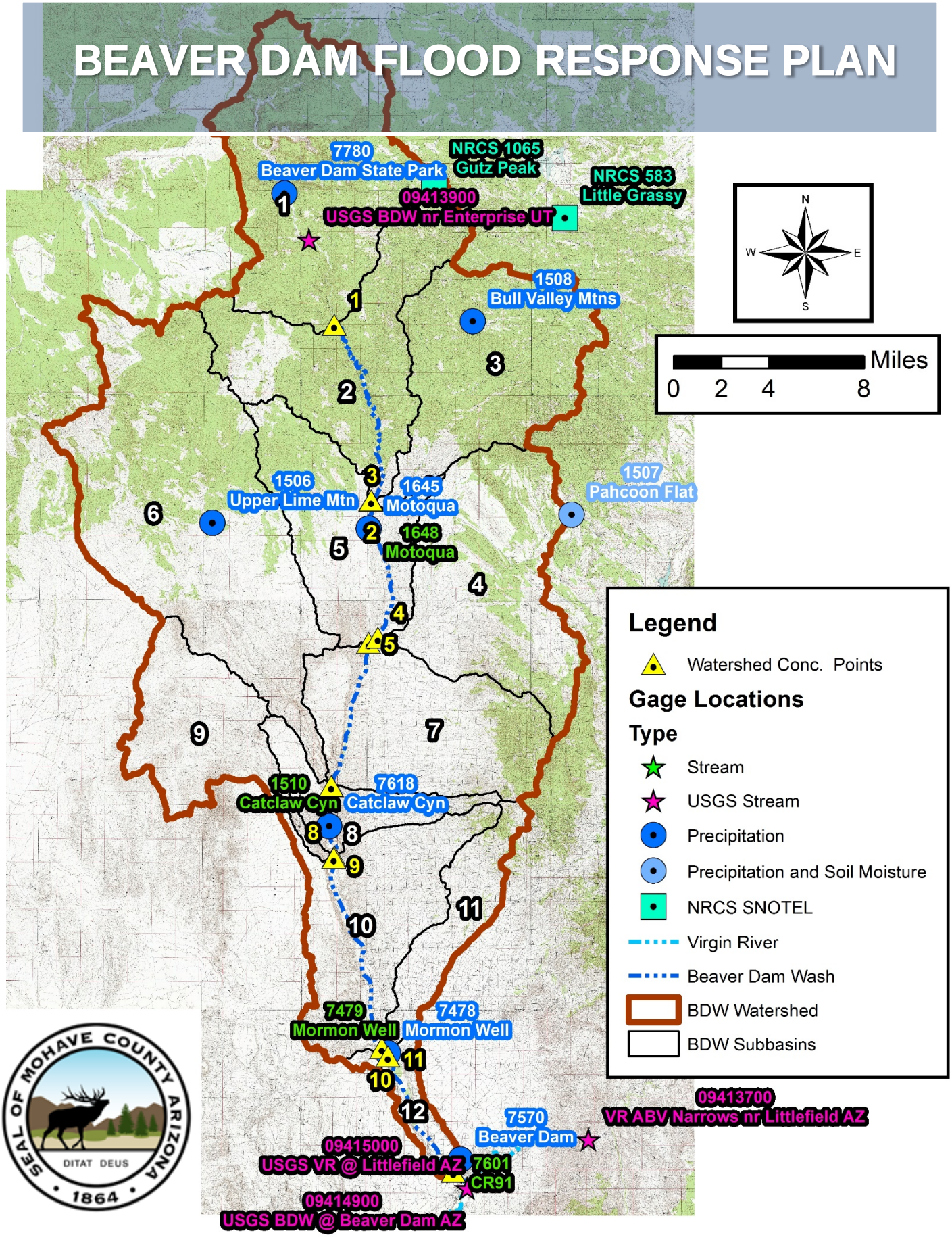
BEAVER DAM FLOOD RESPONSE PLAN



BEAVER DAM FLOOD RESPONSE PLAN

Prepared For:
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November 2017

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NOTICE

THE USER SHOULD READ THE ENTIRE FLOOD RESPONSE PLAN CAREFULLY AND BE AWARE OF ALL ELEMENTS, INCLUDING STRENGTHS AND LIMITATIONS, AND INDIVIDUAL RESPONSIBILITIES. THE FLOOD RESPONSE PLAN PRESENTED HEREIN IS USEFUL AS ONE STEP IN DEVELOPING A FLOOD WARNING SYSTEM FOR THE RESIDENTS WITHIN THE BEAVER DAM STUDY AREA. HOWEVER, THE POSSIBILITY OF INADVERTENT ERROR IN DESIGN OR FAILURE OF EQUIPMENT FUNCTION EXISTS AND MAY PREVENT THE SYSTEM FROM OPERATING PERFECTLY AT ALL TIMES. THEREFORE, NOTHING CONTAINED HEREIN MAY BE CONSTRUED AS A GUARANTEE OF THE SYSTEM OR ITS OPERATION, OR CREATE ANY LIABILITY ON THE PART OF ANY PARTY OR ITS DIRECTORS, OFFICERS, EMPLOYEES OR AGENTS FOR ANY DAMAGE THAT MAY BE ALLEGED TO RESULT FROM THE OPERATION, OR FAILURE TO OPERATE, OF THE SYSTEM OR ANY OF ITS COMPONENT PARTS. THIS CONSTITUTES NOTICE TO ANY AND ALL PERSONS OR PARTIES THAT THE NATIONAL WEATHER SERVICE, MOHAVE COUNTY FLOOD CONTROL DISTRICT, MOHAVE COUNTY DEPARTMENT OF RISK AND EMERGENCY MANAGEMENT, MOHAVE COUNTY SHERIFF'S OFFICE, AND ARID HYDROLOGY & HYDRAULICS, LLC. OR ANY OFFICER, AGENT OR EMPLOYEE THEREOF, SHALL NOT BE LIABLE FOR ANY DEATHS, INJURIES, OR DAMAGES OF WHAT EVER KIND THAT MAY RESULT FROM RELIANCE ON THE TERMS AND CONDITIONS OF THIS SYSTEM.

THE HYDROLOGIC AND HYDRAULIC ANALYSES PERFORMED DURING PREPARATION OF THIS FLOOD RESPONSE PLAN ARE INTENDED TO BE SUPPLEMENTAL AND APPROXIMATE IN NATURE. THEREFORE, THE RESULTS FROM THESE ANALYSES SHOULD NOT BE CONSIDERED DETAILED RESULTS. THE RESULTS HAVE BEEN USED TO ESTIMATE FLOW MAGNITUDE, DEPTH AND VELOCITY THROUGHOUT THE STUDY AREA. APPROXIMIATE FLOW DEPTHS AND FLOW VELOCITIES, COUPLED WITH ENGINEERING JUDGMENT, HAVE BEEN USED TO PREDICT FLOOD HAZARD CLASSIFICATION LEVELS FOR ADULTS, CARS AND HOUSES, FOR EACH STORM SCENARIO MODELED. IT IS NOT RECOMMENDED THAT THE HYDROLOGIC AND HYDRAULIC ANALYSES AND MODELS BE USED FOR ANY OTHER PURPOSE.

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REVISIONS

December 20, 2007. The report was revised to address review comments received from Mohave County.

January 5, 2009. The report was revised to include the stream gage rating curves and supporting documentation in Appendix A. Table 2.2 and Table 2.5 through Table 2.8 were revised, including revisions to the Warning Stage 2 flow criteria and the addition of stage control data to column 6. Mohave County staff revision recommendations were made to Table 2.8 and corresponding revisions made to Table 2.6 and Table 2.7.

January 11, 2009. The report was revised to incorporate final review comments from Mohave County staff and re-sealed.

January 2014. Complete rewrite of report based on changed conditions resulting from the December 2010 flood.

February 2016. Revised Table 2.1 message content for the Stage 2 alert to include reference to “swift water rescue duties.”

July 2016. Revised Table 4.1, Table 4.2 and links in Table 6.1. Fixed document formatting issues.

April 2017. Complete plan update based on new topography, revised hydraulic modeling, the addition of the Mormon Well stream flow and precipitation gage, and a revised hydraulic rating for the CR 91 stream flow gage.

August 2017. Revised some warning level settings in Tables A.3 through A.7.

November 2017. Revised Figure 4.1 to include the Monitored Erosion Evacuation Area. Revised Table A.6 intensity and duration criteria.

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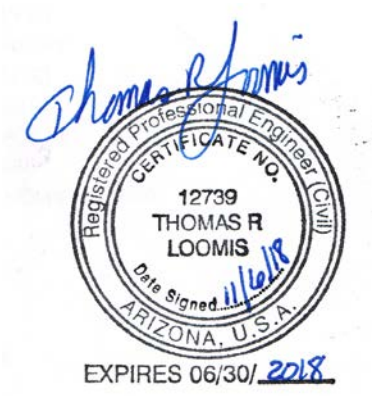

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1 INTRODUCTION

The Mohave County Flood Control District (MCFCD) contracted with Arid Hydrology & Hydraulics, LLC (AridHH) in December 2007 to prepare a Flood Warning Response Plan (FRP) as one component of the Beaver Dam Wash Flood Hazard Assessment (FHA), per Agreement Number 06024. After the December 2010 flood, Mohave County Flood Control District contracted with AridHH to revise the FHA and FRP to reflect the changed conditions in the wash and to adjust the FRP based on lessons learned during the flood fight. Then in September 2014 another significant flow event occurred that changed the wash bed in the Beaver Dam area. In addition, erosion protection along the southwest bank at Beaver Dam Resort was completed, and regrading of various wash areas has been done by residents. MCFCD had the Beaver Dam area and the new Mormon Well gage site flown by Cooper Aerial to obtain current topography and ortho-rectified aerial photographs. MCFCD contracted with AridHH in April 2016 to update the FRP using the new information and to incorporate the Mormon Well stream flow gage.

The project site, located in the extreme northwest corner of Mohave County, is shown on Figure 1.1. The project General Study Area, located in the W1/2 of Section 4 and the E1/2 of Section 5, T40N, R15W, GSRM, Mohave County, Arizona, at the community of Beaver Dam, Arizona is shown on Figure 1.2. In January 2005, Beaver Dam, Arizona was impacted by a large multi-day flood in Beaver Dam Wash. Many homes were flooded and filled with several feet of flood water. Some were washed away or severely damaged by high velocity flows and erosion that affected the structures foundation. In December 2010, another multi-day flood occurred, although smaller in magnitude than the 2005 flood. However, four (4) homes were totally destroyed and two (2) others extensively damaged. Lateral migration of the southwest bank destroyed the homes and removed a portion of Clark Gable Drive and a side street and removed the wastewater lift station.

The purpose of the FRP is to provide guidance to Mohave County staff for identifying and responding to a flood emergency resulting from floods on the Beaver Dam Wash at the community of Beaver Dam. The FRP was developed under the guidance of the MCFCD. In addition, the Mohave County Department of Public Works (MCPW), Mohave County Risk and Emergency Management (MCREM), and the Mohave County Sheriff's Office (MCSO) are included as the primary sources of local emergency response resources.

The FRP consists of three components: 1) Notification and Warnings, 2) Recommended Evacuation Areas, and 3) Resident Action Plan. This report is intentionally short and concise to make it more easily useable during a flood emergency. Supporting technical information is available in the report appendices, and in the *Beaver Dam Flood Response Plan Hydrology and Hydraulics Report* (AridHH, 2013).

Figure 1.1 Location Map

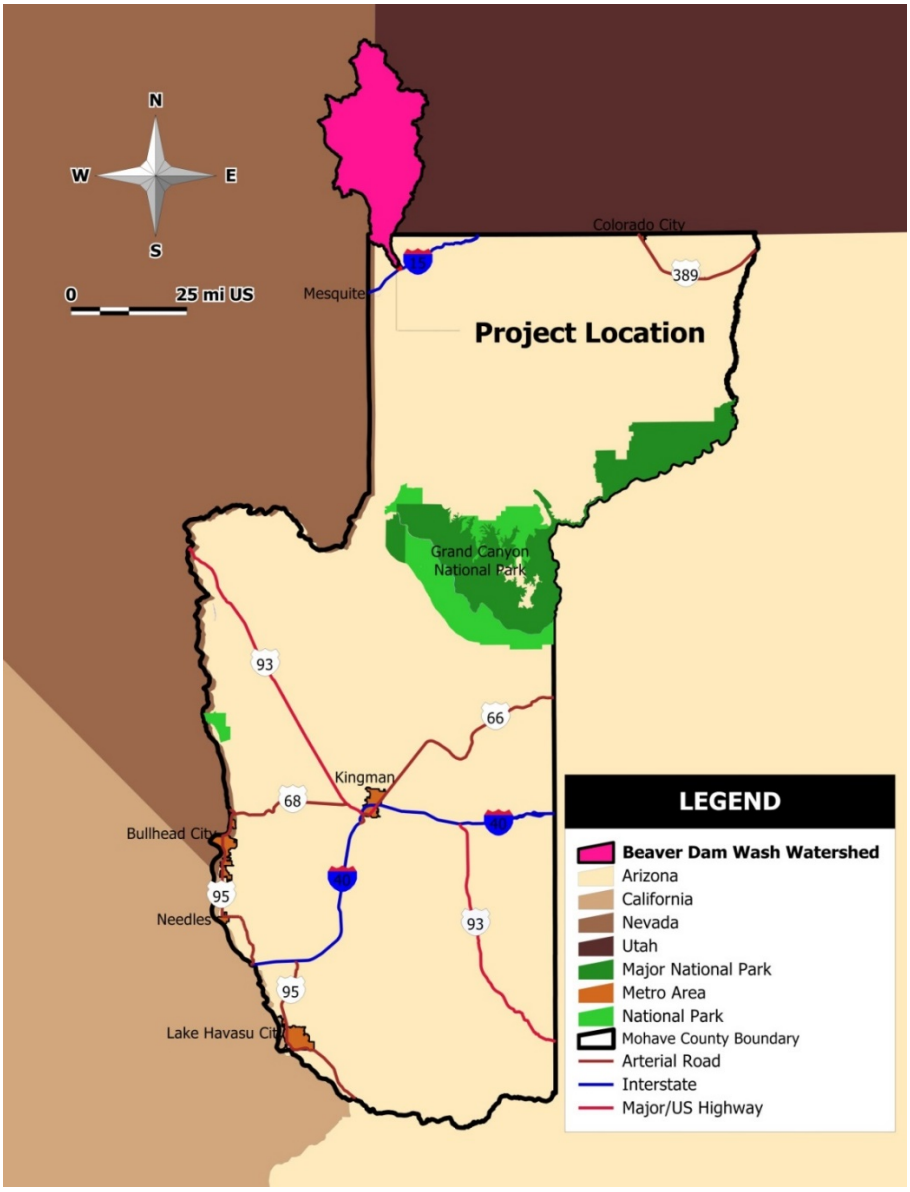
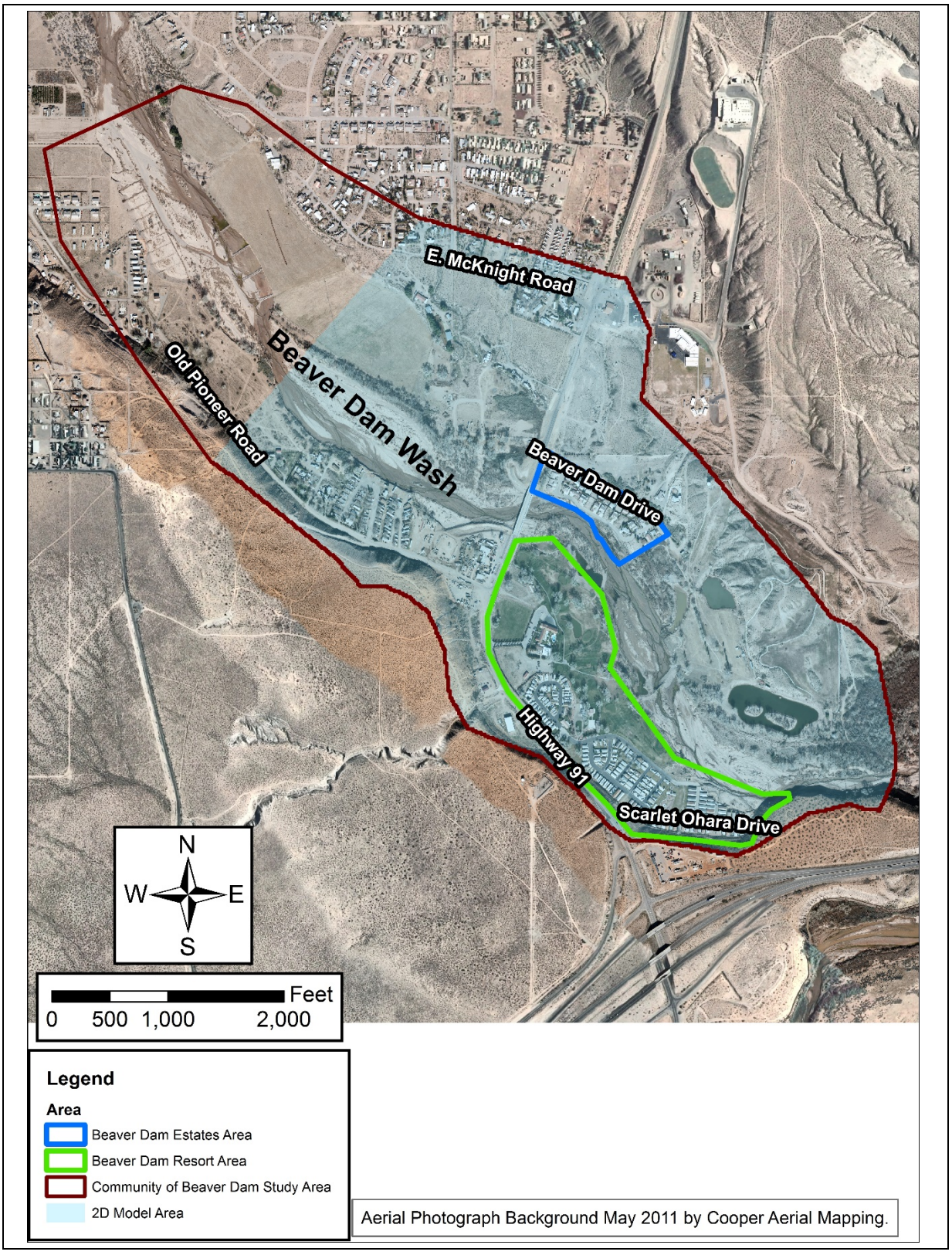


Figure 1.2 Vicinity Map


E. McKnight Road
Beaver Dam Wash
Old Pioneer Road
Beaver Dam Drive
Highway 91
Scarlet Ohara Drive
N
W
E
S
Feet
0 500 1,000 2,000
Legend
Area
Beaver Dam Estates Area
Beaver Dam Resort Area
Community of Beaver Dam Study Area
2D Model Area
Aerial Photograph Background May 2011 by Cooper Aerial Mapping.

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2 NOTIFICATIONS AND WARNINGS

2.1 General

The agency action plan consists of flood detection (described in APPENDIX A), leading to communication with involved emergency response personnel, outside agencies, and the public, finally leading to triggering possible evacuations of people from the flood and erosion hazard areas. Detailed flood warning message sequences are listed in Section 2.2, Section 2.3, and Section 2.4. A summary of flood warning message sequences for triggering a possible evacuation is shown in Table 2.1. It is assumed that residents will be kept informed via the NWS and through the encouraged use of NOAA Weather Radios. Notice of evacuation is recommended to be announced by automated phone warning system such as CodeRED or a statewide alternative system and a wireless emergency alert network, radio/television, door-to-door, and through use of an on-site siren.

Acronyms used in the flood warning sequence descriptions are as follows:

- Mohave County (MC)
- MC Administrator (MCA)
- MC ALERT Flood Warning System (AFWS)
- MC Flood Control and AFWS Staff including AFWS Monitor (AFWSM)
- MC Development Services Director (DSD)
- MC Public Works Director or designee (PWD)
- MC Director of Risk and Emergency Management (DREM)
- MC Emergency Management Coordinator (EMC)
- MC Engineering Manager – Road Maintenance & Operations (EMRM)
- MC Flood Control District Engineer or designee (FCDE)
- Beaver Dam/Littlefield Fire Chief or designee (BDFD)
- Beaver Dam/Littlefield Fire Department Dispatch (BDFDD)
- MC Sherriff's Office Dispatch Center (SODC)
- MC Sherriff's Office personnel on Arizona Strip (SOAS)
- Clark County Office of Emergency Management (OEM)
- Arizona Division of Emergency Management (ADEM)
- Mohave County Risk and Emergency Management (REM)
- MC Board of Supervisors (BOS)

2.2 Stage 1

STAGE 1 BEAVER DAM FLOOD RESPONSE PLAN - NWS forecast indicates flood potential for Beaver Dam area.

1. NWS sends out standard Flood Watch for NW Mohave County (Washington County and Lincoln County watches will also be monitored)
2. ALERT Flood Warning System (AFWS) receives NWS Flood Watch and automatically forwards via e-mail to the following parties:

   a. Flood Control District Engineer or designee
   b. Development Director
   c. Flood Control and AFWS Staff including AFWS Monitor
   d. Public Works Director
   e. County Administrator
   f. MC Board of Supervisors
   g. Engineering Manager (Road Maintenance & Operations)
   h. Beaver Dam/Littlefield Fire Chief or designee
   i. Emergency Management Coordinator
   j. Director of Risk and Emergency Management
   k. Mohave County Sheriff's Office Dispatch Center
   l. Sherriff Office Search and Rescue

   The information forwarded will include the NWS Bulletin in its entirety.
3. Dispatchers should notify MCSO personnel on the Arizona Strip.
4. Flood Control District Engineer or designee and Emergency Management will evaluate the forecasted severity of the weather event in coordination with the NWS and may send additional information to the personnel above, which may include the following message for probable serious flooding:

   "*This is a Beaver Dam Flood Response Plan message. The potential need to evacuate selected areas due to flooding may exist, but is not imminent (effective time).*"

   NOTE: Between STAGE 1 and STAGE 2, as weather events develop, it is possible that the NWS will send out a thunderstorm warning or even a flood warning for Beaver Dam.
5. NWS sends out a standard Flood Watch cancellation for NW Mohave County.
6. Flood Control District Engineer or designee and Emergency Management will evaluate the NWS Flood Watch cancellation and may send additional information to the personnel above, which may include the following message:

   "The Flood Watch in the Beaver Dam area is no longer in effect. The Response Plan Stage 1 Message for the Beaver Dam Area of the Arizona Strip is Canceled."

2.3 Stage 2

STAGE 2 BEAVER DAM FLOOD RESPONSE PLAN- Potential for life-threatening flooding exists.

1. In coordination with NWS, Emergency Management and Flood Control evaluate flood potential of developing storms.
2. Emergency Management and Flood Control determine from evaluation of storm characteristics that a Stage 2 is necessary. AFWSM sends the following message via e-mail and texting to the same personnel as in Stage 1, Step 2 above:

   "This is a Beaver Dam Flood Response Plan Stage 2 message. The potential need to evacuate selected areas is high. Beaver Dam response agencies should activate personnel in preparation for possible evacuation and swift water rescue duties. Residents in Beaver Dam should prepare to evacuate upon receipt of a Beaver Dam Flood Response Plan Stage 3 message and should not cross flooded washes (effective time)."
3. Flood Control District Engineer or designee or Emergency Manager will verify receipt of Stage 2 message by the Sheriff's Office Dispatch Center, Public Works, Beaver Dam Littlefield Fire Department, and Sheriff's Office SAR.
4. Sheriff's Office Dispatch Center verbally notifies Deputies on the Arizona Strip and Beaver Dam/Littlefield Fire Department Dispatch of the Stage 2 Alert; MCSO and BDFD personnel will initiate pre-evacuation door to door notices and distribution of pre-printed evacuation information flyers.
5. Emergency Management contacts Development Services Director or designee and County Administrator or designee to discuss current situation and additional preparatory measures.
6. Emergency Management contacts Beaver Dam/Littlefield Fire District and Sheriff's Deputies on Strip to discuss the deployment of personnel to monitor the situation at observation posts along the Beaver Dam Wash and preparations for possible evacuation.
7. Emergency Management and Flood Control discuss event with Las Vegas NWS; EM notifies Clark County OEM and ADEM of situation.
8. Emergency Management requests that MCSO Dispatch activate STAGE 2 ALERT message (see above) to residents of threatened area via automated call system, coordinates with NWS to forward STAGE 2 ALERT message to Mesquite cable TV and St. George and/or Las Vegas radio stations, and posts STAGE 2 ALERT message on county social networks.
9. Flood Control and Emergency Management activate and staff Department Operations Center, create WebEOC event, initiate Incident Action Plan development, and dispatch EM liaison to Beaver Dam.
10. Engineering Manager (Road Maintenance and Operations) or designee initiates preparatory planning with Road Department and/or Traffic Control for road closures and traffic control in Beaver Dam area and pre-deploys key personnel to Beaver Dam for mobilization and to monitor and report on erosion hazard areas.

