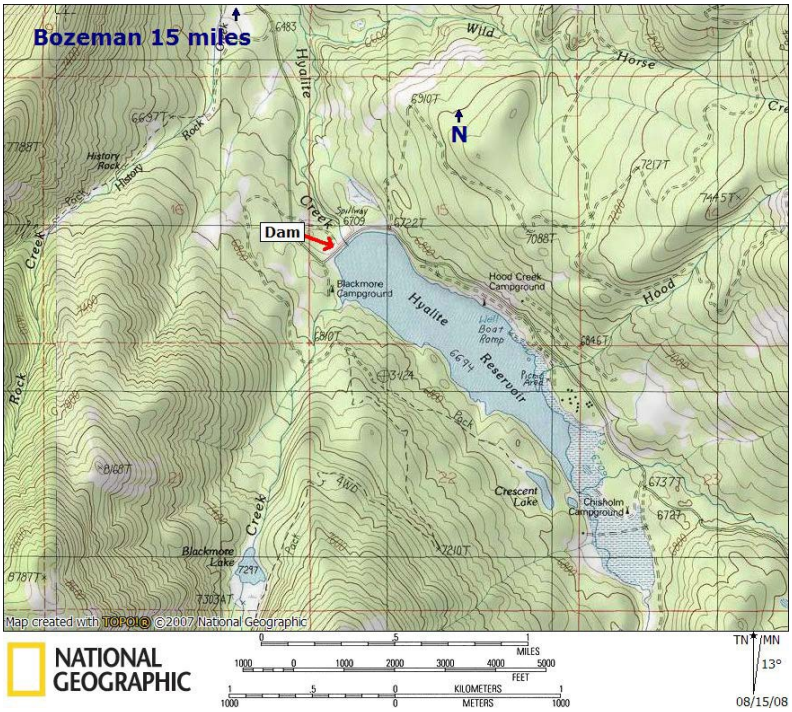
Emergency Action Plan (EAP)

Middle Creek Dam

National Inventory of Dams (NID) No. MT000018
Gallatin County, Montana

Montana Department of Natural Resources and Conservation
Water Resources Division
State Water Projects Bureau
1424 9th Avenue, P.O. Box 201601
Helena, MT 59620-1601

Initial Publication: April 1992
Revised: January 2022



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BASIC EAP DATA

Purpose: The purpose of this EAP is to reduce the risk of human life loss and injury and minimize property damage during an unusual or emergency event at Middle Creek Dam.

Potential Impacted Area: See Flood Inundation Maps in Appendix C-1 *(page 34)* for identification of areas that may be flooded and the estimated time for the flood wave to travel from the dam to the locations.

Dam Description:

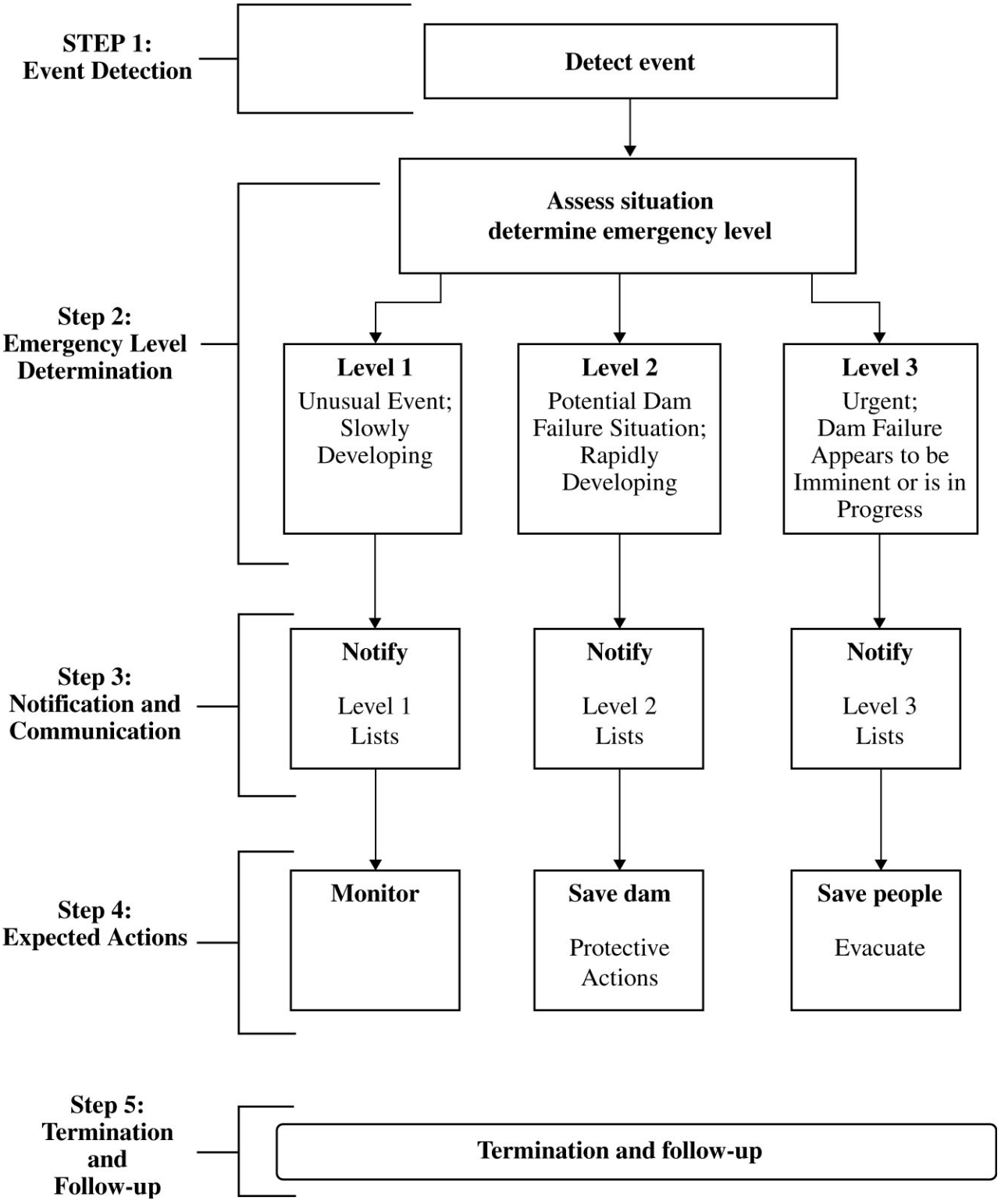
Height: 110 ft.
Built: 1951
Legal Description: Sect. 15, T4S, R6E
Latitude: 45.487 Longitude: -110.978
Dam Designer: State Water Conservation Board

Drainage Area: 28 mi
Hazard Classification: High
Dam Operator: Middle Creek Water Users
Major Property Owner: State of Montana, DNRC
National Inventory of Dams No.: MT0000018

For additional dam and location information see Appendix B.

Directions to dam: Middle Creek Dam is located on the Gallatin-Custer National Forest, 15 mi S of Bozeman on Hyalite Canyon Rd. From Bozeman, drive South on 19th Street for about 5 miles. Follow the curve to the right and drive for another mile, following the signs to take a left onto Hyalite Canyon Road. Follow Hyalite Canyon Road up to the dam and reservoir.

EAP OVERVIEW



ROLES AND RESPONSIBILITIES

Dam Owner - DNRC State Water Projects Bureau (SWPB)

- Immediately determine the emergency level for any emergency event as soon as it is observed or reported (*see Emergency Level Determination, Page 4*).
  - Level 1: Slowly developing unusual event
  - Level 2: Rapidly developing situation with potential dam failure
  - Level 3: Dam failure that is in progress or appears imminent
- Immediately notify the personnel on the notification chart, in the order shown, for the appropriate emergency level. See the Emergency Notification Charts *(pages 9- 11)*.
- Provide updates of the situation to the police/sheriff dispatcher to assist them in making timely and accurate decisions regarding any warnings and evacuations.
- Advise the dam operator of the emergency level determination, if not yet already done, and if time permits
- Advise the dam operator of remedial actions to take if Level 2 event occurs, if time permits
- Annually review and update EAP; provide revised EAP to all who received copies of the original.

Dam Operator - Water User Association (WUA)

- Immediately notify the personnel in the order shown on the Notification Chart for the appropriate emergency level determine (see *Notification Charts, pages 9- 11*).
- Observe the dam's condition/operational performance. Inform DNRC / SWPB of all issues and problems.
- Participate in an annual review and update of the EAP

Incident Commander (County Sheriff)

- Serve as the primary contact person responsible for coordination of all emergency actions
- When a Level 2 situation occurs: Prepare emergency management personnel for possible evacuations that may be needed if a Level 3 situation occurs
- When a Level 3 situation occurs:
  - Initiate warnings and order evacuation of people at risk downstream of the dam
  - Notify local emergency management services to carry out the evacuation of people and close roads within the evacuation area. See the Flood Inundation Maps in Appendix C *(page 34)*.
- Decide when to terminate the emergency.
- Participate in an annual review and update of the EAP.

Emergency Management Services / DES (County and State)

- Maintain communication with media.
- When a Level 2 situation occurs:
  - Prepare emergency management personnel for possible evacuations that may be needed if a Level 3 situation occurs.
  - Alert the public as appropriate.
- When a Level 3 situation occurs:
  - Alert the public.
- Immediately close roads and evacuate people within the evacuation area. See the Flood Inundation Maps in Appendix C-1 *(page 34)*.

- Participate in an annual review and update of the EAP.

Dam Safety – DNRC State Water Operations Bureau (WOP)

- Advise the dam owner of the emergency level, when time permits, if not yet already done.
- Advise the dam owner of remedial actions to take if Level 2 event occurs, when time permits.
- Participate in an annual review and update of the EAP.

THE FIVE-STEP EAP PROCESS

Step 1 Event Detection

Unusual or emergency events may be detected by:

- Observations at or near the dam by government personnel (local, State, or Federal), landowners, visitors to the dam, or the public
- Evaluation of instrumentation data
- Earthquakes felt or reported near the dam
- Forewarning of conditions that may cause an unusual event or emergency event at the dam (for example, severe weather or flash flood forecast)

Step 2 Emergency Level Determination

After an unusual or emergency event is detected or reported, the SWPB is responsible for classifying the event into one of three emergency levels.

See Table 1: Guidance for Determining the Emergency Level (*page 6*) for assistance in evaluating specific events to determine if they are unusual or potential emergency situations.

Emergency Level 1

Nonemergency, unusual event, slowly developing

This situation is not normal, has not yet threatened the operation or structural integrity of the dam, but could be if it continues to develop. DNRC-SWPB officials should be contacted to investigate the situation and recommend actions to take. The condition of the dam should be closely monitored, especially during storm events, to detect any development of a potential or imminent dam failure situation. The Sheriff should be informed if it is determined that the conditions may possibly develop into a worse condition that may require emergency actions.

Emergency Level 2

Potential dam failure situation, rapidly developing

This situation may eventually lead to dam failure and flash flooding downstream, but there is not an immediate threat of dam failure. The Sheriff should be notified of this emergency and placed on alert. The SWPB / WUA should closely monitor the condition of the dam and periodically report the status of the situation to the Sheriff. If the dam condition worsens and failure becomes imminent, the Sheriff must be notified immediately of the change in the emergency level to evacuate the people at risk

downstream.

This emergency level is also applicable when flow through the spillway has or is expected to result in flooding of downstream areas and people near the channel could be endangered. Emergency services should be on alert to initiate evacuations or road closures if the flooding increases.

As time permits, Dam Safety - DNRC State Water Operations Bureau (WOB) should be contacted to evaluate the situation and recommend remedial actions to prevent failure of the dam. The SWPB (in conjunction WOB) should initiate remedial repairs. A list of local resources that may be available are in Appendix B-1 (*page 30*).

Emergency Level 3

Urgent; dam failure appears imminent or is in progress

This is an extremely urgent situation when a dam failure is occurring or is about to occur and cannot be prevented. Flash flooding will occur downstream of the dam. This situation is also applicable when flow through the spillway is causing downstream flooding of people and roads. The Sheriff should be contacted immediately so emergency services can begin evacuations of all at-risk people and close roads. See Flood Inundation Maps in Appendix C-1 (*page 34*).

Table 1: Guidance for Determining the Emergency Level		
Event	**Situation**	**Level**
Spillway flow	High flow events	1
	Spillway flowing with active gully erosion and / or concrete slab loss	2
	Spillway flow that could result in flooding of people downstream if the reservoir level continues to rise	2
	Spillway flowing with advancing head cut that is threatening the control section	3
Embankment overtopping	Reservoir level is 1 foot below the top of the dam	2
	Water from the reservoir is flowing over the top of the dam	3
Seepage	New seepage areas in or near the dam	1
Sinkholes	Observation of new sinkhole in reservoir area or on embankment that is not progressing	1
	Observation of a sinkhole that is progressing	2
	Rapidly enlarging sinkhole that would threaten the embankment or cause downstream flooding	3
Embankment cracking	New cracks in the embankment greater than ¼-inch wide without seepage	1
	Cracks in the embankment with seepage	2
Embankment movement	Visual movement/slippage of the embankment slope	1
	Sudden or rapidly progressing slides of the embankment slopes that have the potential to compromise the crest	3
Instrumentation	Abnormal instrumentation readings	1
Earthquake	Measurable earthquake felt or reported on or within 50 miles of the dam (ie. Site calculated $0.05 < PGA < 0.10$) *	1
	Earthquake resulting in visible damage to the dam or appurtenances	2
	Earthquake resulting in uncontrolled release of water from the dam	3
Security Threat, Sabotage, or Vandalism	Damage to dam or appurtenance with no impacts to the functioning of the dam	1
	Modification to the dam or appurtenances that could adversely impact the functioning of the dam	1
	Verified threat that, if carried out, could result in damage to the dam	2
	Damage to dam or appurtenances that has resulted in seepage flow	2
	Damage to dam or appurtenances that has resulted in uncontrolled water release	3

Emergency Level 1: Nonemergency unusual event, slowly developing
Emergency Level 2: Potential dam failure situation, rapidly developing
Emergency Level 3: Urgent; dam failure appears imminent or is in progress
*PGA = Peak Ground Acceleration, maximum ground acceleration that occurred during an earthquake at a certain location

Step 3 Notification and Communication

After the emergency level has been determined, the people on the appropriate emergency level Notification Chart *(pages 9-11*) shall be notified immediately.

Communication

Emergency Level 1: Nonemergency, unusual event; slowly developing

Contact the DNRC (SWPB and WOB) and request technical assistance on next steps to take.

Emergency Level 2: Emergency event, potential dam failure; rapidly developing

The following message may be used to help describe the emergency to the Sheriff or DES emergency management personnel:

"This is Identify yourself; (name, position). We have an emergency condition at Middle Creek (Hyalite) Dam, located 15 miles south of Bozeman. We have activated the Emergency Action Plan and are currently under Emergency Level 2.

We are implementing predetermined actions to respond to a rapidly developing situation that could result in dam failure.

Please prepare to evacuate the area along low-lying portions downstream of the dam. Reference the Inundation maps, Appendix C-1 (*page 34*)*, in your copy of the Emergency Action Plan. We will advise you when the situation is resolved or if the situation gets worse.*

I can be contacted at the following number: provide your phone number. If you cannot reach me, please call the following alternative number: provide your phone number."

Emergency Level 3: Urgent event; dam failure appears imminent or in progress

The Sheriff should be contacted immediately, and the area evacuated. See Inundation Maps, Appendix C-1 (*page 34*). The following actions should be taken:

1. Call 911. Be sure to say, "*This is an emergency*." They will call other authorities and the media and begin the evacuation. The following message may be used to help describe the emergency to the Sheriff or DES, emergency management personnel:
   "This is an emergency. This is (Identify yourself; name, position).

   Middle Creek (Hyalite) Dam, located 15 miles south of Bozeman is failing. The downstream area must be evacuated immediately. Repeat, Middle Creek (Hyalite) Dam is failing; evacuate the area along low-lying portions downstream of the dam.

   We have activated the Emergency Action Plan for this dam and are currently under Emergency Level 3. Reference the inundation maps, Appendix C-1 (*page 34*)*, in your copy of the Emergency Action Plan.*

   I can be contacted at the following number: provide your phone number. If you cannot reach me, please call the following alternative number: provide your phone number."

2. Do whatever is necessary to bring people in immediate danger to safety (anyone on the dam, downstream from the dam, boating on the reservoir, or evacuees) as directed by the Sheriff.

3. Keep in frequent contact with the Sheriff and emergency services to keep them up-to-date on the condition of the dam. They will tell you how you can help handle the emergency.

4. If all means of communication are lost: (1) try to find out why, (2) try to get to another radio or telephone that works, or (3) get someone else to try to re-establish communications. If these means fail, handle the immediate problems as well as you can, and periodically try to re-establish contact with the Sheriff and emergency services.

