3.12 NV608

Table D.18 NV608 Virgin River Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
100	St. Thomas-Rock outcrop association	0.20	0.08	35
122	Zeheme-St. Thomas-Rock outcrop association	0.29	0.13	17
141	Elbowcanyon-Wechech association	0.42	0.21	0
160	Wechech-Weiser association	0.38	0.19	0
161	Wechech gravelly loam 0 to 2 percent slopes	0.27	0.11	0
314	Weiser-Wechech association	0.40	0.20	0
316	Weiser-Wechech association moist	0.35	0.17	0
Ad	Alluvial land	0.40	0.19	0
Ae	Anthony fine sandy loam	0.40	0.19	0
Af	Anthony fine sandy loam gravelly substratum	0.40	0.19	0
Ah	Anthony fine sandy loam watertable	0.36	0.16	0
AMC	Arada fine sand 2 to 8 percent slopes	1.69	1.16	0
AOB	Arada fine sand gravelly substratum 0 to 4 percent slopes	1.82	1.28	0
ASC	Arada fine sand hardpan variant 2 to 8 percent slopes	2.00	1.82	0
ATA	Arizo fine sand 0 to 2 percent slopes	2.00	2.00	0
AVB	Arizo gravelly fine sand 2 to 4 percent slopes	2.00	1.57	0
AXC	Arizo very gravelly loamy sand 2 to 8 percent slopes	1.96	1.53	0
AYD	Arrolime gravelly silt loam 2 to 15 percent slopes	0.04	0.01	0
BD	Badland	0.31	0.16	0
BFD	Bard gravelly fine sand 4 to 15 percent slopes	0.66	0.35	0
BHC	Bard gravelly fine sandy loam 2 to 8 percent slopes	0.39	0.19	0
BLB	Blacknat-Arada association	1.84	1.52	0
BMD	Bard very gravelly fine sandy loam 2 to 15 percent slopes	0.34	0.16	0
BNB	Bard very stony loam 2 to 4 percent slopes	0.18	0.07	0
BOB	Bard-Rough broken land association gently sloping	0.32	0.15	30
BP	Pits borrow	0.02	0.01	0

Table D.18 NV608 Virgin River Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
BRB	Bard-Tonopah association gently sloping	0.26	0.11	0
BSG	Boxspring-Seralin-Rock outcrop association	0.18	0.08	15
BTC	Bitter Spring-Arizo association moderately sloping	0.41	0.19	0
Bu	Black Butte silt loam	0.07	0.02	0
Bv	Black Butte silt loam watertable	0.07	0.02	0
Bw	Bluepoint loamy fine sand	1.49	0.91	0
By	Bluepoint fine sandy loam strongly saline	0.94	0.54	0
BZF	Boxspring-Zeheme-Rock outcrop complex 15 to 50 to percent slopes MLRA 30	0.24	0.11	15
Ca	Calico fine sandy loam	0.67	0.35	0
CAC	Carrizo association	1.21	0.75	0
Cc	Calico fine sandy loam drained	0.67	0.35	0
Cd	Calico fine sandy loam strongly saline	0.67	0.35	0
CID	Crosgrain-Irongold association	0.22	0.09	0
Cm	Calico clay loam	0.06	0.01	0
Cn	Calico loamy fine sand coarse variant drained	1.50	0.92	0
Co	Calico loamy fine sand coarse variant strongly saline	1.40	0.84	0
CRD	Carrizo-Carrizo-Riverbend association	1.15	0.73	0
CTC	Colorock-Tonopah association moderately sloping	0.17	0.07	0
CYB	Crystal Springs gravelly sandy loam 2 to 4 percent slopes	0.49	0.25	0
Ea	Eastland gravelly sandy loam	0.77	0.42	0
FLC	Flattop gravelly clay loam 2 to 8 percent slopes	0.06	0.01	0
Gd	Gila fine sand	2.00	1.61	0
Ge	Gila loam	0.20	0.07	0
Gf	Gila loam strongly saline	0.27	0.11	0
GHF	Goldroad-Haleburu-Rock outcrop association	0.40	0.20	15
Gm	Gila loam water table	0.31	0.13	0
Gn	Gila loam water table strongly saline	0.31	0.13	0
Go	Glendale fine sand	2.00	1.99	0
GP	Pits gravel	0.02	0.01	0
Gr	Glendale loam	0.30	0.13	0
Gs	Glendale loam strongly saline	0.30	0.13	0
Gv	Grapevine loam	0.36	0.16	0

Table D.18 NV608 Virgin River Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
HEE	Heleweiser association	0.40	0.20	0
HHD	Huevi-Hiller association	0.34	0.17	1
HUF	Huevi-Badland association	0.34	0.17	0
HYB	Hypoint-Bluepoint-Arizo association	0.89	0.50	0
Ir	Ireteba loam	0.32	0.14	0
It	Ireteba loam overflow	0.32	0.14	0
IUC	Irongold-Wechech association	0.27	0.12	0
IWD	Irongold-Weiser association	0.21	0.09	0
La	Land loamy fine sand	0.05	0.01	0
Lc	Land silty clay loam	0.05	0.01	0
Ld	Land silty clay loam wet	0.05	0.01	0
MAE	Moapa-Bluepoint-Rock outcrop association	1.82	1.56	20
MBG	Monger-Bard-Typic Torriorthents association	0.33	0.15	0
MMB	Mormon Mesa loamy fine sand 0 to 4 percent slopes	0.57	0.29	0
MOB	Mormon Mesa fine sandy loam 0 to 8 percent slopes	0.60	0.30	0
NBC	Naye-Bitter Spring association	0.41	0.19	0
NIC	Nickel-Bitter Spring association	0.32	0.15	0
Oc	Overton silty clay	0.04	0.01	0
Oe	Overton silty clay slightly saline	0.05	0.01	0
On	Overton silty clay strongly saline	0.05	0.01	0
Or	Overton clay overwash saline	0.02	0.01	0
Os	Overton silt loam loamy variant slightly saline	0.44	0.24	0
Ot	Overton silt loam loamy variant strongly saline	0.44	0.24	0
Ox	Oxyaquic Torriorthents-Toquop complex 0 to 8 percent slopes	0.22	0.08	0
PL	Playas	0.03	0.01	0
PME	Pulsipher-Rock outcrop complex 15 to 30 percent slopes	0.25	0.10	20
PPE	Pulsipher association hilly	0.08	0.04	0
PRE	Pulsipher gravelly clay loam fine variant 15 to 30 percent slopes	0.01	0.01	0
RBG	Rock outcrop-Moapa-Bluepoint association	1.80	1.58	45
Re	Riverwash	0.26	0.12	0
RHF	Rock outcrop-Redneedle-Heleweiser association	0.53	0.28	35

Table D.18 NV608 Virgin River Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
Ri	Riverwash-Water complex 0 to 2 percent slopes	0.24	0.11	30
RME	Rock land-Moapa association hilly	2.00	1.80	60
RTF	Rock land-St. Thomas association very steep	0.20	0.09	60
SAE	Sandpan-Rositas association	1.23	0.92	0
SEG	Seralin extremely gravelly loam 30 to 75 percent slopes	0.17	0.07	4
SP	Spring silty clay loam	0.04	0.01	0
SQE	St. Thomas association	0.20	0.08	5
STE	St.Thomas-Rock outcrop-Zeheme assocation	0.33	0.16	20
STF	St. Thomas-Rock outcrop complex	0.20	0.08	20
SWC	Sweetspring-Carrizo association	0.18	0.07	0
TAC	Teebar-Sandpan association	0.53	0.29	0
Tb	Tobler fine sandy loam	0.55	0.28	0
Tc	Tobler fine sandy loam strongly saline	0.55	0.28	0
Td	Tobler silt loam wet	0.22	0.08	0
Te	Tobler clay strongly saline	0.02	0.01	0
TGC	Tonopah-Arizo association	0.56	0.30	0
THB	Tonopah gravelly sandy loam 0 to 4 percent slopes	0.61	0.32	0
TMD	Tonopah very gravelly sandy loam 4 to 15 percent slopes	0.47	0.24	0
TnA	Toquop fine sand 0 to 2 percent slopes	2.00	1.38	0
TnB	Toquop fine sand 2 to 8 percent slopes	2.00	1.38	0
TqA	Toquop complex 0 to 2 percent slope	0.46	0.19	0
TsA	Toquop fine sand watertable 0 to 2 percent slopes	2.00	1.27	0
TtA	Toquop fine sandy loam 0 to 2 percent slopes	0.84	0.46	0
TuA	Toquop fine sandy loam watertable 0 to 2 percent slopes	0.91	0.51	0
TvA	Toquop silty clay loam strongly saline 0 to 2 percent slopes	0.07	0.01	0
Ty	Typic Torriorthents-Badland association	0.40	0.20	0
UNB	Underton extremely gravelly fine sandy loam 2 to 8 percent slopes	0.23	0.10	0
UPE	Upperline very gravelly sandy loam 8 to 30 percent slopes	0.52	0.27	0

Table D.18 NV608 Virgin River Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
USE	Upperline-St. Thomas-Upperline association	0.40	0.20	0
UWD	Upperline-Weiser-Whitebasin association	0.49	0.25	0
Vd	Vinton fine sandy loam	0.50	0.25	0
VFG	Virgin Peak-Rock outcrop association	0.30	0.15	15
Vg	Virgin River silty clay	0.02	0.01	0
Vn	Virgin River silty clay strongly saline	0.02	0.01	0
Vr	Virgin River silty clay loam wet variant	0.04	0.01	0
W	Water	0.01	0.01	100
WAC	Wechech association	0.41	0.21	0
WBE	Wechech very gravelly fine sandy loam 8 to 30 percent slopes	0.34	0.17	0
WCE	Wechech-Ifteen association	0.83	0.49	0
WDC	Wechech-Weiser association	0.39	0.20	0
WEE	Weiser cobbly sandy loam 15 to 30 percent slopes	0.37	0.19	0
WFC	Weiser-Arizo association	0.53	0.28	0
WGC	Weiser-Oldspan-Wechech association	0.33	0.16	0
WHE	Whitebasin-Upperline-Hardbasin association	0.66	0.35	0
ZAG	Zeheme-Rock outcrop association	0.33	0.16	20

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D.3.13 NV713

Table D.19 NV713 Meadow Valley Area Nevada, Part of Lincoln County

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1004	Armespan association	0.20	0.08	1004
1010	Linco-Acana-Patter association	0.26	0.11	1010
1025	Aned-Newvil-Decan association	0.08	0.03	1025
1037	Badland	0.31	0.16	1037
1038	Linco loamy fine sand hummocky 2 to 8 percent slopes	0.32	0.14	1038
1039	Ursine association	0.37	0.19	1039
1040	Chuckmill-Qwynn association	0.12	0.04	1040
1051	Xeric Torriorthents-Acana-Holsine association	0.23	0.09	1051
1064	Basket-Xeric Torriorthents-Decathon association	0.05	0.01	1064
1090	Kyler-Eaglepass-Rock outcrop association	0.24	0.11	1090
1091	Kyler-Eaglepass-Rock outcrop association warm	0.25	0.11	1091
1100	Linoyer-Heist association	0.59	0.31	1100
1103	Fifteenmile-Sevenmile complex 0 to 2 percent slopes	0.15	0.05	1103
1107	Armespan-Fifteenmile association	0.16	0.06	1107
1108	Baberwit-Holsine associaton	0.20	0.08	1108
1113	Farepeak-Slockey-Schoolmarm association	0.07	0.02	1113
1114	Slockey-Schoolmarm-Rock outcrop association	0.09	0.03	1114
1116	Springmeadow sandy loam drained 0 to 2 percent slopes	0.43	0.21	1116
1121	Fanu loam 0 to 2 percent slopes	0.50	0.26	1121
1134	Lojet-Chuckmill-Sevenmile association	0.10	0.03	1134
1135	Springmeadow complex 0 to 2 percent slopes	0.07	0.02	1135
1138	Littleailie-Lien-Sevenmile association	0.24	0.11	1138
1140	Minu-Lojet-Acana association	0.10	0.02	1140
1142	Acana-Lojet association	0.17	0.05	1142
1173	Cedaran-Rock outcrop complex 2 to 15 percent slopes	0.03	0.01	1173
1182	Decan-Acoma-Uana association	0.03	0.01	1182
1184	Decan-Acoma-Uana association moist	0.03	0.01	1184
1186	Decan association	0.03	0.01	1186
1201	Decan-Uana association	0.03	0.01	1201

Table D.19 NV713 Meadow Valley Area Nevada, Part of Lincoln County

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1234	Decathon-Basket association	0.03	0.01	1234
1250	Patter-Heist association	0.39	0.19	1250
1264	Chiefpan-Linco association	0.07	0.03	1264
1266	Indicove association	0.06	0.02	1266
1290	Ravendog-Fanu-Fifteenmile association	0.34	0.15	1290
1291	Ravendog-Fanu-Fifteenmile association cool	0.35	0.15	1291
1301	Geer fine sandy loam gravel substratum 0 to 2 percent slopes	0.71	0.39	1301
1302	Flatnosewash silt loam 0 to 2 percent slopes	0.10	0.03	1302
1311	Geer silt loam 0 to 2 percent slopes	0.29	0.12	1311
1331	Geer silt loams 0 to 2 percent slopes	0.32	0.14	1331
1361	Hamtah-Starflyer-Rock outcrop association	0.10	0.03	1361
1362	Deerlodge-Fanu-Newvil association	0.14	0.05	1362
1364	Bamos-Pass Canyon-Rock outcrop association	0.07	0.02	1364
1372	Hamtah-Schoolmarm-Rock outcrop association	0.09	0.03	1372
1374	Denpark-Hamtah-Rock outcrop association	0.15	0.06	1374
1378	Oxvalley-Denpark-Hamtah assocation	0.21	0.10	1378
1390	Heist gravelly ashy sandy loam 0 to 4 percent slopes	0.55	0.28	1390
1401	Heist gravelly ashy sandy loam sand substratum 0 to 8 percent slopes	0.59	0.31	1401
1432	Pagecreek ashy sandy loam 4 to 8 percent slopes	0.06	0.01	1432
1442	Homestake association	0.02	0.01	1442
1444	Homestake-Basket association	0.03	0.01	1444
1460	Wakansapa-Turba-Cedaran association	0.07	0.02	1460
1464	Wakansapa-Rock outcrop-Turba association	0.06	0.02	1464
1472	Zoate-Rock outcrop-Anaud association	0.06	0.02	1472
1492	Eaglepass-Rock outcrop complex 15 to 75 percent slopes	0.19	0.08	1492
1510	Ursine-Jarab-Pamsdel association	0.26	0.12	1510
1514	Jarab-Blackcan association	0.12	0.05	1514
1529	Linco-Acana association	0.28	0.12	1529
1532	Harvan-Linco-Xeric Torriorthents association	0.16	0.06	1532
1534	Minu-Acana-Xeric Torriorthents association	0.13	0.03	1534
1539	Xeric Torriorthents-Linco association	0.20	0.08	1539

Table D.19 NV713 Meadow Valley Area Nevada, Part of Lincoln County

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1542	Linco-Xeric Torriorthents-Armespan association	0.24	0.10	1542
1544	Xeric Torriorthents-Acana association	0.21	0.08	1544
1549	Linco-Patter-Baberwit association	0.23	0.09	1549
1581	Ursine-Holsine association	0.39	0.20	1581
1620	Nevu gravelly ashy sandy loam 4 to 15 percent slopes	0.06	0.02	1620
1630	Pahranagat silt loam drained strongly saline 0 to 2 percent slopes	0.13	0.05	1630
1640	Pahranagat silt loam strongly saline 0 to 2 percent slopes	0.13	0.05	1640
1650	Pahranagat silt loam 0 to 2 percent slopes	0.14	0.05	1650
1660	Pahranagat silt loam drained 0 to 2 percent slopes	0.13	0.05	1660
1692	Fifteenmile association	0.06	0.01	1692
1694	Fifteenmile-Heist-Patter association	0.14	0.04	1694
1696	Medburn-Heist-Patter association	0.45	0.21	1696
1698	Chuffa-Fifteenmile silt loams 0 to 4 percent slopes	0.10	0.03	1698
1704	Chiefrange-Checkett association	0.03	0.01	1704
1706	Checkett extremely gravelly loam 15 to 50 percent slopes	0.05	0.01	1706
1736	Chubard-Rock outcrop-Richinde association	0.10	0.03	1736
1745	Roval-Minu association	0.06	0.01	1745
1770	Veet-Mosida association	0.40	0.20	1770
1771	Veet-Heist association	0.38	0.18	1771
1772	Heist-Veet-Holsine association	0.45	0.22	1772
1773	Holsine-Veet-Heist association	0.45	0.23	1773
1776	Veet association	0.36	0.17	1776
1801	Seval-Roval association	0.07	0.02	1801
1825	Acti-Cedaran-Turba association	0.04	0.02	1825
1828	Cedaran-Wakansapa-Turba association	0.04	0.02	1828
1829	Wakansapa-Cedaran association	0.03	0.01	1829
1840	Slickens	0.13	0.03	1840
1860	Satt-Swisbob association	0.05	0.01	1860
1862	Homestake-Swisbob association	0.03	0.01	1862
1886	Schoolmarm-Starflyer-Rock outcrop association	0.07	0.02	1886
1898	Quazo-Motoqua very gravelly sandy loams 30 to 70 percent slopes	0.09	0.03	1898

Table D.19 NV713 Meadow Valley Area Nevada, Part of Lincoln County

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1922	Quazo-Motoqua-Rock outcrop association	0.09	0.03	1922
1924	Wakansapa-Rock outcrop association	0.05	0.01	1924
1962	Eastmore-Holsine-Xeric Torriorthents association	0.30	0.14	1962
1965	Eastmore-Armespan association	0.41	0.22	1965
1972	Radol-Rock outcrop-Monarch association	0.17	0.07	1972
1994	Rock outcrop-Gabbvally-Tejabe association	0.19	0.08	1994
1998	Gabbvally-Stewval-Rock outcrop association	0.12	0.04	1998
2010	Stewval-Gabbvally association	0.09	0.03	2010
2011	Stewval-Lomoine-Rock outcrop association	0.14	0.06	2011
2042	Denpark-Notellumcreek-Rock outcrop association	0.16	0.06	2042
2044	Nevtah-Denpark-Antennapeak association	0.19	0.08	2044
2046	Antennapeak-Nevtah-Wiltop association	0.20	0.08	2046
2048	Denpark-Greengrove association	0.28	0.13	2048
2050	Denpark-Notellumcreek association	0.15	0.06	2050
2052	Wiltop-Denpark association	0.18	0.08	2052
2054	Notellumcreek-Rock outcrop association	0.07	0.02	2054
2062	Winz gravely ashy loam 30 to 50 percent slopes	0.22	0.09	2062
2118	Lojet-Armespan-Xeric Torriorthents association	0.12	0.03	2118
2121	Lojet-Acana-Linco association	0.15	0.04	2121
2129	Stewval-Gabbvally-Rock outcrop association	0.07	0.03	2129
2130	Richinde-Rock outcrop association	0.08	0.03	2130
2132	Chubard-Richinde-Zoate association	0.07	0.02	2132
2278	Schoolmarm-Rock outcrop association	0.06	0.02	2278
2296	Chubard association	0.11	0.04	2296
2299	Chubard-Rock outcrop association	0.11	0.04	2299
2322	Blackcan-Linco-Xeric Torriorthents association	0.24	0.10	2322
2324	Blackcan association	0.26	0.12	2324
3674	Kyler-Rock outcrop complex 8 to 50 percent slopes	0.24	0.11	3674
3870	Newvil-Chuckmill-Sevenmile association	0.16	0.06	3870
3872	Newvil-Okayview association	0.19	0.07	3872
3880	Nevu-Okayview-Sevenmile association	0.16	0.06	3880
3888	Anaud-Starflyer association	0.15	0.06	3888
3890	Anaud very gravelly ashy loam 2 to 15 percent slopes	0.22	0.10	3890

Table D.19 NV713 Meadow Valley Area Nevada, Part of Lincoln County

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
3892	Slockey-Hamtah-Schoolmarm association	0.10	0.03	3892
3896	Hamtah-Slockey-Farepeak association	0.15	0.06	3896
4020	Schoolmarm-Farepeak-Rock outcrop association	0.06	0.02	4020
4024	Schoolmarm-Slockey association	0.07	0.02	4024
4026	Schoolmarm-Hamtah-Rock outcrop association	0.08	0.03	4026
4027	Slockey-Chubard-Anaud association	0.10	0.03	4027
4029	Slockey-Hamtah-Schoolmarm extremely gravelly association	0.08	0.02	4029
4032	Slockey-Starflyer-Rock outcrop association	0.08	0.02	4032
4036	Starflyer-Rock outcrop-Schoolmarm association	0.07	0.02	4036
9999	Water	0.01	0.01	9999

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D.3.14 NV754

Table D.20 NV754 Lincoln County Nevada South Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1000	Weiser-Wechech-Arizo association	0.38	0.19	0
1001	Weiser-Wechech association	0.28	0.14	0
1004	Armespan association	0.20	0.08	0
1010	Wechech-Weiser association	0.37	0.18	0
1016	Wechech association	0.39	0.20	0
1017	Wechech-Bard-Arizo association	0.42	0.22	0
1020	Kurstan-Wechech association	0.45	0.23	0
1021	Kurstan-Knob Hill association	0.61	0.32	0
1030	Arizo-Bluepoint association	1.08	0.64	0
1031	Arizo association	1.13	0.69	0
1040	Akela-Rock outcrop association	0.48	0.26	20
1041	Akela-Rochpah-Rock outcrop association	0.50	0.27	10
1052	Knob Hill-Arizo association	0.68	0.38	0
1060	St. Thomas-Chinkle-Rock outcrop association	0.34	0.17	20
1061	St. Thomas-Zeheme-Rock outcrop association	0.35	0.17	20
1062	Zeheme-Chinkle-Shankba association	0.29	0.13	8
1063	Zeheme-Kanesprings-Rock outcrop association	0.19	0.07	15
1064	Zeheme-Kanackey-Rock outcrop association	0.11	0.07	20
1065	Zeheme-Rock outcrop association	0.34	0.16	35
1066	Zeheme-Boxspring-Rock outcrop association	0.23	0.10	20
1070	Bellehelen-Brier association	0.08	0.03	7
1080	Kaspal-Canoto association	0.10	0.03	0
1090	Logring-Rock outcrop association	0.20	0.08	20
1091	Logring-Eaglepass-Rock outcrop complex	0.18	0.07	15
1100	Geta-Arizo association	0.70	0.38	0
1101	Geta gravelly sandy loam 2 to 4 percent slopes	0.57	0.30	0
1102	Geta-Bluepoint-Arizo association	1.00	0.58	0
1110	Kanesprings-Kanackey-Rock outcrop association	0.06	0.02	15
1111	Nuhelen-Farepeak association	0.10	0.04	6
1113	Kanesprings-Gabbvally association	0.08	0.02	0
1133	Lojet-Qwynn-Littleailie association	0.18	0.05	0
1160	Silent-Koyen association	0.17	0.04	0

Table D.20 NV754 Lincoln County Nevada South Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1170	Alko-Arizo association	0.48	0.25	0
1172	Alko-Geta assocation	0.49	0.25	0
1180	Acoma-Decan-Cath association	0.04	0.02	0
1182	Decan-Acoma-Uana association	0.03	0.01	2
1190	Minu-Shroe-Acoma association	0.04	0.01	0
1210	Brier-Acoma-Bellehelen association	0.08	0.03	5
1211	Brier-Rock outcrop association	0.11	0.04	30
1220	Lien-Devildog association	0.32	0.16	0
1230	Pahranagat association	0.12	0.05	0
1250	Patter-Heist association	0.43	0.20	0
1260	Hollace-Gabbvally association	0.06	0.01	3
1261	Hollace-Rochpah-Wyva association	0.10	0.03	10
1262	Hollace-Winklo-Wyva association	0.06	0.01	3
1266	Indicove association	0.06	0.02	0
1270	Laross-Rock outcrop association	0.50	0.29	20
1300	Mormount-Arizo association	0.31	0.14	0
1302	Mormount very gravelly sandy loam 2 to 8 percent slopes	0.26	0.11	0
1303	Mormount-Canoto association	0.29	0.13	0
1340	Aymate-Canoto association	0.47	0.24	0
1341	Aymate sandy loam 0 to 2 percent slopes	0.59	0.30	0
1342	Aymate-Mormount-Arizo association	0.45	0.22	0
1350	Bard gravelly fine sandy loam 2 to 8 percent slopes	0.38	0.18	0
1360	Canoto-Arizo association	0.53	0.28	0
1370	Mormon Mesa association	0.58	0.30	0
1371	Mormon Mesa-Naye-Dalian association	0.44	0.22	0
1372	Mormon Mesa-Tonopah-Arada association	0.60	0.32	0
1380	Bracken gravelly fine sandy loam 2 to 8 percent slopes	0.73	0.40	0
1390	Shankba-Chinkle-Kanackey association	0.17	0.09	2
1400	Irongold-Canoto association	0.37	0.17	0
1401	Irongold-Arizo association	0.41	0.20	0
1403	Irongold-Wechech association	0.35	0.17	0
1404	Irongold-Mormount-Canoto association	0.30	0.13	0
1405	Irongold-Zeheme association	0.31	0.14	0
1406	Irongold very gravelly sandy loam 4 to 30 percent slopes	0.30	0.14	0
1420	Kanackey-Rock outcrop association	0.02	0.02	15
1430	Typic Torriorthents-Badlands association	0.20	0.07	0

Table D.20 NV754 Lincoln County Nevada South Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1460	Pintwater-Rochpah association	0.37	0.18	3
1470	Tybo-Keefa-Koyen association	0.53	0.27	0
1471	Tybo-Koyen association	0.53	0.27	0
1472	Tybo-Geer association	0.54	0.28	0
1473	Tybo-Leo association	0.51	0.26	0
1474	Tybo-Delamar association	0.34	0.15	0
1475	Treadwell-Veet association	0.29	0.14	6
1490	Keefa-Penoyer association	0.37	0.15	0
1491	Keefa warm-Penoyer association	0.35	0.14	0
1510	Koyen gravelly sandy loam 2 to 4 percent slopes	0.64	0.35	0
1512	Koyen-Penoyer association	0.28	0.10	0
1520	Geer-Penoyer association	0.31	0.11	0
1529	Linco-Acana association	0.28	0.12	0
1530	Delamar-Leo association	0.17	0.06	0
1531	Delamar-Veet association	0.10	0.03	0
1533	Delamar-Tybo-Koyen association	0.22	0.09	0
1534	Delamar-Koyen association	0.14	0.05	0
1535	Delamar gravelly sandy loam 2 to 8 percent slopes	0.10	0.03	0
1539	Xeric Torriorthents-Linco association	0.20	0.08	0
1541	Oleman-Irongold association	0.10	0.03	0
1542	Oleman gravelly sandy loam 4 to 15 percent slopes	0.06	0.02	0
1550	Pahroc-Leo association	0.26	0.11	0
1551	Pahroc very gravelly very fine sandy loam 4 to 15 percent slopes	0.27	0.13	0
1570	Kyler-Eaglepass-Rock outcrop association warm	0.25	0.11	20
1571	Kyler-Logring-Rock outcrop association warm	0.22	0.10	25
1590	Winklo-Wyva assocation	0.05	0.01	5
1591	Winklo-Rochpah-Rock outcrop association	0.09	0.03	15
1650	Handpah-Veet association	0.11	0.04	0
1660	Dewrust-Veet association	0.09	0.03	0
1680	Rochpah-Hollace-Gabbvally association	0.18	0.07	0
1681	Rochpah-Veet association	0.34	0.17	0
1683	Rochpah-Rock outcrop-Leo association	0.45	0.24	30
1690	Jolan-Geer association	0.46	0.22	0
1700	Sierocliff-Veet association	0.16	0.06	0

Table D.20 NV754 Lincoln County Nevada South Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1704	Chiefrange-Checkett association	0.03	0.01	6
1710	Cliffdown gravelly sandy loam 2 to 8 percent slopes MLRA 29	0.48	0.24	0
1730	Cath-Veet association	0.12	0.04	0
1734	Qwynn-Devildog association	0.45	0.23	0
1741	Slaw silt loam 0 to 2 percent slopes	0.09	0.02	0
1750	Chanybuck-Brier-Rock outcrop association	0.30	0.16	15
1761	Wyva-Rock outcrop association	0.06	0.01	20
1762	Wyva-Slidymtn association	0.06	0.01	0
1770	Veet-Mosida association	0.34	0.17	0
1776	Veet association	0.36	0.17	0
1810	Boxspring-Rock outcrop association	0.14	0.06	20
1811	Boxspring-Theriot-Rock outcrop association MLRA 29	0.20	0.09	15
1821	Turba-Acti association	0.24	0.13	3
1825	Acti-Cedaran-Turba association	0.04	0.02	4
1828	Cedaran-Wakansapa-Turba association	0.04	0.02	7
1829	Wakansapa-Cedaran association	0.03	0.01	8
1830	Zaqua-Winklo association	0.04	0.01	6
1831	Zaqua-Boxspring association	0.05	0.02	5
1832	Zaqua-Winklo-Kanesprings association	0.05	0.01	5
1833	Zaqua-Rock outcrop association	0.05	0.01	30
1850	Rapado-Oleman association	0.06	0.02	0
1851	Rapado-Veet association	0.07	0.02	0
1870	Faleria-Laross association	0.61	0.37	2
1880	Tejabe-Pintwater-Rock outcrop association	0.24	0.11	15
1881	Richinde-Pintwater-Rock outcrop association	0.09	0.02	15
1885	Richinde-Chubard-Richinde very stony association	0.08	0.02	2
1890	Welring-Rock outcrop association	0.16	0.06	20
1898	Quazo-Motoqua very gravelly sandy loams 30 to 70 percent slopes	0.09	0.03	10
1900	Glendale-Bluepoint association	0.17	0.06	0
1910	Land silt loam 0 to 2 percent slopes	0.06	0.01	0
1920	Motoqua-Rock outcrop association	0.07	0.02	15
1921	Motoqua-Thunderbird association	0.06	0.02	5
1940	Chubard stony-Rock outcrop association	0.11	0.04	20
1941	Slidymtn-Capsus-Wyva association	0.05	0.02	0
1942	Richinde-Chubard association	0.08	0.02	2

Table D.20 NV754 Lincoln County Nevada South Part

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1945	Cabinpine association	1.65	1.10	0
1950	Ursine-Lomoine association	0.22	0.10	8
1951	Ursine association	0.18	0.08	0
1955	Treadwell-Chuckridge-Handpah association	0.16	0.06	0
1960	Crystal Springs gravelly sandy loam 2 to 8 percent slopes	0.44	0.22	0
1980	Longjim-Arizo association	0.33	0.15	0
1990	Gabbvally-Rock outcrop association	0.14	0.05	15
1991	Gabbvally-Hollace association	0.09	0.02	0
1992	Gabbvally-Brier-Rock outcrop association	0.12	0.04	10
1993	Richinde-Rock outcrop association	0.08	0.03	15
1994	Rock outcrop-Gabbvally-Tejabe association	0.19	0.08	45
1998	Gabbvally-Stewval-Rock outcrop association	0.12	0.04	15
2000	Playas	0.12	0.05	0
2010	Stewval-Gabbvally association	0.09	0.03	6
2011	Stewval-Lomoine-Rock outcrop association	0.14	0.06	10
2123	Littleailie-Lojet association	0.17	0.06	0
2129	Stewval-Gabbvally-Rock outcrop association	0.07	0.03	15
2290	Richinde-Chubard-Rock outcrop association	0.08	0.02	20
2292	Chubard-Richinde association	0.09	0.02	4
2297	Chubard-Richinde-Rock outcrop association steep	0.10	0.03	15
2298	Chubard-Richinde association steep	0.10	0.03	6
2320	Blackcan association	0.28	0.13	0
3192	Saltydog-Ambush-Panacker association	0.17	0.06	0
3193	Ewelac-Playas association	0.08	0.02	0
3194	Ambush-Panacker-Playas association	0.31	0.14	0

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Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
100	Newera association	0.09	0.03	3
101	Glencarb very fine sandy loam saline	0.05	0.01	0
105	Galehills extremely gravelly fine sandy loam 15 to 50 percent slopes	0.47	0.25	3
106	Galehills-Zeheme association	0.44	0.23	5
107	Galehills-Calwash association	0.24	0.09	0
110	Tenwell-Crosgrain association	0.24	0.10	0
111	Tenwell-Shamock association	0.46	0.23	0
112	Arizo very gravelly loamy sand flooded 0 to 4 percent slopes	0.92	0.54	0
113	Arizo very gravelly fine sandy loam gypsiferous substratum 2 to 8 percent slopes	0.49	0.26	0
115	Whitebasin-Upperline-Hardbasin association	0.66	0.35	0
120	Crosgrain-Tenwell association	0.22	0.09	0
121	Sweetspring-Carrizo association	0.18	0.07	0
125	Bobzbulz-Snapcan association	0.17	0.07	0
134	Newera-Nipton association	0.11	0.04	2
135	Nippeno-Mountmcull-Newera association	0.11	0.03	3
140	Haleburu extremely gravelly sandy loam 4 to 15 percent slopes	0.35	0.17	6
141	Nipton-Haleburu-Rock outcrop association	0.36	0.18	20
143	Haleburu association	0.31	0.15	2
144	Haleburu extremely cobbly-Hiddensun association	0.38	0.19	4
146	Haleburu-Nipton association	0.34	0.17	0
147	Haleburu-Nipton association dry	0.35	0.18	0
148	Haleburu-Seanna association	0.37	0.18	0
150	Hypoint gravelly sandy loam 0 to 4 percent slopes	0.98	0.58	0
151	Bluepoint-Arizo association	1.12	0.68	0
155	Bitterridge-Helkitchen association	0.12	0.04	0
160	Lanip-Kidwell association	0.30	0.13	0
165	Upperline-Weiser-Whitebasin association	0.49	0.25	0
167	Upperline-St. Thomas-Upperline association	0.40	0.20	0

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
168	Upperline very gravelly sandy loam 8 to 30 percent slopes	0.52	0.27	0
170	Tenwell-Lanip association	0.32	0.14	0
175	St. Thomas-Rock outcrop complex	0.20	0.08	20
176	St. Thomas association	0.20	0.08	5
177	St. Thomas-Upperline-Whitebasin complex	0.39	0.18	0
178	St. Thomas-Iceberg-Rock outcrop association	0.30	0.14	25
180	Kidwell-Tenwell association	0.39	0.19	0
185	Lastchance-Commski association	0.22	0.10	0
186	Lastchance-Ferrogold-Commski association	0.21	0.09	0
190	Filaree-Lanip-Nickel association	0.40	0.19	0
191	Bluepoint-Grapevine association	1.18	0.69	0
192	Bluepoint association	1.48	0.90	0
195	Cruzspring-Schader-Rock outcrop association	0.15	0.05	15
200	Commski-Weiser-Threelakes association	0.28	0.14	0
201	Commski extremely gravely loam 8 to 30 percent slopes	0.16	0.07	0
202	Commski-Lastchance association	0.30	0.15	0
203	Commski-Oldspan-Lastchance association	0.34	0.16	0
205	Callville-Badland-Guardian association	0.51	0.27	0
207	Callville association	0.55	0.29	0
210	Nickel-Arizo association	0.60	0.32	0
211	Nickel-Crosgrain association	0.29	0.14	0
220	Haymont-Bluepoint association	0.28	0.11	0
221	Haymont association	0.13	0.03	0
225	Baseline-Callville-Badland association	0.42	0.22	0
226	Baseline extremely gravelly fine sandy loam 2 to 8 percent slopes	0.39	0.20	0
227	Baseline-Gypwash association	0.39	0.20	0
228	Baseline-Guardian association	0.48	0.25	0
230	Wechech-Weiser association	0.39	0.20	0
231	Wechech very gravelly fine sandy loam 2 to 8 percent slopes	0.43	0.22	0
232	Wechech-Upperline association	0.48	0.25	0
233	Wechech-Ifteen association	0.83	0.49	0
234	Wechech very gravelly fine sandy loam 8 to 30 percent slopes	0.34	0.17	0
235	Gypwash-Callville-Carrizo association	0.47	0.25	0