11. Emergency Management and BDLFFD request immediate deployment of swift water rescue and other needed mutual aid resources, working in coordination with County Fire Resources Coordinator
12. Updates on situation will continue with frequent communication among MCSO, MCPW, MCEM, NWS, BDFD, FCDE, and AFWSM.
13. MCEM monitors situation and decides when to notify other response agencies (American Red Cross, Salvation Army, and Arizona Division of Emergency Management) to prepare for possible disaster assistance.
14. NWS sends out a standard Flood Warning cancellation for NW Mohave County.
15. Flood Control District Engineer or designee and Emergency Management will evaluate the NWS Flood Warning cancellation and may send additional information to the personnel above, which may include the following message:

    "The Flood Warning in the Beaver Dam area is no longer in effect. The Response Plan Stage 2 Message for the Beaver Dam Area of the Arizona Strip is Canceled."

2.4 Stage 3

STAGE 3 BEAVER DAM FLOOD RESPONSE PLAN- Life-threatening flooding is imminent or exists.

1. In coordination with NWS, Emergency Management and Flood Control evaluate imminent flooding potential.
2. AFWSM and Flood Control District Engineer notify via telephone the first available person in the following line of succession that the threshold point for evacuation has been reached.
    a. Director of Risk and Emergency Management
    b. Emergency Management Coordinator
    c. Development Services Director or designee
    d. Public Works Director or designee
    e. County Administrator
    f. Sheriff's Office Representative
    g. Beaver Dam / Littlefield Fire Chief or designee
3. Evacuation decision is validated and authorized by the first available person above. If none of the persons on the list are available, the Flood Control District Engineer shall validate the evacuation decision.
4. The Director of Risk and Emergency Management or designee notifies the County Administrator.
5. AFWSM sends the following message via e-mail and texting to the same personnel as in Stage 1, Step 2 above:

    "This is a Beaver Dam Flood Response Plan Stage 3 message. Notify all residents of Beaver Dam (Estates and/or Resort) to evacuate immediately (effective time)."

6. Sheriff's Office Dispatch Center verbally notifies Sheriff's Office personnel on Arizona Strip and Beaver Dam/Littlefield Fire District of the evacuation decision and the Stage 3 alert and coordinates with Las Vegas NWS to forward Evacuation Alert Message to Mesquite cable TV and St. George and/or Las Vegas radio stations.
7. AFWSM and/or Emergency Management request that Sheriff's Office Dispatch Center activate STAGE 3 (EVACUATION) FLOOD ALERT message (see above) to residents of threatened area via automated call system.
8. Sheriff's Deputies or Beaver Dam firefighters on scene at Beaver Dam Estates and/or Resort manually activate siren, then commence door to door warnings of all residents in threatened area.
9. Emergency Management notifies other responders such as the American Red Cross, Salvation Army, and ADEM duty officer, of the evacuation decision.
10. Emergency Management and other designated Public Works personnel respond to the scene; Emergency Management prepares to activate the county EOC if needed.
11. Unified Command at Beaver Dam, composed of Beaver Dam / Littlefield Fire Chief or designee, MC Public Works and Sheriff's Deputies, verbally verifies to Emergency Management and/or the County EOC that all residents have been warned and have been evacuated or otherwise accounted for.
12. NWS sends out a standard Flood Warning cancellation for NW Mohave County.
13. Flood Control District Engineer or designee and Emergency Management will evaluate the NWS Flood Warning cancellation and may send additional information to the personnel above, which may include the following message:

    "The Flood Warning in the Beaver Dam area is no longer in effect. The flood threat is diminishing but hazards to life and property may still exist. Subsequently, the evacuation order may still be in effect. Residents should coordinate with local emergency services and/or law enforcement for more information on their specific situation."

NOTE: The Mohave County Flood Warning Alert System does not extend to radio stations in the Arizona Strip area and will not be used in this scenario. NWS will be relied upon to activate any NOAA radios in the area and send evacuation warnings to TV and radio stations covering the Beaver Dam area.

The above notifications and warnings are summarized in Table 2.1.

Table 2.1 Summary of flood detection warning sequence

Warning Stage	Local Communication	Message Content (includes effective time)	Flood Condition Status
STAGE 1 (triggered by NWS)	NWS: NOAA Weather Radio, Commercial Radio and/or TV	NWS flood watch for Northwest Mohave County	Flooding possible in extreme northwest Mohave County, including Beaver Dam Wash.
	AFWS communicates by email/texting to: PWD, EMRM, EMC, DREM, FCDE, BDFD, SODC, and SOAS	This is a Beaver Dam FRP Stage 1 message. The potential need to evacuate selected areas due to flooding may exist. Residents should not cross flooded washes.	Flooding is possible in the Beaver Dam area of extreme northwest Mohave County.
	NWS: NOAA Weather Radio, Commercial Radio and/or TV	NWS flood watch for Northwest Mohave County is cancelled.	Flooding in extreme northwest Mohave County, including Beaver Dam Wash is no longer expected.
	AFWS communicates by email/texting to: PWD, EMRM, EMC, DREM, FCDE, BDFD, SODC, and SOAS	The Flood Watch in the Beaver Dam area is no longer in effect. The Response Plan Stage 1 Message for the Beaver Dam Area of the Arizona Strip is Canceled.	Flooding in extreme northwest Mohave County, including Beaver Dam Wash is no longer expected.
STAGE 2 (triggered by FCDE)	NWS: NOAA Weather Radio, Commercial Radio and/or TV	NWS Thunderstorm or Flood Warning	Flooding is imminent or occurring in extreme northwest Mohave County, including Beaver Dam.
	FCDE or AFWSM communicates to: PWD, EMRM, EMC, DREM, BDFD, SODC, and SOAS	This is a Beaver Dam FRP Stage 2 message. The potential need to evacuate selected areas is high. Beaver Dam Area response agencies should activate personnel in preparation for possible evacuation and *swift water rescue duties. Residents in Beaver Dam should prepare to evacuate upon receipt of a Beaver Dam Flood Response Plan Stage 3 message and should not cross flooded washes.	Heavy rainfall detected in northwest Mohave County Beaver Dam Wash watershed. Mohave County AFWS detects rainfall values that have exceeded the warning thresholds established for the Beaver Dam Wash watershed. Potential for life-threatening flooding exists.
	NWS: NOAA Weather Radio, Commercial Radio and/or TV	NWS flood warning for Northwest Mohave County is cancelled.	Flooding in extreme northwest Mohave County, including Beaver Dam Wash is no longer expected.
	CDE or AFWSM communicates to: PWD, EMRM, EMC, DREM, BDFD, SODC, and SOAS	The Flood Warning in the Beaver Dam area is no longer in effect. The Response Plan Stage 2 Message for the Beaver Dam Area of the Arizona Strip is Canceled.	Flooding in extreme northwest Mohave County, including Beaver Dam Wash is no longer expected.

Table 2.1 Summary of flood detection warning sequence

Warning Stage	Local Communication	Message Content (includes effective time)	Flood Condition Status
STAGE 3 (triggered by EMC)	EMC communicates to: FCDE, PWD, EGRC, EMRM, DREM, BDFD, SODC, and SOAS	This is a Beaver Dam FRP Stage 3 message. Notify all residents of Beaver Dam Estates to evacuate immediately.	Extreme rainfall detected in northwest Mohave County Beaver Dam Wash watershed. Mohave County AFWS detects/predicts rainfall and streamflow values that and coverage areas associated with Beaver Dam FRP Stage 3.
	NWS: NOAA Weather Radio, Commercial Radio and/or TV	This is a Beaver Dam FRP Stage 3 message for the Beaver Dam Area of the Arizona Strip. All residents of Beaver Dam Estates and/or Resort are to evacuate immediately.	
	SODC sends warning through: Automated Call System, St. George/Las Vegas Radio Stations, Mesquite Cable TV		
STAGE 3 All Clear	NWS: NOAA Weather Radio, Commercial Radio and/or TV	NWS flood warning for Northwest Mohave County is cancelled.	Flooding in extreme northwest Mohave County, including Beaver Dam Wash is no longer expected.
	AFWSM Communicates to: PWD, EGRC, EMC, DREM, FCDE, BDFD, SCDC, and SOAS	The Flood Warning in the Beaver Dam area is no longer in effect. The flood threat is diminishing but hazards to life and property may still exist. Subsequently, the evacuation order may still be in effect. Residents should coordinate with local emergency services and/or law enforcement for more information on their specific situation.	Flood levels on Beaver Dam Wash have dropped below critical depths. Potential for additional extreme flooding is minimal.

* In this geographic area as well as other areas of Mohave County, the Flood Control District relies heavily on response agencies for assistance with evacuations and potential swift water rescues. It is critical that the volunteer swift water rescue teams have sufficient and reliable equipment to perform rescues during these potentially deadly incidents. To assure the effectiveness of these rescues, the Flood Control District occasionally assists with the purchase of new rescue equipment.

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3 RECOMMENDED EVACUATION AREAS

The recommended evacuation areas for the critical threshold locations due to overbank flooding are shown on Figure 3.1. Due to such short flood response lead times for short duration storms, when an evacuation is ordered for storms of this type, the entire area shown should be evacuated.

The recommended possible evacuation area due to failure of existing erosion protection and possible bank migration is shown on Figure 3.2. This area should be closely monitored and evidence of the commencement of bank migration found before ordering an evacuation.

Figure 3.1 Recommended evacuation areas due to overbank flooding

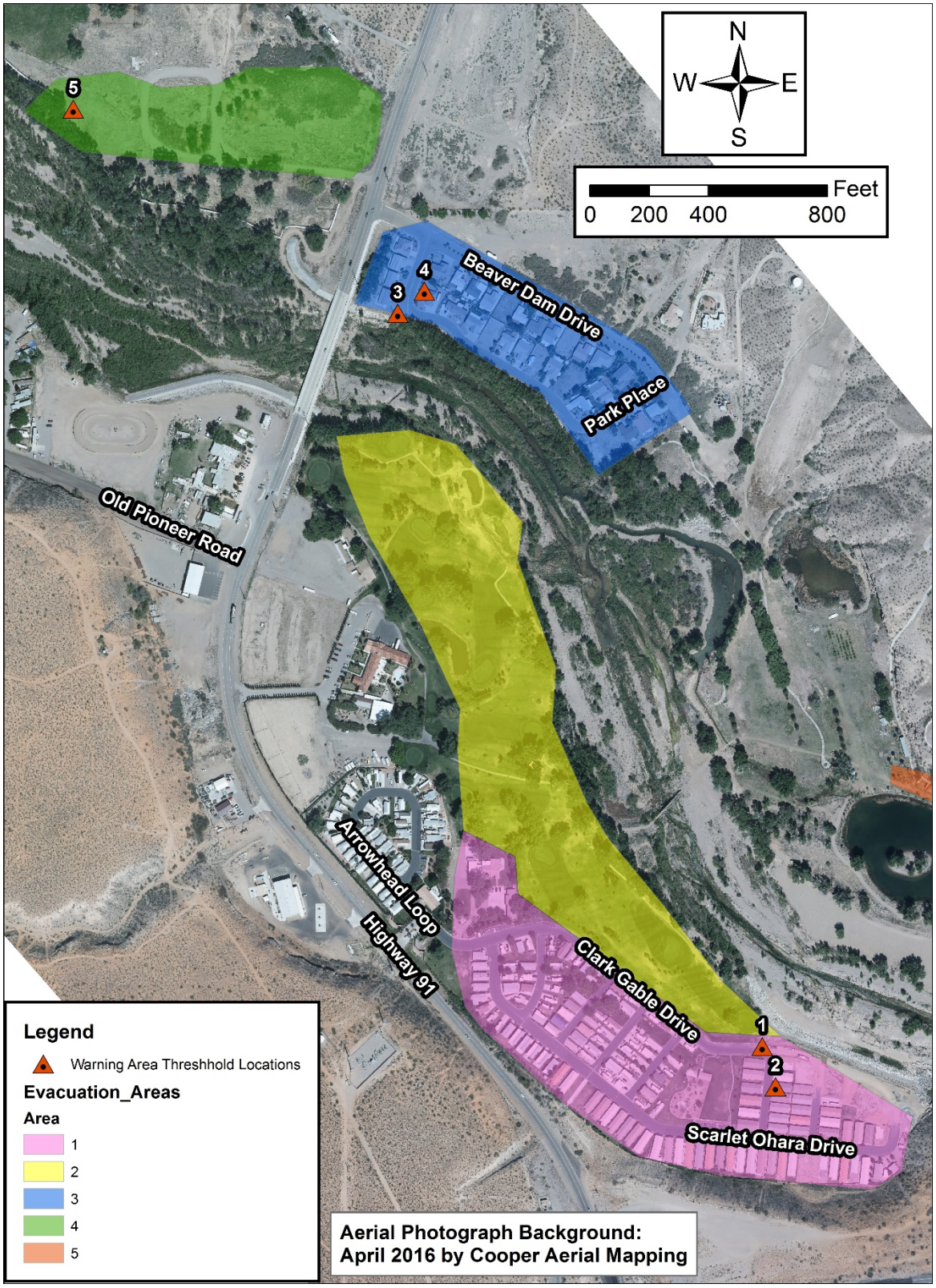
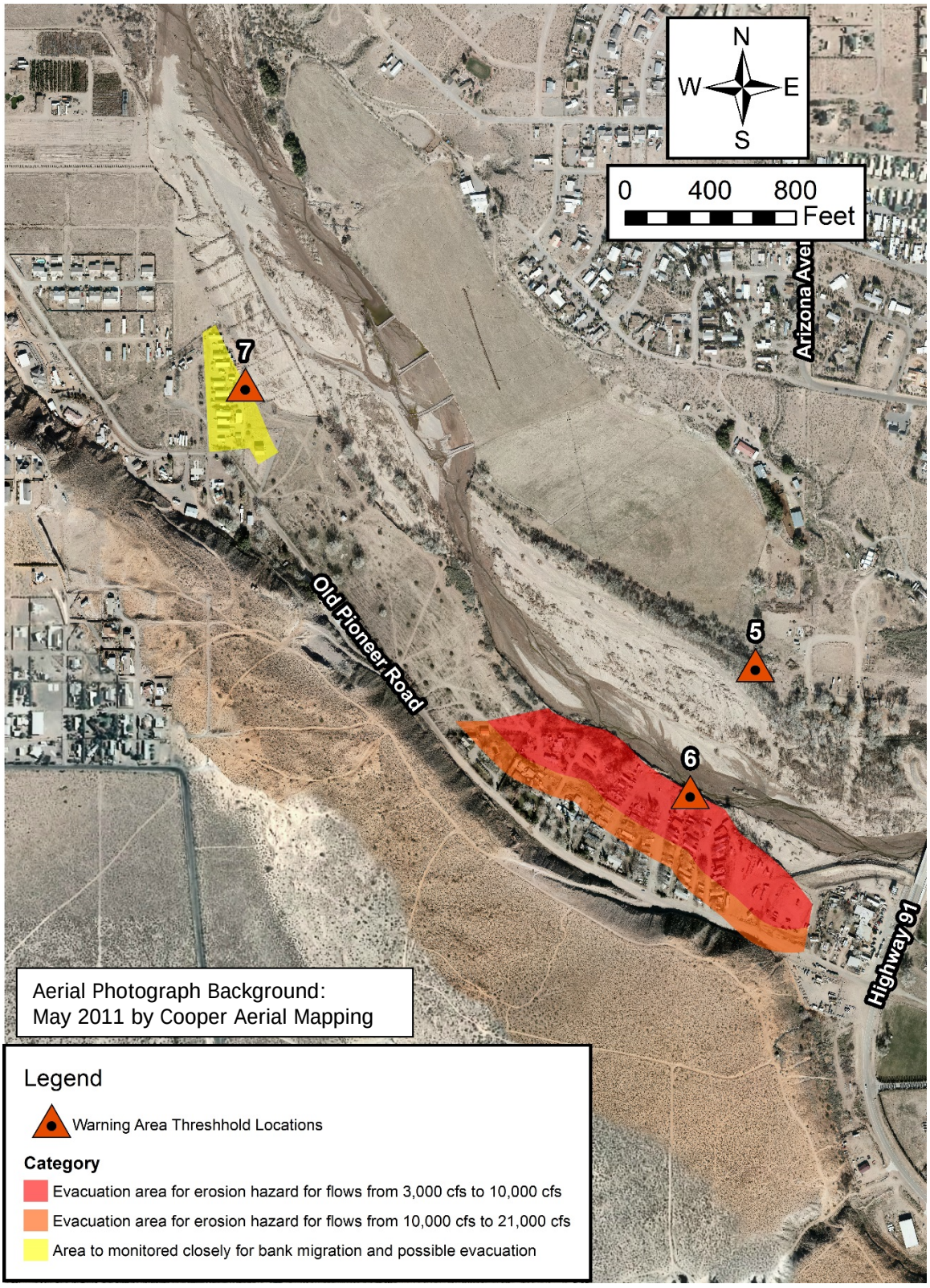


Figure 3.2 Recommended areas to monitor for erosion hazard



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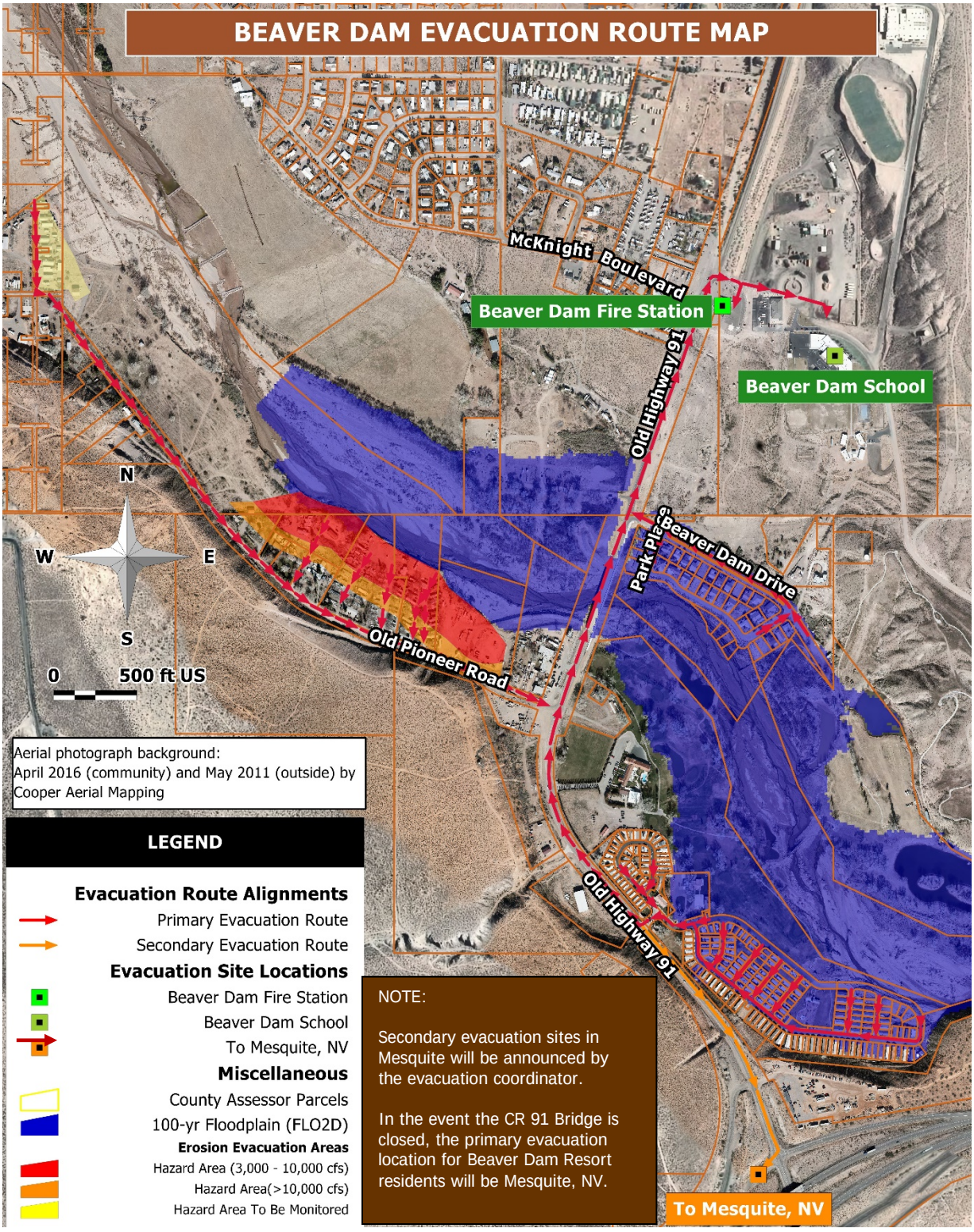
4 RESIDENT ACTION PLAN

The resident action plan is designed to be a plastic laminated handout that residents can keep in their home, on the refrigerator or other visible location. It consists of a descriptive table on the front that lists the various flood messages, a description of what the message means, and a description of actions to take. A map depicting the evacuation routes is on the reverse side.

Table 4.1 Resident action plan

Message	What It Means	What You Need To Do
(NOAA Weather Radio, Radio, TV) NWS Flood Watch	• NWS Flood Watch for Northwestern Mohave County (begin time/end time) • Be Prepared!	Monitor the NOAA weather radio continually for updates. Other sources of flood information: • Some commercial radio and TV stations voluntarily broadcast NWS flood watch and flood warning information • Flood information may be available by monitoring the MCFCD web page at: https://www.mohavecounty.us/ContentPage.aspx?id=124&cid=392 • 24-hour hydrologic and weather information for the entire state is available at: http://www.afws.org
(NOAA Weather Radio, Radio, TV) NWS Flood Warning (begin time/end time)	• Flooding is imminent or occurring in extreme northwest Mohave County, including Beaver Dam. • Prepare for possible evacuation.	• You MAY be instructed to EVACUATE and will need to do so at a moment's notice. You may only have minutes! Take Action! • Monitor the NOAA weather radio continually for updates. • Locate all residents of your home, including pets and livestock. • Collect absolute necessities and load in your vehicle(s). Include a flashlight. Secure premises.
(NOAA Weather Radio, Radio, TV) NWS Severe Flood Alert and MC Evacuation Notice for Beaver Dam (begin time/end time or all clear)	• Extreme rainfall detected in the Beaver Dam Wash watershed. • Critical flow rates detected by stream gages. Severe flooding is imminent or occurring. • Evacuation order has been issued MCSO.	• IMMEDIATELY EVACUATE all residents and pets from your home and get to the evacuation site (see map on reverse). Act quickly! • Turn off lights, heating and air-conditioning units. • Hang a light-colored sheet or towel over your door to indicate to emergency personnel that you have evacuated. • Monitor your NOAA weather radio for updates. • Follow the evacuation route shown on the map. DO NOT cross any barricaded roads! NEVER drive through flooded roadways, especially at night when dangers are harder to recognize. • Report to the evacuation site for registration, even if you do not plan to stay. • Seek medical care at the nearest hospital if needed. Food, clothing, and first aid may be available from emergency aid organizations such as the Red Cross.
(Siren Sounds) Sheriff's Department Conducting Door-to-door Evacuation	• Evacuation order has been issued.	
All Clear Message	• Floods on Beaver Dam Wash have dropped below critical depths. Potential for additional extreme flooding is minimal.	• After authorities have given permission, leave the evacuation site and return to your home using the same route in reverse. • Use flashlights to examine buildings. Flammables may be inside. • Electrical equipment should be dried and checked before being returned to service. • Boil drinking water before using. • Throw out any fresh food that has come in contact with flood waters.

Figure 4.1 Evacuation route map



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5 REFERENCES

Arid Hydrology and Hydraulics, LLC (AridHH),

2009, *Beaver Dam Wash Flood Hazard Assessment, Flood Response Plan*.

2013, *Beaver Dam Flood Response Plan Hydrology and Hydraulics Report*.

Arizona Department of Water Resources (ADWR), 1996, *State Standard for Watercourse System Sediment Balance*, State Standard 5-96.

Mohave County Flood Control District (MCFCD), 2012, *Drainage Design Manual for Mohave County*.

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APPENDIX A FLOOD DETECTION

A.1 Detection and Warning Criteria Description

The flood detection criteria from the January 2009 FRP were revised in 2014 based upon use and analysis of the watershed rainfall and stream flow gage measured data and the results of hydrologic and hydraulic analyses performed following the December 2010 flood. Refer to APPENDIX C for supporting technical data and to AridHH (2013) for a full description of the hydrologic and hydraulic modeling performed. The flood detection criteria were modified in this revision (March 2017) based on the addition of the Mormon Well stream flow gage (Gage 7479) and revised rating curves for the CR91 stream flow gage (Gage 7601). Recommended alarm settings for the Automated Local Evaluation in Real Time (ALERT) system gages are listed in Table A.1.

Seven critical locations within the Beaver Dam community were defined for the purpose of setting peak discharge thresholds. The thresholds were revised as a part of this update (March 2017) based on updated 2D modeling using the 2016 topography. When the estimated flow rate in Beaver Dam Wash exceeds a threshold value for locations 1-7, flow can be expected to begin flooding the area adjacent to the threshold location. Threshold locations 1-6 are shown on Figure A.1 and Figure A.2. Each location is described as follows:

Location 1. Beaver Dam Resort: Clark Gable Drive at Humphrey Bogart Way. When the discharge exceeds the Location 1 threshold value, the Beaver Dam Resort area will begin to experience flooding.

Location 2. Beaver Dam Resort: Lowest Floor (APN 402-87-012). When the discharge exceeds the Location 2 threshold value, the residence at this location, which has the lowest finished floor elevation, will be affected.