   The following pre-scripted message may be used as a guide for the Sheriff or emergency services personnel to communicate the status of the emergency with the public:
   Attention: This is an emergency message from the Sheriff. Listen carefully. Your life may depend on immediate action.

   Middle Creek (Hyalite) Dam, located 15 miles south of Bozeman, is failing. Repeat. Middle Creek (Hyalite) Dam is failing.

   If you are in or near this area, proceed immediately to high ground away from the downstream inundation area. You cannot outrun or drive away from the flood wave. Proceed immediately to high ground away from the valley.

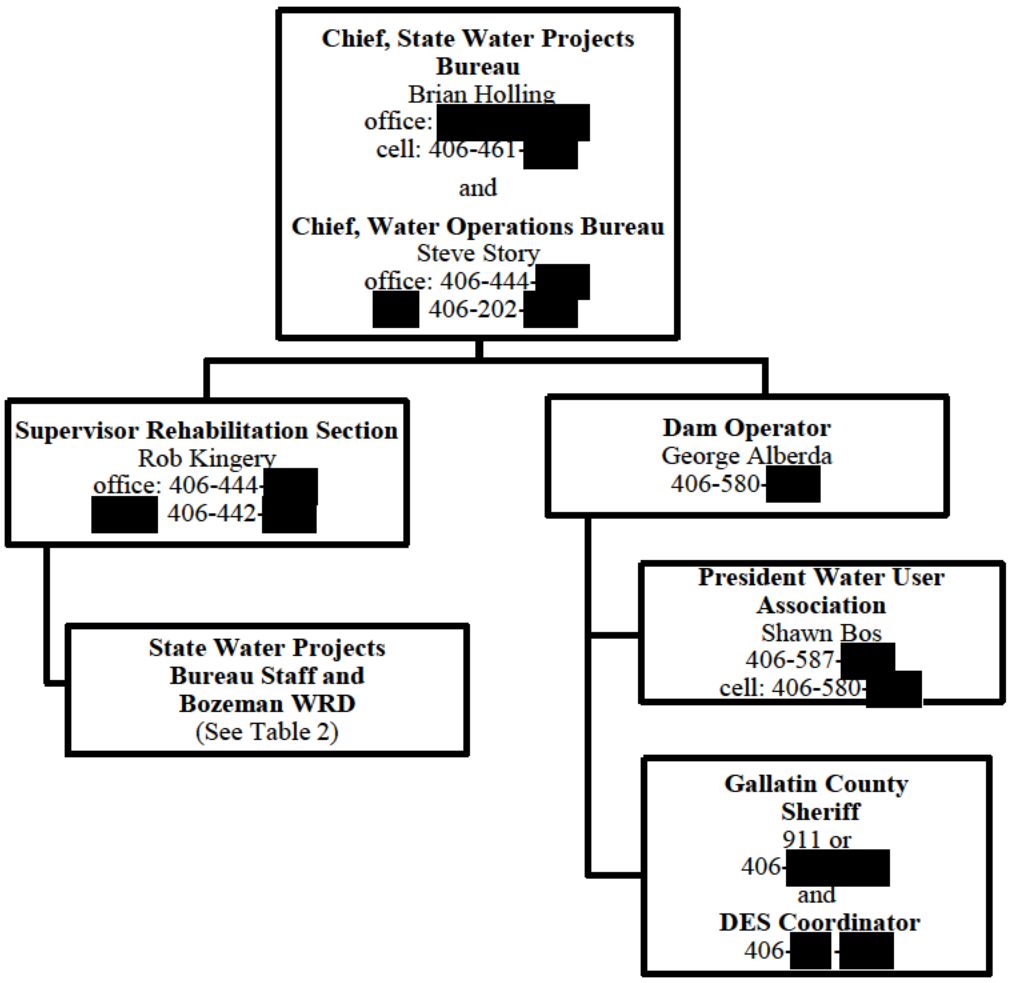
   Repeat message.

Notification Charts

Emergency Level 1 Notifications: Nonemergency unusual event; slowly developing

DO NOT leave recorded messages!!! If you receive a voice mail message, press "0" to get a receptionist. If you receive an answering machine or no answer, call the next available number.

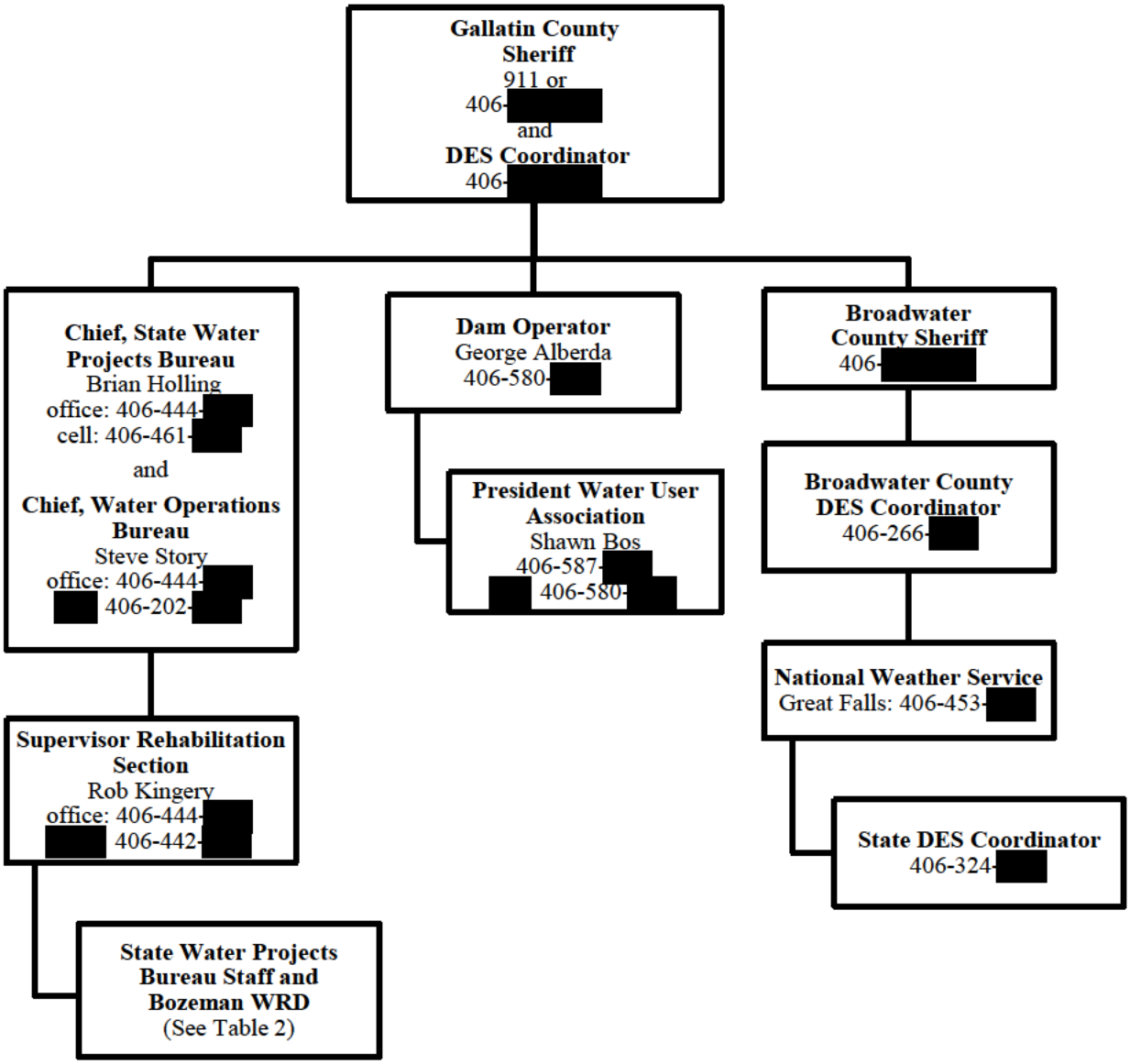
See Tables 2 and 3 *(pages 17 and 18)* for contact information for back-ups to the persons listed and other emergency personnel.



Emergency Level 2 Notifications: Emergency event, potential dam failure situation; rapidly developing

DO NOT leave recorded messages!!! If you receive a voice mail message, press "0" to get a receptionist. If you receive an answering machine or no answer, call the next available number.

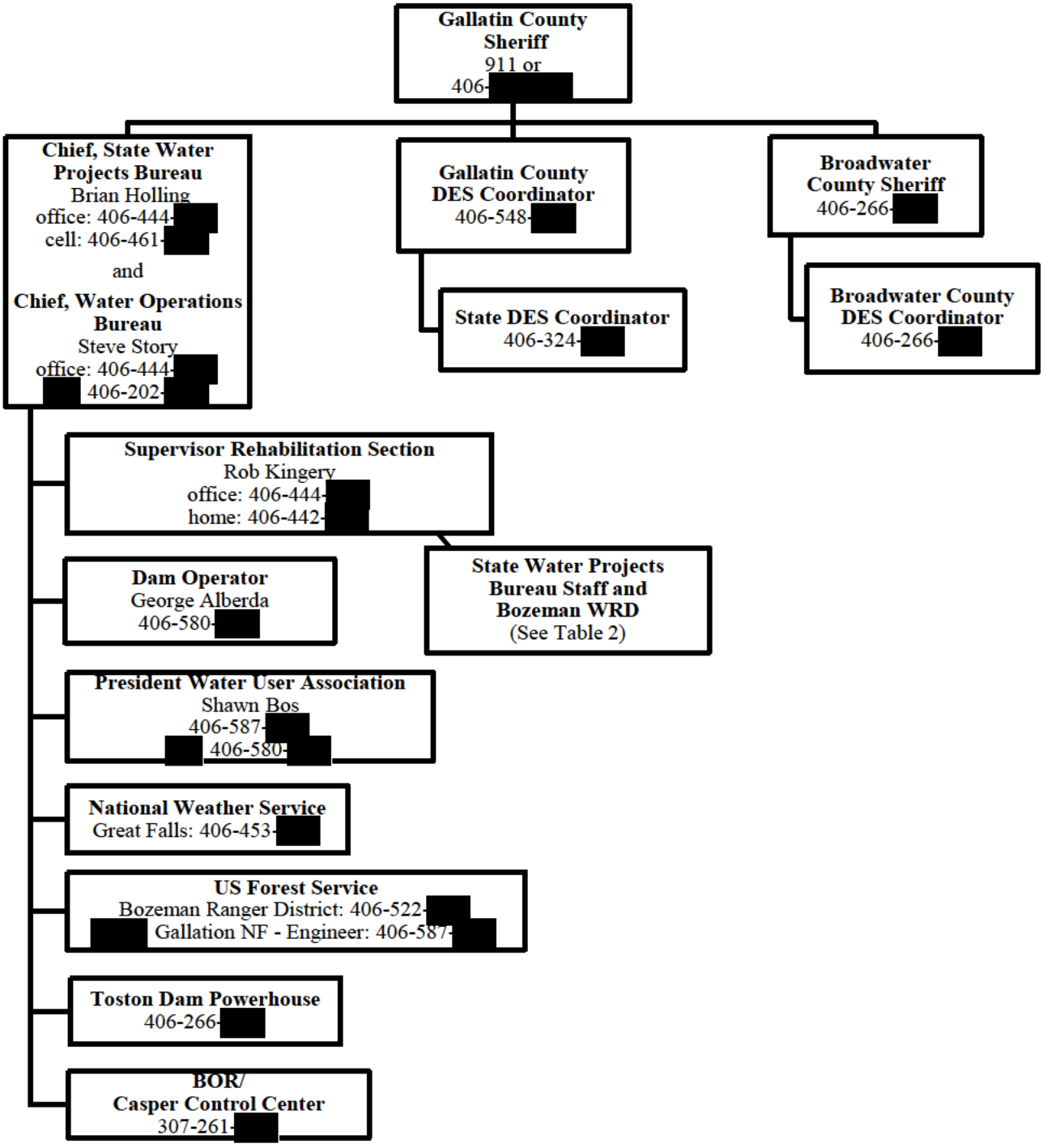
See Tables 2 and 3 *(pages 17 and 18)* for contact information for back-ups to the persons listed and other emergency personnel.



Emergency Level 3: Urgent event, dam failure appears imminent or is in progress.

DO NOT leave recorded messages!!! If you receive a voice mail message, press "0" to get a receptionist. If you receive an answering machine or no answer, call the next available number.

See Tables 2 and 3 *(pages 17 and 18)* for contact information for back-ups to the persons listed and other emergency personnel.



Step 4 Expected Actions

If the police or Sheriff receives a 911 call regarding observations of an unusual or emergency event at the dam, they should immediately contact the SWPB. After the SWPB determines the emergency level, the following actions should be taken:

Emergency Level 1

Nonemergency, unusual event; slowly developing

A. The DNRC / SWPB should contact the individuals/departments shown on the Notification Chart *(page 9)* to report the situation.
B. The Water Users should inspect the dam. At a minimum, inspect the full length of the upstream slope, crest, downstream toe, and downstream slope. Also, check the reservoir area, abutments, and downstream channel for signs of changing conditions**. If increased seepage, erosion, cracking, or settlement are observed, immediately report the observed conditions to the SWPB; refer to the emergency level table for guidance in determining the appropriate event level for the new condition and recommended actions.**
C. Record all contacts that were made on the Contact Checklist in Appendix A–1 *(page 24)*. Record all information, observations, and actions taken on the Event Log Form in Appendix A–2 *(page 25)*. Note the time of changing conditions. Document the situation with photographs and video, if possible.
D. Contact the SWPB and request technical staff to investigate the situation and recommend corrective actions.

Emergency Level 2

Potential dam failure situation; rapidly developing

A. The DNRC / SWPB should contact the County Sherriff (911) and others shown on the Notification Chart *(page 10)* to report the situation.
B. The SWPB will maintain contact with the Sheriff's Office and water users to confirm that the EAP has been activated. If current conditions get worse, an emergency may require evacuation. The Sheriff's Office / local DES will be responsible for initiating possible road closures and evacuations.
C. The DNRC / SWPB / Water Users will provide updates to the Sheriff and emergency services personnel to assist them in making timely decisions concerning the need for warnings, road closures, and evacuations.
D. When time permits, the DNRC / SWPB staff should inspect the dam. At a minimum, inspect the full length of the upstream slope, crest, downstream toe, and downstream slope. Also, check the reservoir area, abutments, and downstream channel for signs of changing conditions.
E. Record all contacts that were made on the Contact Checklist in Appendix A–1 *(page 24)*. Record all information, observations, and actions taken on the Event Log Form in Appendix A–2 *(page 25)*. Note the time of changing conditions. Document the situation with photographs and video, if possible.
F. The following emergency remedial actions should be taken as appropriate, when time permits.

Emergency Level 3

Urgent; dam failure appears imminent or is in progress

A. The DNRC / SWPB shall immediately contact the Sheriff and others shown on the Notification Chart

(page 11).

B. The Sheriff shall lead the efforts to carry out warnings, close roads, and evacuate people at risk downstream from the dam. See Flood Inundation Maps in Appendix C-1 (*page 34*).
C. Emergency management services personnel shall alert the public and immediately evacuate at-risk people and close roads as necessary.
D. The DNRC / SWPB / Water Users shall maintain continuous communication and provide the Sheriff with updates of the situation to assist him/her in making timely decisions concerning warnings and evacuations.
E. All contacts that were made should be documented on the Contact Checklist in Appendix A–1 *(page 24)*. Record all information, observations, and actions taken on the Event Log Form in Appendix A–2 *(page 25)*. Note the time of changing conditions. Document the situation with photographs and video, if possible.
F. Advise people monitoring the dam to follow safe procedures. Everyone should stay away from any of the failing structures or slopes and out of the potential breach inundation areas.

Emergency remedial actions

If time permits, the following emergency remedial actions should be considered for Emergency Level 2 conditions. Immediate implementation of these remedial actions may delay, moderate, or prevent the failure of the dam. Several of the listed adverse or unusual conditions may be apparent at the dam at the same time, requiring implementation of several modes of remedial actions. Close monitoring of the dam must be maintained to confirm the success of any remedial action taken at the dam. Time permitting, any remedial action should be developed through consultation with SWPB / DNRC. See the table of Resources Available in Appendix B–1 *(page 30)* for sources of equipment and materials to assist with remedial actions.

Embankment overtopping

1. If the water level in the reservoir is no longer rising, place sandbags along the low areas of the top of the dam to control wave action, reduce the likelihood of flow concentration during minor overtopping, and to safely direct more water through the spillway.
2. Cover the weak areas of the top of the dam and downstream slope with riprap, sandbags, plastic sheets, or other materials to provide erosion-resistant protection.