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
237	Wechech association	0.41	0.21	0
240	Crosgrain-Irongold-Nickel association	0.20	0.09	0
241	Crosgrain-Typic Torriorthents-Nickel association	0.23	0.10	4
250	Mormon Mesa-Naye association	0.51	0.27	0
255	Tumarion-Nipton association	0.23	0.10	10
260	Naye-Bitter Spring association	0.41	0.19	0
261	Vace-Jean association	0.71	0.38	0
265	Azureridge very gravelly sandy loam 15 to 50 percent slopes	0.46	0.24	0
270	Bard-Nickel-Limewash association	0.57	0.30	8
271	Moapa-Bluepoint association	1.52	1.18	5
272	Moapa-Bluepoint-Rock outcrop association	1.82	1.56	20
285	Heleweiser-Carrizo-Teebar association	0.43	0.22	0
286	Heleweiser-Carrizo association	0.53	0.28	0
287	Heleweiser association	0.40	0.20	0
288	Heleweiser-Teebar association	0.46	0.24	0
289	Heleweiser-Upperline-Nickel association	0.48	0.25	1
290	Rock outcrop-Moapa-Bluepoint association	1.80	1.58	45
291	Rock outcrop-Highland association	0.10	0.03	50
292	Rock outcrop-Nupper association	0.30	0.14	65
294	Rock outcrop sandstone	0.25	0.11	90
298	Rock outcrop-Redneedle-Heleweiser association	0.53	0.28	35
310	Weiser-Arizo association	0.53	0.28	0
311	Weiser-Threelakes association	0.42	0.21	0
313	Weiser-Oldspan-Wechech association	0.33	0.16	0
314	Weiser-Wechech association	0.40	0.20	0
315	Weiser Association	0.33	0.15	0
320	Boxspring-Zeheme-Rock outcrop complex 15 to 50 to percent slopes MLRA 30	0.24	0.11	15
321	Boxspring-Seralin-Rock outcrop association	0.18	0.08	15
322	Boxspring-Potosi-Rock outcrop association	0.18	0.08	10
323	Boxspring-Scrapy-Rock outcrop association	0.26	0.12	15
325	Sandpan-Rositas association	1.23	0.92	0
330	Ramshead-St. Thomas-Rock outcrop association	0.22	0.09	15
335	Teebar very cobbly fine sandy loam 0 to 4 percent slopes	0.40	0.21	7
336	Teebar-Sandpan association	0.53	0.29	0

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
340	Zeheme-Rock outcrop association	0.33	0.16	20
341	Zeheme extremely gravelly fine sandy loam 8 to 30 percent slopes	0.33	0.16	4
342	Zeheme-Potosi-Rock outcrop association	0.28	0.13	15
343	Zeheme-Rock outcrop-Boxspring association	0.30	0.15	20
351	Seralin extremely gravelly loam 30 to 75 percent slopes	0.17	0.07	4
352	Seralin-Traley-Rock outcrop association	0.21	0.09	15
355	Seralin-Devilsthumb-Ednagrey association	0.19	0.08	3
360	Bracken-Arizo-Badland association	0.64	0.37	0
365	Callville-Gypwash-Badland association	0.34	0.17	0
375	Iceberg-Rock outcrop-Helkitchen association	0.20	0.08	25
376	Iceberg-St. Thomas-Rock outcrop association	0.26	0.11	20
380	Tonopah-Arizo association	0.56	0.30	0
390	Tipnat-Hypoint-Grapevine association	0.41	0.19	0
391	Tipnat-Bluepoint-Hypoint association	0.35	0.15	0
400	Arizo-Cafetal association	0.24	0.10	0
405	Oxyaquic Torrifluvents-Gypwash association	0.51	0.26	8
411	Bludiamond-Diamondhil association	0.25	0.11	0
415	Valatier-Goldbutte association	0.16	0.06	2
421	Moentria extremely gravelly loam 15 to 50 percent slopes	0.18	0.07	5
422	Moentria-Purob Association	0.19	0.07	2
430	Bluepoint-Tipnat-Grapevine association	0.61	0.30	0
431	Hypoint-Vegastorm association	1.11	0.65	0
441	Corbilt gravelly loamy fine sand 0 to 4 percent slopes	0.73	0.40	0
450	Arizo association	0.75	0.43	0
451	Arizo-Peskah-Crosgrain association	0.24	0.10	0
454	Arizo-Riverwash association	0.78	0.52	0
455	Arizo-Tenwell association	0.33	0.15	0
460	Pahrump-Wodavar-Vegastorm association	0.23	0.10	0
461	Pahrump-Bluepoint association	0.14	0.05	0
470	Filaree-Seanna association	0.45	0.23	0
475	Guardian-Sunrock-Badland association	0.53	0.28	1
477	Guardian-Baseline-Guardian association	0.59	0.31	0

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
478	Guardian-Baseline association	0.51	0.26	0
480	Vace-Arizo association	0.35	0.16	0
481	Vace-Wechech association	0.31	0.14	0
490	Ifteen extremely gravelly very fine sandy loam 2 to 8 percent slopes	0.49	0.26	0
500	Playas	0.01	0.01	0
501	Dams concrete	0.02	0.01	0
504	Pits quarry	0.02	0.01	0
505	Pits gravel	2.00	2.00	0
506	Pits-Dumps assocation	0.02	0.01	0
508	Landfill	0.02	0.01	0
510	Railroad association	0.38	0.19	2
520	Nolena-Rock outcrop association	0.25	0.11	35
521	Nolena-Nipton association	0.33	0.16	3
522	Nolena-Meadview association	0.36	0.18	1
523	Nolena association	0.35	0.18	0
530	Seanna-Botleg association	0.18	0.07	7
531	Seanna-Rock outcrop association	0.34	0.16	25
532	Seanna-Goldroad-Rock outcrop association	0.34	0.17	15
535	Blackmesa-Sunrock association	0.56	0.29	3
540	Sunrock-Rock outcrop association	0.40	0.20	25
541	Sunrock-Haleburu-Rock outcrop association	0.38	0.19	20
542	Sunrock-Callville-Badland association	0.43	0.22	1
550	Cheme-Riverbend-Carrizo association	0.30	0.13	0
551	Cheme-Carrizo-Huevi association	0.41	0.20	0
552	Cheme-Huevi association	0.26	0.12	1
560	Rositas-Riverbend association	1.75	1.49	5
565	Govwash-Guardian-Badland association	0.34	0.16	0
570	Carrizo association	1.21	0.75	0
571	Carrizo-Carrizo-Riverbend association	1.15	0.73	0
572	Carrizo very cobbly coarse sand 2 to 8 percent slopes	1.28	0.81	0
573	Carrizo-Riverbend association	0.75	0.43	0
574	Carrizo-Sunrock association	0.76	0.43	0
575	Carrizo complex 1 to 5 percent slopes	1.08	0.67	0
581	Threelakes-Weiser association	0.43	0.22	0
590	Riverbend-Carrizo association	0.77	0.45	0
591	Riverbend-Carrwash association	0.63	0.36	0
592	Riverbend-Carrizo frequently flooded association	0.55	0.31	0

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
593	Riverbend-Cheme-Carrizo association	0.44	0.22	0
600	Huevi-Cheme association	0.29	0.14	0
601	Huevi association	0.35	0.18	0
603	Huevi extremely gravelly sandy loam 8 to 30 percent slopes	0.34	0.17	1
604	Huevi-Hiller association	0.31	0.15	1
605	Huevi-Badland association	0.34	0.17	0
606	Huevi-Huevi-Cheme association	0.30	0.14	2
610	Goldroad-Rock outcrop association	0.40	0.20	25
612	Goldroad-Seanna-Rock outcrop association	0.37	0.19	15
613	Goldroad-Haleburu-Rock outcrop association	0.40	0.20	15
620	Arizo-Lanip association	0.43	0.21	0
621	Orwash gravelly loamy coarse sand 2 to 4 percent slopes	1.01	0.59	0
622	Orwash-Arizo-Lanip association	0.53	0.27	0
630	Tenwell very gravelly sandy loam 2 to 4 percent slopes	0.37	0.18	0
635	Aguachiquita-Azureridge association	0.43	0.23	0
640	Cetrepas-Nolena-Rock outcrop association	0.21	0.09	15
645	Goldbutte-Nolena association	0.35	0.17	2
646	Goldbutte-Jumbopeak-Rock outcrop association	0.49	0.26	20
650	Peskah-Crosgrain association	0.14	0.05	0
651	Peskah-Arizo association	0.21	0.08	0
660	Crosgrain extremely gravelly loam 4 to 15 percent slopes	0.16	0.06	0
661	Crosgrain very stony loam 8 to 30 percent slopes	0.17	0.07	0
662	Crosgrain-Arizo association	0.22	0.10	0
663	Crosgrain-Kidwell-Arizo association	0.30	0.14	0
665	Crosgrain-Vace association	0.22	0.09	0
670	Nipton-Highland-Rock outcrop association	0.22	0.09	15
673	Nolena-Newera association	0.16	0.06	3
674	Nipton-Rubble land-Railroad association	0.36	0.18	27
680	Lanfair-Hoppswell association	0.32	0.15	0
690	Hoppswell-Ustidur association	0.16	0.06	0
691	Hoppswell-Jetmine association	0.20	0.08	0
700	Mountmcull-Nippeno association	0.16	0.06	4
701	Nippeno-Nipton association	0.12	0.04	4

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
705	Charkiln-Woodspring-Buckspring association	0.30	0.15	0
710	Arizo-Lanfair-Riverwash association	0.55	0.32	0
715	Troughspring-Charkiln-Buckspring association	0.26	0.13	2
716	Troughspring very gravelly loam 4 to 15 percent slopes	0.31	0.17	0
721	Corncreek-Badland-Pahrump association	0.22	0.09	0
723	Corncreek-Haymont association	0.22	0.08	0
725	Mackscanyon-Purob association	0.16	0.06	0
731	Purob-Irongold association	0.15	0.06	0
732	Purob extremely gravelly loam 8 to 30 percent slopes	0.13	0.05	1
733	Purob extremely gravelly loam 2 to 8 percent slopes	0.12	0.04	2
734	Purob-Niavi association	0.16	0.06	0
740	Varwash association	0.27	0.13	0
741	Varwash-Carrizo association	0.33	0.16	0
750	Haleburu-Crosgrain-Rock outcrop association	0.30	0.14	11
751	Nipton-Nolena association	0.28	0.13	3
752	Nipton-Newera association	0.19	0.08	0
753	Nipton-Hiddensun-Haleburu association	0.38	0.19	2
754	Haleburu-Hiddensun association	0.39	0.20	3
760	Searchlight extremely gravelly sandy loam 2 to 4 percent slopes	0.54	0.29	0
772	Lamadre-Robbersfire association	0.21	0.10	3
775	Ladyofsnow-Robbersfire-Maryjane association	0.19	0.08	2
780	Prisonear fine sand 2 to 8 percent slopes	1.58	1.07	0
781	Prisonear-Bluepoint association	1.70	1.17	0
790	McClanahan-Beerbo association	0.08	0.03	6
801	Nippeno-Newera association	0.07	0.02	2
805	Buckspring-Fletcherpeak-Seralin association	0.20	0.09	3
806	Buckspring-Scrapy association	0.32	0.16	2
810	Straycow-Newera-Rubble land association	0.06	0.02	14
815	Wheelerwell-Wheelerpass association	0.08	0.03	5
820	Newera-Rock outcrop association	0.08	0.02	15

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
821	Helkitchen-St. Thomas complex 15 to 50 percent slopes	0.23	0.10	4
830	Puelzmine extremely gravelly fine sandy loam 4 to 15 percent slopes	0.18	0.08	4
833	Virgin Peak-Rock outcrop association	0.30	0.15	15
840	Potosi-Zeheme-Rock outcrop association	0.25	0.12	10
845	Leecanyon-Goodwater association	0.31	0.15	0
850	Birdspring association	0.35	0.17	6
851	Birdspring-Zeheme-Rock outcrop association	0.23	0.10	15
852	Birdspring-Rock outcrop association	0.45	0.24	20
853	Birdspring-St. Thomas-Rock outcrop association	0.30	0.14	15
854	Birdspring-Birdspring warm-Rock outcrop association	0.42	0.22	20
860	Straycow-Highland association	0.05	0.02	3
865	Mackscanyon very gravelly silt loam 15 to 50 percent slopes	0.19	0.08	0
866	Goodwater-Doespring association 15 to 50 percent slopes	0.35	0.18	0
867	Goodwater very gravelly sandy loam 15 to 50 percent slopes	0.34	0.17	0
868	Mackscanyon-Goodwater association	0.21	0.09	0
870	Irongold extremely gravelly loam 2 to 8 percent slopes	0.19	0.08	0
871	Irongold-Weiser association	0.21	0.09	0
872	Irongold-Wechech association	0.27	0.12	0
875	Kylecanyon-Goodwater association	0.31	0.15	0
880	Nonamewash-Rositas association	1.48	1.02	0
885	Luckystrike gravelly loam 8 to 30 percent slopes	0.14	0.06	2
890	Ripley-Holtville complex	0.06	0.02	0
900	Urban land-Riverbend-Huevi association	0.72	0.43	0
905	Mountmummy-Thesisters-Maryjane association	0.21	0.10	3
910	Carrwash-Riverbend association	0.62	0.35	0
911	Carrwash association	0.64	0.36	0
915	Maryjane-Robbersfire-Kitgram complex 30 to 75 percent slopes	0.16	0.07	1

Table D.21 NV755 Clark County Area

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
916	Maryjane extremely gravelly loam 8 to 30 percent slopes	0.13	0.05	0
920	Tanazza-Wechech-Wodavar association	0.21	0.07	0
925	Lastone association	0.20	0.09	1
930	Cololag-Badland association	0.33	0.17	0
940	Mesabase-Azsand association	0.80	0.49	3
941	Mesabase extremely gravelly sandy loam 2 to 8 percent slopes	0.52	0.28	0
950	Drygyp association	1.49	1.08	0
951	Drygyp-Guardian-Baseline association	0.53	0.28	0
952	Drygyp fine sandy loam 2 to 4 percent slopes	0.68	0.36	0
955	Drygyp-Bluegyp association	0.46	0.24	0
965	Azsand-Mesabase-Rositas association	1.06	0.70	0
970	Rubble land-Charpeak-Rock outcrop complex	0.38	0.20	60
980	Orrubo very gravelly loam 15 to 35 percent slopes	0.18	0.08	0
981	Torriorthents-Haplocalcids-Lava flows complex 10 to 40 percent slopes	0.26	0.12	20
982	Winkel-Rock outcrop complex 2 to 12 percent slopes	0.19	0.08	15
998	Miscellaneous water	0.01	0.01	100
999	Water	0.01	0.01	100

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D.3.16 UT634

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
300	Abela cobbly loam 2 to 8 percent slopes	0.25	0.12	0
301	Abela very gravelly sandy loam 8 to 25 percent slopes	0.41	0.22	0
302	Acord extremely cobbly loam 15 to 40 percent slopes	0.14	0.06	0
303	Annabella very gravelly coarse sandy loam 2 to 8 percent slopes	0.56	0.32	0
304	Annabella very gravelly loam 2 to 15 percent slopes	0.12	0.05	0
305	Antelope Springs loam 0 to 2 percent slopes	0.19	0.07	0
306	Antelope Springs silt loam reclaimed 0 to 2 percent slopes	0.18	0.07	0
307	Ashdown clay loam 0 to 2 percent slopes	0.09	0.03	0
308	Ashdown fine sandy loam 0 to 5 percent slopes	0.46	0.23	0
309	Ashdown loam 2 to 5 percent slopes	0.18	0.07	0
310	Ashdown loam gypsiferous substratum 2 to 5 percent slopes	0.18	0.07	0
311	Ashdown silty clay loam 0 to 1 percent slopes	0.09	0.03	0
312	Baboon very cobbly loam 15 to 50 percent slopes	0.15	0.07	0
313	Badland	0.31	0.16	15
314	Badland-Moondog-Rock outcrop complex 30 to 70 percent slopes	0.12	0.04	15
315	Baird Hollow-Mord complex 15 to 40 percent slopes	0.35	0.20	0
316	Bamos extremely cobbly loam 15 to 40 percent slopes	0.06	0.02	0
317	Bamos extremely gravelly loam 2 to 15 percent slopes	0.07	0.02	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
318	Bamos-Lucero complex 2 to 25 percent slopes	0.13	0.05	0
319	Bamos-Rock outcrop complex 2 to 25 percent slopes	0.08	0.03	25
320	Bandag loam 0 to 2 percent slopes	0.19	0.08	0
321	Bannion gravelly loam 2 to 5 percent slopes	0.15	0.06	0
322	Behanin-Ess complex 25 to 60 percent slopes	0.39	0.23	0
323	Berent loamy fine sand 0 to 10 percent slopes	2.00	1.57	0
324	Beron-Plegomir gravelly sandy loams 2 to 8 percent slopes	0.33	0.15	0
325	Beryl sandy loam 2 to 5 percent slopes	0.51	0.26	0
326	Bess fine sandy loam 2 to 15 percent slopes	0.72	0.42	0
327	Biblesprings fine sandy loam 0 to 2 percent slopes	0.79	0.45	0
328	Biblesprings loam 0 to 2 percent slopes	0.25	0.10	0
329	Biblesprings-Bannion complex 2 to 5 percent slopes	0.67	0.37	0
330	Biblesprings-Blown out land complex 0 to 5 percent slopes	0.39	0.24	0
331	Birdow loam 0 to 5 percent slopes	0.30	0.16	0
332	Blown out land	0.02	0.01	0
333	Braffits loam 0 to 2 percent slopes	0.19	0.08	0
334	Bullion silt loam 0 to 2 percent slopes	0.13	0.04	0
335	Bullion silt loam 0 to 5 percent slopes	0.28	0.12	0
336	Bullion-Antelope Springs complex 0 to 2 percent slopes	0.15	0.05	0
337	Bullion-Berent complex 0 to 10 percent slopes	0.34	0.15	0
338	Bullion-Biblesprings complex 0 to 2 percent slopes	0.16	0.06	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
339	Bullion-Taylorsflat complex 0 to 5 percent slopes	0.30	0.12	0
340	Bushvalley very stony loam 15 to 40 percent slopes	0.22	0.12	0
341	Calcross loam 0 to 2 percent slopes	0.18	0.07	0
342	Calcross loam 2 to 5 percent slopes	0.18	0.07	0
343	Calcross silty clay loam 0 to 1 percent slopes	0.09	0.03	0
344	Canburn silty clay loam 0 to 5 percent slopes	0.15	0.06	0
345	Cathedral-Posant-Rock outcrop complex 25 to 60 percent slopes	0.41	0.24	15
346	Checkett gravelly loam 5 to 40 percent slopes	0.15	0.06	0
347	Checkett-Rock outcrop complex 5 to 40 percent slopes	0.15	0.06	25
348	Checkett-Rock outcrop complex 8 to 25 percent slopes	0.17	0.06	15
349	Chuska-Checkett gravelly loams 8 to 25 percent slopes	0.16	0.06	0
350	Cinder land	2.00	1.56	0
351	Cranbay-Winnemucca complex 10 to 60 percent slopes	0.27	0.14	0
352	Crestline gravelly sandy loam 0 to 5 percent slopes	0.76	0.43	0
353	Crestline sandy loam 0 to 2 percent slopes	0.87	0.51	0
354	Crestline-Sevy sandy loams 0 to 2 percent slopes	0.73	0.41	0
355	Dalcan cobbly loam 2 to 25 percent slopes	0.22	0.10	0
356	Dalcan cobbly loam 15 to 40 percent slopes	0.11	0.04	0
357	Decca sandy loam 0 to 5 percent slopes	0.52	0.27	0
358	Deerlodge gravelly loam 2 to 8 percent slopes	0.16	0.06	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
359	Deerlodge gravelly loam 2 to 15 percent slopes	0.15	0.06	0
360	Deerlodge gravelly loam 5 to 15 percent slopes	0.15	0.06	0
361	Deerlodge-Bannion complex 2 to 5 percent slopes	0.28	0.12	0
362	Deerlodge-Checkett gravelly loams 2 to 8 percent slopes	0.16	0.06	0
363	Deerlodge-Monox gravelly sandy loams 2 to 8 percent slopes	0.31	0.14	0
364	Denmark gravelly loam 2 to 15 percent slopes	0.25	0.12	0
365	Denmark loam 2 to 15 percent slopes	0.23	0.10	0
366	Denmark-Saxby complex 2 to 15 percent slopes	0.21	0.10	0
367	Dennot very gravelly loam 2 to 10 percent slopes	0.15	0.06	0
368	Detra complex 2 to 15 percent slopes	0.38	0.20	0
369	Detra fine sandy loam 15 to 40 percent slopes	0.82	0.51	0
370	Dixie gravelly loam 2 to 8 percent slopes	0.16	0.06	0
371	Dixie-Checkett complex 5 to 40 percent slopes	0.14	0.05	0
372	Doyce loam 2 to 15 percent slopes	0.11	0.04	0
373	Dune land	2.00	1.56	0
374	Elenore gravelly loam 2 to 8 percent slopes	0.20	0.09	0
375	Escalante sandy loam 0 to 5 percent slopes	0.82	0.48	0
376	Escalante sandy loam 1 to 5 percent slopes	0.85	0.49	0
377	Faim clay loam 4 to 25 percent slopes	0.23	0.11	0
378	Faim clay loam 4 to 40 percent slopes	0.23	0.11	0
379	Festus gravelly sandy loam 2 to 8 percent slopes	0.48	0.25	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
380	Fughes-Sheckle loams 4 to 25 percent slopes	0.47	0.27	0
381	Garbo gravelly sandy loam 2 to 5 percent slopes	0.63	0.35	0
382	Garbo-Biblesprings complex 2 to 5 percent slopes	0.67	0.37	0
383	Garbo-Deerlodge complex 2 to 8 percent slopes	0.26	0.11	0
384	Garbo-Sevy complex 2 to 5 percent slopes	0.30	0.13	0
385	Gomine-Vennob-Rock outcrop complex 15 to 40 percent slopes	0.07	0.03	15
386	Gordonpoint loam 1 to 10 percent slopes	0.36	0.19	0
387	Hatu silty clay 0 to 2 percent slopes	0.06	0.02	0
388	Hiko Peak gravelly loam 2 to 25 percent slopes	0.19	0.08	0
389	Hiko Peak gravelly sandy loam 2 to 15 percent slopes	0.59	0.33	0
390	Hoye sandy loam 2 to 5 percent slopes	0.12	0.04	0
391	Ikit-Rock outcrop-Lorhunt complex 25 to 60 percent slopes	0.15	0.06	35
392	Ironco-Quilt complex 25 to 60 percent slopes	0.14	0.06	0
393	Jigsaw silty clay loam 0 to 2 percent slopes	0.09	0.03	0
394	Junkett cobbly sandy loam 2 to 8 percent slopes	0.49	0.27	0
395	Kanarra extremely cobbly clay loam 8 to 25 percent slopes	0.06	0.02	0
396	Kanarra sandy clay loam 2 to 8 percent slopes	0.22	0.09	0
397	Kolob-Detra association 2 to 40 percent slopes	0.35	0.19	0
398	Komo gravelly loam 2 to 15 percent slopes	0.15	0.06	0
399	Krueger loam 2 to 5 percent slopes	0.40	0.22	0
400	Kunz-Detra complex 2 to 40 percent slopes	0.38	0.20	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
401	Kunz-Ramps complex 8 to 25 percent slopes	0.89	0.56	0
402	Lagnaf-Rypod complex 15 to 40 percent slopes	0.19	0.08	0
403	Lava flows	0.01	0.01	85
404	Lavate very cobbly sandy loam 8 to 25 percent slopes	0.43	0.23	0
405	Lodar-Rock outcrop complex 15 to 50 percent slopes	0.17	0.08	25
406	Lucero gravelly sandy loam 2 to 8 percent slopes	0.70	0.40	0
407	Lucero-Checkett complex 15 to 40 percent slopes	0.13	0.05	0
408	Magna silty clay loam 0 to 2 percent slopes	0.09	0.03	0
409	Manderfield gravelly sandy loam 2 to 8 percent slopes	0.70	0.40	0
410	Manselo loam 0 to 2 percent slopes	0.45	0.22	0
411	Manselo loam 0 to 3 percent slopes	0.24	0.11	0
412	Manselo-Antelope Springs silt loams 0 to 2 percent slopes	0.16	0.06	0
413	Manselo-Ashdown complex 0 to 5 percent slopes	0.36	0.16	0
414	Manselo-Berent complex 0 to 10 percent slopes	0.99	0.63	0
415	Manselo-Biblesprings complex 0 to 5 percent slopes	0.43	0.20	0
416	Manselo-Sevy loams 0 to 8 percent slopes	0.20	0.07	0
417	Medburn sandy loam 0 to 2 percent slopes	0.57	0.30	0
418	Medburn sandy loam 2 to 5 percent slopes	0.90	0.52	0
419	Medburn sandy loam saline-alkali 0 to 2 percent slopes	0.91	0.53	0
420	Melling very gravelly loam 8 to 25 percent slopes	0.24	0.12	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
421	Minu gravelly sandy loam 2 to 8 percent slopes	0.48	0.25	0
422	Monox gravelly sandy loam 2 to 8 percent slopes	0.19	0.07	0
423	Monroe loam 0 to 2 percent slopes	0.26	0.11	0
424	Monroe-Wales silt loams 0 to 2 percent slopes	0.18	0.07	0
425	Moondog cobbly loam 15 to 40 percent slopes	0.17	0.06	0
426	Moondog-Lorhunt-Rock outcrop complex 30 to 70 percent slopes	0.08	0.02	15
427	Mord gravelly loam 4 to 25 percent slopes	0.38	0.22	0
428	Mosida fine sandy loam 0 to 2 percent slopes	0.76	0.44	0
429	Motoqua-Rock outcrop complex 15 to 40 percent slopes	0.14	0.06	30
430	Muleypoint very cobbly loam 15 to 40 percent slopes	0.20	0.09	0
431	Musinia silty clay loam 0 to 2 percent slopes	0.13	0.05	0
432	Naplene loam 2 to 5 percent slopes	0.17	0.07	0
433	Ocambee extremely cobbly loam 25 to 40 percent slopes	0.14	0.06	0
434	Ocambee extremely gravelly loam 8 to 25 percent slopes	0.14	0.06	0
435	Onaqui-Tolman-Rock outcrop complex 15 to 50 percent slopes	0.24	0.11	15
436	Orcap very gravelly clay loam 15 to 50 percent slopes	0.12	0.05	0
437	Paragonah silty clay loam 0 to 2 percent slopes	0.06	0.01	0
438	Parowan silt loam 0 to 2 percent slopes	0.07	0.02	0
439	Pass Canyon extremely cobbly loam 15 to 40 percent slopes	0.14	0.06	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
440	Pass Canyon-Lucero complex 4 to 40 percent slopes	0.11	0.03	0
441	Pass Canyon-Red Butte-Rock outcrop association 15 to 40 percent slopes	0.16	0.07	20
442	Pass Canyon-Rock outcrop complex 25 to 60 percent slopes	0.16	0.07	25
443	Paunsaugunt extremely stony loam 25 to 60 percent slopes	0.20	0.10	0
444	Paunsaugunt-Kolob gravelly loams 10 to 40 percent slopes	0.13	0.06	0
445	Pavant cobbly loam 2 to 15 percent slopes	0.20	0.09	0
446	Pavant-Abela complex 2 to 25 percent slopes	0.27	0.13	0
447	Pavant-Lucero cobbly loams 2 to 25 percent slopes	0.20	0.09	0
448	Pits-Dumps complex	0.02	0.01	0
449	Playas	0.09	0.02	0
450	Plegomir gravelly sandy loam 2 to 15 percent slopes	0.49	0.26	0
451	Plegomir-Deerlodge gravelly sandy loams 2 to 8 percent slopes	0.27	0.11	0
452	Plegomir-Manselo complex 2 to 15 percent slopes	0.29	0.13	0
453	Plite sandy loam 2 to 8 percent slopes	0.77	0.46	0
454	Pyrat gravelly loam 2 to 15 percent slopes	0.34	0.16	0
455	Quichipa silty clay loam 0 to 2 percent slopes	0.07	0.02	0
456	Radec very cobbly loam 2 to 15 percent slopes	0.03	0.01	0
457	Radec-Bodacious complex 15 to 60 percent slopes	0.18	0.08	0
458	Radec-Checkett association 8 to 25 percent slopes	0.07	0.02	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
459	Radec-Rock outcrop complex 8 to 25 percent slopes	0.16	0.07	20
460	Red Butte extremely gravelly loam 15 to 40 percent slopes	0.14	0.06	0
461	Red Butte very gravelly loam 2 to 15 percent slopes	0.17	0.07	0
462	Repmis gravelly loam 2 to 15 percent slopes	0.21	0.09	0
463	Revor gravelly loam 2 to 8 percent slopes	0.21	0.09	0
464	Ripgut gravelly loam 2 to 8 percent slopes	0.17	0.06	0
465	Riverwash	2.00	1.56	0
466	Rob Roy extremely cobbly loam 15 to 50 percent slopes	0.16	0.07	0
467	Rock outcrop	0.31	0.16	85
468	Rustico silty clay loam 0 to 2 percent slopes	0.20	0.10	0
469	Rypod very gravelly loam 15 to 40 percent slopes	0.22	0.11	0
470	Sackett loam 2 to 8 percent slopes	0.18	0.07	0
471	Sanpete extremely cobbly loam 8 to 25 percent slopes	0.13	0.05	0
472	Saxby-Rock outcrop-Checkett complex 15 to 40 percent slopes	0.15	0.07	25
473	Seth loam 2 to 15 percent slopes	0.40	0.23	0
474	Seth stony loam 15 to 40 percent slopes	0.32	0.18	0
475	Sevy loam 2 to 8 percent slopes	0.08	0.02	0
476	Sevy sandy loam 0 to 2 percent slopes	0.57	0.30	0
477	Sevy sandy loam 2 to 8 percent slopes	0.55	0.29	0
478	Sevy-Ardnas complex 0 to 5 percent slopes	0.45	0.22	0
479	Sevy-Taylorsflat complex 2 to 8 percent slopes	0.21	0.07	0
480	Simper gravelly loam 2 to 15 percent slopes	0.21	0.09	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
481	Siroco cobbly loam 8 to 25 percent slopes	0.11	0.04	0
482	Skumpah silt loam 0 to 2 percent slopes	0.07	0.02	0
483	Soutin loam 2 to 5 percent slopes	0.17	0.07	0
484	Squawcave silt loam 2 to 15 percent slopes	0.15	0.05	0
485	Streuling-Fontreen very gravelly loams 15 to 50 percent slopes	0.17	0.08	0
486	Studhorse gravelly loam 2 to 8 percent slopes	0.21	0.09	0
487	Studhorse gravelly loam 2 to 15 percent slopes	0.21	0.09	0
488	Syrett-Mudcree complex 25 to 60 percent slopes	0.16	0.07	0
489	Taylorsflat loam 0 to 2 percent slopes	0.24	0.11	0
490	Taylorsflat loam 2 to 5 percent slopes	0.23	0.10	0
491	Taylorsflat loam saline 0 to 5 percent slopes	0.19	0.07	0
492	Taylorsflat-Escalante sandy loams 2 to 5 percent slopes	0.85	0.50	0
493	Tiki-Kinghorn-Rock outcrop complex 15 to 40 percent slopes	0.14	0.06	15
494	Tolman extremely cobbly loam 4 to 25 percent slopes	0.14	0.06	0
495	Tolman-Dalcan-Rock outcrop complex 25 to 60 percent slopes	0.25	0.13	15
496	Tolman-Rock outcrop complex 15 to 40 percent slopes	0.43	0.23	15
497	Tolman-Rock outcrop-Dalcan complex 15 to 50 percent slopes	0.14	0.06	30
498	Tolman-Waltershow-Rock outcrop complex 15 to 40 percent slopes	0.32	0.16	15
499	Tombar cobbly loam 2 to 15 percent slopes	0.21	0.09	0
500	Tombar extremely cobbly loam 15 to 40 percent slopes	0.14	0.06	0
501	Trag stony loam 15 to 60 percent slopes	0.32	0.17	0

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
502	Vennob-Bodacious-Rock outcrop association 15 to 50 percent slopes	0.05	0.02	15
503	Vennob-Rock outcrop complex 15 to 40 percent slopes	0.03	0.01	30
504	Wales loam 0 to 2 percent slopes	0.19	0.07	0
505	Wales loam 2 to 5 percent slopes	0.09	0.03	0
506	Wales loam flooded 0 to 2 percent slopes	0.19	0.07	0
507	Wales sandy loam 0 to 2 percent slopes	0.90	0.52	0
508	Wales silty clay loam 0 to 2 percent slopes	0.09	0.03	0
509	Wales very fine sandy loam 0 to 2 percent slopes	0.84	0.49	0
510	Welring-Menefee-Rock outcrop complex 40 to 80 percent slopes	0.19	0.08	15
511	Wenzel cobbly loam 15 to 40 percent slopes	0.30	0.16	0
512	Whiteman very cobbly very fine sandy loam 1 to 6 percent slopes	0.07	0.02	0
513	Winnemucca loam 2 to 15 percent slopes	0.45	0.27	0
514	Winnemucca-Hoodle association 5 to 30 percent slopes	0.33	0.16	0
515	Woodrow silty clay loam 0 to 2 percent slopes	0.09	0.03	0
516	Woodrow silty clay loam saline 0 to 2 percent slopes	0.07	0.02	0
517	Wye very gravelly loam 15 to 40 percent slopes	0.13	0.05	0
518	Water	0.01	0.01	100
1025	Aned-Newvil-Decan association	0.48	0.25	0
1201	Decan-Uana association	0.08	0.03	0
1290	Ravendog-Fanu-Fifteenmile association	0.33	0.14	0
1362	Deerlodge-Fanu-Newvil association	0.30	0.14	0
1364	Bamos-Pass Canyon-Rock outcrop association	0.06	0.02	15

Table D.22 UT634 Iron-Washington Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1378	Oxvalley-Denpark-Hamtah assocation	0.29	0.14	0
1828	Cedaran-Wakansapa-Turba association	0.17	0.07	0
1829	Wakansapa-Cedaran association	0.08	0.03	0
1886	Schoolmarm-Starflyer-Rock outcrop association	0.65	0.38	20
3892	Slockey-Hamtah-Schoolmarm association	0.21	0.10	0
4026	Schoolmarm-Hamtah-Rock outcrop association	0.31	0.15	15

D.3.17 UT636

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1	Ahlstrom-Osote complex 1 to 15 percent slopes	0.23	0.11	0
2	Alldown clay loam 1 to 2 percent slopes	0.08	0.02	0
3	Alldown clay loam 2 to 5 percent slopes	0.08	0.02	0
4	Alldown loam alkali 1 to 2 percent slopes	0.21	0.09	0
5	Alldown clay loam moist 2 to 5 percent slopes	0.09	0.03	0
6	Andys loam 2 to 15 percent slopes	0.21	0.09	0
7	Andys very cobbly loam 8 to 25 percent slopes	0.24	0.11	0
8	Badland-Cannonville-Rock outcrop complex 30 to 50 percent slopes	0.10	0.05	15
9	Badland-Rock outcrop-Paunsaugunt complex 2 to 20 percent slopes	0.20	0.09	30
10	Baldfield clay 2 to 4 percent slopes	0.02	0.01	0
11	Baldfield clay 2 to 8 percent slopes eroded	0.02	0.01	0
12	Barx fine sandy loam 2 to 10 percent slopes	0.62	0.34	0
13	Bayfield clay 2 to 8 percent slopes	0.03	0.01	0
14	Befar clay 4 to 8 percent slopes	0.03	0.01	0
15	Behanin loam 30 to 70 percent slopes	0.38	0.19	0
16	Blanchard family sand 30 to 70 percent slopes	1.64	1.53	5
17	Borollic Natrargids 0 to 1 percent slopes	0.06	0.01	0
18	Broncho very gravelly sandy loam 2 to 5 percent slopes	0.32	0.15	0
19	Bruman loam 2 to 5 percent slopes	0.30	0.13	0
20	Bruman gravelly loam 2 to 10 percent slopes	0.25	0.11	0
21	Bruman cobbly loam moist 10 to 30 percent slopes	0.28	0.13	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
22	Bruman cobbly loam moist 30 to 50 percent slopes	0.28	0.13	0
23	Bruman very cobbly loam 5 to 30 percent slopes	0.19	0.08	0
24	Bruman very cobbly loam 30 to 50 percent slopes	0.19	0.08	0
25	Brycan very fine sandy loam 1 to 6 percent slopes	0.97	0.60	0
26	Brycan very fine sandy loam 6 to 15 percent slopes	0.83	0.50	0
27	Bushvalley very stony loam 15 to 40 percent slopes	0.18	0.08	0
28	Callings-Winnemucca association 5 to 15 percent slopes	0.46	0.27	0
29	Cannonville clay 30 to 50 percent slopes	0.02	0.01	0
30	Cannonville very stony clay 30 to 50 percent slopes	0.02	0.01	0
31	Castino-Behanin association 20 to 70 percent slopes	0.36	0.20	5
32	Castino-Tica family complex 20 to 70 percent slopes	0.25	0.12	5
33	Castino-Winnemucca association 5 to 30 percent slopes	0.39	0.22	5
34	Circleville-Rock outcrop complex 25 to 60 percent slopes	0.07	0.02	35
35	Clapper cobbly loam 5 to 30 percent slopes	0.13	0.04	0
36	Clapper cobbly loam 30 to 60 percent slopes	0.13	0.05	0
37	Codley silt loam 1 to 2 percent slopes	0.08	0.02	0
38	Codley silt loam 2 to 5 percent slopes	0.09	0.02	0
39	Comodore-Rock outcrop complex 15 to 40 percent slopes	0.06	0.01	30

