FINAL

# Eagle Canyon Fish Passage Improvements in Battle Creek
## Lower and Upper Barrier Sites

## Existing Site and Hydraulic Characterization
## Technical Memorandum



**October 2016**

Prepared for:

**California Department of Fish and Wildlife**
(Agreement Number D1499019)

Prepared by:

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**Attachment A – Project Sites Plan and Profile Drawings**

**Attachment B – Lower Barrier Site Photographs**

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**Attachment F – HEC-RAS Plan View Figures**

**Attachment G – Discharge Rating Curve Data Tables**

**Attachment H – Lower Barrier Water Surface Mapping Results**

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**Attachment J – Lower Barrier SRH-2D Result Figures**

**Attachment K – Upper Barrier Water Surface Mapping Results**

**Attachment L – Upper Barrier HEC-RAS Result Figures and Data Tables**

# 1 INTRODUCTION

Battle Creek has historically been regarded as a uniquely important watershed because of the abundance and broad diversity of Chinook salmon and steelhead that used this stream. The year round influence of cold water springs allowed for such diversity to develop, including winter-run Chinook salmon, which is now in danger of extinction. Hydroelectric facilities and operations and other human factors likely caused the extirpation of winter-run from the Battle Creek watershed in the early 1900s (Reynolds et al. 1993).

After many years of planning, there is currently a major restoration project being completed by many organizations and led by the U.S. Bureau of Reclamation (USBR) on Battle Creek: The Battle Creek Salmon and Steelhead Restoration Project (USBR Restoration Project). Upon its completion, the goal of the USBR Restoration Project is to reestablish approximately 42 miles of prime salmon and steelhead habitat on Battle Creek, plus an additional six miles on its tributaries.

The California Department of Fish and Wildlife (CDFW) has retained the services of Michael Love & Associates, Inc. (MLA) to design and develop construction ready documents to improve upstream fish passage conditions at two natural fish barriers on North Fork Battle Creek (NFBC): Lower Barrier Site (LBS) and Upper Barrier Site (UBS). This Eagle Canyon Fish Passage Improvement Project (Project) is being completed for CDFW under Agreement Number D1499019 (Agreement).

This Technical Memorandum (TM) presents the existing site and hydraulic characterization findings for both sites as required by Task 4 of the Agreement. Per the Agreement, MLA is to complete the following work under Task 4:

- characterize the flow patterns through both barrier reaches over a range of fish passage flows,
- map water surface elevations in, and around, each feature and produce water surface profiles,
- conduct streamflow discharge measurements,
- overlay water surface maps on the base map to shown flow extents,
- document locations where passage conditions are suitable and alternative, or potential, passageways around obstructions exist at specific flows,
- identify where fish passage improvements are required, and
- develop a technical memorandum describing the work completed under this task (this document).

Findings presented in this TM, along with previous work products, serve as the basis for developing the strategic modifications necessary to improve fish passage conditions at the LBS and UBS. Potential fish passage modifications will be presented in the Alternatives Analysis Report, which will be completed subsequent to this TM.

This TM is organized in the following manner:

- **Section 2 Previously Completed Work:** Presents the work completed previously by the MLA Design Team for this Project and work completed by others that are specifically relevant to the introduction of the work presented in this TM.

- **Section 3 Project Location and Site Descriptions:** Presents, in general, the Project location and then in more detail the Project sites.
- **Section 4 Fish Passage Performance Criteria:** Presents the identified fish passage performance criteria utilized for this Project to evaluate the hydraulic conditions as they relate to existing fish passage and future alternatives.
- **Section 5 Hydrology and Fish Passage Flows:** Presents the project hydrology which includes a description of the flow releases from the dams affecting the Project, defining the peak flows used for this Project, and defining the fish passage design flows used for this Project.
- **Section 6 Field Data for Characterizing Hydraulic Conditions:** Presents the field data work completed under Task 4 for this Project.
- **Section 7 Methods for Characterization of Existing Hydraulic Conditions:** Presents the methodology used to characterize the existing hydraulic conditions.
- **Section 8 Characterization of Existing Hydraulic Conditions Results:** Presents the findings of the existing conditions hydraulic assessment.
- **Section 9 Conclusions** Presents the conclusions of this TM.

# 2 PREVIOUSLY COMPLETED WORK

## 2.1 Previously Completed Work by MLA Design Team

Work presented in this Technical Memorandum (TM) is based on work documented in early TMs. Together, this TM, previously completed TMs, and future TMs will serve as a collection of documents detailing the work completed for this Project, each relying on others to minimize repeating information. Table 2-1 presents the previously completed TMs for this Project.

**Table 2-1. A list of previously completed technical memorandums completed for this Project.**

| Associated Task | Technical Memorandum Title | Primary Author | Status |
|---|---|---|---|
| Task 2 | *North Fork Battle Cr Eagle Canyon Survey Report* | GMA Hydrology, Inc. | Finalized, January 2016 |
| Task 2 | *Final Eagle Canyon Fish Passage Improvement Project Task 2: Topographic Surveying and Boulder Mapping Results* | Michael Love & Associates, Inc. | Finalized, May 5, 2016 |
| Task 3 | *Engineering Geologic Investigation Technical Memorandum Eagle Canyon Fish Passage Improvement in Battle Creek* | Cotton, Shires and Associates, Inc. | Finalized, August 2016 |

GMA Hydrology's (GMA's) *North Fork Battle Cr Eagle Canyon Survey Report* presents the work completed to develop the base topographic data for the Project. This included brining control to the Project sites, obtaining LiDAR data, conducting ground base scans, conducting traditional Total Station surveys, conducting sonar-based bathometric surveys, and obtaining low-elevation aerial photographs of the sites.

MLA's *Final Eagle Canyon Fish Passage Improvement Project Task 2: Topographic Surveying and Boulder Mapping Results* technical memorandum provided the findings of the work completed under Task 2 by MLA. This included the labeling of boulders for both sites, identifying hydraulic control for both sites, identifying high and low flow alignments, and delivering all of the electronic information developed by both MLA and GMA.

Cotton, Shires and Associates' (CSA's) *Engineering Geologic Investigation Technical Memorandum Eagle Canyon Fish Passage Improvement in Battle Creek* provided the findings of their engineering geologic investigation. This included a rigorous investigation of the UBS and a more qualitative investigation of the LBS.

## 2.2 Previously Completed and Relevant Studies by Others

This section presents some of the relevant studies completed by others within the Battle Creek watershed that are particularly relevant to this Project.

### 2.2.1 Fish Passage and Fish Monitoring Studies

There have been several fish passage and fish monitoring studies completed for Battle Creek. The most relevant studies obtained for this Project include:

- Thomas R. Payne & Associates' (TRPA's) 1998 *Battle Creek Fisheries Investigations, Task 4: Surveys of Barriers to the Upstream Migration of Anadromous Fish* (TRPA, 1998)

- U.S. Fish and Wildlife Service's *Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from November 2002 through November 2003* (Brown and Alston, 2007)
- U.S. Fish and Wildlife Service's *Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from March through November 2007* (Newton et. al., 2008)
- U.S. Fish and Wildlife Service's (USFWS's) *Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from March through November 2014* (Bottaro and Brown, 2015)
- U.S. Fish and Wildlife Service's *Summary of the Pilot Assessment of Three Potential Fish Barriers on Battle Creek* (Earley, 2014)

The TRPA (1998) study cataloged numerous potential natural passage impediments throughout the Battle Creek watershed. Figure 2-1 presents the map developed by TRPA with the current Project's barrier locations identified. Of the potential barriers identified by TRPA on NFBC below river mile (RM) 6, all were identified as passable at flows greater than 35 cfs with the exception of one. The barrier identified at RM 5.14 (NF5.14) is this Project's LBS. TRPA estimated that NF5.14 was a complete barrier to all fish at all flows but later indicated that some salmonids, in good condition, could pass this falls at very high flows.

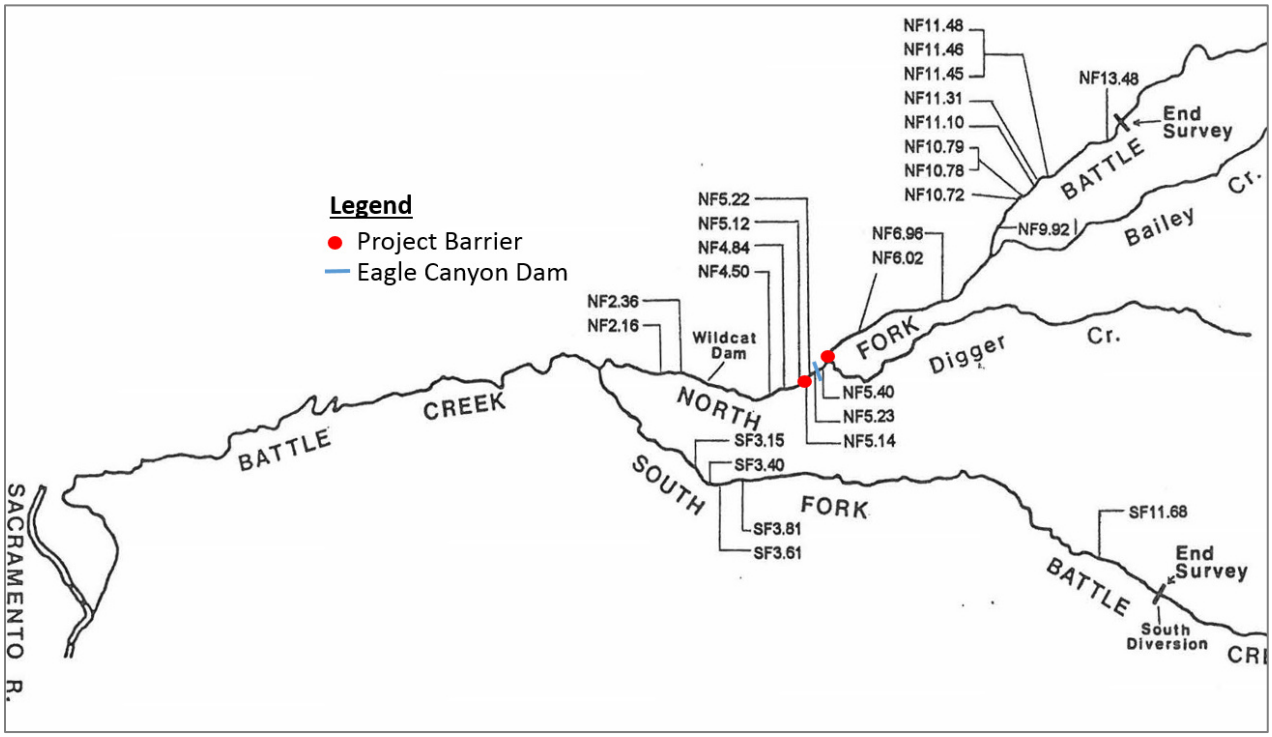



**Figure 2-1. Locations of identified barriers (TRPA, 1998) with the current Project's barriers labeled in red.**

TRPA's barrier NF5.40 was described as consisting of a cascade below a 3.5 feet high falls at approximately 4.5 cubic feet per second (cfs). The horizontal distance from a pool below the cascade to the top of the falls was 8 feet. TRPA concluded that at 35 cfs, the pool below the cascade was large enough to allow Chinook salmon and steelhead passage. NF5.40 is located immediately downstream of this Project's UBS, and downstream of the Digger Creek confluence.

Lacking from the 1998 TRPA study is the identification of the UBS. For reasons unknown, their report makes no mention of this barrier, which is located immediately upstream of the Digger Creek confluence.

U.S. Fish and Wildlife Service has completed monitoring within Battle Creek since 1995. During this monitoring period they have never recorded a redd upstream of the LBS (RM 5.14). They conclude that LBS may block salmonid passage at low and moderate flows, with a potential alternative passageway at infrequent high flows.

Earley (2014) identified the UBS and referred to it as Barrier B. Earley concluded that the UBS was a complete barrier at low and moderate flows, with the potential for an alternative passage route around the barrier at high flows.

### 2.2.2 Hydrology Studies

There have been several studies of Battle Creek hydrology as part of the larger Restoration Project. For this Project, the hydrologic studies most utilized are list below. The data utilized from these studies will be further detailed in Section 5.

- *Battle Creek Salmon and Steelhead Restoration Plan* (Ward and Kier, 1999)
- *Memorandum of Understanding: to Memorialize the Agreement Regarding the Proposed Battle Creek Chinook Salmon and Steelhead Restoration Project, Located in the Battle Creek Watershed in Tehama and Shasta Counties, California* (MOU, 1999)
- *Battle Creek Salmon and Steelhead Restoration Project Fish Ladder and Fish Screen Features: Inskip Diversion, North Battle Creek Feeder Diversion, Eagle Canyon Diversion, Preliminary Engineering Concepts Technical Report* (DWR, 2000)
- *Hydrology of North and South Fork Battle Creeks* (USBR, 2001)

Ward and Kier (1999) developed a restoration plan for the Battle Creek Working Group. They developed a ratio for the flow split between the north and south forks of Battle Creek based on the long term flow gage data collected at the USGS Coleman Hatchery Gage (USGS 11376550).

In 1999 the National Marine Fisheries Service (NMFS), U.S. Bureau of Reclamation (USBR), U.S. Fish and Wildlife Service (USFWS), California of Department of Fish and Game (CDFW), and Pacific Gas and Electric Company (PG&E) entered into a memorandum of understanding (MOU). Amongst other things, the MOU details the instream flow requirements downstream of various diversion dams within the Battle Creek Watershed.

Department of Water Resource (DWR, 2000) utilized the information contained within the MOU and the data developed by Ward and Kier (1999) to develop their conceptual level engineering fish passage solutions for Eagle Canyon Diversion Dam and North Fork Feeder Dam, both on the north fork (see Figure 3-2 in Section 3.1), as well as other dams on the south fork of Battle Creek. DWR, based on discussions with PG&E, slightly modified the flow split ratio developed by Ward and Keir (1999).

During the development of the DWR conceptual designs, USBR prepared a detailed report on the hydrology of Battle Creek (USBR, 2001). The USBR report, along with the MOU, and the field data collected by MLA, provides the basis for the hydrology used for this Project.

# 3 PROJECT LOCATION AND SITE DESCRIPTIONS

## 3.1 Project Location

Battle Creek is located in northern Tehama and southern Shasta counties, California. Battle Creek is tributary to the Sacramento River. Battle Creek is approximately 60 miles long and has a watershed area of approximately 364 square miles. Battle Creek watershed includes the western slopes of Lassen Peak in the southern Cascade Range. In addition to precipitation and snowmelt runoff, Battle Creek receives flow from numerous cold water springs. Battle Creek has the highest base flow (dry-season flow) of any tributary to the Sacramento River between the Feather River and Keswick Dam (Ward and Kier, 1999).

The focus of this Project is two sites located on North Fork Battle Creek (NFBC). Figure 3-2 provides an overview of the USBR Restoration Project components, being completed by USBR, with the location of the two barriers associated with this Project labeled, as well as other important features that will be referred to within this TM.

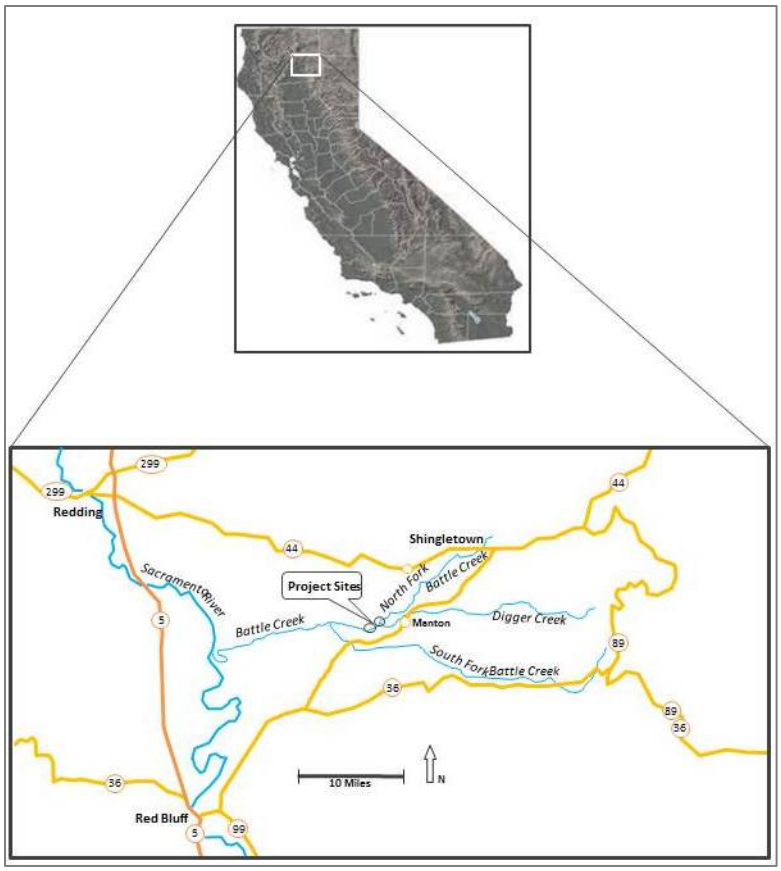



**Figure 3-1. Project location map.**

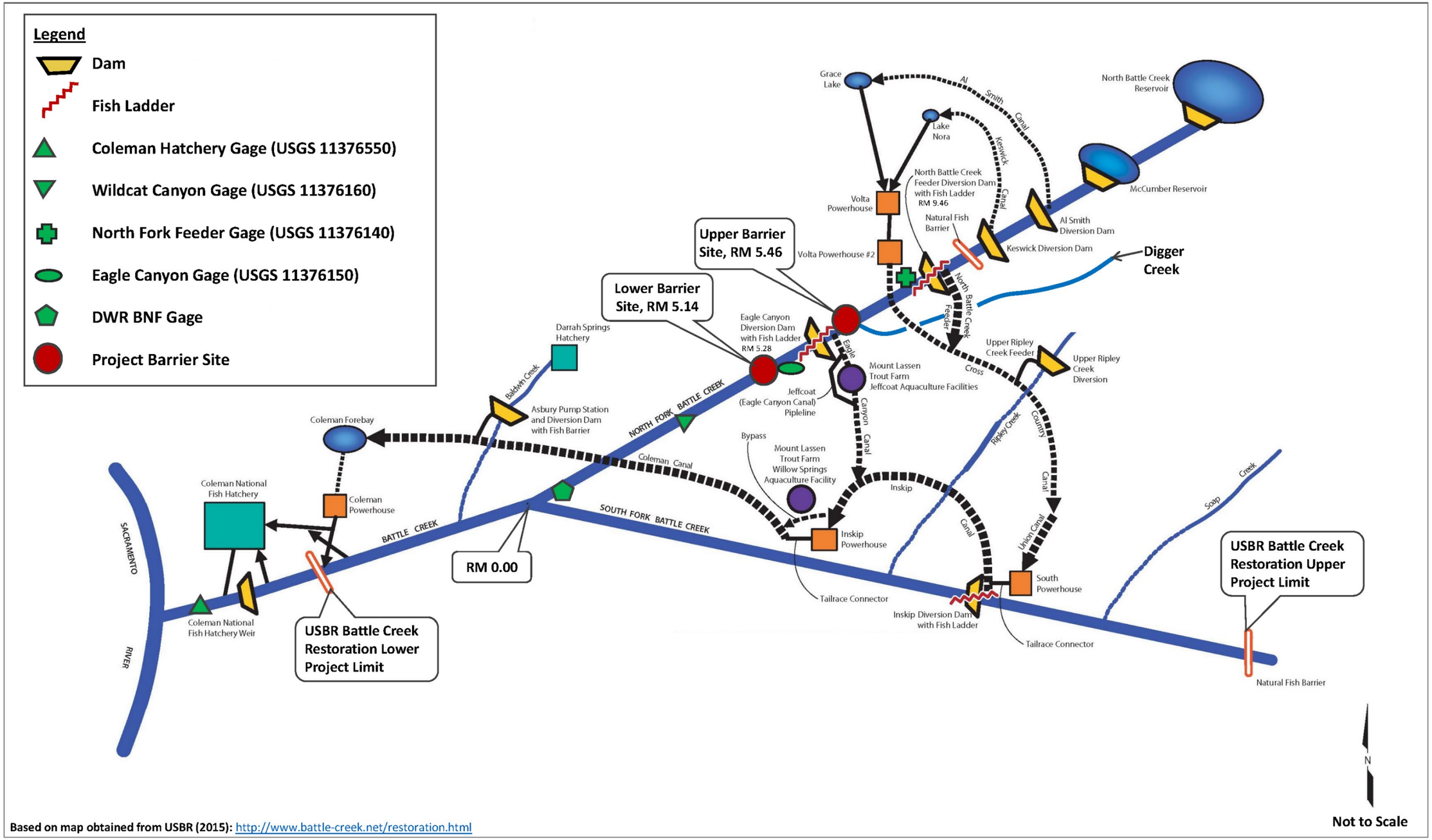



**Figure 3-2. Battle Creek Schematic for USBR Restoration Project with this Project's site locations and the location of various flow gages indicated.**

## 3.2 Eagle Canyon

North Fork Battle Creek created Eagle Canyon as it cut its way through a volcanic plateau. Moving upstream along NFBC, Eagle Canyon begins to form at approximately RM 3.87, where it is approximately 550 feet wide and 106 feet deep. At the LBS (RM 5.14), the canyon is approximately 350 feet wide and 200 feet deep. At the UBS (RM 5.46), the canyon is approximately 50 feet wide and 50 feet deep. The canyon continues to narrow and become less deep moving further upstream.

Digger Creek flows into NFBC at RM 5.44, immediately downstream of the UBS. Digger Creek, at the NFBC confluence, is confined within its own canyon, and has a similar depth and width as NFBC upstream of the UBS.

Figure 3-3 presents the Eagle Canyon long profile from RM 4.65 to RM 5.82 derived from the USFWS provided LiDAR generated digital terrain model. Average slopes and the locations of the LBS and UBS and Eagle Canyon Dam are identified. As seen, the average slope immediately downstream and upstream of the LBS is 7.3 percent and 6.2 percent, respectively. Between Eagle Canyon Dam and the UBS the average channel slope is 7.9 percent. Upstream of the UBS, the slope is much more gradual, at 2.6 percent.

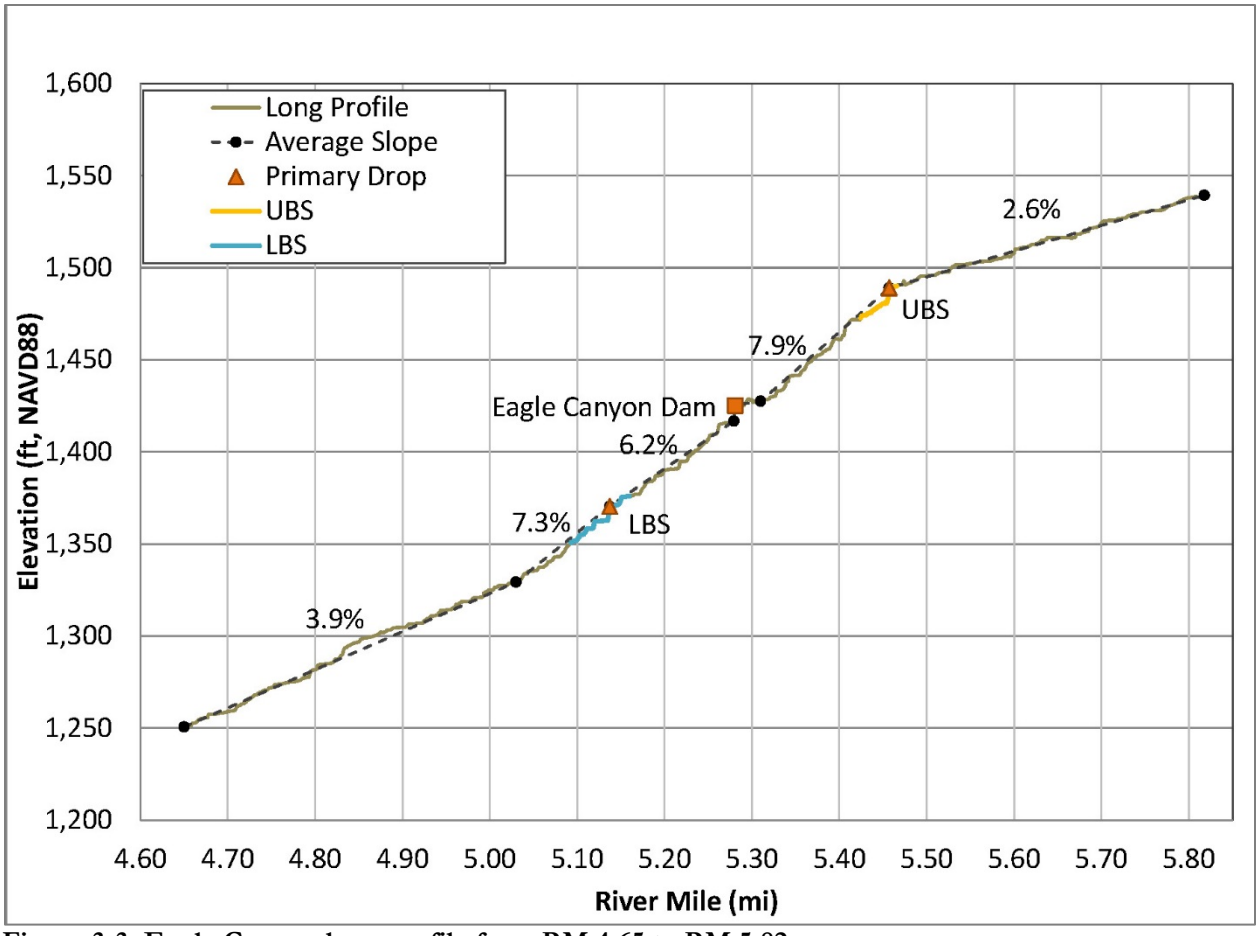



**Figure 3-3. Eagle Canyon long profile from RM 4.65 to RM 5.82.**

## 3.3 Lower Barrier Site

The Lower Barrier Site (LBS) is located approximately 600 feet downstream of the Eagle Canyon Dam (lat: 40.423197°, long: -121.921655°) at RM 5.14. Attachment A includes plan and profile view drawings of the LBS. The following sub-sections describe the general layout of the LBS and the location and arrangement of mapped boulders. Attachment B includes annotated photographs referred to in the below sections.

### 3.3.1 General Site Description

Figure 3-4 presents an aerial photograph of the LBS at a flow of approximately 120 cfs. Figure 3-5 presents the detailed channel profile through the LBS based on field-run survey completed for this Project. Refer to GMA (2016) for additional survey details.

Pool 1 is the downstream most pool surveyed as part of this Project. It receives flow from Pool 2. Pool 2 is approximately 41 feet long with a relatively deep (approximately 7 ft deep under low flow conditions) scour hole located at the head of the pool. Adjacent to Pool 2 along river right is a bedrock shelf that contains several pot holes of varying depths (Figure B-1, Attachment B). To enter Pool 3 from Pool 2, under low flow conditions, a fish must swim through Sieve A, where water flows under a boulder. The exact dimensions of the sieve are not known as it was unsafe to conduct measurements, but as seen in Figure B-1, the sieve can easily convey 120 cfs. Pool 3 is short and approximately 5.7 feet deep under low flow conditions. A second large sieve (Sieve B) separates Pool 3 and Pool 4. Pool 4 is 8 feet long and approximately 3 feet deep at low flow. It is located immediately downstream of the primary drop.

The primary drop and receiving pool, Pool 4, is the focus of this Project for the LBS (Figure B-2 and B-3). The drop is approximately 34.5 feet long and 8.4 feet in height, as measured from the pool water surfaces. The average slope is 32.5 percent, with the lower portion of the drop being much steeper. At the top of the drop, the channel is approximately 22 feet wide, but quickly narrows to approximately 6 feet wide as it is pinched by very large boulders and the bedrock canyon wall.

In October 2012, CDFW conducted an operation to remove a boulder (referred to as R1 in Smelser (2012)) that further restricted the channel width of the primary drop. Explosives were utilized to remove the boulder (RBF, 2012). Although much of the boulder was reduced to small pieces, it is believed that some large fragments of that boulder remain within the primary drop and possibly within Pool 4. Smelser (2012) also identified a bedrock cornice located at the head of the drop. He described it as a remnant pothole rim that protrudes into the flow at the top of the chute that forms the primary drop. No modifications were made to the bedrock cornice during the 2012 effort.

Spawning and redd surveys completed by USFWS between 2001 and 2013 yielded no indications of anadromous fish above the primary drop (Earley, 2014). During the initial site visit for this Project in June 2015, an adult steelhead was observed in Pool 2, but no fish were observed upstream of the primary drop.

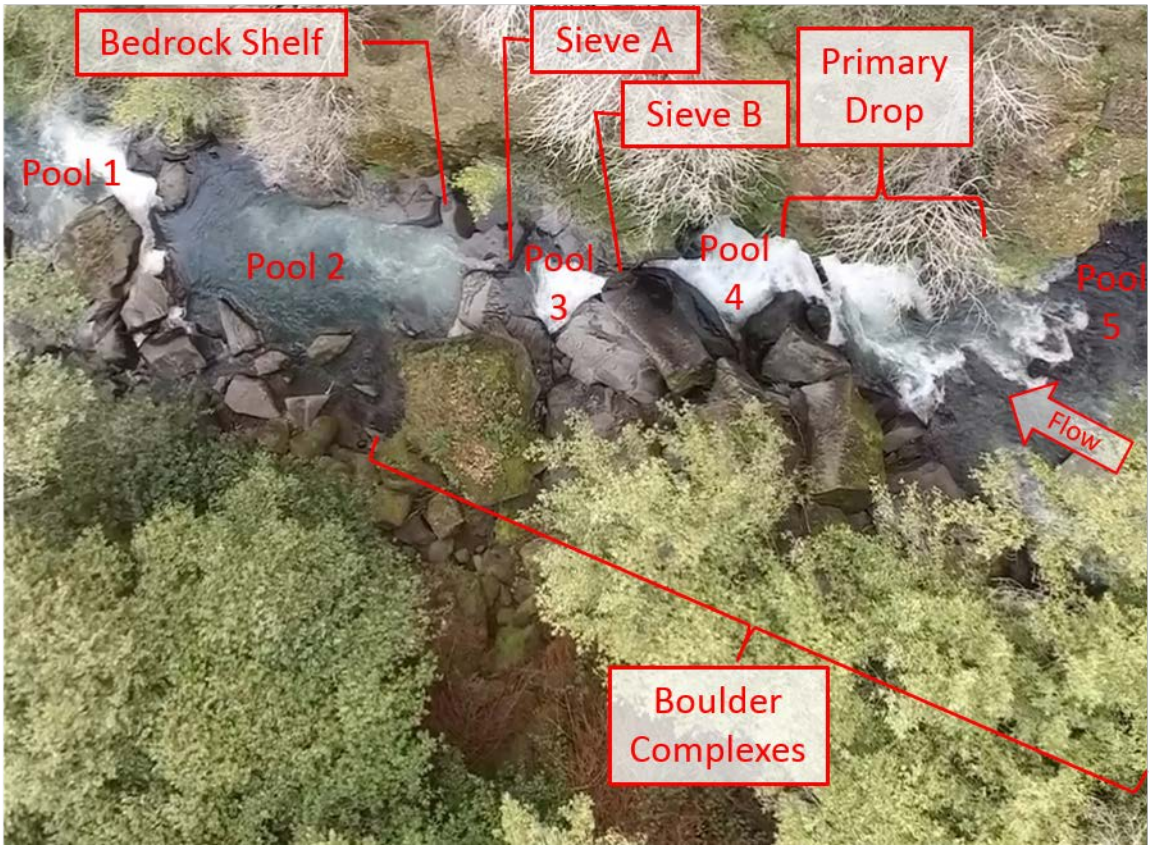



**Figure 3-4. Aerial image of the Lower Barrier Site taken on February 10, 2016 at a flow of 120 cfs.**

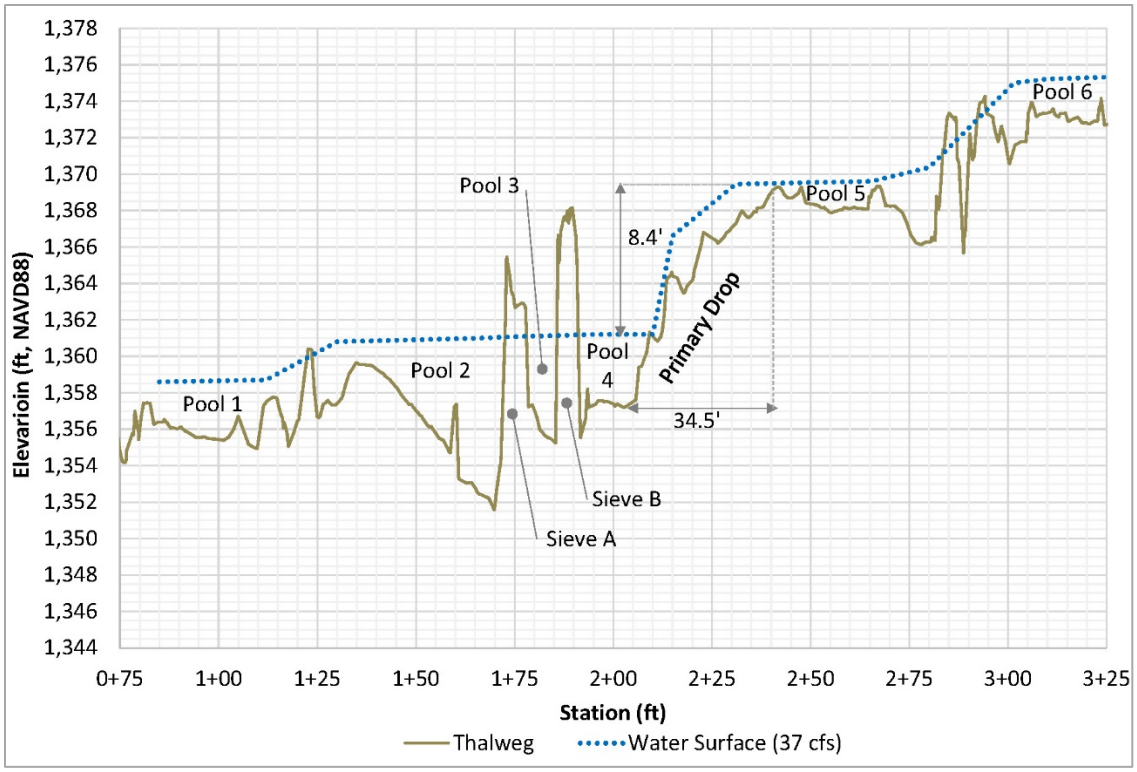



**Figure 3-5. Lower Barrier Site channel profile.**

Upstream of the primary drop is Pool 5 (Figure B-2), marking this Project's upper reach. Pool 5 is approximately 300 feet long and relatively shallow (1.9 residual depth) and wide compared to Pools 2, 3, and 4.

Overall, the LBS contains many large (over ten feet in diameter) boulders. The majority of the large boulders are located on river left (looking downstream) and extend as indicated in Figure 3-4. Smelser (2012) and CSA (2016) both concluded that most of the large boulders originated from the southern (river left) upper canyon wall. Smelser speculated that these large boulders originated from blasting during construction of the Eagle Canyon flume and tunnels, now operated by PG&E. Upslope of these boulders, but below the southern canyon wall and tunnel portal is a slope formed of small (12 inches and smaller) angular rock fragments. These appear to have been spoiled in this location during construction of the adjacent tunnel.