Seepage and sinkholes

1. Open the gate to lower the reservoir level as rapidly as possible to a level that stops or decreases the seepage to a nonerosive velocity. If the gate is damaged or blocked, pumping or siphoning may be required.
   Continue lowering the water level until the seepage stops.
2. If the entrance to the seepage origination point is observed in the reservoir (possible whirlpool) and is accessible, attempt to reduce the flow by plugging the entrance with readily available materials such as hay bales, bentonite, soil or rockfill, or plastic sheeting.
3. Cover the seepage exit area(s) with several feet of sand/gravel to hold fine-grained embankment or foundation materials in place. Alternatively, construct sandbag or other types of ring dikes around seepage exit areas to retain a pool of water, providing backpressure and reducing the erosive nature of the seepage.
4. Prevent vehicles and equipment from driving between the seepage exit points and the embankment to avoid potential loss from the collapse of an underground void.

Embankment movement

1. Open outlet(s) and lower the reservoir to a safe level at a rate commensurate with the urgency and severity of the condition of the slide or slump. If the gate is damaged or blocked, pumping or siphoning may be required.
2. Repair settlement of the crest by placing sandbags or earth and rockfill materials in the damaged area to restore freeboard.
3. Stabilize slides by placing a soil or rockfill buttress against the toe of the slide.

Earthquake

2. Immediately conduct a general overall visual inspection of the dam.
3. Perform a field survey to determine if there has been any, or the extent of, settlement and movement of the dam embankment, spillway, and low-level outlet works.
4. Lower the reservoir, if required.

Step 5 Termination

Whenever the EAP has been activated, an emergency level has been declared, all EAP actions have been completed, and the emergency is over, the EAP operations must eventually be terminated and follow-up procedures completed.

Termination responsibilities

The Sheriff is responsible for terminating EAP operations and relaying this decision to the Water Users / DNRC / SWPB. It is then the responsibility of each person to notify the same group of contacts that were notified during the original event notification process to inform those people that the event has been terminated.

Prior to termination of an Emergency Level 3 event that has not caused actual dam failure, the DNRC (SWPB or WOB) will inspect the dam or require the inspection of the dam to determine whether any damage has occurred that could potentially result in loss of life, injury, or property damage. If it is determined that conditions do not pose a threat to people or property, the Sheriff will be advised to terminate EAP operations as described above.

The SWPB shall assure that the Dam Emergency Situation Report in Appendix A–3 *(page 26)* is completed to document the emergency event and all actions that were taken. The SWPB shall distribute copies of the completed report to the Water Users and other involved agencies.

Examples of Emergency Situations

The following are examples of conditions that usually constitute an emergency that may occur at a dam. Adverse or unusual conditions that can cause the failure of a dam are typically related to aging or design and construction oversights. Extreme weather events that exceed the original designed conditions can cause significant flow or overtopping of the embankment. However, accidental or intentional damage to the dam may also result in emergency conditions. The conditions have been grouped to identify the most likely emergency-level condition. The groupings are provided as guidance only. Not all emergency conditions may be listed, and the SWPB (or WOB) is urged to use conservative judgment in determining whether a specific condition should be defined as an emergency at the dam.

Flows

Emergency Level 2—Potential dam failure situation; rapidly developing:

1. Significant erosion, head cutting, or concrete slab loss is occurring, but the rate does not appear to threaten an imminent breach that would result in an uncontrolled release of the reservoir.
2. Flow is expected to cause flooding that could threaten people, homes, and/or roads downstream from the dam.

Emergency Level 3—Urgent; dam failure appears imminent or is in progress:

1. Significant erosion, head cutting, or concrete slab loss is occurring at a rapid rate, and a breach of the control section appears imminent.
2. Flow is causing flooding, threatening people, homes, and/or roads downstream.

Embankment Overtopping

Emergency Level 2—Potential dam failure situation; rapidly developing:

1. The reservoir level is within 1 foot from the top of the dam.

Emergency Level 3—Urgent; dam failure appears imminent or is in progress:

2. The reservoir level has exceeded the top of the dam, and flow is occurring over the embankment.

Seepage and Sinkholes

Emergency Level 2—Potential dam failure situation; rapidly developing:

1. Cloudy seepage or soil deposits are observed at seepage exit points.
2. New or increased *unusual* areas of wet or muddy soils are present on the downstream slope, abutment, and/or foundation of the dam, and there is an easily detectable and *unusual* increase in volume of downstream seepage.
3. Significant new or enlarging sinkhole(s) near the dam or settlement of the dam is observed.
4. Reservoir level is falling without apparent cause.
5. The following known dam defects are or will soon be inundated by a rise in the reservoir:
    - Sinkhole(s) located on the upstream slope, crest, abutment, and/or foundation of the dam; or
    - Transverse cracks extending through the dam, abutments, or foundation.

Emergency Level 3—Urgent; dam failure appears imminent or is in progress:

1. Rapidly increasing cloudy seepage or soil deposits at seepage exit points to the extent that failure appears imminent or is in progress.
2. Rapid increase in downstream seepage to the extent that failure appears imminent or is in

progress.

3. Water flowing out of holes in the downstream slope, abutment, and/or foundation of the dam to the extent that failure appears imminent or is in progress.
4. Whirlpools or other evidence exists indicating that the reservoir is draining rapidly through the dam or foundation.
5. Rapidly enlarging sinkhole(s) are forming on the dam or abutments to the extent that failure appears imminent or is in progress.
6. Rapidly increasing flow through crack(s) eroding materials to the extent that failure appears imminent or is in progress.

Embankment Movement and Cracking

Emergency Level 2—Potential dam failure situation; rapidly developing:

1. Minor slides, settlement of the crest, slopes, abutments and/or foundation of the dam that may eventually result in breaching of the dam.
2. Significant increase in length, width, or offset of cracks in the crest, slopes, abutments, and/or foundation of the dam that may eventually result in breaching of the dam.

Emergency Level 3—Urgent; dam failure appears imminent or is in progress:

1. Sudden or rapidly proceeding slides, settlement, or cracking of the embankment crest, slopes, abutments, and/or foundation, and breaching of the dam appears imminent or is in progress.

Table 2: Contacts

Agency/Organization	Contact	Address	[redacted]	[redacted]
DNRC - State Water Projects Bureau	Brian Holling Chief	1424 9th Avenue Helena, MT 59620	4	
DNRC - State Water Projects Bureau	Rob Kingery Supervisor	1424 9th Avenue Helena, MT 59620	4	
DNRC - Water Operations Bureau	Steve Story Chief	1424 9th Avenue Helena, MT 59620	4	
DNRC - Water Operations Bureau	Michele Lemieux* Dam Safety Engineer	1424 9th Avenue Helena, MT 59620	4	
DNRC - State Water Projects Bureau	Joshua Gilstrap Dam Safety Engineer	1424 9th Avenue Helena, MT 59620	4	
DNRC - State Water Projects Bureau	Sean West* Civil Engineer	1424 9th Avenue Helena, MT 59620	4	
DNRC - State Water Projects Bureau	Pete Behrends* Civil Engineer	1424 9th Avenue Helena, MT 59620	4	
DNRC - State Water Projects Bureau	Troy Benn* Civil Engineer	1424 9th Avenue Helena, MT 59620	4	
DNRC - Bozeman WRD	Kerri Strasheim Regional Manager	2273 Boot Hill Ct Suite 110 Bozeman, MT 59715	4	
DNRC - Helena WRD	Anna Pakenham Stevenson WRD Administrator	1424 9th Avenue Helena, MT 59620	4	
DNRC - Helena	Cassie Wandersee Communication Director	1539 11th Avenue Helena, MT 59601	4	
DNRC - Helena	Amanda Kaster DNRC Director	1539 11th Avenue Helena, MT 59601	4	
Middle Creek Water Users	George Alberda Dam Operator	27027 Norris Road Bozeman, MT 59718	4	
Middle Creek Water Users	Shawn Bos President	4491 Kent Spur Rd Bozeman, MT 59718	4	
Middle Creek Water Users	Gerry Dusenberry Vice President	5170 Johnson Road Bozeman, MT 59718	4	

*Back-up to primary contact

Table 3: Emergency Contacts

Agency/Organization	Contact	Address		A
Gallatin County	Dan Springer Sheriff	615 S 16th Avenue Room 22 Bozeman, MT 59715	4	
Gallatin County	Patrick Lonergan DES Coordinator	219 East Tamarack Bozeman, MT 59715	4	
Broadwater County	Wynn Meehan Sheriff	519 Broadwater Street Townsend, MT 59644	4	
Broadwater County	Brittany Willis DES Coordinator	515 Broadwater Street Townsend, MT 59644	4	
DNRC Toston Dam Powerhouse		Toston Dam Road Toston, MT 59644	4	
US Forest Service Bozeman Ranger District	Corey Lewellen District Ranger	3710 Fallon Street, Box C Bozeman, MT 59718	4	
US Forest Service Custer Gallatin NF	Parks Frady* Forest Engineer	10 E Babcock St Bozeman, MT 59771	4	
US Forest Service Custer Gallatin NF	Zac Heideman* Facilities Engineer	10 E Babcock St Bozeman, MT 59771	4	
DNRC – Helena	Dave Lofftus Hydropower Manager	1424 9th Avenue Helena, MT 59620	4	4
BOR Casper Control Center	Cathy Woodruff	705 Pendell Blvd Mills, WY 82644	3	
BOR Canyon Ferry Dam Field Office		7700 Canyon Ferry Road Helena, MT 59602	4	
Dept. of Military Affairs State DES			4	
National Weather Service Great Falls			4	

*Back-up to primary contact
Note: See Table 2 for DNRC and WUA contacts

MAINTENANCE - EAP REVIEW AND REVISION

EAP annual review

The SWPB will review and update the EAP at least once each year. The EAP annual review and update will include the following:

- Calling all contacts on the three notification charts in the EAP to verify that the phone numbers and persons in the specified positions are current. The EAP will be revised if any of the contacts have changed.
- Contacting the local law enforcement agency to verify the phone numbers and persons in the specified positions.
- Calling the locally available resources to verify that the phone numbers, addresses, and services are current.

Revisions

The SWPB is responsible for updating the EAP document. The EAP document held by the SWPB is the master document. When revisions occur, the SWPB will provide the revised pages and a revised revision summary page to all the EAP document holders. The document holders are responsible for revising outdated copy of the respective document(s) whenever revisions are received. Outdated pages shall be immediately discarded to avoid any confusion with the revisions.

EAP periodic test

The SWPB / WOB / Water Users will host and facilitate periodic tests of the EAP.

The periodic test will consist of a meeting, including a tabletop exercise. Attendance should include the key SWPB and WOB staff members, Water Users (minimum dam operator and president), at least one representative of the local law enforcement agency, and others with key responsibilities listed in the EAP. At the discretion of the SWPB / WOB, other organizations that may be involved with an unusual or emergency event at the dam are encouraged to participate. Before the tabletop exercise begins, it is recommended that meeting participants visit the dam to familiarize themselves with the site.

The tabletop exercise will begin with the facilitator presenting a scenario of an unusual or emergency event at the dam. The scenario will be developed prior to the exercise. Once the scenario has been presented, the participants will discuss the responses and actions that they would take to address and resolve the scenario. The narrator will control the discussion, ensuring realistic responses and developing the scenario throughout the exercise. SWPB / WOB should complete an event log as they would during an actual event.

After the tabletop exercise, the five sections of the EAP will be reviewed and discussed. Mutual aid agreements and other emergency procedures can be discussed. DNRC will prepare a written summary of the periodic test and revise the EAP, as necessary.

Table 4: Record of Holders of Control Copies of this EAP

Number of Copies	Organization	Person Receiving Copy
2	DNRC / SWPB	Brian Holling
2	DNRC / SWPB	Rob Kingery
2	DNRC / SWPB	Josh Gilstrap
1	DNRC / SWPB	Pete Behrends
1	DNRC / SWPB	Kelley McCarter
1	DNRC / Communication Director	Cassie Wandersee
1	DNRC / Bozeman Regional Office	Kerry Strasheim
*1	DNRC / Dam Safety (WOB)	Michele Lemieux
1	City of Bozeman	Scott Shirley- Director of Public Works
1	WUA	Shawn Bos - President
1	WUA	Gerry Dusenberry - Vice President
2	WUA	George Alberda - Dam Operator
2	Gallatin County	Dan Springer - Sheriff Patrick Lonergan - DES Coordinator
2	Broadwater County	Wynn Meehan - Sheriff Brittany Willis - DES Coordinator
1	BOR Casper Control Center	Cathy Woodruff
1	BOR Canyon Ferry Dam	Field Officer
1	US Forest Service Bozeman Ranger District	Corey Lewellen -District Ranger
*2	US Forest Service Custer Gallatin NF	Parks Frady - Forest Engineer Zac Heideman - Facilities Engineer
1	DNRC / Toston Dam	Dave Lofftus
1	State DES	Ryan Lee/Betsy Ross
1	DES Western District	Audrey Walleser
1	DES Western District	Kyle Sturgill-Simon
1	National Weather Service	Great Falls
27	**Total Copies**	

*electronic copy

Table 5: Record of Revisions and Updates made to this EAP

Revision Number	Date	Revisions Made	By Whom
1	1/1/2022	Update Gallatin Co Sheriff	SWPB
2	1/1/2022	Update DNRC Communication Director	SWPB
3	1/1/2022	Update DES for Western District	SWPB
4	1/1/2022	Update Director of Public Works for Bozeman	SWPB
5	1/1/2022	Update BOR Casper Control Center contact	SWPB
6	1/1/2022	Update Notification Charts	SWPB

APPENDICES

FORMS, GLOSSARY, MAPS, AND SUPPORTING DATA

Appendix A

A-1 Contact Checklist

A-2 Unusual or Emergency Event Log Form

A-3 Dam Emergency Situation Report Form

A-4 Glossary of Terms

Appendix B

B-1 Resources Available

B-2 Location and Vicinity Maps

B-3 Project Information

Appendix C

C-1 Resources Available

C-2 Dam Breach Analysis

APPENDIX A

A-1: Contact Checklist

MIDDLE CREEK DAM, GALLATIN COUNTY DATE: _____

The following contacts should be made immediately after the emergency level is determined (see pages 4 - 6 for guidance to determine the emergency level). The person making the contacts should initial and record the time and who was notified. See the Notification Charts-Emer. Services Contacts, pages 9 - 11.

Emergency Level 1 (see page 9)	Person Contacted	Time	Contacted by
____ SWPB / DNRC			
____ Water Users			
____ Gallatin County Sheriff			
____ Gallatin County DES			

Emergency Level 2 (see page 10)			
_____ Gallatin County Sheriff			
_____ Gallatin County DES			
_____ SWPB / DNRC			
_____ Water Users			
_____ Broadwater County Sheriff			
_____ Broadwater County DES			
_____ National Weather Service			
_____ State DES			

Emergency Level 3 (see page 11)			
_____ Gallatin County Sheriff			
_____ Gallatin County DES			
_____ SWPB / DNRC			
_____ Water Users			
_____ Broadwater County Sheriff			
_____ Broadwater County DES			
_____ National Weather Service			
_____ Forest Service			
_____ DNRC/Toston Dam			
_____ BOR/Casper Control			
_____ State DES			

A-2: Unusual or Emergency Event Log

(to be completed during the emergency)
MIDDLE CREEK DAM, GALLATIN COUNTY DATE: _____
When and how was the event detected?

_____

_____

Weather conditions?

_____

_____

General description of the emergency:

_____

_____

Emergency level determination: _____Made by: _____

Actions and Event Progression

Date	Time	Action/event progression	Taken by

Report prepared by:_____Date: _____

A-3: Dam Emergency Situation Report

(to be completed following the termination of the emergency)

MIDDLE CREEK DAM, National Inventory of Dams (NID) No.: MT000018

Location: 15 miles S of Bozeman, *(City)* Gallatin County, *(County)* Middle Creek *(Stream/River)*

Date:_____ Time:_____

Weather conditions: _____

General description of emergency:

_____

_____

Area(s) of dam affected:

_____

_____

Extent of dam damage:_____

Possible cause(s):_____

_____

Effect on dam's operation:_____

_____

Initial reservoir elevation:_____ Time:_____

Maximum reservoir elevation: _____ Time:_____

Final reservoir elevation: _____ Time:_____

Description of area flooded downstream/damages/injuries/loss of life:

_____

_____

Other data and comments:

_____

_____

Observer's name and telephone number:_____

Report prepared by:_____ Date: _____

A-4: Glossary of Terms

Abutment The part of the valley side against which the dam is constructed. The left and right abutments of dams are defined with the observer looking downstream from the dam.

Acre-foot Unit of volumetric measure that would cover 1 acre to a depth of 1 foot. One acre-foot is equal to 43,560 cubic feet or 325,850 gallons.

Berm Nearly horizontal step (bench) in the upstream or downstream sloping face of the dam.