Location 3. Beaver Dam Estates: North end Park Place at revetment. When the discharge exceeds the Location 3 threshold value, the Beaver Dam Estates area will begin to experience flooding.

Location 4. Beaver Dam Estates: Lowest Floor (APN 402-86-005). When the discharge exceeds the Location 4 threshold value, the residence at this location will be affected.

Location 5. Northeast bank upstream of Hwy 91 Bridge. When the discharge exceeds the Location 5 threshold value, the residences downstream of this area in the Northeast overbank will begin to be affected.

Location 6. Reach along the southwest bank upstream of the CR 91 Bridge subject to potential bank migration.

Location 7. Reach along the southwest bank 4,000 feet upstream of the CR 91 Bridge subject to potential bank migration.

The MCFCD rain and stream gage locations, USGS stream flow gage locations, and the NRCD SNOTEL gage locations are shown graphically on Figure A.3. The number assigned to each MCFCD gage is shown on the figure. The gage number is used when referring to a gage in the following tables. The USGS gages only provide hourly readings so that data will normally only be used for verification purposes.

Four watershed scenarios were defined for setting flood detection and warning criteria: entire watershed, upper watershed, middle watershed and lower watershed. The four watershed scenarios are shown graphically on Figure A.3, Figure A.4, Figure A.5 and Figure A.6.

The threshold gage height and discharge values for each threshold location are listed in Table A.2. Each threshold location has been referenced to the CR 91 stream flow gage (gage number 7601). The gage heights shown in the table are for that gage.

Three storm types are considered in this plan for defining flood detection criteria:

1. Short Duration Storm. A synthetic 24-hour duration storm that includes the peak 15-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 12-hour storms nested and centered at hour 12.
2. Long Duration Storm. A synthetic 112 hour storm based on the December 2010 flood.
3. Warm rain on snow pack.

Storm type 1 would typically result from a fall tropical storm or hurricane storm remnant. It also represents large convective summer storms. Storm type 2 addresses the longer duration general storm that typically occurs in the winter months, but also addresses longer duration tropical storms and hurricane storm residue that normally occur in the fall. Storm type 3 is usually associated with a winter or spring storm, similar to the storm type that is suspected to have resulted in the 2005 flood. Specific criteria for storm type 3 are not provided due to the

high level of uncertainty and variation in conditions that can occur. Instead, suggestions for adjusting the criteria from the short duration storms is provided that could be used to assess conditions as they occur and make a reasonable judgment regarding the potential hazard.

The flood detection criteria for this plan are based upon the rainfall intensities and depths required to produce and exceed the critical stages or discharges corresponding to the threshold locations shown on Figure A.1 and Figure A.2 and listed in Table A.2. These criteria are recommended for use by the MCEM and the National Weather Service (NWS) to disseminate flood warning messages to residents in the warning area and to appropriate emergency response agencies, thereby triggering implementation of the FRP. Table A.3 (entire watershed), Table A.4 (upper watershed), Table A.5 (middle watershed) and Table A.6 (lower watershed) below contain summaries of the threshold criteria for each level of flood alert in the warning sequence for the short duration storm. These criteria are intended for use with storms in the 6-hour to 24-hour duration range, using engineering judgment.

Table A.7 contains summaries of the threshold criteria for each level of flood alert in the warning sequence for the long duration storm. These criteria are intended for use with storm durations in the range of two (2) to seven (7) days, again using engineering judgment.

Each watershed scenario is capable of producing runoff discharges sufficient to reach the threshold values in Table A.2, assuming the average listed amounts of precipitation occur over the watershed area considered.

More detailed supporting technical information is contained in APPENDIX C. Each appendix section contains a description, intended use and limitations discussion. The following is a brief description of the information found in each appendix section.

Appendix C.1: Contains tables and figures that relate peak discharge to total storm rainfall of 24-hour duration for the four watershed scenarios (entire, upper, middle and lower). The intent is to use this information as a storm approaches the watershed by relating the anticipated total rainfall estimated by the NWS to expected peak discharge.

Appendix C.2: Contains graphs of 24-hour precipitation and resulting runoff response over time for each watershed scenario. The information on the four graphs is the basis for the warning stage criteria for short duration storms shown in Table A.3, Table A.4, Table A.5, and Table A.6.

Appendix C.3: Contains a graph (Figure C.9) showing the synthetic storm rainfall distributions developed from the December 2010 storm data. These distributions were then scaled to a 112 –hour storm duration as shown on Figure C.10. The estimated rainfall-runoff response from the entire watershed for a multi-day storm is also shown on Figure C.10. The information on Figure C.10 is the basis for the warning stage criteria for long duration storms shown in Table A.7.

Appendix C.4: Contains a graph of the December 2010 storm gage-measured rainfall and runoff hydrographs. Rainfall intensities for critical portions of the storm that resulted in high runoff rates are identified to help understand how the watershed responded during an event of this type.

Appendix C.5: Contains curves for use in estimating travel times between the Motoqua gage site, the Catclaw Canyon gage site, the Mormon Well, and the CR 91 bridge gage site.

Appendix C.6: Contains the ALERT system hydraulic rating curves for the four flow gages.

Appendix C.7: Contains conservative estimates of areas where lateral migration of the watercourse banks due to erosion is possible.

A.2 Recommended ALERT System Settings

It is recommended that alarms be triggered in the ALERT system at the thresholds listed in Table A.1. When an Alarm level is reached, the rainfall and runoff readings should be carefully evaluated, monitored and compared with the flood warning stage criteria in Section A.4.

Table A.1 Recommended ALERT system alarm settings

Gage	Alarm 1	Alarm 2	Alarm 3
Rain Gages (alarm when total rain AND Intensity criteria met)			
All Rain Gages: Total Rain	0.5 inches ≤ 6 hours	1.0 inches ≤ 6 hrs	1.5 inches ≤ 6 hrs
All Rain Gages: Intensity	0.1 in/hr ≤ 5 hours	2.0 in/hr ≤ 15 min	3.0 in/hr ≤ 30 min
Stream Flow Gages (gage alarm when any single criteria met)			
Motoqua (1648)	≥ 200 cfs	≥ 250 cfs	≥ 500 cfs
Catclaw Canyon (1510)	≥ 1,200 cfs	≥ 2,000 cfs	≥ 10,000 cfs
Mormon Well (7479)	≥ 1,000 cfs	≥ 1,500 cfs	≥ 4,000 cfs
CR 91 (7601)	≥ 300 cfs	≥ 500 cfs	≥ 2,000 cfs

A.3 Watershed Maps

The various maps showing the critical threshold locations and the watershed areas are contained in this section. The USGS gages shown on Figure A.3 are referenced to different horizontal and vertical datums than the Mohave County ALERT system gages that are also shown. If the USGS gage data are used, be aware that the vertical datum for those gages is NGVD 1929, while the Mohave county gages are referenced to NAVD 1988. Also, the bench mark previously located on the northwest abutment of the CR 91 bridge was removed when the new bridge was constructed. Mohave County has placed a new benchmark on the northeast abutment. See Mohave County flood control district staff for the exact location and elevation of the new benchmark.