### 3.3.2 Mapped Boulders and Boulder Complexes

Under Task 2 of this Project, MLA individually labeled each boulder greater than approximately 3 feet in diameter (MLA, 2016). The boulders are labeled in the Attachment A drawings. Figure 3-6 presents an aerial overview of the LBS with eleven boulder/boulder complexes labeled. When Figure 3-6 only lists a single number (e.g. B75) then the label is referring to a single boulder, otherwise the label is indicating many boulders grouped together into a boulder complex. The exception is the bedrock shelf which is neither. The remainder of this section briefly describes each boulder/boulder complex. As the Project progresses these complexes will be separated into individual boulders as necessary to describe various components of the Project.

Description of Labeled boulders and boulder complexes:

- **Boulder B138:** An approximately 18 feet long (parallel with flow), 17 feet wide (perpendicular to flow), and 21 feet tall boulder (Figure B-4). Smelser (2012) concluded that this boulder weighs approximately 650 tons.

- **DS Complex**: A grouping of boulders downstream and behind B138 ranging in size from 8 feet to less than 3 feet in diameter. When entering the LBS, you first enter this complex of boulders.

- **Boulder B95:** An approximately 11 feet long, 12 feet wide, and 7 feet tall boulder (Figure B-4). Sieve A is located between B95 and the bedrock shelf.

- **Boulder 131:** An approximately 15 feet long, 11 feet wide, and 11 feet tall boulder (Figure B-4 and Figure B-5). Boulder B131 is situated on top of the bedrock shelf immediately downstream of Pool 4. Smelser (2012) concluded that this boulder weighs approximately 90 tons.

- **Boulder B71:** An approximately 8 feet long, 16 feet wide, and 6 feet tall boulder. Boulder B71 forms the top of Sieve B. Smelser (2012) concluded that this boulder weighs approximately 140 tons.

- **Middle Complex:** Comprised of numerous boulders ranging in size from 14 feet (boulder near B71) to less than three feet in diameter (Figure B-5 and Figure B-6).

- **Upper Complex:** Comprised of several boulders ranging in size from 7 feet to less than 3 feet in diameter (Figure B-7).

- **B72 Complex**: Includes many large boulders. Boulder B72 is the largest boulder within the complex and is 10 feet long, 17 feet wide, and 7 feet tall. Smelser (2012) concluded that this boulder weighs approximately 170 tons. Smelser (2012) determined the approximate weight for several other boulders within this complex weighing between 80 and 20 tons. Figure B-5, Figure B-6, Figure B-7, Figure B-8, Figure B-9 present different sides of the B72 Complex.

- **Boulder B75:** An approximately 12 feet long, 9 feet wide, and 7 feet tall boulder (Figure B-9). B75 is situated between the B72 Complex and the Bear Hallow Complex.

- **Bear Hallow Complex:** It contains several large boulders with the largest being 17 feet long, 20 feet wide, and 20 feet tall (Figure B-9). A small hollow is formed under these boulders.

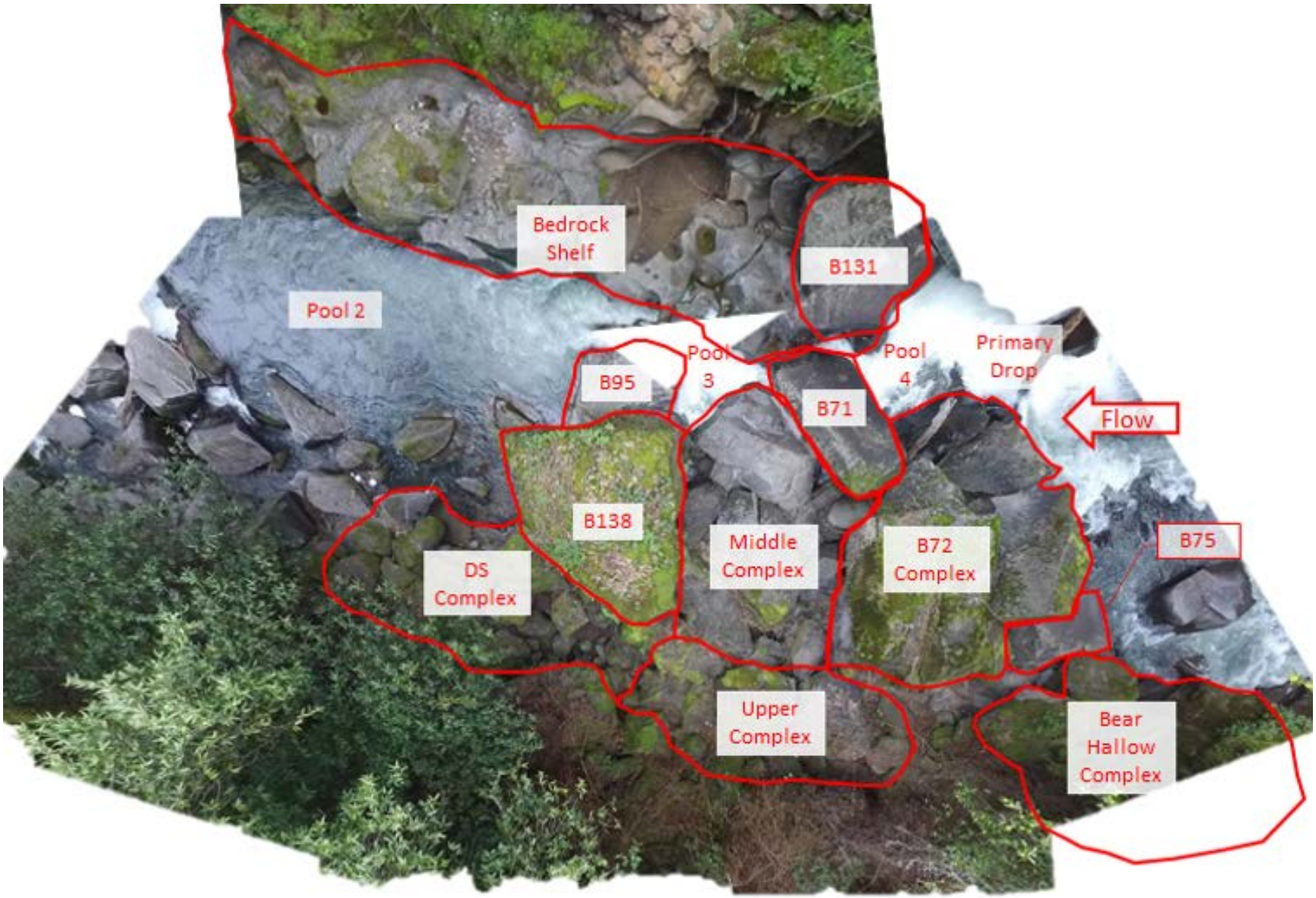



**Figure 3-6. LBS aerial image with boulders and boulder complexes labeled. Flow approximately 120 cfs.**

### 3.3.3 Summary of Geophysical Exploration to Estimate Depth to Bedrock

Cotton, Shires and Associates (CSA) conducted a geophysical exploration of the subsurface conditions at the LBS using Refraction Microtremor (ReMi) technology (CSA, 2016). In total, two ReMi lines (RM1 and RM2) were deployed parallel to, and south of, the channel.

RM1 began near the toe of the bank adjacent to the downstream end of Pool 2 and extended to boulder B75. CSA's interpretation of the results from this ReMi line indicate that bedrock is approximately 14 feet below ground at the mid-point of the line, located at the south east corner of boulder B138 (Figure 3-6). This would place bedrock at approximately elevation 1353.5 feet, which falls between the pool bottoms of Pool 2 and Pool 3 (Figure 3-5).

RM2 was located about 30 feet to the south of RM2, and higher up the slope. Interpretation of RM2 results suggest that the bedrock is approximately 10 feet below ground at the mid-point of this line, which is across from the bedrock shelf and mid-point of Pool 2. This would place the bedrock surface at approximately elevation 1364.0 feet. This elevation is coincidental with portions of the bedrock shelf on the opposite side of the channel.

## 3.4 Upper Barrier Site

The UBS is located approximately 4 miles downstream of the North Battle Creek Feeder Diversion Dam (Feeder Dam) and approximately 600 feet upstream of the Eagle Canyon Dam. (lat: 40.425147°, long: -121.917139°). It is located immediately upstream of the confluence with Digger Creek. Attachment A includes plan and profile view drawings of the UBS. The following sub-sections describe the general layout of the UBS and location and arrangement of mapped boulders. Attachment C includes annotated photographs referred to in the below sections.

### 3.4.1 General Site Description

Figure 3-7 presents an aerial image of the UBS accompanied by a channel profile. Overall, the UBS is larger and more complicated than the LBS. The profile shown in Figure 3-7 is sampled along just one of many potential flow paths. Unlike the discussion for the LBS, the UBS sieves are not labeled in Figure 3-7 due to their complexity. Instead, a separate UBS sieve map is presented at the end of this section.

The UBS study area extends over approximately 350 feet of channel length, from station 1+10 to 2+35 on the profile. The overall channel slope is 8.5 percent. Immediately upstream of station 2+35 is the primary drop. Much of this channel reach is formed and controlled by very large boulders (over 10 feet in diameter) delivered to the channel from the adjacent bedrock cliffs.

Following the profile in Figure 3-7 from downstream to upstream, the UBS study area begins in Pool 1. Pool 1 is approximately 57 feet long and approximately 4.5 feet deep under low flow conditions (Figure C-1, Attachment C). Pool 2 and located at the confluence of NFBC and Digger Creek (Figure C-1). Pool 2 is short at low flows and less than a foot deep. Pool 2 becomes deeper and longer as flows increase. Pool 3 is a small pool that is not located on the profile presented in Figure 3-7. Pool 3 under low flows is approximately 1.75 feet deep and is nearly disconnected from the remainder of the channel (Figure C-2). Under higher flows, flow is conveyed through Pool 3 along the secondary alignment. Flow along the secondary alignment will be discussed in more detail below.

Pool 4 is approximately 20 feet long and has low flow depth of 2 feet. Pool 4 receives flow from a large sieve connected to Pool 5 (Figure C-3), which will be discussed later. Pool 5 is located between a series of sieves and primarily receives flow from Pool 6, but other connections exist which will be discussed in 3.4.3. Figure C-4 provides an overview of the pool configuration looking downstream.

Pool 6 is connected to Pool 7 via a large sieve. Pool 7 is the pool located immediately downstream of the primary drop (Figure C-5 and Figure C-6). Pool 7 contains several large boulders that separate the pool into smaller pools under low flow conditions. The individual pools (connected via sieves) become one large pool at relatively high flows, which will be discussed further in Section 3.4.3.

The primary drop is approximately 12.5 feet long and tall. The face of the drop consists of several large boulders protruding into the flow path. The lower portion of the drop is nearly vertical. Flow approaching the drop is conveyed through Pool 8.

Pool 8 is approximately 6 feet deep under low flow conditions and approximately 30 feet long. The deepest portion of the pool is against the right canyon wall. Flow is constricted between a large boulder located in the center of the channel and the bedrock canyon wall. The constriction causes the channel to make several abrupt turns as it approaches the primary drop (Figure C-7).

Pool 9 is the final pool within the UBS study area (Figure C-7). Pool 9 is approximately 43 feet long and approximately 2.3 feet deep under low flow conditions. Pool 9, like Pool 8 is confined to the right canyon wall under low flow conditions. Upstream of Pool 9 are three large boulders which create a barb into the channel, forcing the majority of flow towards the right canyon wall, except at high flows. These boulders also produce a water surface drop of several feet in height, as observed during higher flows.

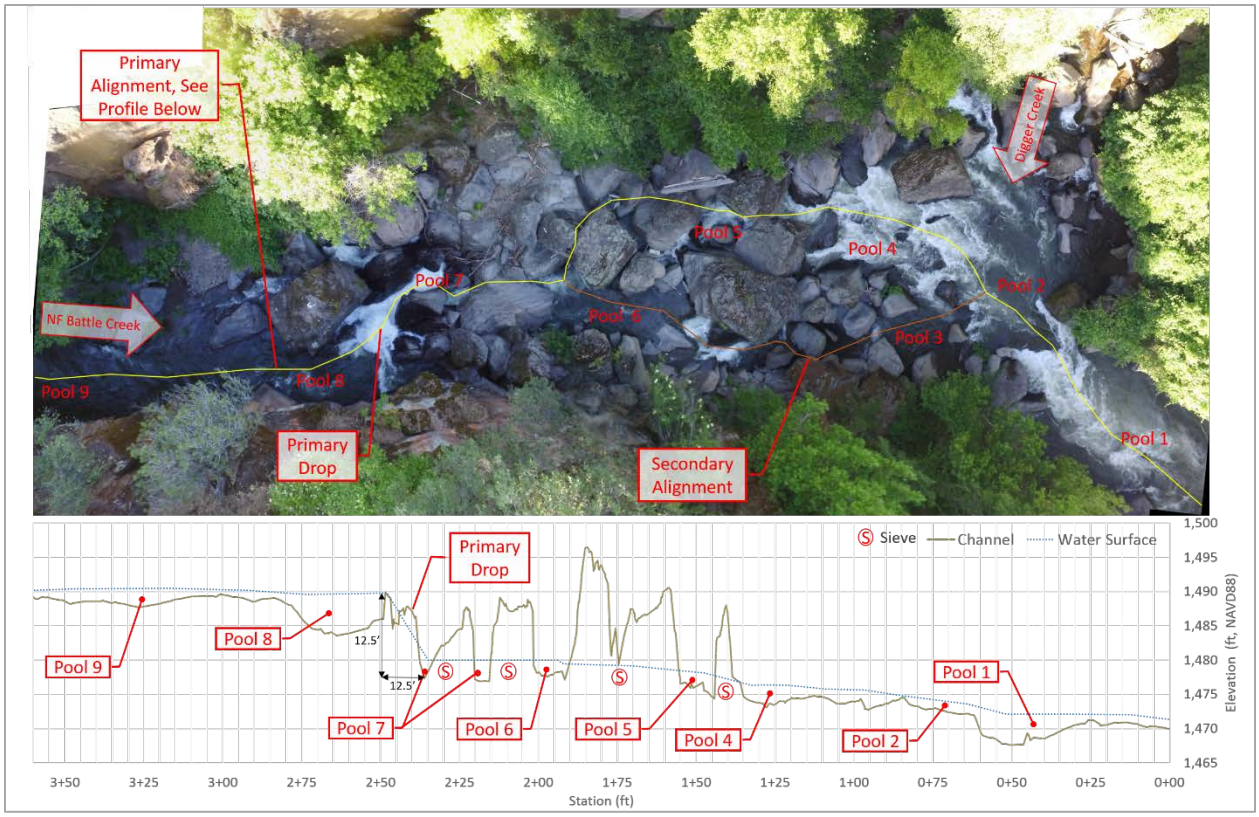



**Figure 3-7. Upper Barrier Site overview aerial image and profile. Photograph with NF Battle Creek flowing at approximately 195 cfs upstream of Digger Creek.**

### 3.4.2 Mapped Boulders and Boulder Complexes

Under Task 2 of this Agreement, MLA individually labeled each boulder greater than approximately 3 feet in diameter (MLA, 2016). The boulders are labeled in the Attachment A drawings. Figure 3-8 presents an aerial overview of the UBS with 16 boulder/boulder complexes labeled. Figure 3-9 and Figure 3-10 provide oblique aerial views of these features. Features labeled as a single number (e.g. B154) refers to a single boulder. Otherwise the label indicates many boulders grouped together into a boulder complex. As the Project progresses, these complexes will be separated into individual boulders as necessary to describe various components of the Project.

CSA (2016) presents the engineering geologic investigation findings for the UBS. CSA provides significantly more detail with respect to the canyon walls and potential rock fall hazards.

The following are brief descriptions of the 16 boulder/boulder complexes identified for the UBS.

- **DS Complex:** Includes all of the boulders in the channel downstream of the other mapped boulder complexes and upstream of Pool 1. These boulders are relatively small compared to the remainder of the boulders discussed for this Project.

- **Next Day Complex**: This complex is dominated by large boulders that previously toppled from the canyon wall's Block Party Complex, which is discussed below. The Next Day Complex extent goes beyond that shown in Figure 3-8. Boulder B167 is a large boulder

within this complex that is partially visible in Figure 3-8, and visible in the forefront of the complex in Figure 3-9. B167 is approximately 14 feet long (parallel with flow), 20 feet wide (perpendicular to flow), and 12 feet tall. This boulder has several other large boulders surrounding it.

- **Block Party Complex:** This complex is described in greater detail in CSA (2016). In summary, the Block Party Complex consists of many blocks that have a high failure potential. Some blocks are detached from the canyon wall, but have yet to topple.

- **Second Complex:** This complex consists of relatively small boulders ranging in size from 9 feet to less than 3 feet in diameter.

- **Pool 6 Complex**: This complex includes boulders located within Pool 6 and includes the boulders controlling the pool elevation along the secondary alignment. The primary boulder within the complex, B64, can be seen in Figure 3-8, Figure 3-9, and Figure 3-10 with the pothole at the water's edge. This boulder is 19 feet long, 13 feet wide, and 4 feet tall.

- **Table Complex:** This complex is dominated by boulder B119. It is referred to as the table complex because B119, from many vantage points, appears to be floating as it is propped up on several smaller boulders. Boulder B119 is 22 feet long, 16 feet wide, and 7 feet tall. It is supported in-part by B154.

- **Boulder B154:** This boulder is 14 feet long, 13 feet wide, and 9 feet tall. B154 is a link between the Table Complex and the Fallen Giants, as both complexes have large boulders resting on B154.

- **Fallen Giants Complex:** This complex includes several large boulders. These boulders may have been derived from the Land of the Giants Complex, discussed next.

- **The Land of the Giants Complex:** This complex is discussed in greater detail within CSA (2016). In summary, this complex includes many, very large and tall blocks that are in various stages of active toppling.

- **Boulder B53 (Tree Boulder):** This is a single, very large boulder. It is approximately 10 feet long, 12 feet wide and 20 feet tall.

- **B116 Complex:** This is a small complex with one relatively large boulder (B116) and other smaller boulders. This complex is sandwiched between the Tree Boulder and the Table Complex and provides tailwater control for Pool 6. Boulder B116 is 6 feet long, 8 feet wide, and 9 feet tall.

- **Upper Complex:** Consists of many boulders of varying sizes. In general, the tops of these boulders have a higher elevation than other boulders within the UBS, although the boulders closer to the center of the channel have portions that are exposed to flow more frequently.

- **B64 Complex:** Consists of several boulders that forms the tailwater control for Pool 7. This complex is dominated by boulder B64, which is beneath the label in both Figure 3-8 and Figure 3-10. Boulder B64 is approximately 16 feet long, 9 feet wide, and 6 feet tall.

- **Toe Complex**: Comprised of relatively smaller boulders. The largest having diameters of 8 feet. These boulders, like the Upper Complex's boulders, are set at a relatively high elevation along the toe of the river right canyon wall.

- **Hidden Complex:** Includes several large boulders that are below the Upper Complex and downstream of the B20 Complex. There are two primary boulders in this complex with diameters of 14 feet and 9 feet.

- **B20 Complex:** Consists of three large boulders. The largest boulder is B20, at 17 feet long, 11 feet wide, and 9 feet tall.

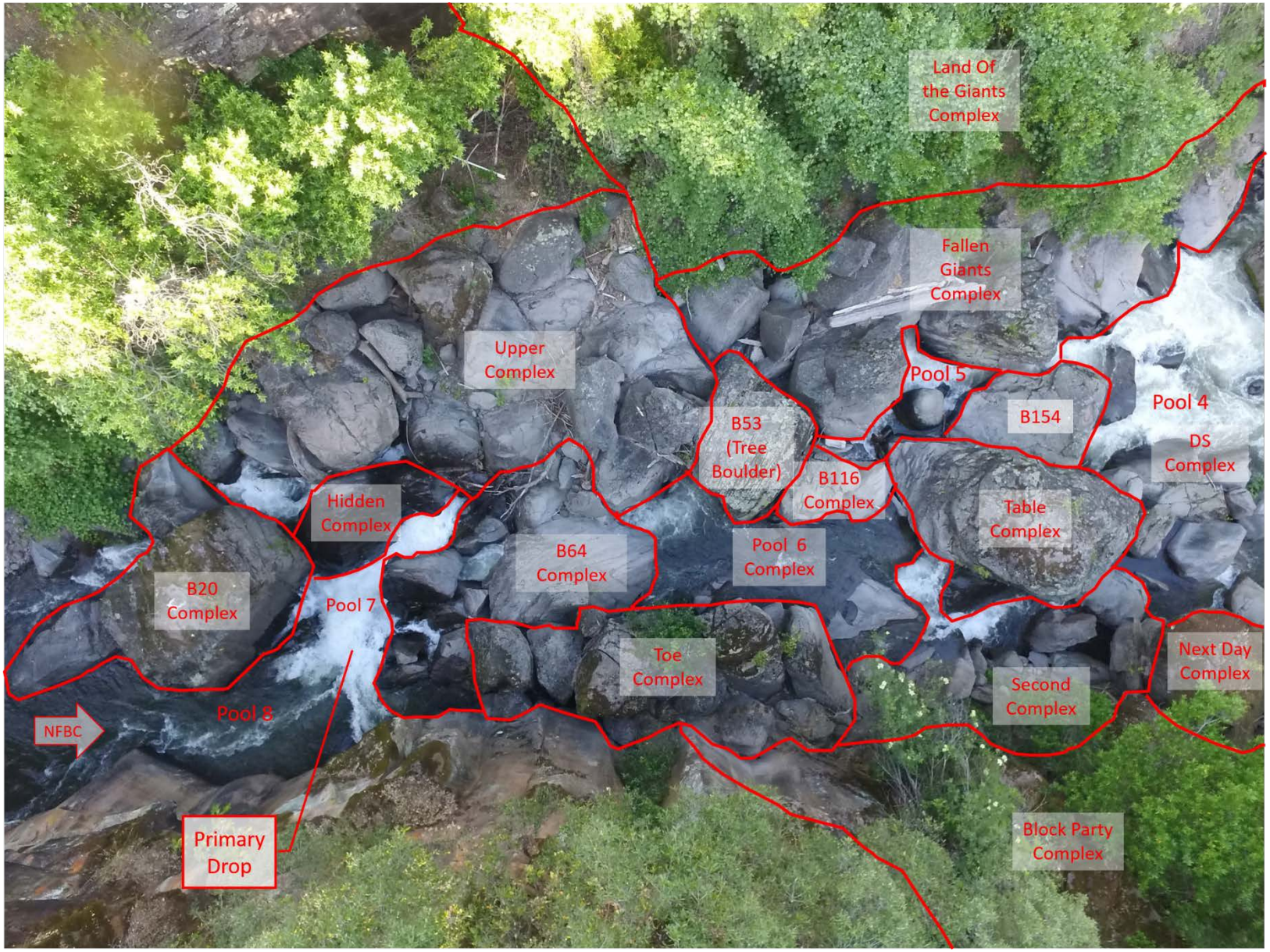



**Figure 3-8. UBS bolder/boulder complexes, upstream. Flow at time of photograph was 195 cfs.**

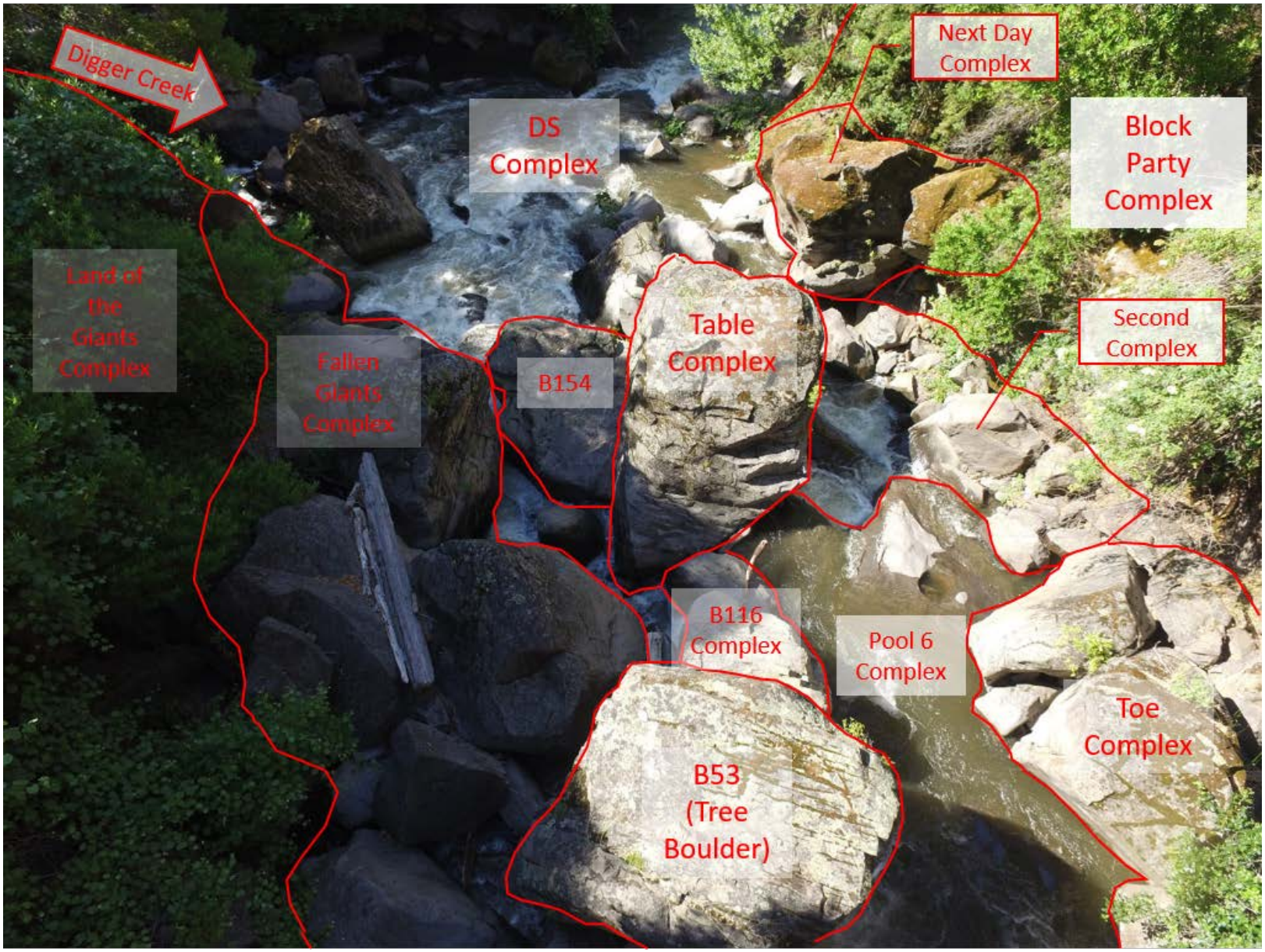



**Figure 3-9. UBS isometric view of boulder/boulder complexes looking downstream when flow 195 cfs.**

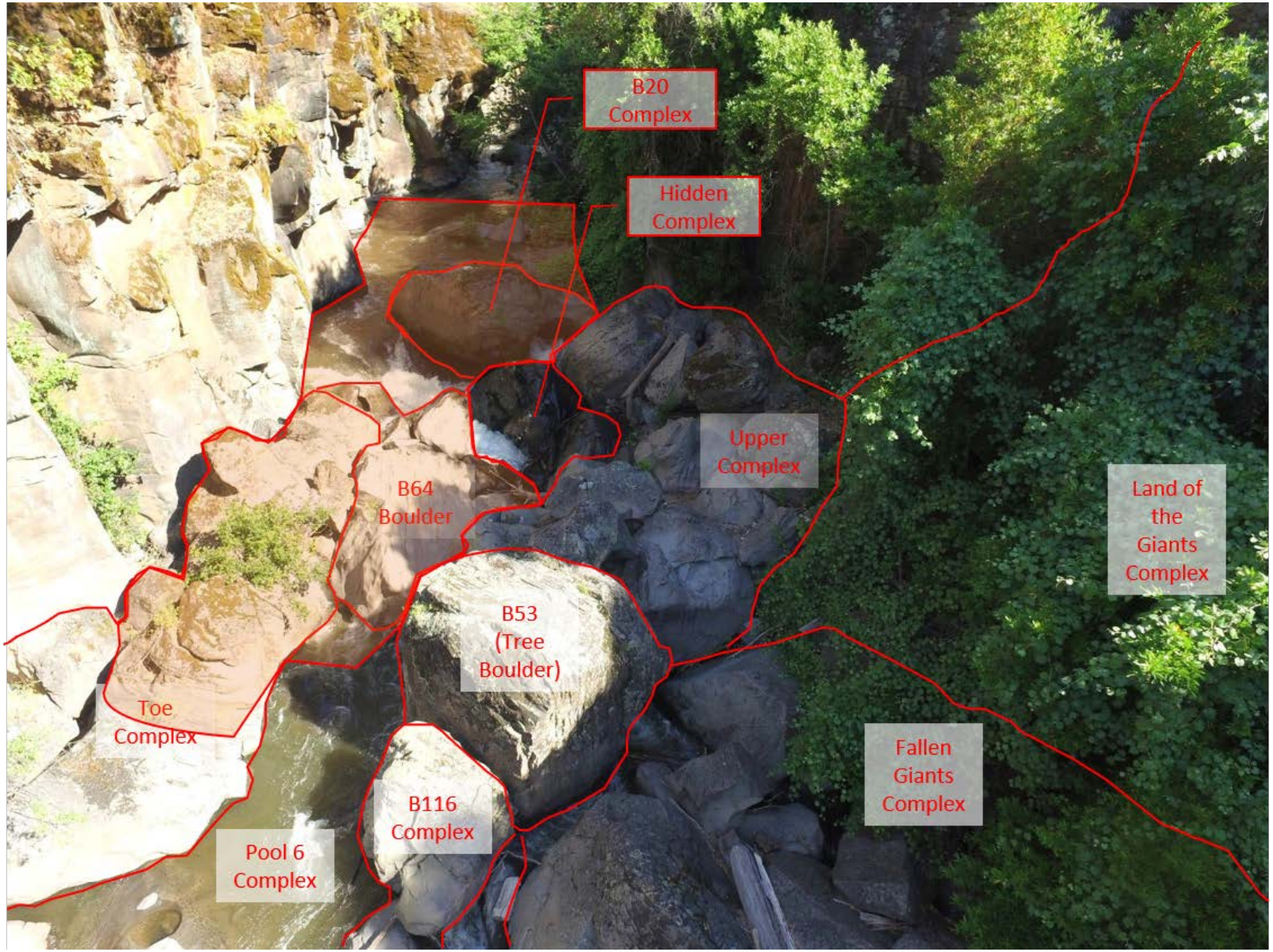



**Figure 3-10. UBS isometric aerial view of boulder/boulder complexes looking upstream when flow 195 cfs.**

### 3.4.3 Mapped Sieves

The UBS has many sieves throughout the reach. These are locations where water flows under the boulders, and is generally hidden from view. The sieves are both large and small. On February 10, 2016, the sieves were mapped at a flow of 87 cfs. On June 7 and 8, 2016, the site was visited from a safe distance due to high flows conditions at 195 cfs, and notes were taken with respect to the sieves. Both dates provided insight into the flow routing through the various sieves and their role in the over hydraulics of the UBS.

In total, 13 sieves have been identified. The sieves have been labeled A through M in Figure 3-11. The red lines indicate the approximate path the flow takes through the sieve, although the precise path for some sieves is unknown. If there is no line associated with a label it indicates that the sieve is directly below the label and that the flow path is short. The following describes each sieve as it is currently understood. See Attachment A, Figures A-6 and A-7, for alignment stations noted in the below descriptions.

- **Sieve A**: A large sieve located on the primary alignment (PA) at station (STA) 1+40 (Figure 3-12 (a)). This sieve conveys all the flow it receives without overtopping the boulders, except at very high flows. Time-lapse camera UB2 captured surging within Pool 5 upstream of Sieve A, but the boulders were not overtopped.

- **Sieve B**: Located beneath the Table Complex and in particular under Boulder B119 (Figure 3-12 (f)). This sieve appears to receive flow from the secondary alignment (SA) at approximately STA S1+60. Although B119 is relatively open to viewing, the flow was not high enough on the February visit to witness the exact path of the flow, and during the June visit, the path was obscured. Regardless, it is believed that this sieve can convey a substantial amount of flow.

- **Sieve C:** The size and path of Sieve C is unknown, but it appears to convey flow at even the lowest of streamflows. A noticeable amount of flow emerges into a perched pool upstream of B199 and then flows over this flat boulder before reentering the main channel.

- **Sieve D:** Located at PA STA 1+60 (Figure 3-12 (b) and (c)), this sieve conveys a substantial portion of the total flow at low and moderate streamflows. The dimensions and configuration of Sieve D are unknown as it has been unsafe to access it, but the ground based survey scans was able to penetrate the opening and provide some insight. The sieve is relatively small and the opening near the water surface is approximately 1.75 feet wide. At higher flows it is assumed the sieve cannot convey the upstream flow and the primary boulder forming the sieve (B123) is overtopped at the contact point with boulders B121 and B120.

- **Sieve E:** At low flows this sieve receives flow from Sieve F, but at moderate flows it is assumed additional flow is received from the pool immediately upstream of Sieve D. Sieve E is slightly larger than Sieve D and is visible in Figure 3-12 (c).

- **Sieve F:** This is a long and narrow sieve located at the toe of the large Tree Boulder (B53) (Figure 3-12 (d)). During the February visit, it was estimated that Sieve F conveyed approximately 10 percent of the flow exiting Pool 6 (Sieve G = 85% and the secondary alignment (SA) = 5%). The upstream end of Sieve F is located at SA STA 1+87.

- **Sieve G:** A large sieve located at the toe of the Tree Boulder (B53) (Figure 3-12 (d)) that conveys a substantial portion of the flow at low and moderate streamflows. Once Pool 6's water level is high enough, water begins to flow down the SA, maintaining a relatively constant water level in Pool 6 and flow through Sieve G. During the February visit, it was estimated that 85 percent of the flow exiting Pool 6 passed through Sieve G. Sieve G is located on the PA at STA 1+85.

- **Sieve H:** Located at PA STA 2+10 (Figure 3-12 (e) and (f)). Sieve H appears to be large in cross sectional area. The sieve is approximately 12 feet long and passes flow from Pool 7 to Pool 6. During the February visit, Sieve H was conveying nearly all the streamflow (87 cfs). During the June visit (195 cfs), a substantial amount of flow was still conveyed by Sieve H, but an nearly equal amount appeared to be conveyed through Sieve I.

- **Sieve I:** Until the June site visit, Sieve I was unknown. Flow in Sieve I disappears and it exact exit point is unknown, but it is currently assumed to exit near the end of Sieve G (Figure 3-12 (f)).

- **Sieve J:** A small sieve separating two of the pools within Pool 7 (Figure 3-12 (f)). Under low flows, Sieve J is dry. During higher flows, the momentum of the flow pushes water directly towards Sieve I's inlet. As the water backs up, it is forced through Sieve J and then flows through Sieve H.

- **Sieve K:** Sieve K is short and conveys water downward to a pool below the boulders of the Upper Complex. Currently is it believed that this flow joins Sieve I.

- **Sieve L:** The first sieve upstream of the primary drop (Figure 3-12 (f)). Water from Pool 8 can flow downward through vertical sieves next to the primary drop and then through Sieve L before make an abrupt left turn and entering Pool 7. Underwater photography indicates that Sieve H is comprised of numerous small openings between a complex of moderate sized boulders rather than on single opening boulders.

- **Sieve M**: As the most upstream sieve, it is located between boulders B20 and B19. The opening is triangle in shape and about 4 feet tall and 2 feet wide at the base. Under low flows, Sieve M is dry. When Pool 8 is elevated, flow begins to enter Sieve M and then pass through Sieve K, or enter Pool 7 under higher flows.