Boil Disruption of the soil surface due to water discharging from below the surface. Eroded soil may be deposited in the form of a ring (miniature volcano) around the disruption.

Breach Opening through the dam that allows draining of the reservoir. A controlled breach is an intentionally constructed opening. An uncontrolled breach is an unintended failure of the dam.

Conduit Closed channel (round pipe or rectangular box) that conveys water through, around, or under the dam.

Control section Usually level segment in the profile of an open channel spillway above which water in the reservoir discharges through the spillway.

Cross section A slice through the dam showing elevation vertically and direction of natural water flow horizontally from left to right. Also, a slice through a spillway showing elevation vertically and left and right sides of the spillway looking downstream.

Dam An artificial barrier generally constructed across a watercourse for impounding or diverting water.

Dam failure Uncontrolled release of a dam's impounded water.

Dam Operator Person(s) or unit(s) of government with responsibility for the operation and maintenance of dam.

Drain, toe or foundation or blanket Water collection system of sand and gravel and typically pipes along the downstream portion of the dam to collect seepage and convey it to a safe outlet.

Drainage area (watershed) Geographic area on which rainfall flows into the dam.

Drawdown Lowering or releasing of the water level in a reservoir over time or the volume lowered or released over a period.

Emergency A condition that develops unexpectedly, endangers the structural integrity of the dam and/or downstream human life and property, and requires immediate action.

Emergency Action Plan (EAP) Formal document identifying potential emergency conditions that may occur at the dam and specifying preplanned actions to minimize potential failure of the dam or minimize failure consequences including loss of life, property damage, and environmental impacts.

Evacuation map Map showing the geographic area downstream of a dam that should be evacuated if it is threatened to be flooded by a breach of the dam or other large discharge.

Filter Layers of sand and gravel in a drain that allow seepage through an embankment to discharge into the drain without eroding the embankment soil.

Freeboard Vertical distance between a stated water level in the reservoir and the top of dam.

Gate, slide or sluice, or regulating Operable, watertight valve to manage the discharge of water from the dam.

Groin Area along the intersection of the face of a dam and the abutment.

Hazard classification System that categorizes dams (high, significant, or low) according to the degree of their potential to create adverse incremental consequences such as loss of life, property damage, or environmental impacts of a failure or improper operation of a dam.

Height, dam Vertical distance between the lowest point along the top of the dam and the lowest point at the downstream toe, which usually occurs in the bed of the outlet channel.

Hydrograph, inflow, outflow, or breach Graphical representation of either the flow rate or flow depth at a specific point above or below the dam over time for a specific flood occurrence.

Incident Commander Highest predetermined official available at the scene of an emergency.

Instrumentation Arrangement of devices installed into or near dams that provide measurements to evaluate the structural behavior and other performance parameters of the dam and appurtenant structures.

Inundation area or map Geographic area downstream of the dam that would be flooded by a breach of the dam or other large discharge.

Notification To immediately inform appropriate individuals, organizations, or agencies about a potentially emergency so they can initiate appropriate actions.

Outlet works (principal spillway) Appurtenant structure that provides for controlled passage of normal water flows through the dam.

Piping Progressive destruction of an embankment or embankment foundation by internal erosion of the soil by seepage flows.

Probable Maximum Precipitation (PMP) or Flood (PMF) Theoretically greatest precipitation or resulting flood that is meteorologically feasible for a given duration over a specific drainage area at a geographical location.

Reservoir Body of water impounded or potentially impounded by the dam.

Riprap Layer of large rock, precast blocks, bags of cement, or other suitable material, generally placed on an embankment or along a watercourse as protection against wave action, erosion, or scour.

Risk Measure of the likelihood and severity of an adverse consequence.

Seepage Natural movement of water through the embankment, foundation, or abutments of the dam.

Slide Movement of a mass of earth down a slope on the embankment or abutment of the dam.

Spillway (auxiliary or emergency) Appurtenant structure that provides the controlled conveyance of excess water through, over, or around the dam.

Spillway capacity Maximum discharge the spillway can safely convey with the reservoir at the maximum design elevation.

Spillway crest Lowest level at which reservoir water can flow into the spillway.

Tailwater Body of water immediately downstream of the embankment at a specific point in time.

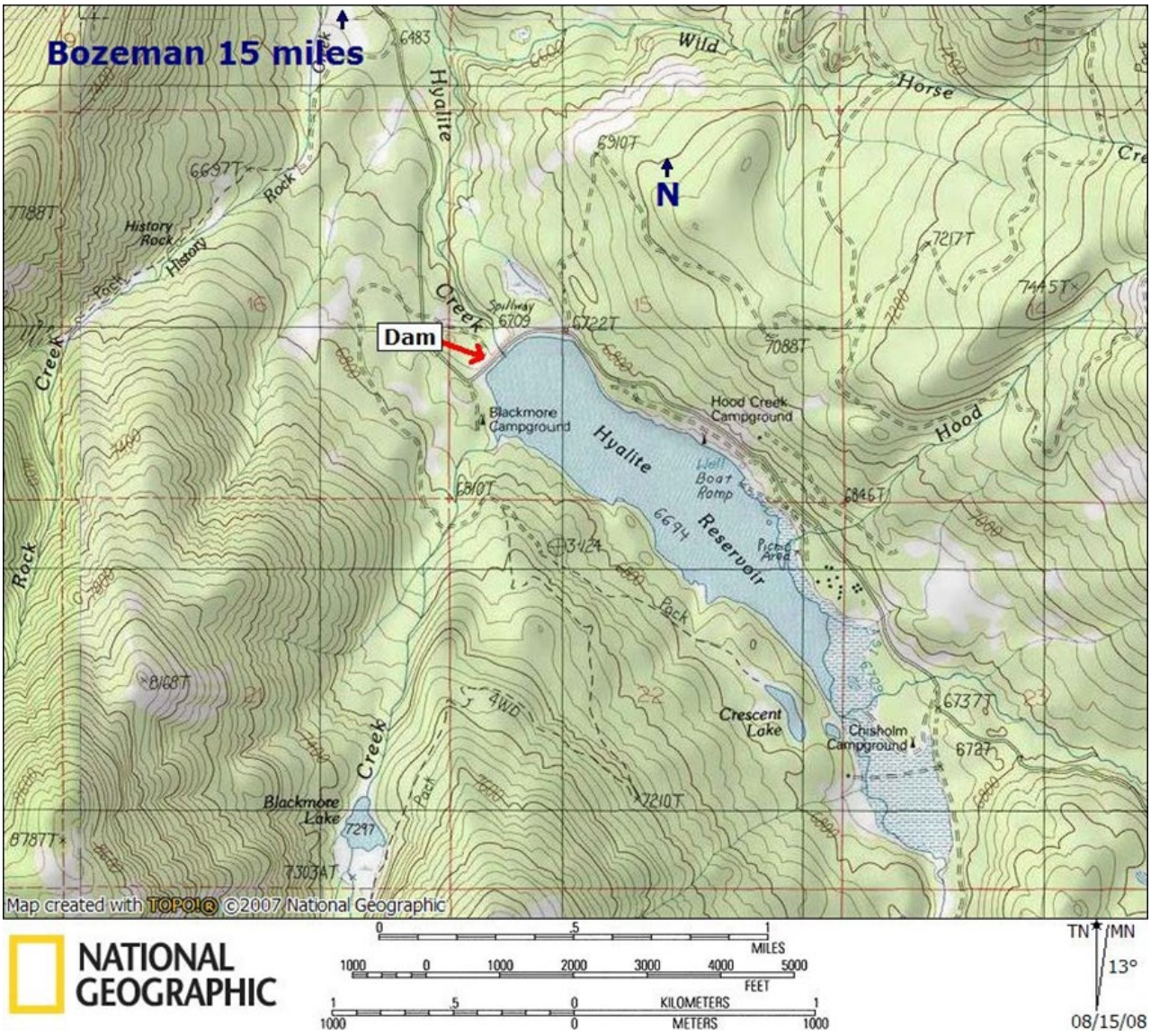
Toe of dam Junction of the upstream or downstream face of an embankment with the ground surface.

Top of dam (crest of dam) Elevation of the uppermost surface of an embankment which can safely impound water behind the dam.

APPENDIX B
B-1: Resources Available

EQUIPMENT-SERVICES CONTACTS	[redacted]	one N	[redacted]
AGENCY / Source of Aircraft			
DNRC	4		
Fixed-wing, helicopters			
Chuck Brenton	4	40	
Tal Williams	4	40	
Scott Bare	4	40	
Hanger	4		
Helena Fire Dispatch	4		
PRIVATE FLYING SERVICES			
Helena			
Exec Air	4		
Fixed-wing / single / twin engine			
John Maxness	4		
Dan Norhton	4		
Fixed-wing /cargo & passenger			
Edwards Jet Service, Inc.	4		
Bozeman			
Central Helicopters Inc	4		
Mark Duffy		40	
Livingston			
Yellowstone Air Service	4		
CONSTRUCTION EQUIPMENT			
Bozeman			
T&E, Cat Rental Store	4		
Sime Construction	4		
Montana Crane Service	4		
Belgrade			
Knife River Corporation	4		
Walker Excavation, Inc.	4		
Three Forks			
BBG Contractors	4		

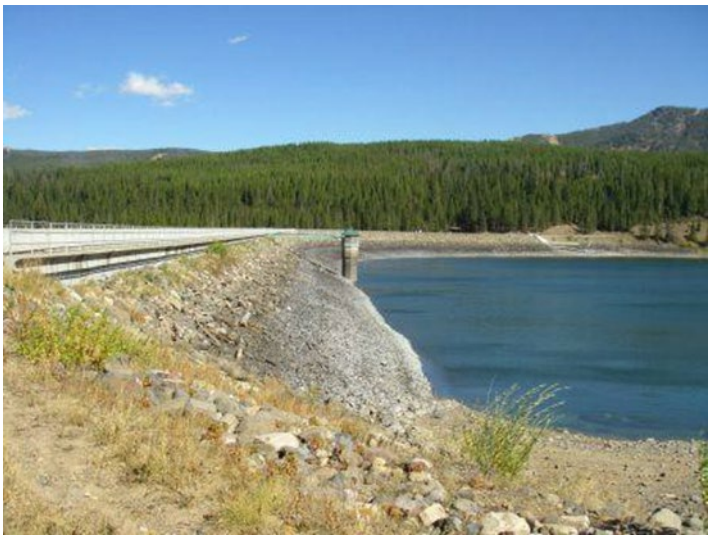
B-2: Location and Vicinity Map



B-3: Project Information

MIDDLE CREEK DAM

PROJECT DESCRIPTION



- Located on Middle Creek in Gallatin County, 15 miles south of Bozeman
- Construction completed in 1951
- Owned by DNRC & managed by SWPB under a U.S. Forest Service Special Use Permit.
- Operated by Middle Creek Water Users Association since 1951
- Project consists of:
  - Earthen dam with mechanically-stabilized earth crest, 125 ft. high & 1,900 ft. long
  - 5-foot diameter, cast in place steel-lined concrete conduit
  - One 54-inch diameter butterfly operating gate and one 54-inch slide guard gate; operated from a tower on the dam crest
  - The principal spillway has a single cycle labyrinth crest inlet and two baffled apron type spillway chutes
  - The auxiliary spillway is earthen with a 530-foot-long concrete crest
- Reservoir stores 10,184 acre-feet at normal full pool, covering 490 surface acres.
- The dam is a "high hazard" structure, which means that its failure could cause loss of life. Farms and ranches, homes, schools, roads, bridges and utilities are in the flood plain.

WATER USE

- Provides irrigation water for 73 farms and ranches and drinking water for 2,000 households (1/3 of the City of Bozeman water supply is provided by the project) through 109 contracts for 10,184 acre-feet of water
- Reservoir is also used for water-based recreation

REHABILITATION SUMMARY

- The dam embankment was raised 8 feet in 1991-1992 as part of a major rehabilitation that included a new spillway, and seepage control measures. Subsequently, the reservoir storage capacity was increased 1,917 acre-feet. Project cost (1992 Dollars): $5,200,000
- An automated instrumentation system was installed in the fall of 2008. The new system improved seepage, drain flow, and reservoir monitoring. Project cost: $122,430
- Gallatin County funded and installed an early warning system in 2010.

FUTURE NEEDS: The project was rehabilitated in 1991-1992 and meets or exceeds current dam safety standards. No deficiencies currently exist.

Downstream face and outlet

Upper spillway baffled drop

Lower spillway baffled drop

APPENDIX C

C-1: Inundation Maps

This section of the Middle Creek Dam Emergency Action Plan includes maps of the approximate areas that would be inundated by the flood resulting from the breach of Middle Creek Dam (Hyalite Creek). The inundated area for the Overtopping Breach is shown with a gradation of blue to violet shading (color varies with depth of flow). Spot data is also provided for various structures within the flooded areas (time of arrival, time to peak elevation, maximum depth and maximum velocity).

Metadata documentation for the Emergency Action Plan Maps is included as Table 6.

The computer model used to estimate the flow, stage, and timing of the breach floods provides a mathematical tool to model and approximate a flood's real-life characteristics. The model has been used to recreate the results of real floods from breached dams with some degree of confidence. However, the results of the model presented here should be viewed as only an approximation of what may occur. Depending on the actual conditions at the time of the flood, more or less area may be flooded, the flood wave may travel faster or slower, and the water depth may vary from that predicted. Therefore, the inundation maps should be used only as a guideline for where and when to evacuate people if Middle Creek Dam (Hyalite Creek) should breach. Officials should caution people neither to cross low-lying areas that may become flooded nor to return to areas that have been evacuated. The flood wave may arrive with sufficient speed and force to destroy bridges and wash vehicles away.

Table 6: Metadata

Identification Information

Map Title:	Middle Creek Dam Breach Analysis Overtopping Inundation Boundary
Geographic Area Covered	From Middle Creek Dam downstream along Hyalite Creek downstream to the West Gallatin River, then to the Missouri River at Trident, Montana (Gallatin County)
Purpose:	Update to previous mapping, using 2D Modeling instead of 1D.
Rules for use	Maps to be used for evacuation orders by local authorities.
Last update date	6/19/2017

Data Quality Information

Engineering model(s) *(Include dates)*	United States Army Corps of Engineers, HEC-RAS 5.0.1, April 2016.
Unit of measure	Imperial, GIS NAD 1983 State Plane MT 2500 (US Feet)
Description of Storm Event (s) *(Include citation of reports used to develop storm events)*	Overtopping breach simulated to coincide with a PMF event. Assumed 100-year event baseflow in Hyalite Creek, 50-year event in West Gallatin & Gallatin Rivers & 25-year event in Missouri River.
Starting reservoir water surface elevation(s)	Spillway Crest: 6721 ft using project datum (and 6725.67 ft using NAVD88 map datum)
Source of cross section data *(USGS topo maps, surveyed data)*	MICROSOFT AND IT'S DATA SUPPLIERS, ESRI, USGS, MT CADASTRAL, MSDI
Accuracy of cross section data *(40 ft contours, survey grade, etc.)*	Where LiDAR was available, elevations are accurate to within 6 inches. Where LiDAR was not available, elevations are accurate to within a 5-meter grid resolution.
Source of reservoir characteristic data *(estimated off USGS topo maps, detailed survey, original design etc.)*	DNRC Reservoir Stage Storage records.
Accuracy of reservoir characteristic data *(rough estimate, detailed survey etc.)*	Original 1939 construction surveys and 1992 HKM survey.
Other engineering assumptions *(range of Manning's n, antecedent conditions, spillway discharge, etc.)*	Overbank Manning's n obtained from 2011 National Land Cover Dataset (NLCD). Channel manning's n obtained from Chow, 1959.
Engineer(s) *(Firm or engineer who completed analysis. Include contact information if appropriate)*	HDR, Ben Fennelly, PE 682 S Ferguson, Ste. 1 Bozeman, MT 59718 Ph 406.577.5019
Location of data, reports, model runs	Saved on DNRC, SWP Bureau Server
Modification(s) *(Summary of modifications to maps, include dates and who made modifications)*	None to date

Spatial Data Organization Information and Spatial Reference

(if maps are in a GIS database, cite location of database and organization that maintains the database. If maps are not in a GIS, leave this section blank)

Inundation maps of the Overtopping Breach scenario were developed by HDR using ESRI ArcMap 10.4.1 to display the depth grid of the Overtopping Breach produced by RAS Mapper. The basemap of the inundation maps is a cached ESRI Basemap service and is cited as 2015 NAIP imagery courtesy of the USDA. The panel index and 8 panel maps in pdf format were made from the above ArcMAP file.