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
40	Crestline fine sandy loam 2 to 4 percent slopes	0.62	0.33	0
41	Dalcan very cobbly loam dry 4 to 25 percent slopes	0.13	0.05	0
42	Descot silt loam dry 1 to 2 percent slopes	0.18	0.06	0
43	Descot silt loam 2 to 5 percent slopes	0.17	0.06	0
44	Dimyaw family gravelly loam 4 to 25 percent slopes eroded	0.12	0.05	0
45	Echard loam 5 to 30 percent slopes	0.33	0.17	0
46	Ess-Callings association 15 to 45 percent slopes	0.57	0.33	0
47	Evanston loam 2 to 8 percent slopes	0.34	0.16	0
48	Evanston very cobbly loam 4 to 25 percent slopes	0.23	0.11	0
49	Frandsen loam dry 1 to 15 percent slopes	0.20	0.08	0
50	Frandsen-Neto association 1 to 8 percent slopes	0.23	0.09	0
51	Frandsen dry-Wiggler complex 15 to 50 percent slopes	0.15	0.06	0
52	Fughes silty clay loam 0 to 4 percent slopes	0.15	0.06	0
53	Gerst family-Rock outcrop complex 20 to 70 percent slopes	0.14	0.04	35
54	Greenhalgh silt loam 1 to 2 percent slopes	0.07	0.02	0
55	Greenhalgh silt loam 2 to 5 percent slopes	0.07	0.02	0
56	Grimm sandy loam 1 to 5 percent slopes	0.61	0.32	0
57	Guben gravelly loam dry 1 to 25 percent slopes	0.31	0.16	0
58	Guben-Showalter complex 2 to 30 percent slopes	0.27	0.13	0
59	Harol very cobbly loam 2 to 15 percent slopes	0.19	0.09	0
60	Harol very cobbly loam 15 to 40 percent slopes	0.18	0.08	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
61	Harol very cobbly loam moist 25 to 50 percent slopes	0.18	0.08	0
62	Hatch-Pahreah complex 5 to 25 percent slopes	0.09	0.03	0
63	Hatch-Swapps complex 5 to 25 percent slopes	0.09	0.03	0
64	Henrieville sandy loam 1 to 2 percent slopes	0.58	0.31	0
65	Henrieville sandy loam 2 to 5 percent slopes	0.58	0.31	0
66	Henrieville sandy loam 5 to 10 percent slopes	0.70	0.38	0
67	Henrieville sandy loam moist 2 to 8 percent slopes	0.49	0.26	0
68	Hernandez family-Clapper complex 2 to 8 percent slopes	0.15	0.05	0
69	Ipson cobbly loam 8 to 25 percent slopes	0.25	0.12	0
70	Ipson very cobbly loam 25 to 60 percent slopes	0.24	0.11	0
71	Ipson very stony loam dry 5 to 25 percent slopes	0.21	0.09	0
72	Jodero loam 1 to 2 percent slopes	0.25	0.12	0
73	Jodero loam moist 2 to 8 percent slopes	0.20	0.09	0
74	Kade silt loam 0 to 2 percent slopes	0.40	0.23	0
75	Lava flows	0.01	0.01	100
76	Lazear-Rock outcrop-Badland complex 8 to 20 percent slopes	0.44	0.23	25
77	Losee gravelly loam 3 to 15 percent slopes	0.36	0.18	0
78	Losee gravelly sandy loam dry 10 to 25 percent slopes	0.63	0.36	0
79	Losee very gravelly loam 30 to 60 percent slopes	0.29	0.13	5
80	Luhon loam 2 to 5 percent slopes	0.14	0.05	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
81	Luhon loam gravelly substratum 1 to 2 percent slopes	0.14	0.05	0
82	Luhon loam gravelly substratum 2 to 5 percent slopes	0.14	0.05	0
83	Luhon loam moist 3 to 15 percent slopes	0.14	0.05	0
84	Luhon very cobbly sandy loam 2 to 15 percent slopes	0.38	0.19	0
85	Mespun loamy fine sand 1 to 3 percent slopes	1.60	1.00	0
86	Mespun loamy fine sand 3 to 8 percent slopes	1.58	0.98	0
87	Mespun loamy fine sand 8 to 15 percent slopes	1.69	1.06	5
88	Mikim sandy loam 2 to 8 percent slopes	0.53	0.26	0
89	Mikim loam dry 1 to 2 percent slopes	0.13	0.04	0
90	Mikim loam 2 to 4 percent slopes	0.15	0.05	0
91	Mikim clay loam dry 1 to 2 percent slopes	0.08	0.03	0
92	Mikim clay loam dry 2 to 5 percent slopes	0.08	0.03	0
93	Mitch silt loam 0 to 3 percent slopes	0.27	0.13	0
94	Mitch-Riverwash association 0 to 3 percent slopes	0.61	0.36	0
95	Mivida fine sandy loam 2 to 10 percent slopes	0.69	0.38	0
96	Neto fine sandy loam 1 to 5 percent slopes	0.73	0.42	0
97	Neto very fine sandy loam wet 0 to 2 percent slopes	0.53	0.29	0
98	Notter loam 1 to 4 percent slopes	0.35	0.17	0
99	Notter loam moist 1 to 8 percent slopes	0.33	0.16	0
100	Notter loam thick surface 4 to 8 percent slopes	0.21	0.09	0
101	Notter gravelly coarse sandy loam 2 to 8 percent slopes	0.77	0.44	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
102	Notter gravelly loam 8 to 25 percent slopes	0.30	0.14	0
103	Notter very cobbly loam 4 to 25 percent slopes	0.24	0.11	0
104	Notter variant loam 1 to 4 percent slopes	0.21	0.09	0
105	Pahreah-Sheege complex 1 to 20 percent slopes	0.38	0.21	5
106	Pahreah-Sielo complex 2 to 25 percent slopes	0.28	0.14	0
107	Pahreah-Swapps complex 25 to 65 percent slopes	0.25	0.12	5
108	Panguitch-Mitch association 0 to 5 percent slopes	0.54	0.30	0
109	Panguitch-Riverwash association 5 to 15 percent slopes	0.48	0.27	0
110	Paunsaugunt gravelly loam 2 to 15 percent slopes	0.16	0.06	5
111	Paunsaugunt-Syrett gravelly loams 2 to 20 percent slopes	0.20	0.08	5
112	Playas	0.12	0.05	0
113	Plite sandy loam 2 to 8 percent slopes	0.59	0.32	0
114	Podo loamy sand 1 to 12 percent slopes	1.36	0.83	0
115	Podo-Wiggler complex 10 to 50 percent slopes	0.11	0.04	5
116	Podo-Rock outcrop complex 10 to 40 percent slopes	0.40	0.19	15
117	Quilt very cobbly loam 4 to 25 percent slopes	0.17	0.07	0
118	Quilt very cobbly loam 25 to 40 percent slopes	0.17	0.08	0
119	Redcreek gravelly sandy loam dry 10 to 40 percent slopes	0.32	0.15	0
120	Redcreek cobbly loam 15 to 50 percent slopes	0.13	0.05	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
121	Riverwash	1.62	1.21	0
122	Rock outcrop	0.01	0.01	100
124	Rubble land	0.01	0.01	100
126	Ruko-Podo complex 15 to 60 percent slopes	0.13	0.04	5
127	Schauson loam 2 to 4 percent slopes	0.45	0.25	0
128	Schauson loam 4 to 15 percent slopes	0.50	0.28	0
129	Sevier-Skutum association 5 to 35 percent slopes	0.89	0.56	5
130	Sheege-Swapps complex 30 to 50 percent slopes	0.18	0.08	5
131	Showalter-Guben complex dry 0 to 8 percent slopes	0.22	0.10	0
132	Shupert silty clay loam wet 0 to 1 percent slopes	0.11	0.04	0
133	Sielo very fine sandy loam 2 to 12 percent slopes	0.35	0.16	0
134	Skutum very fine sandy loam 1 to 6 percent slopes	0.73	0.43	0
135	Skutum fine sandy loam 10 to 35 percent slopes	0.84	0.52	5
136	Swapps gravelly loam 5 to 25 percent slopes	0.29	0.14	0
137	Swapps gravelly loam 25 to 65 percent slopes	0.22	0.10	0
138	Syrett gravelly loam 2 to 12 percent slopes	0.31	0.17	5
139	Syrett-Frandsen association 1 to 12 percent slopes	0.21	0.09	0
140	Syrett-Vanet gravelly loams 20 to 40 percent slopes	0.18	0.08	5
141	Tebbs sandy loam 2 to 5 percent slopes	0.73	0.39	0
142	Tebbs loam 1 to 2 percent slopes	0.17	0.06	0
143	Tebbs loam moist 1 to 2 percent slopes	0.15	0.05	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
144	Tolman very cobbly silt loam 8 to 35 percent slopes	0.11	0.03	1
145	Tolman-Rock outcrop complex 25 to 40 percent slopes	0.21	0.09	25
146	Tridell loam 2 to 4 percent slopes	0.35	0.17	0
147	Tridell gravelly loam moist 4 to 25 percent slopes	0.29	0.14	0
148	Tridell cobbly loam 4 to 25 percent slopes	0.35	0.17	0
149	Tridell moist-Rock outcrop complex 25 to 50 percent slopes	0.13	0.05	15
150	Ustic Torrifluvents occasionally flooded 2 to 8 percent slopes	0.68	0.36	0
151	Venture cobbly loam 4 to 30 percent slopes	0.23	0.10	0
152	Venture very cobbly silt loam 4 to 25 percent slopes	0.16	0.07	0
153	Venture cobbly loam dry 8 to 25 percent slopes	0.24	0.11	0
154	Villy family silty clay loam 0 to 2 percent slopes	0.24	0.12	0
155	Waltershow extremely cobbly loam 8 to 40 percent slopes	0.16	0.07	0
156	Waltershow extremely cobbly loam 40 to 60 percent slopes	0.16	0.07	0
157	Waltershow-Venture-Rock outcrop complex 4 to 40 percent slopes	0.17	0.07	15
158	Whiteman very cobbly very fine sandy loam 1 to 6 percent slopes	0.09	0.03	5
159	Whiteman-Skutum association 10 to 70 percent slopes	0.22	0.09	5
160	Widtsoe gravelly sandy loam 8 to 40 percent slopes	0.31	0.15	0
161	Wiggler channery loam 20 to 50 percent slopes	0.15	0.05	0

Table D.23 UT636 Panguitch Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
162	Wiggler-Guben complex 25 to 50 percent slopes	0.19	0.08	3
163	Wiggler-Rock outcrop-Podo complex 50 to 70 percent slopes	0.10	0.03	25
164	Winetti gravelly sandy loam 2 to 7 percent slopes	0.66	0.38	0
165	Winnemucca-Hoodle association 5 to 30 percent slopes	0.35	0.18	0
166	Yarts loam 1 to 2 percent slopes	0.38	0.18	0
167	Yarts sandy loam 2 to 5 percent slopes	0.54	0.28	0
168	Yarts sandy loam 5 to 10 percent slopes	0.54	0.28	0
169	Yenlo loam 2 to 8 percent slopes	0.09	0.02	0
170	Zillion very cobbly loam 5 to 25 percent slopes	0.20	0.09	0
171	Zinzer loam 3 to 15 percent slopes	0.21	0.09	0
172	Zyme very cobbly loam 30 to 60 percent slopes	0.02	0.01	0
173	Zyme-Lazear-Rock outcrop complex 8 to 60 percent slopes	0.07	0.04	15
174	Water	0.01	0.01	100
175	Pits gravel	2.00	1.93	0
176	Pits borrow	0.02	0.01	0
177	Miscellaneous water	0.01	0.01	100

D.3.18 UT641

Table D.24 UT641 Washington County Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
1898	Quazo-Motoqua very gravelly sandy loams 30 to 70 percent slopes	0.11	0.04	0
1922	Quazo-Motoqua-Rock outcrop association	0.12	0.04	20
BA	Badland	0.31	0.16	0
BB	Badland very steep	0.31	0.16	0
BED	Bermesa fine sandy loam 1 to 10 percent slopes	1.04	0.62	0
BF	Bermesa-Rock land association	1.65	1.06	20
BOD	Bond sandy loam 1 to 10 percent slopes	0.10	0.03	0
BP	Borrow pits	0.96	0.62	0
CaD	Caval fine sandy loam 2 to 10 percent slopes	0.81	0.46	0
CEF	Cave very gravelly sandy loam 7 to 30 percent slopes	0.37	0.19	0
CFD	Cave very gravelly sandy loam low rainfall 2 to 7 percent slopes	0.37	0.19	0
CHF	Chilton gravelly loam 5 to 30 percent slopes	0.27	0.12	0
CI	Cinder land	2.00	1.56	0
CoC	Clovis fine sandy loam 1 to 5 percent slopes	0.56	0.29	0
CPD	Clovis-Pastura complex 1 to 10 percent slopes	0.33	0.15	0
CRF	Collbran very cobbly clay loam 2 to 30 percent slopes	0.09	0.03	0
CSE	Curhollow very gravelly fine sandy loam 2 to 10 percent slopes	0.71	0.41	0
CUF	Curhollow-Rock outcrop complex 10 to 30 percent slopes	0.71	0.41	15
DAG	Dagflat-Motoqua complex 30 to 70 percent slopes	0.33	0.17	0
DBD	Dalcan cobbly loam 0 to 15 percent slopes	0.15	0.06	0

Table D.24 UT641 Washington County Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
DKG	Detra-Kolob complex 20 to 50 percent slopes	0.40	0.21	0
DrB	Draper loam 2 to 5 percent slopes	0.27	0.13	0
DU	Dune land	2.00	1.56	0
EA	Eroded land-Shalet complex	0.37	0.17	0
EB	Eroded land-Shalet complex warm	0.56	0.31	0
FA	Fluvaquents and torrifluvents sandy	2.00	1.81	0
GA	Gullied land	0.96	0.62	0
GP	Gravel pits	2.00	1.56	0
Ha	Hantz silty clay loam	0.06	0.01	0
HbC	Harrisburg fine sandy loam 1 to 5 percent slopes	1.17	0.69	0
HD	Harrisburg-Rock land association	1.17	0.69	15
HG	Hobog-Rock land association	0.19	0.08	40
IAF	Isom cobbly sandy loam 3 to 30 percent slopes	0.60	0.33	0
Ib	Ivins loamy fine sand	2.00	1.54	0
Ic	Ivins loamy fine sand hummocky	2.00	1.54	0
JaB	Junction fine sandy loam 1 to 2 percent slopes	1.10	0.65	0
JaC	Junction fine sandy loam 2 to 5 percent slopes	1.10	0.65	0
KAE	Kinesava fine sandy loam 15 to 25 percent slopes	0.87	0.51	0
KBD	Kinesava-Detra fine sandy loams 2 to 15 percent slopes	0.83	0.49	0
KCE	Kinesava complex 2 to 30 percent slopes	0.40	0.21	0
KD	Kolob-Detra association	0.67	0.38	0
KHC	Kolob-Hogg complex 2 to 8 percent slopes	0.60	0.34	0
KLG	Kolob-Paunsaugunt complex 20 to 60 percent slopes	0.40	0.22	0
LA	Lava flows	0.01	0.01	100
Lb	Lavate sandy loam	0.72	0.40	0

Table D.24 UT641 Washington County Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
LcB	Laverkin fine sandy loam 1 to 2 percent slopes	1.14	0.68	0
LcC	Laverkin fine sandy loam 2 to 5 percent slopes	1.13	0.67	0
LdB	Laverkin silty clay loam 1 to 2 percent slopes	0.06	0.01	0
LeA	Leeds silty clay loam 0 to 1 percent slopes	0.09	0.03	0
LeB	Leeds silty clay loam 1 to 2 percent slopes	0.09	0.03	0
LeD	Leeds silty clay loam 5 to 10 percent slopes	0.09	0.03	0
MAE	Magotsu-Pastura complex 2 to 20 percent slopes	0.08	0.02	0
MBG	Mathis-Rock outcrop complex 20 to 50 percent slopes	1.31	0.82	20
MEG	Menefee-Rock outcrop complex 25 to 60 percent slopes	0.09	0.02	25
MFD	Mespun fine sand 0 to 10 percent slopes	2.00	2.00	0
MMG	Motoqua-Mokiak very cobbly sandy loams 30 to 70 percent slopes	0.44	0.24	0
MOG	Motoqua-Rock outcrop complex 30 to 70 precent slopes	0.28	0.14	15
NaC	Naplene silt loam 2 to 6 percent slopes	0.10	0.03	0
NEF	Nehar very stony sandy loam 3 to 30 percent slopes	0.52	0.29	0
NIF	Nehar-Ildefonso complex 3 to 30 percent slopes	0.46	0.25	0
NkC	Nikey sandy loam 1 to 3 percent slopes	0.90	0.52	0
NLE	Nikey sandy loam 3 to 15 percent slopes	0.90	0.52	0
NME	Nikey very stony sandy loam 2 to 15 percent slopes	0.63	0.35	0
NNE	Nikey-Isom complex 3 to 30 percent slopes	0.78	0.45	0
PAC	Palma loamy fine sand 1 to 5 percent slopes	1.70	1.08	0

Table D.24 UT641 Washington County Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
PbC	Palma fine sandy loam 1 to 5 percent slopes	1.25	0.75	0
PcC	Pastura loam 2 to 5 percent slopes	0.11	0.04	0
PED	Pastura-Esplin complex 0 to 10 percent slopes	0.14	0.05	0
PFG	Paunsaugunt gravelly silt loam 30 to 50 percent slopes	0.27	0.14	0
PG	Paunsaugunt-Kolob association	0.33	0.18	0
PKE	Paunsaugunt-Rock outcrop complex 2 to 30 percent slopes	0.12	0.05	15
PnC	Pintura loamy fine sand 1 to 5 percent slopes	1.40	0.84	0
PoD	Pintura loamy fine sand hummocky 1 to 10 percent slopes	1.40	0.84	0
PTE	Pintura-Toquerville complex 1 to 20 percent slopes	1.64	1.24	0
QMG	Quazo-Motoqua very gravelly sandy loams 30 to 70 percent slopes	0.20	0.09	0
RaC	Redbank fine sandy loam 1 to 5 percent slopes	0.62	0.33	0
RbA	Redbank silty clay loam 0 to 2 percent slopes	0.06	0.01	0
RE	Renbac-Rock land association	0.01	0.01	25
RI	Riverwash	2.00	1.58	0
RO	Rock land	0.01	0.01	80
RP	Rock land stony	0.01	0.01	100
RR	Rock land-Hobog association	0.04	0.03	40
RT	Rock outcrop	0.01	0.01	100
RU	Rough broken land	0.01	0.01	100
Sa	St. George silt loam	0.16	0.06	0
Sb	St. George silt loam strongly saline	0.27	0.11	0
Sc	St. George silty clay loam	0.11	0.04	0

Table D.24 UT641 Washington County Area Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
Sd	St. George silty clay loam moderately saline	0.11	0.04	0
Se	St. George silty clay loam shallow water table	0.11	0.04	0
SH	Schmutz loam	0.23	0.09	0
SPD	Spenlo very fine sandy loam 2 to 10 percent slopes	1.07	0.64	0
SrC	Springerville clay 0 to 5 percent slopes	0.02	0.01	0
SY	Stony colluvial land	0.40	0.22	0
TAG	Tacan very stony sandy loam 30 to 70 percent slopes	0.75	0.46	0
TBF	Tobish very cobbly clay loam 5 to 30 percent slopes	0.04	0.01	0
Tc	Tobler fine sandy loam	0.61	0.32	0
Td	Tobler silty clay loam	0.06	0.01	0
TG	Tortugas-Rock land association	0.14	0.05	20
VeA	Vekol sandy loam 0 to 2 percent slopes	0.41	0.19	0
VFD	Vekol sandy loam 2 to 10 percent slopes	0.41	0.19	0
VHD	Veyo-Curhollow complex 3 to 10 percent slopes	0.13	0.05	0
VPD	Veyo-Pastura complex 1 to 10 percent slopes	0.06	0.02	0
W	Water	0.01	0.01	100
WAG	Welring-Tortugas very gravelly loams 20 to 70 percent slopes	0.15	0.06	0
WBD	Winkel gravelly fine sandy loam 1 to 8 percent slopes	0.91	0.53	0
WCF	Winkel-Rock outcrop complex 8 to 30 percent slopes	0.91	0.53	25
YAF	Yaki very cobbly loam 3 to 35 percent slopes	0.11	0.04	0
YZE	Yaki-Zukan complex 1 to 35 percent slopes	0.20	0.08	0

D.3.19 UT686

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5001	Mido loamy fine sand 2 to 15 percent slopes	2.00	1.44	0
5002	Dune land	2.00	2.00	0
5003	Milok cool-Barx dry complex 1 to 5 percent slopes	0.88	0.50	0
5004	Rock outcrop Navajo Sandstone	0.01	0.01	90
5006	Milok fine sandy loam cool 2 to 8 percent slopes	0.77	0.43	0
5007	Rock outcrop Navajo Sandstone-Nalcase complex 2 to 30 percent slopes	2.00	2.00	65
5008	Simel complex 2 to 60 percent slopes	0.06	0.02	0
5009	Wayneco sandy loam dry 2 to 15 percent slopes	1.07	0.64	0
5010	Retsabal-Lemrac complex 2 to 60 percent slopes	0.46	0.21	0
5011	Badland Carmel Formation-Rizno cool-Nonip complex 5 to 25 percent slopes	0.16	0.06	0
5012	Santrick-Nalcase-Bispen complex 2 to 30 percent slopes	1.85	1.42	0
5013	Mido-Yarts complex 2 to 15 percent slopes	1.83	1.57	0
5015	Mespun fine sand 2 to 15 percent slopes	2.00	2.00	0
5017	Skos dry-Mido-Arches dry complex 2 to 15 percent slopes	1.69	1.28	0
5018	Skos channery loam dry 5 to 30 percent slopes	0.09	0.03	0
5019	Skos dry Rock outcrop Carmel Formation-Arches dry complex 15 to 60 percent slopes	0.26	0.13	30
5020	Rock outcrop Navajo Sandstone-Mespun-Nalcase complex 2 to 30 percent slopes	2.00	1.71	40
5021	Milok-Anasazi complex cool 2 to 8 percent slopes	0.77	0.44	0

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5023	Tsaya channery loam 5 to 25 percent slopes	0.14	0.05	0
5025	Yarts sandy loam 2 to 8 percent slopes	0.53	0.27	0
5026	Rock outcrop Entrada and Carmel Formation	0.01	0.01	95
5027	Badland Tropic Formation Shale-Cannonville-Rock outcrop Dakota Formation complex 30 to 50 percent slopes	0.10	0.05	15
5028	Badland Entrada Formation	0.31	0.16	0
5029	Rock outcrop Straight Cliffs Formation-Atchee family steep-Chilton family complex 50 to 80 percent slopes	0.54	0.30	40
5030	Catahoula-Clapper dry complex 15 to 60 percent slopes	0.29	0.14	0
5031	Moclom-Rock outcrop Morrison Formation complex 2 to 15 percent slopes	2.00	1.80	30
5032	Remorris-Kenzo steep-Rock outcrop Morrison and Entrada Formations complex 30 to 60 percent slopes	0.16	0.07	25
5033	Yarts fine sandy loam 15 to 40 percent slopes eroded	0.81	0.46	0
5034	Nonip very channery loam 5 to 25 percent slopes	0.08	0.03	0
5035	Earlweed-Mido complex 2 to 30 percent slopes	2.00	1.81	0
5037	Barx fine sandy loam 2 to 10 percent slopes	0.64	0.35	0
5038	Mido-Rock outcrop Entrada Formation complex 5 to 40 percent slopes	2.00	2.00	20
5040	Sazi-Milok cool complex 2 to 30 percent slopes	0.71	0.40	0
5041	Seeg warm-Pagina complex 2 to 15 percent slopes	1.16	0.71	0

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5042	Moenkopie warm-Moepitz-Rock outcrop Carmel Formation complex 10 to 30 percent slopes	1.76	1.16	25
5043	Daklos steep-Rock outcrop Morrison Formation and Romana Mesa Sandstone complex 30 to 70 percent slopes	0.48	0.27	40
5044	Dient very stony loam 15 to 50 percent slopes	0.15	0.06	0
5046	Moffat-Sheppard-Nakai complex 2 to 30 percent slopes	1.16	0.68	0
5047	Moffat-Seeg warm-Mack moist complex 2 to 15 percent slopes	1.32	0.81	0
5049	Moffat-Mack moist complex 1 to 5 percent slopes	1.48	0.92	0
5050	Daklos-Arches dry complex 2 to 15 percent slopes	0.62	0.38	0
5052	Yarts-Suwanee complex 1 to 8 percent slopes	0.33	0.14	0
5053	Milok fine sand 2 to 8 percent slopes	2.00	1.47	0
5055	Mivida-Barx dry complex 1 to 8 percent slopes	0.71	0.39	0
5057	Arches dry-Mident-Yarts complex 2 to 40 percent slopes	1.89	1.54	0
5058	Earlweed-Mivida complex 2 to 20 percent slopes	1.16	0.69	0
5059	Mivida-Yarts moist complex 2 to 8 percent slopes	1.08	0.65	0
5060	Ranion-Suzipon-Rock outcrop Navajo Sandstone complex 2 to 30 percent slopes	1.96	1.46	20
5061	Rock outcrop Navajo Sandstone-Suzipon-Peekaboo complex 2 to 30 percent slopes	1.59	1.00	50
5062	Peekaboo-Spooky-Suzipon complex 2 to 15 percent slopes	1.96	1.42	0

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5063	Rock outcrop Navajo and Carmel Formations-Moenkopie warm-Needle complex 15 to 35 percent slopes	0.55	0.29	40
5065	Trail-Sheppard complex 2 to 10 percent slopes	1.82	1.38	0
5067	Ranion-Peekaboo complex 2 to 20 percent slopes	1.62	1.08	0
5068	Seeg warm-Moffat-Needle complex 2 to 25 percent slopes	1.97	1.33	0
5069	Rock outcrop Entrada Formation-Nepalto moist complex 2 to 8 percent slopes	1.01	0.60	60
5071	Somorent-Rock outcrop Morrison Formation complex 15 to 40 percent slopes	0.58	0.30	40
5073	Kenzo-Nalcase complex 2 to 15 percent slopes	1.64	1.16	0
5074	Evpark-Vessilla complex 2 to 15 percent slopes	0.89	0.52	0
5075	Shalona sandy loam 2 to 8 percent slopes	0.92	0.56	0
5076	Daklos-Catahoula complex 2 to 30 percent slopes	0.24	0.11	0
5077	Gompers family-Rock outcrop Straight Cliffs Formation-Sheecal family complex 50 to 80 percent slopes	0.27	0.13	30
5078	Arabrab-Vessilla-Colskel complex 2 to 15 percent slopes	0.47	0.23	0
5079	Colskel-Arabrab-Vessilla complex 15 to 50 percent slopes	0.34	0.17	0
5080	Moffat-Moepitz complex 2 to 25 percent slopes	0.61	0.32	0
5081	Badland and Rock outcrop Straight Cliffs and Wahweap Formations-Kydestea family complex 50 to 80 percent slopes	0.25	0.12	30
5082	Colskel-Menefee-Arabrab complex 2 to 15 percent slopes	0.24	0.10	0

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5083	Colskel-Menefee complex 15 to 50 percent slopes	0.15	0.06	0
5085	Hillburn very channery loam 10 to 70 percent slopes	0.09	0.03	0
5086	Mespun-Bispen-Santrick complex 2 to 15 percent slopes	2.00	2.00	0
5087	Kenzo steep-Rock outcrop (Kayenta Formation) complex 15 to 50 percent slopes	1.01	0.62	25
5088	Calcree-Bowington-Mespun complex 0 to 20 percent slopes	2.00	1.97	0
5089	Bowington-Mespun complex 0 to 15 percent slopes	2.00	2.00	0
5090	Baldfield clay saline 2 to 8 percent slopes	0.02	0.01	0
5091	Brumley fine sandy loam 2 to 8 percent slopes	0.93	0.56	0
5092	Rock outcrop Navajo Formation-Navigon complex 30 to 60 percent slopes	1.55	1.01	50
5093	Robay-Strell complex 5 to 30 percent slopes	1.98	1.52	0
5094	Aridic Ustorthents-Yatne complex 15 to 70 percent slopes	0.15	0.06	0
5095	Daklos-Hideout-Rock outcrop Straight Cliffs Formation complex 2 to 15 percent slopes	0.33	0.17	15
5096	Daklos steep-Rock outcrop Straight Cliffs Formation complex 15 to 50 percent slopes	0.25	0.12	15
5097	Skyvillage-Daklos saline-Rock outcrop Wahweap Formation complex 2 to 15 percent slopes	0.54	0.28	15
5098	Daklos saline-Skyvillage saline-Cannonville complex 15 to 50 percent slopes	0.35	0.20	0
5100	Rock outcrop Wingate Formation-Arches dry complex 2 to 10 percent slopes	0.62	0.33	75

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5101	Polychrome family-Badland Chinle Formation-Gaddes family complex 15 to 60 percent slopes	0.67	0.38	0
5102	Chinchin-Badland chinle Formation complex 25 to 50 percent slopes	0.20	0.09	0
5103	Barx-Remorris complex 5 to 45 percent slopes	0.50	0.24	0
5104	Rock outcrop Shinarump Conglomerate-Hideout complex 5 to 50 percent slopes	0.63	0.37	75
5105	Atchee-Lazear dry-Rock outcrop Shinarump Conglomerate complex 5 to 60 percent slopes	0.18	0.06	15
5106	Hillburn dry-Badland Moenkopi Formation complex 25 to 60 percent slopes	0.12	0.04	0
5107	Simel-Hillburn dry complex 5 to 45 percent slopes	0.07	0.02	0
5108	Hillburn dry-Rock outcrop Moenkopi Formation complex 10 to 60 percent slopes	0.05	0.01	25
5109	Nonip dry-Rock outcrop Moenkopi Formation complex 15 to 50 percent slopes	0.13	0.05	20
5110	Reef very channery sandy loam 5 to 25 percent slopes	0.17	0.07	0
5111	Nonip extremely channery sandy loam dry 5 to 50 percent slopes	0.06	0.01	0
5112	Barx-Radnik moist-Progresso dry complex 2 to 8 percent slopes	0.81	0.46	0
5114	Meriwhitica moist-Mellenthin complex 5 to 15 percent slopes	0.13	0.05	0
5115	Sanostee warm-Daklos-Hideout complex 2 to 15 percent slopes	0.61	0.33	0
5116	Stent-Minchey complex 2 to 15 percent slopes	0.41	0.20	0

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5117	Sheppard-Badland Carmel and Entrada Formations complex 5 to 30 percent slopes	0.95	0.56	0
5118	Mido-Kenzo-Rock outcrop Carmel Formation complex 2 to 30 percent slopes	0.83	0.46	15
5120	Pinepoint-Flatnose complex 2 to 8 percent slopes	1.87	1.35	0
5121	Trail-Riverwash complex 0 to 5 percent slopes	1.95	1.34	0
5122	Mido-Mivida complex 2 to 15 percent slopes	1.79	1.53	0
5123	Billings-Jocity saline complex 0 to 8 percent slopes	0.10	0.03	0
5125	Clapper very gravelly loam 2 to 15 percent slopes	0.13	0.05	0
5126	Pinepoint-Parkwash complex 2 to 15 percent slopes	2.00	1.61	0
5127	Skyvillage-Mikim-Badland Kaiparowits Formation complex 2 to 15 percent slopes	0.77	0.41	0
5128	Curecanti-Zibetod families complex 30 to 70 percent slopes	0.23	0.10	0
5129	Skyvillage-Rock outcrop Wahweap Formation complex 2 to 15 percent slopes	1.04	0.60	35
5130	Progresso-Begay dry complex 1 to 8 percent slopes	0.29	0.12	0
5131	Badland Kaiparowits Formation-Lazear steep complex 15 to 60 percent slopes	0.48	0.22	0
5132	Strych-Horsemountain-Barx complex 2 to 15 percent slopes	0.55	0.29	0
5133	Menefee-Badland Kaiparowits Formation complex 5 to 30 percent slopes	0.48	0.24	0
5136	Suzmayne-Colskel-Rock outcrop Straight Cliffs Formation complex 10 to 40 percent slopes	0.15	0.05	15

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5137	Casmos-Pariette families-Rock outcrop Dakota and Morrison Formation complex 2 to 30 percent slopes	0.28	0.12	15
5138	Nakai-Sheppard complex 2 to 15 percent slopes	2.00	1.98	0
5139	Hetz sandy loam 0 to 3 percent slopes	0.91	0.58	0
5140	Green River-Radnik moist-Suwanee saline complex 0 to 5 percent slopes	0.44	0.21	0
5141	Radnik moist-Suwanee saline-Escavada complex 0 to 8 percent slopes	0.65	0.38	0
5142	Alvey-Atrac complex 1 to 15 percent slopes	0.29	0.13	0
5143	Elias-Mikim complex 1 to 7 percent slopes	0.21	0.09	0
5144	Tsaya-Rock outcrop Straight Cliffs Formation complex 10 to 60 percent slopes	0.08	0.02	25
5146	Moffat-Pagina-Sheppard complex 2 to 20 percent slopes	1.47	0.93	0
5149	Tsaya saline-Rock outcrop Straight Cliffs Formation-Lithic Torriorthents complex 50 to 80 percent slopes	0.07	0.02	30
5150	Chipeta-Hanksville-Badland Tropic Shale complex 2 to 30 percent slopes	0.07	0.02	0
5151	Pinepoint dry-Tenneycanyon-Parkwash complex 2 to 25 percent slopes	1.86	1.42	0
5154	Dient-Crotoncanyon complex 15 to 50 percent slopes	0.11	0.04	0
5155	Sanostee warm-Milok-Lazear warm complex 2 to 15 percent slopes	1.17	0.75	0
5156	Daklos steep-Fourmilebench complex 15 to 50 percent slopes	0.10	0.04	0
5157	Daklos family-Rock outcrop Wahweap Formation complex 50 to 80 percent slopes	0.15	0.06	35

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5158	Mellenthin moist-Rock outcrop Moenkopi Formation complex 25 to 60 percent slopes	0.16	0.07	40
5159	Mellenthin moist-Bowdish complex 2 to 30 percent slopes	0.15	0.06	0
5160	Timpoweap-Evpark-Atarque complex 2 to 15 percent slopes	0.58	0.31	0
5163	Horsemountain fine sandy loam moist 2 to 8 percent slopes	0.53	0.27	0
5164	Badland Chinle Formation	0.31	0.16	0
5166	Hillburn dry-Sazi moist complex 2 to 30 percent slopes	0.34	0.16	0
5167	Progresso cool-Atchee family complex 2 to 15 percent slopes	0.34	0.16	0
5169	Lazear steep-Simel-Rock outcrop Carmel Formation complex 20 to 60 percent slopes	0.20	0.09	20
5170	Lemrac-Simel-Humbug moist complex 2 to 20 percent slopes	0.22	0.09	0
5171	Kenzo-Retsabal-Progresso cool complex 2 to 30 percent slopes	0.22	0.09	0
5172	Ruinpoint-Barx complex 2 to 8 percent slopes	0.11	0.04	0
5173	Simel-Strych moist-Kenzo complex 2 to 20 percent slopes	0.15	0.05	0
5174	Strych-Sazi moist complex 15 to 50 percent slopes	0.55	0.30	0
5180	Pinepoint-Rock outcrop Navajo Sandstone-Parkwash complex 15 to 50 percent slopes	1.86	1.36	30
5181	Parkelei-Plumasano moist-Pinepoint complex 2 to 15 percent slopes	1.27	0.80	0
5182	Arabrab-Colskel-Rock outcrop Carmel Formation complex 15 to 50 percent slopes	0.73	0.42	20