Figure A.1 Warning area threshold locations map 1

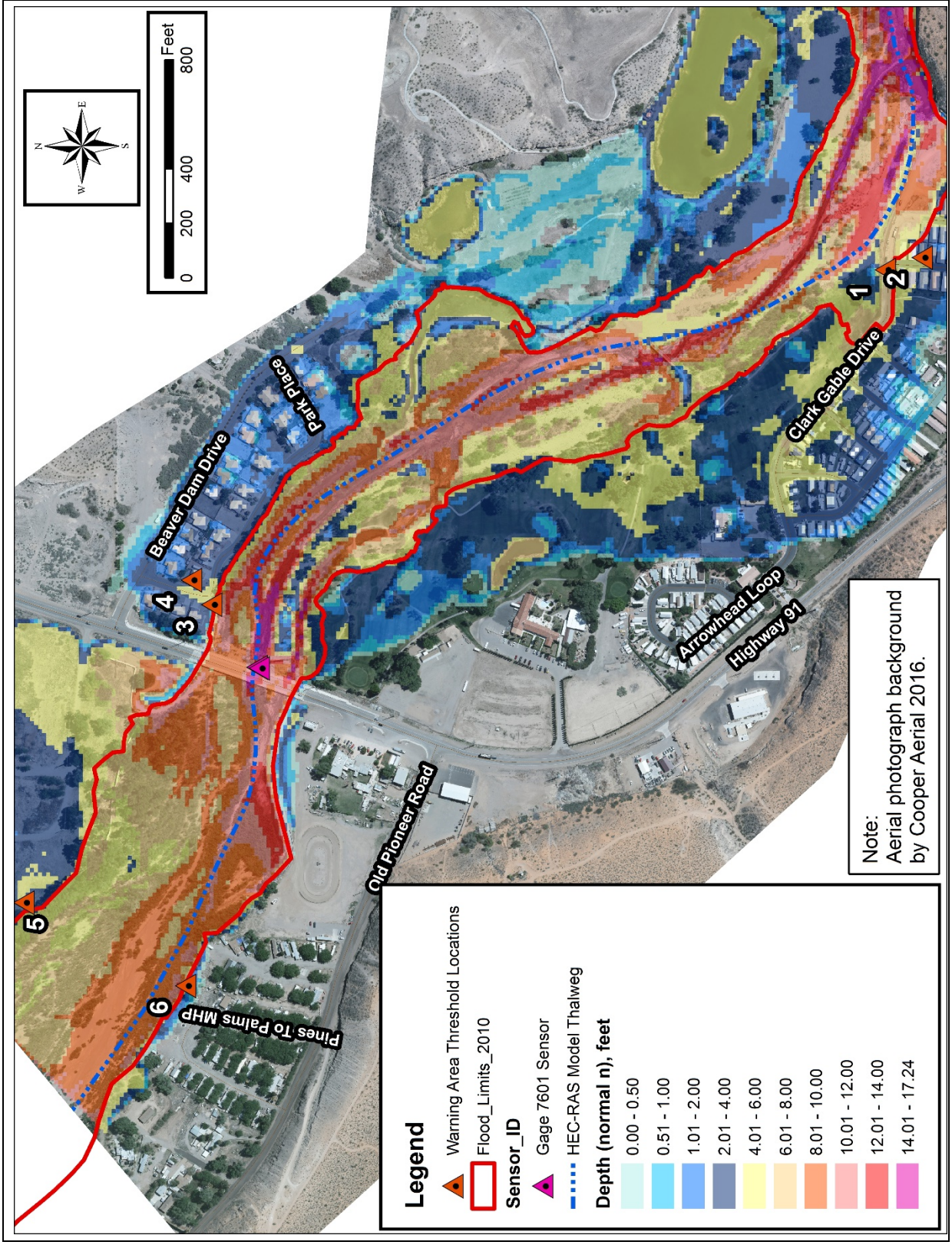


Figure A.2 Warning area threshold locations map 2

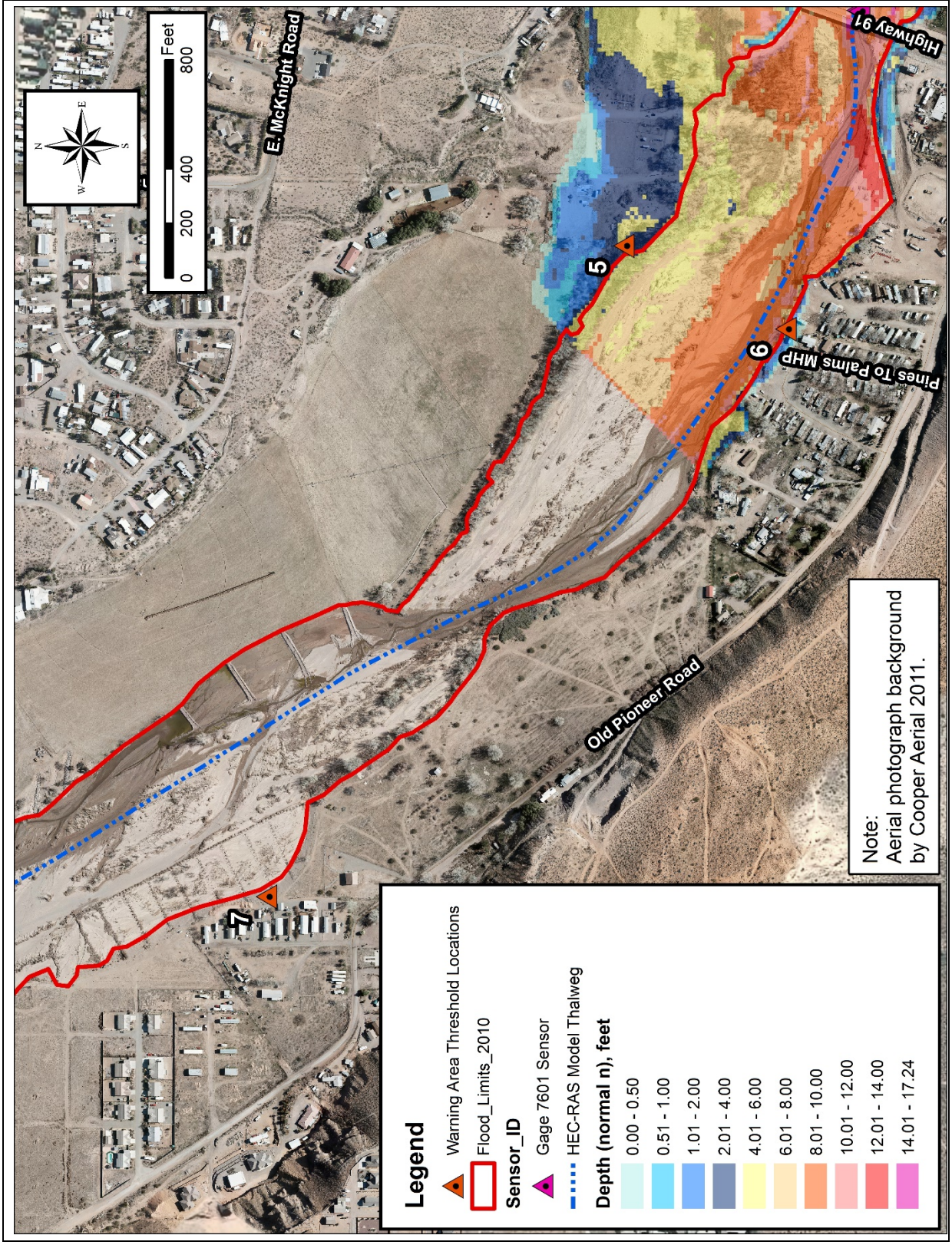


Figure A.3 Beaver Dam Wash Entire Watershed and Gage Locations

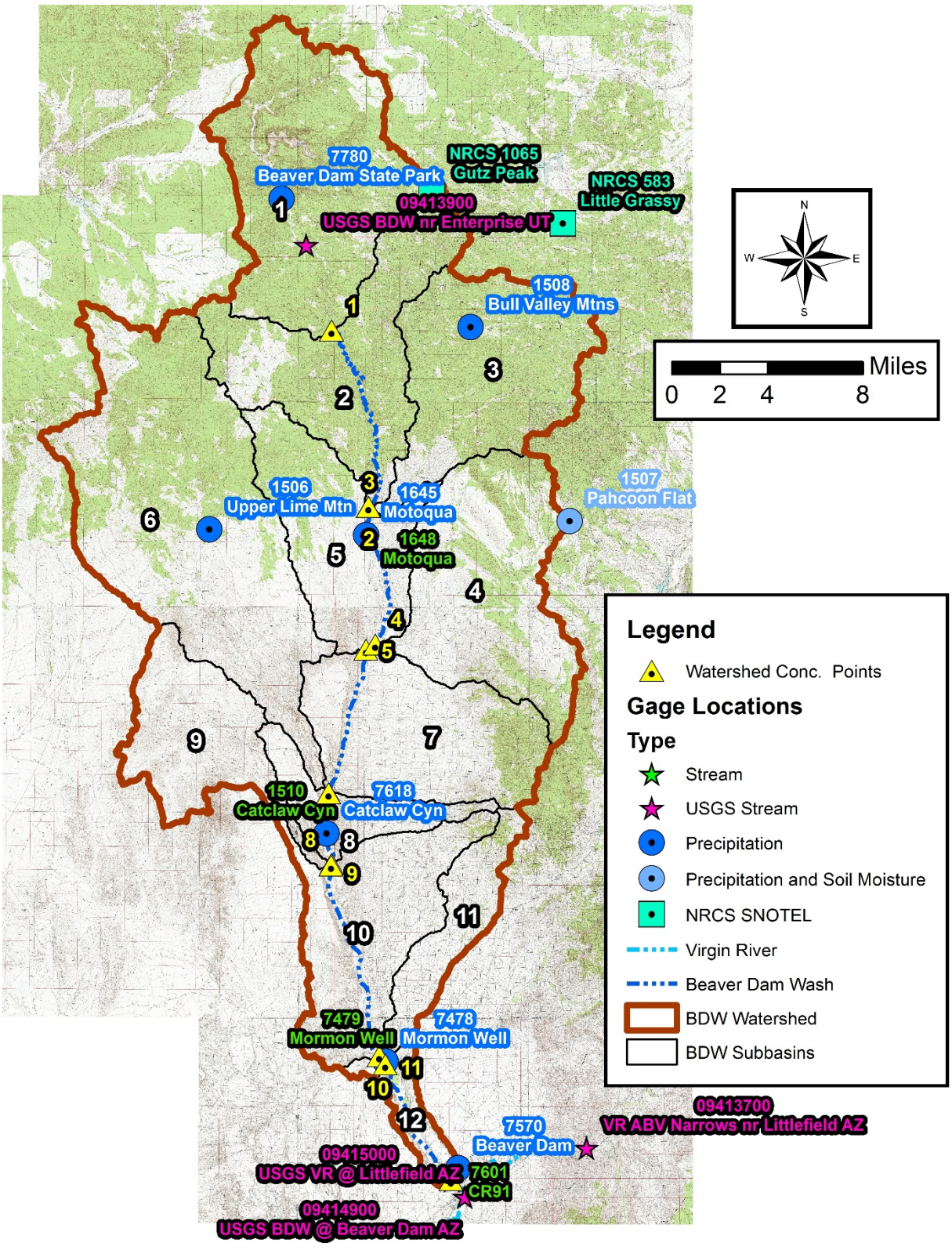


Figure A.4 Upper Beaver Dam Wash Watershed

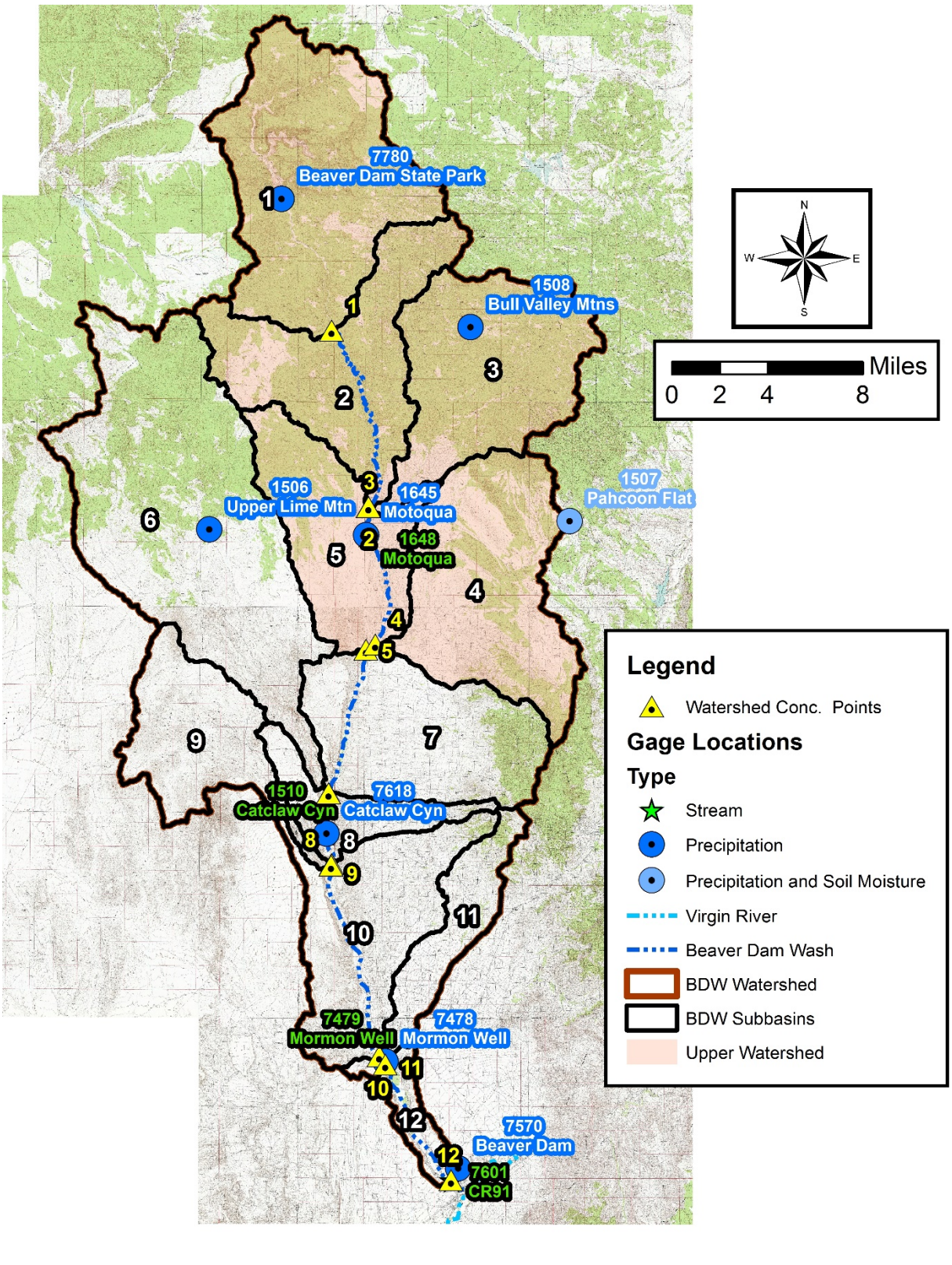


Figure A.5 Middle Beaver Dam Wash Watershed

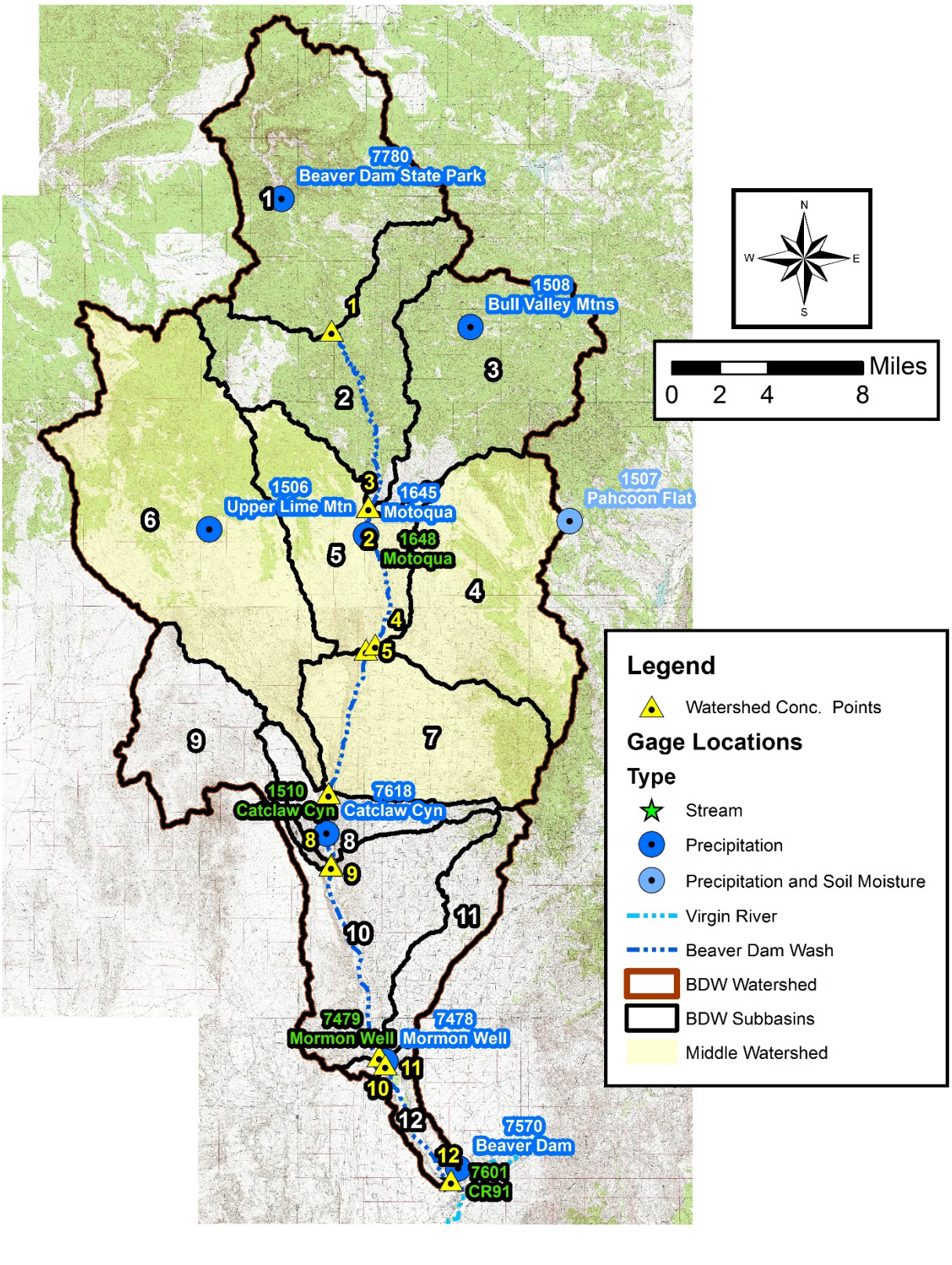
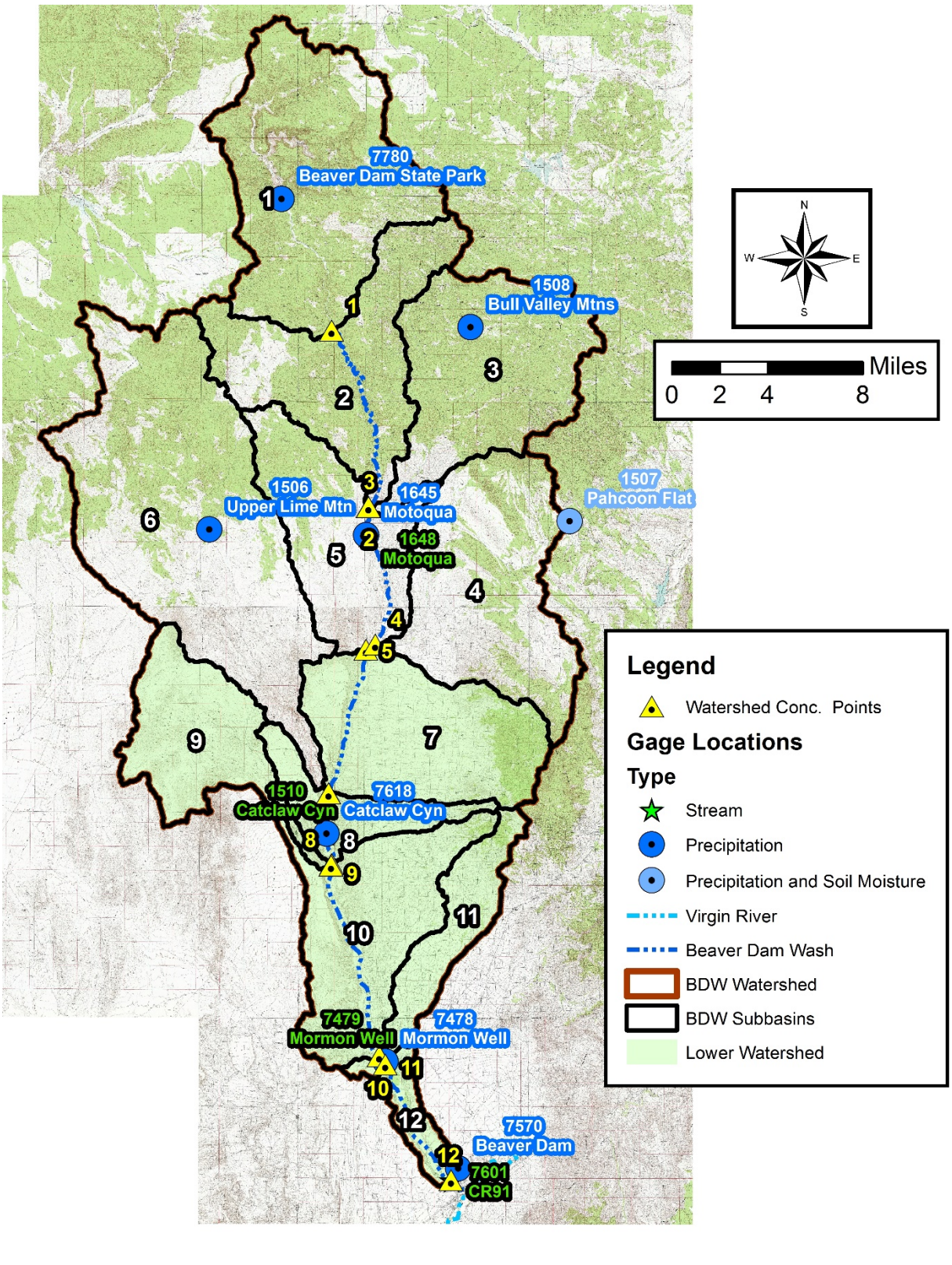


Figure A.6 Lower Beaver Dam Wash Watershed



A.4 Flood Detection and Warning Criteria Tables

Table A.2 Threshold gage heights and discharge values for warning areas

Location Number	Location[1]	CR 91 Gage (7601)		Threshold Discharge, cfs
		Gage Height, ft	WSEL	
(1)	(2)	(3)	(4)	(5)
1	Beaver Dam Resort: Clark Gable Drive at Humphrey Bogart Way.	10.1	1837.9	11,700
2	Beaver Dam Resort: Lowest Floor (APN 402-87-012)	12.0	1839.8	17,400
3	Beaver Dam Estates: North end Park Place at revetment	10.7	1838.4	12,700
4	Beaver Dam Estates: Lowest Floor (APN 402-86-005)	12.0	1839.8	17,400
5	North bank upstream of Hwy 91 Bridge	7.5	1835.3	5,100
6	Southwest overbank upstream from Hwy 91 Bridge. Condition: Possible bank erosion.	9.9	1837.5	10,000
7	Southwest overbank area 4,000 feet upstream of CR 91 Bridge to be monitored for bank erosion	6.4	1833.9	3,000
[1]	Gage heights and threshold discharges are for possible overbank flooding unless otherwise noted.			

Table A.3 Warning criteria for short duration storms (entire watershed)

Flood Warning Stage	Rainfall[1] (AND criteria)		Measured Discharge (AND criteria)			
	Total Depth (≤5hrs)	Intensity & Duration	Motoqua (1648)	Catclaw Canyon (1510)	Mormon Well (7479)	CR 91 (7601)
	Inches	(in/hr, hr)	cfs	cfs	(cfs)	cfs
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	≥ 0.5	≥ 0.1, ≥ 5	≥ 200	≥ 1,200	≥ 1,000	≥ 300
2	≥ 1.0	≥ 2.0, 0.25	≥ 250	≥ 2,000	≥ 1,500	≥ 500
3	≥ 1.5	≥ 2.0, 0.5	≥ 500	≥ 10,000	≥ 4,000	≥ 2,000

[1] Avg. of measured values at gages 1506, 1507, 1508, 7618, 1645, 7478, 7570, & 7780

Table A.4 Warning criteria for short duration storms (upper watershed)

Flood Warning Stage	Rainfall[1] (AND criteria)		Measured Discharge (AND criteria)			
	Total Depth (≤ 5 hrs)	Intensity & Duration	Motoqua (1648)	Catclaw Canyon (1510)	Mormon Well (7479)	CR 91 (7601)
	(in)	(in/hr, hr)	(cfs)	(cfs)	(cfs)	(cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	≥ 0.5	≥ 0.15, ≥ 5	≥ 500	≥ 1,500	≥ 1,500	≥ 300
2	≥ 1.5	≥ 2.5, 0.25	≥ 500	≥ 4,000	≥ 4,500	≥ 500
3	≥ 2.0	≥ 3.0, 0.5	≥ 1,000	≥ 8,500	≥ 8,500	≥ 2,000

[1] Average of measured values at gages 1507, 1508, 1645, & 7780

Table A.5 Warning criteria for short duration storms (middle watershed)

Flood Warning Stage	Rainfall[1] (AND criteria)		Measured Discharge (AND criteria)			
	Total Depth (≤ 5 hrs)	Intensity & Duration	Motoqua (1648)	Catclaw Canyon (1510)	Mormon Well (7479)	CR 91 (7601)
	(in)	(in/hr, hr)	(cfs)	(cfs)	(cfs)	(cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	≥ 0.5	≥ 0.15, ≥ 5	n/a	≥ 750	≥ 800	≥ 300
2	≥ 1.0	≥ 2.0, 0.25	n/a	≥ 3,500	≥ 2,500	≥ 500
3	≥ 1.5	≥ 2.0, 0.5	n/a	≥ 9,500	≥ 8,000	≥ 2,000

[1] Average of measured values at gages 1506, 1507, 7618, & 1645

Table A.6 Warning criteria for short duration storms (lower watershed)

Flood Warning Stage	Rainfall[1] (AND criteria)		Measured Discharge (AND criteria)			
	Total Depth (≤ 5 hrs)	Intensity & Duration	Motoqua (1648)	Catclaw Canyon (1510)	Mormon Well (7479)	CR 91 (7601)
	(in)	(in/hr, hr)	(cfs)	(cfs)	(cfs)	(cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	≥ 0.5	≥ 0.15, ≥ 5	n/a	≥ 300	≥ 500	≥ 500
2	≥ 1.0	≥ 2.0, 0.25	n/a	≥ 1,000	≥ 1,000	≥ 1,000
3	≥ 2.5	≥ 3.0, 0.5	n/a	≥ 9,000	≥ 7,000	≥ 3,000

[1] Average of measured values at gages 7618, 7478, & 7570

Table A.7 Warning criteria for long duration storms (entire watershed)

Flood Warning Stage	Rainfall[1] (OR criteria)		Measured Discharge (AND criteria)			
	Total Depth (≤ 36 hrs)	Intensity & Duration	Motoqua (1648)	Catclaw Canyon (1510)	Mormon Well (7479)	CR 91 (7601)
	(in, hrs)	(in/hr, hrs)	(cfs)	(cfs)	(cfs)	(cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	≥ 1.0	≥ 0.05, ≥ 12	≥ 300	≥ 1,250	≥ 1,000	≥ 1,000
2	≥ 4.0	≥ 0.15, ≥ 6	≥ 1,000	≥ 4,000	≥ 3,000	≥ 3,000
3	≥ 6.0	≥ 0.30, ≥ 4	≥ 1,000	≥ 7,000	≥ 6,000	≥ 5,000

[1] Avg. of measured values at gages 1506, 1507, 1508, 7618, 1645, 7478, 7570, & 7780

A.5 Warm Rain on Snow Pack Storm Types

The upper and middle portions of the watershed range in elevation from 3,000 to over 7,500 feet in elevation and are subject to snow accumulation in the winter months. There are two NRCS SNO-TEL sites in or near the watershed as shown on Figure A.3. A mechanism for high flood volumes and peak discharges in Beaver Dam Wash is to have a large general storm deliver a warm rain on snow pack. This is a difficult scenario to model. Instead, a simplified approach is proposed to estimate the effects of this storm scenario. The steps are as follows:

1. Estimate the average snow pack depth and water content over the upper and or middle watershed areas.
2. Assume 75% of all melted snow will result in runoff (rainfall loss including IA of 25%)
3. Estimate an equivalent depth of water using the snow pack water content and depth added to the total rainfall received. If estimates of snow pack depth and water content cannot be obtained, carefully monitor the rain gages for rapid increases in water resulting from melted snow. Note that this will result in shorter response times.
4. Use Figure C.2 and Figure C.3 to estimate a resulting peak discharge.
5. Closely monitor the Motoqua and Catclaw Canyon gage readings for trends toward reaching the estimated peak discharge.
6. Make Warning Stage judgments based on this information.

For example, the Colorado Basin River Forecast Center indicates the presence of a snow water-equivalent depth of 1.5-inches at the two SNO-TEL sites. The Beaver Dam State Park reports 6-inches of snow depth in and around the park. It is estimated through conversations with the NWS that the water content of the snow pack is about 30%. It has rained an estimated 1-inch on the upper watershed.

Estimated Equivalent Rain at Beaver Dam State Park= 6*0.3*0.75 + 1 = 2.4-inches.

SNO-TEL sites indicate 1.5-inches. Estimated rain equivalent = 1.5 + 1 = 2.5-inches.

Use an estimated rain equivalent of 2.4-inches.

From Figure C.2 and Figure C.3, The peak discharge estimates for 2.4-inches of rain are:

Motoqua: 1,400 cfs, Catclaw Canyon: 14,000 cfs, and CR 91: 12,000 cfs.

A.6 Erosion Hazards

Erosion resulting in lateral migration of the Beaver Dam Wash channel is a significant hazard. The January 2005 flood, with a peak discharge in the range of 17,000 cfs to 25,000 and a flood duration of about 5 days, resulted in lateral migration distances ranging from 75 feet to over 400 feet. The December 2010 flood, with a peak discharge of about 13,700 cfs and a flood duration of seven days, resulted in lateral migration distances ranging from 50 feet to over 275 feet. In the 2010 flood, four homes were totally destroyed due to lateral migration of the channel. Refer to Appendix C.7.

Therefore, considerations for lateral migration of the Beaver Dam Wash channel are a component of this flood response plan. Lateral erosion can be expected to begin occurring for flow rates as low as 3,000 cfs. For this reason, critical threshold estimates are included in Table A.2 for locations 6 and 7. Location 6 is shown on Figure A.1. Note that the entire length of bank where existing structures are located could be affected. The recommended evacuation area for Location 6 is shown on Figure 3.2. The channel bank in both Locations 6 and 7 should be closely monitored during a flood event to determine if bank migration is occurring and to help with an evacuation decision.

Location 7 is an area protected by erosion control measures that could fail. Therefore, it is recommended that this area be monitored during flood events to check for possible bank

erosion. The area that could be affected and is subject to possible evacuation is shown on Figure 3.2.

The Beaver Dam Resort area (Location 1) and the Beaver Dam Estates area (Locations 3 and 4) are protected from bank erosion by structural measures. These areas should also be monitored during a flood event to identify and react to any indications of structural failure.

A.7 CR 91 Stream Flow Gage not Functioning Scenario

In the event the CR 91 stream flow gage is not functioning, the following is the recommended procedure to follow as a backup plan.

1. Keep an appropriate measuring device at the Sheriff's Station Rain Gage storage shed. The device should consist of a nylon-coated steel measuring tape such as the *Keson NR10100 Nylon Coated Steel Blade 100-Foot Measuring Tape In Tenths With Extra Dead Foot And Ring End* or equivalent, and a 16 oz plumb bob (with string) such as an *Stanley 47-974 16 oz Brass Plumb Bob.* An alternative is a laser measuring device such as the *Johnson Laser Distance Measure 40-6004*. The physical approach is preferred as batteries are not required, other than for a flashlight for night time measurements. Pickup a portable light plant during mobilization and install at a location that optimizes use of the ALERT system camera during the nighttime hours.
2. Station a qualified person, with an assistant, at the gage location on the bridge. Refer to Figure A.7.
3. Take measurements every 15-minutes from the bottom of the cabinet at the radar sensor to the water surface directly below the radar sensor cabinet. The average bottom elevation of the radar sensor cabinet is 1852.55. Subtract each reading from 1852.55 to obtain an estimate of the water surface elevation (WSEL). The assistant should record each reading. The WSEL can then be used with the information in Table A.2 for checking warning level thresholds, and with Figure C.18 for estimating peak discharge at the CR 91 Bridge. Figure C.18 is in terms of gage height. To obtain gage height from the physical measurement, subtract 1829.5 from the estimated WSEL. As of April 2016, the average ground elevation, below the radar sensor, is 1827.77.

NOTE: Large debris such as trees can become lodged against the bridge piers resulting in increases in wave action, turbulence and water surface elevation. If this occurs, the readings will not be meaningful. The time of occurrence and duration should be documented.

Figure A.7 Location of CR 91 stream gage radar sensor cabinet

APPENDIX B EFFECTIVE LEAD TIME

The effective lead time available for the implementation of a flood response plan is the time period afforded to the residents of the potential hazard area to evacuate before a flood reaches inescapable proportions. The estimate of that critical evacuation window is the total hydrologic lead time minus the emergency response time. For the purposes of this study, hydrologic lead time is defined as the time to emergency access blockage by flood waters at Location 1 minus the beginning time of rainfall intensity greater than 2 inches/hour plus 15 minutes for short duration storms, and 0.25 inches/hour for long duration storms. The effective lead times for short and long term storms for the watershed-rainfall scenarios are shown in Table B.1. Note that there is very little effective lead time for the short duration storms, especially for such a remote area.

Decision makers in a flood emergency must exercise caution in the use of, and reliance upon, the lead time estimates provided in Table B.1. These lead times are estimates based upon the best available information and should not be strictly applied. There are a number of variables affecting hydrologic response that are storm specific and thus a set of response time estimates based on one or two synthetic storms cannot possibly cover all possible scenarios. Engineering judgment must be applied. Emergency response time is also highly dependent on circumstances during the storm event. The estimated lead times should only be used as an indicator of the urgency of the necessary response actions and as a decision-making tool for prioritization of the response activities.

Table B.1 Estimated lead time for flood response scenarios

Storm Type	Storm Coverage	Hydrologic Lead Time, hours (max)	Emergency Response Time, hours				Effective Lead Time, hours (3)-[(5)+(7)] or (3)-[(4)+(6)]	
			Decision Time		Action Time			
			Min	Max	Min	Max	Min	Max
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Short duration (6-48 hour event)	Entire Watershed	3.2	0.25	0.5	2.0	3.0	0.0	1.0
	Upper Watershed	4.6	0.25	1.0	2.0	3.0	0.0	2.4
	Middle Watershed	4.1	0.25	1.0	2.0	3.0	0.0	1.9
	Lower Watershed	2.7	0.25	0.5	1.0	2.0	0.0	1.5
Long duration (2-7 day event)	Entire Watershed	24-30	12.0	16.0	3.0	6.0	8.0	15.0

APPENDIX C TECHNICAL SUPPORT INFORMATION

C.1 Synthetic 24-hour Storm Rainfall-Runoff Response

C.1.1 Description

The information in this section is derived from HEC-HMS models of the watershed for a 24-hour duration storm using an NRCS Type 2 rainfall distribution. The HEC-HMS model hydrologic and hydraulic parameters were calibrated using measured rainfall and flow rates from the December 2010 flood event. The model was run for scenarios of the entire watershed, the upper watershed, the middle watershed, and the lower watershed as described in APPENDIX A. Each watershed scenario was run for total storm rainfall values of 0.50, 1.0-, 1.5-, 2.0-, 3.0-, and 4.0-inches. This information was then used to estimate the 24-hour total rainfall required to produce the threshold peak discharges in the Beaver Dam area as described in APPENDIX A. The threshold locations are shown graphically on Figure A.1. The threshold discharge values are listed in Table C.1. The results for each watershed scenario are listed in Table C.2, Table C.3, Table C.4, and Table C.5 for the Motoqua, Catclaw Canyon and CR 91 gage sites. These results are shown graphically on Figure C.1, Figure C.2, Figure C.3, and Figure C.4.

C.1.2 Intended Use

This information is intended to provide early guidance when a storm of shorter duration (6 to 24 hours) is approaching the watershed. The forecast total storm rainfall estimates from the NWS can be used to check if any of the critical threshold peak discharges may be reached by the event. This will help with advance notice for early notifications, as response times for these shorter duration, high intensity rainfall events is much shorter than for the longer duration, lower intensity storms such as occurred in 2005 and 2010.

C.1.3 Limitations

The rainfall intensity is based on the peak intensity of the NRCS Type 2 rainfall distribution, which varies from 2.3 to 3.0 inches/hour for these scenarios. The actual rainfall intensity and timing will vary significantly within a natural storm. This approach is also based on the assumption that the total storm rainfall is the average total rainfall over the entire watershed, which will also never be true. The peak discharge estimates are based on a normal soil

moisture condition. This approach is only intended to provide an estimate of what effect an incoming storm may have at Beaver Dam.

Table C.1 Watershed response data to produce threshold peak discharges

Threshold Discharge, cfs	Entire Watershed				Upper Watershed				Middle Watershed			Lower Watershed		
		Discharge, cfs				Discharge, cfs				Discharge, cfs			Discharge, cfs	
	Rain, in[1]	Motoqua	Catclaw	Mormon	Rain, in[1]	Motoqua	Catclaw	Mormon	Rain, in[1]	Catclaw	Mormon	Rain, in[1]	Catclaw	Mormon
3,000	0.86	414	3,171	3,100	1.20	580	3,620	3,140	0.98	3,588	3,196	1.45	2,611	3,089
5,300	0.94	548	5,524	5,448	1.57	741	6,114	5,514	1.19	6,014	5,500	1.83	4,506	5,400
10,000	1.49	697	10,298	10,297	2.17	1,256	10,951	10,300	1.58	10,931	10,215	2.32	7,541	10,068
11,000	1.55	731	11,237	11,290	2.28	1,426	11,985	11,300	1.65	11,959	11,230	2.41	8,135	11,059
12,300	1.63	777	12,447	12,574	2.43	1,648	13,330	12,600	1.74	13,296	12,548	2.53	8,908	12,347
15,800	1.83	899	15,702	16,034	2.83	2,244	16,949	16,100	1.99	16,894	16,097	2.85	10,989	15,815
16,600	1.88	927	16,447	16,824	2.92	2,381	17,776	16,900	2.04	17,712	16,904	2.92	11,465	16,608

[1] Total rainfall over the subject portion of the watershed in 24 hours needed to produce the threshhold discharge at CR 91.

Table C.2 Rainfall-runoff response data for entire watershed

Total 24-hr Rainfall, in	Motoqua Gage		Catclaw Canyon Gage		Mormon Well Gage		CR 91 Gage	
	Q_p	T_p	Q_p	T_p	Q_p	T_p	Q_p	T_p
0.00	0	0:00	0	0:00	0	0:00	0	0:00
0.50	200	18:00	1,100	16:45	1,100	18.30	1,000	20:00
1.00	500	17:15	4,000	16:15	3,900	17:45	3,800	19:00
1.50	700	17:00	10,400	16:00	10,400	17:15	10,100	18:00
2.00	1,000	16:45	18,400	15:45	18,900	16:45	18,700	17:30
3.00	2,500	15:45	37,100	15:45	40,200	16:15	40,000	16:45
4.00	8,300	15:45	60,800	15:45	66,400	16:15	66,300	16:45

Table C.3 Rainfall-runoff response data for upper watershed

Total 24-hr Rainfall, in	Motoqua Gage		Catclaw Canyon Gage		Mormon Well Gage		CR 91 Gage	
	Q_p	T_p	Q_p	T_p	Q_p	T_p	Q_p	T_p
0.00	0	0:00	0	0:00	0	0:00	0	0:00
0.50	200	18:00	700	17:15	500	19:30	400	21:15
1.00	500	17:15	2,300	16:30	1,900	18:15	1,800	19:45
1.50	700	17:00	5,600	16:15	5,000	17:45	4,800	18:30
2.00	1,000	16:45	9,400	16:00	8,800	17:15	8,500	18:00
3.00	2,500	15:45	18,500	16:00	17,600	17:00	17,300	17:45
4.00	8,300	15:45	31,800	16:00	30,700	16:45	30,300	17:15

Table C.4 Rainfall-runoff response data for middle watershed

Total 24-hr Rainfall, in	Motoqua Gage		Catclaw Canyon Gage		Mormon Well Gage		CR 91 Gage	
	Q_p	T_p	Q_p	T_p	Q_p	T_p	Q_p	T_p
0.00	0	0:00	0	0:00	0	0:00	0	0:00
0.50	---	---	1,000	16:45	800	19:00	700	20:30
1.00	---	---	3,700	16:15	3,300	18:00	3,100	19:00
1.50	---	---	9,800	16:00	9,100	17:15	8,900	18:00
2.00	---	---	17,100	15:45	16,300	17:00	16,000	17:30
3.00	---	---	32,400	15:45	31,400	16:30	31,000	17:00
4.00	---	---	48,900	15:45	47,500	16:30	47,100	16:45

Table C.5 Rainfall-runoff response data for lower watershed

Total 24-hr Rainfall, in	Motoqua Gage		Catclaw Canyon Gage		Mormon Well Gage		CR 91 Gage	
	Q_p	T_p	Q_p	T_p	Q_p	T_p	Q_p	T_p
0.00	0	0:00	0	0:00	0	0:00	0	0:00
0.50	---	---	400	15:30	500	15:00	500	17:00
1.00	---	---	1,000	15:15	1,300	16:15	1,300	17:30
1.50	---	---	2,800	15:15	3,300	16:30	3,200	17:30
2.00	---	---	5,400	15:00	6,500	16:00	6,400	17:00
3.00	---	---	12,000	15:00	17,500	15:15	17,500	16:00
4.00	---	---	19,200	14:45	30,000	15:15	30,200	15:45