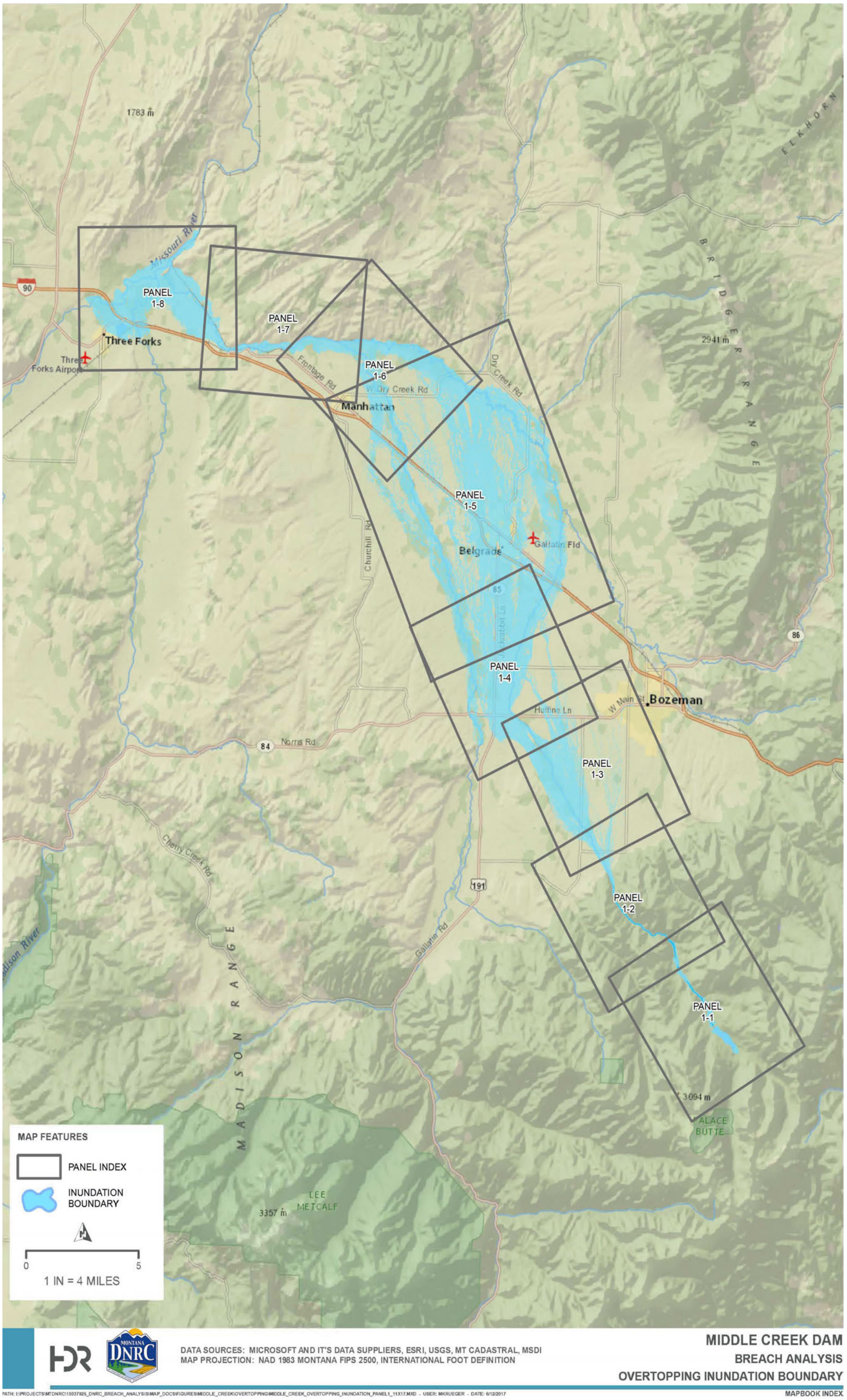
Entity and Attribute Information

(describe units and Reference for measurement)

Channel distance	Dam on Hyalite Creek (south of Bozeman, MT) downstream to Trident, MT Units = Miles Starting Point = Middle Creek Dam Ending Point = Missouri River at Trident, MT Approximately 71.4 miles
Flow	ft^3/s (CFS)
Wave height	Feet
Travel time initial	Hours
Travel time peak	Hours
Velocity	ft/s
Other	Within the maps, various cross sections and points of interest were identified highlighting effects on possible routes of transportation, impacted communities, and emergency management services. At these locations, the maximum discharge, maximum depth, maximum water surface elevation, time of arrival, and time to peak are listed.

Distribution Information

Contact Information:	DNRC Sanna Yost, PE Ph: 406-444-6665 Email: syost@mt.gov	HDR Ben Fennelly, PE Ph: 406-577-5019 Email: Benjamin.Fennelly@hdrinc.com
Available Formats:	Inundation Maps = PDF Format *all information used to create the PDF's are in ArcGIS shapefile format	
Disclaimer:	Due to the method, procedures, and assumptions used to develop the flooded areas, the limits of the flooding shown in the inundation mapping are approximate. Actual areas inundated will depend on actual failure conditions and may differ from the areas shown on the map.	


1783 m
Missouri River
90
PANEL 1-8
PANEL 1-7
PANEL 1-6
PANEL 1-5
PANEL 1-4
PANEL 1-3
PANEL 1-2
PANEL 1-1
Three Forks
Three Forks Airport
Frontage Rd
W Dry Creek Rd
Manhattan
Dry Creek Rd
2941 m
BRIDGER RANGE
ELKHORN
Churchill Rd
Belgrade
Gallatin Fld
85
Churchill Ln
86
W Main St
Bozeman
Hulfine Ln
84
Norris Rd
Cherry Creek Rd
191
Gallatin Rd
MADISON RANGE
Madison River
3094 m
PALACE BUTTE
3357 m
LEE METCALF
MAP FEATURES
PANEL INDEX
INUNDATION BOUNDARY
0
5
1 IN = 4 MILES
DATA SOURCES: MICROSOFT AND IT'S DATA SUPPLIERS, ESRI, USGS, MT CADASTRAL, MSDI
MAP PROJECTION: NAD 1983 MONTANA FIPS 2500, INTERNATIONAL FOOT DEFINITION
MIDDLE CREEK DAM
BREACH ANALYSIS
OVERTOPPING INUNDATION BOUNDARY
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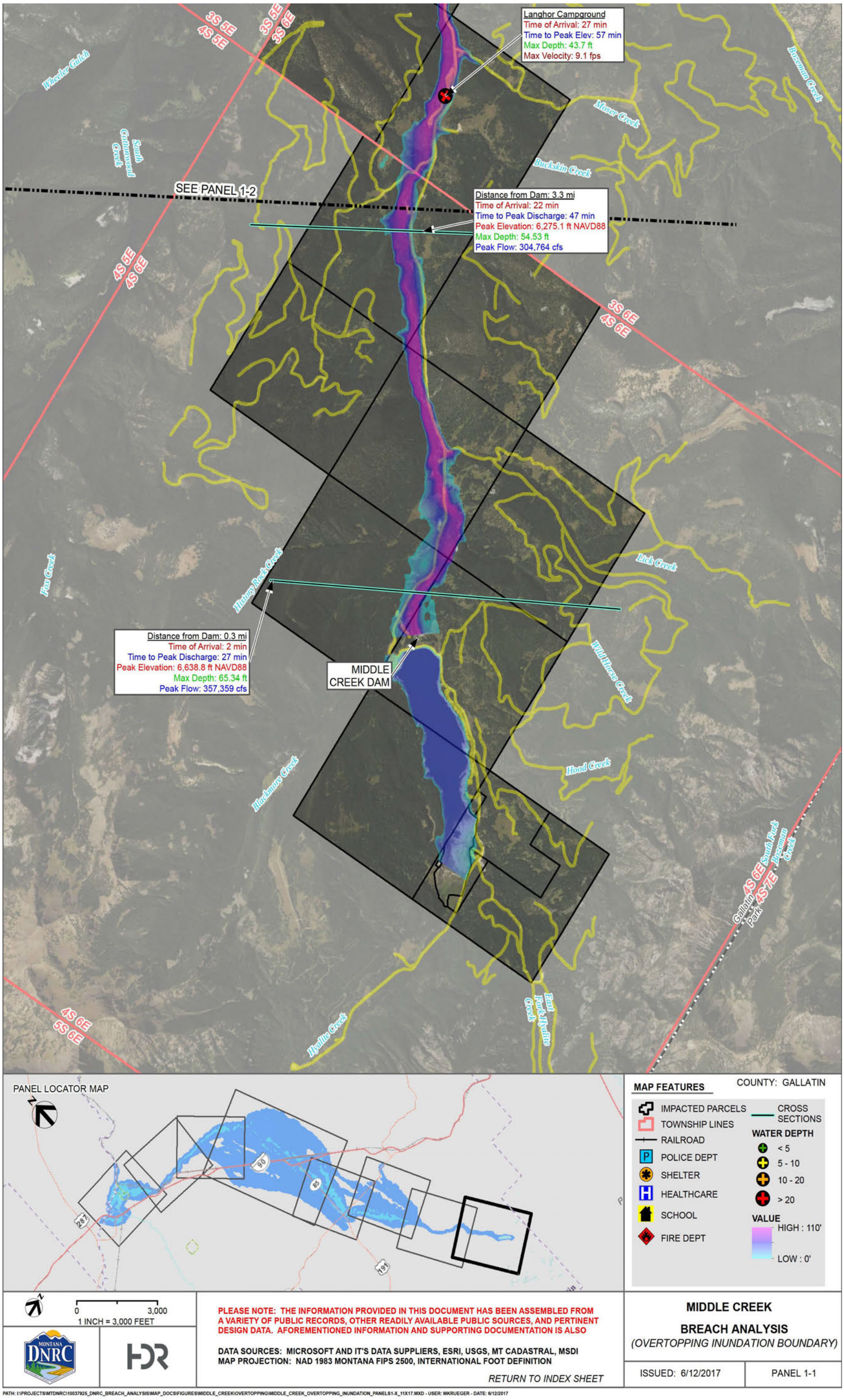
Langhor Campground
Time of Arrival: 27 min
Time to Peak Elev: 57 min
Max Depth: 43.7 ft
Max Velocity: 9.1 fps
SEE PANEL 1-2
Distance from Dam: 3.3 mi
Time of Arrival: 22 min
Time to Peak Discharge: 47 min
Peak Elevation: 6,275.1 ft NAVD88
Max Depth: 54.53 ft
Peak Flow: 304,764 cfs
Distance from Dam: 0.3 mi
Time of Arrival: 2 min
Time to Peak Discharge: 27 min
Peak Elevation: 6,638.8 ft NAVD88
Max Depth: 65.34 ft
Peak Flow: 357,359 cfs
MIDDLE CREEK DAM
Wheeler Gulch
South Cottonwood Creek
Moser Creek
Buckskin Creek
Bozeman Creek
Fox Creek
History Rock Creek
Lick Creek
Wild Horse Creek
Hood Creek
Blackmore Creek
Hyalite Creek
East Fork Hyalite Creek
South Fork Bozeman Creek
3S 5E
4S 5E
3S 6E
4S 6E
5S 6E
4S 7E
Gallatin Park
PANEL LOCATOR MAP
MAP FEATURES
COUNTY: GALLATIN
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
HIGH : 110'
LOW : 0'
0
3,000
1 INCH = 3,000 FEET
PLEASE NOTE: THE INFORMATION PROVIDED IN THIS DOCUMENT HAS BEEN ASSEMBLED FROM A VARIETY OF PUBLIC RECORDS, OTHER READILY AVAILABLE PUBLIC SOURCES, AND PERTINENT DESIGN DATA. AFOREMENTIONED INFORMATION AND SUPPORTING DOCUMENTATION IS ALSO
DATA SOURCES: MICROSOFT AND IT'S DATA SUPPLIERS, ESRI, USGS, MT CADASTRAL, MSDI
MAP PROJECTION: NAD 1983 MONTANA FIPS 2500, INTERNATIONAL FOOT DEFINITION
RETURN TO INDEX SHEET
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BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
ISSUED: 6/12/2017
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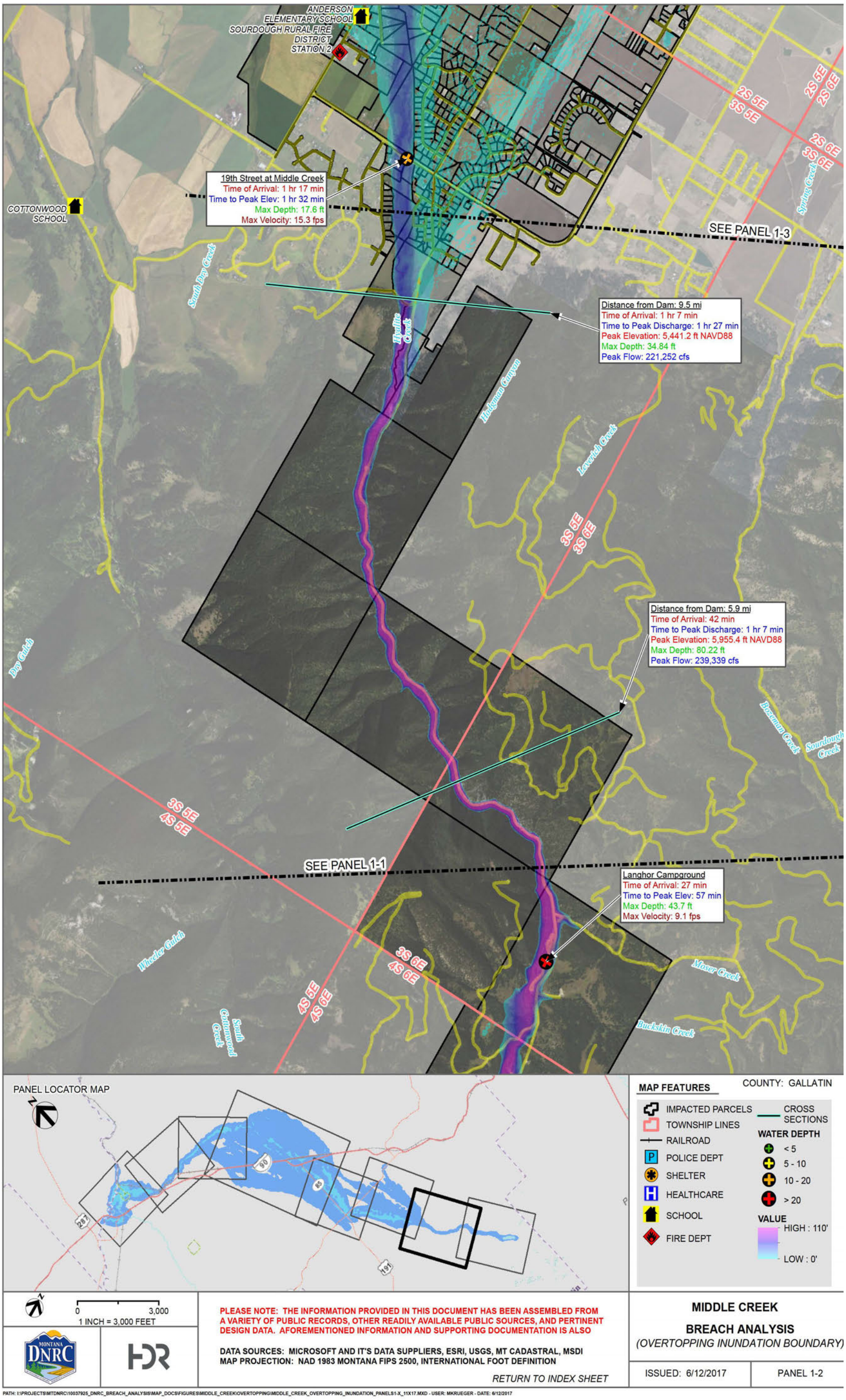
ANDERSON ELEMENTARY SCHOOL
SOURDOUGH RURAL FIRE DISTRICT STATION 2
COTTONWOOD SCHOOL
19th Street at Middle Creek
Time of Arrival: 1 hr 17 min
Time to Peak Elev: 1 hr 32 min
Max Depth: 17.6 ft
Max Velocity: 15.3 fps
SEE PANEL 1-3
Distance from Dam: 9.5 mi
Time of Arrival: 1 hr 7 min
Time to Peak Discharge: 1 hr 27 min
Peak Elevation: 5,441.2 ft NAVD88
Max Depth: 34.84 ft
Peak Flow: 221,252 cfs
Distance from Dam: 5.9 mi
Time of Arrival: 42 min
Time to Peak Discharge: 1 hr 7 min
Peak Elevation: 5,955.4 ft NAVD88
Max Depth: 80.22 ft
Peak Flow: 239,339 cfs
SEE PANEL 1-1
Langhor Campground
Time of Arrival: 27 min
Time to Peak Elev: 57 min
Max Depth: 43.7 ft
Max Velocity: 9.1 fps
South Day Creek
Hyalite Creek
Hodgman Canyon
Leverich Creek
Spring Creek
Day Gulch
Bozeman Creek
Sourdough Creek
Wheeler Gulch
South Cottonwood Creek
Moser Creek
Buckskin Creek
2S 5E
3S 5E
2S 6E
3S 6E
4S 5E
4S 6E
PANEL LOCATOR MAP
MAP FEATURES
COUNTY: GALLATIN
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
HIGH : 110'
LOW : 0'
0
3,000
1 INCH = 3,000 FEET
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MIDDLE CREEK
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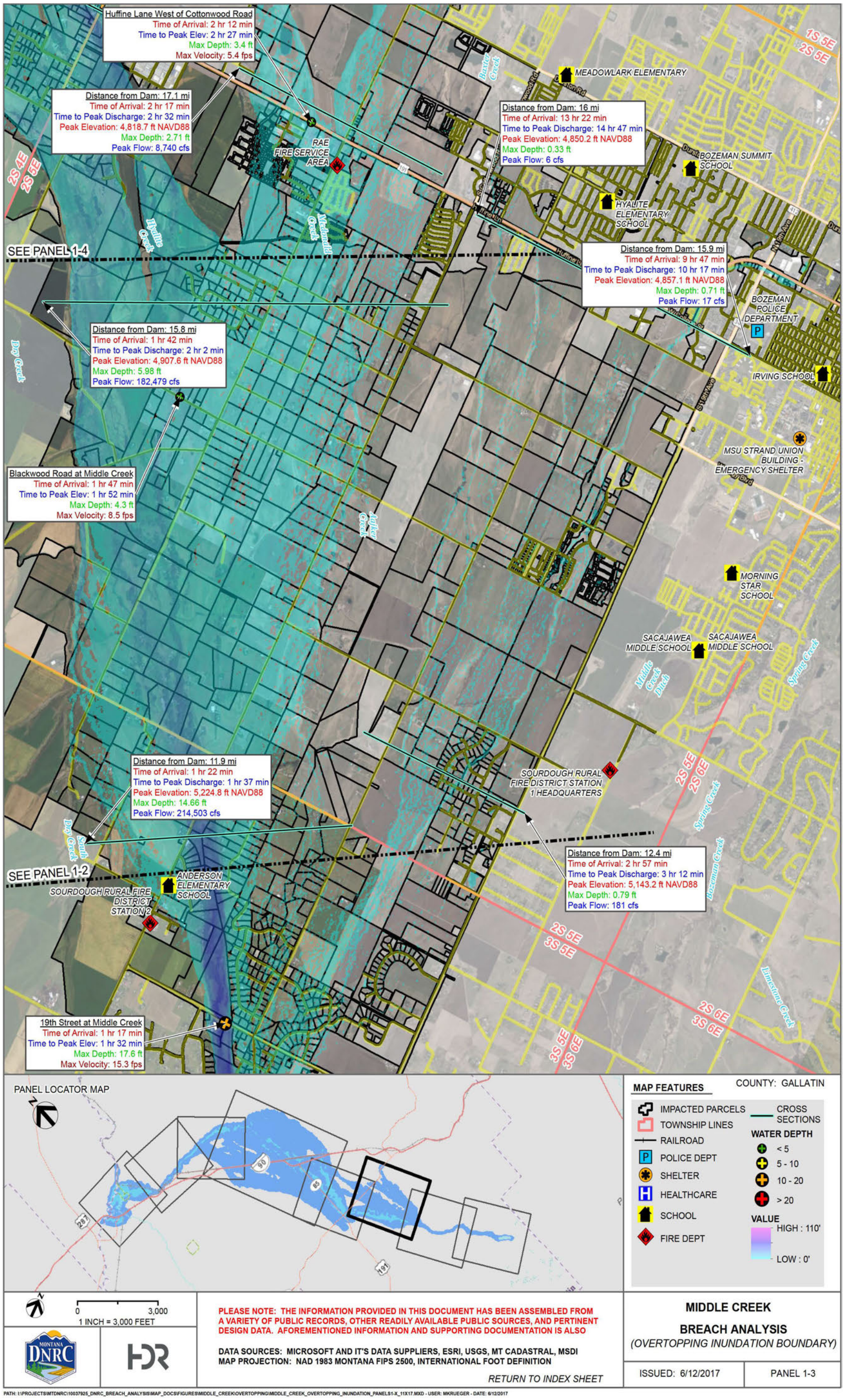
Huffine Lane West of Cottonwood Road
Time of Arrival: 2 hr 12 min
Time to Peak Elev: 2 hr 27 min
Max Depth: 3.4 ft
Max Velocity: 5.4 fps
Distance from Dam: 17.1 mi
Time of Arrival: 2 hr 17 min
Time to Peak Discharge: 2 hr 32 min
Peak Elevation: 4,818.7 ft NAVD88
Max Depth: 2.71 ft
Peak Flow: 8,740 cfs
Distance from Dam: 16 mi
Time of Arrival: 13 hr 22 min
Time to Peak Discharge: 14 hr 47 min
Peak Elevation: 4,850.2 ft NAVD88
Max Depth: 0.33 ft
Peak Flow: 6 cfs
Distance from Dam: 15.9 mi
Time of Arrival: 9 hr 47 min
Time to Peak Discharge: 10 hr 17 min
Peak Elevation: 4,857.1 ft NAVD88
Max Depth: 0.71 ft
Peak Flow: 17 cfs
Distance from Dam: 15.8 mi
Time of Arrival: 1 hr 42 min
Time to Peak Discharge: 2 hr 2 min
Peak Elevation: 4,907.6 ft NAVD88
Max Depth: 5.98 ft
Peak Flow: 182,479 cfs
Blackwood Road at Middle Creek
Time of Arrival: 1 hr 47 min
Time to Peak Elev: 1 hr 52 min
Max Depth: 4.3 ft
Max Velocity: 8.5 fps
Distance from Dam: 11.9 mi
Time of Arrival: 1 hr 22 min
Time to Peak Discharge: 1 hr 37 min
Peak Elevation: 5,224.8 ft NAVD88
Max Depth: 14.66 ft
Peak Flow: 214,503 cfs
Distance from Dam: 12.4 mi
Time of Arrival: 2 hr 57 min
Time to Peak Discharge: 3 hr 12 min
Peak Elevation: 5,143.2 ft NAVD88
Max Depth: 0.79 ft
Peak Flow: 181 cfs
19th Street at Middle Creek
Time of Arrival: 1 hr 17 min
Time to Peak Elev: 1 hr 32 min
Max Depth: 17.6 ft
Max Velocity: 15.3 fps
SEE PANEL 1-4
SEE PANEL 1-2
MEADOWLARK ELEMENTARY
BOZEMAN SUMMIT SCHOOL
HYALITE ELEMENTARY SCHOOL
RAE FIRE SERVICE AREA
BOZEMAN POLICE DEPARTMENT
IRVING SCHOOL
MSU STRAND UNION BUILDING - EMERGENCY SHELTER
MORNING STAR SCHOOL
SACAJAWEA MIDDLE SCHOOL
SACAJAWEA MIDDLE SCHOOL
SOURDOUGH RURAL FIRE DISTRICT STATION 1 HEADQUARTERS
ANDERSON ELEMENTARY SCHOOL
SOURDOUGH RURAL FIRE DISTRICT STATION 2
Baxter Creek
Hyalite Creek
Mcdonald Creek
Dry Creek
Dry Creek South
Ayler Creek
Middle Creek Ditch
Spring Creek
Bozeman Creek
Limestone Creek
1S 5E
2S 5E
2S 4E
2S 5E
2S 6E
3S 5E
3S 6E
PANEL LOCATOR MAP
MAP FEATURES
COUNTY: GALLATIN
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
HIGH : 110'
LOW : 0'
0
3,000
1 INCH = 3,000 FEET
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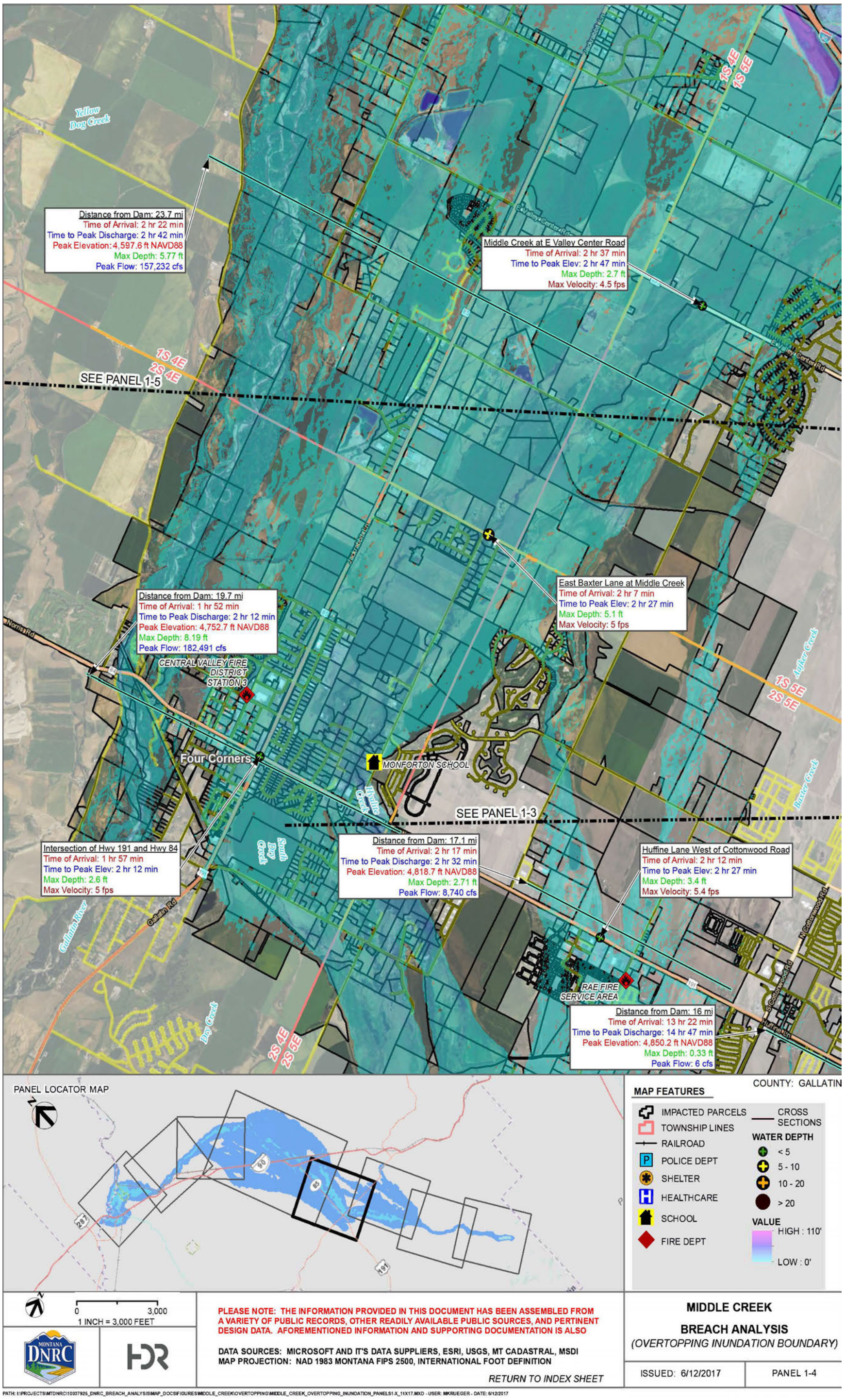
MAP PROJECTION: NAD 1983 MONTANA FIPS 2500, INTERNATIONAL FOOT DEFINITION
RETURN TO INDEX SHEET
MIDDLE CREEK
BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
ISSUED: 6/12/2017
PANEL 1-3
PATH: I:\PROJECTS\MTDNRC\10037925_DNRC_BREACH_ANALYSIS\MAP_DOCS\FIGURES\MIDDLE_CREEK\OVERTOPPING\MIDDLE_CREEK_OVERTOPPING_INUNDATION_PANELS1-X_11X17.MXD - USER: MKRUEGER - DATE: 6/12/2017