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5183	Parkwash-Rock outcrop Navajo Sandstone-Vessilla complex 30 to 65 percent slopes	0.68	0.38	30
5185	Nomrah-Upler complex 2 to 15 percent slopes	0.42	0.22	0
5186	Bodot cool-Sili complex 2 to 8 percent slopes	0.05	0.01	0
5187	Zigzag-Aridic Ustorthents complex 15 to 70 percent slopes	0.11	0.04	0
5188	Frandsen loam 1 to 15 percent slopes	0.28	0.13	0
5189	Widtsoe-Emlin complex 5 to 25 percent slopes	0.37	0.18	0
5190	Podo-Rock outcrop Straight Cliffs and Wahweap Formations complex 15 to 50 percent slopes	0.79	0.44	40
5191	Ruko-Rock outcrop Straight Cliffs and Wahweap Formations-Podo complex 30 to 70 percent slopes	0.12	0.04	30
5192	Gerst family-Cannonville-Rock outcropStraight Cliffs and Dakota Formation complex 20 to 50 percent slopes	0.08	0.03	15
5193	Badland Kaiparowits Formation	1.01	0.58	0
5195	Henrieville sandy loam 2 to 8 percent slopes	1.00	0.61	0
5198	Bigpack clay loam 1 to 8 percent slopes	0.10	0.03	0
5199	Quagmeier-Parkelei complex 2 to 30 percent slopes	0.52	0.29	0
5200	Sojourn family-Retsabal-Colskel complex 10 to 50 percent slopes	0.38	0.20	0
5201	Sojourn family-Aridic Ustorthents complex 15 to 50 percent slopes	1.21	0.75	0
5203	Wiggler-Curecanti family cool complex 25 to 65 percent slopes	0.13	0.05	0

Table D.25 UT686 Grand Staircase-Escalante National Monument Utah

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
5205	Curecanti families cool-Widtsoe complex 2 to 25 percent slopes	0.17	0.07	0
5206	Upler cobbly loam 5 to 50 percent slopes	0.23	0.11	0
5207	Winetti-Riverwash complex 2 to 5 percent slopes	0.48	0.27	0
5210	Elpedro moist-Flatnose complex 2 to 8 percent slopes	0.51	0.27	0
5211	Yarts moist-Sazi moist complex 2 to 8 percent slopes	0.81	0.46	0

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D.3.20 UTAH GENERAL SOIL SURVEY

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s1159	Youngston-Willwood-Tipperary-Clapper-Chroder (s1159)	0.58	0.30	0
s1160	Winona-Travessilla-Schooner-Rock outcrop-Rentsac-Duffymont-Crago (s1160)	0.42	0.21	30
s1161	Zillion-Layoint-Forelle-Emlin-Cathedral (s1161)	0.36	0.18	0
s1185	Rock outcrop-Rentsac-Moyerson-Mikim family-Atchee (s1185)	0.19	0.09	10
s1186	Wallson-Walknolls-Turley-Potts-Penistaja family-Abra (s1186)	0.49	0.24	0
s1199	Ustollic Haplargids-Ustollic Calciorthids-Ustic Torriorthents-Rock outcrop (s1199)	0.53	0.29	30
s1210	Potts-Palma-Kech-Hagerman-Cahona-Begay (s1210)	0.62	0.33	5
s1232	Zyme-Torriorthents-Rock outcrop (s1232)	0.04	0.01	35
s1417	Youngston-Torrifluvents (s1417)	0.19	0.07	0
s1420	Rock outcrop-Redlands-Myton family-Moenkopie-Mack-Farb-Badland (s1420)	0.34	0.16	15
s1422	Uzona-Rock outcrop-Myton family-Claysprings (s1422)	0.04	0.01	10
s1424	Romberg-Rock outcrop-Rizno-Littlenan-Cragola-Bodot (s1424)	0.06	0.02	15
s1435	Rock outcrop-Rizno-Mido-Ignacio-Begay (s1435)	0.24	0.10	25
s1436	Strych-Redbank-Moab-Begay (s1436)	0.61	0.34	0
s1437	Witt-Northdale-Monticello-Chaseville-Bond (s1437)	0.39	0.19	0
s1778	Richville-Leavitt-Dagan-Cokeville-Boundridge variant (s1778)	0.26	0.12	0
s1791	Windernot-Preston-Kidman (s1791)	0.57	0.32	5
s1811	Manila-Lonigan-Copenhagen-Broadhead (s1811)	0.28	0.14	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s1815	Parleys-Logan-Langless-Lagonot-Hans-Fridlo (s1815)	0.29	0.14	0
s1826	Ridgecrest-Hondoho (s1826)	0.32	0.16	0
s1834	Strevell-Stanrod-Mellor-Idahome-Declo-Darkbull (s1834)	0.26	0.11	0
s1836	Declo-Darkbull (s1836)	0.31	0.14	0
s1844	Rock outcrop-Ola-Itca-Birchcreek-Arbone (s1844)	0.38	0.19	16
s1846	Coalbank-Chen-Bluehill (s1846)	0.91	0.55	0
s1975	Wilsongulch-Tomsherry-Cottonthomas-Coalbank-Bluehill (s1975)	0.76	0.44	0
s2168	Nielsen-Dranyon-Dra (s2168)	0.26	0.13	0
s2179	Sprollow-Cooley variant-Bezzant (s2179)	0.28	0.13	0
s2180	Zeale-Geneva-Dateman-Aspen (s2180)	0.38	0.20	0
s342	Rock outcrop-Moenkopie (s342)	0.70	0.38	50
s343	Nakai-Monue-Blackston (s343)	1.28	0.76	0
s351	Wayneco-Sazi-Rock outcrop-Rizno-Palma-Mespun (s351)	0.98	0.58	10
s359	Spenlo-Schmutz-Redbank family-Palma family-Naplene-Lavate-Ildefonso family-Clovis family-Caval (s359)	0.47	0.23	0
s362	Rock outcrop (s362)	0.37	0.16	83
s392	Sogzie-Sheppard-Rock outcrop-Aneth (s392)	1.36	0.93	10
s393	Shedado-Rock outcrop-Mespun-Begay-Anasazi (s393)	1.16	0.71	15
s394	Ustollic Haplargids-Rock outcrop-Namon (s394)	0.56	0.33	30
s398	Sheppard-Rock outcrop-Monue-Moepitz (s398)	1.50	1.06	10
s5228	Tocito-Mesa-Cudei-Badland (s5228)	0.20	0.08	7
s5229	Persayo-Nataani-Littlehat-Awet (s5229)	0.19	0.06	2
s5453	Zadvar-Sanpete-Breko (s5453)	0.41	0.21	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s5484	Paranat-Equis-Duffer (s5484)	0.10	0.04	0
s5563	Segura-Rock outcrop-Itca family-Cropper (s5563)	0.15	0.06	10
s5571	Tarnach-Cliffdown (s5571)	0.15	0.06	0
s5577	Cave family-Cave-Ajo (s5577)	0.21	0.09	0
s5598	Pioche-Motoqua-Gabbvally (s5598)	0.11	0.04	1
s5742	Typic Torriorthents-Gypill-Cave-Badland (s5742)	0.43	0.22	5
s5878	Rock outcrop-Podmor family-Logring-Kyler-Flygare family-Eaglepass (s5878)	0.30	0.15	10
s7755	Waas-Tomasaki-Nortez-Herm-Fivepine-Falcon (s7755)	0.27	0.13	5
s7756	Thedalund family-Shalako-Rock outcrop-Killpack-Hanksville family (s7756)	0.10	0.03	10
s7757	Toddler family-Redbank family-Ravola family-Leeko (s7757)	0.09	0.02	0
s7758	Shalako-Rock outcrop-Reva family-Falcon family-Dast family (s7758)	0.46	0.23	20
s7759	Utso-Tosca-Sula family-Seeprid-Reva family-Razorba family (s7759)	0.53	0.30	5
s7760	Walknolls-Rock outcrop-Potts-Gaynor-Badland (s7760)	0.18	0.08	15
s7761	Uffens-Mikim family-Clapper (s7761)	0.16	0.06	0
s7762	Yamac-Stunner-Poposhia-McFadden-Luhon-Grieves (s7762)	0.24	0.10	0
s7763	Dahlquist variant-Dahlquist-Brownsto variant-Brownsto (s7763)	0.53	0.29	0
s7764	Thermopolis-Sinkson-Rock outcrop-Delphill-Blazon (s7764)	0.16	0.06	10
s7765	Morset-McFadden-Luhon-Fluetsch (s7765)	0.30	0.13	0
s7766	Uinta-Lail-Gelkie-Barrett-Amsden (s7766)	0.34	0.16	3
s7767	Turner-Fluetsch (s7767)	0.45	0.25	0
s7768	Strych-Sandoval-Persayo-Fruita-Barx-Avalon (s7768)	0.20	0.08	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7769	Witt-Sharps-Ruinpoint-Rizno-Cahona (s7769)	0.18	0.07	0
s7770	Sheppard-Rock outcrop-Oljeto-Neskahi-Mota (s7770)	1.58	1.03	10
s7771	Rock outcrop-Piute-Moenkopie-Hoskinnini (s7771)	0.40	0.19	20
s7772	Whit-Sogzie-Sheppard-Rock outcrop (s7772)	0.49	0.26	10
s7773	Rock outcrop-Piute-Pickrell-Badland (s7773)	1.42	0.91	15
s7774	Rock outcrop-Lithic Torriorthents-Badland (s7774)	0.28	0.13	50
s7775	Skumpah-Playas (s7775)	0.08	0.03	0
s7776	Rock outcrop-Promo-Cliffdown (s7776)	0.29	0.14	15
s7777	Lembos-Kunzler-Kawich-Acana (s7777)	0.38	0.19	0
s7778	Tosser-Sitar-Hiko Peak-Bezzant (s7778)	0.29	0.13	0
s7779	Kapod-Fontreen-Donnardo-Collard (s7779)	0.26	0.12	0
s7780	Raftriver-Dahar-Codquin-Bullump (s7780)	0.49	0.27	0
s7781	Rock outcrop-Rexmont-Clavicon (s7781)	0.27	0.14	27
s7782	Tarnach-Cliffdown (s7782)	0.15	0.06	0
s7783	Ridgecrest family-Parkay family-Eyre family-Broad Canyon family-Bickmore family (s7783)	0.79	0.55	0
s7784	Ridgecrest family-Parkay family-Broad Canyon family-Bickmore family (s7784)	0.70	0.47	0
s7785	Sterling-Sheep Creek-Richmond-Foxol-Elzinga-Agassiz (s7785)	0.26	0.13	5
s7786	Middle-Broad (s7786)	0.34	0.19	0
s7787	Sterling-Samaria (s7787)	0.36	0.18	0
s7788	Timpanogos-Parleys-Kearns-Fielding (s7788)	0.20	0.09	0
s7789	Thiokol-Stingal-Sanpete-Hansel (s7789)	0.25	0.11	0
s7790	Kilburn-Kidman-Fielding (s7790)	0.36	0.18	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7791	Thiokol-Mellor-Heydlauff-Bram (s7791)	0.15	0.06	0
s7792	Roshe Springs-Logan-Kirkham-Honeyville-Greenson-Collett (s7792)	0.21	0.10	0
s7793	Stokes-Placeritos-Lasil-Fridlo-Airport (s7793)	0.19	0.08	0
s7794	Rock outcrop-Ridd-Barton (s7794)	0.55	0.31	25
s7795	Pleasant View-Kilburn-Francis (s7795)	0.65	0.38	0
s7796	Preston-Kidman-Francis (s7796)	1.79	1.53	0
s7797	Timpanogos-Parleys-Kidman (s7797)	0.37	0.17	0
s7798	Layton-Kidman (s7798)	1.10	0.69	0
s7799	Sunset-Steed-Refuge-Martini-Kirkham (s7799)	0.40	0.21	0
s7800	Logan-Leland-Ironton-Harrisville-Draper (s7800)	0.41	0.23	0
s7801	Warm Springs-Syracuse-Layton (s7801)	0.90	0.52	0
s7802	Warm Springs-Syracuse-Payson-Leland (s7802)	0.33	0.15	0
s7803	Salt Lake-Logan-Cardon-Airport (s7803)	0.22	0.11	0
s7804	Trenton-Jordan-Cache (s7804)	0.12	0.04	0
s7805	Roshe Springs-Nibley-Millville-Greenson-Collett (s7805)	0.22	0.10	0
s7806	Quinney-Lewiston-Layton-Kidman (s7806)	0.78	0.44	0
s7807	Wheelon-Mendon-Curtis Creek (s7807)	0.25	0.12	0
s7808	Wheelon-Parleys-Collinston (s7808)	0.14	0.05	0
s7809	Timpanogos-Sterling-Ricks-Parleys-Nibley-McMurdie (s7809)	0.28	0.13	0
s7810	Sterling-Nebeker-Hendricks-Crowshaw (s7810)	0.41	0.23	0
s7811	Yeates Hollow-Obray-LaPlatta-Goring-Ant Flat (s7811)	0.19	0.09	0
s7812	Sheep Creek-Hoskin-Curtis Creek-Agassiz (s7812)	0.25	0.12	0

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Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7813	Dateman-Bradshaw-Bickmore-Agassiz (s7813)	0.21	0.10	5
s7814	Poleline-Lucky Star-Cluff-Bickmore (s7814)	0.51	0.32	0
s7815	Wader variant-Wader-Saleratus-Bear Lake (s7815)	0.31	0.16	0
s7816	Saleratus-Rich-Cowco (s7816)	0.14	0.06	0
s7817	Cowco-Bockston (s7817)	0.34	0.17	0
s7818	Woodpass-Wiscow-Poposhia-Pancheri-Lariat-Alhark (s7818)	0.17	0.06	0
s7819	Slinger-Duckree (s7819)	0.38	0.21	0
s7820	Thatcher-Richsum-Kearl-Econ (s7820)	0.20	0.08	0
s7821	Jebo-Dennot-Cutoff (s7821)	0.39	0.21	0
s7822	Solak-Rexmont-Highams variant-Gridge-Falula-Ellett (s7822)	0.24	0.11	0
s7823	Yeljack-Lucky Star-Charcol-Baird Hollow (s7823)	0.53	0.32	0
s7824	Sambrito-Lucky Star-Condie (s7824)	0.55	0.33	0
s7825	Utaba-Sunset-Steed-Redola-Pringle-Eastcan-Crooked Creek-Brownlee (s7825)	0.39	0.21	0
s7826	Stoda-Parleys-Nebeker-Manila-Lamondi (s7826)	0.29	0.14	0
s7827	Ostler-Manila-Hawkins-Donner-Bertag (s7827)	0.24	0.12	0
s7828	Yeates Hollow-Durfee (s7828)	0.24	0.12	0
s7829	Wallsburg-Van Wagoner-Rock outcrop-Harkers (s7829)	0.36	0.19	30
s7830	Kilfoil-Isbell-Hades-Croydon (s7830)	0.28	0.14	0
s7831	Yeates Hollow-Guilder-Etchen-Bullnel (s7831)	0.25	0.13	0
s7832	Smarts-Rock outcrop-Horrocks-Durst-Burgi (s7832)	0.30	0.15	10
s7833	Yeates Hollow-St marys-Moweba-Hoskin-Holmes (s7833)	0.22	0.11	0

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Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7834	Sessions-Poleline-Patio (s7834)	0.28	0.15	0
s7835	Lucky Star-Charcol (s7835)	0.54	0.33	0
s7836	Rock outcrop-Geertson-Cristo-Broad Canyon (s7836)	0.27	0.13	10
s7837	Yence-Richens-Lucky Star-Herd-Ercan (s7837)	0.24	0.12	0
s7838	Rock outcrop-Patio-Nagisty-Broad Canyon (s7838)	0.28	0.15	25
s7839	Timpanogos-Parleys-Kearns-Fielding (s7839)	0.20	0.09	0
s7840	Picayune family-Lucky Star-Hades-Ant Flat (s7840)	0.37	0.20	0
s7841	Tooele-Timpie-Cliffdown (s7841)	0.33	0.15	0
s7842	Yenrab-Skumpah-Dynal (s7842)	0.22	0.09	0
s7843	Kapod-Donnardo-Borvant-Abela (s7843)	0.30	0.15	0
s7844	Taylorsflat-Medburn-Hiko Peak-Berent (s7844)	0.37	0.17	0
s7845	Skumpah-Saltair-Logan-Kanosh-Bramwell (s7845)	0.19	0.08	0
s7846	Timpanogos-Parleys-Bluffdale-Bingham (s7846)	0.19	0.08	0
s7847	Wallsburg-Rock outcrop-Harkers-Broad-Agassiz (s7847)	0.30	0.16	15
s7848	Wallsburg-Rock outcrop-Horrocks-Butterfield-Agassiz (s7848)	0.22	0.11	10
s7849	Rock outcrop-Henefer-Harkers-Gappmayer (s7849)	0.30	0.15	10
s7850	Wasatch-Ridd-Kilburn (s7850)	0.62	0.36	7
s7851	Woodrow-Mellor-Harding-Genola-Cheebe (s7851)	0.09	0.03	0
s7852	Terminal-Saltair-Lasil-Decker-Bramwell variant (s7852)	0.22	0.09	0
s7853	Taylorsville-Hillfield-Harrisville-Bramwell-Bluffdale (s7853)	0.16	0.06	0

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Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7854	Wagonbox-Magna-Ironton-Decker-Bramwell (s7854)	0.25	0.12	0
s7855	Welby-Parleys-Kidman (s7855)	0.33	0.15	0
s7856	Wasatch-Knutsen-Kearns-Bingham (s7856)	0.83	0.49	0
s7857	Rock outcrop-Picayune-Emigration-Deer Creek-Brad-Agassiz (s7857)	0.26	0.13	20
s7858	Provo Bay-McBeth-Holdaway-Chipman (s7858)	0.22	0.11	0
s7859	Typic Fluvaquents-Payson-Logan-Jordan-Arave (s7859)	0.20	0.09	0
s7860	Welby-Vineyard-Taylorsville-Bramwell (s7860)	0.18	0.07	0
s7861	Sunset-Pleasant Vale-Martini-Kirkham-Benjamin (s7861)	0.36	0.19	0
s7862	Steed-Redola-Provo-Pleasant View-Pleasant Vale-Keigley (s7862)	0.53	0.30	0
s7863	Kirkham-Benjamin (s7863)	0.11	0.04	0
s7864	Pleasant Grove-Kilburn-Cleverly (s7864)	0.60	0.37	0
s7865	Preston-Layton-Lakewin (s7865)	0.97	0.60	0
s7866	Welby-Taylorsville-Hillfield (s7866)	0.21	0.09	0
s7867	Rake-Picayune variant-Picayune (s7867)	0.19	0.09	5
s7868	Towave-Podo-Minnimaud-Cabba family (s7868)	0.20	0.09	5
s7869	Uinta family-Trag-Senchert family-Senchert-Midfork family-Croydon (s7869)	0.56	0.35	0
s7870	Walknolls-Casmos-Badland (s7870)	0.14	0.06	5
s7871	Pathead-Guben-Curecanti family (s7871)	0.35	0.18	0
s7872	Trag-Senchert-Midfork family-Falcon-Beje (s7872)	0.33	0.17	0
s7873	Nelman-Lanver-Atchee (s7873)	0.37	0.19	5
s7874	Rock outcrop-Mikim family-Atchee (s7874)	0.24	0.11	10

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SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7875	Winteridge-Towave-Castner-Atchee (s7875)	0.17	0.07	4
s7876	Whetrock-Towave-Rock outcrop-Pathead-Castner-Atchee (s7876)	0.23	0.11	10
s7877	Walknolls family-Thedalund family-Pennell (s7877)	0.20	0.08	0
s7878	Thedalund family-Dast family (s7878)	0.16	0.06	5
s7879	Travessilla family-Travessilla-Rock outcrop-Gerst (s7879)	0.29	0.13	25
s7880	Walknolls-Rock outcrop-Casmos-Atchee (s7880)	0.17	0.06	10
s7881	Tipperary-Denco-Badland (s7881)	0.30	0.13	7
s7882	Yeates Hollow-Obrast-Deer Creek-Bagard (s7882)	0.15	0.06	0
s7883	Towave-Tosca-Sheepcan-Badland-Atchee (s7883)	0.20	0.08	5
s7884	Roundy-Fitzgerald-Daybell (s7884)	0.29	0.15	3
s7885	Flygare-Clayburn-Baird Hollow (s7885)	0.54	0.33	0
s7886	Yeates Hollow-Lucky Star-Hoskin-Horrocks-Gappmayer-Cloud Rim-Bradshaw-Ant Flat (s7886)	0.30	0.16	5
s7887	Trag-Skutum family-Kovich-Coberly variant (s7887)	0.27	0.13	0
s7888	Zillion family-Luhon family-Blazon-Abra family (s7888)	0.22	0.09	3
s7889	Zillion family-Uinta-Senchert-Geertson-Croydon (s7889)	0.40	0.22	4
s7890	Little Pole-Broadhead-Ayoub (s7890)	0.21	0.10	5
s7891	Poleline-Hailman-Fitzgerald (s7891)	0.40	0.22	3
s7892	Yeates Hollow-Wallsburg-Manila-Henefer-Gappmayer (s7892)	0.29	0.15	3
s7893	Van Wagoner-Rock outcrop-McPhie-Cloud Rim (s7893)	0.44	0.24	13

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SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7894	Yeates Hollow-Watkins Ridge-Deer Creek-Clegg (s7894)	0.27	0.14	5
s7895	Rasband-Kovich-Holmes-Center Creek (s7895)	0.39	0.20	0
s7896	Kovich variant-Kovich-Fluventic Haploborolls-Cudahy-Crooked Creek (s7896)	0.40	0.23	5
s7897	Moweba-Manila-Kovich (s7897)	0.42	0.24	0
s7898	Watkins Ridge-Sowcan-Pringle-Kovich-Irim family-Ant Flat (s7898)	0.64	0.41	0
s7899	Richsum-Cutoff family-Ayoub (s7899)	0.19	0.08	3
s7900	Starley-Rock outcrop-Poleline (s7900)	0.29	0.15	35
s7901	Tipperary-Nakoy-Hiko Springs-Fruitland (s7901)	0.81	0.43	0
s7902	Turzo-Poganeab-Green River (s7902)	0.16	0.05	1
s7903	Travessilla family-Rock outcrop-Montwel-Begay (s7903)	0.37	0.17	10
s7904	Winona-Rock outcrop-Honlu-Clapper (s7904)	0.21	0.09	10
s7905	Travessilla family-Strell-Rock outcrop-Reepo (s7905)	1.10	0.77	30
s7906	Tyzak-Tridell-Atchee (s7906)	0.20	0.08	5
s7907	Tipperary-Nakoy-Montwel-Mivida (s7907)	0.54	0.25	3
s7908	Worland family-Montwel-Gerst-Denco-Badland (s7908)	0.15	0.05	0
s7909	Winona-Tridell-Honlu-Clapper (s7909)	0.19	0.08	4
s7910	Hanksville (s7910)	0.05	0.01	0
s7911	Utaline-Avalon (s7911)	0.19	0.07	0
s7912	Werlog-Turzo-Fruitland (s7912)	0.15	0.05	0
s7913	Morval family-Flynncove-Diagulch (s7913)	0.37	0.19	0
s7914	Zillion family-Namon-Flynncove-Dahlquist family (s7914)	0.26	0.13	0

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SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7915	Tolman family-Namon-Lap family-Grapit (s7915)	0.22	0.09	0
s7916	Utaline-Minchey-Leeko-Greybull-Avalon (s7916)	0.20	0.07	0
s7917	Walknolls-Rock outcrop-Muff family-Motto-Crustown-Casmos (s7917)	0.17	0.06	20
s7918	Vasquez-Shakespeare-Mirror Lake-Marsell-Duchesne (s7918)	0.60	0.36	6
s7919	Vasquez-Teewinot-Rubble land-Rock outcrop-Mirror-Haverly (s7919)	0.56	0.32	25
s7920	Sessions family-Mirror Lake-Clark Fork family (s7920)	0.42	0.23	0
s7921	Yarts-Tridell-Travessilla family-Strell-Honlu-Henrieville-Boxwell family (s7921)	0.45	0.22	5
s7922	Tridell-Flynncove-Dahlquist family-Clapper-Brownsto (s7922)	0.37	0.19	2
s7923	Utaline-Uffens-Turzo-Muff family-Greybull-Badland (s7923)	0.22	0.08	5
s7924	Greybull-Clapper-Badland-Abra family (s7924)	0.23	0.10	0
s7925	Yarts-Paradox family-Hillto-Clapper-Ashley (s7925)	0.35	0.17	2
s7926	Uinta-Skutum-Lucky Star (s7926)	0.47	0.28	0
s7927	Yarts-Mivida-Henrieville-Gerst-Clapper (s7927)	0.35	0.17	0
s7928	Swissvale-Rentsac family-Circleville-Brownsto (s7928)	0.20	0.08	5
s7929	Windham family-Namon family (s7929)	0.26	0.13	3
s7930	Yarts-Tebbs-Patent family-Mikim family-Henrieville-Glendive-Countryman (s7930)	0.49	0.24	0
s7931	Henefer-Gappmayer-Fitzgerald (s7931)	0.26	0.13	7
s7932	Mespun-Honlu-Hillto-Clapper (s7932)	0.63	0.36	5
s7933	Turzo-Stutzman family-Green River variant-Gotho-Fruitland (s7933)	0.18	0.06	0

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SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7934	Menefee-Lockerby-Hovenweep (s7934)	0.10	0.03	0
s7935	Rock outcrop-Montvale-Monticello (s7935)	0.36	0.18	20
s7936	Northdale-Monticello-Hovenweep (s7936)	0.33	0.16	0
s7937	Shay-Northdale-Monticello (s7937)	0.32	0.15	0
s7938	Ruinpoint-Rizno-Cahona (s7938)	0.06	0.02	0
s7939	Rock outcrop-Rizno-Mellenthin-Littlenan-Bodot (s7939)	0.12	0.03	12
s7940	Strych-Rock outcrop-Rizno-Montvale-Monticello (s7940)	0.28	0.13	30
s7941	Strych-Shay-Pack-Menefee-Abajo (s7941)	0.16	0.06	0
s7942	Strych-Pring-Cahona (s7942)	0.55	0.30	0
s7943	Strych-Skos-Bookcliff (s7943)	0.23	0.10	0
s7944	Rock outcrop-Myton family-Moenkopie (s7944)	0.47	0.25	37
s7945	Nakai-Limeridge-Bluechief (s7945)	0.57	0.29	0
s7946	Skos-Rock outcrop-Piute-Mido (s7946)	0.32	0.14	53
s7947	Sheppard-Rock outcrop-Piute (s7947)	1.80	1.15	41
s7948	Strych-Rizno (s7948)	0.22	0.09	0
s7949	Yarts-Rizno-Barx (s7949)	0.41	0.19	0
s7950	Skos-Rizno-Myton family-Milok (s7950)	0.12	0.04	0
s7951	Rock outcrop-Moenkopie (s7951)	1.15	0.70	78
s7952	Rock outcrop-Moenkopie-Hoskinnini (s7952)	0.59	0.29	22
s7953	Thoroughfare-Sheppard-Nakai (s7953)	1.22	0.82	0
s7954	Ustic Torriorthents-Rock outcrop-Lithic Torriorthents (s7954)	0.66	0.38	26
s7955	Rock outcrop-Rizno-Mido (s7955)	0.36	0.16	65
s7956	Redbank-Moab-Kidman (s7956)	0.76	0.43	0
s7957	Rock outcrop-Rizno (s7957)	0.12	0.04	36
s7958	Hagerman-Cahona-Begay (s7958)	0.85	0.49	0
s7959	Rock outcrop-Rizno (s7959)	0.12	0.04	44

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7960	Ustollic Haplargids-Ustollic Calciorthids-Ustic Torriorthents (s7960)	0.54	0.29	0
s7961	Waas-Tomasaki-Herm-Falcon (s7961)	0.56	0.34	0
s7962	Toone-Tomasaki-Herm-Falcon (s7962)	0.58	0.36	0
s7963	Toone-Skylick-Flygare (s7963)	0.88	0.62	0
s7964	Leighcan-Duchesne-Broad Canyon (s7964)	0.34	0.18	0
s7965	Rubble land-Meredith-Leighcan (s7965)	0.28	0.13	50
s7966	Ravola-Hunting-Billings (s7966)	0.19	0.08	0
s7967	Persayo-Chipeta-Badland (s7967)	0.13	0.04	0
s7968	Ravola-Persayo-Moffat (s7968)	0.26	0.11	0
s7969	Travessilla-Strych-Stormitt (s7969)	0.41	0.20	0
s7970	Strych-Mivida-Hernandez family (s7970)	0.35	0.17	0
s7971	Travessilla-Strych-Gerst (s7971)	0.36	0.18	5
s7972	Travessilla-Rock outcrop-Midfork family (s7972)	0.42	0.23	33
s7973	Podo-Pathead-Beje (s7973)	0.27	0.13	0
s7974	Rock outcrop-Midfork family-Guben (s7974)	0.44	0.27	27
s7975	Yenrab-Uvada family-Uvada-Lynndyl-Hiko Springs family (s7975)	0.72	0.37	0
s7976	Trook-Sagers-Ravola (s7976)	0.19	0.06	0
s7977	Sheppard-Nakai-Moffat (s7977)	1.72	1.22	0
s7978	Sheppard-Rock outcrop-Moenkopie (s7978)	0.99	0.62	29
s7979	Rock outcrop-Moffat-Moenkopie (s7979)	1.13	0.68	20
s7980	Nakai-Moenkopie-Milok (s7980)	0.91	0.50	0
s7981	Casmos-Badland-Antelope Springs (s7981)	0.17	0.06	0
s7982	Sagers-Killpack-Chipeta (s7982)	0.08	0.02	0
s7983	Trachute-Sandbench-Moenkopie (s7983)	1.31	0.79	0
s7984	Stormitt-Chipeta-Badland (s7984)	0.12	0.05	0
s7985	Welring-Strych (s7985)	0.20	0.08	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s7986	Roshe Springs-Logan-Fridlo-Airport (s7986)	0.31	0.16	0
s7987	Wayneco-Travessilla-Milok (s7987)	0.85	0.49	0
s7988	Mesa-Mack-Chipeta (s7988)	0.33	0.16	0
s7989	Skumpah-Killpack-Blueflat (s7989)	0.07	0.02	0
s7990	Rock outcrop-Moenkopie-Badland (s7990)	0.31	0.15	36
s7991	Rock outcrop-Nakai-Moenkopie (s7991)	0.62	0.33	18
s7992	Rock outcrop-Rizno-Begay (s7992)	0.69	0.38	24
s7993	Rogert family-Myton family-Kamack-Castino family (s7993)	0.30	0.15	2
s7994	Ute-Richens-Kildor-Embargo-Cluff-Castino (s7994)	0.36	0.20	0
s7995	Zeesix-Sessions-Perinos-Pahreah-Adobe (s7995)	0.30	0.16	0
s7996	Repp family-Falcon family-Detra (s7996)	0.19	0.07	5
s7997	Wiggler family-Repp family-Podo-Pathead-Caval-Ahlstrom (s7997)	0.34	0.15	5
s7998	Rabbitex family-Guben-Doney family-Datino family (s7998)	0.42	0.22	0
s7999	Senchert family-Pando family-Elwood-Bundo (s7999)	0.48	0.28	0
s8000	Faim-Embargo-Cluff-Clayburn family (s8000)	0.40	0.22	0
s8001	Tolman family-Harpole-Falcon family-Cabin-Bookcliff (s8001)	0.28	0.12	0
s8002	Namon family-Flygare family-Dranyon-Broad Canyon family (s8002)	0.46	0.27	5
s8003	Tomasaki-Sessions-Richens-Harpole-Broad Canyon family (s8003)	0.31	0.15	0
s8004	Sheppard-Moffat-Blackston (s8004)	0.96	0.55	0
s8005	Sheppard-Robroost-Mivida-Goblin-Farb (s8005)	0.79	0.43	0
s8006	Hanksville-Chipeta (s8006)	0.08	0.03	5

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8007	Pennell-Moenkopie-Farb (s8007)	0.78	0.43	5
s8008	Rock outcrop-Farb-Chipeta-Badland (s8008)	0.28	0.13	20
s8009	Rock outcrop-Moenkopie-Arches (s8009)	0.84	0.48	55
s8010	Rock outcrop-Mido (s8010)	1.52	0.95	90
s8011	Yarts-Wayneco-Moffat-Milok-Mido-Begay (s8011)	1.33	0.83	0
s8012	Wayneco-Moffat-Mido-Mellenthin-Begay-Arches (s8012)	1.39	0.88	5
s8013	Yarts-Wayneco-Travessilla-Stormitt-Shedado (s8013)	0.58	0.31	0
s8014	Rizno-Chipeta-Begay (s8014)	0.43	0.21	0
s8015	Tolman-Stormitt-Montosa family-Circleville-Blazon (s8015)	0.21	0.09	5
s8016	Stormitt-Makoti family-Delson-Datino family-Circleville (s8016)	0.25	0.13	0
s8017	Rogert-Rock outcrop-Pando family-Olnes family (s8017)	0.39	0.22	30
s8018	Rock outcrop-Redcreek family (s8018)	0.33	0.16	40
s8019	Riverwash-Neto-Fluvaquents-Bruman (s8019)	0.52	0.26	0
s8020	Parkay-Forsey-Faim (s8020)	0.24	0.12	5
s8021	Parkay-Forsey-Faim (s8021)	0.29	0.15	0
s8022	Dune land-Bushvalley (s8022)	0.84	0.62	0
s8023	Handy-Eldgin (s8023)	0.13	0.05	0
s8024	Watkins Ridge-Wallsburg-Vicking-Trove-Henefer-Acord (s8024)	0.24	0.11	0
s8025	Krueger-Haulings-Eldgin-Dacore (s8025)	0.25	0.11	0
s8026	Tolman family-Rock outcrop-Paunsaugunt-Panguitch-Circleville (s8026)	0.14	0.06	10
s8027	Spager family-Neponset-Goldrun-Etchen-Declo-Crestline (s8027)	0.29	0.13	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8028	Vicking-Van Wagoner-Rock outcrop-Noobab-Horrocks (s8028)	0.36	0.19	15
s8029	Van Wagoner-Rock outcrop-Pastorius-Horrocks (s8029)	0.36	0.19	25
s8030	Vicking-Van Wagoner-Rock outcrop-Horrocks-Agassiz (s8030)	0.21	0.09	20
s8031	Saxby-Rock outcrop-Noobab-Lodar family-Agassiz (s8031)	0.24	0.11	40
s8032	Spager family-Noobab-Neponset-Mountainville-Hiko Peak family (s8032)	0.19	0.08	0
s8033	Sterling-Mountainville (s8033)	0.32	0.16	0
s8034	Teton-Rubble land-Parkay-Hoosan-Elwood-Condie (s8034)	0.31	0.16	15
s8035	Sessions-Merino family-Hoodle-Herd-Faim-Cebone (s8035)	0.37	0.20	0
s8036	Zinzer-Youga-Rock outcrop-Redcreek family-Patent family-Evanston family-Cabbart (s8036)	0.26	0.12	10
s8037	Rock outcrop-Redcreek family-Patent family-Mayoworth-Luhon family-Grobutte (s8037)	0.21	0.09	10
s8038	Seitz-Rubble land-Namon-Knep-Embargo-Beardall (s8038)	0.22	0.10	10
s8039	Scandard-Rogert family-Hechtman-Elwood-Bickmore (s8039)	0.32	0.16	0
s8040	Water-Parkay-Namon-Granile-Forsey (s8040)	0.34	0.18	20
s8041	Kamack-Hourglass-Elwood-Bickmore family-Adel family (s8041)	0.50	0.30	0
s8042	Scandard-Passar-Nielsen family-Granile-Elwood-Bickmore family (s8042)	0.45	0.27	0
s8043	Parkay-Forsey-Embargo-Croydon-Condie (s8043)	0.29	0.15	0
s8044	Youga-Patent family-Hatch-Faim-Bowen-Almy (s8044)	0.21	0.10	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8045	Sanpitch-Poorman-Eoj-Eldgin-Dacore-Carstump (s8045)	0.16	0.07	0
s8046	Youga-Skutum-Sessions-Passar-Clayburn family-Bear Basin (s8046)	0.50	0.29	0
s8047	Whitecap-Sessions-Mirror Lake-Merino family-Croydon-Clayburn (s8047)	0.62	0.36	0
s8048	Youga-Ranruff-Neponset-Golsum-Eoj-Eldgin (s8048)	0.25	0.12	0
s8049	Zegro-Teton-Sessions-Faim-Ellett-Duncom (s8049)	0.27	0.13	0
s8050	Tiki-Sanpitch-Hymas-Hansel family-Ellett-Eldgin (s8050)	0.25	0.11	0
s8051	Siroco-Ellett-Eldgin-Dacore-Agassiz (s8051)	0.12	0.04	0
s8052	Zinzer-Rock outcrop-Redcreek family-Patent family-Mirror Lake-Cabbart (s8052)	0.33	0.15	15
s8053	Kinghorn-Hiko Peak family-Entmoot family-Credo-Alhark-Agassiz (s8053)	0.21	0.09	0
s8054	Namon-Mine-Kamack-Granile-Croydon-Clayburn (s8054)	0.50	0.28	0
s8055	Nielsen family-Hoodle-Genoa-Embargo-Bickmore family (s8055)	0.39	0.21	0
s8056	Swapps-Sula family-Scout family-Orcap-Mirror Lake (s8056)	0.15	0.04	0
s8057	Rock outcrop-Hiko Peak family-Ellett-Dacore-Bowen-Agassiz (s8057)	0.16	0.06	10
s8058	Tellura-Rock outcrop-Pando family-Cebone-Bowen-Bickmore (s8058)	0.25	0.12	10
s8059	Rock outcrop-Hiko Peak family-Denay-Dacore-Agassiz (s8059)	0.19	0.08	15
s8060	Sessions-Mortenson-Kamack-Faim-Behanin (s8060)	0.37	0.20	0
s8061	Sessions-Faim-Embargo-Elwood-Clayburn family-Bickmore family (s8061)	0.43	0.25	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8062	Pando family-Herd-Condie-Cluff-Cebone-Bickmore family (s8062)	0.30	0.16	0
s8063	Passar-Eldgin-Dacore-Bowen-Agassiz (s8063)	0.19	0.08	0
s8064	Tellura-Sessions-Golsum-Gabica (s8064)	0.29	0.15	0
s8065	Scout-Parkay-Hourglass-Condie (s8065)	0.36	0.18	0
s8066	Scout-Granile-Condie-Bickmore family (s8066)	0.33	0.17	0
s8067	Scout-Scandard-Rubble land-Rogert family-Rock outcrop-Blanca (s8067)	0.50	0.27	30
s8068	Tatiyee-Rock outcrop-Nielsen family-Golsum-Condie (s8068)	0.27	0.13	15
s8069	Nielsen family-Nayped-Golsum-Deer Creek-Castino family (s8069)	0.32	0.16	0
s8070	Tellura-Sessions-Rock outcrop-Reywat-Golsum-Clayburn (s8070)	0.22	0.11	10
s8071	Scout-Rubble land-Dateman family-Condie (s8071)	0.36	0.19	10
s8072	Tatiyee-Rock outcrop-Nielsen family-Genoa-Forsey (s8072)	0.33	0.18	35
s8073	Scout-Rubble land-Losee-Blanca (s8073)	0.46	0.24	10
s8074	Scout-Rubble land-Hoodle-Genoa-Forsey-Condie (s8074)	0.27	0.13	30
s8075	Scout-Nielsen family-Condie (s8075)	0.36	0.19	5
s8076	Tatiyee-Scout-Forsey-Condie (s8076)	0.33	0.17	0
s8077	Tatiyee-Sessions-Relley-Parkay-Golsum-Faim (s8077)	0.28	0.13	0
s8078	Rock outcrop-Reywat-Promo-Pernty-Golsum-Dahlquist (s8078)	0.21	0.10	20
s8079	Van Wagoner-Rock outcrop-Relley-Golsum-Dunford-Belmill (s8079)	0.23	0.10	20
s8080	Reywat-Red Butte-Pharo family-Kanarra-Bowen-Amtoft family (s8080)	0.11	0.04	0