Figure C.1 24-hour storm rainfall-runoff response for entire watershed

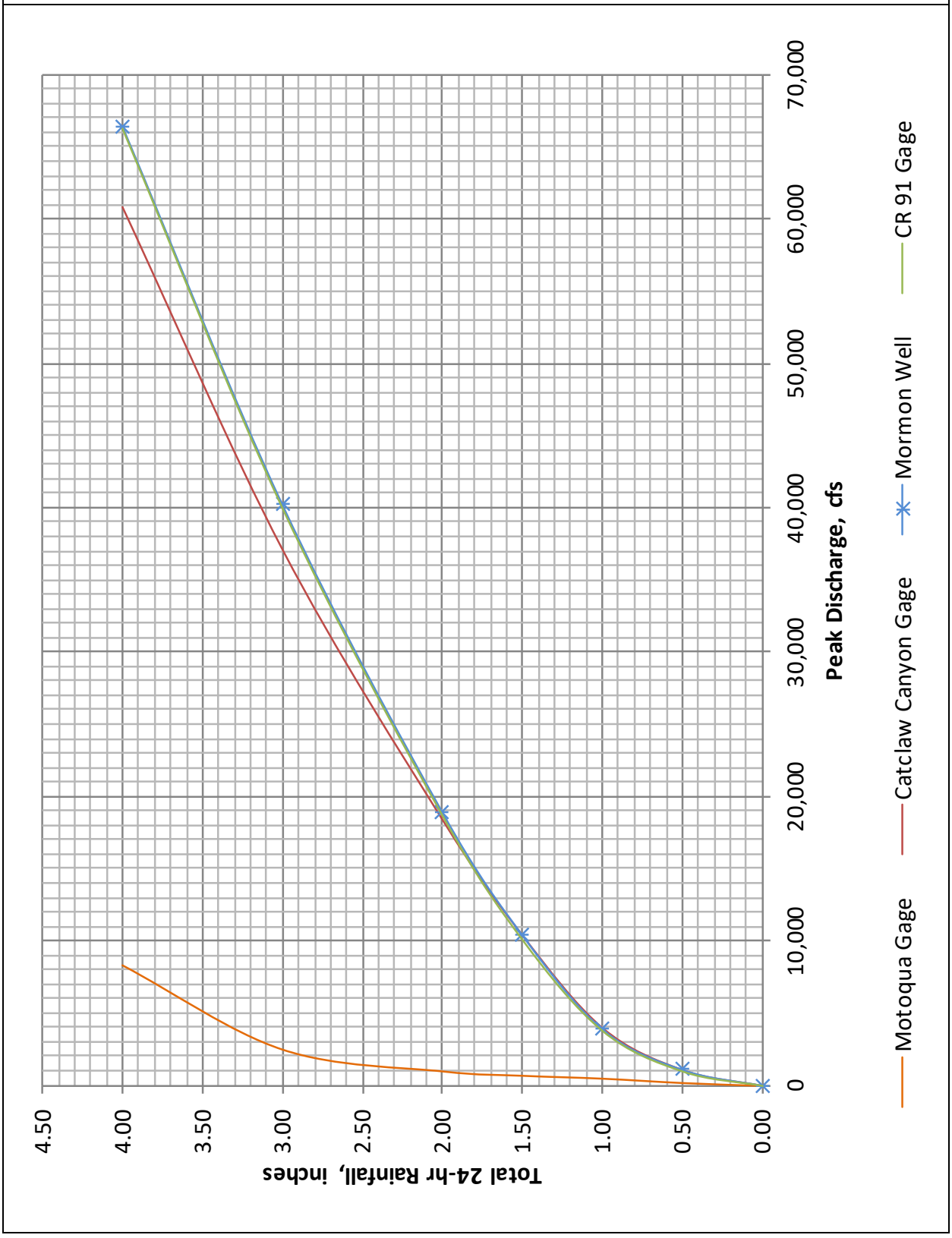


Figure C.2 24-hour storm rainfall-runoff response for upper watershed

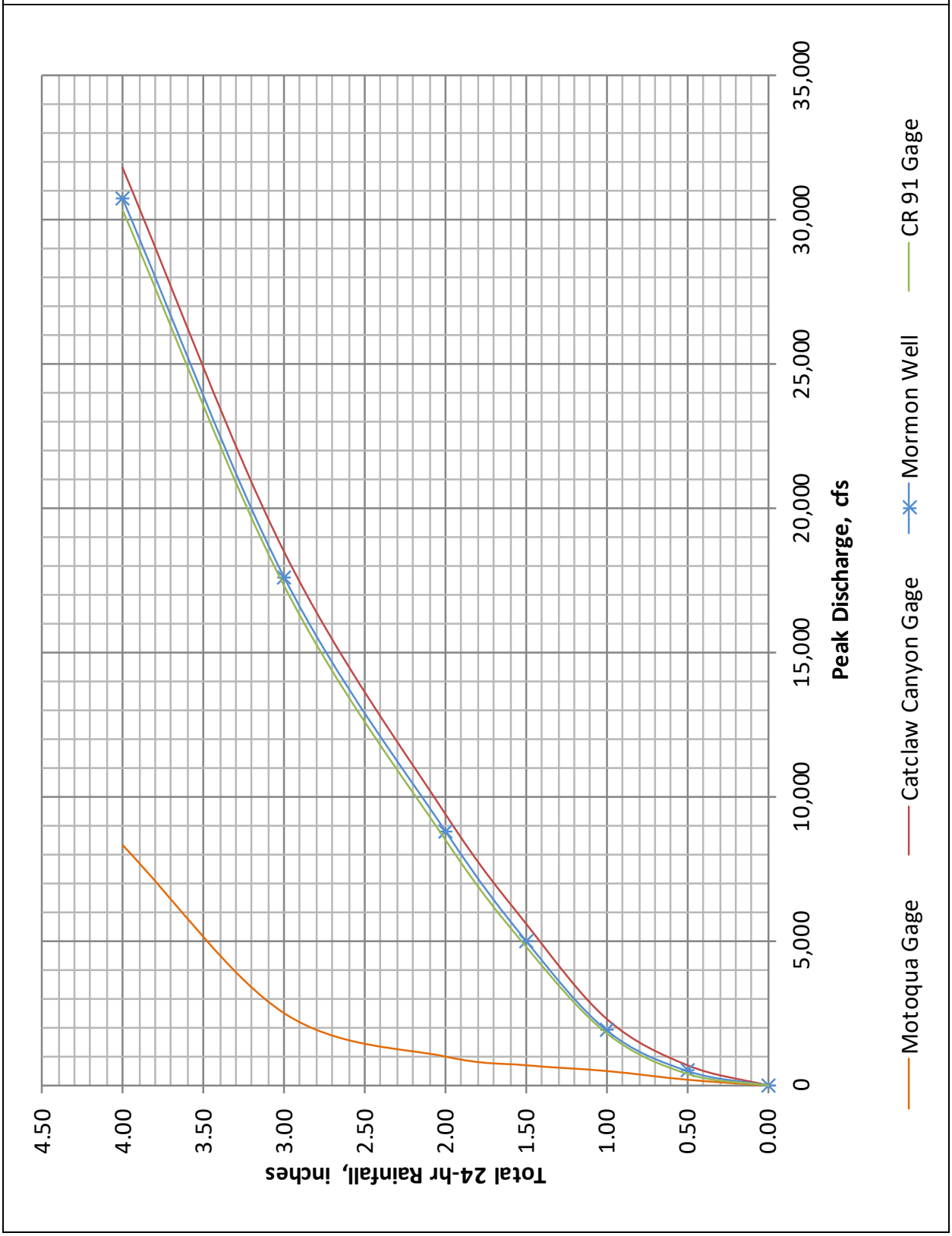


Figure C.3 24-hour storm rainfall-runoff response for middle watershed

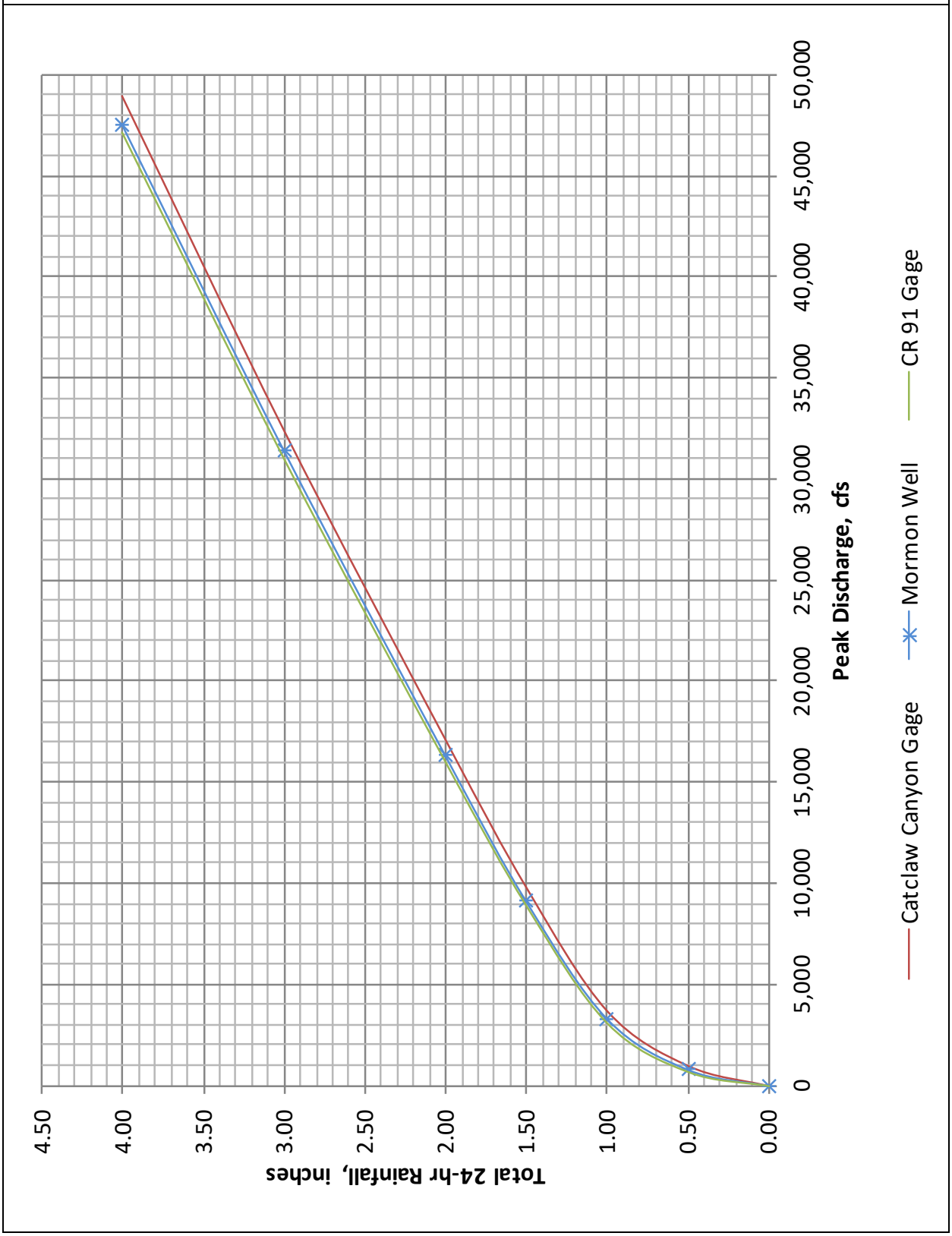
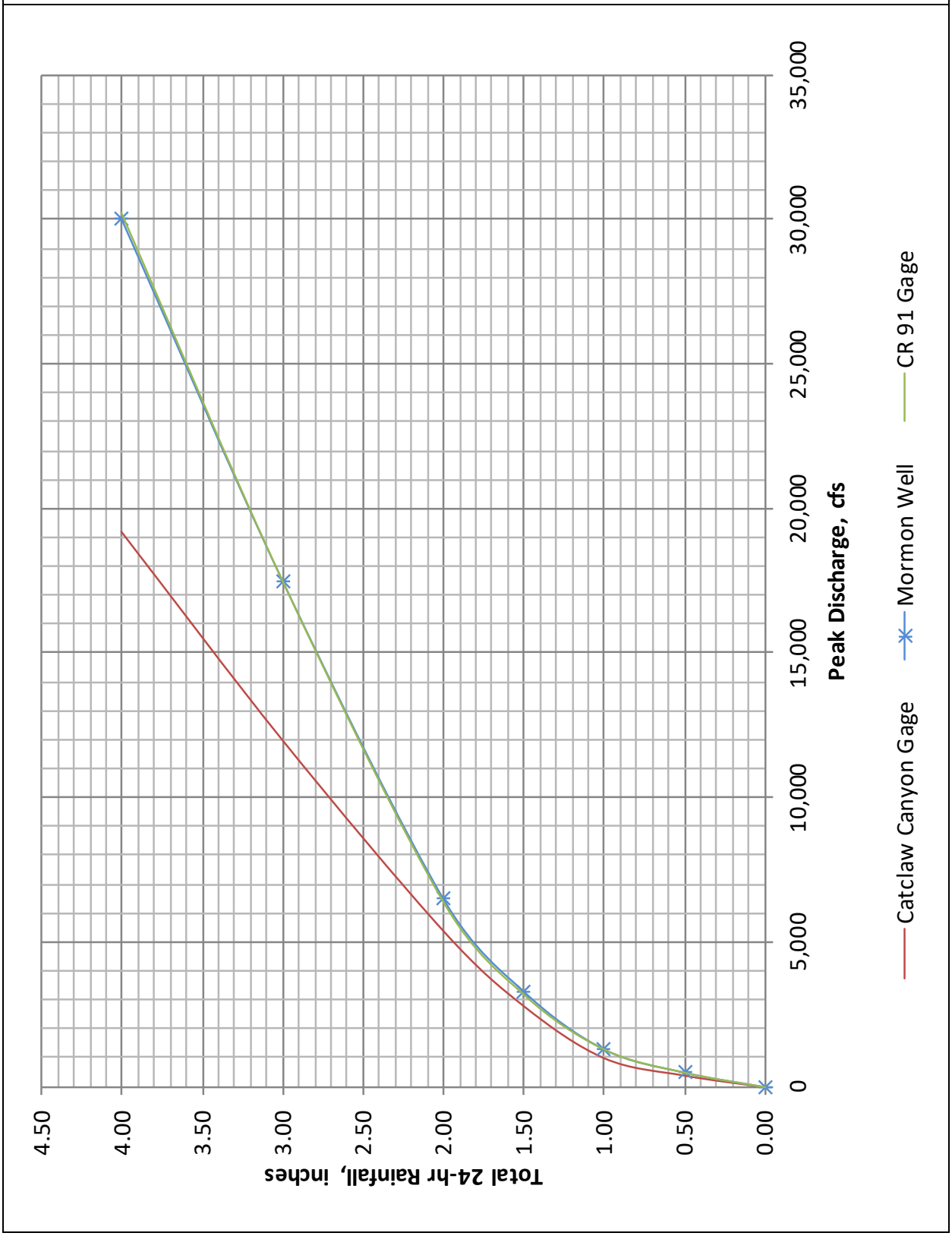


Figure C.4 24-hour storm rainfall-runoff response for lower watershed



C.2 Synthetic 24-hour Storm Rainfall-Runoff Hydrographs

C.2.1 Description

The same HEC-HMS models described in Section C.1 were used to prepare the figures in this section. The hydrographs for each watershed scenario and rainfall event described in Section C.1 are plotted on Figure C.5, Figure C.6, Figure C.7, and Figure C.8. Other critical information shown includes:

- where the threshold location peak discharges plot on each hydrograph
- a table of model results for each threshold location
- the rainfall intensity for the hydrograph rising limb.

C.2.2 Intended Use

The figures provide a visualization of the relationship between modeled rainfall intensity and runoff for each watershed scenario. As rain gage data for the storm event begins to be tabulated, the measured intensity at each gage can be checked against the figures to estimate what the watershed response might be. For each watershed scenario, the following gages should be checked for total rainfall and intensity:

1. Entire Watershed: All Beaver Dam Wash watershed rain gages;
2. Upper Watershed: Beaver Dam State Park (BDSP), Bull Valley Mountains (BVM), Motoqua (M), and Pahcoon Flat (PF);
3. Middle Watershed: Upper Lime Mountain (ULM), Motoqua (M) and Pahcoon Flat (PF); and
4. Lower Watershed: Beaver Dam Sheriff's Station (BD) and Catclaw Canyon (CC).

Rainfall intensities in the range of 2 to 3 inches/hour for a prolonged period greater than 15 minutes could result in the threshold discharges being met or exceeded. Extended rainfall intensities of 0.2 inches/hour or greater for longer periods (hours or days) could also cause the threshold discharges to be met or exceeded. Refer to Section C.3 for these long duration scenarios. Note that the response time between threshold locations is virtually zero for these scenarios.

C.2.3 Limitations

Same as described in Section C.1.