### 3.4.4 Summary of Geophysical Exploration to Estimate Depth to Bedrock

CSA conducted a geophysical exploration of the subsurface conditions at the UBS using Refraction Microtremor (ReMi) technology (CSA, 2016). In total, two ReMi lines (RM1 and RM2) were deployed parallel to the channel: one adjacent to the primary drop at the upstream end of the study reach and the other located adjacent to Pool 1 at the downstream end of the study reach.

RM1 began upstream of the primary drop and extended downstream, across from Pool 6. CSA's interpretation of the results from this ReMi line indicate that weathered bedrock is approximately 5.6 feet below ground at the mid-point of the line, located a short distance upstream of the primary drop and boulder B20. This would place bedrock at approximately elevation 1485.5 feet. This elevation matches the existing pool bottom elevation at Pool 8, immediately upstream of the primary drop.

RM2 was located along the right bank adjacent to Pools 1, 2, and 3. CSA concluded that the top of weathered bedrock at the center of this line was approximately 8.6 feet below the ground surface, at elevation 1469. The pool bottom elevation in adjacent Pool 1 is at approximately the same elevation.

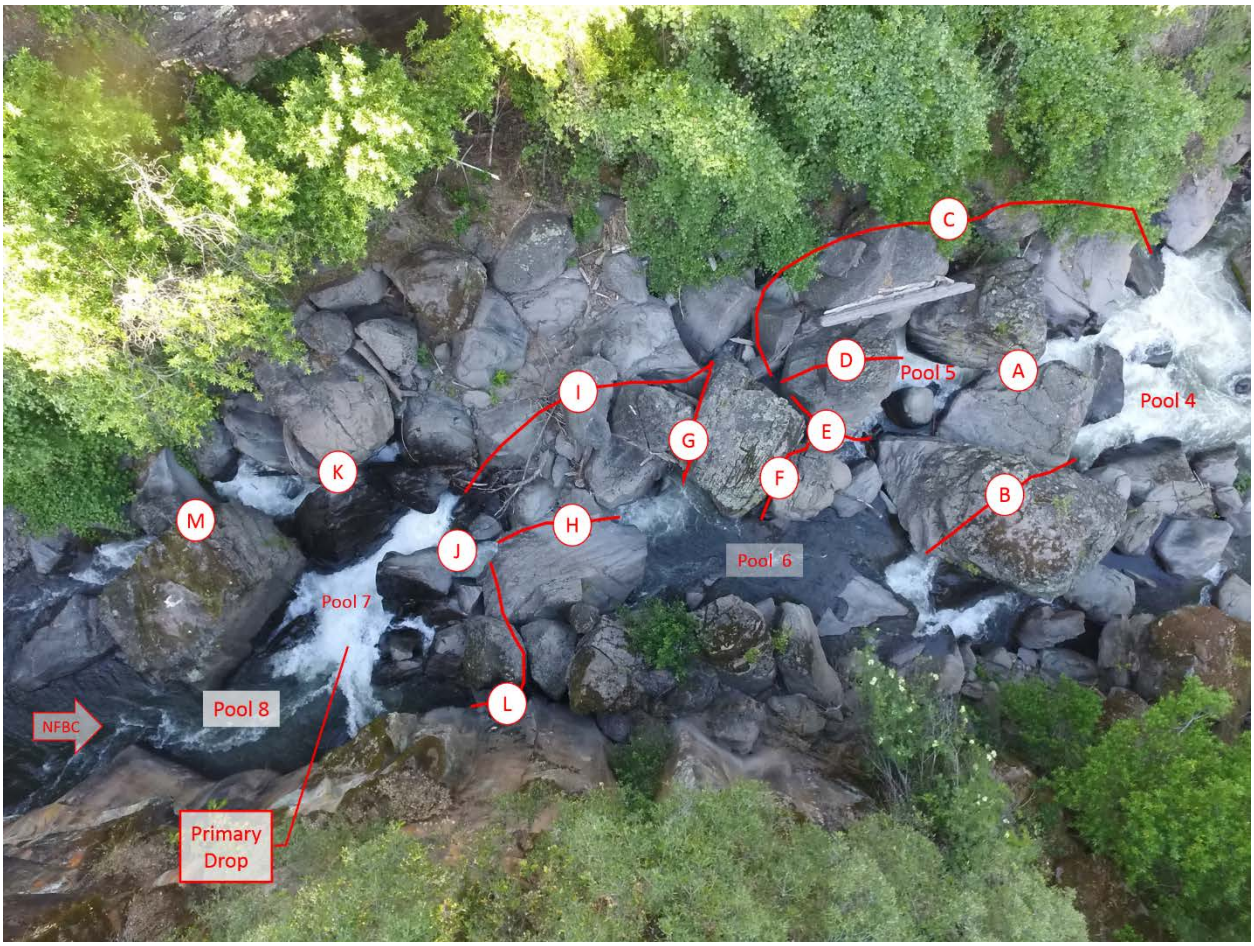



**Figure 3-11. UBS sieve map with approximate flow alignments. Aerial photograph taken on June 8, 2016 during 195 cfs flow event.**

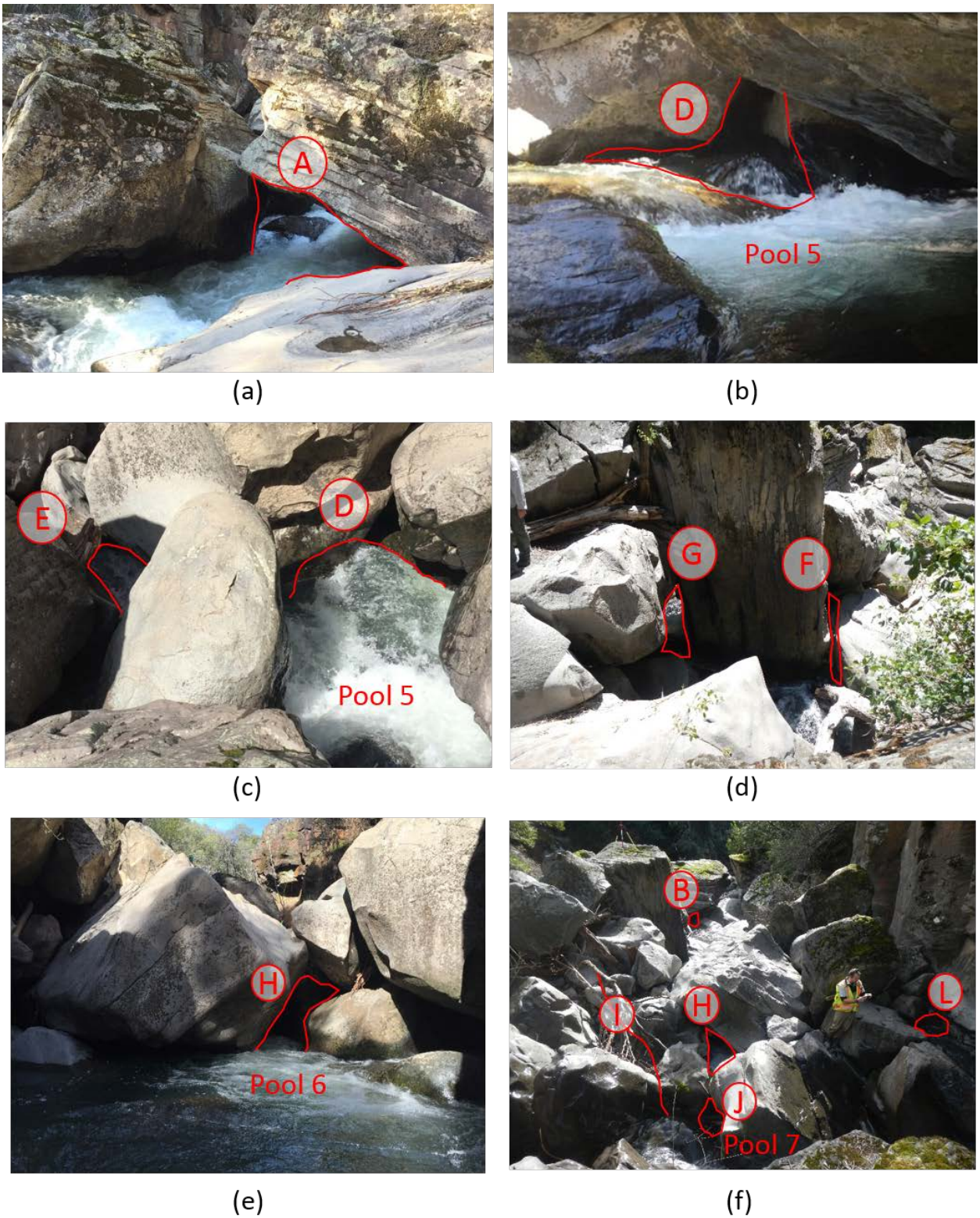



**Figure 3-12. Photographs of UBS sieves: (a) Sieve A, NFBC flow 87 cfs (b) Sieve D, NFBC flow 17 cfs (c) Sieves D and E, NFBC flow 87 cfs (d) Sieves G and F, NFBC flow 17 cfs (e) Sieve H, NFBC flow 87 cfs (f) Sieves B, H, I, and L, NFBC flow 87 cfs.**

# 4 FISH PASSAGE PERFORMANCE CRITERIA

This section identifies the fish passage assessment criteria used in conjunction with the existing hydraulic conditions characterization to conduct the existing fish passage assessment for the LBS and UBS. The following sub-sections identify the fish passage assessment criteria used with respect to swimming abilities, leaping abilities, pool depth, and turbulence for the target fish species and life stage.

## 4.1 Target Fish Species and Life Stage

Historically, NFBC supported steelhead and all four runs of Chinook: winter-, spring-, fall-, and late fall-run. This project is intended to improve upstream passage conditions for adult anadromous Chinook salmon and steelhead trout that are expected to migrate from the ocean to NFBC, and attempt to pass through the LBS and UBS to use upstream spawning habitat.

The returning steelhead, listed as threatened by Federal Endangered Species Act (ESA) are from the California Central Valley (CCV) steelhead Distinct Population Segment (DPS) as defined by NMFS (2014). The returning winter-run Chinook, listed as endangered by both state and federal ESAs, are within the Sacramento River winter-run Chinook Evolutionarily Significant Unit (ESU) as defined by NMFS (2014). The returning spring-run Chinook, listed as threatened under state and federal ESAs, are within the spring-run Chinook ESU as defined by NMFS (2014). Fall- and late fall-run Chinook are currently listed as a species of concern under the federal ESA.

The target species and life stages for this Project include steelhead and Chinook adults. Juvenile upstream passage is not considered. Where appropriate, downstream passage of juvenile or steelhead kelts will be discussed.

## 4.2 Migration Timing

Timing of salmon and steelhead migration in the Sacramento River tributaries is summarized in Table 4-1, along with general timing for spawning and rearing. The migration period for spring and winter Chinook and steelhead trout, the three focus races and species of salmonids for this project, have migration periods that overlap and extend throughout the entire year. Therefore, the hydrology throughout the entire year should be considered when evaluating fish passage flows.

## 4.3 Fish Size

The swimming ability of a fish is often directly related to the size, or length, of the fish. USFWS provided the size of adult wild spring run Chinook (*Oncorhynchus tshawytscha*) and steelhead/rainbow trout (*Oncorhynchus mykiss*) returning to Battle Creek. These measurements were taken from fish trapped, measured, and passed over the Coleman Fish Hatchery weir between 2001 and 2016. A histogram and cumulative frequency curve of the spring-run Chinook and steelhead are provided in Figure 4-1 and Figure 4-2. The provided data for *O. mykiss* appeared to include both adult resident rainbow trout and anadromous steelhead. Therefore, a cutoff of 16 inches (40 cm) was used to differentiate between adult resident (less than 16 inches) and anadromous forms of the fish. The data was provided in fork length, but much of the fish swim speed literature uses total length. Therefore, fork length was converted to total length using ratios provided in FishBase (Froese and Pauly, 2016). They reported the ratio of total length-to-fork length as 1.03 and 1.02 for Chinook and steelhead, respectively.

**Table 4-1. Seasonal occurrence of select life stages of anadromous salmonids in the Upper Sacramento River, from Ward and Kier (1999), based on Schafter (1980) and Vogel and Marine (1991)**

| Life Stage | Species | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. |
| Adult Migration | Winter Chinook | | | | X | | | | | | | | |
| | Spring Chinook | | | | | X | | | | | | | |
| | Fall Chinook | | | | | | | | | | X | | |
| | Late-Fall Chinook | X | | | | | | | | | | | |
| | Steelhead | | | | | | | | | | | | |
| Spawning | Winter Chinook | | | | | | X | | | | | | |
| | Spring Chinook | | | | | | | | | X | | | |
| | Fall Chinook | | | | | | | | | | | X | |
| | Late-Fall Chinook | | X | | | | | | | | | | |
| | Steelhead | | | | | | | | | | | | |
| Juvenile Residence | Winter Chinook | | | | | | | | | | | | |
| | Spring Chinook | | | | | | | | | | | | |
| | Fall Chinook | | | | | | | | | | | | |
| | Late-Fall Chinook | | | | | | | | | | | | |
| | Steelhead | | | | | | | | | | | | |

X = Denotes approximate peak of life stage if a significant peak occurs.

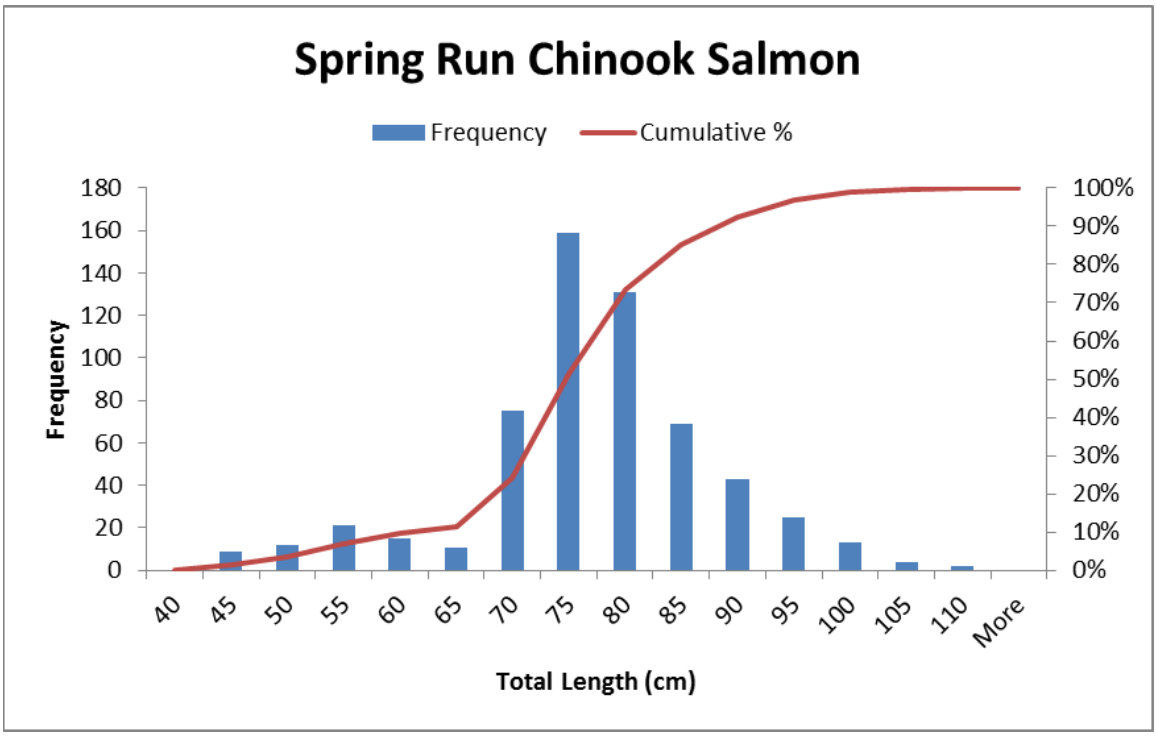



**Figure 4-1. Length of wild spring-run Chinook salmon captured and released upstream of the Colman Fish Hatchery weir on Battle Creek.**

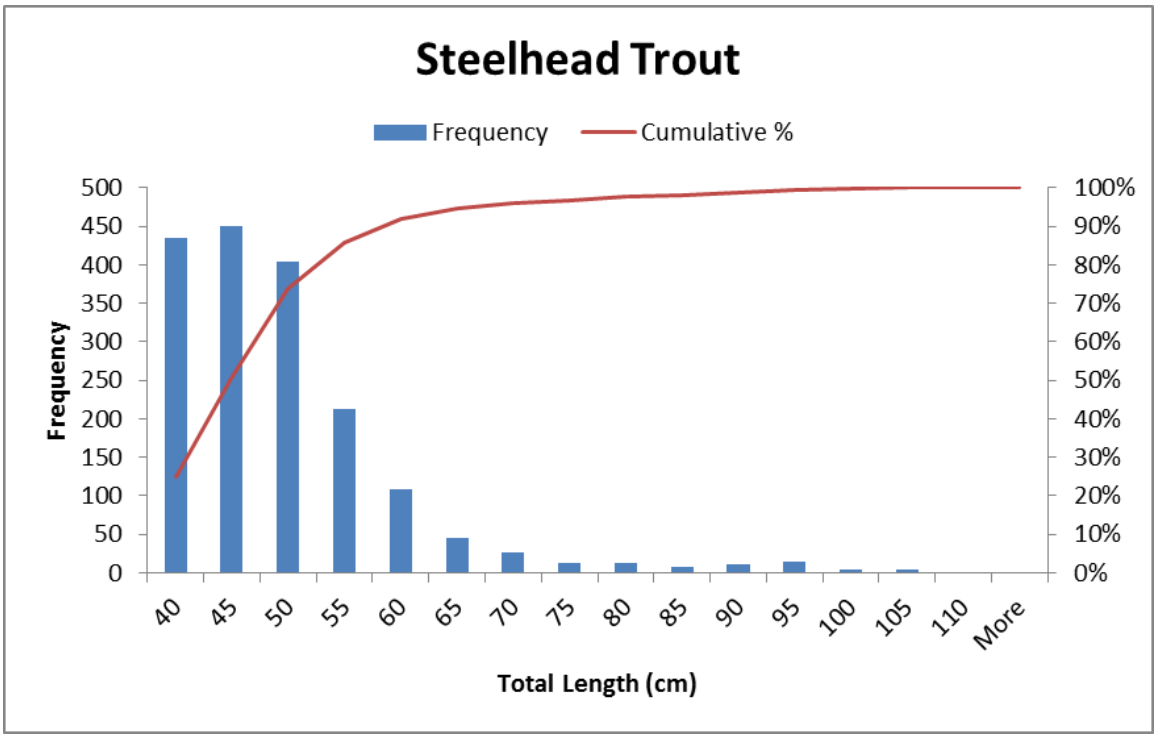



**Figure 4-2. Length of presumed anadromous steelhead captured and released upstream of the Colman Fish Hatchery weir on Battle Creek. A minimum length of 40 cm was used to differentiate between adult resident and anadromous trout.**

## 4.4 Minimum Depth for Swimming

The current scope of work recommends minimum water depth over features (i.e. weirs) of 0.5 feet. For longer distances, such as through a chute or bypass channel, the minimum water depth is typically defined as the flow sufficient to submerge the fish's body. This requires an estimate of the fish body depth (excluding fins). *FishBase* (Froese and Pauly, 2012) used photographs to develop a morphometric relationship of total fish length-to-body depth of 0.215 for Chinook and 0.228 for steelhead. Table 4-2 provides calculated body depths for various lengths of Chinook and steelhead.

**Table 4-2. Typical body depth of Chinook and steelhead based on fish length (Froese and Pauly, 2012)**

| Fish Length | | Chinook Body Depth (inches) | Steelhead Body Depth (inches) |
|---|---|---|---|
| (inches) | (cm) | | |
| 18 | 46 | 3.9 | 4.1 |
| 22 | 56 | 4.7 | 5.0 |
| 24 | 61 | 5.2 | 5.5 |
| 26 | 66 | 5.6 | 5.9 |
| 28 | 71 | 6.0 | 6.4 |
| 30 | 76 | 6.5 | 6.8 |
| 34 | 86.36 | 7.31 | 7.8 |
| 38 | 96.52 | 8.17 | 8.7 |

## 4.5 Adult Anadromous Salmonid Swimming Abilities

Fish swimming abilities are often broken into three categories: sustained (cruising), prolonged, and burst (sprinting or darting). Bell (1991) defined three categories as the following:

- Sustained – a speed that can be maintained for a long period of time (hours),
- Prolonged – a speed that can be maintained for minutes, and
- Burst – a single effort, not sustainable for more than seconds

CDFW, per the current scope of work for this project, recommends a maximum water velocity of 4 feet per second (fps) for any proposed fish passage facilities at the LBS and UBS. This water velocity is considered conservative and aimed at passage of weaker individual fish swimming at prolonged speeds for a distances between 100 and 200 feet (CDFG, 2002). However, the current task is to evaluate existing fish passage conditions at the sites. Therefore, published swim speed and time to fatigue (exhaustion) data was reviewed to establish the range of swimming abilities among the population of the two species of adult anadromous salmonids, Chinook salmon and steelhead trout.

### 4.5.1 Adult Chinook Swim Speeds

Bell (1991) provided a range of swim speeds for Chinook salmon, with the a mean swim speeds reported as follows: sustained speed of 2 fps, prolonged speed of 7.5 fps, and burst speed of 16 fps. Hunter and Mayor (1986) developed swim speed equation using data from Weaver (1963) for burst swim speed ($V_{Burst}$) of Chinook salmon in meter/second (m/s):

$$V_{Burst} = 11.49 L_{TL}^{0.32} t^{-0.5}$$ **Equation 4-1**

Where; $L_{TL}$ = Total Fish Length (m)
$t$ = time to exhaustion (s)

Time to exhaustion for the swim speeds used to develop this equation ranged from 1.9 to 5.2 seconds. The data was derived from swim tests with both wild and hatchery Chinook salmon. A plot of burst swim speeds for various times to exhaustion and fish lengths are plotted in Figure 4-3 for Chinook salmon. These curves may be used to evaluate passage through short challenging sections within Eagle Canyon where burst swimming is most applicable.

Geist et al. (2003) performed critical swim speed tests on adult Chinook salmon and reported a mean prolonged swim speed of 5.1 fps with a standard deviation of 0.7 fps. The mean fish length was 75.5 cm, similar to the mean length of the spring-run Chinook in Battle Creek. Therefore, a prolonged swim speed of approximately 5 fps seems reasonable for assessing passage success through challenging sections that are too long to be passable using burst swimming.

### 4.5.2 Adult Steelhead Swim Speeds

Bell (1991) provided a range of swim speeds for steelhead (fish lengths of 2.0 to 2.7 feet), with a mean swim speeds reported as follows: sustained speed of 2.5 fps, prolonged speed of 10 fps, and burst speed of 21 fps. Hunter and Mayor (1986) developed swim speed equation using a combination of data for burst swim speed of adult steelhead in m/s:

$$V_{Burst} = 12.81 L_{TL}^{1.07} t^{-0.48}$$ **Equation 4-2**

A plot of burst swim speeds for various times to exhaustion and fish lengths are plotted in Figure 4-4 for steelhead. Note that the steelhead burst speeds and swim times used by Hunter and Mayor were from tests where the fish did not reach exhaustion. For this reason, this swim speed equation likely under-predicts burst swimming abilities. Therefore, it may be more appropriate to apply the Chinook burst swim speed curves to evaluating existing passage conditions for steelhead at the LBS and UBS of Eagle Canyon.

Paulik et al. (1957) tested prolonged swimming abilities of 21 wild steelhead from Soos Creek, near Seattle, Washington. MLA (2007) utilized the fish size, swim speed, and time to fatigue from this study to develop the following prolonged swim speed equation:

$$U_S = \frac{6.466 - \ln(t)}{0.487}$$ **Equation 4-3**

Where:

$U_S$ =Swim speed in body lengths per second
$t$ = time to exhaustion (s)

Equation 4-3 could be used to evaluate steelhead passage conditions where the distances are too long to utilize burst swimming mode.

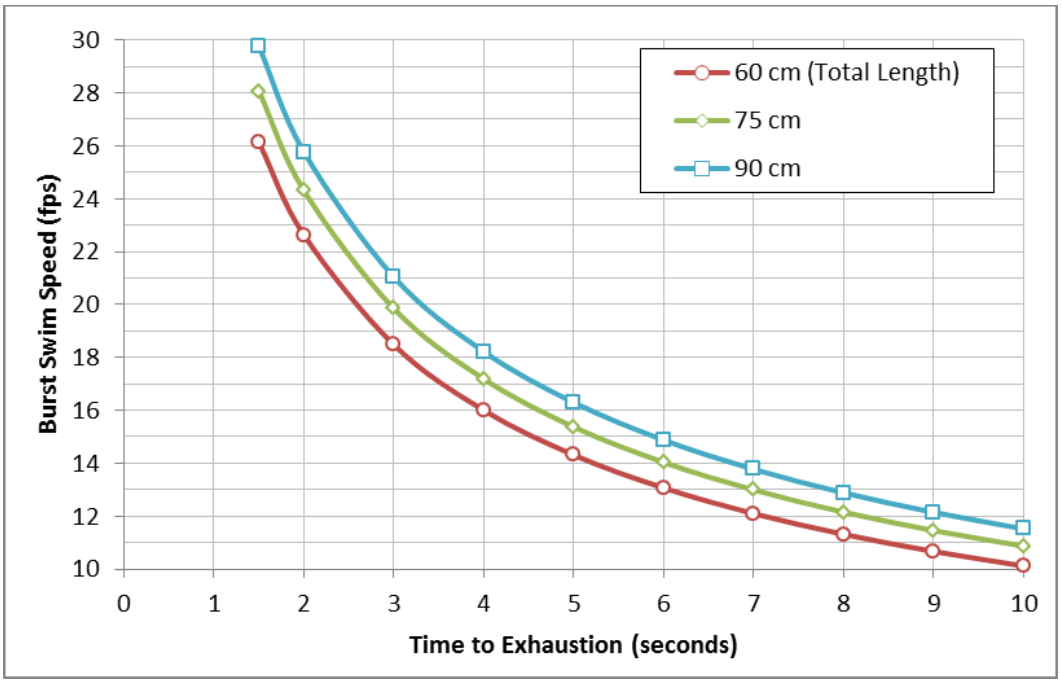



**Figure 4-3. Chinook salmon maximum swim speed verses time to exhaustion for various lengths of fish, calculated using equation developed by Hunter and Mayor (1986).**

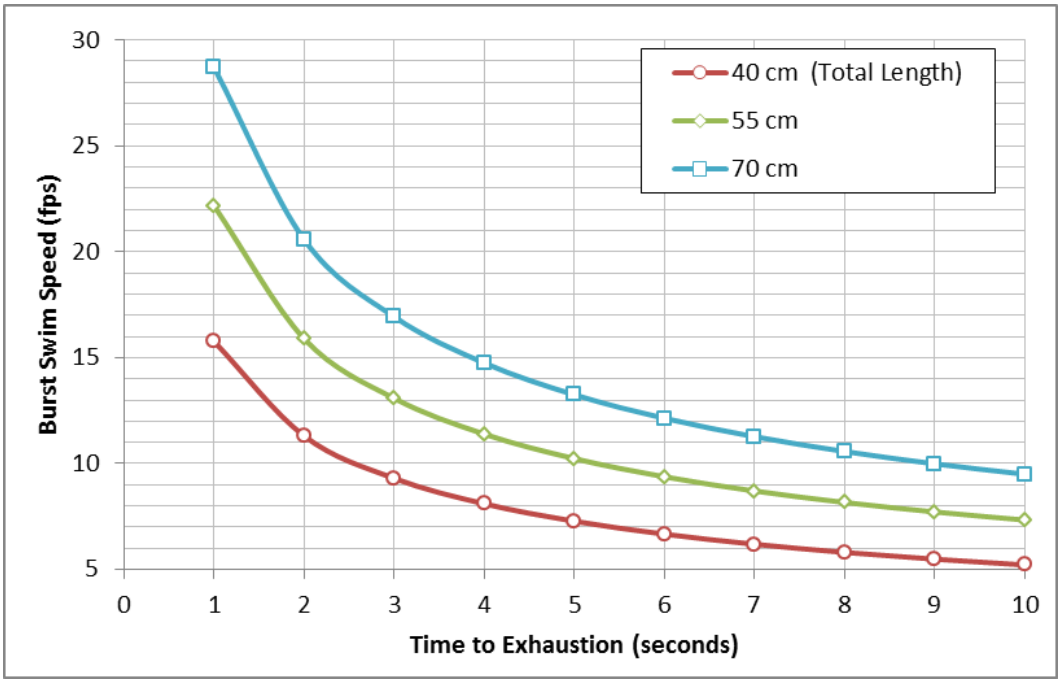



**Figure 4-4. Steelhead trout maximum swim speed verses time to exhaustion for various lengths of fish, calculated using equation developed by Hunter and Mayor (1986).**

### 4.5.3 Routing Fish through High Velocities using 2-D Model Results

To evaluate the size of fish able to pass through a section of channel with high velocities, the swim speed equations may be combined with 1-D or 2-D hydraulic results. In the event of 2-D model results, a swimming route is selected that has sufficient depth. Then the water velocities at each node along that route are exported. A fish routing model is then used following methods outlined by Castro-Santos (2006) to swim the fish from node to node along its route. The cumulative percent of exhaustion is summed along the route. If the fish is able to swim the entire route without exceeding 100% exhaustion, then passage is successful for that size of fish. The variables in this analysis are the size (body length) of the fish and the time to exhaustion used in the swim speed equation, which may vary from node to node. In the analysis used for this project, the time to exhaustion was optimized between each node, such that the percent exhaustion was minimized.

Although this method provides a quantitative analysis of fish swimming through challenging features, it does not account for extreme turbulence and aeration of the water column that can produce barriers. These conditions should be given ample consideration when analyzing passage.

## 4.6 Leaping Abilities

The scope of work recommends maximum water surface drops over features of 1 foot. However, the natural channel has numerous drops exceeding 1 foot. Therefore, to evaluate existing passage conditions where there are water surface drops that a fish would attempt to leap over, methods outlined by Powers and Osborn (1985) are utilized. This method uses projectile physics to determine if a fish can leap over a specific drop. The speed the fish leaps combined with the angle it exits the water determines how far vertically and horizontally it travels in the air. For estimating the maximum speed a Chinook and steelhead can leap out of the water, a minimum time to exhaustion of one second is used in the burst swim speed equations to arrive at the maximum burst speed. Powers & Osborn recommends using a coefficient of fish condition of 0.75 for fish that have traveled some distance from the ocean. Common leap angles are between 60 and 85. In conditions that require lower angles, the hydraulics are more of a chute than a free surface drop and fish tends to swim rather than leap over the feature.

Based on observed conditions at the LBS and UBS, the features that challenge fish passage are best described as chutes rather than discrete free-surface drop in the water. Therefore, it is believed that fish will attempt to swim up these chutes rather than leap over them. If conditions are discovered that would likely initiate leaping behavior of the fish rather than swimming, than the method described above and by Powers and Osborn (1985) should be used to evaluate existing passage conditions.

## 4.7 Pool Depth for Leaping

In general, a pool used for leaping should be deep enough to accommodate the body length of the fish as it angles upward to leap out of the water, and should have sufficient volume to dissipate the energy of the plunging flow without becoming excessively turbulent. A common minimum pool depth criterion in pool- and-weir style fish ladders is 2 feet (CDFG, 2002); however, this depth is based on water surface drops of 1 foot or less. An extensive literature search into pool depth requirements was conducted as part of developing the FishXing software to evaluate fish leaping conditions at culvert outlets (USFS, 2006). The literature search found relatively little information regarding adequate pool depth for leaping verses water surface drop. Aaserude and Orsborn (1985) suggest that the pool depth for leaping be (1) deeper than the penetrating depth of the falling water

(nappe), and (2) on the order of, or greater than, the length of the fish attempting to pass. Unfortunately, predicting the depth of penetration is not practical in most situations due to the numerous variables involved. Lauritzen (2002) studied leaping success of Kokanee salmon (*Oncorhynchus nerka*) attempting passage over varying drop heights, and found a significant relationship between leaping success and the ratio of the pool depth to drop height. The ratio that best supported leaping varied between 0.6 and 1.2, with higher drops having smaller ratios.

Based on this information, and best professional judgment, the minimum pool depth criteria applied to this project for evaluating fish passage conditions is as follows:

> A minimum pool depth-to-drop height ratio of 0.6, but not shallower than 3.0 feet deep (36 inches), which is the approximate length of a large steelhead and Chinook.

### 4.8 Turbulence

Turbulence is the fluctuation in water velocity and flow direction in a localized area, usually below hydraulic drops or associated with roughness elements. Turbulence is a primary means of energy dissipation. High levels of turbulence, combined with air entrainment, can disorient fish and create a passage barrier. The effect of turbulence varies with the size of fish relative to the scale of turbulence. In standard pool and weir fishways, the Energy Dissipation Factor (EDF) is a common metric of turbulence in the pools. This is the calculated rate energy is dissipated per volume of water within the pool. The threshold criteria for this metric, EDF less than 4 foot-pounds per second per cubic foot (ft-lb/s/ft$^3$), was developed in fishways with water surface drops of less than 2 feet. This EDF threshold is not considered applicable at locations with larger drops, likely due to scaling factors that are not well understood. For example, at natural falls where steelhead frequently ascend, EDF can far exceed 10 ft-lb/s/ft$^3$.

Another turbulence metric, for which there is a growing body of literature, is Turbulent Kinetic Energy (TKE), which is the temporal variance in velocity at a point. TKE can only be measured in the laboratory or field, and cannot be calculated for a proposed design. At this time, there is a lack of study relating the interactions of fish with the TKE metric. TKE fails to describe the size, strength, or orientation of eddies, all of which could presumably affect fish swimming ability and/or behavior.

Given the lack of a suitable metric for evaluating turbulence on fish passage in NFBC, a qualitative approach was applied that relies on professional judgment and an understanding of passage conditions that steelhead and Chinook commonly ascend within natural channels.

## 5 HYDROLOGY AND FISH PASSAGE FLOWS

Previous studies (Ward and Keir, 1999; DWR, 2000; USBR 2001) have provided detailed description of the watershed and hydrology. Provided here is a brief description of existing hydrologic data sources, hydrologic findings previously reported for Battle Creek, the minimum instream bypass flow agreement for PG&E facilities, definitions of the peak flows for use in project development, and an introduction to potential fish passage migration flows for use in evaluating existing and proposed fish passage conditions.

### 5.1 Available Hydrologic Data Sources

Figure 3-2 (page 7) presented the location of active and historical streamflow gages within the watershed. Table 5-1 lists the metadata for the flow gaging stations used to evaluate hydrologic conditions at the LBS and UBS as part of this project. Additionally, the stage-discharge rating table

for the BNF gage was obtained from DWR. During field visits in water year (WY) 2016, manual stage readings were made at the existing BNF stage plate to estimate flows. The stream bed at the location of the BNF gage is comprised of boulders and appears relatively stable, suggesting that only minimal shifts in the rating table may have occurred since station maintenance was discontinued in September 2015.

## 5.2 Fraction of Flow Contributing to USGS Coleman Fish Hatchery Gage

The USGS streamflow gaging station 11376550 at Coleman Fish Hatchery, located near the confluence of Battle Creek with the Sacramento River, is the only long-term stream gage on Battle Creek, operating from Water Year 1962 to present. Ward and Keir (1999) estimated the fraction of flow contributed from the North Fork Battle Creek (NFBC) and South Fork Battle Creek (SFBC) to the total flow recorded at the USGS Coleman gage. DWR (2000), based on discussions with PG&E, updated these fractions.