Yellow Dog Creek
Distance from Dam: 23.7 mi
Time of Arrival: 2 hr 22 min
Time to Peak Discharge: 2 hr 42 min
Peak Elevation: 4,597.6 ft NAVD88
Max Depth: 5.77 ft
Peak Flow: 157,232 cfs
Middle Creek at E Valley Center Road
Time of Arrival: 2 hr 37 min
Time to Peak Elev: 2 hr 47 min
Max Depth: 2.7 ft
Max Velocity: 4.5 fps
1S 4E
1S 5E
2S 4E
SEE PANEL 1-5
Distance from Dam: 19.7 mi
Time of Arrival: 1 hr 52 min
Time to Peak Discharge: 2 hr 12 min
Peak Elevation: 4,752.7 ft NAVD88
Max Depth: 8.19 ft
Peak Flow: 182,491 cfs
East Baxter Lane at Middle Creek
Time of Arrival: 2 hr 7 min
Time to Peak Elev: 2 hr 27 min
Max Depth: 5.1 ft
Max Velocity: 5 fps
CENTRAL VALLEY FIRE DISTRICT STATION 3
Four Corners
MONFORTON SCHOOL
Hyalite Creek
Aajker Creek
Baxter Creek
SEE PANEL 1-3
Intersection of Hwy 191 and Hwy 84
Time of Arrival: 1 hr 57 min
Time to Peak Elev: 2 hr 12 min
Max Depth: 2.6 ft
Max Velocity: 5 fps
Distance from Dam: 17.1 mi
Time of Arrival: 2 hr 17 min
Time to Peak Discharge: 2 hr 32 min
Peak Elevation: 4,818.7 ft NAVD88
Max Depth: 2.71 ft
Peak Flow: 8,740 cfs
Huffine Lane West of Cottonwood Road
Time of Arrival: 2 hr 12 min
Time to Peak Elev: 2 hr 27 min
Max Depth: 3.4 ft
Max Velocity: 5.4 fps
Gallatin River
Dry Creek
RAE FIRE SERVICE AREA
Distance from Dam: 16 mi
Time of Arrival: 13 hr 22 min
Time to Peak Discharge: 14 hr 47 min
Peak Elevation: 4,850.2 ft NAVD88
Max Depth: 0.33 ft
Peak Flow: 6 cfs
2S 5E
PANEL LOCATOR MAP
COUNTY: GALLATIN
MAP FEATURES
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
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0
3,000
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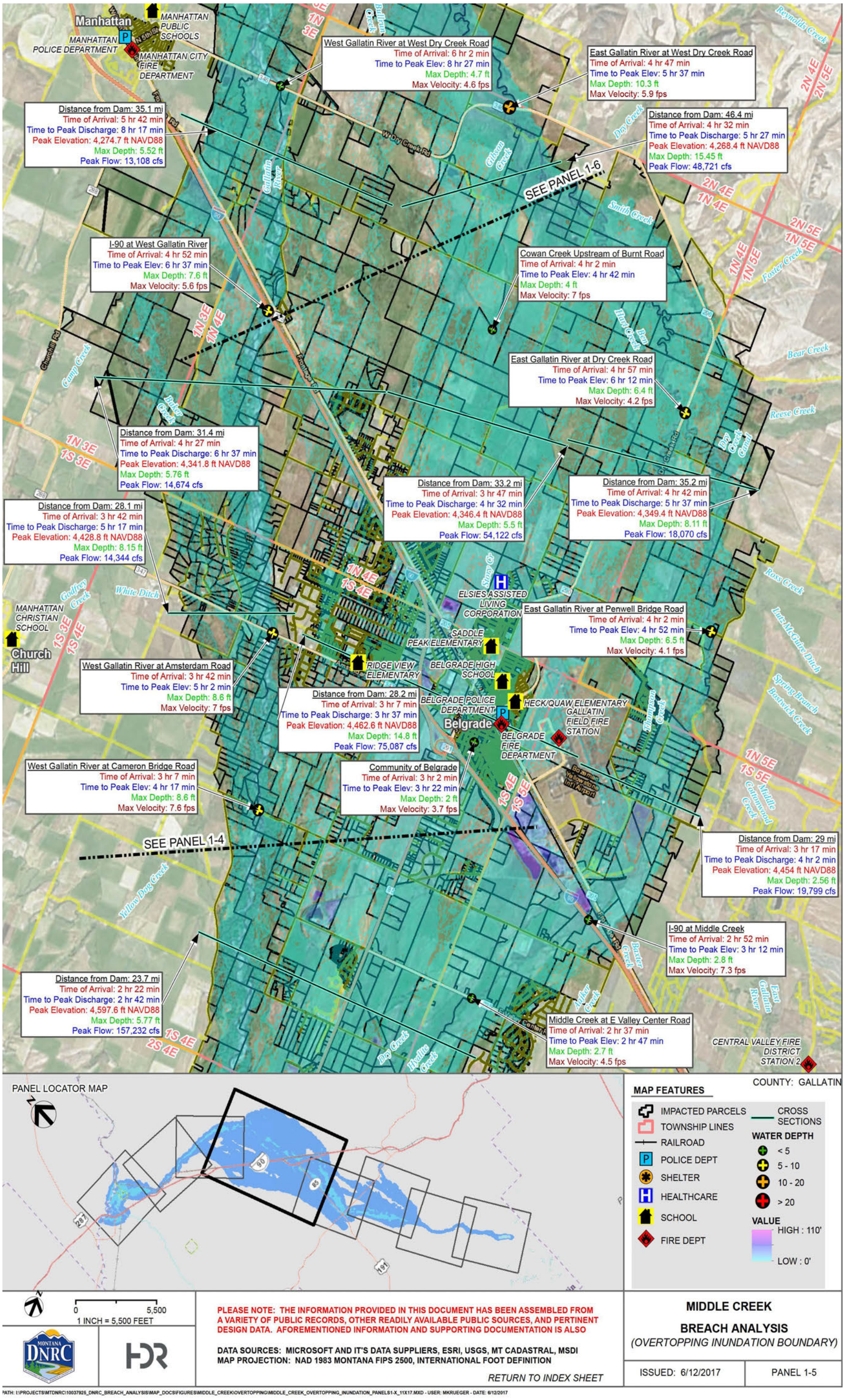
MIDDLE CREEK
BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
ISSUED: 6/12/2017
PANEL 1-4
PATH: I:\PROJECTS\MTDNRC\10037925_DNRC_BREACH_ANALYSIS\MAP_DOCS\FIGURES\MIDDLE_CREEK\OVERTOPPING\MIDDLE_CREEK_OVERTOPPING_INUNDATION_PANELS1-X_11X17.MXD - USER: MKRUEGER - DATE: 6/12/2017