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Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8081	Sessions-Poorman-Deer Creek-Dateman family-Clayburn-Castino family (s8081)	0.36	0.19	0
s8082	Rock outcrop-Pernty-Genoa-Forsey-Clayburn-Agassiz (s8082)	0.13	0.05	15
s8083	Forsey-Faim-Embargo-Dateman family-Clayburn-Adel family (s8083)	0.50	0.31	0
s8084	Relley-Golsum-Gabica-Deer Creek-Dacore-Castino family (s8084)	0.19	0.08	0
s8085	Reywat-Pernty-Mountainville-Hiko Peak-Golsum-Dacore (s8085)	0.15	0.06	0
s8086	Shotwell-Rock outcrop-Ranruff-Puett-Promo-Ellett (s8086)	0.24	0.10	20
s8087	Pernty-Leaps-Holmes-Dacore-Agassiz (s8087)	0.10	0.04	5
s8088	Rock outcrop-Nielsen family-Namon-Hourglass-Hoodle-Condie (s8088)	0.45	0.27	15
s8089	Whiteman-Parkay-Nielsen family-Namon-Elwood-Duchesne (s8089)	0.35	0.18	0
s8090	Rock outcrop-Ranruff-Elwood-Ellett-Condie (s8090)	0.24	0.11	20
s8091	Yeates Hollow-Snowville-Rake-Ostler-Dunford (s8091)	0.26	0.13	0
s8092	Winnemucca-Passar-Forsey-Condie-Clayburn-Adel family (s8092)	0.25	0.12	0
s8093	Rock outcrop-Kamack-Hourglass-Eyre family-Elwood-Condie (s8093)	0.51	0.30	15
s8094	Yeates Hollow-Pernty-Ostler-Dunford-Bowen-Agassiz (s8094)	0.18	0.08	0
s8095	Winnemucca-Passar-Forsey-Entmoot family-Condie-Clayburn (s8095)	0.25	0.12	0
s8096	Tatiyee-Parkay-Golsum-Condie (s8096)	0.32	0.17	0
s8097	Vanajo-Poganeab-Green River-Fluvaquents-Anco-Abcal (s8097)	0.19	0.07	0
s8098	Logan-Hiko Peak-Bertelson (s8098)	0.38	0.21	0

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SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8099	Playas (s8099)	0.03	0.01	0
s8100	Yuba family-Uvada family-Playas-Mondey family (s8100)	0.05	0.01	0
s8101	Ursine-Uffens family-Skumpah family (s8101)	0.17	0.06	0
s8102	Skumpah-Saltair-Playas-Dynal (s8102)	0.09	0.03	3
s8103	Swingler family-Penoyer family-Mazuma family-Goshute family (s8103)	0.13	0.04	0
s8104	Tosser-Sitar-Hiko Peak (s8104)	0.35	0.17	0
s8105	Yuba-Yenrab family-Biddleman family (s8105)	0.32	0.14	0
s8106	Yenrab-Uvada family-Uvada-Lynndyl-Hiko Springs family (s8106)	0.72	0.37	0
s8107	Sugarloaf-Nehar-Heist family-Goldrun family (s8107)	1.05	0.63	0
s8108	Uvada family-Papoose family-Goshute family-Dera family (s8108)	0.10	0.04	0
s8109	Sanpete family-Dera family (s8109)	0.20	0.08	0
s8110	Shabliss-Red Butte-Hiko Peak (s8110)	0.36	0.18	0
s8111	Robozo-Avalon family (s8111)	0.25	0.10	0
s8112	Rock outcrop-Hiko Peak-Cliffdown-Checkett family-Amtoft (s8112)	0.27	0.12	16
s8113	Lodar family-Amtoft family (s8113)	0.26	0.11	0
s8114	Reywat family-Lodar family-Kyler-Eaglepass (s8114)	0.27	0.12	9
s8115	Manassa-Bayfield family (s8115)	0.01	0.01	0
s8116	Yuba-Uvada-Uffens-Playas-Abbott (s8116)	0.10	0.03	0
s8117	Poganeab-Anco-Abraham-Abbott (s8117)	0.09	0.03	0
s8118	Toddler-Saltair-Playas (s8118)	0.11	0.04	0
s8119	Uvada-Rock outcrop-Hiko Springs-Checkett-Bluewing family (s8119)	0.27	0.11	13
s8120	Yenrab-Drum (s8120)	0.33	0.15	0
s8121	Sheeprock-Hiko Peak-Decca (s8121)	0.34	0.16	0

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Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8122	Penoyer variant-Kessler-Hiko Peak-Escalante-Antelope Springs (s8122)	0.21	0.09	0
s8123	Ushar-Red Butte-Phage-Manderfield-Flowell-Deer Creek (s8123)	0.18	0.08	0
s8124	Ushar-Snake Hollow-Sheeprock-Phage-Blue Star-Blackett (s8124)	0.49	0.25	0
s8125	Ushar-Pharo-Mill Hollow (s8125)	0.15	0.06	0
s8126	Ushar-Mosida-Etta (s8126)	0.30	0.14	0
s8127	Pharo-Pass Canyon (s8127)	0.24	0.11	0
s8128	Shotwell-Oakden-McQuarrie-Firmage (s8128)	0.16	0.06	5
s8129	Paice-Black Ridge (s8129)	0.14	0.04	5
s8130	Deer Creek-Clegg (s8130)	0.24	0.12	0
s8131	Yardley-Wallsburg-Mineral Mountain-Maple Mountain (s8131)	0.19	0.08	0
s8132	Rock outcrop-May Day-Cowers-Bearskin (s8132)	0.57	0.31	40
s8133	Riverwash-Poganeab-James Canyon family-Draper-Chipman (s8133)	0.26	0.13	0
s8134	Rock outcrop-Ravola variant-Hiko Peak-Badland (s8134)	0.23	0.10	15
s8135	Rypod-Musinia-McCornick-Ebbs-Boxelder (s8135)	0.25	0.11	0
s8136	Uvada-Hiko Springs-Curdli (s8136)	0.26	0.11	0
s8137	Woodrow-Toddler-Swingler family (s8137)	0.08	0.03	0
s8138	Uvada-Goldrun (s8138)	0.72	0.35	0
s8139	Yenrab-McCornick-Kessler-Kanosh-Goldrun (s8139)	0.83	0.46	0
s8140	Kanosh-Deseret (s8140)	0.24	0.10	0
s8141	Pavant-Doyce-Donnardo-Borvant (s8141)	0.25	0.11	0
s8142	Yeates Hollow-Rake-Millard-Flowell (s8142)	0.17	0.08	0
s8143	Pavant-Donnardo-Calita (s8143)	0.22	0.10	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8144	Ephraim-Calita-Abcal (s8144)	0.16	0.07	0
s8145	Saltair-Roshe Springs-Provo Bay-Bramwell-Benjamin (s8145)	0.16	0.06	0
s8146	Tridell-Rock outcrop-Comodore-Bruman (s8146)	0.16	0.07	10
s8147	Medburn-Linoyer-Genola (s8147)	0.33	0.14	0
s8148	Truesdale-Linoyer (s8148)	0.53	0.27	0
s8149	Scalade-Medburn-Jericho-Hiko Peak (s8149)	0.42	0.21	0
s8150	Goldrun-Dune land (s8150)	1.42	1.01	0
s8151	Nephi-Juab (s8151)	0.19	0.08	0
s8152	Yenrab-Uvada (s8152)	1.23	0.74	0
s8153	Xeric Torriorthents-Rock outcrop-Lodar (s8153)	0.20	0.08	20
s8154	Wallsburg-Rock outcrop-Broadhead-Agassiz (s8154)	0.21	0.10	25
s8155	Rock outcrop-Parkay-Kitchell-Flygare-Agassiz (s8155)	0.38	0.22	25
s8156	Woodrow-Quaker-Linoyer-Genola (s8156)	0.14	0.05	0
s8157	Sanpete-Lisade-Freedom-Denmark-Arapien (s8157)	0.46	0.23	0
s8158	Stillman-Sigurd-Sanpete (s8158)	0.47	0.24	0
s8159	Moroni-Keigley-Doyce-Collard-Birdow (s8159)	0.33	0.16	0
s8160	Watkins Ridge-Toehead-Manila-Deer Creek-Ant Flat (s8160)	0.25	0.11	0
s8161	Lodar-Fontreen-Borvant (s8161)	0.25	0.12	2
s8162	Sanpete-Rock outcrop-Amtoft (s8162)	0.33	0.17	10
s8163	Rock outcrop-Atepic-Amtoft (s8163)	0.12	0.04	50
s8164	Pavant-Mountainville-Doyce-Donnardo-Borvant (s8164)	0.30	0.14	0
s8165	Slickspots-Skumpah-Ravola-Mayfield (s8165)	0.04	0.02	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8166	Xerofluvents-Quaker-Mellor-Manassa-Harding-Dyreng (s8166)	0.14	0.05	0
s8167	Shumway-Poganeab-Peteetneet-Kjar-Fluvaquents-Chipman-Abcal (s8167)	0.20	0.09	0
s8168	Rock outcrop-Mower-Lundy-Lizzant-Hamtah-Agassiz (s8168)	0.22	0.10	10
s8169	Povey-Pavohroo-Northwater-Hymas-Clayburn (s8169)	0.36	0.19	0
s8170	Zeesix-Toze-Tingey-Skylick-Pritchett-Mortenson (s8170)	0.41	0.23	0
s8171	Starley family-Losee family-Kamack family-Cowood family-Bickmore family (s8171)	0.20	0.08	5
s8172	Tatiyee family-Security family-Scout family-Quilt family-Parkay family-Jemez family-Hesperus family (s8172)	0.20	0.09	0
s8173	Tingey-Scout family-Namon family (s8173)	0.19	0.08	5
s8174	Windwhistle family-Telephone family-Seleez family-Security family-Rock outcrop-Bond family-Atchee family (s8174)	0.47	0.23	20
s8175	Rock outcrop-Pinitos family-Montez-Canlon family (s8175)	0.25	0.11	40
s8176	Rock outcrop-Olot family-Gralic family-Falcon family-Eyre family (s8176)	0.18	0.07	30
s8177	Pioche family-McQuarrie family-Kanarra family-Indiano family-Decan family-Bodacious family (s8177)	0.16	0.06	0
s8178	Security family-Podmor family-Pastorius family-Fughes family-Dalcan family (s8178)	0.16	0.06	0
s8179	Rock outcrop-Motoqua family-Falcon family-Dotsero family-Bernal family (s8179)	0.12	0.04	40

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8180	Wye family-Sampson family-Pastorius family-Nehar family-Muzzler family-Mokiak family-Bernal family (s8180)	0.08	0.02	0
s8181	Tobler-St. George-Nikey-Junction-Harrisburg (s8181)	0.52	0.26	0
s8182	Winkel-Renbac-Hobog-Bermesa (s8182)	0.50	0.29	0
s8183	Toquerville-Tobler-Pintura-Ivins-Dune land (s8183)	1.43	0.96	0
s8184	Shalet-Badland (s8184)	0.26	0.12	5
s8185	Mathis-Bond family (s8185)	0.20	0.06	3
s8186	Rock outcrop-Redbank family-Mespun-Caval (s8186)	1.33	0.82	15
s8187	Pastura family-Magotsu-Curhollow (s8187)	0.25	0.11	5
s8188	Walknolls family-Rock outcrop-Rizno-Moenkopie (s8188)	0.57	0.30	55
s8189	Rock outcrop-Clapper-Badland (s8189)	0.29	0.13	30
s8190	Rock outcrop-Chipeta-Casmos family-Badland (s8190)	0.11	0.04	10
s8191	Rock outcrop-Mellenthin (s8191)	0.45	0.23	30
s8192	Windwhistle-Rock outcrop-Rizno-Palma (s8192)	0.60	0.32	15
s8193	Skyvillage-Palma-Mellenthin-Clapper-Atchee (s8193)	0.27	0.12	5
s8194	Palma-Gerst family-Barx-Arches (s8194)	0.32	0.13	3
s8195	Rock outcrop-Palma-Mespun-Arches (s8195)	1.22	0.72	25
s8196	Rock outcrop-Mespun-Arches (s8196)	1.79	1.18	10
s8197	Yarts-Palma-Neville family-Barx-Atchee (s8197)	0.38	0.17	5
s8198	Skos-Rock outcrop (s8198)	0.07	0.02	20
s8199	Sedillo-Gaynor-Clapper (s8199)	0.06	0.02	0
s8200	Dune land (s8200)	2.00	2.00	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8201	Rock outcrop-Mathis-Krueger-Arches (s8201)	1.08	0.64	60
s8202	Uana family-Nevu family-Minu family-Decathon family-Buster family-Aned family (s8202)	0.27	0.12	0
s8203	Tombar-Pavant-Hiko Peak-Denmark-Bamos (s8203)	0.16	0.06	0
s8204	Garbo-Deerlodge family-Biblesprings (s8204)	0.33	0.15	0
s8205	Unius family-Taylorsflat-Sevy-Manselo-Hiko Peak-Escalante (s8205)	0.29	0.12	0
s8206	Wales-Taylorsflat-Sevy (s8206)	0.28	0.12	0
s8207	Wales-Taylorsflat-Medburn-Kanarra-Ashdown (s8207)	0.17	0.06	0
s8208	Sevy-Manderfield-Komo-Calcross-Ashdown (s8208)	0.13	0.04	0
s8209	Rock outcrop-Ocambee-Kinghorn (s8209)	0.17	0.07	15
s8210	Red Butte-Pavant-Hiko Peak-Dixie-Checkett-Bamos (s8210)	0.15	0.06	0
s8211	Rock outcrop-Pass Canyon-Bamos-Abela (s8211)	0.13	0.05	12
s8212	Uvada-Manselo-Antelope Springs (s8212)	0.19	0.07	0
s8213	Tolman family-Rob Roy-Doyce (s8213)	0.15	0.06	6
s8214	Wye-Motoqua-Lucero-Ironco (s8214)	0.19	0.08	3
s8215	Rypod-Poorman-Lagnaf-Acord (s8215)	0.23	0.11	0
s8216	Winnemucca-Seth-Faim (s8216)	0.29	0.15	0
s8217	Paunsaugunt-Kolob-Detra-Dalcan (s8217)	0.33	0.17	4
s8218	Welring-Tortugas family-Rock outcrop-Chilton family (s8218)	0.15	0.06	25
s8219	Tobish-Tacan-Nehar-Collbran family (s8219)	0.14	0.05	6
s8220	Villy family-Tebbs-Alldown (s8220)	0.31	0.14	0
s8221	Descot-Codley (s8221)	0.11	0.03	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8222	Yarts-Mikim-Henrieville-Befar-Barx (s8222)	0.15	0.07	0
s8223	Playas-Frandsen (s8223)	0.16	0.06	0
s8224	Zillion-Showalter-Panguitch-Notter-Guben (s8224)	0.31	0.15	0
s8225	Yenlo-Mikim-Lazear-Clapper-Cannonville-Bayfield (s8225)	0.06	0.02	0
s8226	Venture-Tridell-Notter-Ipson-Bruman (s8226)	0.34	0.16	0
s8227	Zinzer-Yenlo-Tridell-Notter-Luhon (s8227)	0.22	0.09	0
s8228	Tridell-Ipson (s8228)	0.26	0.12	4
s8229	Zillion-Waltershow-Venture-Quilt-Ipson-Harol-Andys (s8229)	0.18	0.08	0
s8230	Waltershow-Tolman-Rock outcrop-Ipson-Comodore (s8230)	0.13	0.05	10
s8231	Tolman-Harol-Fughes-Dalcan-Bushvalley (s8231)	0.20	0.09	0
s8232	Syrett-Swapps-Skutum-Sheege-Ruko-Rock outcrop-Frandsen (s8232)	0.21	0.08	17
s8233	Zyme-Vanet-Syrett-Rock outcrop-Badland (s8233)	0.14	0.07	20
s8234	Syrett-Swapps-Skutum-Pahreah-Badland (s8234)	0.32	0.16	0
s8235	Ruko-Rock outcrop-Podo-Lazear-Dimyaw family-Cannonville-Badland (s8235)	0.16	0.07	15
s8236	Rock outcrop-Circleville-Castino (s8236)	0.21	0.10	29
s8237	Winnemucca-Echard-Callings-Behanin-Beardall (s8237)	0.44	0.24	0
s8238	Winnemucca-Tica family-Hoodle-Castino-Callings (s8238)	0.35	0.18	0
s8239	Shedado-Rock outcrop-Mespun-Batterson (s8239)	1.10	0.64	50
s8240	Rock outcrop-Rizno-Chilton family (s8240)	0.31	0.14	25
s8241	Sheppard-Rock outcrop-Arches (s8241)	1.51	1.10	50
s8242	Rock outcrop-Rizno (s8242)	0.92	0.53	70

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s8243	Sheppard-Nakai-Monue-Deleco-Cataract-Bluechief (s8243)	1.13	0.65	6
s8244	Yarts-Shedado-Rock outcrop-Rizno-Palma-Mivida-Barx (s8244)	0.49	0.24	10
s8245	Uvada-Sevy-McLoughlin-Decca-Crestline (s8245)	0.11	0.03	0
s8246	Rustico-Musinia-Monroe-Hiko Peak-Bandag (s8246)	0.19	0.08	0
s8247	McLoughlin-Hiko Peak-Decca-Avalon (s8247)	0.16	0.06	0
s8248	McLoughlin-Hiko Peak-Decca-Crestline (s8248)	0.24	0.10	0
s8249	Sanpete-Rock outcrop-Hiko Peak-Badland-Amtoft (s8249)	0.23	0.11	10
s8250	Redview-Redfield-Quaker-Naser (s8250)	0.12	0.04	0
s8251	Monroe-Genola-Bertelson-Annabella variant (s8251)	0.24	0.10	0
s8252	Rock outcrop-Red Butte-Logan-Hoye-Hiko Peak (s8252)	0.27	0.14	10
s8253	Rock outcrop-Red Butte-Pernty-Hiko Peak-Handy-Dacore (s8253)	0.16	0.07	20
s8254	Rock outcrop-Hiko Peak-Dacore-Checkett (s8254)	0.15	0.06	15
s8255	Poganeab-Linoyer-Haulings-Green River-Fluvaquents-Anco (s8255)	0.28	0.12	0
s8256	Tosser-Hiko Peak-Bertelson (s8256)	0.40	0.20	0
s8257	Monroe-Medburn-Green River (s8257)	0.55	0.30	0
s8258	Poganeab-Manassa-Kirkham (s8258)	0.09	0.03	0
s8259	Trook-Gypsum land-Goblin (s8259)	0.34	0.17	0
s8260	Travessilla-Rock outcrop-Gerst (s8260)	0.36	0.18	40
s8369	Water (s8369)	0.01	0.01	100
s9012	Uinta-Scout-Rock outcrop-Miracle-Millpot-Leavitt-Chittum (s9012)	0.48	0.26	10
s9014	Turson-Tetonville-Moslander (s9014)	0.38	0.20	0

Table D.26 UT STATSGO Utah General Soil Survey

Soil Map Unit Composite XKSAT and RTIMP Values

SMU	Soil Map Unit Name	XKSAT, in/hr		Natural RTIMP, %
		DF = 1.0	DF = 1.1	
(1)	(2)	(3)	(4)	(5)
s9016	Terada-Spool-Rock outcrop-Huguston-Blackhall (s9016)	0.90	0.51	40
s9017	Pando-Libeg-Lail-Bear Basin-Amsden variant-Amsden (s9017)	0.39	0.21	0
s9046	Outlet-McKinney-Gas Creek-Dobrow-Canburn-Absher (s9046)	0.33	0.17	0

E. CHECKLISTS

E.1 PURPOSE

These checklists are intended for two purposes as follows:

1. Internal use by County/District employees as a guide for reviewing drainage studies, reports and construction plans, including those submitted by the public and prepared internally at the County/District and by other agencies.

2. External use by the public for preparing drainage studies, reports and construction plans that will be reviewed by the County/District.

This should help expedite the review process and help the public better understand what the County/District will be looking for when performing a review. These checklists are not intended to be applicable for every situation. They are intended to be helpful and not mandatory. Checklist items that do not apply to a given situation should have the "N/A" box checked. The column headed with an "*" should be checked if more information or comments are necessary. Additional information and comments should be placed in the "COMMENTS" section provided at the end of each table, with the appropriate checklist item number listed at the start of the comment. Such additional information or comments may also be provided on additional pages. The engineer is encouraged to provide the appropriate checklist as a part of the study or report, as shown in Section 18. The general intended uses for each checklist are as follows:

Checklist 1: Drainage Design Report Checklist. Drainage Design Reports for subdivision preliminary and final plats, street improvement projects and drainage improvement projects. Portions of the checklist may also be appropriate for grading and drainage plans.

Checklist 2: Hydrology Specific Checklist. This checklist is to be applied for flood insurance studies, drainage planning studies, and for Drainage Design Reports where new hydrology calculations or modeling is prepared.

Checklist 3: HEC-RAS Hydraulics Specific Checklist. This checklist is to be applied for flood insurance studies, drainage planning studies, and for Drainage Design Reports and drainage and grading plans where new hydraulic modeling is done using HEC-RAS (preferable) or HEC-2.

Checklist 4: Technical Data Notebook Checklist. This checklist is to be applied for flood insurance studies.

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E.2 CHECKLIST 1: DRAINAGE DESIGN REPORT CHECKLIST

Checklist 1: Drainage Design Report Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
SECTION 1: GENERAL					
1	PROJECT NAME: REVISION NO: DATE:				
2	SELECT PROJECT TYPE: Preliminary Plat [ ] Final Plat [ ] Street Imp. [ ] Drainage Design [ ] Grading and Drainage Plan [ ] Other [ ]				
3	REVIEWED BY:				
4	Is this a complete drainage report, sealed by a professional Civil Engineer currently licensed to practice in Arizona?				
5	Is the *Hydrology Specific Checklist* included and completed, if appropriate?				
6	Is the *HECRAS Hydraulics Specific Checklist* included and completed, if appropriate?				
7	Is this report for floodplain delineation purposes, requiring use of the TDN format and checklist?				
8	Does the report discuss whether the site is in a subsidence area or if there are fissures present?				
9	If in a subsidence area or fissures are present, are facilities appropriately sited and designed?				
10	If a construction project, has an SWPPP been developed and an NOI submitted per ADEQ requirements?				
11	If a construction project, has a copy of the SWPPP and NOI been included in the report?				
12	Have all permit requirements been met (ie. Floodplain, Drainage Clearance, Right-of-Way, Zoning, Stormwater Quality, 401/404, etc)?				
13	Is there a section on Conclusions and Recommendations, and is it adequate?				
SECTION 2: FIELD SURVEY AND MAPPING					
1	Are company name, project number, and dates of surveying specified?				
2	Is the report sealed and signed by a professional Land Surveyor currently registered in the State of Arizona?				
3	Are the mapping and map control used in the study fully described?				
4	Are both horizontal and vertical mapping datums specified?				
5	Are the date of aerial photography, mapping scale, and contour interval specified?				
6	Other.				
SECTION 3: DRAINAGE AREA MAP					
1	Is there a drainage area map at an appropriate scale?				
2	Is each sub-basin area delineated and uniquely labeled with alpha-numeric characters in a consistent manner on the Drainage Area Map?				

Checklist 1: Drainage Design Report Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
3	Are directional drainage arrows shown on all streets, parking lots, paved areas, and vacant land?				
4	Is the existing zoning shown on each parcel?				
5	Are existing and proposed catch basins shown and clearly identified?				
6	Does each catch basin number correspond to the number of the sub-basin area which contributes to it?				
7	Are catch basins numbered, beginning with number 1 as the first catch basin contributing to the storm drain at the upstream end? The following catch basins contributing should be numbered consecutively.				
8	Is the same catch basin number used throughout the project – on the drainage area map, in the design report, on the Storm Drain Design Summary Sheet, and on the plans?				
SECTION 4: STORMWATER COLLECTION SYSTEMS					
1	Is the hydrologic design criteria described and does it match the jurisdiction's requirements?				
2	Is the street drainage network described (i.e. longitudinal and cross slopes, curb height, gutter width)?				
3	Is the storm drain network described (i.e. inlet and catch basin design)?				
4	Is a Storm Drain Design Summary Sheet included?				
5	Is conformance with previous drainage studies checked and differences discussed?				
6	Has a Hydraulic & Energy Grade Line Profile been submitted?				
7	Is the pipe velocity for $0.5*Q_{design} \geq 3$ fps, $Q_{design} \geq 5$ fps, and ≤ 15 fps?				
8	Are dry lane requirements met?				
9	Are appropriate drainage runoff volumes and discharges used?				
10	Are the diameter, length, slope, and construction material of storm drainpipe (RCP, CMP, or other) specified?				
11	Are appropriate clogging factors applied for inlets, in conformance with the jurisdiction's requirements?				
12	Is the maximum hydraulic grade line ≥ 1 ft below the grate elevation of all catch basins and inlets?				
13	Is the maximum energy grade line at or below the adjacent gutter flow line elevation?				
14	Other.				
SECTION 5: CULVERTS					
1	Is the application described (ie, roadway classification, design setting, erosion/deposition concerns)				
2	Is the hydrologic design criteria used described and does it meet or exceed the minimum standards?				
3	Is the number, diameter, length, and construction material specified appropriately? (ie, CMP, RCP, or other)				
4	For existing condition studies, are appropriate n-values assigned for pipe condition?				

Checklist 1: Drainage Design Report Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
5	Are appropriate clogging factors applied for inlets, in conformance with the jurisdiction's requirements?				
6	Does the culvert design for Q_{design} meet the requirements of Table 6.7?				
7	Does the inlet headwater elevation for Q_{100} meet the requirements of Table 6.7?				
8	Does the flow depth over the road for Q_{100} meet the requirements of Table 6.7?				
9	Does backwater at the inlet overtop adjacent land features and drain elsewhere, other than through the culvert?				
10	Does backwater at the inlet affect adjacent parcels of land, requiring ponding easements or establishment of minimum finish floor elevations?				
11	Is the outlet velocity ≤ 15 fps?				
12	Is outlet protection necessary?				
13	If a low water crossing is specified, are cut-off walls provided along the upstream and downstream edges of pavement to limits of flow?				
14	Is a profile provided for each culvert depicting length, slope, cover, road side slopes, design headwater elevation, and any utility conflicts?				
15	Other.				
SECTION 6: RETENTION BASINS					
1	Is the hydrologic design criteria used described and does it match the jurisdiction's requirements?				
2	Have stormwater storage and first flush requirements been met?				
3	Are stormwater storage and first flush calculations included and documented in the report?				
4	Does the maximum basin depth meet the jurisdiction's criteria?				
5	Is an emergency spillway/overflow identified in an appropriate location, and adequately protected from scour?				
6	Are side slopes 4:1 or flatter?				
7	Are appropriate clogging factors applied for inlets, in conformance with the jurisdiction's requirements?				
8	Are debris barriers specified for inlets?				
9	Are access barriers specified for outlets 18 inches in diameter and greater?				
10	Is an upstream siltation basin included if necessary?				
11	Other.				
SECTION 7: FCD FLOOD RETARDING STRUCTURES					
1	Name of structure(s):				
2	Identify phase of FCD Structures Assessment Program and any hydrologic investigations performed as part of the program.				
3	Specify hydrologic design criteria for reservoir, i.e. SPF, 100-yr.				

Checklist 1: Drainage Design Report Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
4	Specify inflow design flood for spillway, i.e. 100-yr, or % PMF (dependent on hazard classification).				
5	Other.				
SECTION 8: CANALS					
1	Are any canals located within the project boundaries?				
2	Is a discussion of backwater and overtopping issues provided, and are they adequately addressed?				
3	Other.				
SECTION 9: CONSTRUCTION PLANS					
1	Are all underground utilities identified in plan & profile?				
2	Is a utility “potholes requested” letter (as needed) for capital improvement projects provided?				
3	Are water, and sewer, and natural gas service taps shown in plan & profile?				
4	Are all sanitary sewer manhole rim and invert elevations shown on plans?				
5	Is any existing Portland Cement concrete pavement underlay shown?				
6	Are storm drain conflicts with other utilities identified and addressed?				
7	Have SRP, RID, and private irrigation facilities been checked for conflicts?				
8	Are waterline thrust block conflicts identified and addressed?				
9	Are pipe support locations for sanitary sewer lines above main storm drains identified?				
10	Are existing topography and buildings shown at least 30 feet beyond street R.O.W.?				
11	Are intersecting side street elevations at least 100 feet beyond curb returns noted on plans?				
12	Are potential ponding locations behind sidewalks checked and resolved?				
13	Are driveway/catch basin conflicts checked and resolved?				
14	Are finished floors appropriately elevated relative to the peak 100-year water surface elevations?				
15	Is one typical full-street cross-section with storm drain and applicable other underground utilities shown to scale on each storm drain profile sheet?				
16	Does the mainline storm drain have a minimum of 4-foot of cover (unless otherwise approved)?				
17	Is the farthest upstream catch basin located to meet the flow depth criteria in Table 6.7?				
18	Do all catch basins have a maximum spacing meeting the criteria in Table 6.9?				
19	Have soil boring(s) extending at least 2 feet below the proposed storm drain been taken and shown on the plans or provided in a report?				
20	Are soil boring logs and information including pH and resistivity shown on plans or provided in a report?				

Checklist 1: Drainage Design Report Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
21	Are pipe materials designed to accommodate soil conditions? Do existing soil conditions meet requirements for cast-in-place concrete pipe or concrete lined corrugated metal pipe?				
22	Are existing and proposed ground elevations shown for all mainline and connector pipe profiles?				
23	Is a *Storm Drain Key Map* included?				
24	Is a complete alternate pipe chart included?				
25	Does the alternate pipe chart show storm drain pipe diameters 6-inches larger than designed pre-cast concrete pipe diameters? The calculated pipe wall thickness for cast-in-place pipe is based on the required larger size.				
26	Does the alternate pipe chart show cast-in-place concrete pipe to be no smaller than 30 inches in diameter?				
27	Check for permanent pipe supports.				
28	Are there any ACP waterline crossings?				
29	Is there a completed *Storm Drain Design Summary* sheet included with plans?				
30	Are temporary construction easement lines for drainage work shown, if required? Are easement and right-of-way lines shown?				
31	Is the type of work on existing facilities indicated?				
32	Is the direction of flow indicated for ditches, channels, natural waterways, etc.?				
33	Are inlet and outlet elevations shown for all drainage facilities?				
34	Are existing ground line (dashed line) and finished grade line (solid line) profiles shown and labeled?				
35	Is the design slope of profile lines for drainage facilities (ditch, channel, etc.) shown as decimal in ft/ft?				
36	Are pipe culvert material and dimensions labeled?				
37	Are inlet and outlet facilities, if any, such as headwalls, wingwalls, cutoff walls and erosion protection shown and dimensioned?				
38	Are reinforced concrete box culvert dimensions and number of cells shown coupled with wingwall type/dimensions?				
39	Are the type and thickness of drainage facility linings shown?				
SECTION 10: *ADDITIONAL COMMENTS					

Checklist 1: Drainage Design Report Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****

Checklist 1: Drainage Design Report Checklist					
Item	Description	YES	NO	N/A	*

E.3 CKECKLIST 2: HYDROLOGY SPECIFIC CHECKLIST

Checklist 2: Hydrology Specific Checklist					
Item	Description	YES	NO	N/A	*
SECTION 1: PROJECT DETAILS					
1	PROJECT NAME: REVISION NO: DATE:				
2	SELECT PROJECT TYPE: ADMS[ ] ADMP [ ] WCMP [ ] FDS [ ] Development Review [ ] Regulatory Review [ ] Hydrology Study [ ] Other [ ]				
3	REVIEWED BY:				
4	Are both hard and electronic copies of HEC-1 input and output files included with submittal?				
5	Is the report sealed and signed by a professional Civil Engineer currently licensed to practice in Arizona?				
6	REPORT TITLE:				
7	CONSULTANT:				
8	LIST SOFTWARE, VERSION, and FILE NAMES:				
9	Is this a CIP PROJECT?				
10	Is the development located in a flood hazard area? Check Category: Floodway[ ] Floodplain: A [ ] AH [ ] AE [ ] AO [ ] X [ ] EHZ [ ]				
11	Is there a section on Conclusions and Recommendations, and is it adequate?				
SECTION 2: HYDROLOGY MAPS					
1	Is a map provided that shows study area boundary, sub-basin boundaries, and concentration points?				
2	Check the sub-basin delineation. Are areas, soil and land use types, and topography homogenous for each sub-basin?				
3	Check sub-basin areas. Are areas measured correctly?				
4	Is the naming convention for sub-basins, concentration points, routing reaches, reservoir routes, and flow diversions identified?				
5	Is a map provided that shows time of concentration and hydrograph routing paths?				
6	Is a map provided that shows soils boundaries?				
7	Is a map provided that shows land use boundaries for both existing and developed conditions?				
8	Is the basis and method for estimating vegetation cover (existing and developed) described? Is the method appropriate?				