USBR (2001) expanded upon the earlier work to update the flow fractions and to define the flow fractions at several additional locations beyond the confluence of the two forks. These include at the North Battle Creek Feeder (NBCF) Dam, Eagle Canyon Dam, and Wildcat Dam (now removed). USBR did additional analysis and concluded that South Fork Battle Creek (SFBC) experiences higher peak flows than NFBC even though it has a smaller drainage area. However, in terms of long term average flows the NFBC contributes a greater portion of the flow. They recommended using the DWR flow fractions for annual average flows and developed flow fractions for high flow events (Table 5-2).

## 5.3 Historical Flow Conditions

As part of developing fish passage improvements for PG&E facilities throughout Battle Creek, PG&E provided DWR with estimates of flows and diversion rates during typical, wet and dry year conditions. These flows are provided in Attachment D. Note that these flows do not represent future conditions, when the in-stream flow agreement is implemented (see discussion in Section 5.4). However, they provide insight into the range and magnitude of monthly average flows that occur at Feeder Dam, upstream of the UBS, and at Eagle Canyon Dam.

**Table 5-1. Streamflow gages on Battle Creek and North Fork Battle Creek utilized as part of this project.**

| Operator/ Station ID | Station Name | Drainage Area | Available Records | Period of Record (WY) | Notes |
|---|---|---|---|---|---|
| USGS 11376550 | BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA | 357 $mi^2$ | Daily Average 15 min. Annual Peak | 1962 to present | Downstream of NFBC and SFPC confluence |
| DWR BNF | North Fork Battle Creek | 191.5 $mi^2$ | Daily Average | 10/21/1999 to 9/30/2015 | 2015 rating table used for spot estimations of flows in 2016 based on staff readings |
| PG&E* 11376160 | NF BATTLE C BL DIV TO WILDCAT CN NR MANTON CA | 188 $mi^2$ | Daily Average | 1984 to 2015 | Low-flow gage only. Max. flow reported is 60 cfs |
| PG&E BTW | NF BATTLE CK BLW DIV TO WILDCAT CANAL | | Hourly | Starting Jun. 1, 2016 | Instantaneous data placed on CDEC. Includes high flows. |
| PG&E* 11376150 | NF BATTLE C BL DIV TO EAGLE CY CN NR MANTON CA | 186 $mi^2$ | Daily Average | 1984 to 2015 | Low-flow gage only. Max. flow reported is 50 cfs |
| PG&E* 11376140 | NF BATTLE C BL DIV TO XCOUNTRY CN NR MANTON CA | 133 $mi^2$ | Daily Average | 1984 to 2015 | Flow below North Battle Creek Feeder Dam. Max. flow reported is 39 cfs Numerous gaps. |

* Data reviewed by USGS annually. Approved data is placed on USGS server.

**Table 5-2. Flow fractions for annual average flow and high flows at various points within Battle Creek (USBR, 2001).**

| Data | Coleman | NFBC | SFBC | Wildcat | Eagle Canyon Dam | Feeder Dam |
|---|---|---|---|---|---|---|
| **Drainage Area ($mi^2$)** | 357 | 212.8 | 123.6 | 189 | 186 | 133 |
| **Annual Average Flow Fraction** | 1.0 | 0.53 | 0.47 | 0.53 | 0.53 | 0.44 |
| **High Flow Fraction** | 1.0 | 0.38 | 0.60 | 0.38 | 0.38 | 0.32 |

## 5.4 Minimum Instream Bypass Flows

In February 1999, the National Marine Fisheries Service, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, California of Department of Fish and Game, and Pacific Gas and Electric Company entered into a Memorandum of Understanding (MOU). The MOU outlined the roles and responsibilities regarding actions that to be undertaken as part of the Battle Creek Chinook Salmon and Steelhead Restoration Project. Amongst other details, the MOU outlined minimum instream flow releases below the various diversion dams within the anadromous reaches of North and South Forks of Battle Creek. Table 5-3 presents minimum instream flow releases at Feeder Dam and Eagle Canyon Dam by month. Currently, PG&E is operating under interim instream flow requirements, but generally operates to provide the MOU prescribed minimum instream bypass flow below Eagle Canyon Dam.

There is limited to no flow contributions between the Feeder Dam and the UBS. Therefore, the flow at UBS is generally equal to the flow bypassing the Feeder Dam, except during rainfall-runoff events. Once the instream flow agreement is fully implemented, all flow will be bypassed over the Feeder Dam when the available streamflow is equal to or less than the minimum instream bypass flow. PG&E provided the Feeder Dam daily average flow records for extreme drought years of WY2014 and WY2015. These records were evaluated to characterize future low-flow conditions at the UBS. They showed that the lowest streamflow arriving at Feeder Dam was in September of 2015, at 32 cfs. Otherwise, available flow at Feeder Dam generally remained above 40 cfs. Therefore, even during drought years, low-flows at the UBS will likely remain at or above 32 cfs.

**Table 5-3. Minimum instream flow releases by month for the Feeder Dam upstream of the UBS and Eagle Canyon Dam upstream of the LBS (from the 1999 MOU).**

| | Minimum Instream Bypass Flow (cfs) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diversion Dam | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| NBCF[1] | 88 | 88 | 67 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 88 |
| Eagle Canyon[2] | 46 | 46 | 46 | 46 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 46 |

1. On occasion the release is not attainable due to the quantity of inflow reaching the dam. Additional inflows to the North Battle Creek Feeder reach are occasionally received from the junction box of the Volta 2 Powerhouse Tailrace and Cross-Country Canal a short distance downstream.

2. Eagle Canyon Dam releases reported on this table include releases from Eagle Canyon Springs (the springs located downstream of Eagle Canyon Dam).

The Eagle Canyon Dam minimum instream flow requirements include an estimated 10 cfs contribution from the Eagle Canyon Springs, which discharges from the south canyon wall downstream of the dam (DWR, 2000). Therefore, instream flows are monitored at the Wildcat gaging station, located downstream of the springs and the LBS. Based on field observations, it appears most of the spring-derived inputs occur upstream of the LBS. Therefore, flows at the LBS are approximately equal to streamflows recorded at the Wildcat and BNF gages. Records indicate

that flows currently remain at or above the minimum instream bypass flows shown in Table 5-3, even during drought years.

## 5.5 Fish Passage Flows and Migration Delays

Fish passage assessment and design flows should be coincident with the range of flows utilized for upstream movement by the target species/lifestage, which includes winter and spring run Chinook salmon and steelhead. Winter and spring run Chinook salmon typically hold within the stream for weeks or months prior to spawning. Therefore, high-flow migration delays short to moderate in duration may result in no impact on the location or timing of their spawning. This is especially true in spring-fed and snow-melt driven systems such as NFBC, where suitable migration conditions persist for extended periods. A CDFW biologist stated in meeting notes from 12/7/1999 (provided in DWR (2000)) that among the target species, a high-flow migration delay impacts steelhead spawning the most.

Migration delays due to low flows may have more substantial impacts on timing and location of spawning, as low flows often persist over extended periods. Therefore, looking at minimum instream bypass flows and low-flow records may provide guidance on selecting an appropriate low passage flow for assessment and design.

The following describes previous analysis conducted to identify acceptable fish passage design flows on NFBC at several other project facilities.

### 5.5.1 3-Day High-Flow Migration Delay

Previous efforts to define a high fish passage design flow for PG&E passage facilities on Battle Creek included an evaluation of potential multi-day high-flow migration delay. An analysis completed by DWR (2000) examined maximum annual 3-day high-flow events calculated using daily average flow records from the USGS Coleman gage, scaled by drainage area and other unspecified factors. The flow magnitudes associated with various return periods were calculated using the annual maximum three consecutive day flow event (Figure 5-1). It is unclear if the influence of the flow diversion on the maximum annual 3-day high-flow was accounted for in this analysis.

### 5.5.2 Feeder Dam Fish Passage Design Flows

DWR (2000) selected a high passage design flow for the Feeder Dam based on the 10-year 3-day maximum annual flow. The estimated 10-year, 3-day maximum discharge for the Feeder Dam is 1,100 cfs (Figure 5-1). At this design flow the fishway is intended to convey at least 10% of the total flow.

The minimum in-stream bypass flow for the Feeder Dam is 47 cfs. However, gaging records indicate that flows can frequently be less than 47 cfs during the dry season (Attachment D); no flows will be diverted under these conditions.

The selected pool and chute fishway at the Feeder Dam may operate at flows as low as 4 cfs, if both orifices in each weir are closed-off. At flows below 20 cfs, at least one of the orifices at the bottom of each weir should be closed-off to maintain some flow over the weirs and prevent draining of the pools.

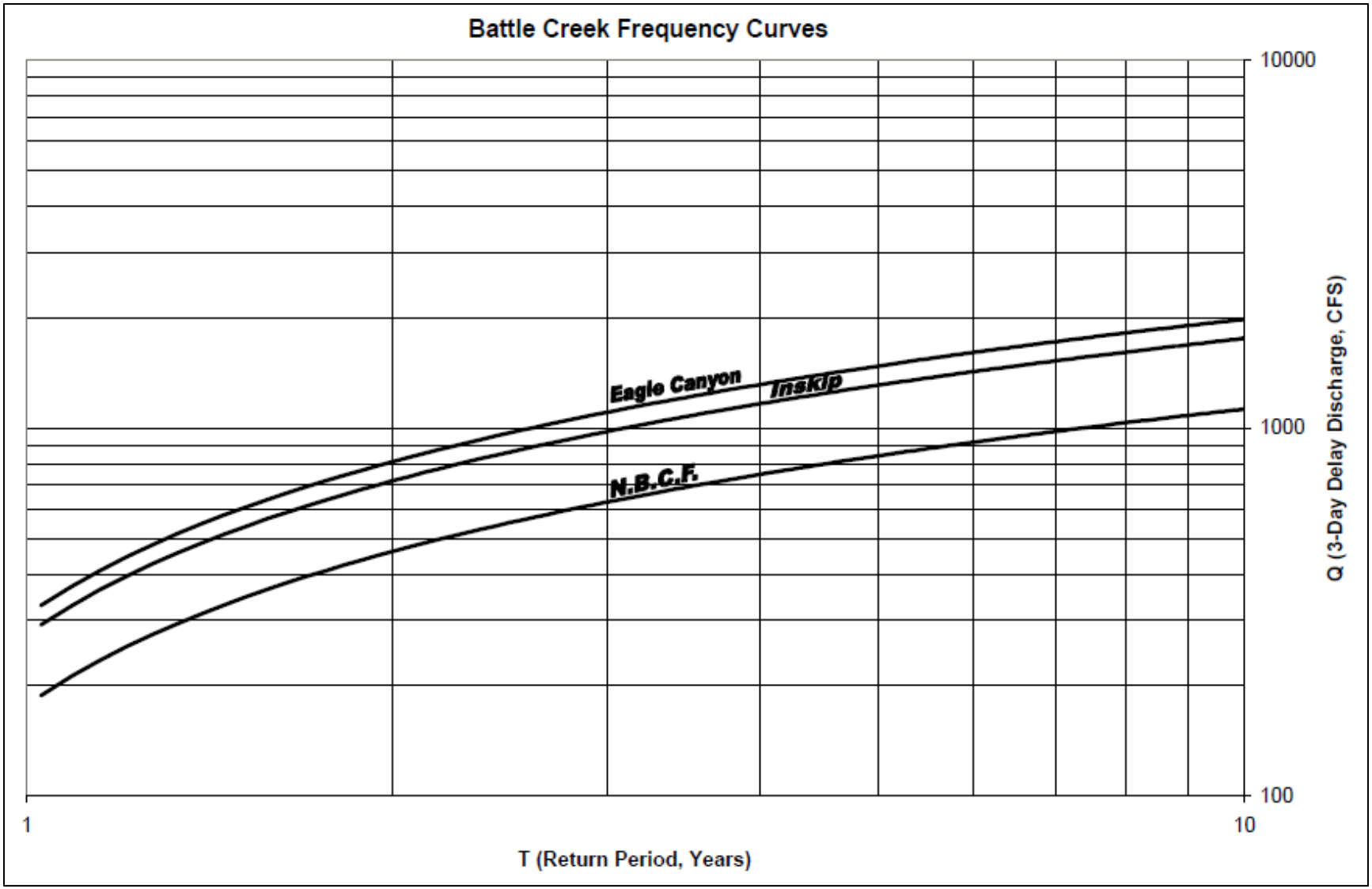



**Figure 5-1. Return period of annual maximum three consecutive day discharge for NBCF and Eagle Canyon Dam, from DWR (2000).**

### 5.5.3 Eagle Canyon Dam Fish Passage Design Flows

DWR (2000) considered using the 10-year, 3-day maximum annual flow of 1,900 cfs as the high fish passage design discharge for a fishway at Eagle Canyon Dam (Figure 5-1). DWR noted that upstream of the dam (and downstream of the UBS) is a "channel constriction" they considered impassible to salmon at flows above 800 cfs. They ultimately reduced the high passage design flow to 610 cfs due to site limitations and the desire to avoid use of an auxiliary water system for attraction to the fishway. At this flow the fishway conveys 10 percent of the total flow; the minimum attraction flow criterion for the project. However, the selected vertical slot fishway at Eagle Canyon Dam remains operational up to a total flow of 1,600 cfs, but the fishway flow becomes only approximately 4.4 percent of the total flow.

DWR (2000) reports the vertical slot fishway may operate at flows as low as 20 cfs. However, this would require installation of sills within each slot to provide adequate depth downstream of each slot.

### 5.5.4 Flow Duration Analysis

Fish passage design flows in California are commonly defined based on daily average exceedance flows obtained from flow duration curves (FDCs). CDFG (2002) and NMFS (2001) define the high fish passage design flow for adult anadromous salmonids as the annual 1% exceedance flow. These documents also define the low passage design flow for adult anadromous salmonids as the annual 50% exceedance flow.

The DWR operated BNF gaging station located on NFBC downstream of the LBS provides daily average flows for 16 water years (WY2000 to WY2015). This flow record was utilized to develop flow duration curves for the LBS and UBS. Rather than create a flow duration curve using the combined 16 year period, an alternative method was used to define fish passage flows as outlined in Vogel and Fennessey (1994) and used in Lang et al. (2004). The alternative method avoids outlier water years skewing results and allows for more in-depth interpretation of exceedance flows between water years.

The method involved using the BNF record to calculate exceedance flows for each of the 16 water year. For each exceedance value (i.e. 1% exceedance value) this produced 16 exceedance flows, one for each year. Then, the median of the exceedance flows was computed for each exceedance value to create the annual flow duration curve. This curve represents the median annual exceedance flows, where half of the water years the exceedance flow was greater than indicated and half were less than indicated.

Next, lower and upper 10% confidence intervals were constructed around the median annual flow duration curve. The confidence intervals bracket the range of annual exceedance flows, such that 80% of the years the flow associated with the indicated exceedance value fell between the confidence intervals. The BNF median annual FDC and each water year's FDC are provided in Attachment D.

### 5.5.5 LBS Flow Duration

The LBS FDC was constructed using the BNF FDC scaled to the drainage area of LBS. It is presented in Figure 5-2. The drainage area of LBS is 188.0 square miles, which is only 3.5

square miles less than at BNF. Therefore, the constructed LBS FDC provides an accurate representation of flow conditions at the LBS.

*LBS Low Passage Flows*

Under nearly all hydrologic conditions, flows at the LBS are expected to remain at or above 35 cfs, which is the minimum instream flow release downstream of Eagle Canyon Dam. The flow duration curve for the LBS had a minimum flow of 32 cfs that occurred for only a few days in the 16 year record. Therefore, a low passage design flow of 35 cfs appears appropriate.

*LBS High Passage Flows*

Based on this flow duration analysis and recommendations by CDFG (2002) and NMFS (2001), use of the 1% exceedance flow of 241 cfs seems appropriate. Figure 5-2 shows that for half of the water years flows were less than 241 cfs for 99% of the time. The upper 10% bounds also indicates that for 90% of the water years the flow remained below 241 cfs 80% or more of the time.

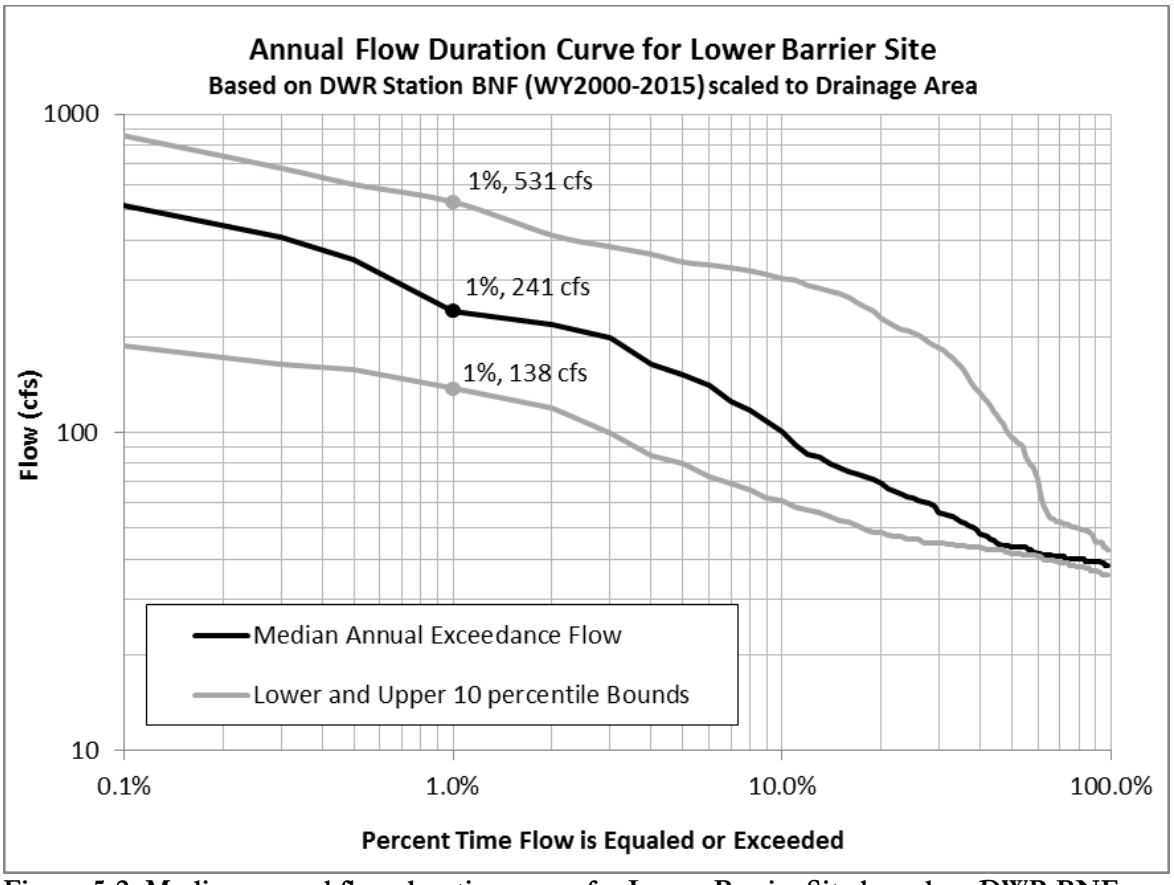



**Figure 5-2. Median annual flow duration curve for Lower Barrier Site based on DWR BNF daily average flow record. Exceedance flows for a given year will fall between the lower and upper bounds 80% of the time.**

### 5.5.6 UBS Flow Duration

The UBS FDC was constructed using the BNF FDC, but subtracting 10 cfs to account for Eagle Canyon Springs input between UBS and BNF and then scaling the flows by the difference in drainage area. The UBS FDC is presented in Figure 5-3. The drainage area of the UBS is 147.7 square miles, which is 77% of the BNF contributing drainage area. Digger Creek, which flows into North Fork Battle Creek immediately downstream of the UBS is the primary contributor to the difference in drainage area. This difference likely results in more error associated with the constructed UBS FDC compared to the LBS, especially at lower flows when flow releases from Feeder Dam govern the flowrate.

*UBS Low Passage Flows*

The UBS receives flows that bypass the Feeder Dam. There are minimal inflows between Feeder Dam and UBS. Therefore, flows at the UBS are nearly identical to flows measured below the Feeder Dam. Once the MOU bypass flows are implemented, minimum required bypass flows at the dam will be as lows as 47 cfs, when available. The flow at the UBS may be less than 47 cfs when the available flow at the Feeder Dam is less than 47 cfs (e.g. during the dry season).

To characterize how low UBS streamflows may become during the dry season, flow arriving at Feeder Dam in drought years of WY2014 and WY2015 were provided by PG&E. As shown in Attachment D, during these two drought years there was less the 47 cfs available to bypass downstream of Feeder Dam for 26% of the days. During these low-flow periods, flow remained above 35 cfs for approximately 90% of the days and above 33.2 cfs for 99% of the days. Therefore, a low passage design flow less than 47 cfs should be used for the UBS. CDFW, per the current scope of work for this Project, recommended using 35 cfs for the UBS, as well as the LBS. Based on this analysis, a low passage design flow of 35 cfs seems appropriate.

*UBS High Passage Flows*

Like the LBS, the high passage design flow for the UBS will be limited by site conditions and design constraints. Conditions within the downstream channel reach should also be considered. At higher flows there are rapids between the Eagle Canyon Dam and UBS that produce extreme turbulence and large water surface drops that likely prevent fish from migrating upstream at high flows.

The flow duration curves for the UBS (Figure 5-3) indicates that the median annual 1% exceedance flow is 182 cfs, with 90% of water years having flows below 182 cfs for more than 80% of the time. Based on this flow duration analysis and recommendations by CDFG (2002) and NMFS (2001), use of the 1% exceedance flow of 182 cfs seems reasonable.

## 5.6 Peak Flows

USBR (2001) developed peak flows for several locations within the watershed (Table 5-4). For this Project peak flows were estimated for the LBS, UBS, and Digger Creek based on the previous work by USBR. The UBS flows were estimated by scaling the Feeder Dam flows to the drainage area at the UBS. The LBS was estimated by scaling the Eagle Canyon Dam flows to the drainage area at the LBS. Digger Creek flows were estimate by taking the difference between Eagle Canyon Dam and UBS flows.

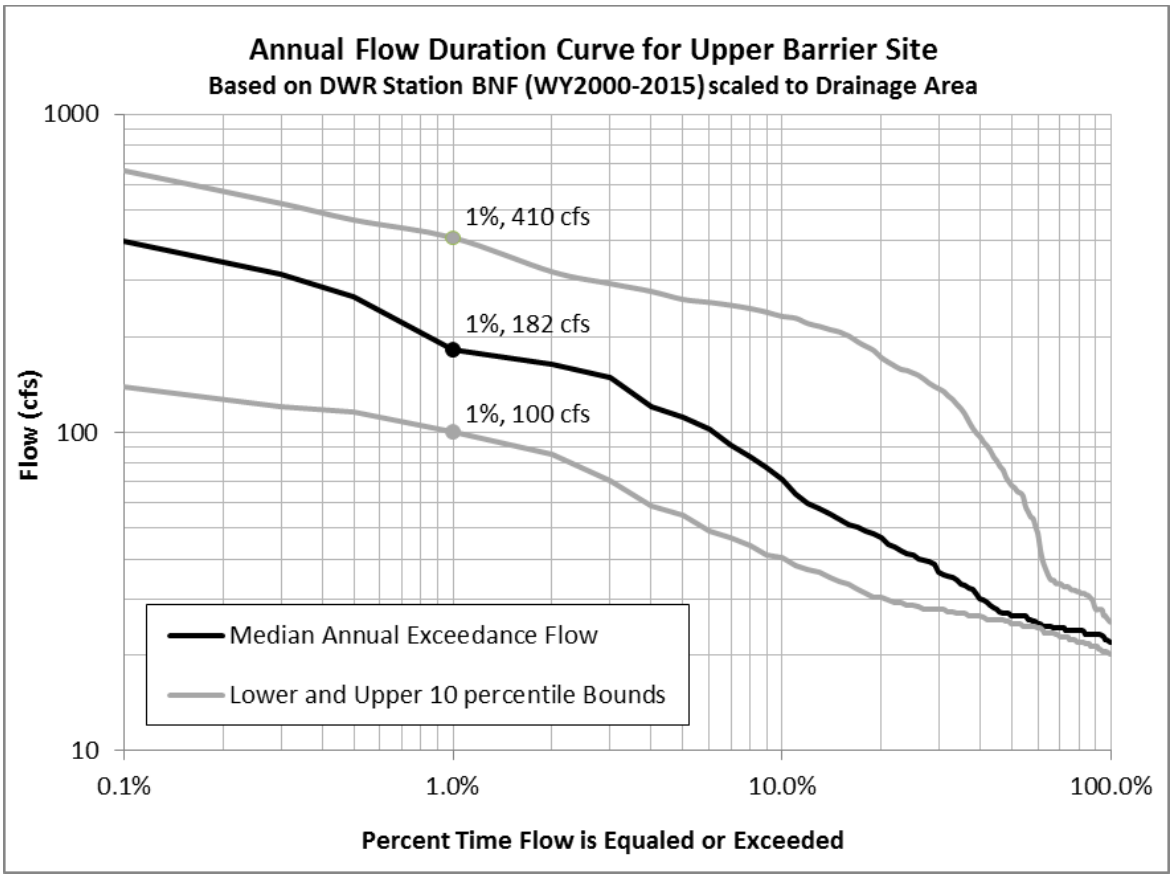



**Figure 5-3. Median annual flow duration curve for Lower Barrier Site based on DWR BNF daily average flow record. Exceedance flows for a given year will fall between the lower and upper bounds 80% of the time.**

**Table 5-4. Peak flows for various return periods at locations along NFBC based on USBR (2001).**

| Return Period (year) | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | Feeder Dam (133 $mi^2$) | Upper Barrier Site (147.7 $mi^2$) | Digger Creek (39.9 $mi^2$) | Eagle Canyon Dam (187.7 $mi^2$) | Lower Barrier Site (188 $mi^2$) |
| 2 | 2,100 | 2,332 | 168 | 2,500 | 2,504 |
| 2.33 | 2,400 | 2,665 | 235 | 2,900 | 2,905 |
| 5 | 3,700 | 4,109 | 291 | 4,400 | 4,407 |
| 10 | 4,800 | 5,331 | 369 | 5,700 | 5,709 |
| 25 | 6,300 | 6,996 | 504 | 7,500 | 7,512 |
| 50 | 7,500 | 8,329 | 571 | 8,900 | 8,914 |
| 100 | 8,600 | 9,551 | 649 | 10,200 | 10,216 |

# 6 FIELD DATA FOR CHARACTERIZING HYDRAULIC CONDITIONS

The following sections describe the field data collected by MLA at the two barrier reaches and a brief description of how the data is being used with respect to this Project. Table 6-1 presents the field work completed for each MLA work date. Surveys utilized control points set by GMA (see GMA, 2016).

**Table 6-1. Data collection date and description of work completed at the LBS and UBS by MLA. Refer to GMA (2016) and CSA (2016) for additional field work completed for this Project.**

| Data Collection Event | Date | Field Tasks Completed |
|---|---|---|
| **Lower Barrier Site:** | | |
| LBS1 | 9/23/15 | Installed one time-lapse camera and two water level loggers |
| LBS2 | 10/28/15 | Installed second time-lapse camera and downloaded water level loggers |
| LBS3 | 2/29/16 – 3/1/16 | Water surface mapping, high-flow debris line mapping, hydraulic section mapping, flowline mapping, relocated one time-lapse camera, downloaded water level logger |
| LBS4 | 6/7/16 | Downloaded water level loggers, downloaded and removed time-lapse cameras, boulder complex mapping |
| **Upper Barrier Site** | | |
| UBS1 | 9/22/15 – 9/25/15 | Water surface mapping, hydraulic control mapping, flowline mapping, installed two time-lapse cameras, installed two water level loggers and one atmospheric pressure logger |
| UBS2 | 10/28/15 | Downloaded two water level loggers and atmospheric logger |
| UBS3 | 2/10/16 | Water surface mapping, boulder complex mapping, high debris flowline mapping, discharge measurements, downloaded water level gage logger, abandoned water level gage UB2, downloaded atmospheric logger |
| UBS4 | 3/1/16 | Met with CSA to assist with layout of RM1 and RM2 (CSA, 2016) and conducted aerial photography |
| UBS5 | 6/7/16 – 6/8/16 | Water surface mapping, downloaded and removed time-lapse camera UB2, and conducted aerial photography (high flows, 195 cfs, limited access to the site), Digger Creek discharge measurement |

## 6.1 Boulder and Flowline Mapping

As presented in Table 6-1, MLA conducted several mapping exercises at the project sites. This included water surface mapping, hydraulic section mapping, high and low flowline mapping, peak flow debris line mapping, boulder complex mapping, and sieve mapping. Most of this mapping was conducted using a Total Station, on printouts of project basemaps, and from field notes. All survey efforts utilized the control points described in GMA (2016).

Hydraulic section mapping was conducted in the field to identify the location of hydraulic controls throughout the LBS and UBS. Location of these controls were then used in developing hydraulic models.

High and low flowline mapping was completed in the field. The objective of this mapping was to determine the multiple flow paths throughout the LBS and UBS. For the LBS, four different alignments were identified: primary, secondary, tertiary, and quaternary. For the UBS, a primary and secondary alignment was identified. These alignments for the UBS do not account for every sieve path, but only represent the surface flow paths that dominate the site. The flowline ranking indicates the order in which the alignments begin to receive flow as streamflows increase. These alignments are presented in the figures included in Attachment A and their profiles and water surface elevations for the different water surface mapping events are presented in Section 8.1.2 for the LBS and Section 8.2.2 for the UBS.

Boulder complex mapping included the numbering of individual boulders that are greater than approximately 3 feet in diameter at both sites. This data was presented in MLA (2016). Since then MLA conducted another site visit to further understand the relationships between boulders (e.g. which boulder is supported by other boulders).

Sieve mapping was conducted in the field primarily through field sketches that were later used to develop the sieve maps.

## 6.2 Time-Lapse Cameras

MLA installed two time-lapse cameras at each site. The objective of the cameras was to capture high flow events, when staff could not be present. The photographs generated from these cameras have provided insight into high-flow paths, inundation extents, and water surface elevations in pools.

## 6.3 Water Level Loggers

MLA installed two submersible water level loggers at each site and one atmospheric pressure logger in Eagle Canyon that was used for both sites. The water level loggers were installed to record the water surface elevation over time. The gages were HOBO U20L set to collect a water level every 15 minutes. The loggers were installed in 3 inch PVC pipe secured to t-posts and/or concrete form stakes anchored into the bed of the channel (Figure 6-1). The pipe was capped on both ends and holes drilled into the base. To correlate water levels to the project vertical datum (NAVD88), top of t-post elevation was tied to the project control using a Total Station.



**Figure 6-1. Water level gage installed in Pool 2 of the LBS on river left. Photograph looking downstream and flow is approximately 37 cfs.**

## 6.4 Lower Barrier Site

### 6.4.1 Water Surface Mapping

Water surface mapping was conducted for three different events at the LBS (Table 6-2). High debris mapping was used to generate water surface mapping event 3 (WSME-3). This involved surveying the 2016 high water mark at the time of the survey. Indicators were identified along the banks of the channel. This includes racking of wood debris as well as scour of moss from boulders, amongst other techniques. This data was then compared to the stage recorded by adjacent the water level loggers.

A June 7, 2016 site visit (WSME-4) provided additional observations of conditions at high flow, but detailed mapping was not performed. Data from these events was used to generate water surface profiles and to calibrate hydraulic models. The results of the mapping are presented in Section 8.1.2.

### 6.4.2 Timelapse Camera Installations

The LBS cameras were set to take photographs every 10 minutes during daylight hours. Camera LB1 was a Wingscape TimelapseCam model WCT-00122 and LB2 was model WCT-00121. LB1 was installed on September 24, 2015 on river left, looking downstream at the primary drop. The second camera (LB2) was installed on October 28, 2015 on river right, looking upstream and focusing on Pool 3.

**Table 6-2. LBS water surface mapping events, dates, streamflow, and methods.**

| Water Surface Mapping Event | Date | Flow | Mapping Methods and Flow Determination Methods |
|---|---|---|---|
| WSME-1 | 10/14/15 | 37 cfs | Water surface elevation (WSE) mapping based on point cloud scan by GMA (GMA, 2016). Flow based on Eagle Canyon Dam Gage[1]. |
| WSME-2 | 2/29/16 | 120 cfs | Total Station Survey conducted on this date for WSE mapping. Flow based on stage reading by MLA at the DWR BNF staff plate, converted to discharge using DWR provided rating table, and then scaled by drainage area. |
| WSME-3 | 1/29/16 | 2,010 cfs | Total Station survey conducted on 2/29/16 that identified the high debris lines, which correspond to the January 29, 2016 peak flow, which was the highest flow of the water year at the time. Flow based on debris line at the DWR BNF staff plate, converted to discharge using DWR provided rating table, and then scaled by drainage area. |
| WSME-4 | 6/7/16 | 248 cfs | No survey was conducted except to record the water surface elevation at each of the water level gages. Flow was obtained from the Wildcat gage. |

1. Recorded flow at Eagle Canyon gage (USGS NO 11376150) on 9/30/2015 was used. LBS water level logger LB2 showed only 0.05 ft change in stage between 9/30/2015 and 10/14/2015.

### 6.4.3 Water Level Logger Installation

The upstream water level logger (LB1) was installed in Pool 5 on river left at the Bear Hallow Complex, upstream of the primary drop. The downstream water level logger (LB2) was installed in Pool 2 on river left at the DS Complex.

Figure 6-2 presents the stage hydrograph through June 7, 2016 for LB1 and LB2. A gap is present in the data due to the data being corrupted during the download procedure. Within this gap was a storm event slightly greater in magnitude than the other peak event on January 29, 2016.

### 6.4.4 Discharge Measurements

Several attempts were made to measure flow within or adjacent to the LBS, but either the flow was too high to safely conduct the measurement or there was no acceptable, reachable location to conduct the measurement.

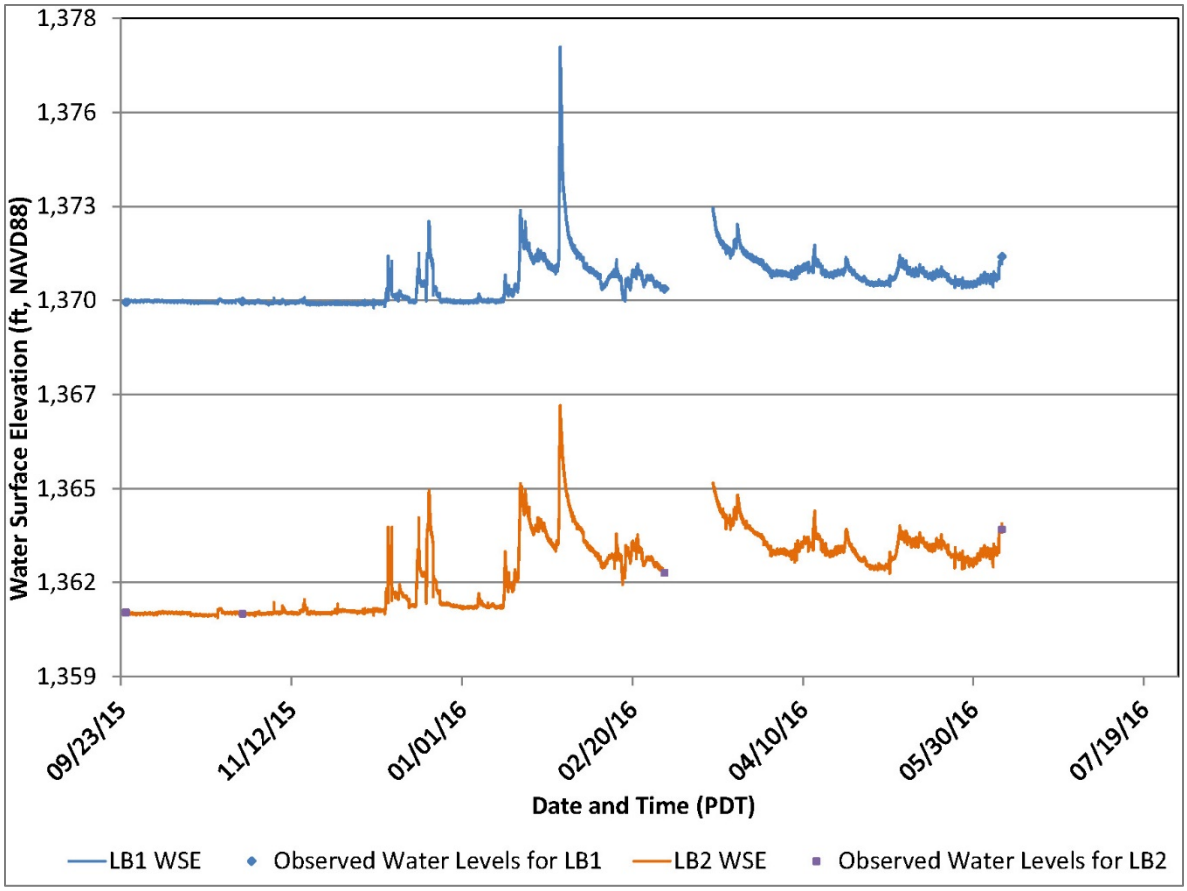



**Figure 6-2. LBS stage hydrographs for LB1 and LB2.**

## 6.5 Upper Barrier Site

### 6.5.1 Water Surface Mapping

Water surface mapping was conducted for four different events at the UBS (Table 6-3). The third event (WSME-3) was mapped using high flow debris lines that captured the peak water surface elevation in 2016 occurring prior to the survey. There was one larger peak event in WY2016 subsequent to this event.