Manhattan
MANHATTAN PUBLIC SCHOOLS
MANHATTAN POLICE DEPARTMENT
MANHATTAN CITY FIRE DEPARTMENT
West Gallatin River at West Dry Creek Road
Time of Arrival: 6 hr 2 min
Time to Peak Elev: 8 hr 27 min
Max Depth: 4.7 ft
Max Velocity: 4.6 fps
East Gallatin River at West Dry Creek Road
Time of Arrival: 4 hr 47 min
Time to Peak Elev: 5 hr 37 min
Max Depth: 10.3 ft
Max Velocity: 5.9 fps
Distance from Dam: 35.1 mi
Time of Arrival: 5 hr 42 min
Time to Peak Discharge: 8 hr 17 min
Peak Elevation: 4,274.7 ft NAVD88
Max Depth: 5.52 ft
Peak Flow: 13,108 cfs
Distance from Dam: 46.4 mi
Time of Arrival: 4 hr 32 min
Time to Peak Discharge: 5 hr 27 min
Peak Elevation: 4,268.4 ft NAVD88
Max Depth: 15.45 ft
Peak Flow: 48,721 cfs
SEE PANEL 1-6
I-90 at West Gallatin River
Time of Arrival: 4 hr 52 min
Time to Peak Elev: 6 hr 37 min
Max Depth: 7.6 ft
Max Velocity: 5.6 fps
Cowan Creek Upstream of Burnt Road
Time of Arrival: 4 hr 2 min
Time to Peak Elev: 4 hr 42 min
Max Depth: 4 ft
Max Velocity: 7 fps
East Gallatin River at Dry Creek Road
Time of Arrival: 4 hr 57 min
Time to Peak Elev: 6 hr 12 min
Max Depth: 6.4 ft
Max Velocity: 4.2 fps
Distance from Dam: 31.4 mi
Time of Arrival: 4 hr 27 min
Time to Peak Discharge: 6 hr 37 min
Peak Elevation: 4,341.8 ft NAVD88
Max Depth: 5.76 ft
Peak Flow: 14,674 cfs
Distance from Dam: 33.2 mi
Time of Arrival: 3 hr 47 min
Time to Peak Discharge: 4 hr 32 min
Peak Elevation: 4,346.4 ft NAVD88
Max Depth: 5.5 ft
Peak Flow: 54,122 cfs
Distance from Dam: 35.2 mi
Time of Arrival: 4 hr 42 min
Time to Peak Discharge: 5 hr 37 min
Peak Elevation: 4,349.4 ft NAVD88
Max Depth: 8.11 ft
Peak Flow: 18,070 cfs
Distance from Dam: 28.1 mi
Time of Arrival: 3 hr 42 min
Time to Peak Discharge: 5 hr 17 min
Peak Elevation: 4,428.8 ft NAVD88
Max Depth: 8.15 ft
Peak Flow: 14,344 cfs
ELSIES ASSISTED LIVING CORPORATION
East Gallatin River at Penwell Bridge Road
Time of Arrival: 4 hr 2 min
Time to Peak Elev: 4 hr 52 min
Max Depth: 6.5 ft
Max Velocity: 4.1 fps
MANHATTAN CHRISTIAN SCHOOL
Church Hill
SADDLE PEAK ELEMENTARY
RIDGE VIEW ELEMENTARY
BELGRADE HIGH SCHOOL
West Gallatin River at Amsterdam Road
Time of Arrival: 3 hr 42 min
Time to Peak Elev: 5 hr 2 min
Max Depth: 8.6 ft
Max Velocity: 7 fps
Distance from Dam: 28.2 mi
Time of Arrival: 3 hr 7 min
Time to Peak Discharge: 3 hr 37 min
Peak Elevation: 4,462.6 ft NAVD88
Max Depth: 14.8 ft
Peak Flow: 75,087 cfs
BELGRADE POLICE DEPARTMENT
Belgrade
HECK/QUAW ELEMENTARY
GALLATIN FIELD FIRE STATION
BELGRADE FIRE DEPARTMENT
West Gallatin River at Cameron Bridge Road
Time of Arrival: 3 hr 7 min
Time to Peak Elev: 4 hr 17 min
Max Depth: 8.6 ft
Max Velocity: 7.6 fps
Community of Belgrade
Time of Arrival: 3 hr 2 min
Time to Peak Elev: 3 hr 22 min
Max Depth: 2 ft
Max Velocity: 3.7 fps
SEE PANEL 1-4
Distance from Dam: 29 mi
Time of Arrival: 3 hr 17 min
Time to Peak Discharge: 4 hr 2 min
Peak Elevation: 4,454 ft NAVD88
Max Depth: 2.56 ft
Peak Flow: 19,799 cfs
I-90 at Middle Creek
Time of Arrival: 2 hr 52 min
Time to Peak Elev: 3 hr 12 min
Max Depth: 2.8 ft
Max Velocity: 7.3 fps
Distance from Dam: 23.7 mi
Time of Arrival: 2 hr 22 min
Time to Peak Discharge: 2 hr 42 min
Peak Elevation: 4,597.6 ft NAVD88
Max Depth: 5.77 ft
Peak Flow: 157,232 cfs
Middle Creek at E Valley Center Road
Time of Arrival: 2 hr 37 min
Time to Peak Elev: 2 hr 47 min
Max Depth: 2.7 ft
Max Velocity: 4.5 fps
CENTRAL VALLEY FIRE DISTRICT STATION 2
PANEL LOCATOR MAP
COUNTY: GALLATIN
MAP FEATURES
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
HIGH : 110'
LOW : 0'
0
5,500
1 INCH = 5,500 FEET
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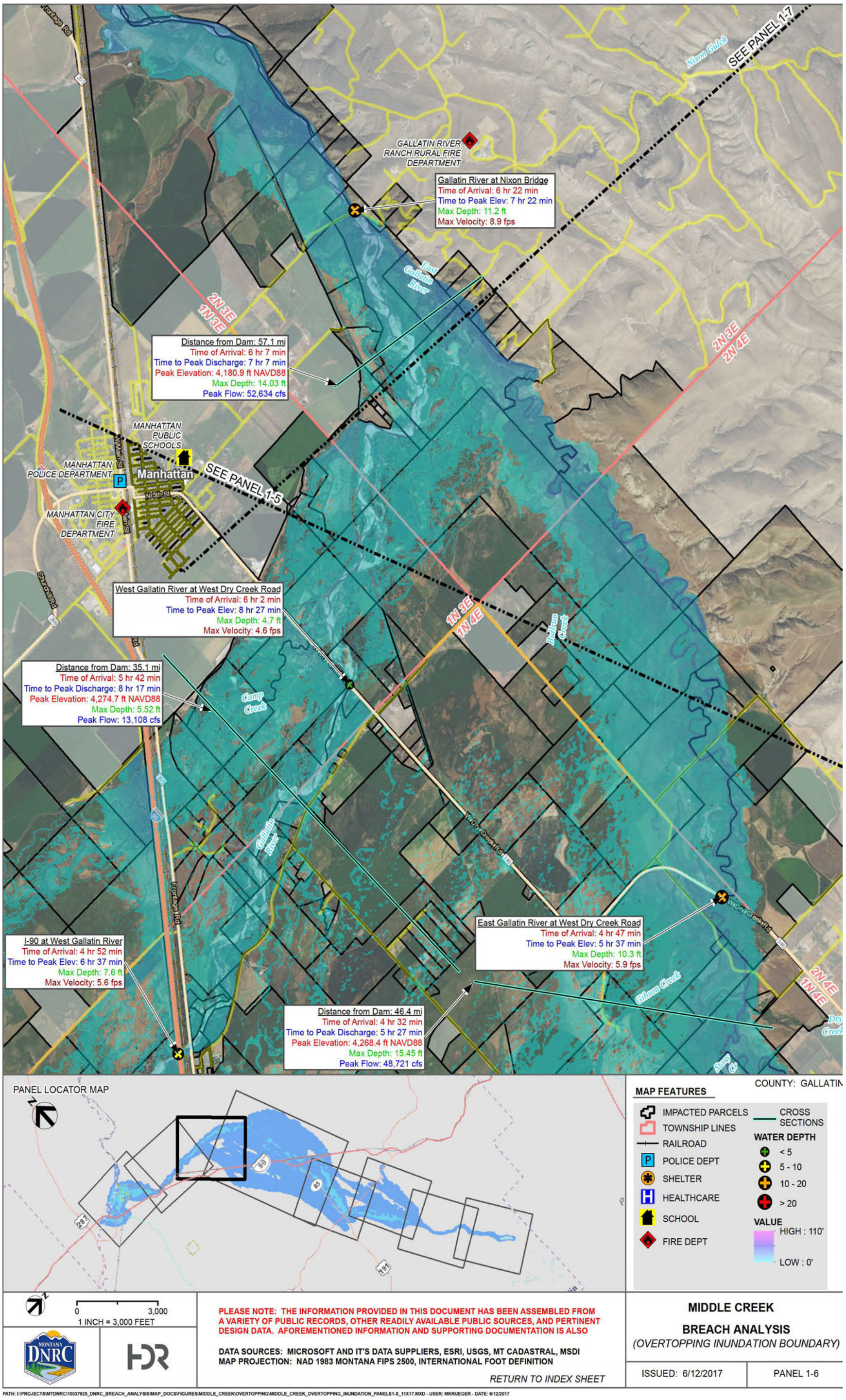
MAP PROJECTION: NAD 1983 MONTANA FIPS 2500, INTERNATIONAL FOOT DEFINITION
RETURN TO INDEX SHEET
MIDDLE CREEK
BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
ISSUED: 6/12/2017
PANEL 1-5
PATH: I:\PROJECTS\MTDNRC\10037925_DNRC_BREACH_ANALYSIS\MAP_DOCS\FIGURES\MIDDLE_CREEK\OVERTOPPING\MIDDLE_CREEK_OVERTOPPING_INUNDATION_PANELS1-X_11X17.MXD - USER: MKRUEGER - DATE: 6/12/2017