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
9	Was "no contributing runoff" assumed for properties with existing 100-year on-site retention, or properties with plans for 100-year on-site retention, which have been reviewed and approved by Maricopa County Planning & Development Services?				
10	Is there a description of watershed condition and watershed resistance? Is selection of K_b and/or K_n values discussed appropriately in that context?				
11	Other.				
SECTION 3: RATIONAL METHOD					
1	Is the maximum individual basin area less than or equal to 160 acres?				
2	If not, then the unit hydrograph method must be used.				
3	Are Runoff C Coefficients and K_b values selected appropriately for each land use type per Tables 6.3 and 6.4?				
4	Have existing land-use runoff coefficients been used where contributory land is vacant or developed prior to storm water storage requirements?				
5	If the Runoff C Coefficients or K_b values do not match the values for the appropriate land use categories in Tables 6.3 and 6.4, is there appropriate written justification and computations?				
6	Are there multiple land use types within individual basins?				
7	If so, are Runoff C Coefficients and K_b values area-averaged appropriately?				
8	Are site specific Depth-Duration-Frequency (D-D-F) values computed properly using PREFRE, and a printout and digital input/output files provided?				
9	Is the T_c path of appropriate location and length on the map?				
10	Is the T_c computed using the District's Rational Method computer program?				
11	If so, is a printout provided and do the input parameters match the report values?				
12	If not, check the iterative computations closely for each basin. Are they correct?				
13	Is each T_c value at least 10-minutes?				
14	Is the peak discharge for each basin computed properly and are the values reasonable?				
15	Is the Rational Method being used to compute peak discharges at intermediate locations within a drainage area less than 160 acres in size?				
16	If so, is the procedure outlined in Section 3.6.2 of the Hydrology Manual followed?				
17	Other.				
SECTION 4: UNIT HYDROGRAPH METHOD					
1	HEC-1 JOB CONTROL RECORDS				
a.	ID record. Are dates, project name, and modeler's name specified? Are they consistent with reports?				
b.	ID record. Are model revisions clearly identified on subsequent ID records?				

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
c.	IT record (NMIN). If NMIN has been revised, or changed for different models, were dependent parameters (UI, RM, NSTPS) adjusted appropriately?				
d.	IT record (NMIN). Is 0.1 T_c ≤ NMIN ≤ 0.25 T_c for the average value of T_c for the watershed, and the maximum and minimum values? Double check sub-basin delineation if extreme values of T_c make NMIN significantly outside the range.				
e.	IT record (NMIN). Is NMIN < 0.25*T_c for the sub-basin with the shortest T_c?				
f.	IT record (NMIN). Can NMIN be adjusted so that NMIN is approximately equal to 0.15 T_c for the average value of T_c?				
g.	IT record (NMIN). Is 60/NMIN an integer?				
h.	IT record (NMIN). Is NMIN equal to or evenly divisible by JXMIN on the IN record?				
I.	IT record (NMIN, NQ). Is NMIN*NQ at least as long as the storm duration?				
j.	IN record (JXMIN). Is the IN record used correctly?				
k.	Is *DIAGRAM specified for at least one HEC-1 model in the study? One for each model with differences other than storm frequency.				
l.	IO record (IPRT). Is Level 3 or lower output used for at least one HEC-1 model in the study? One for each model with differences other than storm frequency? Level 3 should be used for the model of the largest storm.				
m.	JP record. Is (NPLAN*NRATIO) < 45?				
n.	JP record. Is (NPLAN*NRATIO*NQ) < 4800?				
o.	JD record. Are JD records used and applied appropriately?				
p.	JD record. When using JD records for FRS volume computation, were the interpolated volumes from each sub-basin used?				
q.	Other.				
2	PRECIPITATION AND RAINFALL DISTRIBUTION				
a.	Check rainfall frequency and duration in the report and HEC-1 files. Identify the source of rainfall data, i.e. NOAA Atlas 2, HMR-49. Is the source appropriate for the study area and type?				
b.	PB record. Specify rainfall depth. Is areal reduction applied correctly and discussed in the text?				
c.	PI and PC records. Were PC or PI records checked against the IN record?				
d.	PI and PC records. Were PC or PI records checked against distribution patterns?				
e.	Are design storm distributions applied correctly?				
f.	Other.				
3	RAINFALL LOSSES				
a.	Are Green-Ampt loss rate parameters specified and are the selected values for IA, DTHETA, XKSAT, PSIF, and RTIMP reasonable?				
b.	Is the watershed moisture condition assumption described for the selection of DTHETA?				
c.	Are there different moisture condition land uses present within individual sub-basins (agricultural and natural, for instance)?				
d.	If so, are the values area averaged appropriately?				

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*
e.	Is area averaging of Green & Ampt parameters performed using the current version of DDMSW, or by external means or old versions of DDMSW/MCUHP? Check those that use older versions of DDMSW/MCUHP more closely. Check those using external means very closely.				
f.	Is bare ground XKSAT adjusted for vegetation cover? Is the adjustment appropriate?				
g.	Does the watershed span multiple NRCS (SCS) Soil Surveys? Are differences in soil texture between adjacent soil surveys discussed in the text and addressed if necessary in the models?				
h.	Is there a discussion of natural RTIMP present in the watershed?				
I.	Is natural RTIMP assumed to be hydraulically connected, have any adjustments been made to the percentages listed for the soil types, and are the revisions reasonable and adequately documented?				
j.	Other.				
4	HYDROGRAPHS				
a.	Specify method of hydrograph generation, i.e. Clark, S-graph. Is the method appropriate?				
b.	UC record (T_c). Are T_c parameters L, S, and K_b reasonable?				
c.	Is T_c < 90 minutes for each sub-basin?				
d.	Does T_c exceed the duration of rainfall excess for any sub-basin? This should be documented in the text.				
e.	UC record (R). Is R ≥ 0.5xNMIN?				
f.	UC record (T_c). Check against similar sub-basins. Are T_c values reasonable?				
g.	UC record (T_c). Were Tc values checked to ensure that average velocities throughout the watershed are reasonable?				
h.	HC record. Are hydrographs combined properly?				
i.	HC record. Is HC ≤ 5?				
j.	HC record (TAREA). Is total area correct? Was area above the concentration point manually recalculated for diverted hydrographs?				
k.	Other.				
5	CHANNEL/PIPE ROUTING METHODS				
a.	Are specific channel/pipe routing method(s) specified, i.e. modified Puls, normal depth, Muskingum, Muskingum-Cunge, kinematic wave, and are the methods appropriate?				
b.	RC record (RLNTH). Check reach lengths. Were lengths measured correctly?				
c.	RC record (ANL, ANCH, ANR). Were Manning's "n" values developed using methodology in *Estimated Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona* (April 1991)?				
d.	RC record (ANL, ANCH, ANR). Are Manning's "n" values reasonable?				
e.	RX and RY records. Are cross sections typical for the routing reach? If not, does the reach need to be broken into multiple reaches?				
f.	Are NSTPS generally equal to L/(V_{avg} * NMIN)?				
g.	Is NSTEP for each reach within +/- 1 of TT/NMIN, where TT is the travel time for the reach computed by HEC-1?				

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*
h.	Are transmission losses modeled? If so, is there an acceptable discussion of the reasons for modeling losses, and the source of the parameters?				
i.	Are there questionable routing operations identified above that warrant plotting and visual examination of the hydrograph?				
j.	Other.				
6	RESERVOIR (STORAGE) ROUTING METHODS				
a.	Are USGS, FCD, NWS, or other rain or stream gages used in hydrologic analysis or model calibration identified and discussed?				
b.	Are stage-storage relationships modeled correctly?				
c.	Are stage-discharge relationships modeled correctly?				
d.	RS record. Are NSTPS = 1? If NSTPS is changed, travel time and attenuation will be affected.				
e.	RS record (ITYP, RSVRIC). Are starting conditions modeled appropriately?				
f.	Are rating curves for storage and outflow hydraulics included? Are the rating curves reasonable?				
g.	Is there an acceptable discussion of the basis for estimation of storage and outflow parameters in the text, and a discussion of reservoir routing results?				
h.	Other.				
7	DIVERSION DATA				
a.	DI/DQ records. Are diversions/split flows modeled correctly?				
b.	Are hydraulic computations for diversions done appropriately and included in the report?				
c.	Are rating curves for each diversion plotted and included in the report?				
d.	Are watershed areas corrected using the HC record where diverted hydrographs are recalled into the model?				
e.	Other.				
SECTION 5: HEC-1 OUTPUT					
1	ERROR AND WARNING MESSAGES				
a.	Are there error or warning messages related to hydrograph generation or combination that are not adequately addressed in the test, or are critical?				
b.	Are there error or warning messages related to routing that are not adequately addressed in the text? Specifically check for peak discharge outside of specified range warnings and lack of hydraulic capacity for the reach cross-section.				
c.	Have error and warning messages been checked and corrected? Are error and warning messages explained adequately?				
d.	Other.				
2	SCHEMATIC DIAGRAM				
a.	Compare the schematic to the watershed map. Is the structure logical? Are all points labeled clearly? Specify any problems.				
b.	Are there < 9 hanging hydrographs?				
c.	Have all of the diverted hydrographs been accounted for?				
d.	Are all sub-areas attached and combined in the proper sequence?				
e.	Other.				
3	DRAINAGE AREA				

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*
a.	Has the area associated with all returned diverted hydrographs been returned?				
b.	Check total drainage area. Is it accurate?				
c.	Other.				
4	RAINFALL LOSSES				
a.	Check the total rainfall, total losses, and total runoff for each sub-basin. Are there zeros or very small numbers? Explain.				
b.	Other.				
5	HYDROGRAPH ROUTING				
a.	Is outflow peak discharge < inflow peak discharge?				
b.	Is flow contained within x-sections?				
c.	Check travel time. Does travel time appear to be too short or too long? If so, check input parameters for routing. Check routing steps in the input against the output velocity.				
d.	Is attenuation of peak flows reasonable?				
e.	For kinematic wave routing, is the peak flow attenuated? If so, check model and revise.				
f.	Other.				
6	PEAK RUNOFF				
a.	Is specific yield (cfs/sq mi) for each sub-basin included in the report?				
b.	Other.				
7	TIME TO PEAK				
a.	Check the time to peak column in the HEC-1 summary table. Do times to peak increase with increasing drainage area?				
b.	Are all times to peak very close or identical to one another? If so, NMIN and routing operations may need to be revised.				
c.	Do all times to peak occur after the most intense period of rainfall (about half the rainfall duration)?				
d.	Other.				
8	RUNOFF VOLUMES				
a.	Are runoff volumes reasonable?				
b.	Other.				
SECTION 6: MODEL CALIBRATION AND INDIRECT METHODS VERIFICATION					
1	INSTRUMENTATION				
a.	Identify USGS, FCD, NWS, or other rain or stream gages used in hydrologic analysis or model calibration.				
b.	Have any gages been relocated during the period of record? Discuss.				
c.	Other.				
2	INDIRECT METHODS/STATISTICAL ANALYSES				
a.	Have statistical analyses been performed and are the results discussed?				
b.	Are USGS regression equations used, the sources identified, and are they appropriate and implemented correctly?				
c.	Is the period of record adequate for use with *Water Resources Council Bulletin 17B* (March 1982)?				
d.	Are any other Indirect Methods used, the sources identified, and are they appropriate and implemented correctly?				
e.	Are the model results reasonable based on comparisons with the results of the application of Indirect Methods?				

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*
f.	Other.				
SECTION 7: ADDITIONAL COMMENTS					

Checklist 2: Hydrology Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****

E.4 CHECKLIST 3: HEC-RAS HYDRAULICS SPECIFIC CHECKLIST

Checklist 3: HEC-RAS Hydraulics Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
SECTION 1: PROJECT DESCRIPTION					
1	PROJECT NAME: REVISION NO: DATE:				
2	SELECT PROJECT TYPE: ADMS[ ] ADMP [ ] WCMP [ ] FDS [ ] Development Review [ ] Regulatory Review [ ] Hydrology Study [ ] Other [ ]				
3	REVIEWED BY:				
4	Is there a project description?				
5	Does the description include the study name, District contract number, consultant name and address?				
6	Does the description include the purpose of the model (floodplain delineation study, channel project, …)?				
7	Are the data sources identified?				
8	Are general assumptions listed?				
9	Are the events being modeled identified (100-year, SPF, multiple year, …)?				
10	Is the project file name appropriate for the project? Names like a, b, job 1, and FIS are not acceptable.				
11	Is there an adequate map that shows the topography, cross sections, thalwegs, labels, floodplain and floodway limits, and left and right bank locations?				
12	Is the version of the hydraulic model used to do the study listed?				
13	Is there a section on Conclusions and Recommendations, and is it adequate?				
SECTION 2: FILES					
1	Note the number of geometry, flow data, and plan files. Should multiple models be created?				
2	Are the file names appropriate?				
3	Do the file names reflect the project name, and what each file includes?				
SECTION 3: FLOW DATA					
1	Are the changes in discharge input at the correct locations, and are the values correct?				
2	For floodplain studies are Floodplain (or FP) and Floodway (or FW) being used for the profile names?				
3	For other studies do the profile names reflect what is being modeled (25-yr, 50-yr, …)?				
4	Are the upstream and downstream boundary conditions appropriate for the model?				
5	Are any internal rating curves or fixed changes in water surface elevations being used?				
SECTION 4: GEOMETRY FILE					
1	Are rivers and reaches named correctly? Names like a, b, and Job 1 are not acceptable.				
2	Are the junction names acceptable?				
3	Are the cross sections identified in river miles for floodplain delineations (feet may be used for Non-FEMA delineations)?				

Checklist 3: HEC-RAS Hydraulics Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
4	Do cross section start and stop locations and length on the map match the geometry file?				
5	Are cross sections oriented with stationing from left to right looking downstream?				
6	Are cross sections stationed using 10,000 at the thalweg?				
7	Are comments included where appropriate in the cross section descriptions?				
8	Are reach lengths measured correctly? They should be measured at the center of the mass of flow.				
9	Are the bank station locations appropriate? Bank stations can be different for different events.				
10	Are contraction/expansion coefficients appropriate? (note: culverts may use larger values than bridges)				
11	Are blocked flow, levees, or ineffective flow being used, and used correctly?				
12	Are the n values appropriate? (for design projects there should be a range of n values)				
13	Are bridges and culverts being modeled correctly? Is there pressure flow, weir flow, or both?				
14	Are any inline weirs or spillways being used?				
15	If yes, are weir coefficients acceptable and are they modeled appropriately?				
16	Are interpolated cross sections being used? If yes, why?				
SECTION 5: CALCULATIONS					
1	Does the plan file have an adequate description?				
2	Are the correct flow and geometry files being used?				
3	Is an appropriate starting WSEL method used and explained, and is it applied correctly?				
4	Are ineffective flow areas identified and addressed appropriately?				
5	Are there any breakouts?				
6	Are bridges and culverts modeled appropriately, including ineffective flow?				
6	Is the correct flow regime (sub, mixed, or super) being used (subcritical only for floodplain studies)?				
8	Are encroachments used?				
9	If encroachments are used, are they applied properly using the water surface or energy grade line and show < 1.0 foot increases at every cross section?				
10	Are the floodplain and floodway delineations done in accordance ADWR State Standards 2-96, 3-94 and 9-02?				
11	Is the flow distribution option turned on, if appropriate?				
12	Is the appropriate method used for conveyance calculations and the friction slope?				
SECTION 6: REPORT FILE					
1	Does the Report File printouts of all the input data including (geometry, flow, plan)?				
2	Are all the profiles included in the output results?				
3	Are appropriate summary tables included?				
SECTION 7: REVIEWING THE RESULTS					

Checklist 3: HEC-RAS Hydraulics Specific Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
1	Check the Froude numbers, does critical flow (or close to critical flow) occur anywhere?				
2	Does at least a portion of the flow occupy the channel?				
3	Is the percentage of flow in the main channel less than 25%? Examine model carefully if yes.				
4	Are there large changes in depth and/or velocity between cross sections?				
SECTION 8: ERRORS					
1	Are there any extended cross sections?				
2	Does divided flow occur?				
SECTION 9: *ADDITIONAL COMMENTS					

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E.5 CHECKLIST 4: TECHNICAL DATA NOTEBOOK CHECKLIST

Checklist 4: Technical Data Notebook Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
SECTION 1: COVER SHEET					
1	Is the Study Name included, and is it correct?				
2	Is the date correct?				
3	Are revision dates included?				
4	Is the consultant's name (address and telephone number) included?				
5	Is the District's contract number included?				
6	Are the cover and Table of Contents sealed by a professional Civil Engineer currently licensed to practice in Arizona?				
SECTION 2: DOCUMENT FORMAT AND LAYOUT					
1	Is the document prepared in accordance with ADWR SS 1-96?				
2	If new topographic mapping, survey notes and data are included, are they sealed by professional Land Surveyor currently licensed to practice in Arizona?				
3	Does the TDN Binder include all the labels and logos of the study partners, including FEMA?				
4	Are Section Corners labeled on the Study Maps?				
SECTION 3: MODEL PRINTOUT					
1	Are printouts from the hydrologic and hydraulic models included? Hydrologic and hydraulic models need to be fully documented in a way that isn't subject to change, therefore printouts of the models must be included in the TDN.				
2	Do the printouts include the input data and the results?				
3	For HEC-RAS models, is a HEC-RAS generated report included?				
4	Do HEC-RAS report files include both the input data and the detailed calculation results? Printouts which contain only HEC-RAS summary tables are not acceptable.				
5	Do the units shown on the flood profiles, such as River Miles, match those used in the hydraulic models?				
6	Are all modeled reaches included in the Floodway tables?				
SECTION 4: COMPACT DISKS					
1	Are electronic copies of the hydrologic and hydraulic models included on CD? (mandatory)? CDs are the only acceptable mediums at this time.				
2	Are all of the input and output files for all computer models used included on CD? (mandatory)? In general the input files shouldn't be zipped, but if space is a problem it is acceptable to zip the output files.				
3	Is the CD labeled with such items as the study name, contract number, consultant's name, date, general description of what is on the CD, the names of all the watercourses studied or the names of all the files on the CD? (mandatory)				
4	Is a "README" file included on the CD, and in ASCII text file format?				

Checklist 4: Technical Data Notebook Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****
5	Does the minimum information in the "README" file include: Name and address of study contractor; name, county and state of the community; name of the hydrologic/hydraulic computer program used; and the name of each input and output file including a model description, stream name and date of creation? The consultant should include additional information as is necessary.				
6	Is a printed copy of the "README" file located in the TDN next to the CD? (mandatory)				
7	In the case of multiple models, is a simple line diagram included depicting the relative location of the models to each other?				
8	Are all file names unique to the project, and worded in a manner related to the project and the scenario(s) being modeled? File names like a, b, c, job 1, floodplain, and FIS are not acceptable types of names and their use should be avoided.				
9	Has the consultant included on the CD scanned images of the final (signed and sealed) drawings or exhibits, original CAD files, the TDN in electronic format, and any other electronic files the consultant may have generated? (not mandatory, but preferred)				
SECTION 5: *ADDITIONAL COMMENTS					

Checklist 4: Technical Data Notebook Checklist					
Item	**Description**	**YES**	**NO**	**N/A**	*****

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F. DATA FOR INDIRECT METHODS

F.1 METHOD 2 USGS DATA LISTING

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
1	1.26	9419623	3	40	104	189	321	517
1	1.79	9338500	21	118	222	334	482	676
1	3.81	9378630	12	62	108	154	209	276
1	4.04	9460150	43	712	1,940	3,690	6,550	11,000
1	4.75	9442630	61	140	191	234	281	332
1	9.33	9442695	226	866	1,420	1,960	2,610	3,400
1	9.87	9406300	144	601	1,010	1,410	1,900	2,490
1	12.10	9369500	103	270	379	471	570	678
1	16.30	9489200	103	245	332	401	474	551
1	16.80	9383600	71	221	331	428	537	660
1	18.80	9408400	68	230	358	475	613	774
1	20.40	9338000	199	375	469	540	612	686
1	23.10	9343500	189	403	526	623	724	829
1	28.90	9383400	163	403	555	681	816	963
1	29.40	9405420	213	589	859	1,100	1,370	1,680
1	31.80	9442660	169	873	1,550	2,230	3,080	4,130
1	34.50	9365500	408	921	1,220	1,460	1,700	1,960
1	35.20	9336000	418	1,620	2,610	3,550	4,670	5,990
1	37.30	9378650	127	590	1,000	1,400	1,880	2,450
1	38.40	9489070	241	925	1,470	1,960	2,540	3,190
1	39.50	9368500	320	802	1,120	1,380	1,670	1,990
1	39.80	9490800	184	323	397	454	513	573
1	44.40	9336400	744	2,390	3,680	4,870	6,260	7,900
1	45.30	9331500	186	592	896	1,170	1,480	1,830
1	46.80	9492400	259	700	1,020	1,310	1,650	2,030
1	67.60	9337000	181	551	807	1,030	1,260	1,530
1	73.10	9430600	847	4,940	9,310	14,000	20,000	27,900
1	75.20	9366000	241	836	1,330	1,790	2,350	3,010
1	78.50	9491000	412	1,020	1,420	1,770	2,160	2,590

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
1	83.40	9383500	93	357	575	777	1,020	1,300
1	90.40	9429900	200	762	1,220	1,630	2,120	2,690
1	95.60	9442692	72	354	615	870	1,180	1,560
1	105.00	9329900	75	417	771	1,140	1,620	2,230
1	105.00	9330500	489	1,550	2,380	3,160	4,070	5,140
1	114.00	9489700	647	2,290	3,610	4,820	6,260	7,920
1	128.00	9346200	1,030	1,820	2,250	2,570	2,900	3,240
1	130.00	9503800	531	1,600	2,370	3,050	3,810	4,660
1	144.00	9386100	269	687	959	1,190	1,440	1,710
1	309.00	9366500	641	2,180	3,440	4,640	6,080	7,800
1	314.00	9489100	1,730	6,260	10,000	13,600	17,900	23,100
1	319.00	9337500	848	2,350	3,340	4,180	5,100	6,090
1	333.00	9442680	841	3,540	6,150	8,840	12,300	16,700
1	419.00	9442740	311	1,310	2,160	2,970	3,930	5,050
1	556.00	9489500	2,160	7,220	11,200	14,800	19,000	23,900
1	711.00	9384000	706	2,640	4,340	5,990	8,040	10,600
2	0.10	9401300	11	47	79	110	147	193
2	0.22	9357200	127	376	548	694	855	1,030
2	0.24	9384200	41	77	96	111	127	142
2	0.27	9404310	13	66	119	173	243	330
2	0.34	9395850	120	158	174	185	195	205
2	0.35	9385800	52	205	339	468	626	816
2	0.37	9395600	72	281	452	609	792	1,000
2	0.71	9403750	4	53	129	230	383	609
2	0.78	9396400	189	558	814	1,040	1,280	1,550
2	0.79	9401245	116	246	321	380	442	506
2	0.98	9379980	68	140	181	213	247	283
2	1.06	9367400	63	312	563	825	1,160	1,600
2	1.27	9395100	36	110	164	212	266	327
2	1.31	9379060	17	80	138	197	272	363
2	1.78	9400560	119	341	496	631	782	950
2	2.05	9367840	273	894	1,350	1,760	2,210	2,730
2	2.20	9368020	125	506	829	1,140	1,500	1,940
2	2.95	9367530	96	337	532	714	931	1,190

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
2	3.16	9403930	22	212	465	763	1,180	1,760
2	3.22	9356400	311	888	1,300	1,660	2,070	2,540
2	3.23	9400910	5	59	138	238	387	598
2	4.68	9367550	125	958	1,970	3,110	4,680	6,770
2	4.75	9383020	18	252	650	1,190	2,030	3,300
2	5.04	9350700	11	76	158	253	386	570
2	5.41	9400580	86	534	1,030	1,560	2,260	3,170
2	5.42	9392800	30	402	1,010	1,810	3,050	4,890
2	5.43	9401210	27	70	99	122	149	177
2	5.93	9400530	66	179	254	318	389	467
2	6.00	9379560	480	1,370	2,010	2,580	3,220	3,940
2	6.18	9400650	40	244	458	684	974	1,340
2	6.40	9400565	340	1,000	1,470	1,880	2,330	2,840
2	7.06	9367900	455	1,720	2,740	3,680	4,760	6,020
2	7.92	9400100	222	849	1,370	1,870	2,460	3,150
2	8.81	9367860	1,080	3,760	5,830	7,690	9,820	12,200
2	9.10	9356520	67	405	765	1,140	1,640	2,260
2	15.40	9408000	150	1,340	2,990	5,010	7,980	12,200
2	16.70	9395200	96	519	950	1,400	1,970	2,700
2	17.80	9363100	214	533	736	905	1,090	1,280
2	19.80	9400290	641	896	1,010	1,090	1,170	1,240
2	20.40	9387050	73	264	422	570	747	957
2	21.60	9367980	146	1,230	2,690	4,460	7,040	10,700
2	22.00	9381100	897	3,270	5,260	7,160	9,450	12,200
2	22.10	9355700	314	1,090	1,690	2,240	2,880	3,620
2	26.70	9367880	1,660	4,110	5,660	6,940	8,310	9,790
2	27.50	9397800	134	473	740	984	1,270	1,600
2	45.70	9367930	805	1,400	1,710	1,940	2,180	2,410
2	56.30	9330120	525	1,880	2,950	3,930	5,070	6,380
2	58.00	9355000	395	907	1,240	1,520	1,840	2,180
2	60.20	9350800	140	751	1,370	2,010	2,840	3,880
2	65.50	9379300	2,200	6,090	8,720	11,000	13,400	16,100
2	68.00	9390500	311	2,570	5,530	9,040	14,000	21,000
2	68.90	9400300	621	1,360	1,800	2,150	2,510	2,900

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
2	74.50	9404450	101	361	582	794	1,050	1,370
2	76.50	9403500	725	1,780	2,450	3,010	3,600	4,240
2	77.40	9379030	740	2,540	3,900	5,110	6,500	8,060
2	90.90	9379800	1,350	3,970	5,790	7,360	9,110	11,100
2	101.00	9403000	433	1,560	2,520	3,430	4,530	5,850
2	113.00	9409100	93	559	1,080	1,660	2,440	3,470
2	136.00	9367561	177	1,750	3,960	6,690	10,700	16,300
2	136.00	9334000	1,190	5,000	8,340	11,600	15,400	20,100
2	148.00	9400583	442	1,110	1,540	1,900	2,290	2,720
2	194.00	9403600	332	1,650	2,920	4,210	5,830	7,830
2	199.00	9381500	2,730	6,210	8,330	10,100	11,900	13,900
2	204.00	9378700	1,100	4,620	7,860	11,100	15,200	20,200
2	251.00	9399400	455	2,490	4,530	6,620	9,270	12,600
2	257.00	9404222	455	1,680	2,690	3,630	4,740	6,050
2	272.00	9397500	1,670	9,940	18,600	27,600	39,200	53,900
2	276.00	9404208	1,640	7,720	13,500	19,200	26,400	35,200
2	277.00	9334500	2,200	5,970	8,510	10,700	13,100	15,700
2	317.00	9404900	800	3,160	5,120	6,940	9,100	11,600
2	318.00	9398500	2,430	12,200	21,600	30,900	42,500	56,800
2	346.00	9372000	920	2,040	2,700	3,240	3,800	4,390
2	478.00	9401110	1,180	2,550	3,370	4,030	4,720	5,450
2	494.00	9395900	2,480	6,010	8,200	9,980	11,900	13,900
2	527.00	9371000	1,110	2,750	3,800	4,680	5,630	6,670
2	549.00	9395500	1,670	6,860	11,300	15,500	20,500	26,500
2	578.00	9367680	593	1,810	2,730	3,570	4,530	5,650
2	607.00	9399000	2,380	13,500	25,300	37,800	54,200	75,200
2	647.00	9381800	2,570	6,790	9,630	12,000	14,700	17,700
2	759.00	9398000	2,550	10,100	16,800	23,300	31,400	41,300
2	812.00	9397100	4,660	7,120	8,310	9,170	10,000	10,900
2	840.00	9393500	2,580	7,690	11,400	14,600	18,200	22,200
2	922.00	9406000	3,770	9,780	13,900	17,300	21,200	25,600
2	1124.00	9403780	864	2,990	4,650	6,170	7,930	9,960
2	1231.00	9401260	3,180	7,170	9,530	11,400	13,400	15,500
2	1362.00	9382000	3,090	8,710	12,500	15,600	19,100	22,800

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
2	1393.00	9401280	6,850	14,600	19,100	22,600	26,300	30,200
2	1450.00	9408150	4,410	10,600	14,400	17,400	20,600	24,000
2	1731.00	9401400	3,560	8,290	11,100	13,400	15,900	18,400
2	1749.00	9386200	441	2,220	4,060	6,030	8,630	12,000
2	1881.00	9401500	3,400	6,650	8,470	9,890	11,400	12,900
2	2160.00	9396100	4,840	12,400	17,200	21,100	25,400	30,000
2	3612.00	9379200	2,060	5,950	8,730	11,200	13,900	17,000
2	3854.00	9413200	3,830	12,000	17,800	22,800	28,500	34,800
2	4370.00	9367950	3,820	6,240	7,430	8,310	9,190	10,100
2	4858.00	9415000	4,560	13,900	21,000	27,500	35,000	43,800
2	7652.00	9394500	3,720	10,500	15,000	18,700	22,900	27,300
3	0.15	9429510	27	92	142	189	242	304
3	0.28	9424050	40	96	130	159	190	223
3	0.44	9520350	17	73	123	172	232	306
3	0.56	9520110	135	223	267	299	331	362
3	0.58	7093	85	344	499	612	719	819
3	0.63	9424700	12	145	348	608	998	1,560
3	0.83	9520300	136	329	450	550	658	775
3	0.84	9517200	106	380	595	790	1,020	1,280
3	0.87	9423350	26	355	930	1,730	3,040	5,090
3	0.91	9428545	41	163	266	361	475	607
3	1.01	9512700	310	702	942	1,140	1,350	1,570
3	1.12	9428570	67	278	461	636	849	1,100
3	1.22	9419590	31	196	382	588	866	1,230
3	1.53	9520230	133	397	584	747	929	1,130
3	1.80	9427700	16	232	597	1,090	1,860	3,030
3	1.83	7113	215	705	1,080	1,420	1,820	2,280
3	1.85	9520160	204	920	1,550	2,160	2,880	3,750
3	1.87	9424430	31	442	1,140	2,090	3,590	5,880
3	2.82	9423300	44	262	495	742	1,060	1,470
3	3.13	9429150	84	484	890	1,310	1,840	2,500
3	3.64	9519600	303	692	929	1,120	1,330	1,540
3	3.92	5588	210	1,250	2,310	3,410	4,820	6,570
3	5.44	9515800	278	1,530	2,790	4,070	5,690	7,710

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
3	6.21	9516600	325	1,240	2,000	2,710	3,570	4,580
3	6.35	9520130	518	1,310	1,800	2,210	2,650	3,110
3	8.41	9423760	31	476	1,270	2,370	4,150	6,890
3	8.64	7083	300	2,180	4,450	7,010	10,500	15,300
3	9.29	9512970	515	1,470	2,130	2,700	3,340	4,050
3	10.80	5583	154	1,090	1,850	2,470	3,120	3,780
3	11.00	9520100	202	929	1,590	2,240	3,030	3,990
3	11.60	9513820	558	1,760	2,390	2,840	3,260	3,640
3	11.80	9535200	1,820	2,740	3,170	3,480	3,770	4,070
3	12.20	9520200	396	827	1,070	1,270	1,470	1,670
3	12.80	9428800	314	1,320	2,170	2,970	3,920	5,040
3	14.60	9428550	323	1,800	3,300	4,850	6,820	9,280
3	14.90	9423900	39	751	2,130	4,140	7,460	12,700
3	17.70	9419680	3	188	793	1,990	4,500	9,450
3	18.30	6953	630	1,950	2,670	3,190	3,690	4,160
3	27.50	9419682	75	1,290	3,510	6,630	11,700	19,500
3	31.70	9419545	151	2,270	6,200	11,900	21,300	36,500
3	49.60	5108	637	1,260	1,600	1,860	2,140	2,420
3	59.20	9418990	10	898	4,390	12,000	29,300	65,400
3	59.80	9512100	367	3,390	7,460	12,300	19,300	28,900
3	59.90	9512860	930	4,490	7,830	11,200	15,300	20,300
3	63.90	9517400	650	1,670	2,360	2,940	3,580	4,290
3	65.00	9513860	940	7,130	14,400	22,400	33,200	47,300
3	66.10	9419647	42	798	2,270	4,430	8,020	13,800
3	68.40	9513780	1,870	12,200	23,400	35,200	50,700	70,300
3	69.50	9519750	528	2,270	3,800	5,260	7,040	9,160
3	72.80	9512280	1,010	8,380	17,500	27,800	42,000	60,700
3	84.70	9517280	1,150	4,050	6,280	8,290	10,600	13,200
3	84.70	9513800	2,760	13,500	23,700	33,800	46,300	61,600
3	109.00	7013	1,080	8,960	18,900	30,200	45,900	67,100
3	118.00	7043	534	4,130	8,760	14,200	22,100	32,900
3	123.00	9512300	1,540	7,880	13,900	20,000	27,500	36,700
3	126.00	9519760	576	2,110	3,330	4,460	5,770	7,280
3	138.00	9516800	1,040	7,510	15,000	23,300	34,400	48,900

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
3	153.00	9516790	699	2,620	4,150	5,540	7,150	9,000
3	186.00	9513835	2,360	13,700	25,300	37,400	52,800	72,100
3	244.00	9520170	2,980	6,300	8,250	9,810	11,500	13,200
3	253.00	9417300	224	2,520	6,170	11,000	18,600	30,100
3	345.00	6833	568	2,420	3,580	4,450	5,290	6,090
3	375.00	9404343	1,240	7,620	14,600	22,000	31,800	44,400
3	416.00	9515500	4,040	18,400	31,100	43,400	58,300	76,100
3	416.00	5308	2,520	17,500	34,600	53,400	78,400	111,000
3	418.00	9514200	884	3,900	6,570	9,150	12,300	16,000
3	579.00	9535100	1,000	3,720	6,060	8,310	11,100	14,400
3	606.00	9513890	3,370	19,900	37,100	55,100	78,300	108,000
3	623.00	9513910	1,780	14,500	30,100	47,700	71,700	104,000
3	709.00	5228	2,600	17,200	33,400	50,800	73,800	103,000
3	773.00	9423820	1,970	9,880	17,400	24,900	34,300	45,800
3	796.00	9516500	3,070	16,200	29,200	42,500	59,400	80,400
3	1111.00	9512800	6,650	31,700	55,700	79,900	110,000	148,000
3	1290.00	9535300	897	2,630	3,960	5,170	6,590	8,250
3	1423.00	9517000	2,800	13,700	24,100	34,500	47,600	63,500
3	1433.00	9425500	2,930	19,900	38,600	58,500	84,500	118,000
3	1681.00	9517490	681	6,820	15,300	25,400	39,900	60,000
3	3854.00	9416000	210	1,120	2,120	3,230	4,740	6,770
4	0.11	9451800	15	58	93	126	164	210
4	0.17	9504800	3	48	130	243	425	704
4	0.53	9505900	20	145	293	457	679	970
4	0.73	9451900	102	262	368	456	553	658
4	0.85	9504100	3	59	180	366	691	1,230
4	0.86	9468300	22	247	576	985	1,590	2,430
4	0.98	9512420	173	470	677	855	1,050	1,280
4	1.08	9498503	10	98	219	366	577	871
4	1.11	9456680	78	355	601	840	1,130	1,470
4	1.16	9456820	69	221	335	439	558	695
4	1.19	9504400	104	343	527	694	886	1,110
4	1.20	9455800	95	232	317	387	462	542
4	1.36	9505220	39	227	438	674	994	1,420