The fourth event (WSME-4) was conducted during elevated flows. Due to high flow safety concerns, the site survey was conducted using the "prism-less" setting on the Total Station to survey the edge of water. Some of the GMA control points were visible within the field of view and used to obtain horizontal and vertical control. The results of the effort were sufficient to complete a fourth mapping event. Data from each mapping event was then used to generate water surface profiles that were utilized in calibration of hydraulic models. The results of the mapping are presented in Section 8.2.2.

**Table 6-3. UBS water surface mapping events, dates and methods.**

| Water Surface Mapping Event | Date | Flow[1] | Mapping Methods and Flow Determination Methods |
|---|---|---|---|
| WSME-1 | 9/22/15 | NFBC 17 cfs, Digger 5 cfs | MLA survey WSE. Flow estimated using Feeder Dam flow plus 1 cfs. Digger estimated based on previous measurements. |
| WSME-2 | 2/10/16 | NFBC 87 cfs, Digger 25 cfs | MLA survey with WSE. Flows measured using current meter. |
| WSME-3 | 1/29/16 | NFBC 1,580 cfs, Digger 427 cfs | Survey on 2/29/16 of debris lines from peak flow event that occurred on January 29, 2016. Flow estimated using debris line at the DWR BNF and using DWR provided rating table, and then scaling by drainage area. |
| WSME-4 | 6/7/16 | NFBC 195 cfs, Digger 32 cfs | MLA survey of WSE. Flow estimated from the Wildcat gage and adjusted for the inflow from Eagle Canyon Springs (10 cfs) and inflow from Digger Creek flow, which was measured in the field. |

[1]NFBC is defined as upstream of Digger Creek confluence

### 6.5.2 Timelapse Camera Installations

Cameras were installed at the UBS on September 23-24, 2015. The UB1 camera was installed in the center of the channel on top of a boulder and focused on the primary drop. The UB2 camera was installed downstream of the Digger Creek confluence on river left and oriented looking upstream towards Pools 3 and 4.

### 6.5.3 Water Level Logger Installation

The UBS upstream water level logger (UB1) was installed in Pool 9 on river left, upstream of the primary drop. The downstream water level logger (UB2) was installed in Pool 4 in the center of the channel within the boulders that separate Pool 4 and Pool 2. UB2 was removed on February 10, 2016 because high flow had pulled out the main t-post. The PVC and gage were still connected to a second t-post and were recovered.

Figure 6-3 presents the stage hydrograph through July 21, 2016 for UB1, UB2 data terminates on February 10. There is a gap in the UB1 data due to the data being corrupted during the download procedure. During this gap, there was a flow event with a slightly higher magnitude peak than the other peak event captured by the data on January 29, 2016.

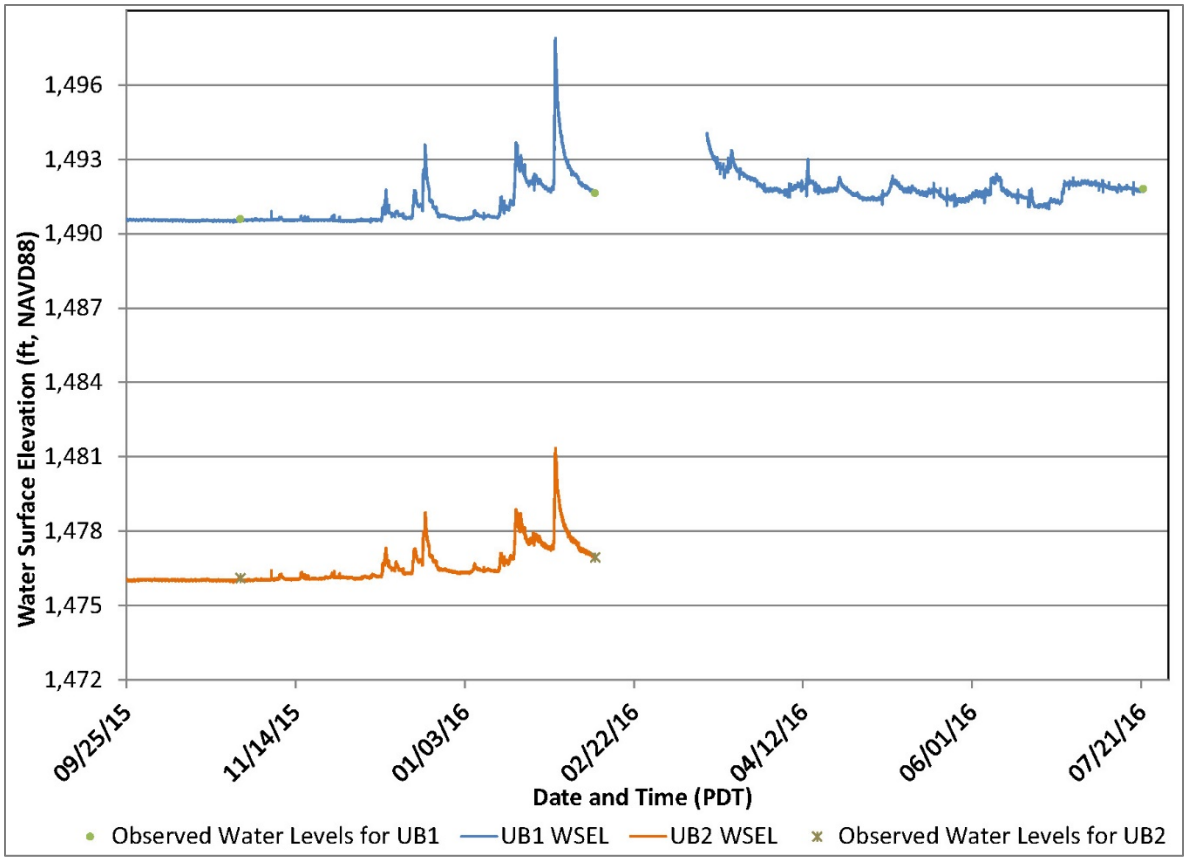



**Figure 6-3. UBS stage hydrographs for UB1 and UB2.**

### 6.5.4 Discharge Measurements

Discharge measurements were completed on two occasions for the UBS (Table 6-4). On February 10, 2016 GMA conducted a discharge measurement using a USGS pygmy current meter near the location of the UB1 gage, upstream of the primary drop. On that same day they measured the discharge within Digger Creek. The raw results are included in Attachment E.

On June 7, 2016, MLA conducted a discharge measurement of Digger Creek using a USGS pygmy current meter. A discharge measurement was not completed in NFBC, upstream of Digger Creek due to high flows. The Digger Creek discharge measurement allowed tributary flow to be removed from the total flow reported at the Wildcat Gage to define the flow within NFBC at the time of the WSME-4.

**Table 6-4. Results of discharge measurements in NFBC and Digger Creek.**

| Date | Location | Flow |
|---|---|---|
| February 10, 2016 | NF Battle Creek | 87.2 cfs |
| February 10, 2016 | Digger Creek | 24.6 cfs |
| June 7, 2016 | Digger Creek | 32.2 cfs |

# 7 METHODS FOR CHARACTERIZING EXISTING HYDRAULIC CONDITIONS

The methodology used to characterize existing hydraulic conditions for the LBS and UBS is presented in this section. This includes a description of the discharge rating curve development, model development for the evaluation of peak flow hydraulics, and fish passage flow hydraulics. The results are then presented in Section 8.

The project sites are extremely complex topographically and hydraulically; especially the UBS. Both sites have large boulders, creating overhangs and sieves that convey flow below the boulders. Due to the limitations of developing a topographic surface model (e.g. within CAD software), the overhanging portions of boulders and the sieves below them are not included in the surface. A triangulated irregular network (TIN) surface cannot have two z-values (elevation) for a single point on the x- and y- horizontal plane. Therefore, when creating the surface, the outside edge of a boulder, as viewed in plan, simply drapes to the surface below, removing any overhangs or sieves located underneath. Use of the surface in hydraulic modeling, which does not include overhangs and sieves, affects model results due to the reduction in conveyance area. The subsequent sections describes how these surface deviations from the actual topography was addressed when developing the hydraulic models for the project.

## 7.1 Stage-Discharge Rating Curves

Stage-discharge rating curves were developed for both sites at multiple locations. These were developed to assist in calibrating models and to define tailwater elevations for future alternatives.

### 7.1.1 Lower Barrier Site

Two stage-discharge rating curves were developed for the LBS. The first was developed for Pool 5, immediately upstream of the primary drop, based data from the LB1 water level logger and flow estimates from the four water surface mapping events. The second rating curve was developed for Pool 2, downstream of the primary drop, based on data from the LB2 water level logger and flow estimates from the four water surface mapping events.

### 7.1.2 Upper Barrier Site

Five stage-discharge rating curves were developed for the UBS. The curves were developed for the following pools:

- Pool 9 (gage UB1 pool)
- Pool 7 (receiving pool below primary drop)
- Pool 6
- Pool 4 (gage UB2 pool)
- Pool 1 (downstream most pool in project area)

*Pool 9 (UB1)*

The water level logger UB1 is located within Pool 9. The rating curve for Pool 9 was based on conducting a slope-area method analysis (Dalrymple and Benson, 1968). Sections controlling Pool 9 water levels were used. Three section pairings and three flows were evaluated to

calculate water surface slopes and Manning's roughness coefficients at each flow. The water surface elevations and flows used corresponded to the water surface mapping events WSME-1, WSME-2, and WSME-3. Using the back-calculated Manning's coefficients and water surface slopes from the three flows events, a rating table was generated providing flow estimates at 0.5 foot stage intervals in Pool 9.

Using the Pool 9 stage-discharge rating curve, the UB1 water level data was then converted to discharge. This provided a continuous flow record for the UB1 gage location. Given the inherent error associated with the slope-area method and the less-than ideal channel configuration the resulting flow record is considered to be of relatively poor quality.

*Pool 7 (Primary Drop Pool)*

Using photographs from the time-lapse camera UB1, the UBS point cloud, and the Pool 9 discharge record provided the base data used to develop the stage-discharge rating curve for Pool 7. As discussed previously, Pool 7 is below the primary drop. At low flows it becomes several small pools, but as the flow increases the pools converge into one single pool. The time-lapse camera UB1 is oriented directly at Pool 7. The photographs were reviewed over a wide range of flows. At various flows, the water surface seen in the photographs were identified using the point cloud data and the corresponding flow was determined using the recorded time-lapse camera timestamp and the Pool 9 discharge record. This provided the data necessary to construct a stag-discharge rating curve for Pool 7.

*Pool 6*

The stage-discharge rating curve for Pool 6 was developed using the four water surface mapping events and the flow occurring during those events.

*Pool 4 (UB2)*

Developing the Pool 4 stage-discharge rating curve used a combination of approaches. Time-lapse camera UB2 was used to identify water surfaces of interest and the time-lapse camera timestamp was used to obtain the approximate streamflow from the Pool 9 flow record.

*Pool 1*

The Pool 1 stage-discharge rating curve was developed from the four water surface mapping events.

## 7.2 Hydraulic Model Development: Peak Flow Events

A steady state hydraulic model was developed for both project sites for evaluating peak flow events (i.e. 100-year return period flow). The U.S. Army Corp of Engineers' (ACOE's) Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 4.1.0 was used. HEC-RAS is a one-dimensional model (ACOE, 2010). The following sections describe the models developed for the LBS and UBS, respectively. Flow events with the following return periods were analyzed: 10-, 25- 50, 100-year. See Table 5-4 (page 42), for corresponding flows.

### 7.2.1 Lower Barrier Site

A plan view of the LBS HEC-RAS section locations is provided in Attachment F. The model spans approximately 330 feet reach of the LBS. As described in Section 3.3, there are two large sieves located in the main channel; there are other smaller sieves at higher flows that were considered to have negligible influence during extreme flow events. The LBS existing surface

model was altered to simulate flow conveyance through these sieves by adding slots within the surface model at the sieve locations. An approximately 7.7 feet wide slot was added to the surface model to mimic Sieve B. The slot's width was minimized to best match measured conditions. The slot's depth was linearly interpolated between the channel elevations upstream and downstream of the sieve. Similar approaches were used to mimic the other sieves at this site.

The LBS HEC-RAS model's sections are dense due to the ever-changing cross-sectional area of the channel. The upstream boundary of the model is located approximately 120 feet upstream of the primary drop and is modeled at critical depth. The downstream boundary condition is located approximately 205 feet downstream of the primary drop as is modeled at normal depth with a 6.9 percent slope.

The LBS HEC-RAS model was calibrated using the four water surface events presented in Section 8.1.2. The results of the calibration are presented in Table 7-1. The model's parameters were adjusted until a satisfactory model water surface elevation (WSE) was achieved based on the LB1 and LB2 stage data. The primary parameters adjusted were Manning's roughness coefficient and the expansion and contraction coefficients. The Manning's roughness coefficient was set at 0.08 for all sections upstream of Station 2+00 and 0.04 for all sections below this station; there was no change in the roughness horizontally within any sections. The contraction and expansion coefficients sensitivity were evaluated but the final values remained the default, 0.1 and 0.3, respectively. As seen in Table 7-1, the model's lower flow results were less than the measured data but at higher flows the opposite is true. The differences at low flows for the LB1 results were accepted because this HEC-RAS model was primarily used for peak flow analysis, while the SRH -2D model was used for fish passage flow analysis (see Section 7.3.1). The model results for the higher flows were accepted due to the extreme turbulence captured by the time-lapse cameras during the 2,010 cfs event. The water surface was fluctuating between the difference of the model and field data results. The results of the LBS peak flow analysis is presented in Section 8.1.3.

**Table 7-1. LBS HEC-RAS Model Calibration Results.**

| Water Surface Map Event | Flow (cfs) | Pool 5 Model Calibration Results (LB1 Gage vs. STA 2+44) | | | Pool 2 Model Calibration Results (LB2 Gage vs. STA 1+42) | | |
|---|---|---|---|---|---|---|---|
| | | Model WSE (ft) | Measured WSE (ft) | Difference (ft) | Model WSE (ft) | Measured WSE (ft) | Difference (ft) |
| WSME-1 | 37 | 1369.48 | 1370.1 | -0.62 | 1360.86 | 1360.94 | -0.08 |
| WSME-2 | 120 | 1370.38 | 1370.77 | -0.39 | 1362.03 | 1362.32 | -0.29 |
| WSME-4 | 248 | 1371.21 | 1371.43 | -0.22 | 1363.08 | 1363.13 | -0.05 |
| WSME-3 | 2010 | 1378.04 | 1377.57 | 0.47 | 1367.67 | 1367.07 | 0.60 |

### 7.2.2 Upper Barrier Site

A plan view of the UBS HEC-RAS section locations is provided in Attachment F. The model spans a 326-foot reach of the UBS. As described in Section 3.4, several large sieves are located within the UBS. Unlike the LBS HEC-RAS model, it is not possible to add a slot for each sieve within the UBS; the size, capacity, and discharge locations of the sieves is not fully

understood, as discussed in Section 3.4.3. This is a limitation of the model, but because this analysis is for peak flow events, neglecting the sieves provides a conservative result considered satisfactory for its applications.

The UBS HEC-RAS model's sections are dense due to the ever-changing cross-sectional area of the channel. The upstream boundary of the model is located approximately 100 feet upstream of the primary drop and is modeled at critical depth. The downstream boundary condition is located approximately 215 feet downstream of the primary drop as is modeled at normal depth with a 7.2 percent slope.

The UBS HEC-RAS was calibrated using water surface mapping event 3 (WSME-3) (1,580 cfs in NFBC, 427 cfs in Digger Creek), which corresponds to the January 29, 2016 flow event, which is less than the 2-year return flow event (2,332 cfs NFBC). The Manning's roughness coefficient was set at 0.04 for all sections. As discussed previously, it was not possible to mimic the sieves for the UBS due to the number of them and their complexity. This results in less capacity across any section within the model when compared to the actual conditions. Because of this, the model's Manning's roughness is lower than would normally be expected. Due to the changing sectional area between adjacent sections, the contraction and expansion coefficients were updated increased to 0.3 and 0.5, respectively. The calibration results are presented in Table 7-2.

The model reported a water surface 0.75 feet greater than was recorded at UB1 and 0.14 feet less than was recorded at UB2. Due to the extreme turbulence seen in the time-lapse photographs, this difference was accepted as reasonable for peak flow analysis. The results of the UBS peak flow analysis is presented in Section 8.2.3.

**Table 7-2. UBS HEC-RAS Model Calibration Results.**

| | UB1 Model Calibration Results (UB1 Gage vs. STA 2+91) | | | UB2 Model Calibration Results (UB2 Gage vs. STA 1+15) | | |
|---|---|---|---|---|---|---|
| Flow (cfs) | Model WSE (ft) | Measured WSE (ft) | Difference (ft) | Model WSE (ft) | Measured WSE (ft) | Difference (ft) |
| 1580 | 1498.50 | 1497.75 | 0.75 | 1480.91 | 1481.05 | -0.14 |

## 7.3 Hydraulic Model Development: Fish Passage Flows

Modeling the existing conditions for the two sites was conducted using the USBR's Sedimentation and River Hydraulics – Two-Dimensional model (SRH-2D) version 4. SRH-2D is a two dimensional hydrodynamic model. SRH-2D is a grid-based model that solves the standard St. Venants equations for gradually varying flow using finite-volume methods. The developed models were executed as steady state.

SMS version 12.1, a graphical user interface, was used for pre- and post-processing. SMS also has the ability to generate boundary rating curves. For most of the model simulations, SMS generate critical depth rating curves were use as the downstream boundary condition. The critical depth curve created by SMS was compared to HEC-RAS and the two were similar. SMS can also generate a boundary condition curve using normal depth calculations. A normal

depth curve was developed within SMS and due to the relative steep nature of this site, SMS reported a normal depth curve that was similar to the critical depth curve. The critical depth curve was used as the boundary condition, unless otherwise noted.

Because the 2D model is built from the surface, overhangs and sieves evident in the point cloud are not represented in the model. This has some influence on the accuracy of the results and required some modifications to the surface to better represent these topographic conditions.

The surface model exported from Civil 3D as a .xml file is convert by SMS to a mesh surface. A SRH-2D mesh surface can contain both rectangular and triangle shaped elements; both UBS and LBS models were completely comprised of triangle shaped elements. The smaller the elements, the more refined the surface model, but there is a computational penalty. Because both sites are topographically complex, the element sizes were small but with consideration given to computational run-time. The end result were models that took approximately 3 hours to stabilize.

The SRH-2D models were developed to assist with evaluating existing fish passage conditions and to set a base condition for comparing future alternatives. Model simulations were also conducted at higher flows. To evaluate fish passage conditions under a variety of flows, SMS's post processing raster calculator was used to show velocities at only locations with sufficient depth for passage. This provides a useful graphic to better understand the hydraulics of the two sites as they relate to fish passage.

The following sections describe the SRH-2D model data with respect to the two sites. The results are presented in Section 8.

### 7.3.1 Lower Barrier Site SRH-2D Development

The LBS surface model was altered to mimic the existence of the two primary and a third small sieve by creating slots in the surface used in the SRH-2D model. The elements surrounding the slots were dense (0.5 feet) to more accurately capture the steep walls of the slot but in general, the triangular elements within the main channel were approximately 1.5 feet long along each side and the elements outside the channel approximately 3 feet along each side.

Three of the four water surface mapping events were used to calibrate the model to match the recorded water level data at UB1 and UB2 gage. The results are presented in Table 7-3 and Figure 7-1. The results shown in Table 7-3 were collected at the gage locations. The results shown in Figure 7-1 are along the LBS primary alignment. The difference for the lower flow events shown in Figure 7-1 is largely due to the number and location of field data points. For example, near the primary drop at 120 cfs the field water surface elevation is recorded as being much greater than the model data. This is due to the location of the field data point being collected on the water's edge, where a "finger" of water has yet to cascade over the drop. Based on field observations and field photographs, the model provides a more accurate depiction of the surface profile over the primary drop. The difference for WSME-1 and -2 reported in Table 7-3 is within reason as the water had some surging during measurements.

For the high flow event, the model and field data are in agreement within and downstream of Pool 2 in Figure 7-1. Upstream of Pool 2, the model is not converging on a solution. When reviewing the model over a wide range of time steps, a wave is propagating through the primary drop and Pool 5. When reviewing the model results at 1,600 cfs, the model does not report this same wave formation. The wave propagation is likely due to the complex nature of the boulder configuration and the model having difficulty solving the equations as elements high on boulders wet and dry.

This wave propagation is affecting the results presented for Pool 5 in Table 7-3. The difference presented for Pool 2 is less, but still greater than is generally accepted. The model does show relatively good agreement along the primary alignment but at the gage, the model may be having difficulty with wetting and drying elements, which would affect the results. Based on time-lapse photography there was a large amount of surging occurring during this event, which, once accounted for, could improve this difference result.

Overall, the model's inability to simulate overhangs and sieves and the complex nature of the boulder configurations appears be the reasons for high flow calibration difficulties shown in Table 7-3. After substantial effort to improve the calibration, the model was accepted with the error presented in Table 7-3 and as shown in Figure 7-1. The primary use of this model is for lower fish passage flows, which the model appears sufficiently calibrated. For analysis at high flows, the error presented should be taken into consideration.

**Table 7-3. LBS SRH-2D model calibration results for the water surface events.**

| Water Surface Map Event | Flow (cfs) | Pool 5 Model Calibration Results | | | Pool 2 Model Calibration Results | | |
|---|---|---|---|---|---|---|---|
| | | Model WSE (ft) | Measured WSE (ft) | Difference (ft) | Model WSE (ft) | Measured WSE (ft) | Difference (ft) |
| WSME-1 | 37 | 1370.20 | 1370.10 | 0.10 | 1360.99 | 1360.94 | 0.05 |
| WSME-2 | 120 | 1370.56 | 1370.77 | -0.21 | 1362.49 | 1362.32 | 0.17 |
| WSME-3 | 2010 | 1380.60 | 1377.57 | 3.03 | 1368.80 | 1367.07 | 1.73 |

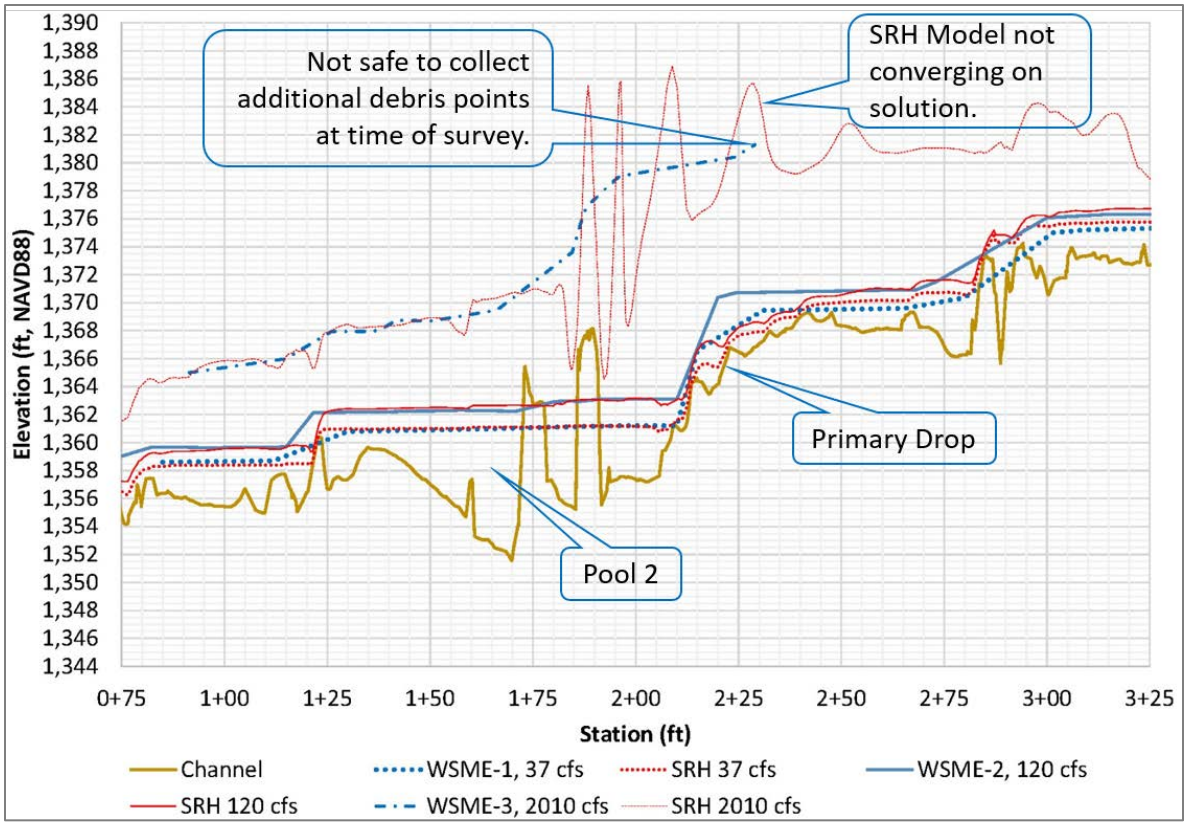



**Figure 7-1. Water surface profiles and SRH-2D model results for selected flows along the primary alignment.**

### 7.3.2 Upper Barrier Site SRH-2D Development

The sieves and overhanging boulders at the UBS proved too complex to return any reasonable results from SRH-2D. The conveyance through the sieves is substantial, and neglecting them in the model gave erroneous results. Creating slots in the surface to simulate the sieves was also not feasible given the number of sieves and the limited information available on their lengths, size, and internal hydraulics controls.

The reach from the primary drop to the upstream end of the survey boundary is less complex and does not contain sieves. A 2D model was developed for this shorter reach with the downstream boundary condition located in Pool 7. The rating curve developed for Pool 7 was used as the downstream boundary condition (see Section 7.1 for discussions about the development of the Pool 7 rating curve). The objective of this model was to better understand the hydraulics of this reach for evaluating fish passage and developing some of the fish passage alternatives. Unfortunately, SRH-2D struggled with the topography at the downstream boundary due to the large drop entering the pool and the large boulder (B20). The results did not provide sufficient accuracy and the model was rejected.

Observations and field measurements provided more accurate and informative information for evaluating the UBS than SRH-2D. Although this provides less quantitative hydraulic information to evaluate fish passage conditions, it is considered sufficient for developing fish passage alternatives.

# 8 CHARACTERIZATION OF EXISTING HYDRAULIC CONDITIONS RESULTS

The existing hydraulic conditions characterization is presented in this section. This includes the results for both sites with respect to discharge rating curves, water surface mapping, extreme flow hydraulics, fish passage hydraulics, and conclusions. These characterizations are intended for evaluating current fish passage conditions and to aid in identifying opportunities and hydraulic constraints that inform the development of fish passage improvement alternatives.

## 8.1 Lower Barrier Reach

### 8.1.1 Discharge Rating Curves

As presented in Section 7.1.1, two discharge rating curves were developed for the LBS. The two rating curves are presented in Figure 8-1 and the data tables are included in Attachment G. The difference between the two curves indicates the overall water surface drop across the LBS at a specific flow. The primary drop height varies from 8 feet to 4 feet at flows up to 2,000 cfs. These rating curves will be used in the development of alternatives, which are being completed in a separate document.

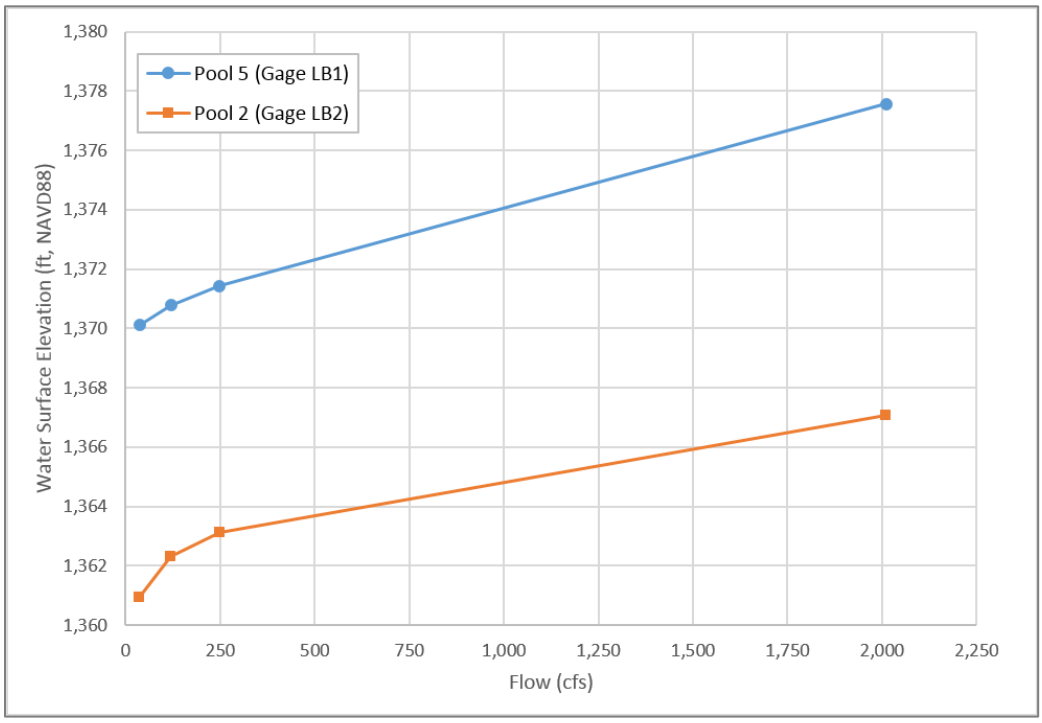



**Figure 8-1. LBS discharge rating curves for Pool 2 and Pool 5.**

### 8.1.2 Water Surface Mapping

As seen in Attachment A, Figures A-2 and A-3, there are four alignments identified as potential flow paths through the LBS. Figure 8-2, Figure 8-3, and Figure 8-4 present the results of the mapping for the three different events in profile view for three of the four alignments:

primary alignment (PA), secondary alignment (SA), and quaternary alignment (QA). The tertiary alignment (TA) was not included because it is a very short span between the SA and QA alignments and the water surface elevation can be inferred from the data provided.

Within each profile figure, if the water surface line (blue lines) passes through the channel line, then flow was passing through a sieve or between boulders along the alignment. If the water surface line terminates at the channel line, then that is the edge of water and the channel surface was not wet for the event. The details of each event are discussed further in the following sub-sections. Attachment H presents plan view drawings, showing water surface extents, and profile drawings for each water surface mapping event.

*Event 1*

Water surface mapping event 1 (WSME-1) was conducted on October 14, 2015 when NFBC flow was 37 cfs through the LBS. Figure H-1 (see Attachment H) presents the LBS in plan view with the limits of water indicated by the blue hatching. This event was conducted at the lowest flow of any event. Based on the water level logger data, the flow was nearly constant from the deployment of the water level loggers (September, 2015) until the first storms arrived in the fall. Based on the MOU (1999), this is approximately the minimum instream for May to November. During the remaining months of the year, the minimum instream requirement is 46 cfs and therefore, the inundation extents would be expected to expand, but only slightly.