Figure C.5 3-inch 24-hour storm hydrographs for entire watershed

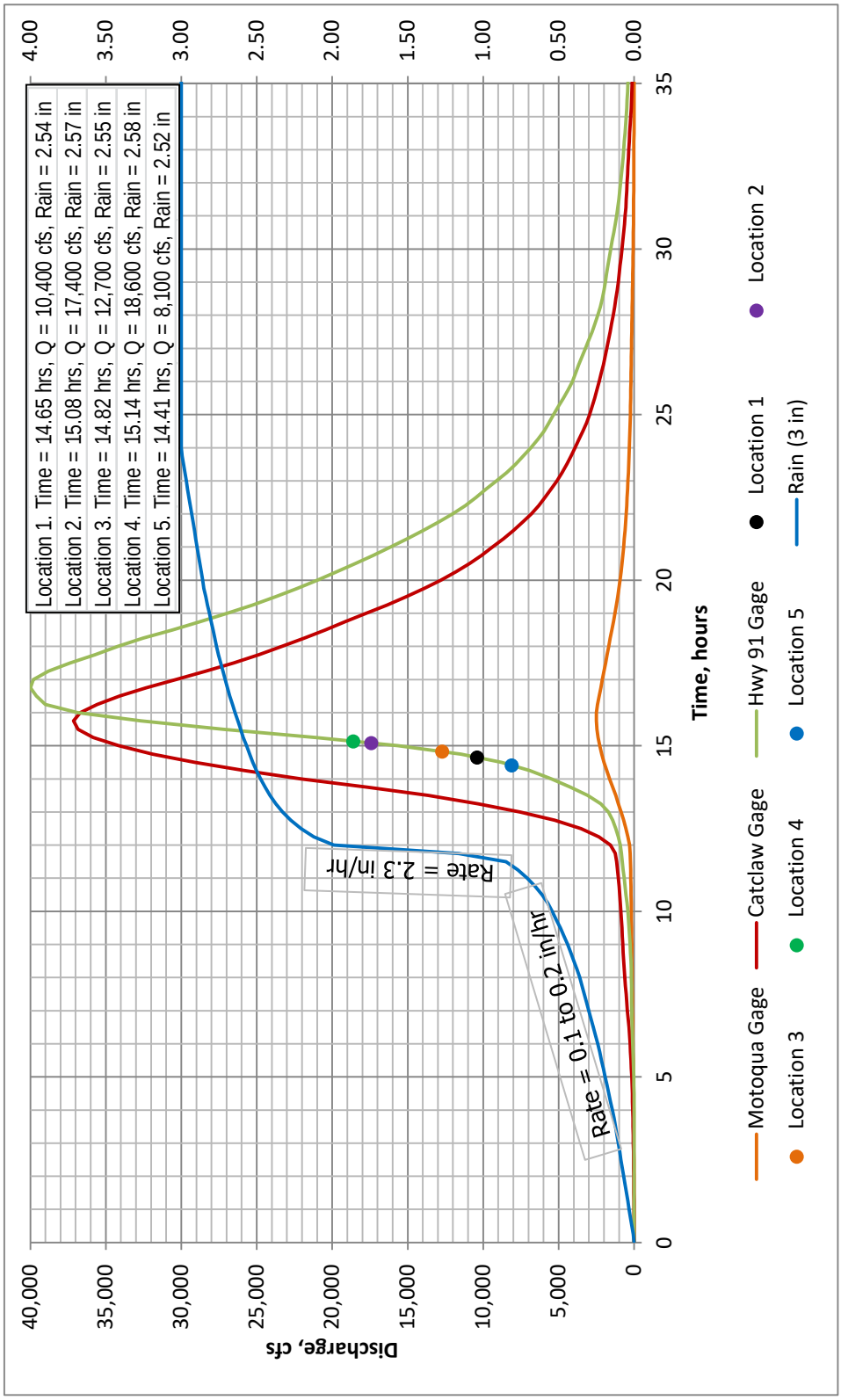


Figure C.6 4-inch 24-hour storm hydrographs for upper watershed

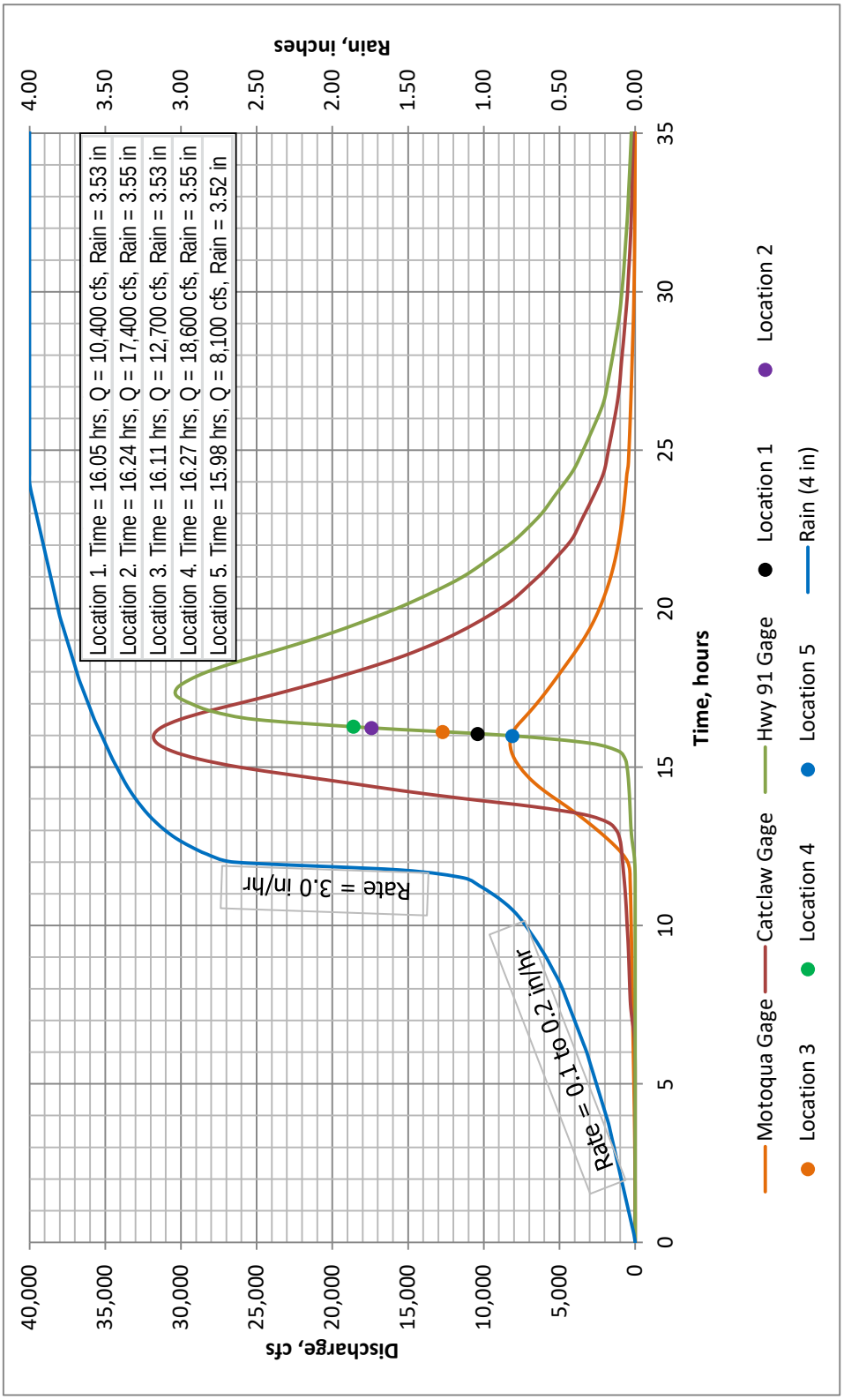


Figure C.7 3-inch 24-hour storm hydrographs for middle watershed

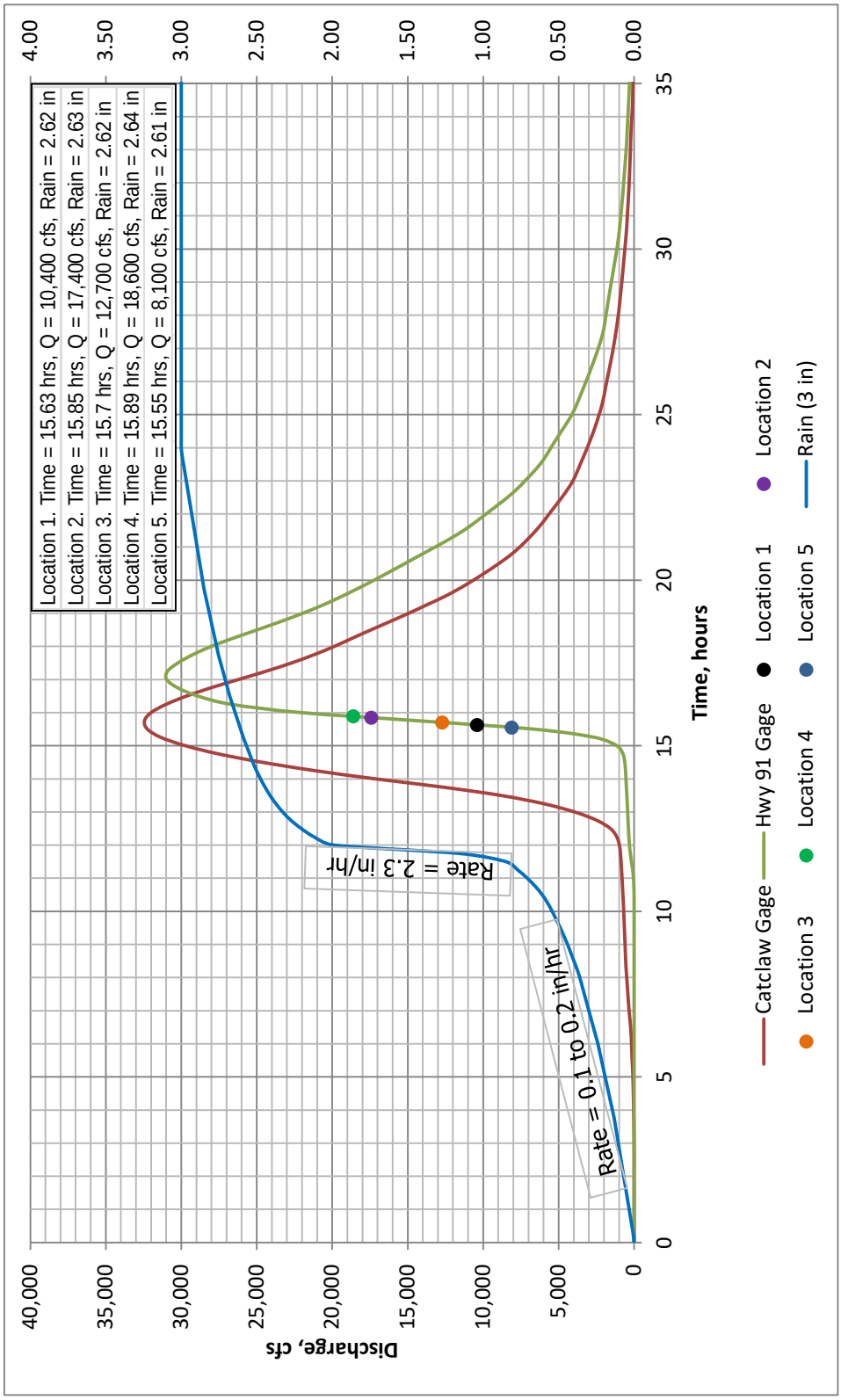
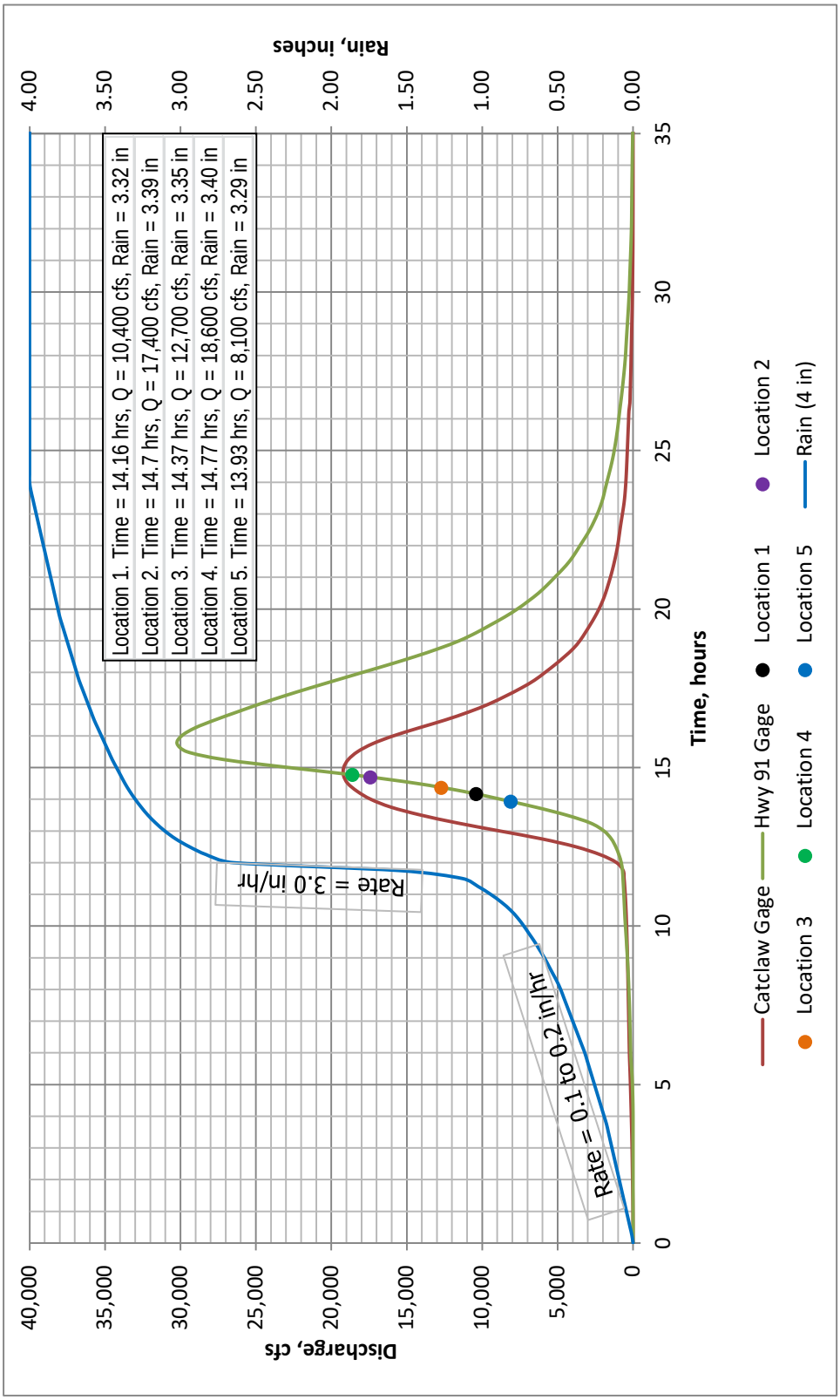


Figure C.8 4-inch 24-hour storm hydrographs for lower watershed



C.3 Synthetic 112-hour Storm Rainfall-Runoff Hydrograph

C.3.1 Description

The information in this section is derived from HEC-HMS models of the watershed for a 112-hour duration storm using a synthetic rainfall distribution for each rainfall gage. The synthetic rainfall distributions were derived from the December 2010 storm gage measured data as shown on Figure C.9. The December 2010 storm lasted a little under seven days. The storm duration was scaled to 112 hours and the total synthetic storm rainfall set at 20 inches. This equates to an average rainfall intensity of 0.18 inches/hour. The duration and total rainfall were based on engineering judgment. The intent is to simulate the business portion of the 2010 storm and to extrapolate the severity in order to result in peak discharges high enough to flood the areas of concern in Beaver Dam. The HEC-HMS model hydrologic and hydraulic parameters were calibrated using measured rainfall and flow rates from the December 2010 flood event. The model was only run for the entire watershed scenario as a general storm of this type will typically extend over the entire watershed. The results are shown on Figure C.10. Other critical information shown includes:

- where the threshold location peak discharges plot on the hydrograph rising limb;
- a table of model results for each threshold location; and
- rainfall intensity values.

C.3.2 Intended Use

Figure C.10 provides a visualization of a possible general or tropical storm scenario relationship between gage-measured rainfall and runoff for the entire watershed. As rain gage data for the storm event begins to be tabulated, the measured intensity at each gage can be checked against the figure to estimate what the watershed response might be. The synthetic rainfall distributions used represent the existing rain gages as follows:

1. Synthetic 1: Beaver Dam State Park (BDSP), Upper Lime Mountain (ULM), Bull Valley Mountains (BVM), and Pahcoon Flat (PF);
2. Synthetic 2: Motoqua (M); and
3. Synthetic 3: Beaver Dam Sheriff's Station (BD) and Catclaw Canyon (CC).

Extended rainfall intensities of 0.1 to 0.3 inches/hour or greater for long periods (4 days in this scenario) could cause the threshold discharges to be met or exceeded.

This scenario is also intended to provide an estimate of response time to reach the various threshold location peak discharges. Figure C.10 can be used as a basis for estimating how much time will elapse between critical thresholds.

C.3.3 Limitations

The rainfall intensity is based on the intensities that occurred during the December 2010 storm event, although the variations in intensity have been smoothed out for the synthetic storm distributions. The intent is to depict how the watershed may respond to long duration uniform rainfall. The actual rainfall intensity, duration and timing will vary significantly within a natural storm. This approach is only intended to provide an estimate of what effect an incoming storm may have at Beaver Dam.

This scenario is based on the initial soil moisture and initial abstraction estimates made for the modeling of the December 2010 storm. The initial moisture content (DTHETA) is assumed to be "normal" as defined in Mohave County (2012). The initial abstraction values were calibrated using the available gage data. Actual initial soil moisture content and abstraction will vary and will impact the watershed response.

The synthetic rainfall distributions assigned to the rain gage locations are based on the December 2010 storm. Actual rainfall distributions could vary dramatically from storm to storm and within any given storm.

The HEC-HMS routing parameters were taken from a calibrated HEC-RAS model of Beaver Dam Wash. The calibration effort was only done for the 2010 flood peak travel times. Routing results for very low and very high peak discharges have the potential for more error than peak discharges in the 8,000 to 15,000 cfs range.

Figure C.9 2010 storm synthetic cumulative rainfall distributions

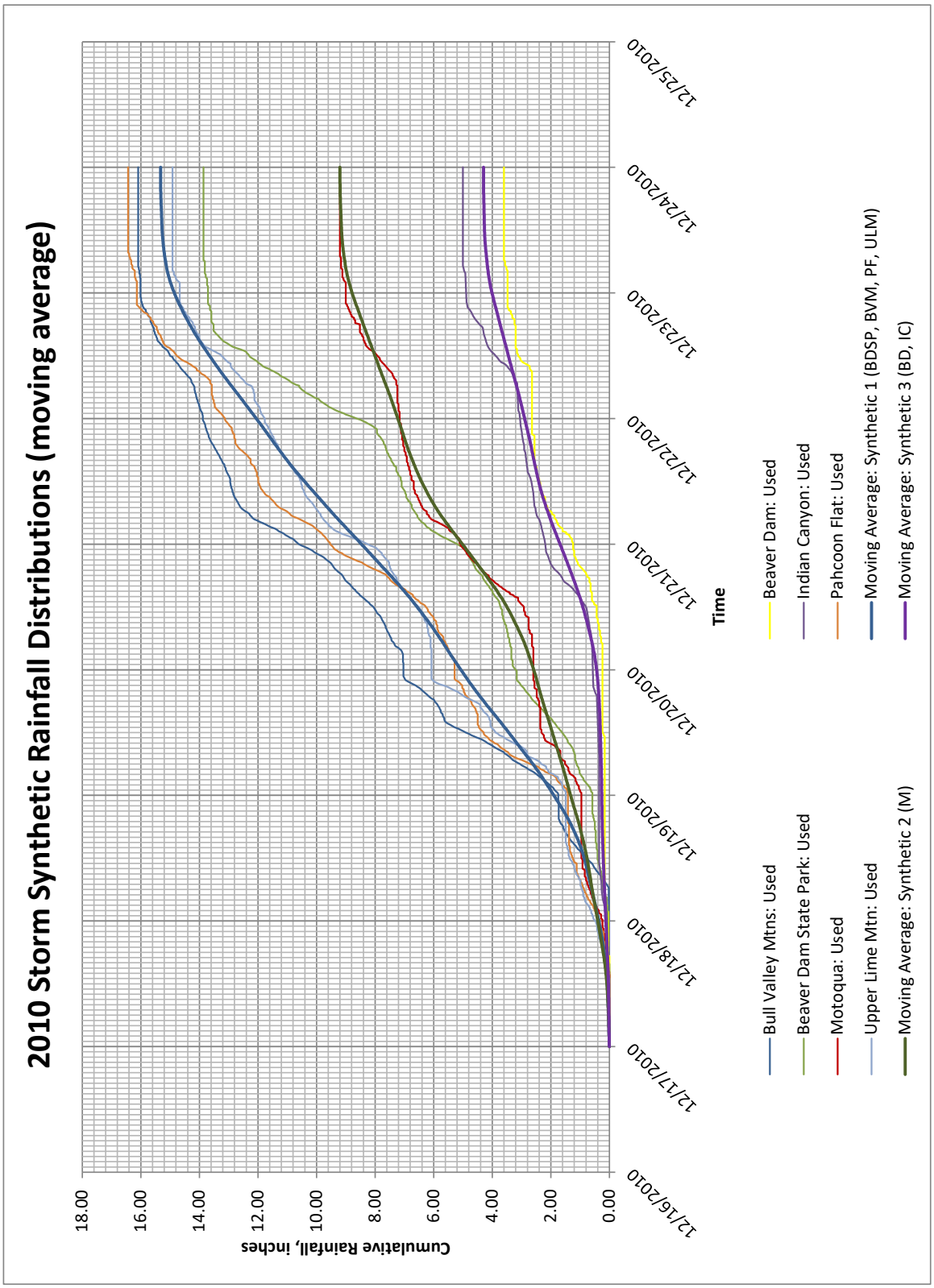
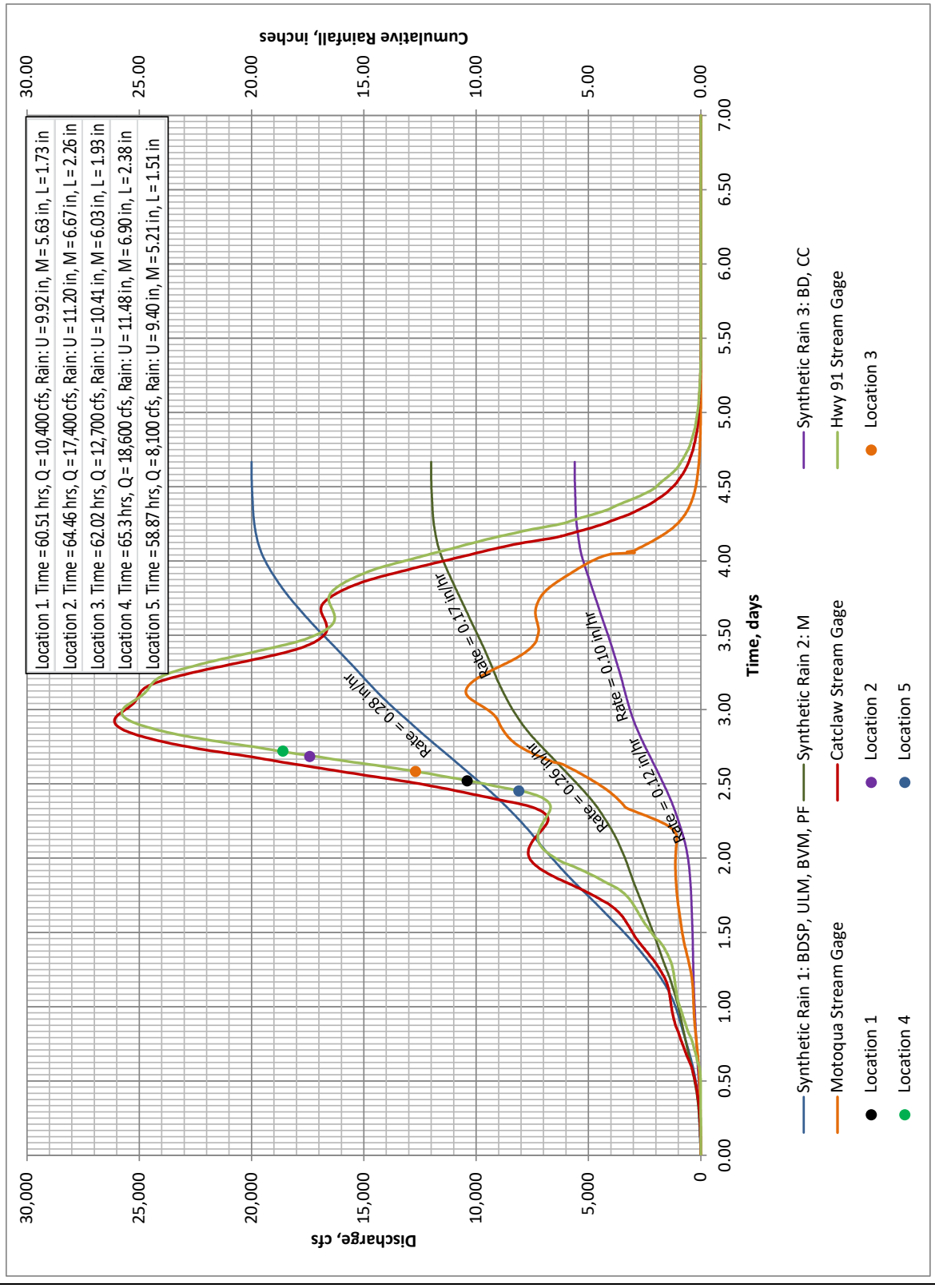


Figure C.10 20-inch 112-hour storm hydrograph



C.4 December 2010 Storm Rainfall-Runoff Response

C.4.1 Description

The information in this section is derived from the calibrated HEC-HMS model of the December 2010 storm. The gage-measured and HEC-HMS modeled hydrographs for that storm are shown on Figure C.11 along with locations of highest rainfall intensity. Also shown are the actual rainfall distributions from each rain gage. Note that the measured hydrograph at CR 91 stops on 12/22/12 at 8 PM. The observed readings after that point are highly suspect as a large cottonwood tree caused an obstruction to flow at about that time.

C.4.2 Intended Use

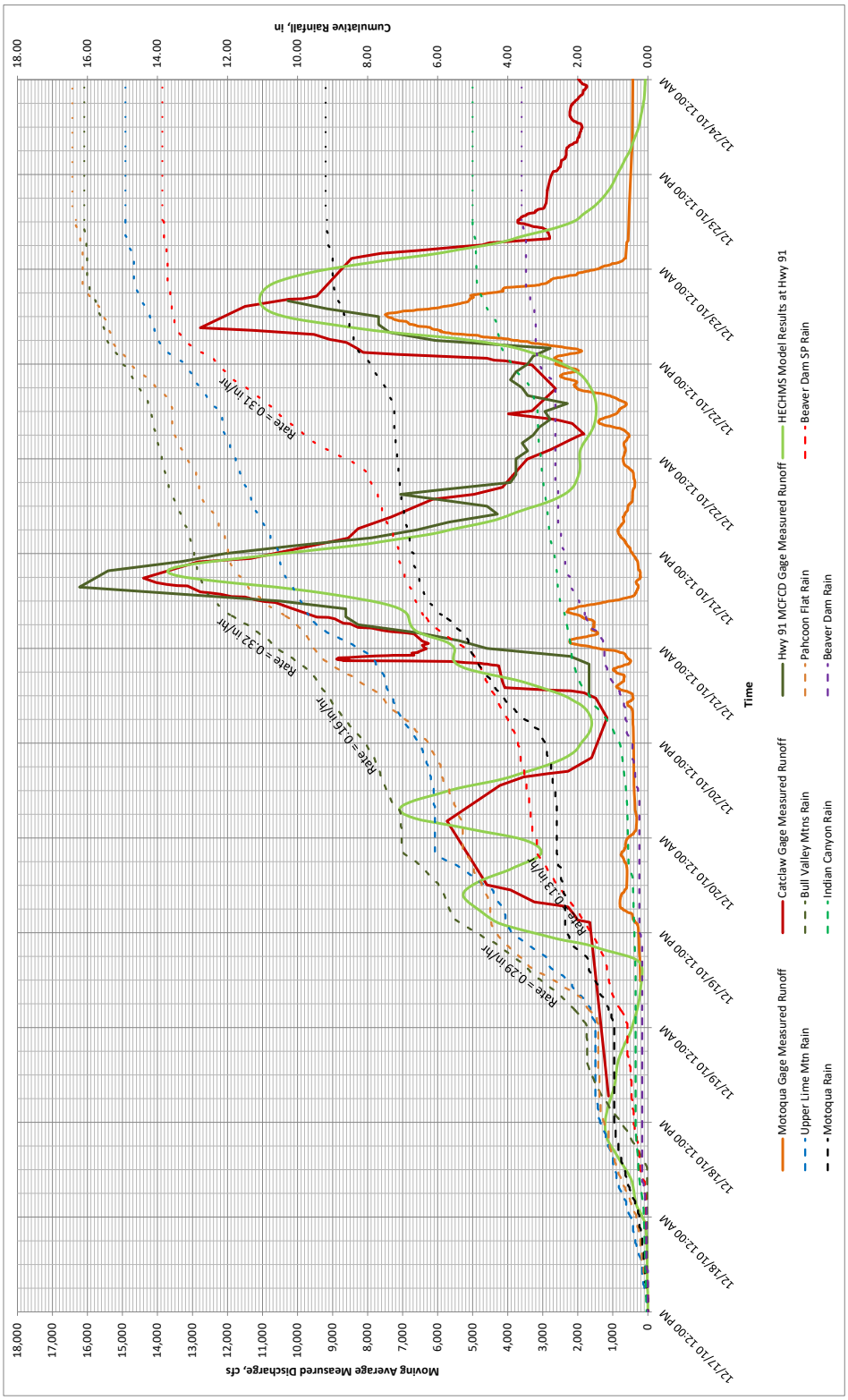
The intention is to show how the watershed responded to the rainfall event of December 2010, and to learn from that information. Note how increases in discharge correspond to increases with rainfall intensity. When the rainfall intensity exceeds 0.1 inches/hour, runoff increases significantly. When gage readings during an actual event are similar to what was observed in 2010, a similar watershed response can be expected. This example also shows how much variation in rainfall can occur within a storm event, even a long general storm.

C.4.3 Limitations

The rain gage readings for Upper Lime Mountain, Pahcoon Flat, Bull Valley Mountains, and Beaver Dam State Park are all suspect for the December 2010 storm. A faulty snow tube design at each gage resulted in higher readings than actually occurred. An attempt was made by Mohave County staff to determine a correction factor, and the adjustments recommended were refined by AridHH during the model calibration process. It should be kept in mind that the measurements at these gages have a higher than normal degree of error.

The stream gage readings are also suspect. The Indian Canyon gage did not provide meaningful data due to flow being concentrated in a different area of the very broad floodplain. The new CR 91 gage was not installed yet and the Motogua and Catclaw Canyon gages sustained damage. There was also extensive bed movement during the event at all the locations. The final bed topography after the event was used to create revised hydraulic rating curves for each gage. The actual bed elevations during the event are unknown.

Figure C.11 2010 storm hydrograph



There did seem to be good correlation between the measured rainfall, watershed response, and observed flood limits at the gage locations.

C.5 Travel Time Curves

C.5.1 Description

A HEC-RAS model was created of the entire length of Beaver Dam Wash between the Motoqua gage and the Virgin River. Post 2010 flood detailed topographic mapping was available from the Virgin River to the Catclaw Canyon gage, and for the Motoqua gage site. The USGS National Elevation Data (NED) was used where detailed topographic mapping was not available. The HEC-RAS model was calibrated to match measured travel times of peak discharge between gage sites for the December 2010 flood and to match observed high water marks. The model was run in steady state mixed flow regime mode for a range of peak discharges between 50 and 40,000 cfs. The model results were used to prepare travel time curves for various flow rates. Refer to Figure C.12, Figure C.13, and Figure C.14. Curves are provided for minimum, normal and maximum roughness estimates.

C.5.2 Intended Use

These curves are intended to be used as a tool to estimate travel time between the Motoqua, Catclaw Canyon and CR 91 gage sites. If a very high peak discharge is observed at the Catclaw Canyon gage, for instance, the curves can be used to estimate when that peak discharge will arrive at Beaver Dam.

C.5.3 Limitations

The HEC-HMS routing parameters were taken from a calibrated HEC-RAS model of Beaver Dam Wash. The calibration effort was only done for the 2010 flood peak travel times. Routing results for very low and very high peak discharges have the potential for more error than peak discharges in the 8,000 to 15,000 cfs range.

Rainfall occurring in the watershed can dramatically influence when flood peaks arrive in Beaver Dam. If rainfall in the lower watershed is occurring simultaneously with rain in the middle watershed, a peak discharge at Catclaw Canyon could be replicated at nearly the same time at CR 91.