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
4	1.76	9462200	444	785	960	1,090	1,230	1,360
4	2.34	9424410	14	185	461	823	1,380	2,210
4	2.72	9510170	92	300	456	595	753	933
4	3.96	9430300	99	291	431	554	693	851
4	4.51	9510100	43	427	973	1,650	2,650	4,070
4	4.60	9496800	284	1,020	1,610	2,170	2,820	3,600
4	4.62	9510070	38	502	1,260	2,260	3,810	6,120
4	4.67	9458200	72	381	704	1,050	1,500	2,090
4	4.76	9507700	92	536	1,020	1,550	2,250	3,170
4	6.35	9507600	295	1,780	3,440	5,260	7,700	10,900
4	6.55	9498900	264	1,480	2,700	3,970	5,570	7,570
4	8.18	9424480	139	917	1,820	2,820	4,180	5,980
4	9.83	9510080	67	959	2,470	4,510	7,700	12,500
4	14.50	9503750	240	1,600	3,170	4,910	7,270	10,400
4	15.00	9456400	495	1,900	3,060	4,130	5,400	6,880
4	15.20	9510180	999	2,540	3,560	4,420	5,360	6,400
4	25.10	9505300	767	2,850	4,520	6,050	7,840	9,910
4	29.20	9501300	1,030	5,210	9,190	13,200	18,100	24,100
4	30.20	9502960	1,530	3,220	4,220	5,010	5,850	6,730
4	34.60	9467120	790	2,790	4,370	5,820	7,500	9,450
4	36.30	9508300	1,430	6,920	12,000	17,100	23,300	30,800
4	36.40	9498501	550	2,920	5,400	8,050	11,500	16,000
4	39.40	9503000	1,180	3,320	4,730	5,910	7,190	8,580
4	51.00	9505250	693	3,120	5,390	7,660	10,500	14,000
4	52.40	9510150	840	4,850	9,060	13,500	19,300	26,700
4	77.80	5352	560	4,430	9,110	14,400	21,500	31,000
4	83.50	9438200	641	1,930	2,840	3,640	4,520	5,510
4	89.30	9512600	1,730	5,490	8,260	10,700	13,500	16,600
4	102.00	9498502	1,400	5,480	8,990	12,400	16,500	21,400
4	107.00	9445500	665	2,000	2,970	3,820	4,780	5,870
4	109.00	9505200	3,040	7,510	10,300	12,700	15,200	17,900
4	123.00	9498870	3,290	10,400	16,000	21,200	27,200	34,300
4	135.00	9424200	3,680	7,060	8,880	10,300	11,700	13,100
4	142.00	9505350	3,430	13,700	22,200	30,200	39,600	50,600

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
4	155.00	9446000	1,290	4,430	6,860	9,060	11,600	14,500
4	164.00	9510200	2,480	12,700	22,400	32,100	44,200	59,000
4	194.00	9431130	785	3,430	5,730	7,920	10,600	13,700
4	195.00	9498400	1,350	3,510	4,930	6,120	7,410	8,810
4	200.00	9497980	1,600	8,690	15,800	23,100	32,400	43,900
4	206.00	9496000	1,110	7,870	15,700	24,500	36,200	51,700
4	226.00	9430900	3,070	6,180	7,880	9,180	10,500	11,900
4	233.00	9504420	2,890	12,300	20,500	28,400	37,900	49,400
4	241.00	9505800	3,710	13,100	20,400	27,100	34,800	43,600
4	255.00	9502800	1,520	7,600	13,400	19,300	26,700	35,800
4	290.00	9497800	3,840	10,400	14,700	18,300	22,200	26,400
4	302.00	9447800	1,150	6,510	12,200	18,200	26,100	36,200
4	326.00	9507980	4,380	14,900	22,800	29,900	38,100	47,300
4	355.00	9504500	4,430	17,700	28,600	38,700	50,500	64,100
4	383.00	9446500	2,550	9,780	15,900	21,700	28,600	36,900
4	433.00	9498800	8,750	34,000	55,200	75,100	98,800	127,000
4	441.00	9496500	2,700	12,200	20,700	28,800	38,700	50,500
4	505.00	9444200	3,430	11,500	17,800	23,700	30,500	38,400
4	585.00	9512500	5,430	16,100	23,700	30,400	37,900	46,300
4	611.00	9424447	9,670	49,100	87,300	126,000	174,000	234,000
4	621.00	9447000	2,630	13,700	24,400	35,200	48,600	65,100
4	628.00	9494000	2,910	8,190	12,100	15,700	19,800	24,500
4	672.00	9499000	11,100	34,400	50,900	65,300	81,300	99,000
4	823.00	9456000	4,150	4,900	5,190	5,390	5,580	5,750
4	1026.00	9468500	6,930	25,300	39,400	52,100	66,500	82,900
4	1130.00	9424900	4,610	16,800	26,400	35,100	45,300	57,100
4	1224.00	9490500	6,710	29,900	50,400	69,900	93,500	122,000
4	1856.00	9430500	2,120	11,300	21,100	31,500	45,300	63,300
4	2149.00	9503700	1,300	8,490	16,700	25,800	38,200	54,400
4	2243.00	9457000	4,500	9,800	13,000	15,600	18,300	21,200
4	2433.00	9431000	5,660	13,700	18,500	22,400	26,500	30,800
4	2562.00	9424450	8,610	39,100	66,300	92,600	125,000	163,000
4	2765.00	9444500	6,550	30,000	51,800	73,400	100,000	133,000
4	2828.00	9431500	5,940	17,100	25,400	32,800	41,400	51,300

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
4	2831.00	9497500	9,810	37,800	62,300	86,000	115,000	150,000
4	3143.00	9504000	5,210	22,200	37,200	51,700	69,200	90,100
4	3200.00	9432000	5,300	18,100	28,000	37,000	47,400	59,400
4	4007.00	9442000	5,850	16,900	25,100	32,400	40,900	50,600
4	4289.00	9498500	14,700	53,800	85,100	114,000	147,000	186,000
4	4650.00	9506000	8,800	42,500	75,100	108,000	150,000	202,000
4	5499.00	9508500	14,200	53,500	84,700	113,000	146,000	184,000
4	7888.00	9448500	9,490	39,200	65,900	92,100	125,000	164,000
5	0.15	9481800	25	86	132	174	223	279
5	0.21	9471087	107	329	491	633	795	977
5	0.34	9486700	141	308	410	493	583	679
5	0.38	9478600	67	194	283	361	448	546
5	0.39	9479200	43	193	326	454	610	796
5	0.47	9483040	113	254	338	406	476	551
5	0.66	9536350	45	160	251	333	430	540
5	0.68	9487140	183	502	717	899	1,100	1,320
5	0.80	9482330	97	283	412	523	646	782
5	0.90	9536100	145	318	422	505	594	687
5	1.70	9487400	168	534	806	1,050	1,320	1,640
5	1.91	9483200	91	347	554	744	966	1,220
5	1.95	9485950	109	436	712	973	1,280	1,650
5	2.37	9471700	180	729	1,200	1,640	2,170	2,800
5	3.08	9471120	320	1,530	2,640	3,720	5,050	6,660
5	3.14	9482480	60	683	1,610	2,770	4,470	6,910
5	3.34	9483300	186	381	489	573	659	747
5	3.59	9471180	155	741	1,280	1,820	2,480	3,280
5	3.59	9473200	487	2,320	4,040	5,760	7,900	10,500
5	4.16	9470750	8	112	276	487	805	1,270
5	4.43	9473600	350	767	1,020	1,230	1,450	1,680
5	4.95	9485900	67	259	418	566	742	948
5	5.24	9471195	239	1,420	2,630	3,890	5,500	7,510
5	5.70	9471130	567	2,090	3,330	4,490	5,860	7,470
5	6.33	9484510	141	240	288	324	359	395
5	6.38	9471080	354	995	1,440	1,820	2,250	2,720

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
5	7.11	2170	414	2,190	3,930	5,680	7,870	10,600
5	7.22	9470900	367	1,670	2,810	3,890	5,180	6,680
5	8.60	9470800	26	212	443	706	1,070	1,550
5	9.19	9471110	369	1,570	2,600	3,590	4,770	6,170
5	9.21	9471090	500	1,670	2,550	3,340	4,240	5,250
5	9.80	9482350	179	888	1,560	2,240	3,080	4,110
5	10.30	9481700	290	1,040	1,630	2,170	2,780	3,490
5	12.00	9488600	302	1,220	2,010	2,770	3,690	4,780
5	12.80	9487100	839	2,660	4,060	5,320	6,790	8,490
5	13.00	9482370	156	852	1,540	2,240	3,120	4,220
5	13.90	9484580	817	1,520	1,890	2,180	2,460	2,760
5	14.80	9478200	420	2,150	3,820	5,510	7,620	10,200
5	16.90	9484200	358	942	1,330	1,660	2,020	2,410
5	19.60	9482420	422	1,140	1,620	2,020	2,470	2,950
5	23.00	2070	476	2,650	4,840	7,090	9,940	13,500
5	24.00	9482200	573	1,580	2,280	2,900	3,590	4,370
5	34.10	9486590	83	1,260	3,290	6,040	10,400	17,000
5	35.20	9484000	1,240	5,350	8,920	12,300	16,400	21,200
5	36.10	9471140	1,100	3,490	5,200	6,680	8,350	10,200
5	37.10	9482450	222	751	1,170	1,550	1,990	2,510
5	38.60	9484570	838	4,670	8,760	13,200	19,000	26,600
5	42.20	1080	551	2,110	3,490	4,840	6,500	8,540
5	43.10	9483100	1,440	4,880	7,560	10,000	12,900	16,200
5	43.20	2090	1,550	9,450	18,000	27,200	39,300	54,800
5	43.30	9471190	1,040	4,260	7,050	9,740	13,000	16,900
5	44.70	9485000	842	5,050	9,350	13,800	19,400	26,300
5	50.40	4310	1,960	3,220	3,840	4,290	4,730	5,170
5	50.40	9484590	1,620	5,110	7,660	9,900	12,400	15,300
5	57.10	9471200	951	3,830	6,150	8,270	10,700	13,500
5	64.80	1100	489	3,420	6,800	10,500	15,500	22,100
5	78.80	9537200	530	3,240	6,150	9,230	13,200	18,400
5	82.00	9480000	1,320	4,760	7,410	9,790	12,500	15,600
5	143.00	9478500	3,250	11,900	19,000	25,800	33,800	43,300
5	148.00	9488650	1,010	5,760	10,800	16,100	23,100	32,000

Table F.1 USGS stream gage LP3 data listing

with drainage areas between 0.1 and 10,000 square miles

(sorted by Flood Region then by drainage area in ascending order)

Flood Region	Drainage Area sq. miles	Gage No.	LP3 Data From Paretti, Kennedy, Turney and Veilleux (2014), cfs					
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
5	156.00	9471380	1,940	5,860	8,710	11,200	14,100	17,300
5	166.00	9481750	1,970	6,490	9,960	13,100	16,700	20,900
5	209.00	9481500	2,950	7,380	10,200	12,600	15,200	18,000
5	220.00	9484500	3,340	10,300	15,400	19,900	25,100	30,900
5	250.00	9486300	2,930	10,700	16,800	22,300	28,800	36,200
5	289.00	9484560	2,080	6,750	10,400	13,800	17,800	22,500
5	289.00	4280	831	4,850	8,950	13,200	18,500	25,200
5	303.00	9471400	1,310	4,930	7,980	10,900	14,400	18,600
5	456.00	9484600	2,670	10,500	16,900	22,800	29,600	37,500
5	466.00	9486800	3,580	8,940	12,400	15,300	18,500	22,000
5	532.00	9480500	3,540	10,300	15,100	19,400	24,200	29,700
5	538.00	9473000	3,970	11,900	17,800	23,100	29,300	36,300
5	599.00	9485500	2,150	9,880	16,900	23,800	32,100	42,200
5	738.00	9470500	5,560	13,300	18,200	22,200	26,400	31,000
5	785.00	9487000	3,420	9,410	13,500	17,100	21,000	25,400
5	905.00	9486000	5,050	13,400	18,900	23,500	28,400	33,800
5	1199.00	9487250	1,220	6,880	12,700	18,700	26,500	36,300
5	1213.00	9481740	2,330	7,300	11,100	14,500	18,500	23,100
5	1216.00	9471000	5,990	16,600	24,400	31,400	39,500	48,800
5	1673.00	9482000	3,210	11,700	18,600	25,200	33,000	42,300
5	1729.00	9471550	5,560	16,700	24,900	32,300	40,700	50,300
5	1734.00	9488500	1,490	7,620	13,800	20,200	28,400	38,700
5	2046.00	6040	3,460	13,900	22,600	30,900	40,700	52,200
5	2192.00	9482500	5,300	13,900	19,700	24,500	29,900	35,700
5	2487.00	9471800	6,460	17,100	24,300	30,500	37,500	45,200
5	2925.00	9472000	6,730	20,700	30,800	39,800	50,000	61,500
5	3461.00	9486500	8,380	19,800	27,300	33,700	40,800	48,500
5	3566.00	9486520	5,110	13,800	19,500	24,300	29,600	35,300
5	4451.00	9473500	7,980	25,000	38,000	49,700	63,400	79,100

F.2 METHOD 3 USGS DATA LISTING

The following is a description of each field in Table F.2:

Gage ID: The USGS or cooperating technical partner gage number.

Gage Location: Gage name and location.

Flood Region: The USGS regression equations flood region. Refer to Section 7.11 for a location map.

Area: The area of the watershed upstreram of the gage in square miles.

Location: The latitude and longitude of the gage location.

Elevation: The mean elevation of the upstream watershed. The independent variable *ELEV* is the elevastion divided by 1,000.

PRECIP: The independent variable average annual precipitation of the upstream watershed in inches.

Used: If "Yes", the gage was used in the generation of the regression equations. If "No", the gage was not used.

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9419623	Deer Creek near Charleston Park, NV	1	1.26	36.31246	-115.62029	9,680	26.2	Yes
9489080	Hannagan Creek near Hannagan Meadow, AZ	1	1.74	33.64728	-109.28952	9,040	32.1	No
9338500	East Fork Deer Creek near Boulder, UT	1	1.79	38.00138	-111.38962	9,440	19.8	Yes
9378630	Recapture Creek near Blanding, UT	1	3.81	37.75555	-109.47651	8,680	25.7	Yes
9460150	Frye Creek near Thatcher, AZ	1	4.04	32.74396	-109.83814	8,130	33.6	No
9442630	Mail Hollow near Luna, NM	1	4.75	33.79389	-108.95028	7,780	20.8	Yes
9419610	Lee Canyon near Charleston Park, NV	1	9.25	36.34030	-115.65223	9,170	21.1	No
9442695	Negro Canyon at Aragon, NM	1	9.33	33.88339	-108.55062	7,660	15.8	No
9406300	Kanarra Creek at Kanarraville, UT	1	9.87	37.53803	-113.16856	7,770	20.1	Yes
9415515	Water Canyon Creek near Preston, NV	1	10.70	38.98772	-114.95835	8,080	16.5	No

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9369500	Middle Mancos River near Mancos, CO	1	12.10	37.37389	-108.23064	9,390	30.7	Yes
9395400	Milk Ranch Canyon near Ft. Wingate, NM	1	14.40	35.43194	-108.55500	7,870	18.5	No
9489200	Pacheta Creek at Maverick, AZ	1	16.30	33.73977	-109.54064	8,600	32.9	Yes
9383600	Fish Creek near Eagar, AZ	1	16.80	34.07644	-109.46315	9,150	30.2	Yes
9408400	Santa Clara River near Pine Valley, UT	1	18.80	37.38331	-113.48329	8,640	25.4	Yes
9338000	East Fork Boulder Creek near Boulder, UT	1	20.40	38.04193	-111.45017	10,700	23.8	Yes
9343500	Rito Blanco near Pagosa Springs, CO	1	23.10	37.19362	-106.90531	9,270	33.0	Yes
9383400	Little Colorado River at Greer, AZ	1	28.90	34.01671	-109.45731	9,440	32.8	Yes
9405420	North Fork Virgin River below Bulloch Canyon near Glendale, UT	1	29.40	37.41831	-112.80049	7,820	20.7	Yes
9442660	Trout Creek at Luna, NM	1	31.80	33.84611	-108.95167	8,630	24.1	Yes
9365500	La Plata River at Hesperus, CO	1	34.50	37.28972	-108.04063	10,200	38.8	Yes
9336000	Birch Creek near Escalante, UT	1	35.20	37.76249	-111.73824	8,380	18.8	Yes
9419640	Kyle Canyon near Charleston Park, NV	1	35.40	36.27774	-115.47029	7,850	22.0	No
9378650	Recapture Creek below Johnson Creek near Blanding, UT	1	37.30	37.68083	-109.46262	7,920	21.9	Yes
9489070	North Fork Of East Fork Black River near Alpine, AZ	1	38.40	33.90311	-109.32286	9,050	28.9	Yes
9368500	West Mancos River near Mancos, CO	1	39.50	37.38166	-108.25814	9,700	33.6	Yes
9490800	North Fork White River near Greer, AZ	1	39.80	34.01394	-109.64232	9,520	36.4	Yes
9336400	Upper Valley Creek near Escalante, UT	1	44.40	37.73332	-111.71740	7,800	15.3	Yes
9331500	Ivie Creek above Diversions near Emery, UT	1	45.30	38.75831	-111.42157	8,790	18.9	Yes
9492400	East Fork White River near Fort Apache, AZ	1	46.80	33.82227	-109.81454	8,420	35.5	Yes
9337000	Pine Creek near Escalante, UT	1	67.60	37.86249	-111.63601	9,380	21.3	Yes
9338900	Deer Creek near Boulder, UT	1	68.60	37.85332	-111.35517	7,720	14.1	No
9430600	Mogollon Creek near Cliff, NM	1	73.10	33.16667	-108.64972	7,790	26.5	No
9366000	Cherry Creek near Red Mesa, CO	1	75.20	37.11889	-108.19869	7,840	21.2	Yes
9491000	North Fork White River near McNary, AZ	1	78.50	34.04588	-109.73816	9,260	37.7	Yes

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9383500	Nutrioso Creek above Nelson Res near Springerville, AZ	1	83.40	34.03033	-109.18647	8,530	23.4	Yes
9429900	Snow creek near Mogollon, NM	1	90.40	33.41395	-108.49506	8,100	22.0	Yes
9442692	Tularosa River above Aragon, NM	1	95.60	33.89144	-108.51562	7,710	16.4	No
9329900	Pine Creek near Bicknell, UT	1	105.00	38.26943	-111.58407	9,340	19.2	Yes
9330500	Muddy Creek near Emery, UT	1	105.00	38.98192	-111.24934	8,920	23.5	Yes
9442700	Apache Creek near Apache Creek, NM	1	112.00	33.93061	-108.66312	7,770	17.2	No
9489700	Big Bonito Creek near Fort Apache, AZ	1	114.00	33.66727	-109.84676	8,080	31.3	Yes
9346200	Rio Amargo at Dulce, NM	1	128.00	36.93258	-106.99857	7,650	--	Yes
9503800	Volunteer Wash near Bellemont, AZ	1	130.00	35.15057	-111.89905	7,550	23.4	Yes
9386100	Largo Creek near Quemado, NM	1	144.00	34.32333	-108.52750	8,000	15.4	Yes
9366500	La Plata River at Colorado-NM, State Line	1	309.00	36.99972	-108.18869	7,600	20.2	Yes
9489100	Black River near Maverick, AZ	1	314.00	33.70755	-109.44731	8,540	28.7	Yes
9337500	Escalante River near Escalante, UT	1	319.00	37.77804	-111.57462	8,120	16.8	Yes
9442680	San Francisco River near Reserve, NM	1	333.00	33.73672	-108.77118	7,800	21.0	Yes
9442740	Tularosa River near Reserve, NM	1	419.00	33.73222	-108.70250	7,580	18.1	No
9489500	Black River below Pumping Plant near Point of Pines, AZ	1	556.00	33.47672	-109.76398	8,060	27.7	No
9384000	Little Colorado River above Lyman Lake near St. Johns, AZ	1	711.00	34.31449	-109.36232	7,830	18.4	Yes
9401300	Hamblin Wash Tributary near Cedar Ridge, AZ	2	0.10	36.34860	-111.50487	5,890	7.6	Yes
9400200	Steamboat Wash Tributary near Ganado, AZ	2	0.17	35.76390	-109.80067	6,780	11.4	No
9357200	Gallegos Canyon Tributary near Nageezi, NM	2	0.22	36.41652	-107.86324	6,930	--	Yes
9384200	Lyman Reservoir Tributary near St Johns, AZ	2	0.24	34.39171	-109.38065	6,100	11.6	No
9404310	Yampai Canyon Tributary near Peach Springs, AZ	2	0.27	35.55194	-113.38882	5,330	11.8	Yes
9357230	West Draw near Farmington, NM	2	0.31	36.59091	-108.18517	5,960	--	No
9395850	Black Creek Tributary near Window Rock, AZ	2	0.34	35.65419	-109.08954	6,800	11.2	Yes
9385800	Little Colorado River Tributary near St Johns, AZ	2	0.35	34.45115	-109.25704	6,350	11.1	Yes
9395600	Wagon Trail Wash near Gamerco, NM	2	0.37	35.65002	-108.78397	6,700	12.4	Yes

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9403750	Sagebrush Draw near Fredonia, AZ	2	0.71	36.90138	-112.37714	5,280	11.8	Yes
9396400	Dead Wash Tributary near Holbrook, AZ	2	0.78	35.07502	-109.75067	5,710	10.6	Yes
9401245	Klethla Valley Tributary near Kayenta, AZ	2	0.79	36.49805	-110.62153	6,740	11.5	Yes
9379980	Jack Bench Wash Tributary near Page, AZ	2	0.98	36.71388	-111.59238	6,170	9.4	Yes
9367400	La Plata River Tributary near Farmington, NM	2	1.06	36.78611	-108.22600	5,650	9.9	Yes
9395100	Carr Lake Draw Tributary near Holbrook, AZ	2	1.27	34.83475	-109.93400	5,460	10.2	Yes
9379060	Lukachukai Creek Tributary near Lukachukai, AZ	2	1.31	36.46945	-109.40622	5,830	8.9	Yes
9379100	Long House Wash near Kayenta, AZ	2	1.31	36.56722	-110.48875	6,960	12.2	No
9400560	Oraibi Wash Tributary near Oraibi, AZ	2	1.78	35.87223	-110.55625	5,970	10.0	Yes
9400680	Switzer Canyon at Flagstaff, AZ	2	1.99	35.21223	-111.63988	7,130	21.7	No
9367840	Yazzie Wash near Mexican Springs, NM	2	2.05	35.84374	-108.88610	7,210	13.5	Yes
9368020	Malpais Arroyo near Shiprock, NM	2	2.20	36.92583	-108.72500	5,330	9.0	Yes
9403800	Bitter Seeps Wash Tributary near Fredonia, AZ	2	2.34	36.85693	-112.75909	5,230	13.0	No
9367530	Locke Arroyo near Kirtland, NM	2	2.95	36.73826	-108.29235	5,500	9.3	Yes
9403930	West Cataract Creek near Williams, AZ	2	3.16	35.24779	-112.22517	7,210	23.1	Yes
9356400	Manzanares Canyon near Turley, NM	2	3.22	36.73657	-107.70622	6,460	--	Yes
9400910	Fay Canyon near Flagstaff, AZ	2	3.23	35.13501	-111.63071	7,020	24.0	Yes
9367550	Stevens Arroyo near Kirtland, NM	2	4.68	36.76667	-108.37008	5,470	9.0	Yes
9383020	House Rock Wash Tributary near Marble Canyon, AZ	2	4.75	36.70138	-111.92989	5,960	12.1	Yes
9404050	Spring Valley Wash Tributary near Williams, AZ	2	4.91	35.57444	-112.15405	6,130	11.8	No
9350700	Ruben Canyon near Gobernador, NM	2	5.04	36.74083	-107.24028	7,280	--	No
9400580	Castle Butte Wash near Winslow, AZ	2	5.41	35.32501	-110.42291	5,810	9.7	Yes
9392800	Long Lake Tributary near Show Low, AZ	2	5.42	34.26115	-109.99539	6,770	22.4	Yes
9401210	Slate Mountain Wash near Flagstaff, AZ	2	5.43	35.51528	-111.83544	7,350	19.7	No
9400530	Cow Canyon near Winslow, AZ	2	5.93	35.10002	-110.98820	5,420	9.8	Yes
9379560	El Capitan Wash near Kayenta, AZ	2	6.00	36.85889	-110.26597	5,650	7.8	Yes

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9400650	Sinclair Wash at Flagstaff, AZ	2	6.18	35.16390	-111.68072	7,150	23.0	Yes
9400565	Polacca Wash Tributary near Chinle, AZ	2	6.40	36.04723	-110.08123	6,860	10.7	Yes
9367900	Black Springs Wash near Mexican Springs, NM	2	7.06	35.75917	-108.81639	6,790	11.4	Yes
9400100	Ganado Wash Tributary near Ganado, AZ	2	7.92	35.71113	-109.49788	6,740	12.2	Yes
9367860	Chusca Wash near Mexican Springs, NM	2	8.81	35.81058	-108.85008	7,250	13.3	No
9356520	Burro Canyon near Lindrith, NM	2	9.10	36.27250	-107.24667	7,250	--	Yes
9408000	Leeds Creek near Leeds, UT	2	15.40	37.26748	-113.37078	6,320	17.9	Yes
9395200	Decker Wash near Snowflake, AZ	2	16.70	34.46115	-110.40484	6,700	19.6	Yes
9363100	Salt Creek near Oxford, CO	2	17.80	37.13973	-107.75340	6,760	16.9	Yes
9400290	Teshbito Wash Tributary near Holbrook, AZ	2	19.80	35.48057	-110.08818	6,320	11.6	Yes
9387050	Galestena Canyon Tributary near Black Rock, NM	2	20.40	34.97139	-108.67028	7,410	15.3	Yes
9367980	Rattlesnake Arroyo near Shiprock, NM	2	21.60	36.77055	-108.72620	5,230	7.9	Yes
9381100	Henrieville Creek at Henrieville, UT	2	22.00	37.56665	-111.98408	7,170	13.1	Yes
9355700	Gobernador Canyon near Gobernador, NM	2	22.10	36.68444	-107.42000	6,740	--	Yes
9367880	Catron Wash near Mexican Springs, NM	2	26.70	35.77080	-108.82893	7,090	13.0	Yes
9397800	Brookbank Canyon near Heber, AZ	2	27.50	34.47226	-110.64790	6,960	22.5	Yes
9367930	Hunter Wash at Bisti Trading Post, NM	2	45.70	36.27649	-108.25476	6,180	9.4	Yes
9330120	Sulphur Creek near Fruita, UT	2	56.30	38.29998	-111.26739	7,310	11.8	Yes
9355000	Spring Creek at La Boca, CO	2	58.00	37.01528	-107.59533	6,940	17.4	Yes
9350800	Vaqueros Canyon near Gobernador, NM	2	60.20	36.72306	-107.27972	7,390	--	Yes
9379300	Lime Creek near Mexican Hat, UT	2	65.50	37.21667	-109.81735	5,370	8.6	Yes
9390500	Show Low Creek near Lakeside, AZ	2	68.00	34.17949	-109.98789	7,290	27.6	Yes
9400300	Teshbito Wash near Holbrook, AZ	2	68.90	35.44862	-110.06873	6,170	11.4	Yes
9404450	East Fork Virgin River near Glendale, UT	2	74.50	37.33943	-112.60438	7,260	18.0	Yes
9403500	Kanab Creek near Glendale, UT	2	76.50	37.28332	-112.48410	7,220	18.0	Yes
9379030	Black Mountain Wash near Chinle, AZ	2	77.40	36.33334	-109.62428	5,910	8.3	Yes
9379800	Coyote Creek near Kanab, UT	2	90.90	37.13332	-111.75073	5,030	9.7	Yes

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9403000	Bright Angel Creek near Grand Canyon, AZ	2	101.00	36.10304	-112.09628	7,310	22.1	Yes
9409100	Santa Clara River above Baker Reservoir near Central, UT	2	113.00	37.38470	-113.63191	7,400	21.7	Yes
9334000	North Wash near Hanksville (Hite), UT	2	136.00	37.89860	-110.44931	5,440	7.6	Yes
9367561	Shumway Arroyo near Waterflow, NM	2	136.00	36.77333	-108.44119	5,780	10.8	Yes
9400583	Jeddito Wash near Jeddito, AZ	2	148.00	35.57751	-110.46235	6,370	10.8	Yes
9403600	Kanab Creek near Kanab, UT	2	194.00	37.10054	-112.54798	6,530	16.8	Yes
9381500	Paria River near Cannonville, UT	2	199.00	37.48110	-112.02158	6,910	13.0	Yes
9378700	Cottonwood Wash near Blanding, UT	2	204.00	37.56055	-109.57874	6,810	15.3	Yes
9399400	Jacks Canyon Creek near Winslow, AZ	2	251.00	34.92141	-110.79764	6,500	19.1	Yes
9404222	Spencer Creek near Peach Springs, AZ	2	257.00	35.80082	-113.65883	4,780	12.8	Yes
9397500	Chevelon Fork below Wildcat Canyon near Winslow, AZ	2	272.00	34.63642	-110.71430	7,070	24.8	No
9404208	Diamond Creek near Peach Springs, AZ	2	276.00	35.76499	-113.36827	4,920	12.0	Yes
9334500	White Canyon near Hanksville, UT	2	277.00	37.79860	-110.37653	6,080	11.8	Yes
9404900	East Fork Virgin River near Springdale, UT	2	317.00	37.16415	-112.95855	6,350	16.7	Yes
9398500	Clear Creek below Willow Creek near Winslow, AZ	2	318.00	34.66753	-111.00763	7,170	27.0	No
9372000	McElmo Creek near Colorado-Utah State Line	2	346.00	37.32416	-109.01567	6,410	14.9	Yes
9379180	Laguna Creek at Dennehotso, AZ	2	454.00	36.85389	-109.84595	6,050	9.1	No
9401110	Dinnebito Wash near Sand Springs, AZ	2	478.00	35.78111	-110.93320	6,300	10.4	Yes
9395900	Black Creek near Lupton, AZ	2	494.00	35.45252	-109.12648	7,410	14.5	Yes
9371000	Mancos River near Towaoc, CO	2	527.00	37.02749	-108.74148	7,220	19.0	Yes
9395500	Puerco River at Gallup, NM	2	549.00	35.52919	-108.74536	7,280	14.6	Yes
9401220	Cedar Wash near Cameron, AZ	2	555.00	35.85861	-111.44292	6,330	13.2	No
9367680	Chaco Wash at Chaco Canyon National Monument, NM	2	578.00	36.02837	-107.91898	6,720	10.5	Yes
9399000	Clear Creek near Winslow, AZ	2	607.00	34.96947	-110.64513	6,560	20.8	No
9381800	Paria River near Kanab, UT	2	647.00	37.10748	-111.90601	6,330	12.1	No
9400562	Oraibi Wash near Tolani Lake, AZ	2	665.00	35.57973	-110.77403	6,280	10.4	No

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9398000	Chevelon Creek near Winslow, AZ	2	759.00	34.92641	-110.53152	6,550	19.5	No
9397100	Leroux Wash near Holbrook, AZ	2	812.00	34.90503	-110.20151	6,150	11.5	Yes
9393500	Silver Creek near Snowflake, AZ	2	840.00	34.66670	-110.04234	6,350	18.0	Yes
9400568	Polacca Wash near Second Mesa, AZ	2	912.00	35.65584	-110.56208	6,410	10.1	No
9406000	Virgin River at Virgin, UT	2	922.00	37.20415	-113.18078	6,450	18.3	Yes
9403780	Kanab Creek near Fredonia, AZ	2	1,120.00	36.86388	-112.57992	6,000	15.0	Yes
9401260	Moenkopi Wash at Moenkopi, AZ	2	1,230.00	36.10499	-111.20181	6,120	9.7	No
9382000	Paria River at Lees Ferry, AZ	2	1,360.00	36.87221	-111.59461	6,140	11.9	Yes
9401280	Moenkopi Wash near Tuba, AZ	2	1,390.00	36.10499	-111.20181	6,040	9.5	No
9408150	Virgin River near Hurricane, UT	2	1,450.00	37.16276	-113.39523	6,080	--	No
9401400	Moenkopi Wash near Tuba City, AZ	2	1,730.00	36.02360	-111.39736	5,890	9.1	No
9386200	Carrizo Creek near Salt Lake, NM	2	1,750.00	34.51088	-109.02703	7,290	13.6	Yes
9401500	Moenkopi Wash near Cameron, AZ	2	1,880.00	35.92499	-111.42153	5,810	8.9	No
9386250	Carrizo Wash near St. Johns, AZ	2	2,140.00	34.61476	-109.31843	7,120	13.3	No
9396100	Puerco River near Chambers, AZ	2	2,160.00	35.18225	-109.44705	7,000	13.6	No
9379200	Chinle Creek near Mexican Water, AZ	2	3,610.00	36.94389	-109.71067	6,240	10.1	Yes
9413200	Truxton wash near Valentine-Truxton Wash at Valentine, AZ	2	3,850.00	37.07054	-113.58273	5,410	14.7	No
9367950	Chaco River near Waterflow, NM	2	4,370.00	36.72445	-108.59147	6,330	9.9	No
9415000	Virgin River at Littlefield, AZ	2	4,860.00	36.89164	-113.92441	5,170	14.4	Yes
9394500	Little Colorado River at Woodruff, AZ	2	7,850.00	34.78281	-110.04428	6,810	14.4	Yes
9397000	Little Colorado River at Holbrook, AZ	2	11,400.00	34.89780	-110.16318	6,740	14.1	No
9397300	Little Colorado River near Joseph City, AZ	2	12,300.00	34.90114	-110.25540	6,690	13.9	No
9400350	Little Colorado River near Winslow, AZ	2	16,000.00	35.01169	-110.65124	6,590	14.1	Yes
9401000	Little Colorado River at Grand Falls, AZ	2	20,600.00	35.43334	-111.20070	6,470	13.7	No
9402000	Little Colorado River near Cameron, AZ	2	26,300.00	35.92638	-111.56737	6,320	12.8	No
9423400	Tin Can Creek near Needles, CA	3	0.08	34.85695	-114.88275	2,810	7.1	Yes
9429510	Mittry Lake Tributary near Yuma, AZ	3	0.15	32.85977	-114.43550	283	3.7	Yes

Table F.2 USGS data for stream gages used for regional regression equations

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Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9424050	Chemehuevi Wash Tributary near Needles, CA	3	0.28	34.50834	-114.60357	1,680	6.4	Yes
9428560	Colorado River Tributary No. 2 near Vidal, CA	3	0.42	33.98641	-114.49662	736	4.3	No
9520350	Mohawk Pass Wash at Mohawk, AZ	3	0.44	32.72894	-113.74242	607	4.4	Yes
9429240	Ogilby Wash near Palo Verde, CA	3	0.56	33.33892	-114.77996	865	4.4	No
9520110	Hot Shot Arroyo near Ajo, AZ	3	0.56	32.34700	-112.80932	1,750	7.7	Yes
9429250	Ogilby Wash No. 2 near Palo Verde, CA	3	0.57	33.34031	-114.77996	861	4.4	No
7093	Casandro Wash, AZ	3	0.58	33.96206	-112.76525	2,340	12.5	Yes
9424700	Iron Spring Wash Tributary near Bagdad, AZ	3	0.63	34.52224	-113.11269	3,410	13.7	Yes
9520300	Alamo Wash Tributary near Ajo, AZ	3	0.83	32.10006	-112.77154	2,030	10.1	Yes
9517200	Centennial Wash Tributary near Wenden, AZ	3	0.84	33.84448	-113.45076	2,110	9.0	Yes
9423350	Caruthers Creek near Ivanpah, CA	3	0.87	35.24499	-115.29888	6,400	11.7	Yes
9428545	Cunningham Wash Tributary near Wenden, AZ	3	0.91	34.00697	-113.57854	2,630	11.4	Yes
9512700	Agua Fria River Tributary No. 2 near Rock Springs, AZ	3	1.01	34.03337	-112.14571	2,170	14.1	Yes
9428570	Colorado River Tributary near Vidal, CA	3	1.12	33.97974	-114.50718	841	4.1	Yes
9419590	Detrital Wash Tributary near Chloride, AZ	3	1.22	35.43194	-114.28551	3,710	11.0	Yes
9520230	Crater Range Wash near Ajo, AZ	3	1.53	32.56228	-112.87766	1,400	7.1	Yes
9427700	Monkeys Head Wash near Parker, AZ	3	1.80	34.27779	-114.13022	1,230	6.7	Yes
7113	Powder House Wash, AZ	3	1.83	33.98083	-112.71731	2,350	12.9	Yes
9520160	Gibson Arroyo at Ajo, AZ	3	1.85	32.38006	-112.86182	2,160	8.1	Yes
9424430	Kaiser Spring Canyon Tributary near Wikieup, AZ	3	1.87	34.57224	-113.47854	2,790	12.1	Yes
9520400	Ligurta Wash at Ligurta, AZ	3	1.99	32.67588	-114.29466	497	4.2	No
9429400	Indian Wash Tributary near Yuma, AZ	3	2.24	33.10921	-114.29550	1,220	5.3	No
9423300	Piute Wash Tributary at Searchlight, NV	3	2.82	35.46666	-114.93970	3,670	7.8	Yes
9429150	Creosote Wash near Ehrenberg, AZ	3	3.13	33.62086	-114.49551	562	4.5	Yes
9519600	Rainbow Wash Tributary near Buckeye, AZ	3	3.64	33.24310	-112.63822	966	8.0	Yes
5588	Skunk Creek at New River, AZ	3	3.92	33.92614	-112.08267	2,550	15.5	Yes
9415100	Pulsipher Wash near Mesquite, NV	3	4.70	36.80109	-114.11108	1,890	6.7	No