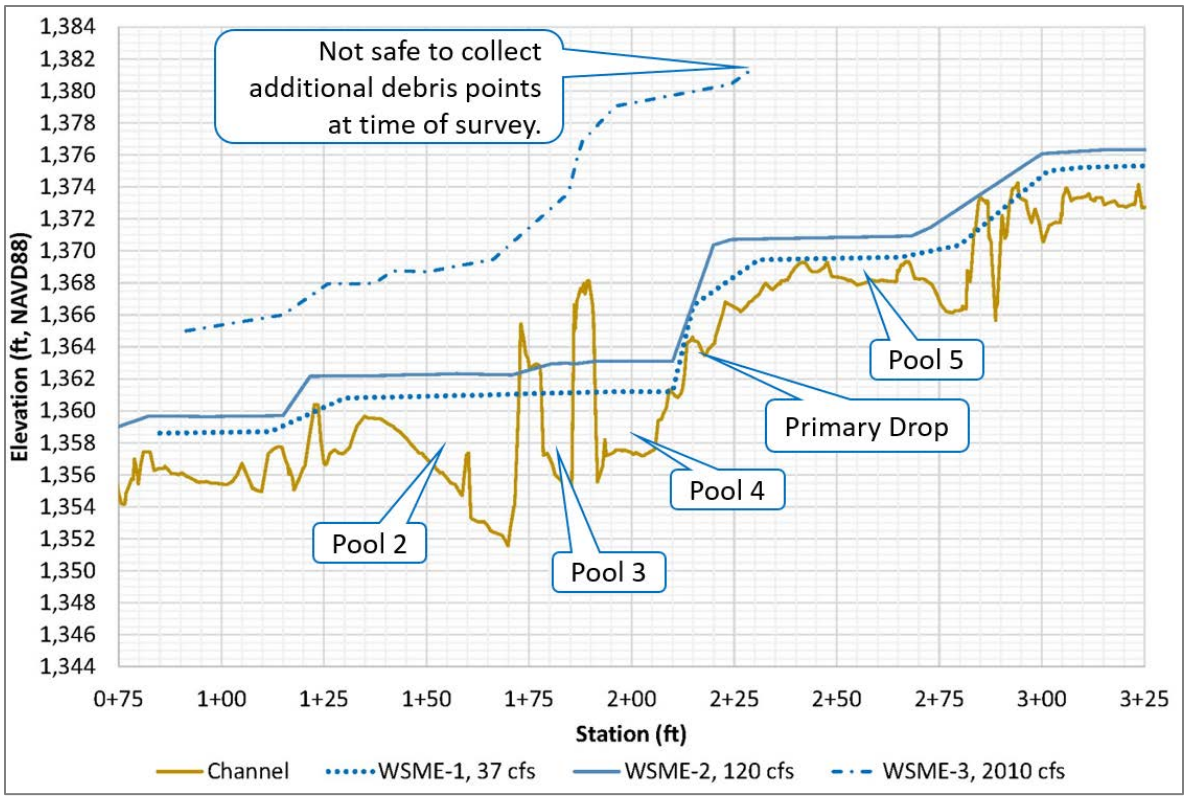



**Figure 8-2. LBS primary alignment water surface profiles for the three water surface mapping events.**

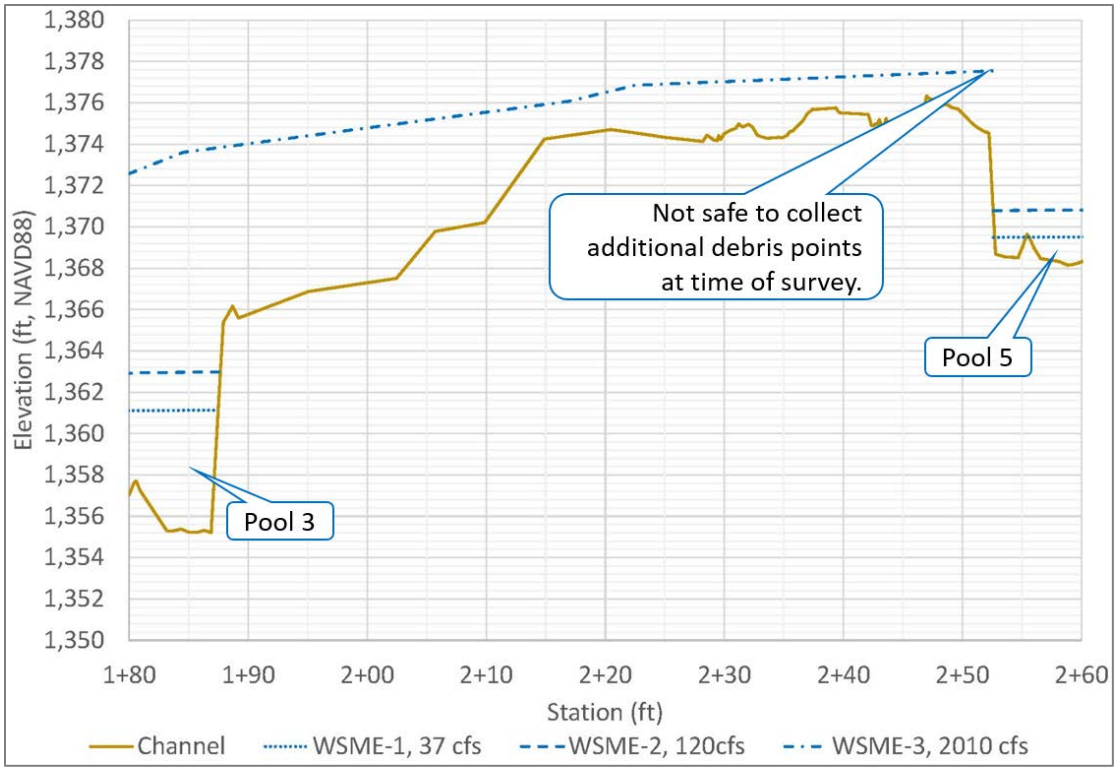



**Figure 8-3. LBS secondary alignment water surface profiles for the three water surface mapping events.**

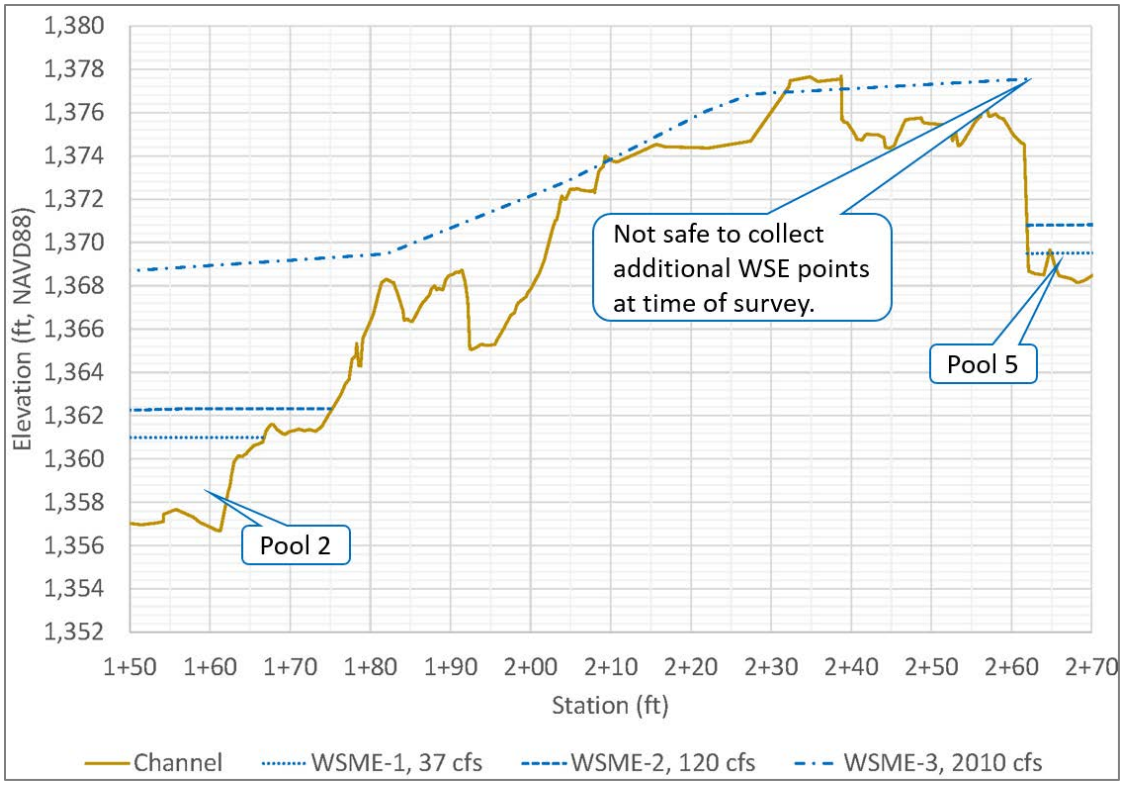



**Figure 8-4. LBS Quaternary Alignment water surface profiles for the three water surface mapping events.**

As seen in Figure H-1, all the flow is passing through the two sieves that lie between Pools 2, 3, and 4 (PA station (STA) 1+75 and 1+90). The SA, TA, and QA alignments did not convey any flow during this mapped flow event.

Figure H-1 also presents two photographs of the LBS during the mapping event. As seen the flow is relatively calm through the sieve and within Pool 2 (LB2 photograph). The LB1 photograph shows the rough nature of the primary drop and the accelerated velocities. Flow in the primary drop and the receiving Pool 4, which are both very narrow, were extremely turbulent and aerated. Note that upstream of the primary drop, near PA 2+95, is a water surface drop of approximately 5.0 feet at this flow. Unlike the primary drop, this drop has multiple flow paths and substantially less turbulence in the receiving Pool 5.

*Event 2*

Water surface mapping event 2 (WSME-2) was conducted on February 29, 2016 when NFBC flow was 120 cfs through the LBS. Figure H-3 presents the LBS in plan view with the limits of water indicated in blue. The measured water surface points are also shown.

Although the flow is three times greater for this event than the WSME-1, the water extents are similar. This is due to the steep canyon walls on river right and the large boulders on river left confining the flow.

Figure H-3 also presents two photographs of the LBS during the mapping event. As seen in the LB2 photograph, the flow is has become more turbulent at the outlet of Sieve B and to a lesser degree at Sieve A. Pool 2 still remains calm. The LB1 photograph continues to show the turbulent nature of the primary drop as the flow accelerates and impacts submerged boulders along the chute. Pool 4 is more visible and appears turbulent. The drop upstream of the primary drop, between Pools 5 and 6, maintained an overall water surface drop of approximately 5 feet, with multiple flow paths around the constricting boulders

*Event 3*

Water surface mapping event 3 (WSME-3) was based on high debris lines surveyed on February 29, 2016 that were the result of the January 29, 2016 flow event when NFBC flow was approximately 2,010 cfs through the LBS. Figure H-5 presents the LBS in plan view with the limits of water indicated in blue. The measured high debris points are also shown.

As seen in Figure H-1, the inundation extents increased substantially compared to the other two mapped flows. The data indicated that water flowed along the SA and TA, and QA may have also been wetted with shallow flow that but may not have been fully connected. It appears that at this flow, the constriction at the primary drop forces some flow around the river left side of the B72 Complex. It is also appears flow becomes backed up at Sieve B, and inundates the Middle Complex which then causes flow to around the left side of B138 and through the DS Complex.

Figure H-5 also provides two photographs of the LBS during the mapping event. As seen in the LB2 photograph, the flow has become extremely turbulent as it passes through Pools 2 and 3. Water is flowing over the shoulders of B71 and B131, at their contact point. Flow is also visibly passing around B71, which could be flow passing through a sieve between B71 and

the B72 Complex or flow moving through the Middle Complex after passing to the river right of the B72 Complex. Although more difficult to see due the rain drops on the camera, the LB1 photograph shows that the drop has been fully inundated but that there is still a decent draw down over the feature. The flow is turbulent throughout. Some boulders from the B72 Complex can be seen on the left of the photograph.

### 8.1.3 HEC-RAS Hydraulic Results

Figure 8-5 presents the water surface profiles for peak flows with specified return periods generated from HEC-RAS for existing conditions. The model was evaluated at four different peak flows: Q10, Q25, Q50, and Q100. As seen in Figure 8-5, the flow is a mixture of super- and sub-critical flows. This information will be used during alternative development. Attachment I contains additional results from this analysis.

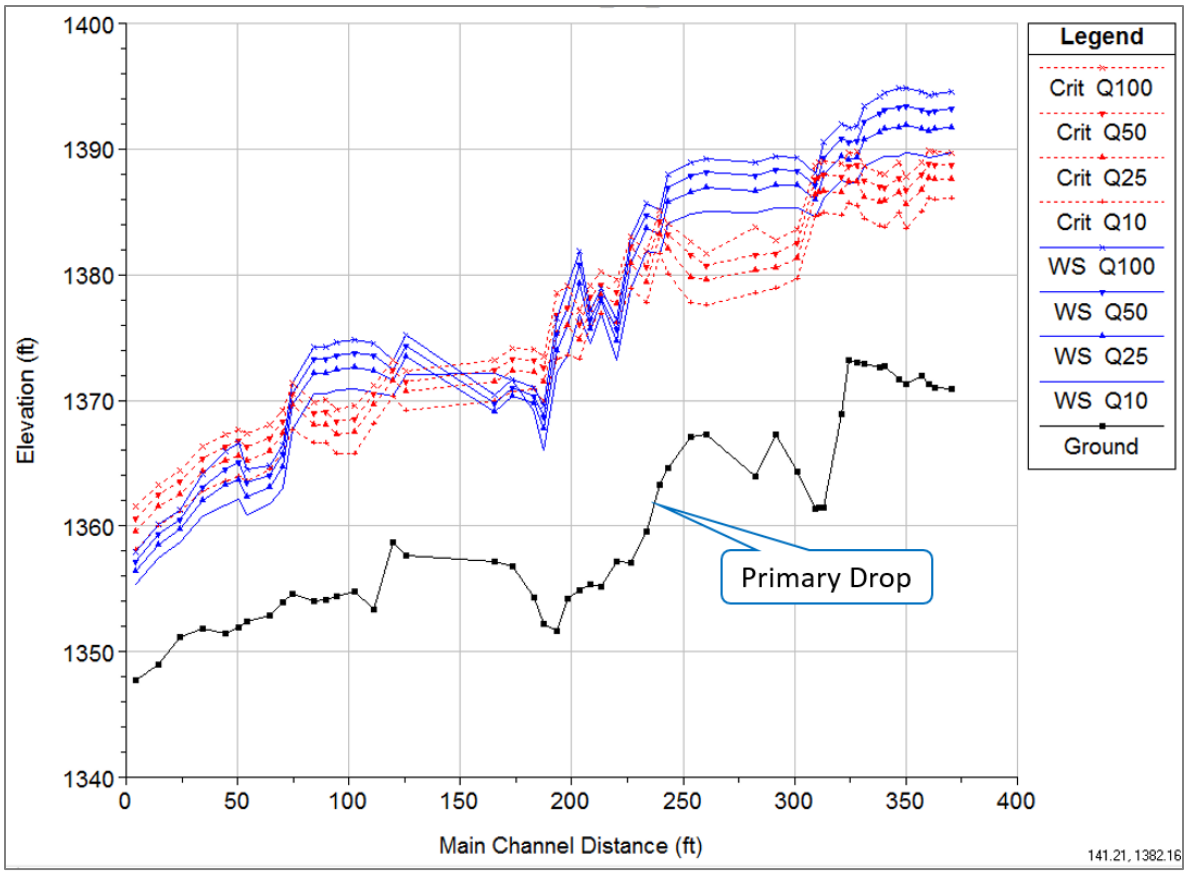



**Figure 8-5. HEC-RAS profile results from the LBS peak flow analysis.**

### 8.1.4 Fish Passage Hydraulic Modeling Results

For the LBS, fish passage conditions were assessed using a combination of observations, field measurements and hydraulic model results. Attachment J includes the SRH-2D fish passage modeling results for selected flows between 37 cfs and 2,010 cfs.

Figure 8-6 provides SHR predicted profiles of water surface elevations, water depth, and water velocities along the primary alignment of the LBS for the seven different streamflows. The SRH-2D results are informative in terms of water depths and velocities, but fail to characterize

turbulence and aeration of the water column. In general, the turbulence within Pool 4 immediately downstream of the primary drop and within the primary drop itself is very turbulent, even under low flow conditions

Water depth for passage does not appear to be the limiting factor at evaluated flows. At the lowest evaluated flow of 37 cfs there are a few feet of channel along the profile with depth less than 0.5 feet. Otherwise, water depths are generally sufficient to submerge the body of adult salmon and steelhead at all fish passage flows.

Water velocities at the LBS are relatively high in the primary drop at all assessed flows, ranging from 10.9 fps to 15.5 fps at flows from 37 cfs to 1,600 cfs, respectively. At flows above 500 cfs the water velocities in the sieves downstream of the primary drop exceed 8 fps. Although these velocities are high, they only persist for short distances of 20 to 40 feet.

The fish passage hydraulics at the primary drop of the LBS are summarized in Table 8-1. This table also includes the minimum body length of a Chinook salmon required to swim through the velocities within the primary drop based on swim speed Equation 4-1 and the size distribution of spring-run Chinook in Battle Creek shown in Figure 4-1 (page 28). Based on this distribution, it appears that all but the smallest fish can overcome the water velocities at 37 cfs. At 200 cfs only the largest approximate 10 percentile of fish can swim through the velocities. At higher flows very few to none of the Chinook would have the swimming abilities to pass through the velocities in the primary drop. This analysis does not account for the extreme large-scale turbulence observed throughout the primary drop and receiving pool at flows as low as 37 cfs. It also does not account for the prolonged and burst swimming required at higher flows to pass through the sieves and other features downstream of the LBS. This may explain why adult anadromous fish have been observed in Pool 2 immediately downstream of the LBS, none have been observed upstream of the LBS primary drop.

Secondary passageways for upstream migrating salmon and steelhead were evaluated, including the secondary and quaternary alignments that go around the primary drop and the sieves. Based on the SRH results and mapping of debris lines from the high flow event, these routes do not receive sufficient flow to provide a continuous route with at least 0.5 feet of depth until flows exceed 2,000 cfs. Based on time-lapse camera footage, the entire channel, including the sieves and Pools 2, 4, and 5 are extremely turbulent. Additionally, the channel features downstream and immediately upstream of the LBS are also extremely turbulent and form large water surface drops. Therefore, it seems very unlikely that fish would be attempting to migrate upstream at the flows in which these secondary passageways would become usable by fish.

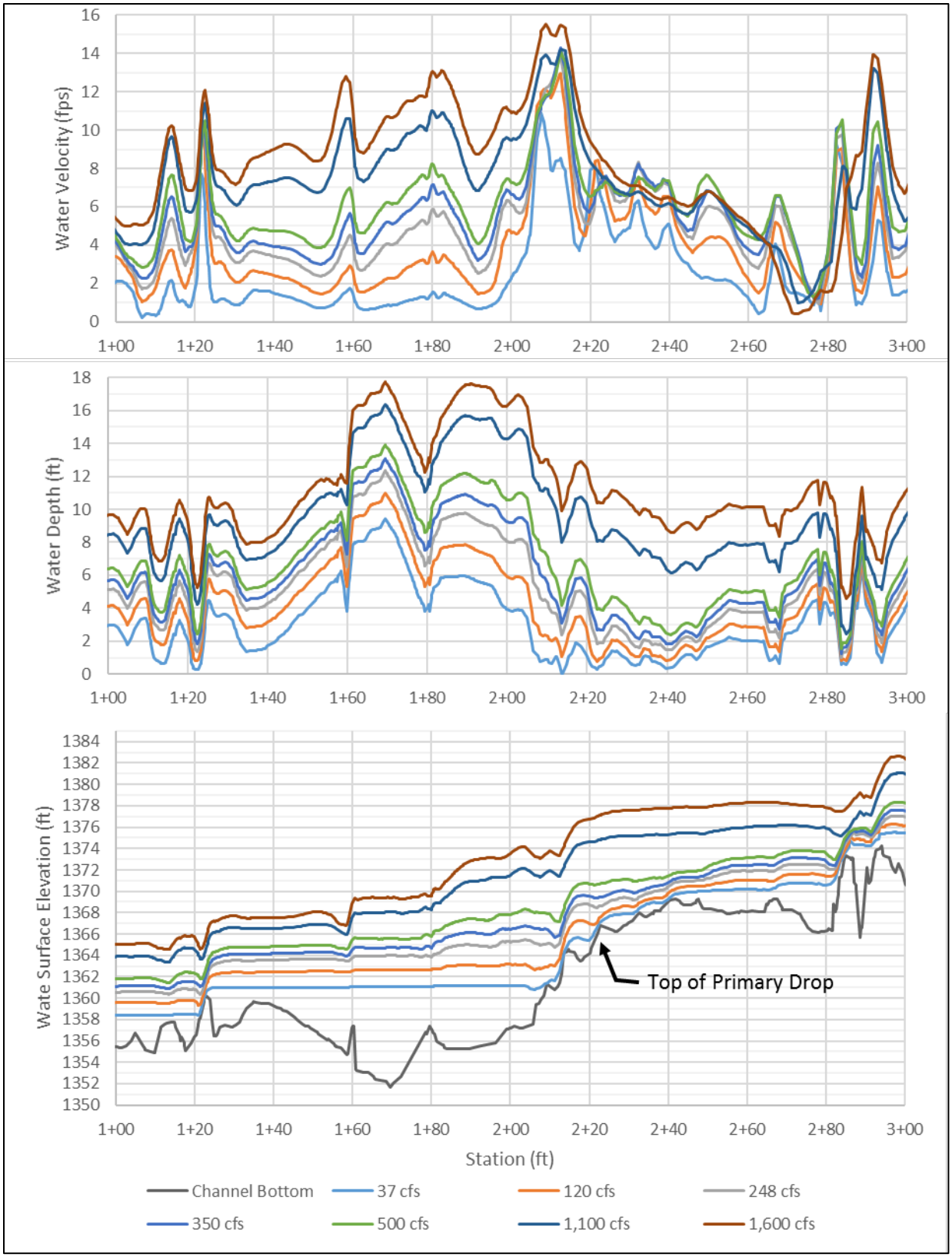



**Figure 8-6. SRH predicted water surface profiles, depths and velocities along the LBS primary alignment.**

**Table 8-1. Summary of LBS fish passage hydraulic conditions and length of Chinook salmon able to swim through the primary drop velocities without reaching exhaustion.**

| Parameter | Flow | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 37 cfs | 120 cfs | 200 cfs | 248 cfs | 350 cfs | 500 cfs | 1,100 cfs | 1,600 cfs |
| **Primary Drop (PA STA 2+00 to 2+50)** | | | | | | | | |
| **Drop Height (ft)** | 8 | 7 | 6.1 | 5.6 | 4.8 | 3.7 | 3.4 | 4 |
| **Length of Drop (ft)** | 31 | 30 | 23 | 16 | 16 | 14 | 14 | 14 |
| **Ave. Slope of Water Surface Drop** | 26% | 23% | 27% | 35% | 30% | 26% | 24% | 29% |
| **Average Depth (ft)** | 1.0 | 1.8 | 2.9 | 2.9 | 3.6 | 4.6 | 8.5 | 10.7 |
| **Min. Depth (ft)** | 0.44 | 0.77 | 1.45 | 1.45 | 1.84 | 2.4 | 6.14 | 8.58 |
| **Average Velocity (fps)** | 7.3 | 7.7 | 7.9 | 7.9 | 8.2 | 8.4 | 9.2 | 10.1 |
| **Max Velocity (fps)** | 10.9 | 12.9 | 13.8 | 13.9 | 14.3 | 14.1 | 14.2 | 15.5 |
| **Min Chinook Size for Passing through Velocity Field (cm)** | 46 | 77 | 85 | 87 | 93 | 95 | 108 | >110 |

### 8.1.5 Fish Passage Conclusions

Evaluating fish passage conditions at natural barriers by examining hydraulic conditions involves some level of subjectivism and professional judgement. Swimming abilities range widely among a population of fish and in some cases behavioral factors can be more important than swimming and leaping abilities in determining the degree a natural feature inhibits fish passage. Although the ability of turbulent flow to block passage of adult salmon and steelhead is well recognized, it remains difficult to measure and quantify thresholds in natural systems. Even with these uncertainties, observations, measurements, and modeling of hydraulics over a range of flows can provide sufficient insight to make a well informed judgement about passage conditions for the general fish population being considered.

Based on the existing hydraulic characterization of the LBS outlined in this Technical Memorandum it is our opinion that the LBS is effectively a total barrier to adult Chinook salmon and steelhead at all flows. High water velocity and large-scale turbulence within the narrow 30-foot long chute that forms the primary drop also propagates through the narrow and shallow receiving pool. These conditions, which persist from the minimum instream flowrate of 35 cfs to the highest flows, will prevent most, if not all, fish from reaching upstream habitat. Secondary passageways do not become suitable for fish until approximately 2,000 cfs, which has a return period of slightly less than 2-years. At this high flow, both the entrance and exit conditions to these passageways are extremely turbulent, and fish would likely not attempt to move upstream.

There are other chutes and complex water surface drops with similar drop heights as the LBS in several locations in Eagle Canyon that are deemed only partial barriers at high flows. The main difference is that these drops and the receiving pool below the drops are not constricted to the extent that occurs at the LBS. Therefore, widening the primary drop chute and receiving pool through removal of large boulders may create a passage window at the LBS.

## 8.2 Upper Barrier Reach

### 8.2.1 Discharge Rating Curves

As presented in Section 7.1.2, five discharge rating curves were developed for the UBS. The five rating curves are presented in Figure 8-7 and the data tables are included in Attachment G. The differences between curves can be used to evaluate the overall water surface drop from pool to pool as part of the passage assessment. These rating tables will also be utilized during alternative and final design development.

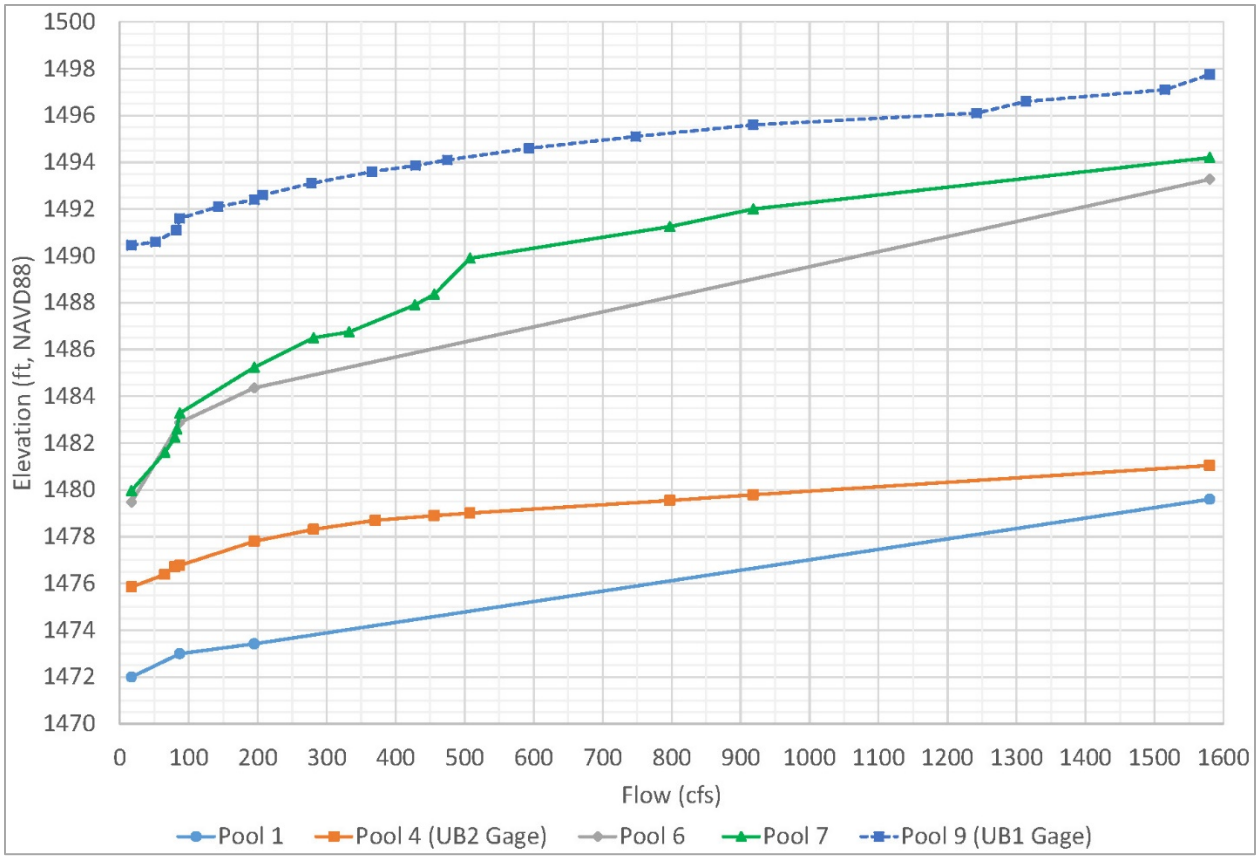



**Figure 8-7. UBS flow rating curves for several pools.**

### 8.2.2 Water Surface Mapping and Observations

Water surface mapping was completed for four different events for the UBS. The methods for collecting the water surface data and the flow determination are provided in Section 6.5. As seen in Figures A-5 through A-8 (see Attachment A), there are two alignments identified as potential flow paths through the UBS. Figure 8-8 and Figure 8-9 present the results of the mapping for the four different events in profile view for the two alignments: primary alignment (PA) and secondary alignment (SA).

Within each profile figure, if the water surface line (blue lines) passes through the channel line, then flow was passing through a sieve or between boulders along the alignment. If the water surface line terminates at the channel line, then that is the edge of water and the channel surface was not wet for the event. The details of each event are discussed further in the following sections. Attachment K presents plan view drawings showing water surface extents, and profile drawings showing water surface elevations for each water surface mapping event. The results with respect to fish passage are presented in Section 8.2.4.

The water surface mapping event 4 (WSME-4) was completed during high flows, which made conducting a complete survey unsafe. Instead, the survey was completed from two different vantage points. Although the survey did not completely cover the UBS, the information gathered was sufficient to provide insight into the hydraulics at the time. Any blanks in the profiles indicated that a point shot was not possible and therefore there is no data.

*Water Surface Mapping Event 1*

Water surface mapping event 1 (WSME-1) was conducted on September 24, 2015 when NFBC flow was 17 cfs and Digger Creek was flowing 5 cfs. Figure K-1 (see Attachment K) presents the UBS in plan view with the limits of water indicated by the blue hatching and the measured water surface points shown.

As seen in Figure K-1, all the flow is following in the PA and passing through the various sieves along this alignment. Upstream of the primary drop, the water is located against the right canyon wall. The SA is dry except for the small portion of it within Pool 6 and then again within and downstream of Pool 2. At this flow, Pool 2 is very calm with little flow passing through. It remains wet due to a backwatering affect from Pool 4.

Figure K-1 also presents two photographs of the UBS during the mapping event. As seen in in the UB2 photograph, the flow is meandering its way through Pool 4. The water in the UB1 photograph is barely visible, partly because of the wood in the channel but also because it quickly disappears below the boulders and sieves within Pool 7.

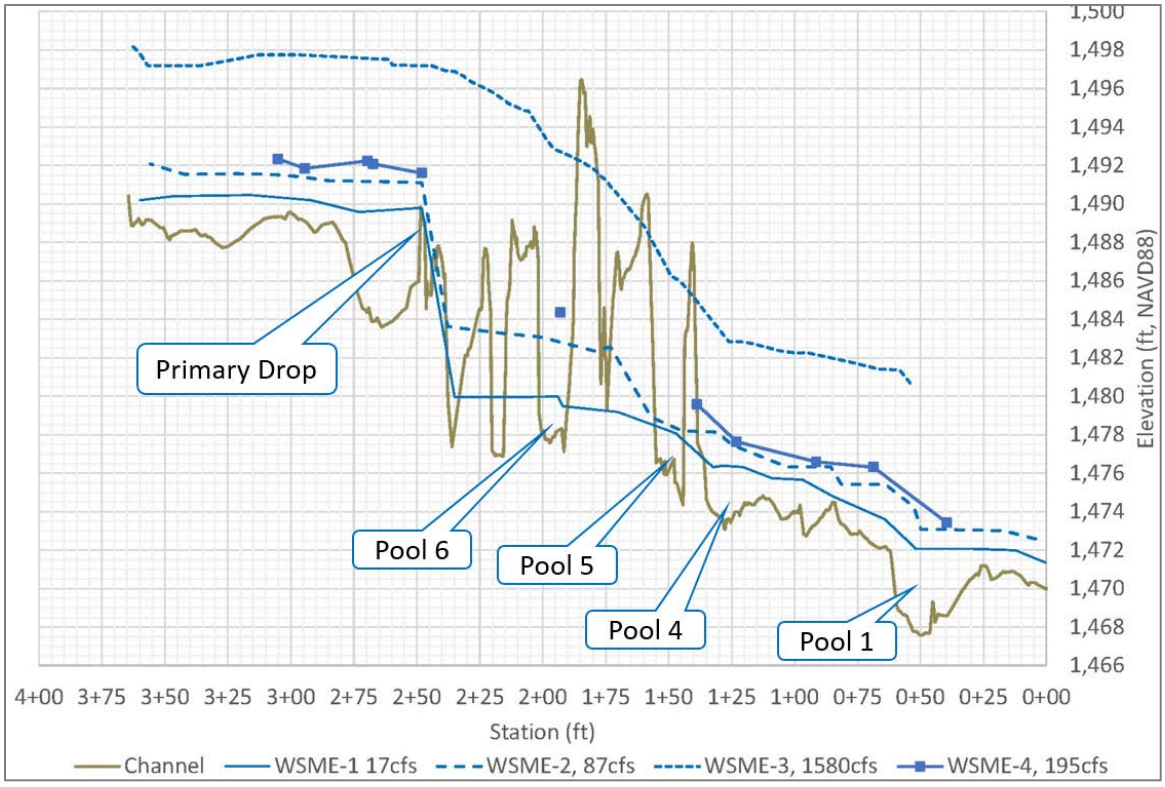



**Figure 8-8. UBS primary alignment water surface profiles for the four water surface mapping events.**

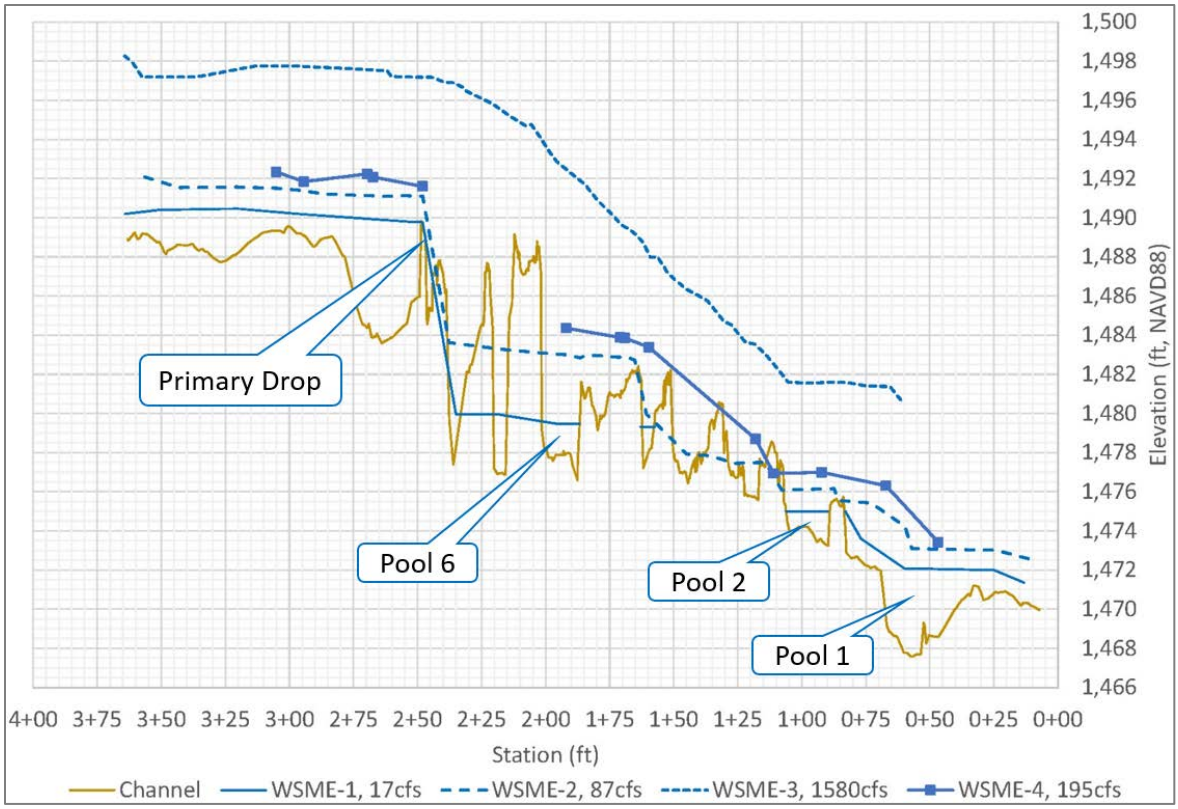



**Figure 8-9. UBS secondary alignment water surface profiles.**

*Water Surface Mapping Event 2*

Water surface mapping event 2 (WSME-2) was conducted on February 10, 2016 when NFBC flow was 87 cfs and Digger Creek was flowing at 24 cfs. Figure K-3 presents the UBS in plan view with the limits of water indicated by the blue hatching and the measured water surface points shown.

As seen in Figure K-3, not all the flow is following the PA for this event, although the majority of the flow is following the PA. The SA does have water in some of its pools, but the pools are disconnected and water is flowing subsurface or directed back towards the PA through sieves (e.g. Sieve B).

Figure K-3 also presents two photographs of the UBS during the mapping event. As seen in the UB2 photograph the flow in Pool 4 has become slightly more turbulent, but many paths through it remain. Pool 3, on the left of the photograph, is relatively still, but as shown in Figure K-1, the SA is not fully connected to Pool 6.

Figure K-3 also presents photographs taken during the flow event. Within the UB1 photograph the water is much more visible during this event than WSME-1, partly because the wood in the channel has moved but also because there is much more water. As flow cascades over the primary drop, it becomes turbulent. The two smaller pools within Pool 7 are visible in the UB1 photograph; one of the pools is near the bottom center and is turbulent, and the other is on the right of the photograph and is also turbulent. The pool near the bottom center is directly connected to Sieve H. The pool on the photo's right is not high enough to be noticeably connected to Sieve I. The two pools are connected to each other by Sieve J.