Figure C.12 Estimated travel times for minimum roughness

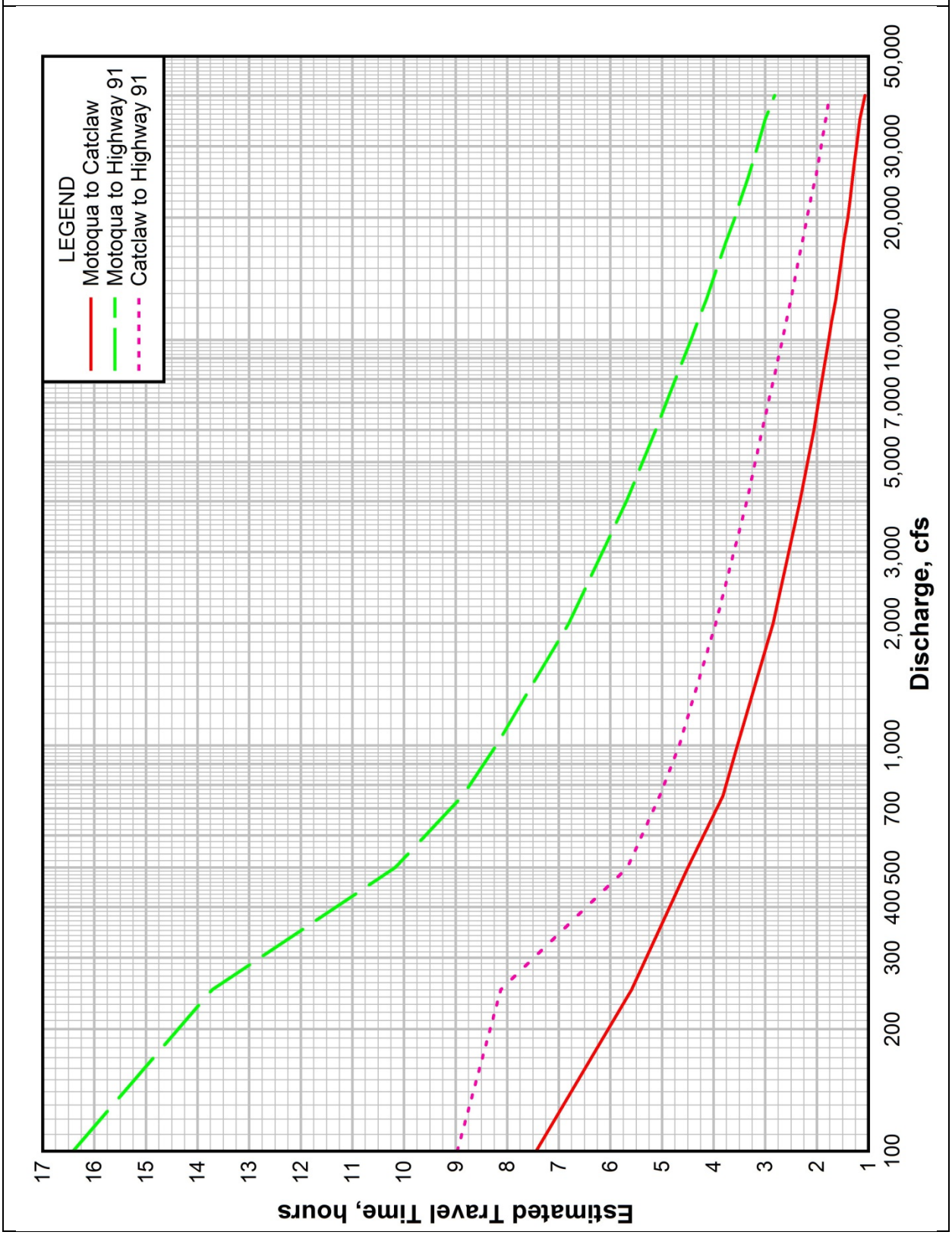


Figure C.13 Estimated travel times for normal roughness

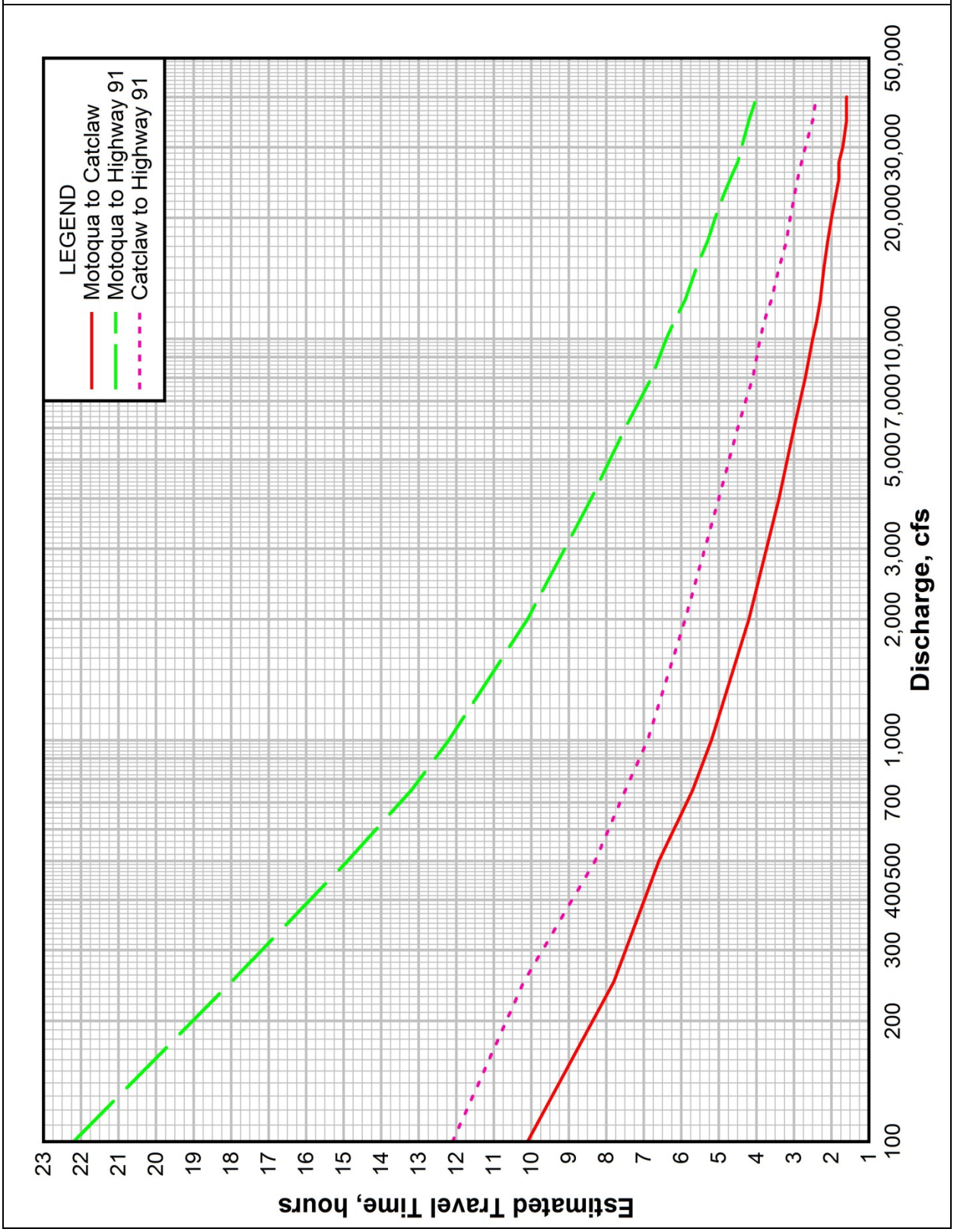
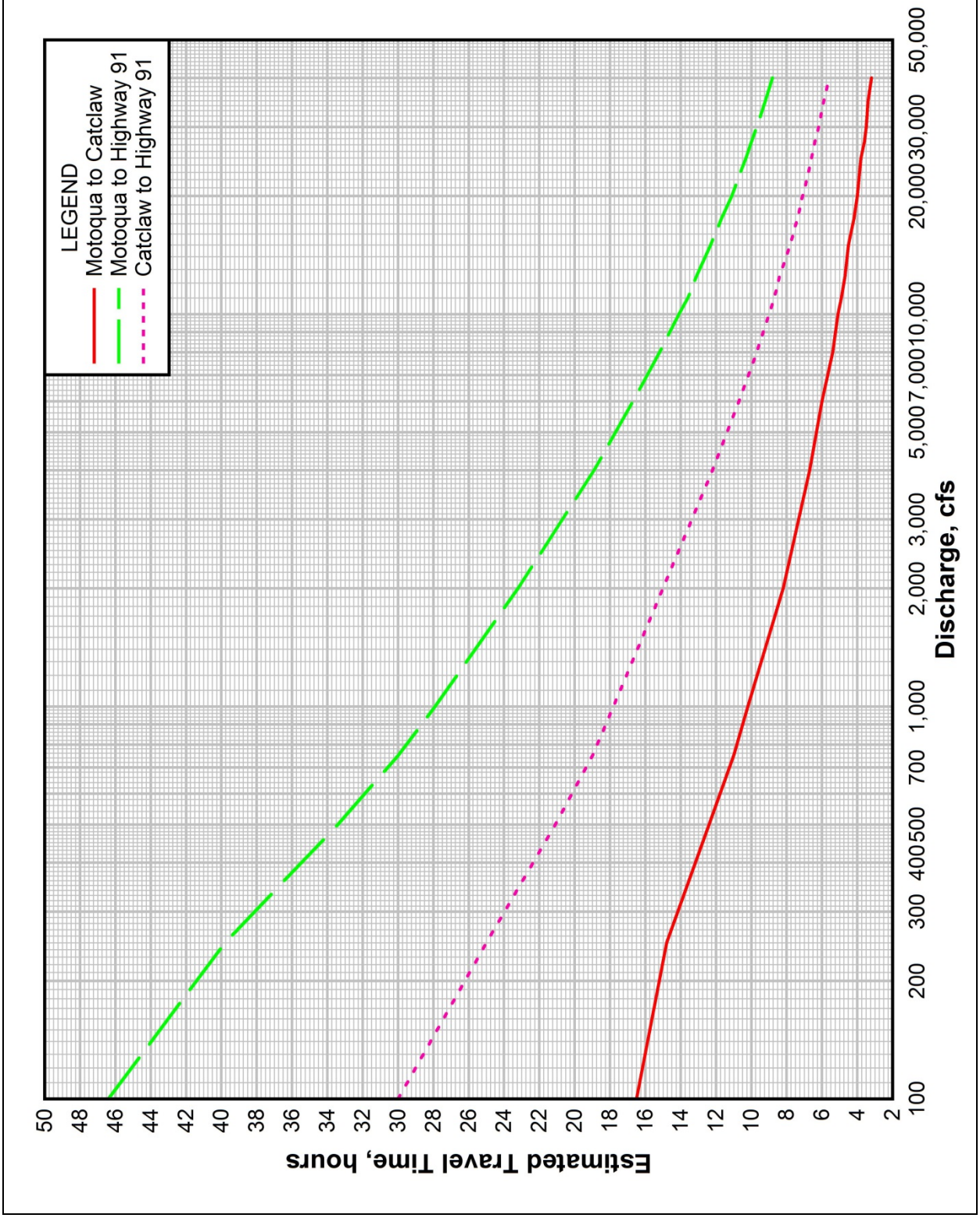


Figure C.14 Estimated travel times for maximum roughness



C.6 Stream Flow Gage Rating Curves

C.6.1 Description

Hydraulic rating curves were developed as a part of this study for four (4) stream flow gages. These curves were developed for use with the Mohave County flood warning ALERT system. The rating curves are shown in tabular form in Table C.6 and graphically on Figure C.15 through Figure C.18. The Motoqua and Catclaw Canyon rating curves are based on HEC-RAS model results. The Mormon Well and CR 91 Bridge rating curves are based on FLO-2D Pro models. All the data shown in Table C.6 are based on a normal n-value condition. Refer to Figure C.15 through Figure C.18 for the minimum and maximum roughness condition rating curves. A rating curve is included for the upstream side of the CR 91 bridge for use with a staff gage that Mohave County added to the upstream face of the pier adjacent to the stream flow gage. The rating curves for the staff gage are shown on Figure C.19. That figure is based on data from FLO-2D grid 29259. The zero (0) level on the staff gage corresponds to elevation 1830.00.

C.6.2 Intended Use

These curves are intended to be used as a tool to estimate peak discharge from stream gage readings.

C.6.3 Limitations

The HEC-HMS routing parameters were taken from a calibrated HEC-RAS model of Beaver Dam Wash. The calibration effort was only done for the 2010 flood peak travel times. Routing results for very low and very high peak discharges have the potential for more error than peak discharges in the 8,000 to 15,000 cfs range.

Rainfall occurring in the watershed can dramatically influence when flood peaks arrive in Beaver Dam. If rainfall in the lower watershed is occurring simultaneously with rain in the middle watershed, a peak discharge at Catclaw Canyon could be replicated at nearly the same time at CR 91.

Table C.6 Rating curve data for stream flow gages

Discharge	Motoqua		Catclaw Canyon		Mormon Well		CR 91 Bridge	
	Height	WSEL	Height	WSEL	Height	WSEL	Height	WSEL
cfs	ft	ft	ft	ft	ft	ft	ft	ft
	0.00	3424.84	0.00	2632.32	0.00	2083.14	0.30	1827.85
100	0.90	3425.74	0.00	2633.63	0.00	2083.21	1.22	1828.77
250	1.47	3426.31	0.00	2634.18	0.04	2083.31	2.24	1829.79
500	1.93	3426.77	0.26	2634.62	0.21	2083.48	3.11	1830.66
750	2.40	3427.24	0.58	2634.94	0.37	2083.64	3.69	1831.24
1,000	2.72	3427.56	0.85	2635.21	0.54	2083.81	4.22	1831.77
2,000	3.47	3428.31	1.48	2635.84	0.81	2084.08	5.65	1833.20
4,000	4.28	3429.12	2.39	2636.75	1.29	2084.56	7.14	1834.69
6,000	4.86	3429.70	2.96	2637.32	1.69	2084.96	8.21	1835.76
8,000	5.21	3430.05	3.41	2637.77	1.98	2085.25	9.11	1836.66
10,000	5.39	3430.23	3.78	2638.14	2.22	2085.49	9.94	1837.49
11,000	5.63	3430.47	3.94	2638.30	2.34	2085.61	10.31	1837.86
12,500	5.90	3430.74	4.13	2638.49	2.50	2085.77	10.82	1838.37
15,000	6.16	3431.00	4.46	2638.82	2.74	2086.01	11.58	1839.13
17,500	6.44	3431.28	4.76	2639.12	2.95	2086.22	12.23	1839.78
20,000	6.70	3431.54	5.03	2639.39	3.16	2086.43	12.77	1840.32
22,500	6.93	3431.77	5.31	2639.67	3.35	2086.62	13.27	1840.82
25,000	7.20	3432.04	5.56	2639.92	3.54	2086.81	13.73	1841.28
27,500	7.27	3432.11	5.81	2640.17	3.72	2086.99	14.15	1841.70
30,000	7.46	3432.30	6.05	2640.41	3.90	2087.17	14.52	1842.07
35,000	7.79	3432.63	6.50	2640.86	4.23	2087.50	15.20	1842.75
40,000	8.13	3432.97	6.93	2641.29	4.47	2087.74	15.88	1843.43
Sensor Elev:	3424.63		2634.36		2083.27		1827.55 (ground)	
	Height above Pressure Transducer Sensor							
	Height above average ground elevation below radar transmitter.							