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9515800	Hartman Wash near Wickenburg, AZ	3	5.44	33.96281	-112.82851	2,680	13.2	Yes
9516600	Ox Wash near Morristown, AZ	3	6.21	33.88337	-112.65073	2,290	12.6	Yes
9520130	Darby Arroyo near Ajo, AZ	3	6.35	32.35534	-112.82599	1,920	7.9	Yes
9423760	Little Meadow Creek near Oatman, AZ	3	8.41	35.03056	-114.30912	3,390	9.7	Yes
7083	Flying E Wash, AZ	3	8.64	33.96225	-112.78289	2,580	13.0	Yes
9512970	Cottonwood Creek near Waddell Dam, AZ	3	9.29	33.89865	-112.31155	2,300	15.3	Yes
5583	Virgin River near Bloomington, UT	3	10.80	33.90100	-112.05500	2,970	17.7	Yes
9520100	Military Wash near Sentinel, AZ	3	11.00	32.84533	-113.27963	668	5.0	Yes
9513820	Deadman Wash near New River, AZ	3	11.60	33.84170	-112.14516	1,970	13.0	Yes
9535200	Sells Wash Tributary at Sells, AZ	3	11.80	31.91536	-111.87901	2,590	14.9	Yes
9520200	Black Gap Wash near Ajo, AZ	3	12.20	32.70644	-112.84600	1,290	7.1	Yes
9428800	Tyson Wash Tributary near Quartzsite, AZ	3	12.80	33.51253	-114.21744	1,530	5.5	Yes
9428550	Bouse Wash Tributary near Bouse, AZ	3	14.60	33.90141	-113.97439	1,230	6.4	Yes
9423900	Sacramento Wash Tributary near Topock, AZ	3	14.90	34.72973	-114.31329	1,760	8.2	Yes
9419680	Cottonwood Valley near Blue Diamond, NV	3	17.70	36.00969	-115.43139	5,450	14.4	Yes
6953	Rainbow Wash, AZ	3	18.30	33.23560	-112.63920	1,080	8.2	Yes
9419682	Oak Creek near Blue Diamond, NV	3	27.50	36.04469	-115.37806	4,340	10.9	Yes
9423780	Walnut Creek near Kingman, AZ	3	31.40	35.03334	-114.01884	5,030	13.6	No
9419545	Valley Of Fire Wash near Overton, NV	3	31.70	36.40498	-114.41887	2,260	6.6	Yes
5108	Delaney Wash, AZ	3	49.60	33.46981	-112.97714	1,710	8.7	Yes
9413900	Beaver Dam Wash near Enterprise, UT	3	58.00	37.46998	-114.04665	5,950	21.5	No
9418990	Weiser Wash near Glendale, NV	3	59.20	36.66803	-114.53693	2,890	7.7	Yes
9512100	Indian Bend Wash at Scottsdale, AZ	3	59.80	33.53865	-111.91653	1,430	10.1	Yes
9512860	Humbug Creek near Castle Hot Springs	3	59.90	33.96726	-112.29350	3,960	22.2	Yes
9517400	Winters Wash near Tonopah, AZ	3	63.90	33.48948	-112.91879	1,670	8.8	Yes
9513860	Skunk Creek near Phoenix, AZ	3	65.00	33.72921	-112.11988	2,240	13.9	Yes
9419647	Las Vegas Wash Tributary near North Las Vegas, NV	3	66.10	36.30275	-115.13973	3,730	6.3	Yes

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9513780	New River near Rock Springs, AZ	3	68.40	33.97420	-112.09905	3,970	20.8	No
9519750	Bender Wash near Gila Bend, AZ	3	69.50	32.90699	-112.55210	1,930	8.7	Yes
9512280	Cave Creek below Cottonwood Creek near Cave Creek, AZ	3	72.80	33.88726	-111.95404	3,770	20.0	No
9513800	New River at New River, AZ	3	84.70	33.91142	-112.14127	3,640	19.6	No
9517280	Tiger Wash near Aguila, AZ	3	84.70	33.74170	-113.27936	2,570	10.6	Yes
7013	Martinez Creek, AZ	3	109.00	34.02911	-112.79103	3,430	15.6	Yes
9419620	Mormon Wells Wash near Las Vegas, NV	3	111.00	36.44580	-115.25362	6,440	12.0	No
7043	Cline Creek, AZ	3	118.00	33.98742	-112.79297	2,800	12.9	Yes
9512300	Cave Creek near Cave Creek, AZ	3	123.00	33.78337	-112.00737	3,310	18.1	No
9519760	Sauceda Wash near Gila Bend, AZ	3	126.00	32.87060	-112.75905	1,990	8.4	Yes
9516800	Jack Rabbit Wash near Tonopah, AZ	3	138.00	33.65892	-112.82851	2,250	10.6	Yes
9516790	Star Wash near Tonopah, AZ	3	153.00	33.63306	-112.77889	2,000	11.1	Yes
9513835	New River at Bell Road near Peoria	3	186.00	33.63837	-112.24016	2,600	15.4	Yes
9520170	Rio Cornez near Ajo, AZ	3	244.00	32.49950	-112.88127	1,930	8.4	Yes
9417300	California Wash near Moapa, NV	3	253.00	36.61025	-114.66110	2,490	6.4	Yes
6833	Waterman Wash at Rainbow, AZ	3	345.00	33.26150	-112.44400	1,480	8.5	No
9404343	Sols Wash near Matthie, AZ	3	375.00	35.38416	-113.65772	5,110	14.9	No
9515500	Hassayampa River at Box Damsite near Wickenburg, AZ	3	416.00	34.04503	-112.70990	4,540	19.8	No
5308	Hassayampa River at Box Canyon	3	416.00	34.04500	-112.71008	4,530	19.8	No
9514200	Waterman Wash near Buckeye, AZ	3	418.00	33.33032	-112.50988	1,420	8.5	Yes
9535100	San Simon Wash near Pisinimo, AZ	3	579.00	32.04424	-112.37097	2,230	10.2	Yes
9513890	New River at Peoria, AZ	3	606.00	33.59532	-112.26321	2,330	13.9	Yes
9513910	New River near Glendale, AZ	3	623.00	33.53671	-112.28182	2,290	13.8	No
5228	Hassayampa River at US60, AZ	3	709.00	33.97031	-112.72703	3,890	17.4	Yes
9423820	Sacramento Wash near Yucca, AZ	3	773.00	34.81112	-114.16190	3,300	10.3	Yes
9516500	Hassayampa River near Morristown, AZ	3	796.00	33.88503	-112.66212	3,750	17.0	No
9512800	Agua Fria River near Rock Springs, AZ	3	1,110.00	34.01559	-112.16794	4,530	19.4	No
9535300	Vamori Wash at Kom Vo, AZ	3	1,290.00	31.95118	-112.34791	2,660	14.5	No

Table F.2 USGS data for stream gages used for regional regression equations

(From Paretti, Kennedy, Turney and Veilleux (2014))

Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9517000	Hassayampa River near Arlington, AZ	3	1,420.00	33.34726	-112.72573	2,900	14.0	Yes
9425500	Santa Maria River near Alamo, AZ	3	1,430.00	34.30002	-113.51743	3,720	15.9	No
9517490	Centennial Wash at Southern Pacific Railroad Brdg, AZ	3	1,680.00	33.31032	-112.88184	1,860	8.9	No
9416000	Muddy River near Moapa, NV	3	3,850.00	36.71108	-114.69527	5,240	10.7	No
9496600	Cibecue 1 Tributary Carrizo Creek near Show Low, AZ	4	0.06	33.99116	-110.32483	5,430	21.0	Yes
9496700	Cibecue 2 Tributary Carrizo Cr, AZ	4	0.06	33.98810	-110.31122	5,220	20.6	Yes
9451800	Tollgate Wash Tributary near Clifton, AZ	4	0.11	32.85007	-109.33813	4,750	15.4	Yes
9504800	Oak Creek Tributary near Cornville, AZ	4	0.17	34.71252	-111.88127	3,580	16.0	Yes
9505900	Cottonwood Wash near Camp Verde, AZ	4	0.53	34.50558	-111.75348	3,620	16.6	Yes
9498600	Cristopher Creek Tributary near Kohl's Ranch, AZ	4	0.66	34.32226	-111.06735	6,070	34.8	No
9451900	Agricul Resrch Serv Safford Watershed W-I, AZ	4	0.73	32.84090	-109.52202	3,330	10.8	Yes
9504100	Hull Canyon near Jerome, AZ	4	0.85	34.73891	-112.14377	7,050	26.2	Yes
9468300	Sevenmile Wash Tributary near Globe, AZ	4	0.86	33.58616	-110.65066	4,410	21.1	Yes
9512420	Lynx Creek Tributary near Prescott, AZ	4	0.98	34.54753	-112.40017	5,880	22.1	Yes
9498503	South Fork Parker Creek near Roosevelt, AZ	4	1.08	33.79727	-110.96040	6,650	33.5	Yes
9456680	Agricultural Research Service Safford Watershed W-V, AZ	4	1.11	32.42229	-109.65812	4,540	14.4	Yes
9456820	Agricultural Research Service Safford Watershed W-IV, AZ	4	1.16	32.62507	-109.60063	3,620	12.9	Yes
9504400	Munds Canyon Tributary near Sedona, AZ	4	1.19	34.92224	-111.64515	6,860	27.2	Yes
9455800	Steins Creek at Steins, NM	4	1.20	32.22556	-109.00444	4,540	11.8	Yes
9505220	Rocky Gulch near Rimrock, AZ	4	1.36	34.74697	-111.49459	7,180	26.9	Yes
9462200	Agricultural Research Service Safford Watershed W-II, AZ	4	1.76	32.83562	-109.99425	3,750	13.8	Yes
9424410	Big Sandy River Tributary near Kingman, AZ	4	2.34	35.09167	-113.65911	3,680	11.0	Yes
9510170	Camp Creek near Sunflower, AZ	4	2.72	33.75977	-111.49625	3,520	23.0	No
9505600	Dirty Neck Canyon near Clints Well, AZ	4	3.33	34.51253	-111.35903	7,260	32.5	No
9430300	Copperas Canyon near Pinos Altos, NM	4	3.96	33.07840	-108.20449	7,040	21.0	Yes

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9510100	East Fork Sycamore Creek near Sunflower, AZ	4	4.51	33.94949	-111.46152	5,230	30.5	Yes
9496800	Carrizo Creek Tributary near Show Low, AZ	4	4.60	33.95449	-110.33205	5,750	21.3	Yes
9510070	West Fork Sycamore Creek above Mcfarland Canyon near Sunflower, AZ	4	4.62	33.96060	-111.48736	5,440	31.9	Yes
9458200	Deadman Creek near Safford, AZ	4	4.67	32.73312	-109.81647	7,360	29.1	Yes
9507700	Webber Creek above West Fork Webber Creek near Pine, AZ	4	4.76	34.41114	-111.37292	7,030	33.3	Yes
9507600	East Verde River near Pine, AZ	4	6.35	34.39170	-111.26875	6,400	31.7	Yes
9498900	Gold Creek near Payson, AZ	4	6.55	34.00282	-111.35902	4,700	25.9	Yes
9424480	Ash Creek near Kirkland, AZ	4	8.18	34.45336	-112.79657	4,790	20.0	Yes
9510080	West Fork Sycamore Creek near Sunflower, AZ	4	9.83	33.94587	-111.48541	5,340	31.5	Yes
9503750	Limestone Canyon near Paulden, AZ	4	14.50	34.98002	-112.40212	5,440	17.6	Yes
9456400	Gold Gulch near Bowie, AZ	4	15.00	32.34785	-109.60340	5,180	16.8	Yes
9510180	Rock Creek near Sunflower, AZ	4	15.20	33.73032	-111.50847	3,700	23.7	Yes
9505300	Rattlesnake Canyon near Rimrock, AZ	4	25.10	34.76696	-111.67376	6,450	25.8	Yes
9501300	Tortilla Creek at Tortilla Flat, AZ	4	29.20	33.52727	-111.38763	3,270	19.2	Yes
9502960	Granite Creek at Prescott, AZ	4	30.20	34.55197	-112.46239	5,950	22.6	Yes
9467120	Salt Creek near Peridot, AZ	4	34.60	33.27089	-110.30482	4,160	17.0	Yes
9508300	Wet Bottom Creek near Childs, AZ	4	36.30	34.16087	-111.69292	4,920	24.3	Yes
9498501	Pinto Creek below Haunted Canyon near Miami, AZ	4	36.40	33.41867	-111.00956	4,420	24.4	No
9503000	Granite Creek near Prescott, AZ	4	39.40	34.56308	-112.44489	5,910	22.4	Yes
9502900	Del Rio Springs near Chino Valley, AZ	4	39.90	34.82558	-112.44461	4,760	13.0	No
9505250	Red Tank Draw near Rimrock, AZ	4	51.00	34.69530	-111.71432	6,060	24.3	Yes
9510150	Sycamore Creek near Sunflower, AZ	4	52.40	33.85143	-111.45319	4,560	27.9	Yes
5352	Hassayampa River at Wagoner, AZ	4	77.80	34.31014	-112.56867	5,460	22.6	No
9438200	Animas Creek near Cloverdale, NM	4	83.50	31.57083	-108.87500	5,520	18.5	Yes
9512600	Turkey Creek near Cleator, AZ	4	89.30	34.28225	-112.20766	5,270	21.8	Yes
9498502	Pinto Creek near Miami, AZ	4	102.00	33.48783	-110.99539	4,220	23.0	Yes
9445500	Willow Creek near Point Of Pines near Morenci, AZ	4	107.00	33.37922	-109.65064	6,300	21.0	No

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9505200	Wet Beaver Creek near Rimrock, AZ	4	109.00	34.67474	-111.67209	6,550	25.0	Yes
9498870	Rye Creek near Gisela, AZ	4	123.00	34.03337	-111.29236	4,290	22.9	Yes
9424200	Cottonwood Wash No. 1 near Kingman, AZ	4	135.00	35.18112	-113.46966	5,360	19.3	Yes
9505350	Dry Beaver Creek near Rimrock, AZ	4	142.00	34.72863	-111.77571	6,190	25.1	Yes
9446000	Willow Creek near Double Circle Ranch near Morenci, AZ	4	155.00	33.35423	-109.52564	6,240	21.0	Yes
9510200	Sycamore Creek near Fort Mcdowell, AZ	4	164.00	33.69421	-111.54180	3,800	24.3	Yes
9431130	Mangas Creek near Cliff, NM	4	194.00	32.86083	-108.56694	5,770	17.3	Yes
9498400	Pinal Creek at Inspiration Dam near Globe, AZ	4	195.00	33.57311	-110.90123	4,170	21.0	No
9497980	Cherry Creek near Globe, AZ	4	200.00	33.82783	-110.85623	5,540	26.8	Yes
9496000	Corduroy Creek near Mouth near Show Low, AZ	4	206.00	34.01838	-110.24233	6,370	22.3	No
9430900	Duck Creek at Cliff, NM	4	226.00	32.96472	-108.61111	5,630	18.1	Yes
9504420	Oak Creek near Sedona, AZ	4	233.00	34.86168	-111.76182	6,730	27.1	No
9505800	West Clear Creek near Camp Verde, AZ	4	241.00	34.53864	-111.69404	6,640	26.1	Yes
9502800	Williamson Valley Wash near Paulden, AZ	4	255.00	34.86669	-112.61323	5,140	16.6	Yes
9497800	Cibecue Creek near Chrysotile, AZ	4	290.00	33.84311	-110.55761	5,740	23.2	Yes
9447800	Bonita Creek near Morenci, AZ	4	302.00	32.95562	-109.53119	5,250	17.4	Yes
9507980	East Verde River near Childs, AZ	4	326.00	34.27642	-111.63876	5,250	26.5	Yes
9504500	Oak Creek near Cornville, AZ	4	355.00	34.76446	-111.89099	6,110	24.8	Yes
9446500	Eagle Creek near Double Circle Ranch near Morenci, AZ	4	383.00	33.30006	-109.49230	6,280	21.3	No
9498800	Tonto Creek near Gisela, AZ	4	433.00	34.12893	-111.25541	5,540	27.9	Yes
9496500	Carrizo Creek near Show Low, AZ	4	441.00	33.98588	-110.28094	6,330	22.2	Yes
9444200	Blue River near Clifton, AZ	4	505.00	33.29090	-109.19618	6,850	23.1	Yes
9512500	Agua Fria River near Mayer, AZ	4	585.00	34.31531	-112.06405	4,940	19.2	Yes
9424447	Burro Creek at Old Us 93 Bridge near Bagdad, AZ	4	611.00	34.54168	-113.44521	4,660	18.4	Yes
9447000	Eagle Creek above Pumping Plant near Morenci, AZ	4	621.00	33.06451	-109.44230	6,010	20.5	Yes
9494000	White River near Fort Apache, AZ	4	628.00	33.73644	-110.16677	7,240	29.1	Yes
9499000	Tonto Creek above Gun Creek near Roosevelt, AZ	4	672.00	33.98004	-111.30347	5,080	25.9	Yes

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Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9456000	San Simon River near San Simon, AZ	4	823.00	32.22508	-109.17561	4,880	16.2	No
9468500	San Carlos River near Peridot, AZ	4	1,030.00	33.29645	-110.45149	4,440	19.1	Yes
9424900	Santa Maria River near Bagdad, AZ	4	1,130.00	34.30585	-113.34714	3,990	16.9	Yes
9490500	Black River near Fort Apache, AZ	4	1,220.00	33.71283	-110.21177	7,220	25.5	Yes
9430500	Gila River near Gila, NM	4	1,860.00	33.06150	-108.53739	7,450	20.4	Yes
9457000	San Simon River near Solomon, AZ	4	2,240.00	32.80173	-109.63924	4,330	14.1	No
9431000	Gila River near Cliff, NM	4	2,430.00	32.93896	-108.60616	7,120	20.2	No
9503700	Verde River near Paulden, AZ	4	2,510.00	34.89502	-112.34295	5,460	16.2	No
9424450	Big Sandy River near Wikieup, AZ	4	2,560.00	34.46252	-113.62438	4,330	15.7	Yes
9444500	San Francisco River at Clifton, AZ	4	2,760.00	33.04951	-109.29590	6,810	20.9	Yes
9431500	Gila River near Redrock, NM	4	2,830.00	32.72694	-108.67556	6,900	19.8	No
9497500	Salt River near Chrysotile, AZ	4	2,830.00	33.79811	-110.49983	6,760	25.1	No
9432000	Gila River below Blue Creek near Virden, NM	4	3,200.00	32.64813	-108.84589	6,690	19.3	No
9504000	Verde River near Clarkdale, AZ	4	3,510.00	34.85224	-112.06599	5,620	17.3	Yes
9442000	Gila River near Clifton, AZ	4	4,010.00	32.96590	-109.31035	6,230	18.1	Yes
9498500	Salt River near Roosevelt, AZ	4	4,290.00	33.61950	-110.92150	6,180	24.5	Yes
9506000	Verde River near Camp Verde, AZ	4	5,020.00	34.44836	-111.78987	5,570	18.7	No
9508500	Verde River below Tangle Creek above Horseshoe Dam, AZ	4	5,870.00	34.07309	-111.71626	5,440	19.4	Yes
9448500	Gila River at Head of Safford Valley near Solomon, AZ	4	7,890.00	32.86840	-109.51119	6,330	19.2	Yes
9458500	Gila River at Safford, AZ	4	10,500.00	32.84729	-109.71591	5,830	17.9	No
9466500	Gila River at Calva, AZ	4	11,500.00	33.18561	-110.22009	5,660	17.6	No
9474000	Gila River at Kelvin, AZ	4	18,000.00	33.10284	-110.97650	5,160	17.7	Yes
9471185	Walnut Gulch 63.103 near Tombstone, AZ	5	0.01	31.74406	-110.05342	4,500	14.1	No
9481800	Demetrie Wash Tributary Near Continental, AZ	5	0.15	31.87092	-111.08815	3,630	15.6	Yes
9485100	Saguaro Corners Wash near Tucson, AZ	5	0.18	32.16980	-110.73814	3,080	15.2	No
9471087	Walnut Gulch 63.111 near Tombstone az	5	0.21	31.73454	-109.94841	5,010	16.0	Yes
9486700	Chiltepines Wash near Sasabe, AZ	5	0.34	31.81897	-111.43844	3,190	14.7	Yes
9478600	Queen Creek Tributary No. 3 at Whitlow Dam, AZ	5	0.38	33.29172	-111.28124	2,300	14.2	Yes

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9479200	Queen Creek Tributary A Apache Junc, AZ	5	0.39	33.40366	-111.54152	1,770	11.9	Yes
9483040	West Speedway Wash near Tucson, AZ	5	0.47	32.23897	-111.04593	2,660	12.6	Yes
9536350	Surprise Canyon near Dos Cabezas, AZ	5	0.66	32.01120	-109.35395	6,240	23.3	Yes
9487140	San Joaquin Wash near Tucson, AZ	5	0.68	32.16869	-111.13343	2,580	12.2	Yes
9471600	Canary Wash near Benson, AZ	5	0.75	31.87647	-110.34230	5,280	18.0	No
9482330	Pumping Wash near Vail, AZ	5	0.80	32.06952	-110.80703	3,000	14.6	Yes
9536100	Pitchfork Canyon Tributary near Fort Grant, AZ	5	0.90	32.58896	-109.91174	5,070	16.2	Yes
9487400	Quijotoa Wash Tributary near Quijotoa, AZ	5	1.70	32.17368	-112.10902	2,720	13.3	Yes
9512200	Salt River Tributary in South Mountain Park Phoenix, AZ	5	1.73	33.34699	-112.08487	1,800	8.8	No
9483200	Agua Caliente Wash Tributary near Tucson, AZ	5	1.91	32.26869	-110.73814	3,520	16.7	Yes
9485950	Geronimo Wash near Tucson, AZ	5	1.95	32.33230	-110.94426	3,600	17.7	Yes
9472400	Mammoth Wash near Mammoth, AZ	5	2.00	32.67646	-110.68538	3,720	17.5	No
9483030	Anklam Wash at Tucson, AZ	5	2.10	32.22508	-111.03121	2,760	13.2	No
9471700	Fenner Wash near Benson, AZ	5	2.37	31.98036	-110.21646	4,150	15.5	Yes
9471120	Walnut Gulch 63.011 near Tombstone, AZ	5	3.08	31.74120	-109.99508	4,880	15.3	Yes
9482480	Big Wash at Tucson, AZ	5	3.14	32.18619	-111.00259	2,780	13.2	Yes
9483300	Sabino Creek near Mount Lemmon, AZ	5	3.34	32.42230	-110.75204	8,040	37.8	No
9471180	Walnut Gulch 63.003 near Tombstone, AZ	5	3.59	31.73259	-110.05758	4,620	14.5	Yes
9473200	Green Lantern Wash near Winkelman, AZ	5	3.59	32.92507	-110.72705	2,590	16.2	Yes
9471310	Huachuca Canyon near Fort Huachuca, AZ	5	4.11	31.51806	-110.38722	6,810	26.4	No
9470750	Ramsey Canyon near Sierra Vista, AZ	5	4.16	31.44667	-110.30583	7,320	28.5	Yes
9473600	Tam O'shanter Wash near Hayden, AZ	5	4.43	33.02951	-110.87344	3,050	17.8	Yes
9485900	Pima Wash near Tucson, AZ	5	4.95	32.33758	-110.96037	4,520	21.2	Yes
9471195	Walnut Gulch 63.007 near Tombstone, AZ	5	5.24	31.73287	-110.09813	4,490	14.1	Yes
9471130	Walnut Gulch 63.008 near Tombstone, AZ	5	5.70	31.72315	-110.04480	4,770	15.0	Yes
9484510	Ventana Canyon Wash near Tucson, AZ	5	6.33	32.30980	-110.83953	4,660	24.0	No
9471080	Walnut Gulch 63.010 near Tombstone, AZ	5	6.38	31.72037	-110.02563	5,000	16.3	Yes

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2170	Ventana Canyon Wash at Sunrise Road, AZ	5	7.11	32.30875	-110.83898	4,530	23.3	No
9470900	San Pedro River Tributary near Bisbee, AZ	5	7.22	31.57010	-110.02730	4,800	15.5	Yes
9470800	Garden Canyon near Fort Huachuca, AZ	5	8.60	31.47288	-110.34786	6,710	25.8	Yes
9471110	Walnut Gulch 63.015 near Tombstone, AZ	5	9.19	31.71287	-110.04091	4,690	14.6	No
9471090	Walnut Gulch 63.009 near Tombstone, AZ	5	9.21	31.71787	-110.02508	4,850	15.4	Yes
9482350	South Fork Airport Wash near Tucson, AZ	5	9.80	32.10008	-110.90898	2,850	13.7	Yes
9481700	Calabasas Canyon near Nogales, AZ	5	10.30	31.45704	-110.98648	4,130	20.2	Yes
9488600	Silver Reef Wash near Casa Grande, AZ	5	12.00	32.68228	-111.83485	1,600	9.7	Yes
9487100	Little Brawley Wash near Three Points, AZ	5	12.80	32.12369	-111.32983	2,780	12.8	Yes
9482370	North Fork Airport Wash near Tucson, AZ	5	13.00	32.11119	-110.90898	2,970	14.4	Yes
9484580	Barrel Canyon near Sonoita, AZ	5	13.90	31.86175	-110.69119	5,010	23.7	Yes
9478200	Durham Wash near Florence, AZ	5	14.80	32.72229	-111.10900	3,670	17.4	Yes
9484200	Bear Creek near Tucson, AZ	5	16.90	32.30619	-110.80148	5,780	27.9	Yes
9482420	Julian Wash at Tucson, AZ	5	19.60	32.17091	-110.94092	2,820	13.5	Yes
2070	Tanque Verde Wash 0.5 Miles South Of Chiva Tank, AZ	5	23.00	32.26790	-110.60698	5,090	22.1	Yes
9482200	Flato Wash near Sahuarita, AZ	5	24.00	32.04536	-110.95065	3,490	16.7	Yes
9486590	Arivaca Creek near Arivaca, AZ	5	34.10	31.57231	-111.33232	4,080	21.0	Yes
9484000	Sabino Creek near Tucson, AZ	5	35.20	32.31674	-110.81037	6,080	30.2	Yes
9471140	Walnut Gulch 63.006 near Tombstone, AZ	5	36.10	31.72454	-110.05535	4,800	15.1	No
9482450	West Branch Santa Cruz River at Tucson, AZ	5	37.10	32.13341	-111.00898	3,020	13.8	Yes
9484570	Mescal Arroyo near Pantano, AZ	5	38.60	31.98980	-110.56508	4,180	17.7	Yes
1080	CaDada Del Oro Wash Northeast Of Saddlebrooke, AZ	5	42.20	32.56421	-110.84783	5,340	25.8	No
9483100	Tanque Verde Creek near Tucson, AZ	5	43.10	32.24674	-110.68008	4,860	21.3	No
2090	Tanque Verde Wash at Tanque Verde Guest Ranch, AZ	5	43.20	32.24580	-110.68277	4,860	21.3	No
9471190	Walnut Gulch 63.002 near Tombstone, AZ	5	43.30	31.73481	-110.09841	4,750	15.0	No

Table F.2 USGS data for stream gages used for regional regression equations

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Gage ID	Gage Location	Flood Region	Area, sm	Location		Elevation	*PRECIP*	Used
				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9485000	Rincon Creek near Tucson, AZ	5	44.70	32.12952	-110.62591	5,100	21.4	Yes
9484590	Davidson Canyon Wash near Vail, AZ	5	50.40	31.99369	-110.64508	4,510	21.1	No
4310	Davidson Canyon Wash 0.25 Miles South Of Interstate 10, AZ	5	50.40	31.99358	-110.64517	4,510	21.1	No
9471200	Walnut Gulch 63.001 near Tombstone, AZ	5	57.10	31.72926	-110.15341	4,660	14.7	Yes
1100	CaDada Del Oro Wash at Golder Ranch Road, AZ	5	64.80	32.47808	-110.89885	4,810	23.2	Yes
9537200	Leslie Creek near McNeal, AZ	5	78.80	31.59010	-109.50896	5,330	18.2	Yes
9480000	Santa Cruz River near Lochiel, AZ	5	82.00	31.35538	-110.58953	5,090	19.7	Yes
9478500	Queen Creek below Whitlow Dam near Superior, AZ	5	143.00	33.29922	-111.27763	3,220	18.9	Yes
9488650	Vekol Wash near Stanfield	5	148.00	32.84172	-112.25181	2,260	10.0	Yes
9471380	Upper Babocomari River near Huachuca City, AZ	5	156.00	31.63500	-110.42472	5,140	18.6	Yes
9481750	Sopori Wash at Amado, AZ	5	166.00	31.72370	-111.06176	3,810	18.6	Yes
9481500	Sonoita Creek near Patagonia, AZ	5	209.00	31.49982	-110.81814	4,920	21.2	Yes
9484500	Tanque Verde Creek at Tucson, AZ	5	220.00	32.26535	-110.84120	4,370	21.1	Yes
6723	Queen Creek at Cap, AZ	5	220.00	33.23217	-111.50314	2,940	17.5	No
9486300	Canada Del Oro near Tucson, AZ	5	250.00	32.37424	-111.00927	3,930	19.0	Yes
9484560	Cienega Creek near Pantano, AZ	5	289.00	31.98564	-110.56647	4,840	19.2	No
4280	Cienega Creek at Interstate 10, AZ	5	289.00	31.98596	-110.56798	4,840	19.2	No
9471400	Babocomari River near Tombstone, AZ	5	303.00	31.70028	-110.22639	5,000	17.8	Yes
9484600	Pantano Wash near Vail, AZ	5	456.00	32.03591	-110.67758	4,620	19.1	Yes
9486800	Altar Wash near Three Points, AZ	5	466.00	31.83897	-111.40427	3,740	18.6	No
9480500	Santa Cruz River near Nogales, AZ	5	532.00	31.34454	-110.85147	4,890	19.8	Yes
9473000	Aravaipa Creek near Mammoth, AZ	5	538.00	32.84423	-110.63010	4,570	18.6	Yes
9485500	Pantano Wash near Tucson, AZ	5	599.00	32.25008	-110.85064	4,430	18.7	Yes
9470500	San Pedro River at Palominas, AZ	5	738.00	31.38010	-110.11119	5,030	19.2	No
9487000	Brawley Wash near Three Points, AZ	5	785.00	32.07563	-111.33872	3,620	17.5	Yes
9486000	Rillito Creek near Tucson, AZ	5	905.00	32.29452	-110.98537	4,300	19.1	Yes
9487250	Los Robles Wash near Marana, AZ	5	1,200.00	32.43785	-111.30427	3,290	15.8	Yes

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9481740	Santa Cruz River at Tubac, AZ	5	1,210.00	31.61287	-111.04148	4,620	20.1	Yes
9471000	San Pedro River at Charleston, AZ	5	1,220.00	31.62593	-110.17452	4,940	18.1	Yes
9537500	Whitewater Draw near Douglas, AZ	5	1,230.00	31.35233	-109.58507	4,740	15.8	No
9482000	Santa Cruz River at Continental, AZ	5	1,670.00	31.87147	-110.98009	4,390	19.6	Yes
9471550	San Pedro River near Tombstone, AZ	5	1,730.00	31.75092	-110.20119	4,900	17.7	No
9488500	Santa Rosa Wash near Vaiva Vo, AZ	5	1,730.00	32.66756	-111.92819	2,220	11.1	Yes
6040	Santa Cruz River at Valencia Road, AZ	5	2,050.00	32.13306	-110.99309	4,190	18.9	Yes
9482500	Santa Cruz River at Tucson, AZ	5	2,190.00	32.22119	-110.98176	4,100	18.5	No
9471800	San Pedro River near Benson, AZ	5	2,490.00	32.12647	-110.29007	4,750	17.1	No
9472000	San Pedro River near Redington, AZ	5	2,920.00	32.38063	-110.44647	4,680	17.1	No
9486500	Santa Cruz River at Cortaro, AZ	5	3,460.00	32.35119	-111.09454	4,080	18.5	No
9486520	Santa Cruz River at Trico Road near Marana, AZ	5	3,570.00	32.47146	-111.30761	4,040	18.3	No
9473500	San Pedro River at Winkelman, AZ	5	4,450.00	32.97729	-110.77038	4,440	17.4	No
9419623	Deer Creek near Charleston Park, NV	1	1.26	36.31246	-115.62029	9,680	26.2	Yes
9489080	Hannagan Creek near Hannagan Meadow, AZ	1	1.74	33.64728	-109.28952	9,040	32.1	No
9338500	East Fork Deer Creek near Boulder, UT	1	1.79	38.00138	-111.38962	9,440	19.8	Yes
9378630	Recapture Creek near Blanding, UT	1	3.81	37.75555	-109.47651	8,680	25.7	Yes
9460150	Frye Creek near Thatcher, AZ	1	4.04	32.74396	-109.83814	8,130	33.6	No
9442630	Mail Hollow near Luna, NM	1	4.75	33.79389	-108.95028	7,780	20.8	Yes
9419610	Lee Canyon near Charleston Park, NV	1	9.25	36.34030	-115.65223	9,170	21.1	No
9442695	Negro Canyon at Aragon, NM	1	9.33	33.88339	-108.55062	7,660	15.8	No
9406300	Kanarra Creek at Kanarraville, UT	1	9.87	37.53803	-113.16856	7,770	20.1	Yes
9415515	Water Canyon Creek near Preston, NV	1	10.70	38.98772	-114.95835	8,080	16.5	No
9369500	Middle Mancos River near Mancos, CO	1	12.10	37.37389	-108.23064	9,390	30.7	Yes
9395400	Milk Ranch Canyon near Ft. Wingate, NM	1	14.40	35.43194	-108.55500	7,870	18.5	No
9489200	Pacheta Creek at Maverick, AZ	1	16.30	33.73977	-109.54064	8,600	32.9	Yes
9383600	Fish Creek near Eagar, AZ	1	16.80	34.07644	-109.46315	9,150	30.2	Yes

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				Lat	Long			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9408400	Santa Clara River near Pine Valley, UT	1	18.80	37.38331	-113.48329	8,640	25.4	Yes
9338000	East Fork Boulder Creek near Boulder, UT	1	20.40	38.04193	-111.45017	10,700	23.8	Yes
9343500	Rito Blanco near Pagosa Springs, CO	1	23.10	37.19362	-106.90531	9,270	33.0	Yes
9383400	Little Colorado River at Greer, AZ	1	28.90	34.01671	-109.45731	9,440	32.8	Yes
9405420	North Fork Virgin River below Bulloch Canyon near Glendale, UT	1	29.40	37.41831	-112.80049	7,820	20.7	Yes
9442660	Trout Creek at Luna, NM	1	31.80	33.84611	-108.95167	8,630	24.1	Yes
9365500	La Plata River at Hesperus, CO	1	34.50	37.28972	-108.04063	10,200	38.8	Yes
9336000	Birch Creek near Escalante, UT	1	35.20	37.76249	-111.73824	8,380	18.8	Yes
9419640	Kyle Canyon near Charleston Park, NV	1	35.40	36.27774	-115.47029	7,850	22.0	No
9378650	Recapture Creek below Johnson Creek near Blanding, UT	1	37.30	37.68083	-109.46262	7,920	21.9	Yes
9489070	North Fork Of East Fork Black River near Alpine, AZ	1	38.40	33.90311	-109.32286	9,050	28.9	Yes