*Water Surface Mapping Event 3*

Water surface mapping event 3 (WSME-3) was based on high debris lines surveyed on February 10, 2016 that were the result of the January 29, 2016 flow event when NFBC flow was 1,580 cfs and Digger Creek was flowing 427 cfs. Figure K-5 presents the UBS in plan view with the limits of water indicated by the blue hatching and the measured water surface points shown.

This was the highest flow of the mapped events. As seen in Figure K-5, the flow extends from canyon wall to canyon wall upstream of the primary drop. At the upstream end of the Upper Complex on river left, the flow is forced away from the canyon wall as it begins to cascade through the large boulders within the UBS. Under this flow event, both the PA and SA are fully wet. Flow has over topped the tailwater control boulders of Pool 7, connecting it to Pool 6 with a 3 feet drop. Pool 6 and Pool 5 have also become directly connected.

Figure K-5 also presents two photographs of the UBS during the mapping event. These photographs were taken at dusk and the peak of the flow event occurred several hours later. As seen in the UB2 photograph, the flow in Pool 4 has become very turbulent. The SA is flowing full and appears very turbulent. Every sieve is likely overwhelmed with the exception of Sieve A which is still passing all the flow it receives. Flow is visibly overtopping the boulders at Sieve E.

The UB1 photograph indicates that the flow becomes very turbulent under these conditions. Only one boulder is visible and field data indicates that it too was overtopped, but after dark. During this event, flow is traveling over the primary drop and around the B20 Complex.

*Water Surface Mapping Event 4*

Water surface mapping event 4 (WSME-4) was conducted on June 7, 2016 when NFBC flow was 195 cfs and Digger Creek was flowing at 32.2 cfs. Figure K-7 presents the UBS in plan view with the limits of water indicated by the blue hatching and the measured water surface points shown.

Flow during WSME-4 was eight times less than WSME-3 and two times larger than WSME-4. As seen in Figure K-7, flow nearly spans the channel upstream of the primary drop, and a decent amount of flow was witnessed passing through Sieve M. It was during this field visit that it became apparent that Sieve I is present and can pass a good percentage of the total flow. During this flow, Pool 6 is spilling into the SA and the SA is flowing along its full length. Pool 6 is also spilling directly into Pool 5 and Sieve B is passing a lot of water below the Table Complex. Compared to the first two events, this event provided the most variety of flow paths through the UBS.

Figure K-7 also presents two photographs of the UBS under flows similar to those during the mapping event. Time-lapse camera UB2 batteries were exhausted prior to the event and the flows were too high to safely reach time-lapse camera UB1. Instead, the water level gage data and point shots taken during the event were used to identify another time when the conditions were similar.

As seen in the UB2 photograph, the flow in Pool 4 has become slightly more turbulent than during WSME-2, but many paths through it remain. Pool 3, on the left of the photograph, is still relatively calm. The SA is fully connected partly visible in the UB2 photograph.

The UB1 photograph looks very similar here as it did for the WSME-2 but, as mentioned previously, water is flowing into Sieve I under these conditions but not during WSME-2.

### 8.2.3 HEC-RAS Hydraulic Results

Figure 8-10 presents the water surface profiles for peak flows with specified return periods generated from HEC-RAS for existing conditions. The model was evaluated at four different peak flows: Q10, Q25, Q50, and Q100. As seen in Figure 8-10, the flow is a mixture of super- and sub-critical flows. This information will be used during the alternative development. Attachment L contains additional results from this analysis.

### 8.2.4 Fish Passage Hydraulic Discussion

As described in Section 7.3.2, the SRH-2D model for the UBS was rejected. In lieu of modeling hydraulic conditions at the UBS, field based measurements and observations will be used as the framework to describe the fish passage conditions. The discussion is separated by channel features including the primary drop, Pool 7, Sieve H, Pool 6, Sieve G, Sieve D, Pool 5, and the secondary alignment flow path. Section 8.2.5 will summarize the discussion with respect to the overall fish passage conditions at the UBS.

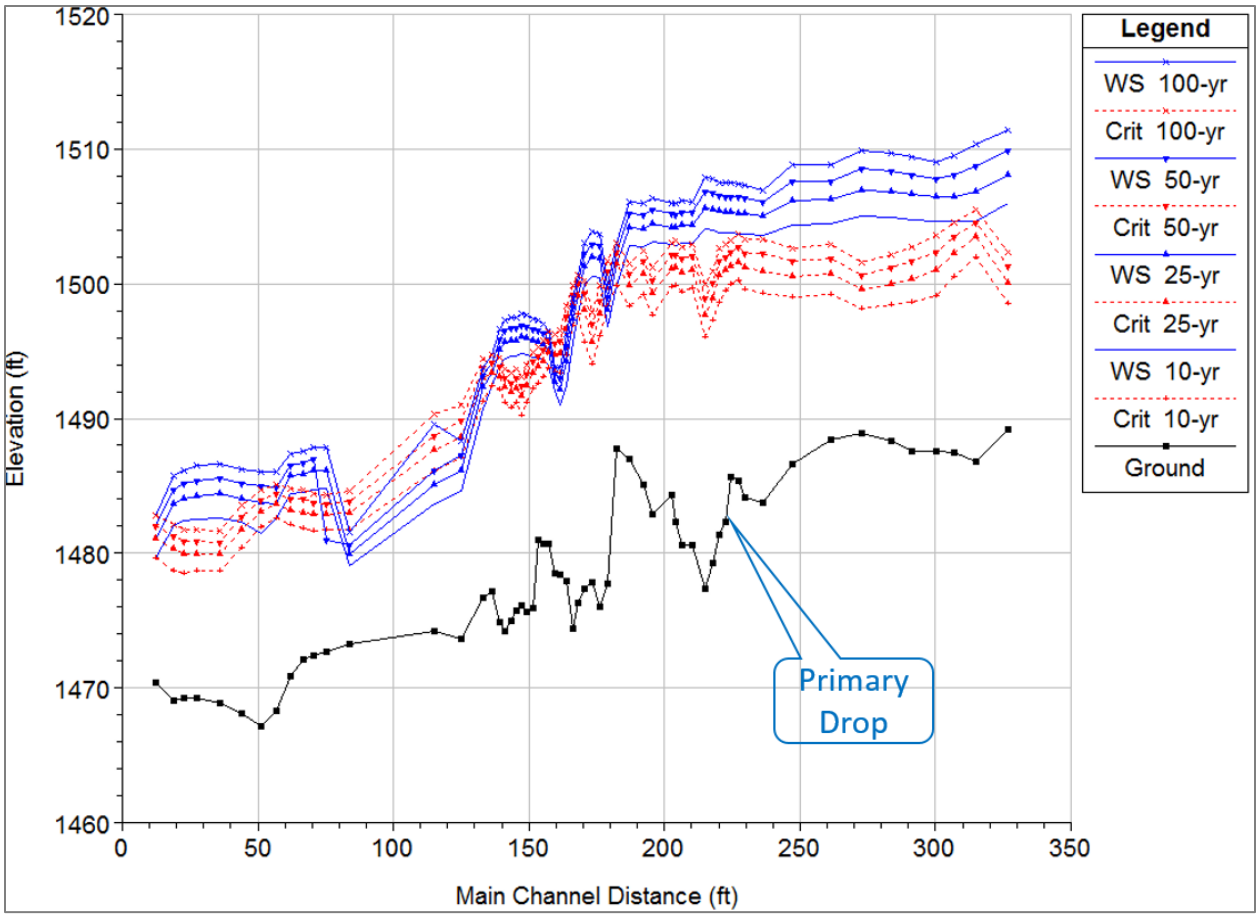



**Figure 8-10. HEC-RAS profile results from the UBS peak flow analysis.**

*The Primary Drop*

The primary drop is the easiest potential barrier to identify within the UBS. At lower flows, when conditions are safe to access the site, the primary drop forms a steep chute that visibly creates a total fish barrier. It produces a combination of high water velocities with extreme turbulence and

aeration in the chute, which discharges into a shallow to nearly non-existent pool filled with boulders that take-up the little pool volume that exists. The primary question is whether fish passage conditions improve at the primary drop at higher flows. For the primary drop to become passable, the difference in water surface between Pool 7 (below the drop) and Pool 8 (above the drop) must decrease and the velocity and turbulence must become suitable for passage.

Figure 8-11 presents the Pool 7 discharge rating curve and the difference in the pool elevations of Pool 7 and Pool 9. Pool 8 does not have a rating curve developed, and at higher flows Pool 8 joins with Pool 9. As seen in the figure, the WSE difference quickly decreases from greater than 10 feet at 17 cfs to approximately 4 feet at 500 cfs. Based on the photo of the primary drop at approximately 500 cfs in Figure 8-12, passage might look possible for strong fish, but when the time-lapse camera photos are watched in quick succession the flow appears very turbulent and appears unlikely that even strong fish would be able to pass under these conditions. Therefore, due to poor conditions the primary drop is considered a barrier at all flows.

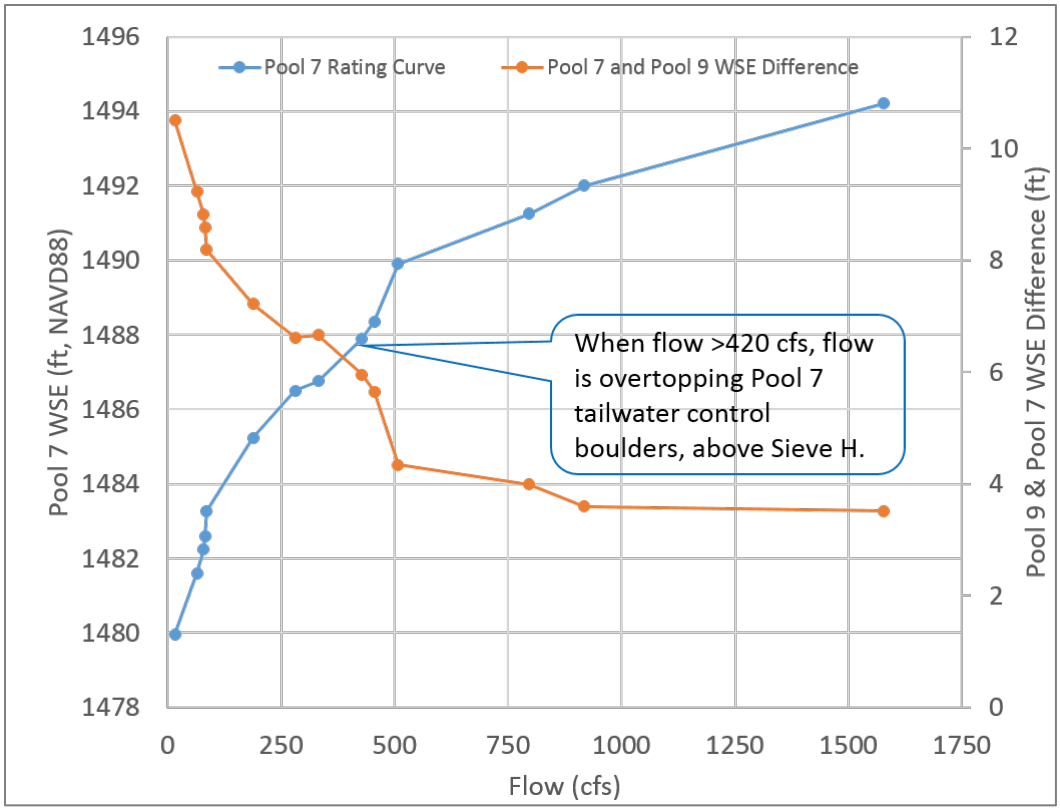



**Figure 8-11. Pool 7 rating curve with Pool 7 and Pool 9 water surface elevation difference.**



**Figure 8-12. UBS primary drop when flow approximately 500 cfs.**

*Pool 7*

Pool 7, located immediately downstream of the primary drop, consists of several small pools at low flows that converge into a single pool at greater flows, approximately 430 cfs. Under low flows, the pools are very shallow with large boulder protruding the water surface. Under these conditions, water quickly moves through Pool 7 into Sieve H. A migrating fish would have difficulty reaching the base of the primary drop until flow is approximately 430 cfs, primarily due to shallow depths and the disconnected nature of the sub-pools. At flows above 430 a fish may be able to hold and attempt to pass the primary drop, but the pool would be turbulent and aeriated (Figure 8-12).

*Sieve H*

Sieve H is approximately 15 feet long. The sectional dimensions are unknown but based on site visits during elevated flow conditions it can pass a relatively large portion of the flow. At 195 cfs, flow from Pool 7 is split between Sieve I (not a fish passage route) and Sieve H (Figure 3-11, page 24). Due to the turbulent nature of the water within Pool 7 it is difficult to determine the amount of flow entering each sieve, but it is reasonable to assume that half of the flow is entering each. Under this condition, the jet at the Sieve H exit (into Pool 6) appears relatively calm, which indicates that the velocity within Sieve H may not be a limiting factor for fish passage under this flow.

When flow is approximately 430 cfs, water begins to overtop the boulders above Sieve H. The head difference between the inlet and outlet of Sieve H is approximately 2 feet (Figure 8-7). No photographs of this portion of the channel exists under these conditions and so it is difficult to state what the fish passage conditions are within Sieve H at 430 cfs but if the velocity is too great for a fish to navigate the sieve, then it may be possible for them to leap from Pool 6 to Pool 7 directly. As flows continue to increase, the head difference between Pools 6 and 7 increases to approximately 3.7

feet based on the data presented in Figure 8-7 and then slowly begins to converge as flows approach 1,600 cfs.

*Pool 6*

At low flows, Pool 6 is approximately 14 feet long and wide and has an average depth of 1.5 feet. Under these flow conditions, all flow is leaving Pool 6 via Sieves G and F; under these conditions Sieve G is a potential fish passage route while Sieve F is not. As flows increase, the pool extends further downstream until flow begins to crest the tailwater control along the secondary alignment, which occurs when the total NFBC flow is approximately 86 cfs. Under this and greater flows, Pool 6 is approximately 40 feet long, the width remains approximately 14 feet. The depth increases to approximately 4 feet.

Figure 3-11 (page 24) shows an aerial image of Pool 6 when flow is 195 cfs. Under these conditions, Pool 6 appears calm and could serve as a holding pool for fish attempting to move further upstream. No other photographs of this pool under higher flows exist, but it is assumed that Pool 6 remains relatively calm as flows increase. When flow is approximately 430 cfs, water begins to overtop the Pool 7 tailwater control (above Sieve H) and plunge into Pool 6. This would increase the turbulence, but at this point Pool 6's length is expected to provide some relatively calm holding areas.

*Sieve G*

Under low flows, nearly all the flow passes through Sieve G. As flow increases, water begins to move through Sieves I and F. Neither of these Sieves are considered a fish passage route. The dimensions of Sieve G are not known because it has not been safe to approach, but as seen in Figure 3-12 (d), the shape is triangular and based on the point cloud data is approximately 6 feet tall and greater than 4 feet wide (the point cloud does not have sufficient data to measure the width). Based on the Pool 6 flow rating curve (Figure 8-7), Sieve G may become fully inundated when the NFBC flow is approximately 450 cfs. The hydraulics under these higher flows are difficult to quantify, but if passage is not feasible under these conditions, other flow paths exist (see Secondary Alignment discussion below).

*Sieve D*

Sieve D is relatively small when compared to other sieves along the primary alignment but still conveys a large portion of the flow and provides one of the main passage routes leading to the primary drop. Under low flows, nearly all the stream's flow goes through this sieve (Figure 8-13). Based on Figure 8-13, it appears that there is an upwelling as flow exits the sieve, which indicates that the flow may be, at least partly, traveling under the large boulders to exit through the sieve. The opening is approximately 1.75 feet wide. Under low flow conditions, a fish would need to leap or swim over the drop and into the sieve.

The photograph presented in Figure 8-14 was taken when NFBC flow was 87 cfs. At the time of the photograph, Sieve D was conveying a majority of the flow. The velocity of the flow exiting the sieve high and may be challenging for some fish, especially considering the small size and turbulence within the receiving Pool 5. When NFBC flow is 87 cfs, the secondary alignment is just beginning to receive flow, but the flow does not travel the full length until NFBC flow is approximately 125 cfs and does not appear passable until the NFBC flow is 195 cfs. However, at approximately 145 cfs there appeared to be alternative routes to arrive at Pools 6, including Sieves B, E, and F. When observed, some of them appeared to lack good attraction and depth, but at slightly higher flows, some of these passageways may have improved conditions.

Overall, Sieve D's impact on fish passage is indeterminate. Future design should review the boulder configurations associated with this sieve to determine if they can be altered to improve the passage conditions.



**Figure 8-13. Sieve D, outlined in red, under low flow conditions (17 cfs).**



**Figure 8-14. Sieve D when NFBC flow is 87 cfs.**

*Pool 5*

Pool 5 is relatively fixed in its length and width dimensions due to the large boulders surrounding it. The pool is approximately 4.5 feet long and 10 feet wide. Pool 5 primarily receives flow from Sieve D but can receive flow from Sieve E as flows increase and directly from Pool 6 as flows increase even further. Boulder B122 is approximately 5.7 feet long (parallel to flow), 4 feet wide (perpendicular to flow), and 6 feet tall and consumes a large portion of Pool 5's volume. There are other smaller boulders within the pool that also limit its volume. As seen in Figure 8-14, at 87 cfs, the water within Pool 5 is moderately turbulent and may prove difficult for a fish to hold while it waits to move into Sieve D. At higher flows, this turbulence likely increases in the main portion of the pool receiving flow from Sieve D, but there are calmer regions along the edge. Once flow is moving through Sieve E and directly from Pool 6, the turbulence likely increases but the additional fish passage routes also become available.

*Secondary Alignment*

Under low flows (up to approximately 87 cfs) the secondary alignment is nearly dry. The exceptions include a couple isolated pools that receive subsurface flow. At 87 cfs, the first trickle of flow begins to leave Pool 6 and navigate the secondary alignment. When NFBC's flow is approximately 125 cfs, flow is continuous along the secondary alignment from Pool 6 to Pool 3.

During a site visit when NFBC flow was 195 cfs, the secondary alignment appeared passable (Figure 8-16 and Figure 3-11). At this point, the flow is continuous along the entire alignment. There are some drops within the alignment but they appear to be in concert with the drops throughout Eagle Canyon and in some cases there are pathways around the drops. Because of the multiple pathways along the secondary alignment, it is possible that passage conditions may be suitable at a lower flow

than 195 cfs. The secondary alignment begins to appear impassable when NFBC is approximately 500 cfs (Figure 8-17). At this flow, the water becomes visibly turbulent, similar to fishways that have been found to have excess turbulence.

It should be noted that the time difference from the photograph in Figure 8-15 to the photographs in Figure 8-16 and Figure 8-17 is 2 hours 40 minutes and 4 hours 20 minutes, respectively, for the January 29, 2016 flow event. Therefore, the secondary alignment channel only had a window of 1 hour 40 minutes on the rising limb of the flow. The same flow event's receding limb provided passable flows for 34.5 hours.

It is recommended that improvements to the secondary alignment channel be examined during the next phase of work to possibly improve the passage conditions at a lower flow than 195 cfs. This could likely be accomplished by rearranging the boulders and possibly adding material to the channel.



**Figure 8-15. The secondary alignment, outlined in red, when NFBC flow is 125 cfs. Flow is just being connected along the secondary alignment from Pool 6 to Pool 4.**



**Figure 8-16. The secondary alignment when NFBC flow is 195 cfs. Secondary alignment begins to appear passable based partly on this photograph and additional field observations.**



**Figure 8-17. The secondary alignment when NFBC flow is 500 cfs. Secondary alignment begins to appear impassable.**

### 8.2.5 Fish Passage Conclusions

Similar to the LBS, evaluating fish passage conditions at natural barriers involves some level of subjectivism and professional judgement. The UBS is substantially more complex, and contains more challenging hydraulic features, than the LBS. Many of these challenging reaches are long sieves that produce a hydraulic environment difficult to characterize at higher flows. As a result, there is additional uncertainty regarding passage conditions at the UBS when compared to the LBS.

Figure 8-18 provides a graphical interpretation of the fish passage characterization conclusions for selected UBS features. A question mark indicates that a particular bound has not been identified, but the color gradient for that feature indicates where passage may remain suitable while it moves to less than suitable (white).

Based on observations, it appears that passage conditions are suitable under most flows up to about 500 cfs for fish to reach Pool 6, although there is some uncertainty with respect to the conditions within Pool 5 and through Sieve D and when the secondary alignment becomes passable. Pool 6 appears to maintain favorable passage/holding conditions up to at least 500 cfs. Sieve H does appear to provide suitable passage conditions up to flows of 300 cfs, but data is lacking to quantify the upper bound for when conditions become less than suitable.

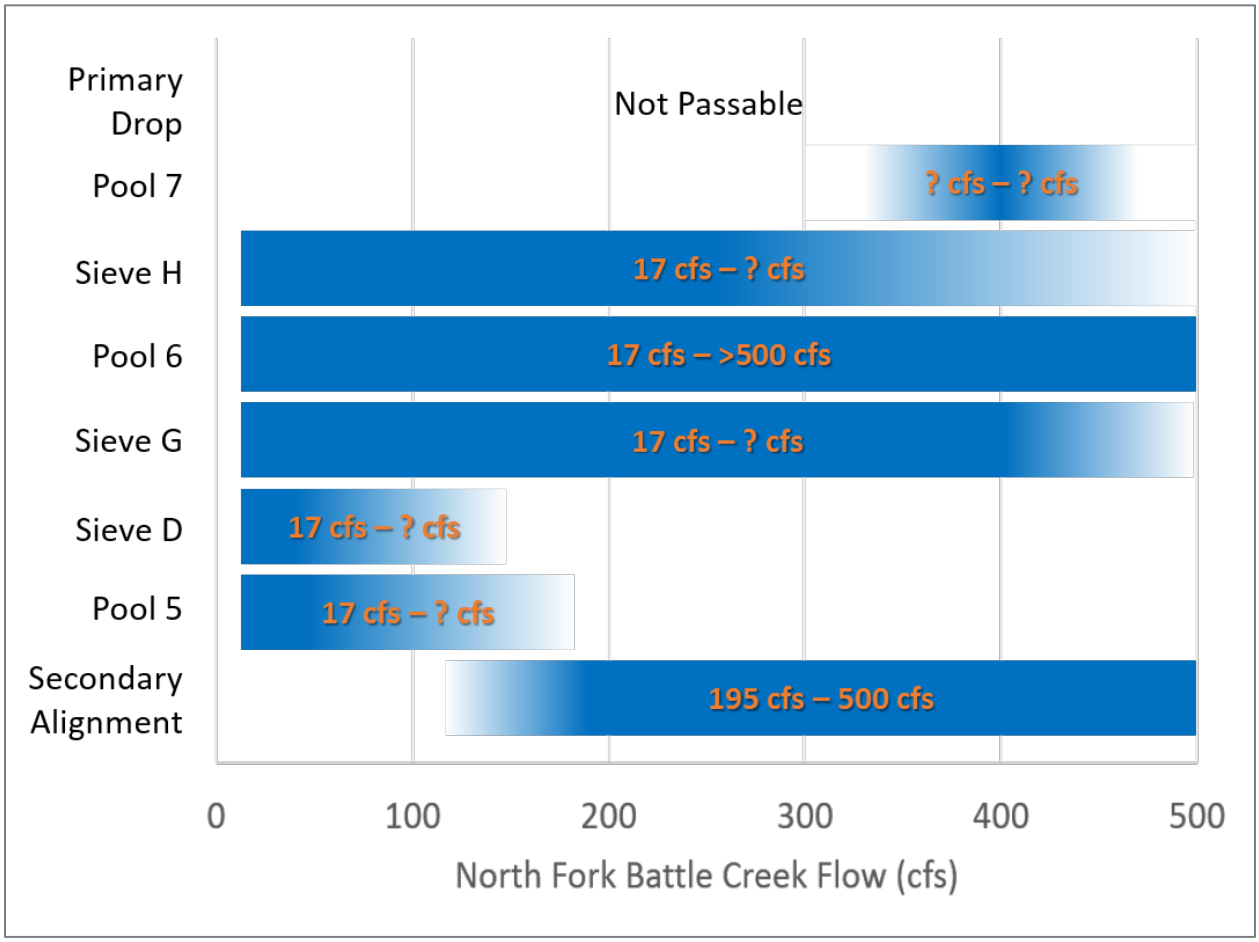



**Figure 8-18. UBS fish passage conclusions for selected features.**

Pool 7 is undefined on both ends of the spectrum with respect to passage conditions. At low to moderate flows, the pool has insufficient depth or remains disconnected into sub-pools separated by large boulders, making in very difficult for a fish to approach to bottom of the primary drop. At higher flows the pool becomes very turbulent which may disorient fish or make holding difficult.

The primary drop is likely a complete barrier at all flows. Passage improvements should focus passage between Pool 6 and Pool 8, including the primary drop. To ensure access to Pool 6 over a wide range of passage flows, additional improvements may be desirable for along the various sieves and the secondary alignment that lead to Pool 6.

Radio telemetry studies using tagged salmon placed immediately downstream of the LBS at various flows may help identify locations that fish have difficulty as they attempt to reach Pool 6 and/or Pool 7. These same studies may consider placing the fish downstream of another section of rapids between the Eagle Canyon Dam and the LBS to make sure these rapids are also passable.

# 9 CONCLUSIONS

Fish passage conditions at the North Fork Battle Creek Lower Barrier Site (LBS) and Upper Barrier Site (UBS) were evaluated for a range of fish passage flows using direct observation, measurements, hydraulic modeling, and fish passage modeling. Both sites are considered total barriers to the target fish species and life stages: adult anadromous Chinook salmon and steelhead. There is the potential that one or more individual fish may be able to pass through these barriers at certain flow conditions, but in general these sites will preclude passage for nearly the entire fish population. To meet the Battle Creek Salmon and Steelhead Restoration Project objective of providing passage for these fish to reach spawning and rearing habitat upstream of the North Battle Creek Feeder diversion dam, the LBS and UBS should be modified to improve passage conditions. The data and analysis presented in this Technical Memorandum will be used to develop alternatives for improving passage at the LBS and UBS, which should result in preferred alternatives to be implemented at both sites.

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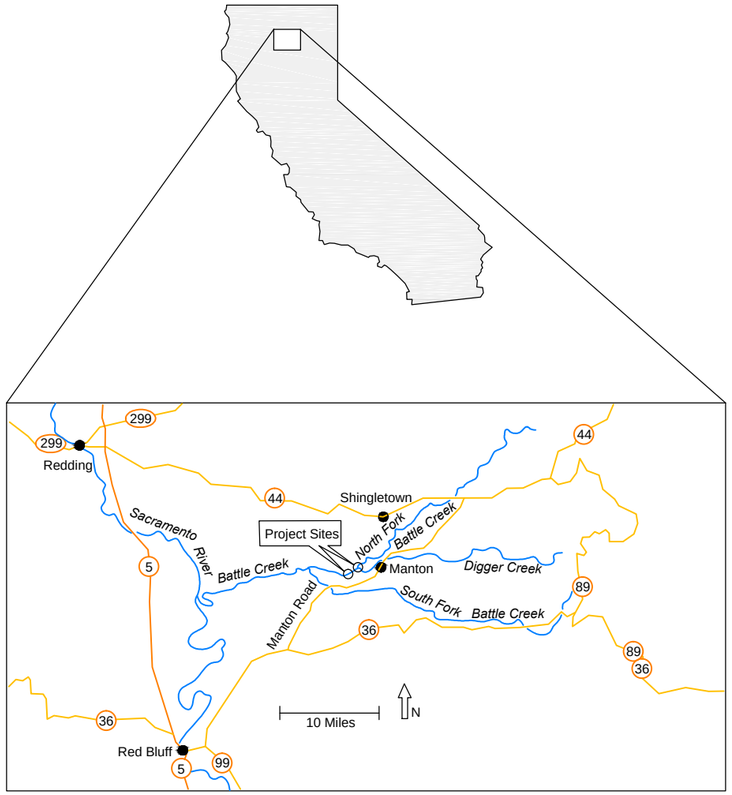
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Attachment A **Project Sites Plan and Profile Drawings**




PROJECT LOCATION





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N.F. BATTLE CREEK, EAGLE CANYON

# PROJECT LOCATION MAP AND SHEET INDEX

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FIGURE
**A-1**

TIMELAPSE CAMERA
OCT 28, 2015 – FEB 29, 2016

TIME LAPSE CAMERA, FEB. 29, 2016 – JUNE 7, 2016

WATER LEVEL GAGE, LB2

POOL 1

POOL 2

POOL 3

POOL 4

PRIMARY ALIGNMENT

TERTIARY ALIGNMENT

SECONDARY ALIGNMENT

QUATERNARY ALIGNMENT

PRIMARY DROP

SIEVE, TYP

CONTROL POINT, TYP

TOE_B55

TOP_B55

TOE_B57

TOE_B53

PLAN

0 5' 10'

GRAPHIC SCALE

N

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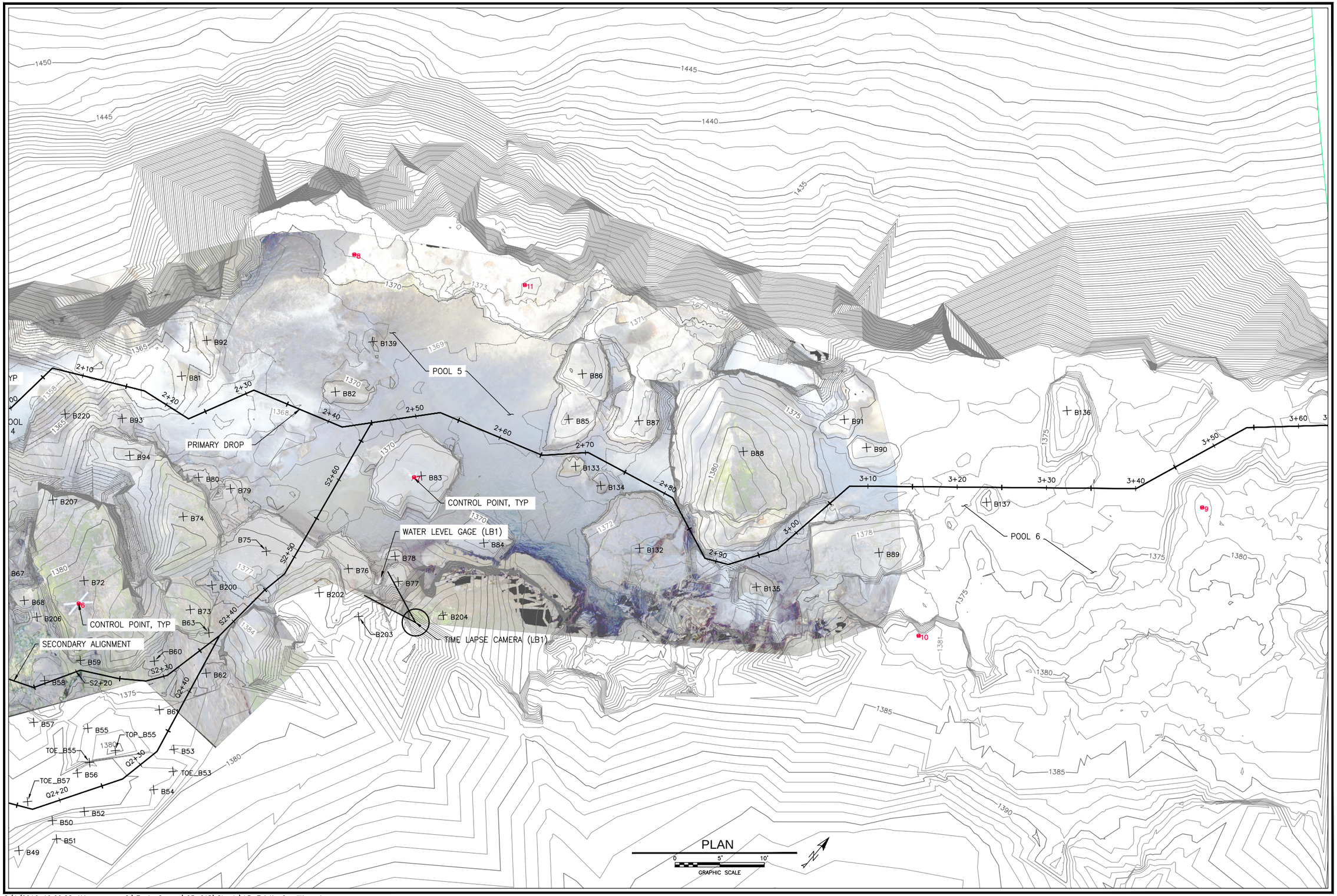
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# LOWER BARRIER
# EXISTING CONDITIONS PLAN, 1 OF 2

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FIGURE
A-2




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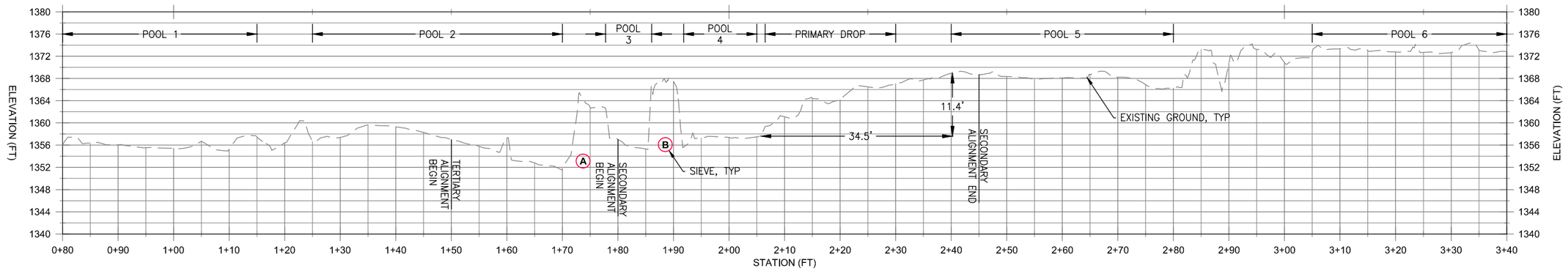
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# EXISTING CONDITIONS PLAN, 2 OF 2

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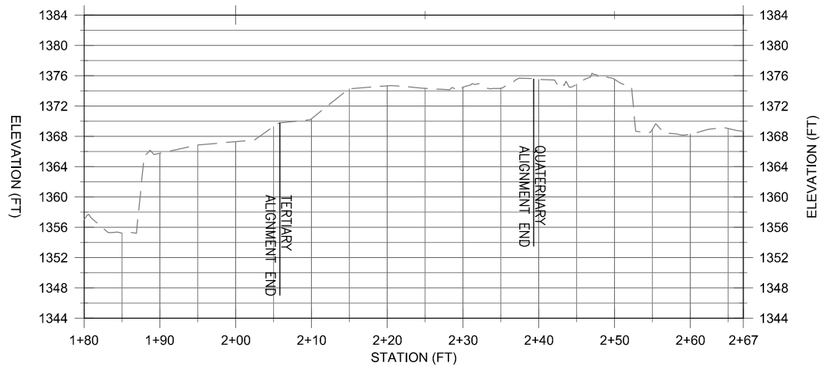
FIGURE
**A-3**

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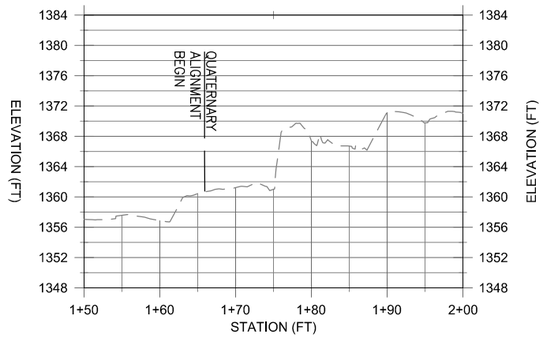