Figure C.15 Motoqua gage rating curve

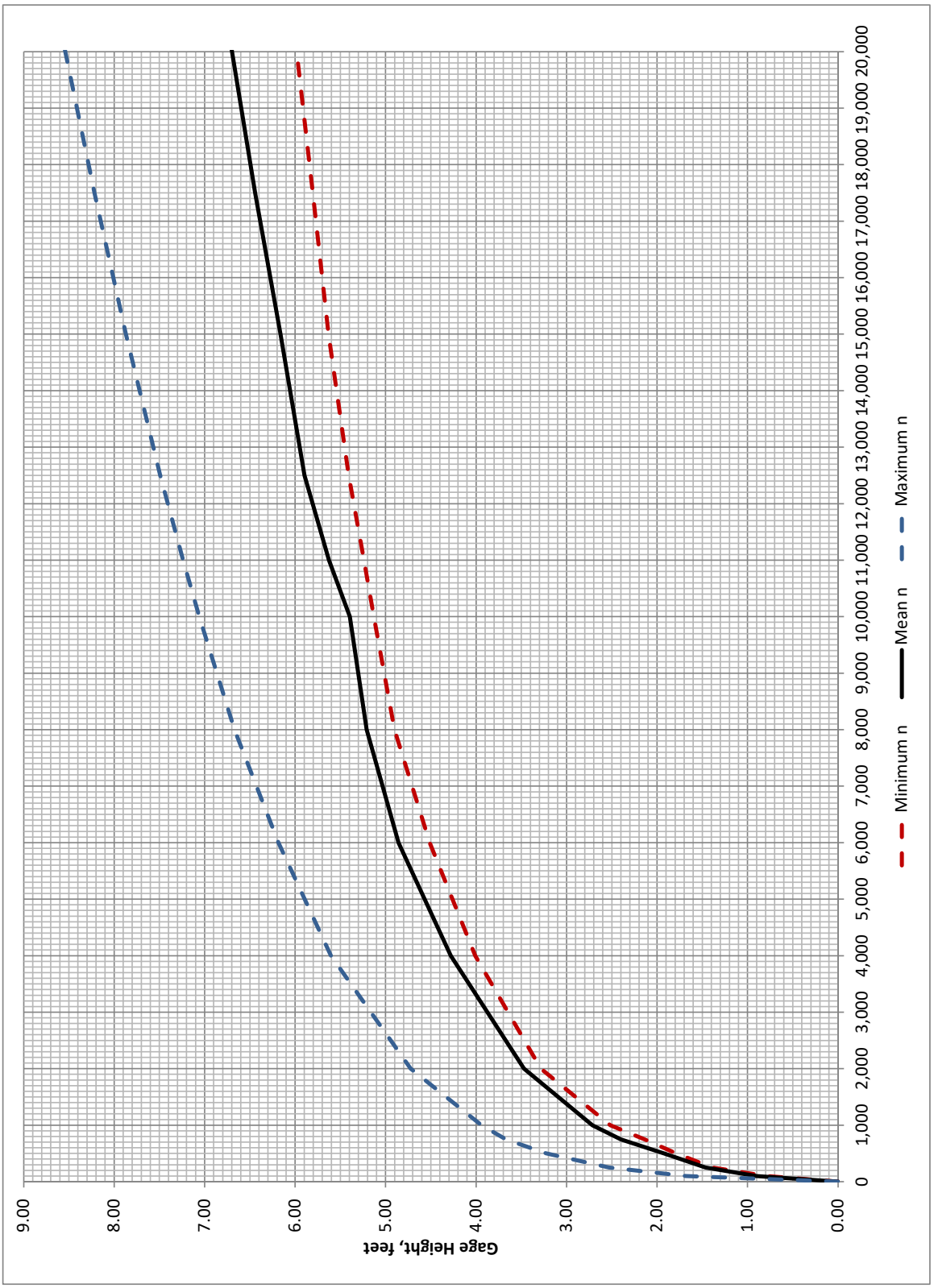


Figure C.16 Catclaw Canyon gage rating curve

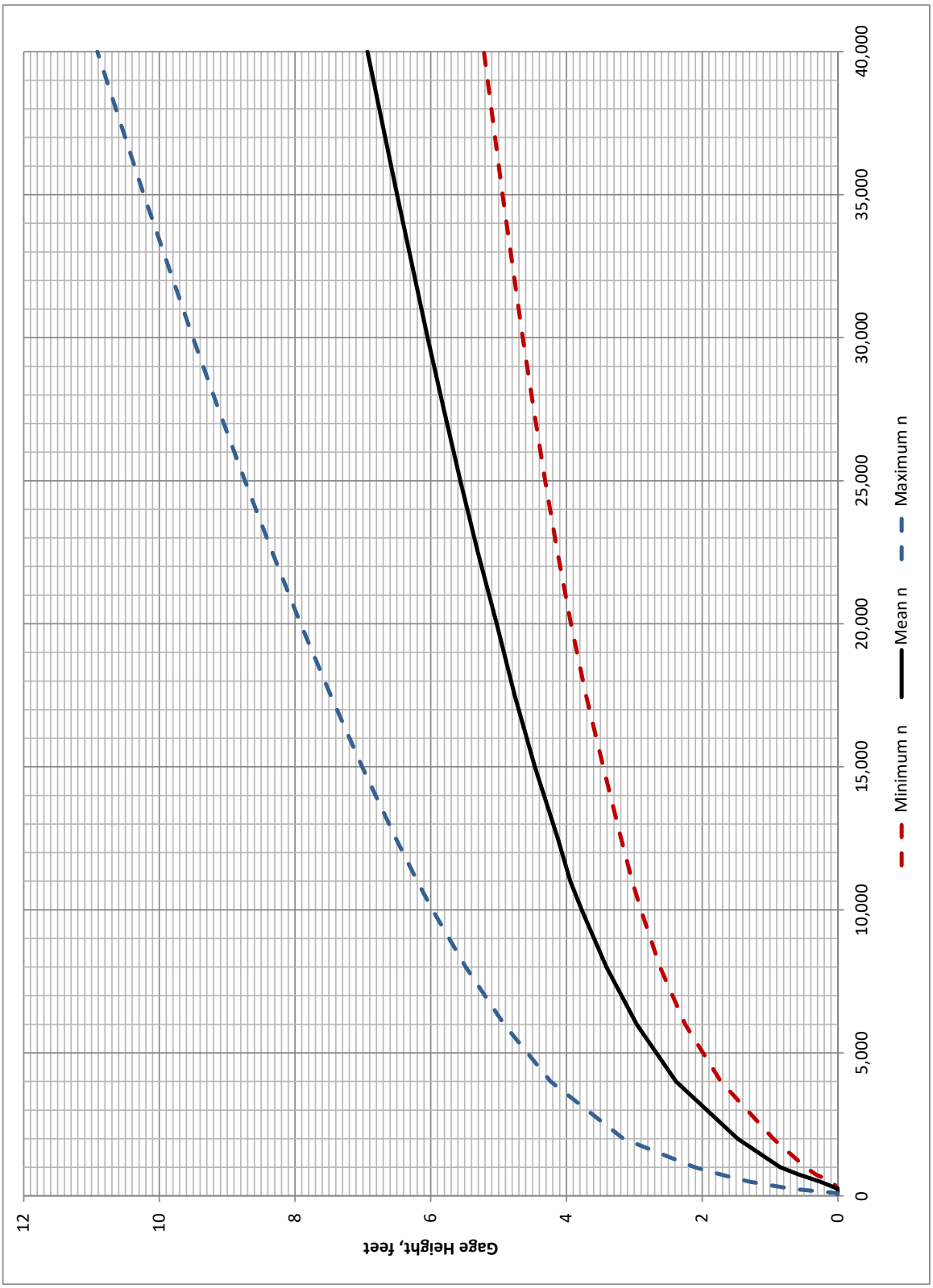


Figure C.17 Mormon Well gage rating curve

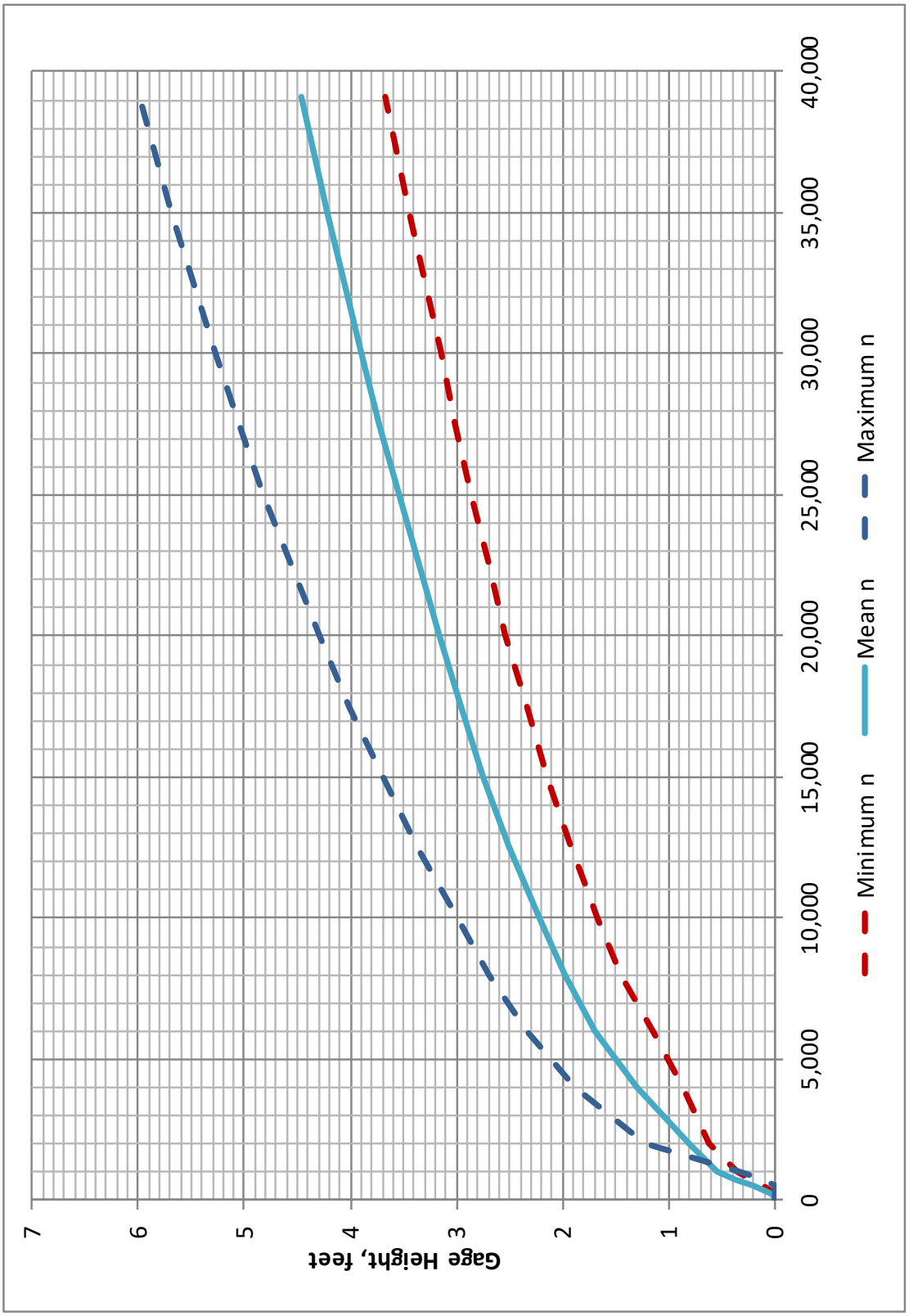


Figure C.18 CR 91 Bridge gage rating curve

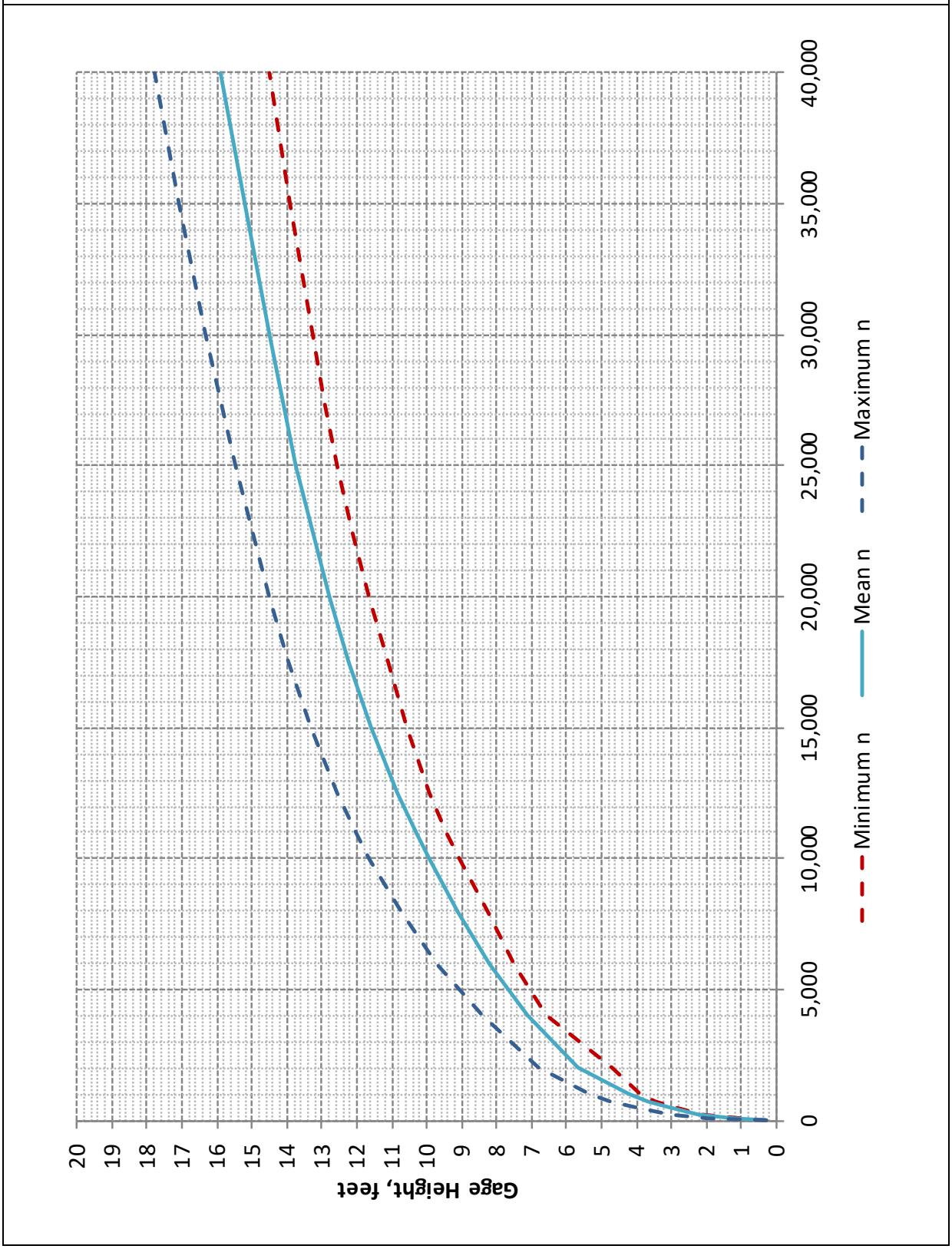
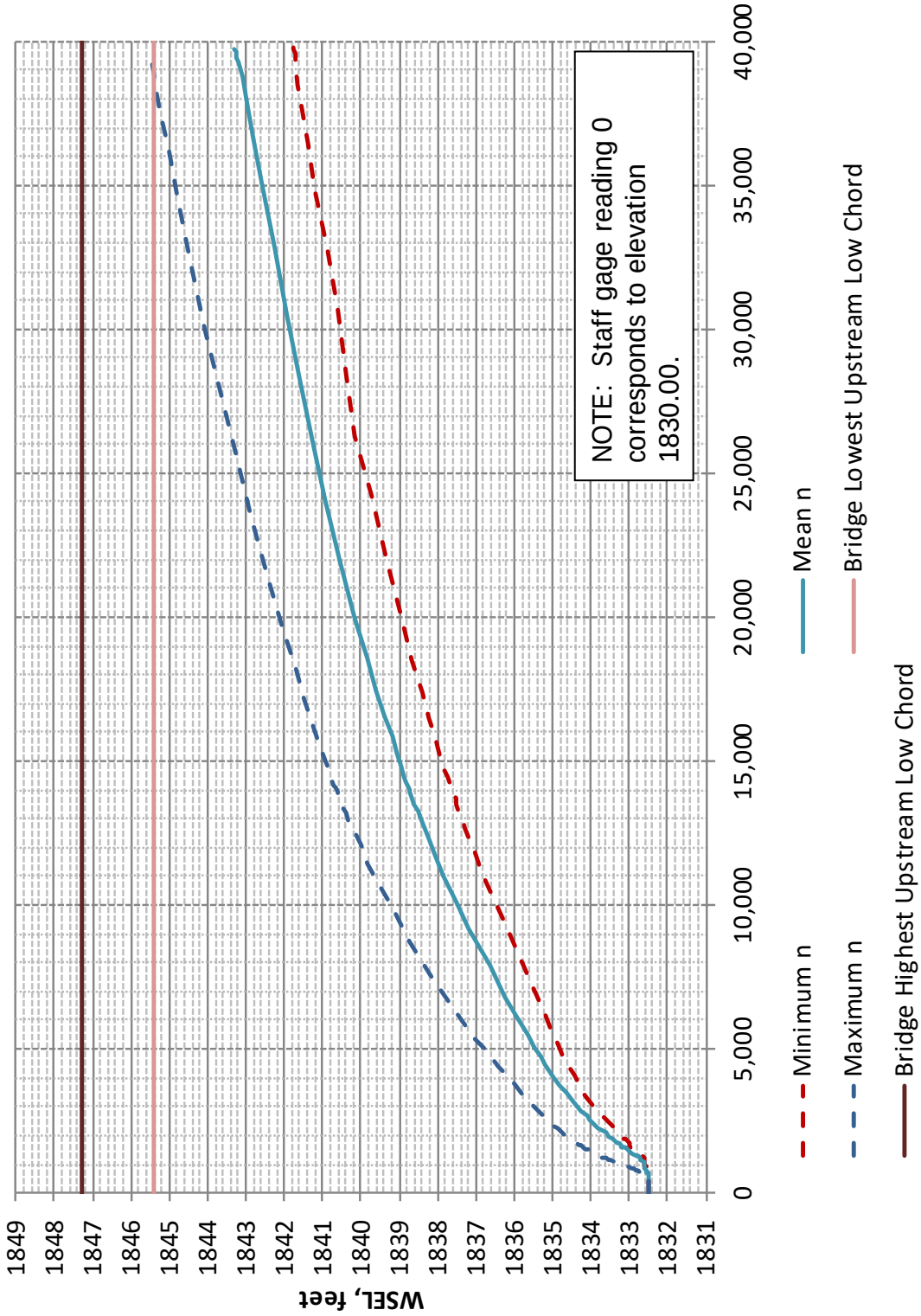


Figure C.19 CR 91 Bridge upstream side rating curve at pier near gage



C.7 Erosion Hazards

C.7.1 Description

Erosion hazards are known to exist in Beaver Dam due to channel bank migration that occurred during the January 2005 and December 2010 flood events. Refer to Figure C.20, Figure C.21, and Figure C.22 for maps showing estimates of the extent of the channel migration. These estimates were made based on aerial photographs taken before and after each event. Channel bank migration distances for the 2005 event ranged from 0 feet to over 415 feet. Channel bank migration distances for the 2010 event ranged from 0 feet to over 275 feet. These estimates were checked against the equations in ADWR (1996), which are used for estimating erosion setback distances. Those equations are recommended by ADWR to be limited to watershed sizes less than 30 square miles. The peak discharges for the 2005 and 2010 events are estimated to be 25,000 cfs and 13,700 cfs, respectively. Applying the ADWR equation for *channels with obvious curvature or channel bend* assuming that the equation applies for any discharge, not just the 100-year peak, yields:

Setback = $2.5Q_{100}^{0.5}$ = 2.5 x $(25{,}000)^{0.5}$ = 395 feet, which is a reasonable check against the estimated 415 feet that actually occurred.

Setback = $2.5Q_{100}^{0.5}$ = 2.5 x $(13{,}700)^{0.5}$ = 293 feet, which is a reasonable check against the estimated 275 feet that actually occurred.

Using the above equation for threshold discharges of 10,000 cfs and 21,000 cfs, erosion hazard zones were determined using setback distances of 250 feet and 360 feet, respectively. The setbacks are measured from the post December 2010 flood bank limits. Those zones are shown on Figure C.23.

C.7.2 Intended Use

This information was used as the basis for the recommended evacuation areas due to channel migration and erosion shown on Figure 3.1 and Figure 3.2.

Figure C.20 Bank migration as a result of the January 2005 flood event

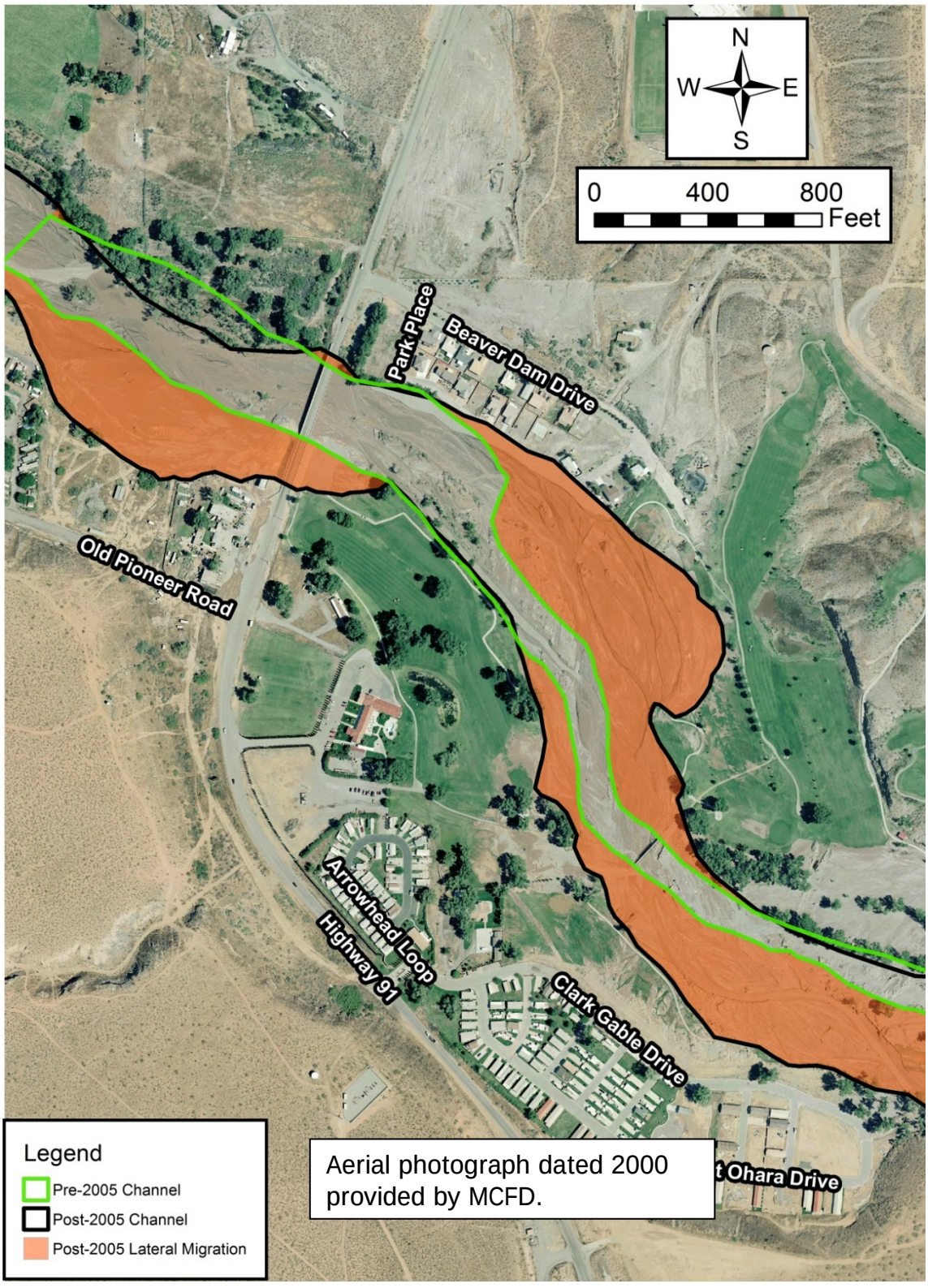


Figure C.21 Bank migration as a result of December 2010 flood event 1

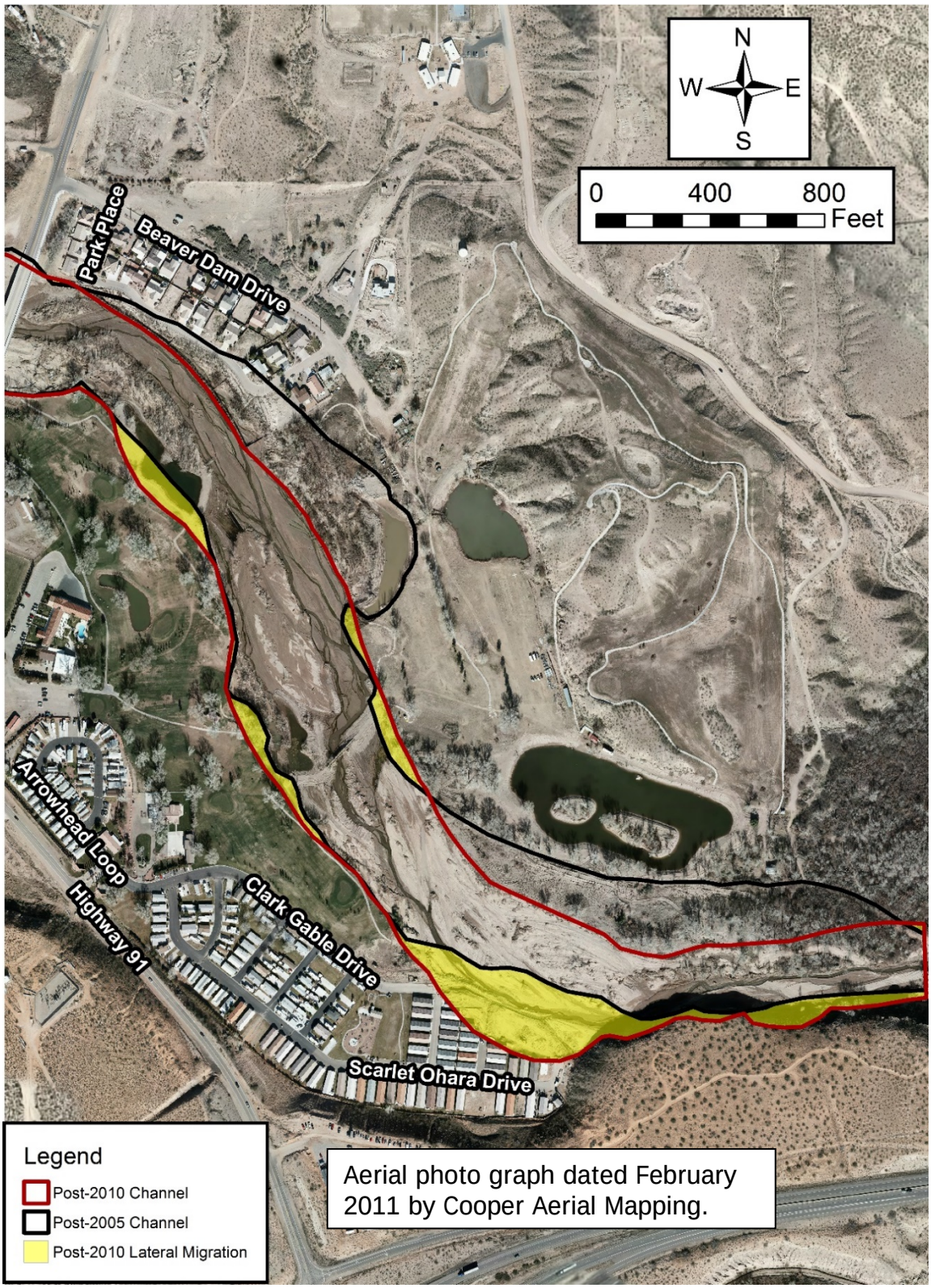


Figure C.22 Bank migration as a result of January 2010 flood event 2

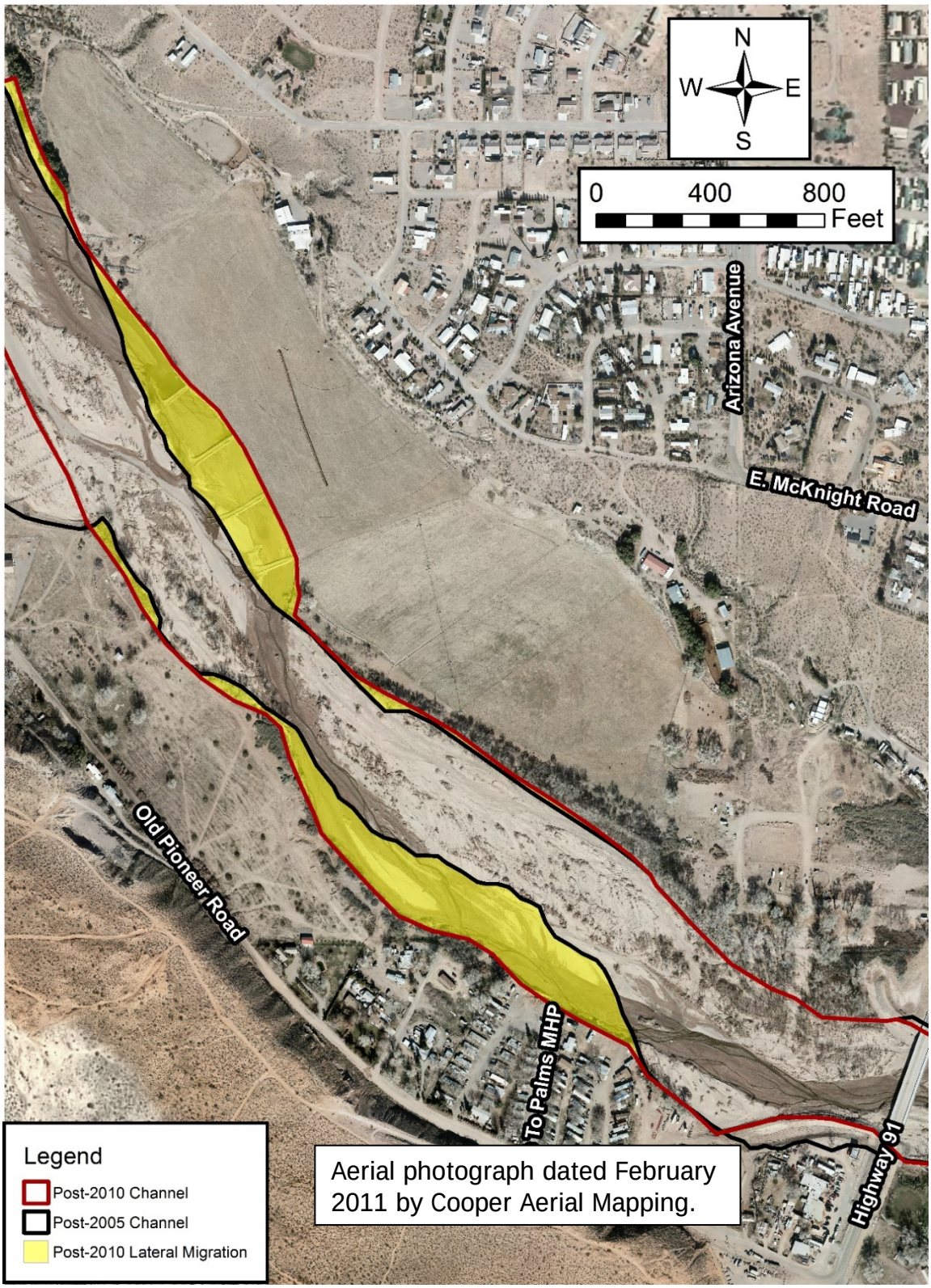
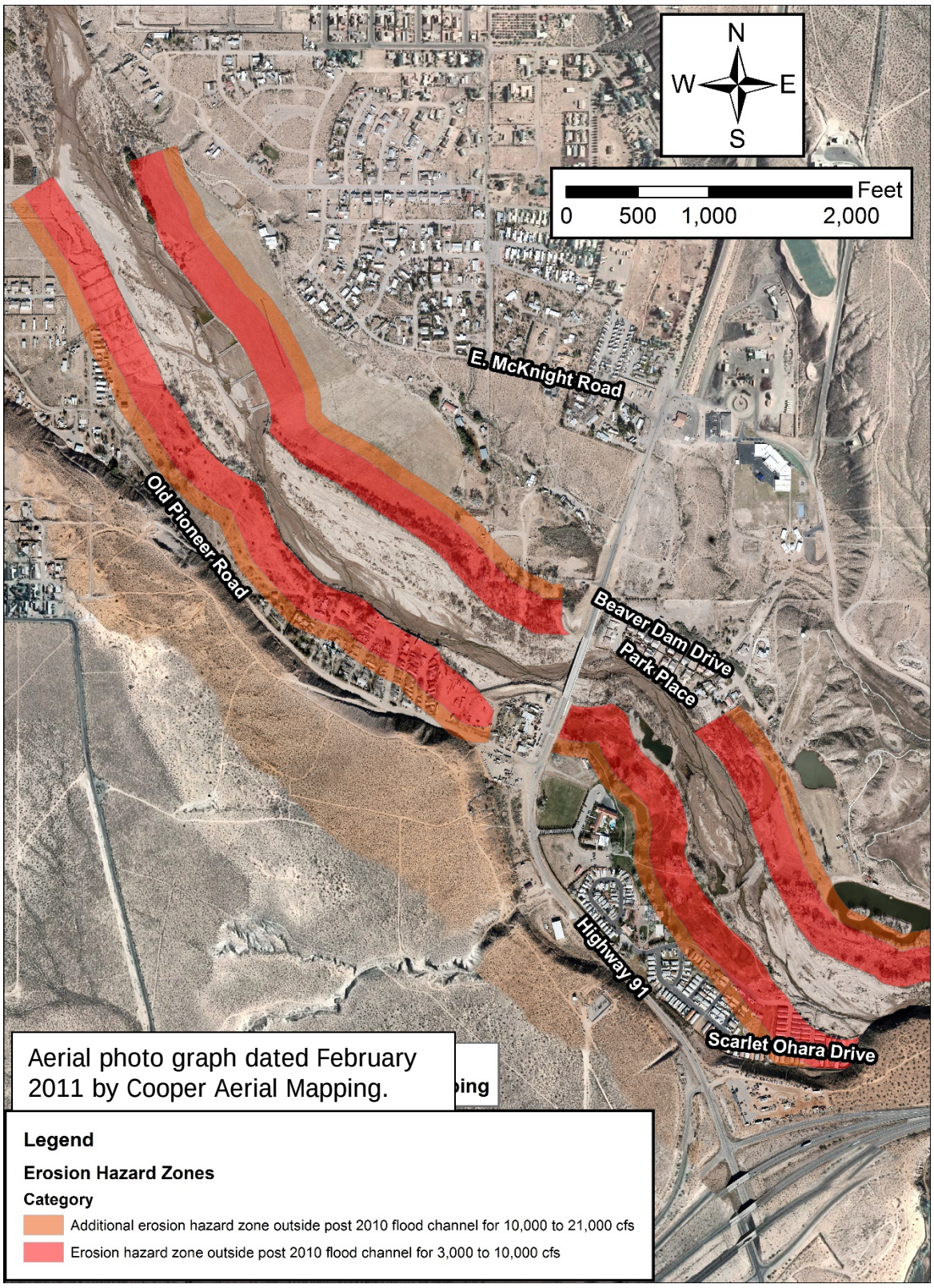


Figure C.23 Erosion setback zones for critical threshold discharges



C.7.3 Limitations

Actual erosion or bank movement at any given location could be negligible or even more severe depending on the discharge and duration of flow. These areas should be closely monitored and judgment exercised when applying this information during a flood event.