SEE PANEL 1-7
Nixon Gulch
GALLATIN RIVER RANCH RURAL FIRE DEPARTMENT
Gallatin River at Nixon Bridge
Time of Arrival: 6 hr 22 min
Time to Peak Elev: 7 hr 22 min
Max Depth: 11.2 ft
Max Velocity: 8.9 fps
East Gallatin River
2N 3E
1N 3E
2N 3E
2N 4E
Distance from Dam: 57.1 mi
Time of Arrival: 6 hr 7 min
Time to Peak Discharge: 7 hr 7 min
Peak Elevation: 4,180.9 ft NAVD88
Max Depth: 14.03 ft
Peak Flow: 52,634 cfs
MANHATTAN PUBLIC SCHOOLS
MANHATTAN POLICE DEPARTMENT
Manhattan
SEE PANEL 1-5
N 5th St
MANHATTAN CITY FIRE DEPARTMENT
W Main St
Churchill Rd
Frontage Rd
West Gallatin River at West Dry Creek Road
Time of Arrival: 6 hr 2 min
Time to Peak Elev: 8 hr 27 min
Max Depth: 4.7 ft
Max Velocity: 4.6 fps
1N 3E
1N 4E
Bullrun Creek
Distance from Dam: 35.1 mi
Time of Arrival: 5 hr 42 min
Time to Peak Discharge: 8 hr 17 min
Peak Elevation: 4,274.7 ft NAVD88
Max Depth: 5.52 ft
Peak Flow: 13,108 cfs
Camp Creek
Gallatin River
W Dry Creek Rd
I-90 at West Gallatin River
Time of Arrival: 4 hr 52 min
Time to Peak Elev: 6 hr 37 min
Max Depth: 7.6 ft
Max Velocity: 5.6 fps
East Gallatin River at West Dry Creek Road
Time of Arrival: 4 hr 47 min
Time to Peak Elev: 5 hr 37 min
Max Depth: 10.3 ft
Max Velocity: 5.9 fps
Gibson Creek
2N 4E
1N 4E
Distance from Dam: 46.4 mi
Time of Arrival: 4 hr 32 min
Time to Peak Discharge: 5 hr 27 min
Peak Elevation: 4,268.4 ft NAVD88
Max Depth: 15.45 ft
Peak Flow: 48,721 cfs
PANEL LOCATOR MAP
90
65
287
191
COUNTY: GALLATIN
MAP FEATURES
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
HIGH : 110'
LOW : 0'
0
3,000
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RETURN TO INDEX SHEET
MIDDLE CREEK
BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
ISSUED: 6/12/2017
PANEL 1-6
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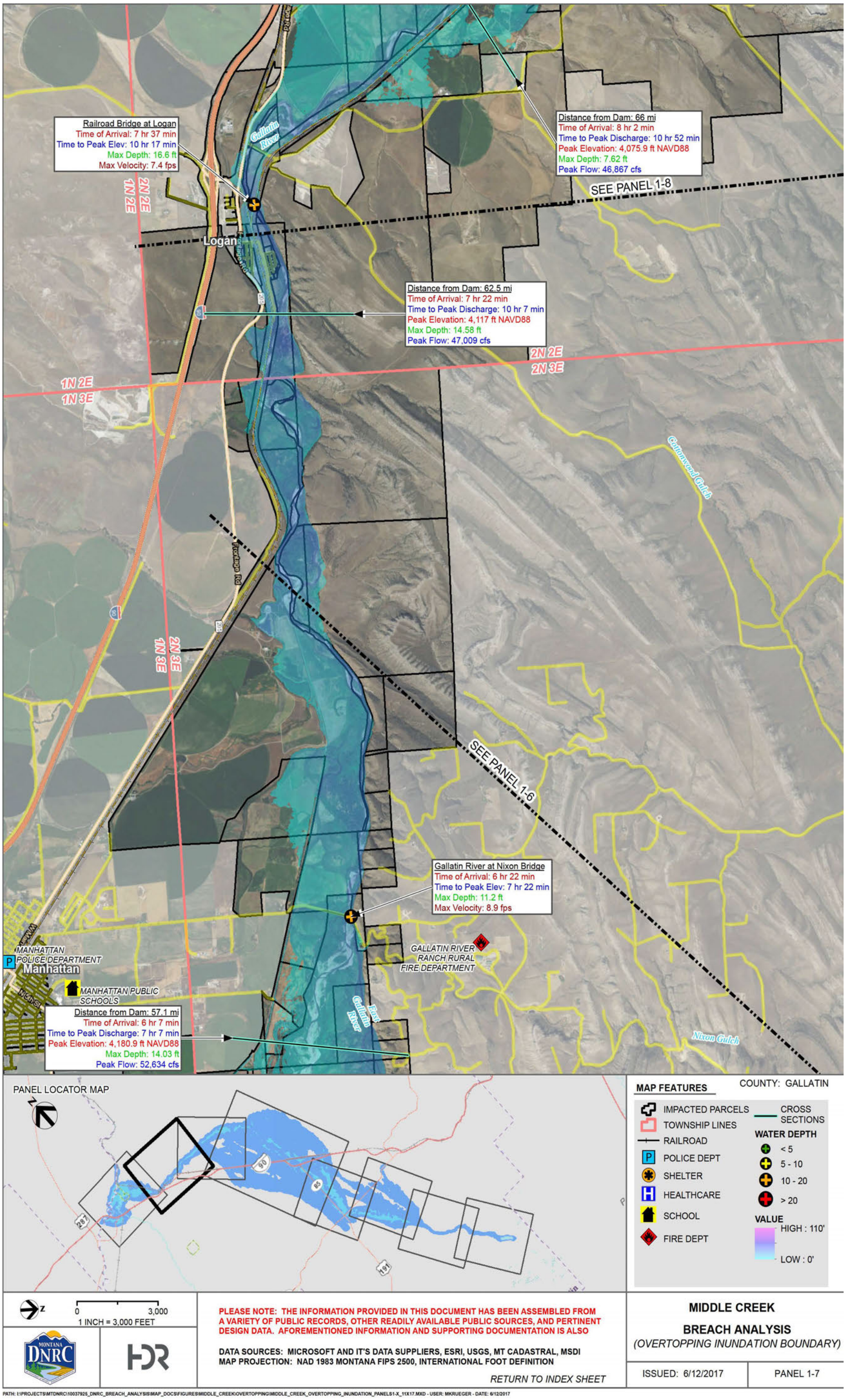
Railroad Bridge at Logan
Time of Arrival: 7 hr 37 min
Time to Peak Elev: 10 hr 17 min
Max Depth: 16.6 ft
Max Velocity: 7.4 fps
Distance from Dam: 66 mi
Time of Arrival: 8 hr 2 min
Time to Peak Discharge: 10 hr 52 min
Peak Elevation: 4,075.9 ft NAVD88
Max Depth: 7.62 ft
Peak Flow: 46,867 cfs
Distance from Dam: 62.5 mi
Time of Arrival: 7 hr 22 min
Time to Peak Discharge: 10 hr 7 min
Peak Elevation: 4,117 ft NAVD88
Max Depth: 14.58 ft
Peak Flow: 47,009 cfs
Gallatin River at Nixon Bridge
Time of Arrival: 6 hr 22 min
Time to Peak Elev: 7 hr 22 min
Max Depth: 11.2 ft
Max Velocity: 8.9 fps
Distance from Dam: 57.1 mi
Time of Arrival: 6 hr 7 min
Time to Peak Discharge: 7 hr 7 min
Peak Elevation: 4,180.9 ft NAVD88
Max Depth: 14.03 ft
Peak Flow: 52,634 cfs
SEE PANEL 1-8
SEE PANEL 1-6
Logan
Gallatin River
Frontage Rd
Cottonwood Gulch
Nixon Gulch
East Gallatin River
1N 2E
2N 2E
2N 3E
1N 3E
MANHATTAN POLICE DEPARTMENT
Manhattan
MANHATTAN PUBLIC SCHOOLS
GALLATIN RIVER RANCH RURAL FIRE DEPARTMENT
PANEL LOCATOR MAP
MAP FEATURES
COUNTY: GALLATIN
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
HIGH : 110'
LOW : 0'
0
3,000
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MAP PROJECTION: NAD 1983 MONTANA FIPS 2500, INTERNATIONAL FOOT DEFINITION
RETURN TO INDEX SHEET
MIDDLE CREEK
BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
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PANEL 1-7
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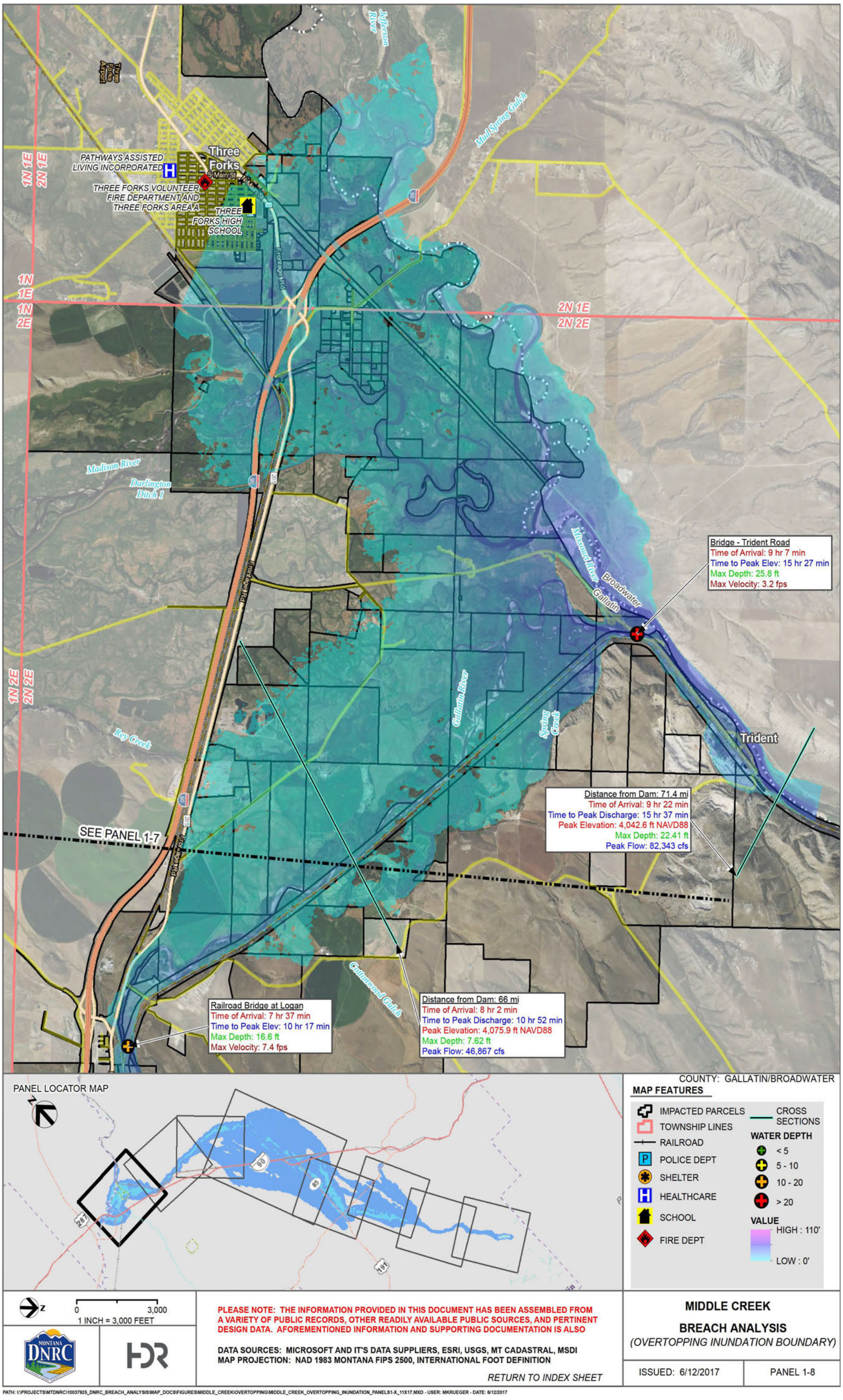
Three Forks Airport
Jefferson River
Mud Spring Gulch
PATHWAYS ASSISTED LIVING INCORPORATED
Three Forks
S Main St
THREE FORKS VOLUNTEER FIRE DEPARTMENT AND THREE FORKS AREA A
THREE FORKS HIGH SCHOOL
Frontage Rd
1N 1E
2N 1E
1N 2E
2N 2E
Madison River
Darlington Ditch 1
Missouri River
Broadwater
Gallatin
Gallatin River
Spring Creek
Trident
Rey Creek
Cottonwood Gulch
SEE PANEL 1-7
Bridge - Trident Road
Time of Arrival: 9 hr 7 min
Time to Peak Elev: 15 hr 27 min
Max Depth: 25.8 ft
Max Velocity: 3.2 fps
Distance from Dam: 71.4 mi
Time of Arrival: 9 hr 22 min
Time to Peak Discharge: 15 hr 37 min
Peak Elevation: 4,042.6 ft NAVD88
Max Depth: 22.41 ft
Peak Flow: 82,343 cfs
Railroad Bridge at Logan
Time of Arrival: 7 hr 37 min
Time to Peak Elev: 10 hr 17 min
Max Depth: 16.6 ft
Max Velocity: 7.4 fps
Distance from Dam: 66 mi
Time of Arrival: 8 hr 2 min
Time to Peak Discharge: 10 hr 52 min
Peak Elevation: 4,075.9 ft NAVD88
Max Depth: 7.62 ft
Peak Flow: 46,867 cfs
PANEL LOCATOR MAP
COUNTY: GALLATIN/BROADWATER
MAP FEATURES
IMPACTED PARCELS
TOWNSHIP LINES
RAILROAD
POLICE DEPT
SHELTER
HEALTHCARE
SCHOOL
FIRE DEPT
CROSS SECTIONS
WATER DEPTH
< 5
5 - 10
10 - 20
> 20
VALUE
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0
3,000
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MIDDLE CREEK
BREACH ANALYSIS
(OVERTOPPING INUNDATION BOUNDARY)
ISSUED: 6/12/2017
PANEL 1-8
PATH: I:\PROJECTS\MTDNRC\10037925_DNRC_BREACH_ANALYSIS\MAP_DOCS\FIGURES\MIDDLE_CREEK\OVERTOPPING\MIDDLE_CREEK_OVERTOPPING_INUNDATION_PANELS1-X_11X17.MXD - USER: MKRUEGER - DATE: 6/12/2017

C-2: Dam Breach Analysis

A flood induced breach scenario was evaluated to determine the extent of the downstream area that would be affected should Middle Creek Dam breach during the probable maximum flood (PMF). This is referred to as the "Overtopping Breach" even though the dam is not overtopped. The breach modeling was performed using the two dimensional (2-D) finite volume solution available within the U.S. Army Corps of Engineers Hydraulic Engineer Center's River Analysis System Version 5.0.1 (Reference 13). HDR (Reference 6) conducted the analysis using the full momentum equations.

The probable maximum flood (PMF) inflow hydrograph was routed through the reservoir with an established stable baseflow in the receiving streams. The reservoir elevation at the beginning of the PMF was set at the principal spillway crest elevation. Given that Middle Creek Dam has a full PMF spillway, the inflow into the reservoir does not exceed the available storage. Therefore, the breach was triggered to occur coincident with the peak of the PMF.

The probable maximum flood (PMF) was determined by HKM in 1990 (Reference 7). The PMF has a calculated peak inflow (without baseflow) of 30,284 cubic feet per second (cfs) and a total volume of 41,068 acre-feet. The 100-year baseflow of Middle Creek at the dam is 1,004 cfs and is added to the PMF during the breach analysis.

The Overtopping Breach was analyzed downstream to the location where the discharge of the Simplified Breach was less than the 100-yr discharge. As specified in DNRC's Technical Note 3 (Reference 11), the Simplified Breach is an overtopping breach which occurs with the reservoir's water surface elevation equal to the top of the dam, but with no downstream baseflow or additional discharge related to the spillway or outlet works.

The Overtopping Breach was routed approximately 71.4 miles downstream from Middle Creek Dam to a point on the Missouri River at Trident, Montana.

HYDROLOGIC ANALYSIS

The hydrologic analysis defined baseflow conditions for the stream reaches between the dam and the downstream terminus of the model at Trident, Montana using downstream drainage areas per FHWA's guidance in HEC-22 (Reference 4). The results from this analysis determined that the baseflows would equal the 100-year discharge for Middle Creek, a coincident 50-year discharge for the West Gallatin River and a coincident 25-year flow for the Missouri River (Reference 6).

TERRAIN DEVELOPMENT

The terrain for the hydraulic analyses consists of a combination of data consisting of the following sources:

- Light Detection and Radar (LiDAR) received from the Floodplain Division of the DNRC. The data utilized in the present study was acquired in 2013 by Photo Science (Reference 12). The data was supplied in Montana State Plane with units of feet using the NAD83 horizontal datum and the NAVD88 vertical datum.

- USGS 10-m Digital Elevation Models (DEM) were downloaded from the USGS' National Map data download service (Reference 15). The data was supplied in GCS North American Datum 1983 with units of feet using the NAD83 horizontal datum and the NAVD88 vertical datum.
- 5-m grids gathered through interferometric synthetic aperture radar (IFSAR) acquired by Intermap, Inc. The data was purchased by DNRC through Digital Data Services (DDS) in November 2016 (Reference 9). The bare earth grid files received from DDS use the NAD83 horizontal datum, the NAVD88 vertical datum, and were converted from meters to feet.

Preliminary analyses utilized the LiDAR and 10-m data mosaicked together using the RAS Mapper utility of HEC-RAS 5.0.3 (Reference 13). Where the two datasets overlapped, the LiDAR overrode the less accurate 10-m data. This mosaicked dataset was utilized to develop the project extents of the analyzed breach.

Once the extents of the breach were determined, the 10-m data was replaced with the 5-m data. The extents of the utilized topographic sources are displayed in the Breach Analyses Report (Reference 6).

ROADWAYS AND HYDRAULIC STRUCTURES

Hydraulic structures and roadways within the flow path causes uncertainty as it is unknown if the structure and associated embankment will be washed away during a breach. If included, additional areas are inundated by ponding water and conversely, flood wave attenuation is accelerated. To balance these effects, bridges and culverts were excluded and only the roadways and embankments visible within the utilized topography were utilized.

BREACH PARAMETERS

The input parameters used in the Overtopping Breach (Reference 5)were:

Dam Crest Elevation (ft)	6734.67 (NAVD88)
Reservoir Elevation at Breach (ft)	6731.62
Breach Bottom Elevation (ft)	6610.47
Breach Height (ft)	124.2
Breach Volume (acre-ft)	12,561
Breach Side Slopes (H:V)	1:1

The results (Reference 6) were:

Time to Full Breach Formation (hr)	0.58
Breach Bottom Width (ft)	142.8

HYDRAULIC RESULTS

The dam breach was initiated coincident with the peak reservoir elevation during the PMF inflow (6731.62 feet, NAVD88). The breach development time after initiation is 0.58 hours. The peak breach discharge was calculated to be 392,426 cfs.

Results of the Overtopping Breach analysis for the Middle Creek Dam are listed in Table C-1.

Table 7: Middle Creek Dam Breach Analysis

MIDDLE CREEK DAM BREACH ANALYSIS

* Based on 1990 PMF and 2017 HEC-RAS 5.0.1 (2-D) Analysis								
Panel	**Distance from Dam**	**Time of Arrival**		**Time to Peak Discharge**		**Peak Elevation (NAVD88)**	**Max Depth**	**Peak Flow**
	miles	**hour**	**min**	**hour**	**min**	**feet**	**feet**	**cfs**
1-1*	0	0	0	0	22	6,702.84	93.63	392,426
1-1	0.3	0	2	0	27	6,638.80	65.34	357,359
1-1	3.3	0	22	0	47	6,275.10	54.53	304,764
1-2	5.9	0	27	0	57	5,955.40	80.22	239,339
1-2	9.5	1	7	1	27	5,441.20	34.84	221,252
1-3	11.9	1	22	1	37	5,224.80	14.66	214,503
Flow splits								
1-3	15.8a	1	42	2	2	4,907.60	5.98	182,479
1-3	15.9b	9	47	10	17	4,857.10	0.71	17
1-3	16.0c	13	22	14	47	4,850.20	0.33	6
1-4	17.1a	2	17	2	32	4,818.70	2.71	8,740
1-4	19.7b	1	52	2	12	4,752.70	8.19	182,491
1-4	23.7c	2	22	2	42	4,597.60	5.77	157,232
1-5	28.1a	3	42	5	17	4,428.80	8.15	14,344
1-5	28.2b	3	7	3	37	4,462.60	14.8	75,087
1-5	29.0c	3	17	4	2	4,454.00	2.56	19,799
1-5	31.4a	4	27	6	37	4,341.80	5.76	14,674
1-5	33.2b	3	47	4	32	4,346.40	5.5	54,122
1-5	35.2c	4	42	5	37	4,349.40	8.11	18,070
1-6	35.1a	5	42	8	17	4,274.70	5.52	13,108
1-6	46.4b	4	32	5	27	4,268.40	15.45	48,721
Flow comes back together								
1-6	57.1	6	7	7	7	4,180.90	14.03	52,634
1-7	62.5	7	22	10	7	4,117.00	14.58	47,009
1-8	66	8	2	10	52	4,075.90	7.62	46,867
1-8	71.4	9	22	15	37	4,042.60	22.41	82,343

* Datum	Project Datum (-4.67 ft)	Map Datum NAVD 88
* Upper Principal Spillway Crest Elevation	6721.00	6725.67
* Emergency Spillway Crest	6723.00	6727.67
* Max Breach Elevation at Spillway Crest	6730.00	6734.67
* Dam Crest Elevation	6730.00	6734.67

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