PRIMARY ALIGNMENT PROFILE

GRAPHIC SCALE 0 10' 20'



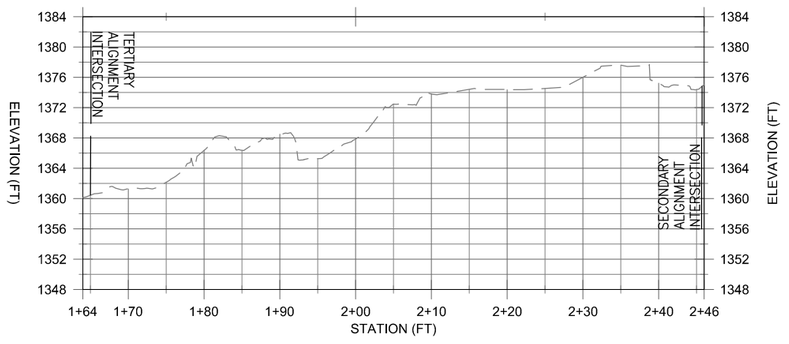

SECONDARY ALIGNMENT PROFILE

GRAPHIC SCALE 0 10' 20'




TERTIARY ALIGNMENT PROFILE

GRAPHIC SCALE 0 10' 20'




QUATERNARY ALIGNMENT PROFILE

GRAPHIC SCALE 0 10' 20'

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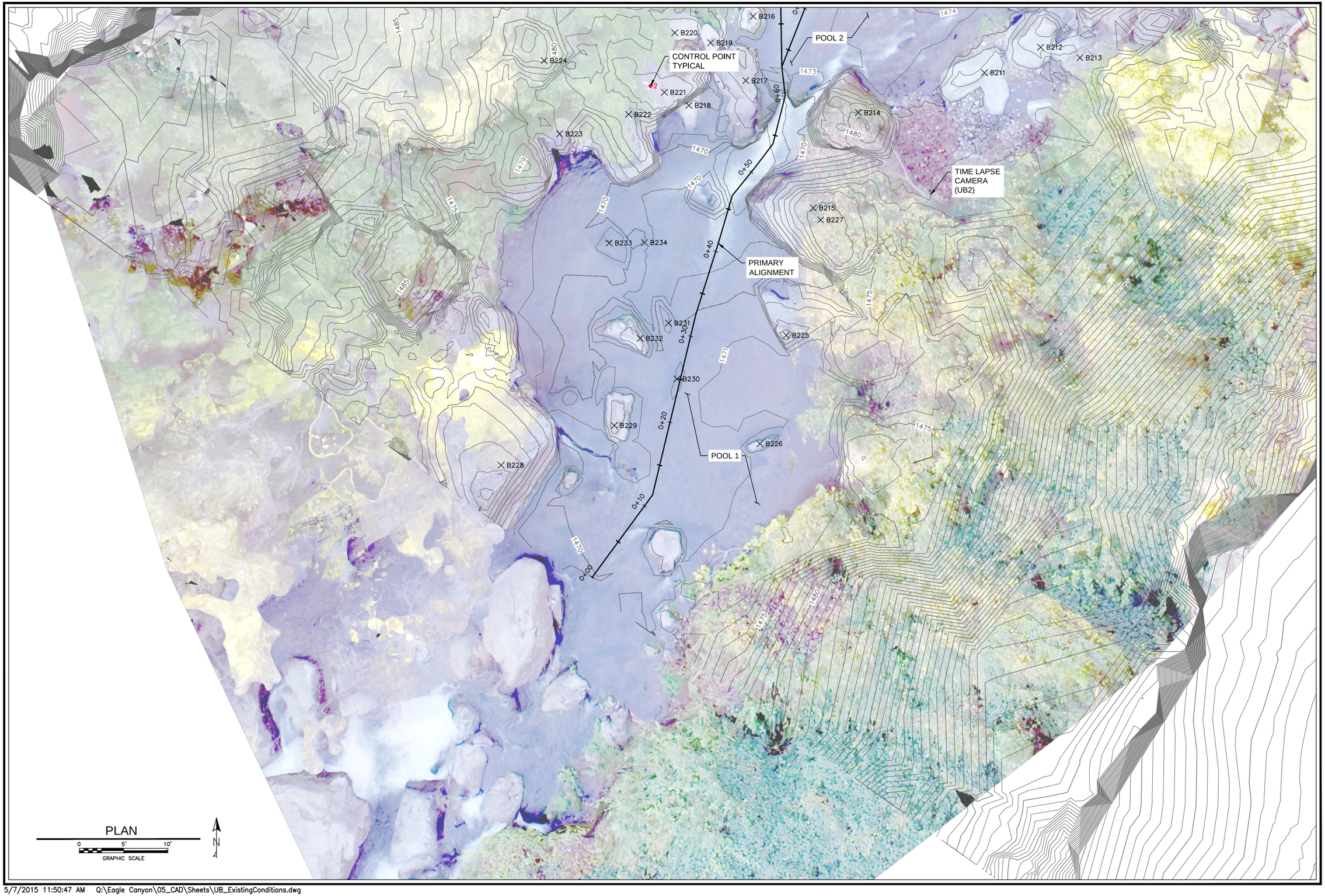
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# EXISTING CONDITIONS PROFILES

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FIGURE
**A-4**




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# UPPER BARRRIER
# EXISTING CONDITIONS PLAN, 1 OF 4

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FIGURE
**A-5**

SIEVE ID AND APPROXIMATE FLOW PATH, TYP

SECONDARY ALIGNMENT

POOL 5

POOL 4

POOL 3

POOL 2

WATER LEVEL GAGE (UB2)

CONTROL POINT TYPICAL

BOULDER ID, TYP

PLAN

0 5' 10'

GRAPHIC SCALE

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# UPPER BARRIER
# EXISTING CONDITIONS PLAN, 2 OF 4

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FIGURE
**A-6**

POOL 8

POOL 7

POOL 6

CONTROL POINT TYPICAL

(E) PRIMARY DROP

TIME LAPSE CAMERA (UB1)

SIEVE ID AND APPROXIMATE FLOW PATH, TYP

PLAN

0 5' 10'

GRAPHIC SCALE

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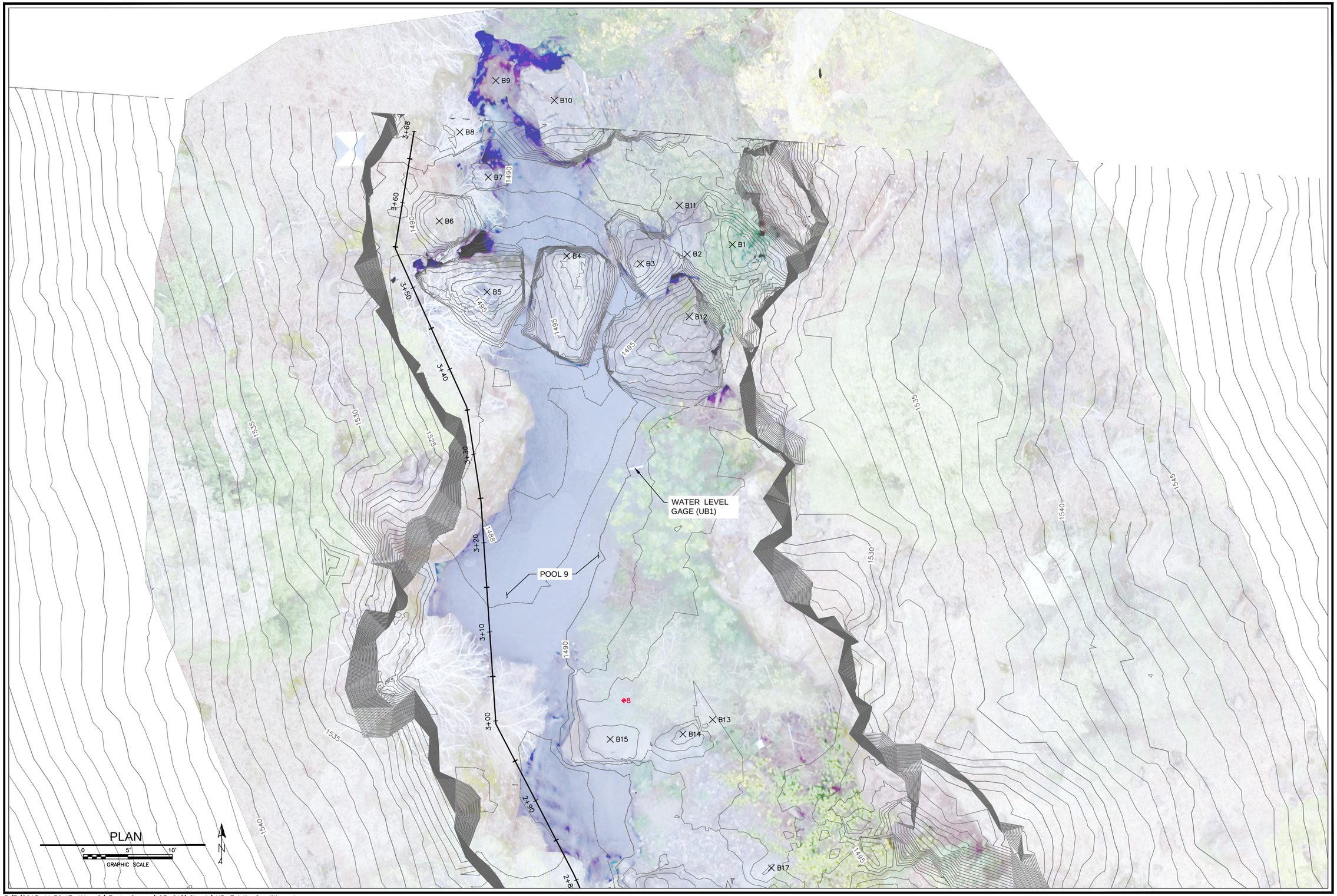
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# UPPER BARRIER
# EXISTING CONDITIONS PLAN, 3 OF 4

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FIGURE
A-7




PLAN

0 5' 10'

GRAPHIC SCALE

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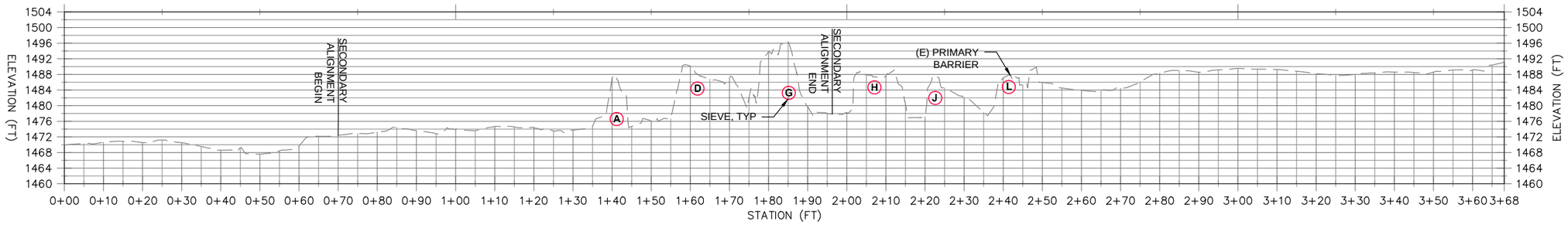
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# UPPER BARRIER
# EXISTING CONDITIONS PLAN, 4 OF 4

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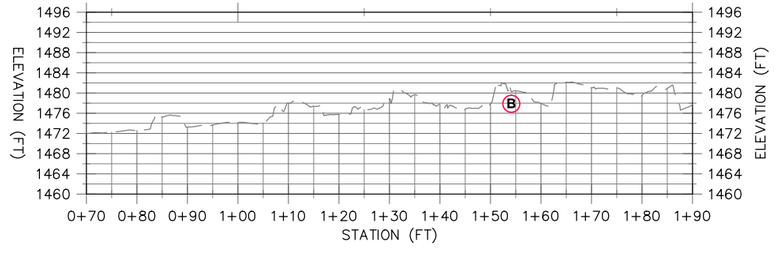
FIGURE
**A-8**




PRIMARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE


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**UPPER BARRIER**
**EXISTIG CONDITIONS PROFILES**

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FIGURE
**A-9**

Attachment B **Lower Barrier Site Photographs**

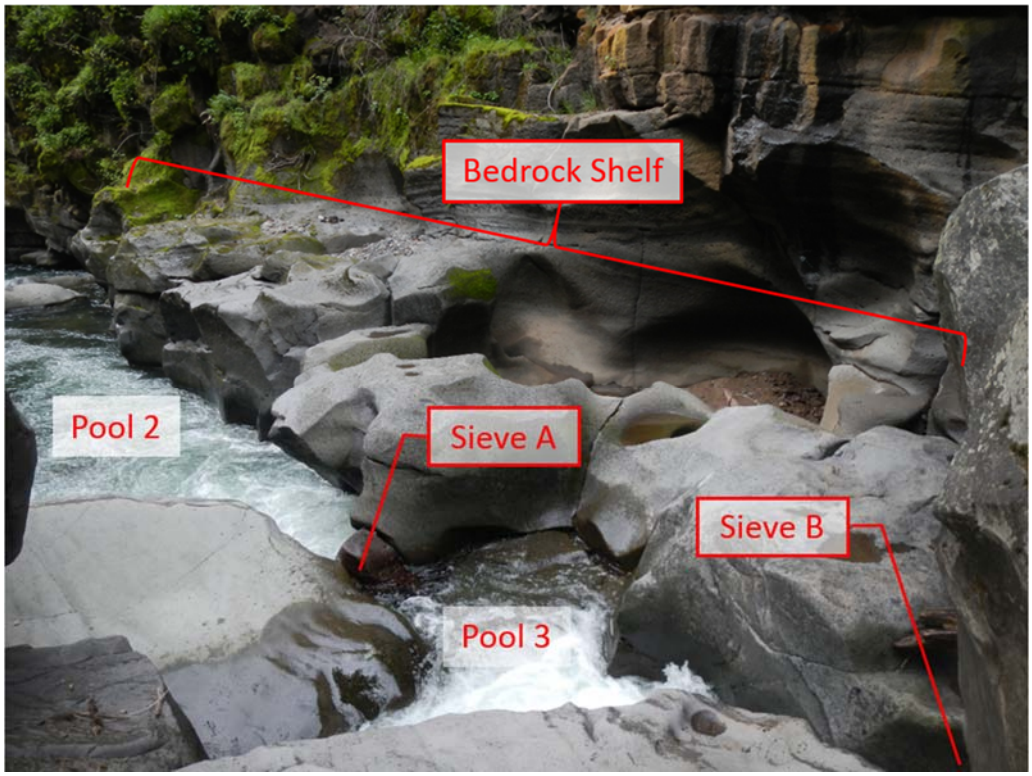



**Figure B-1. LBS river right bedrock shelf, looking downstream, at a flow of 120 cfs.**

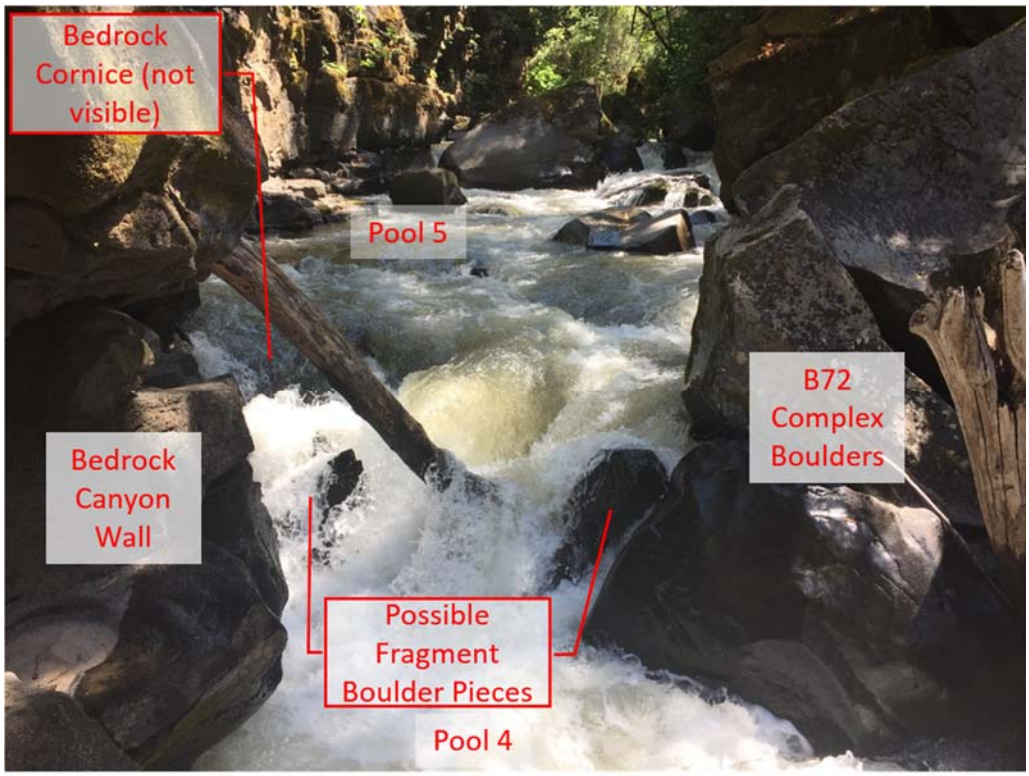



**Figure B-2. LBS primary drop looking upstream at a flow of 248 cfs, with possible boulder fragments from the 2012 removal effort visible within the drop.**

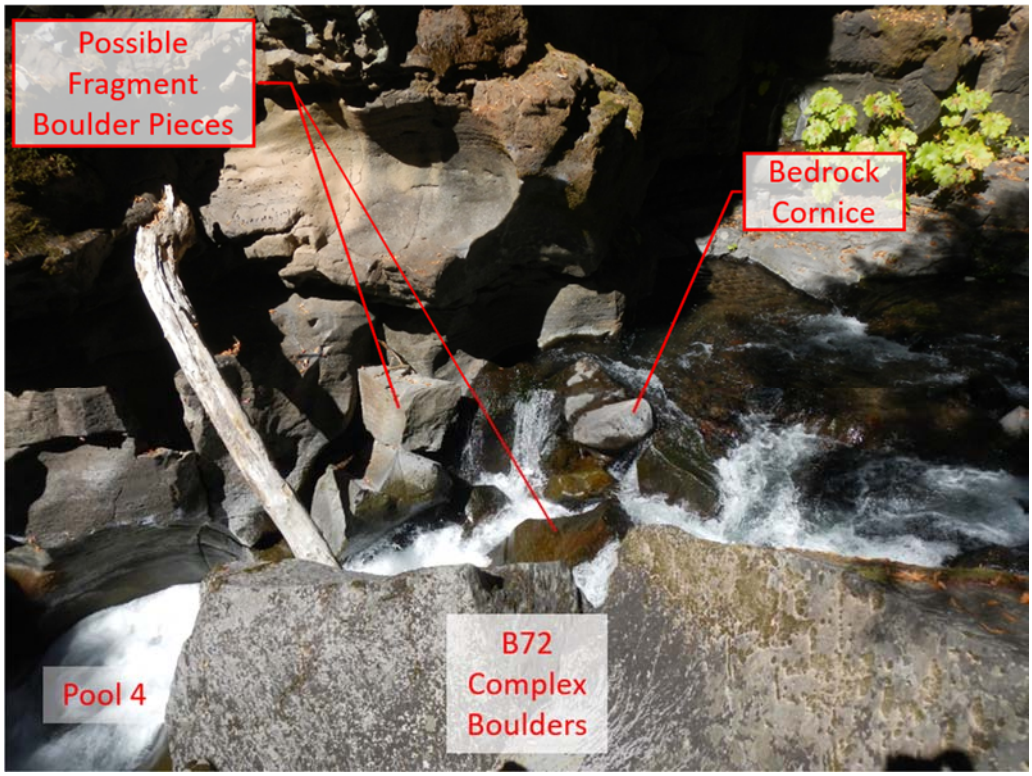



**Figure B-3. LBS primary drop with bedrock cornice and possible boulder fragments visible, flow 37 cfs, right to left.**

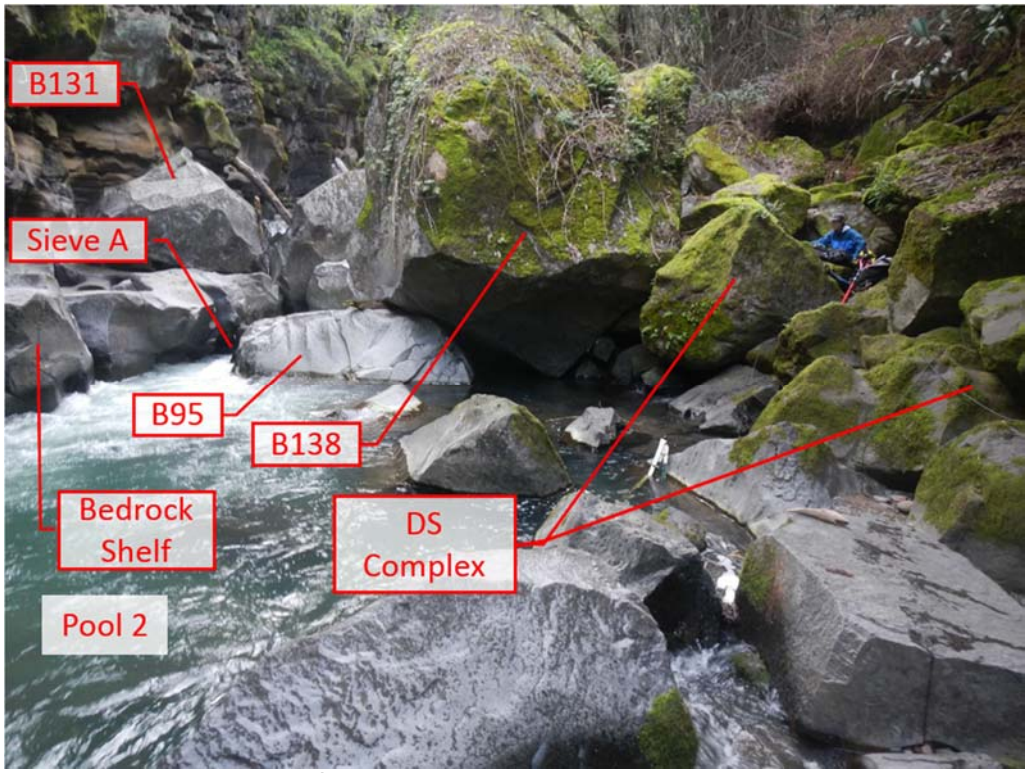



**Figure B-4. LBS boulder/boulder complexes B95, B138, DS Complex, and B131. Photograph looking upstream with flow at 120 cfs.**

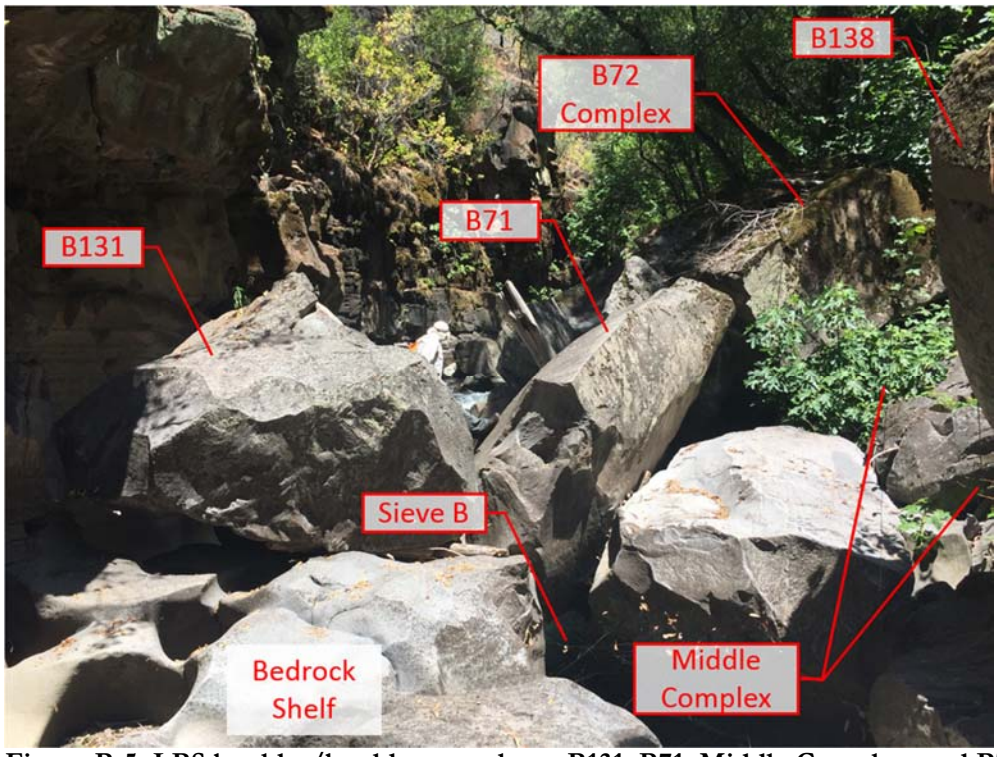



**Figure B-5. LBS boulder/boulder complexes B131, B71, Middle Complex, and B72 Complex. Photograph looking upstream with flow at 37 cfs.**

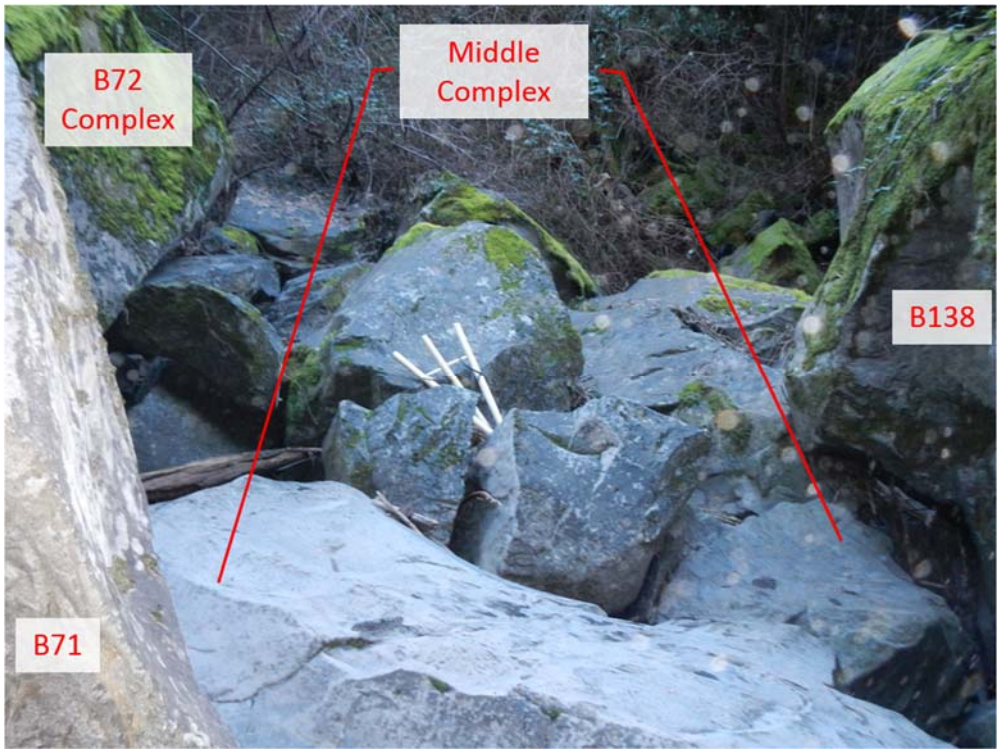



**Figure B-6. LBS boulder/boulder complexes Middle Complex, B72 Complex, B138, and B71.**

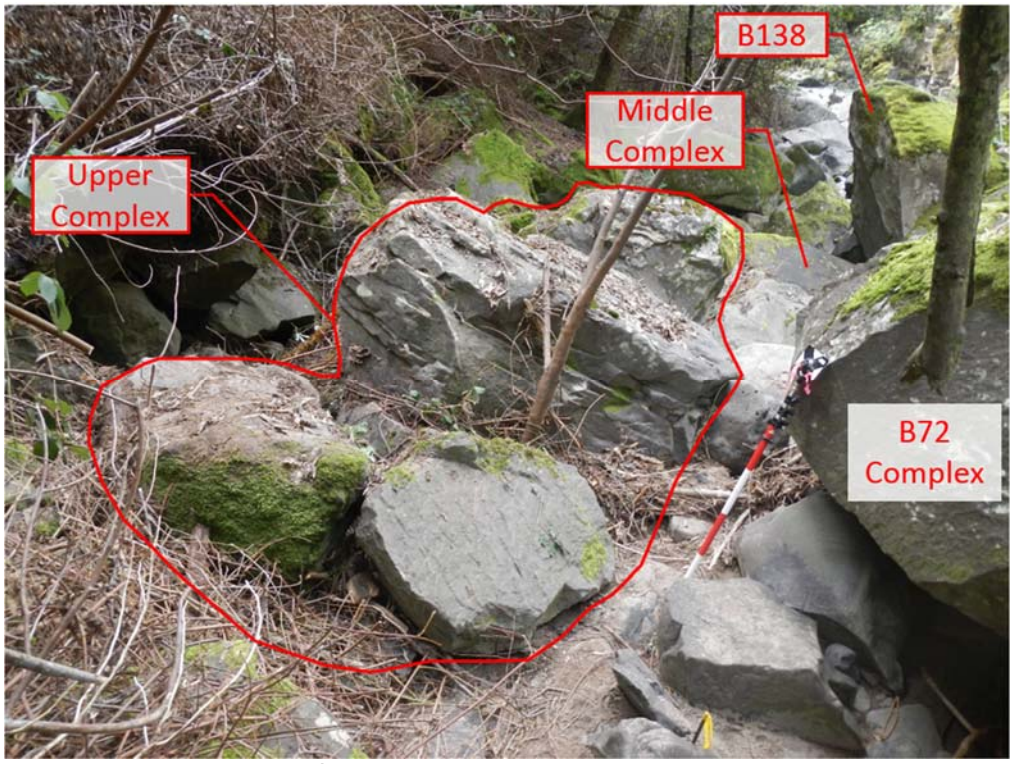



**Figure B-7. LBS boulder/boulder complexes Upper Complex, B72 Complex, Middle Complex, and B138, looking downstream.**

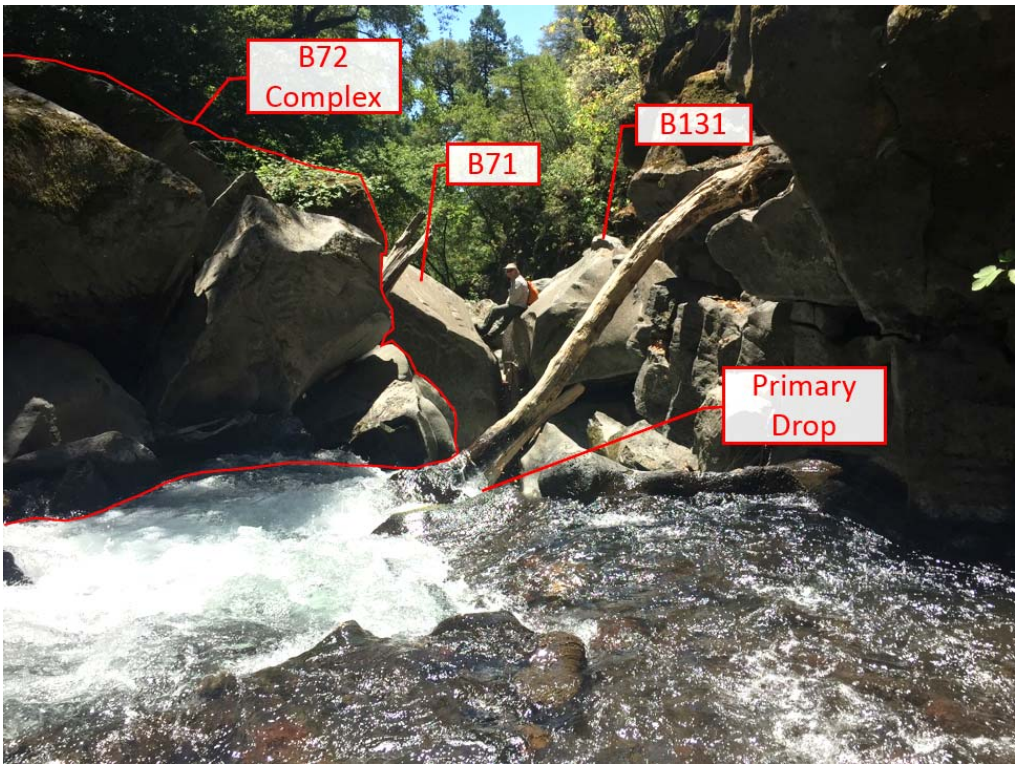



**Figure B-8. LBS boulder/boulder complexes B72 Complex, B71, and B131. Photograph is looking downstream, flow 37 cfs.**

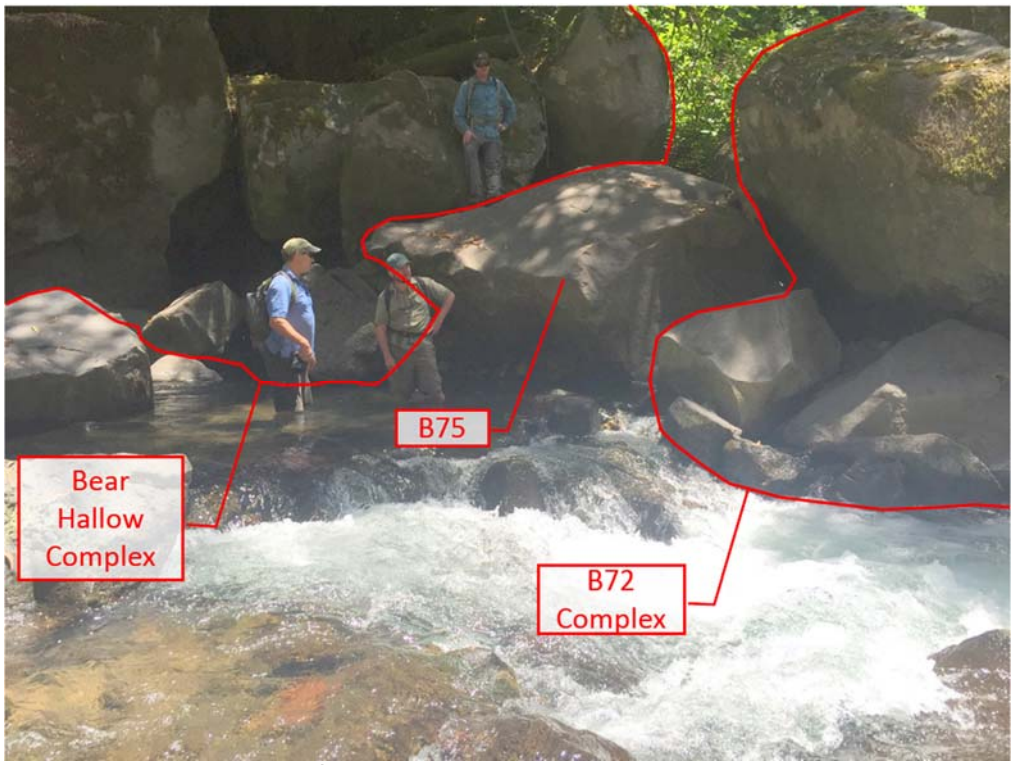



**Figure B-9. LBS boulder/boulder complexes B72 Complex, Bear Hallow Complex, and B75. Photograph looking at left bank from top of primary drop. Flow from left to right, 37 cfs.**

Attachment C **Upper Barrier Site Photographs**

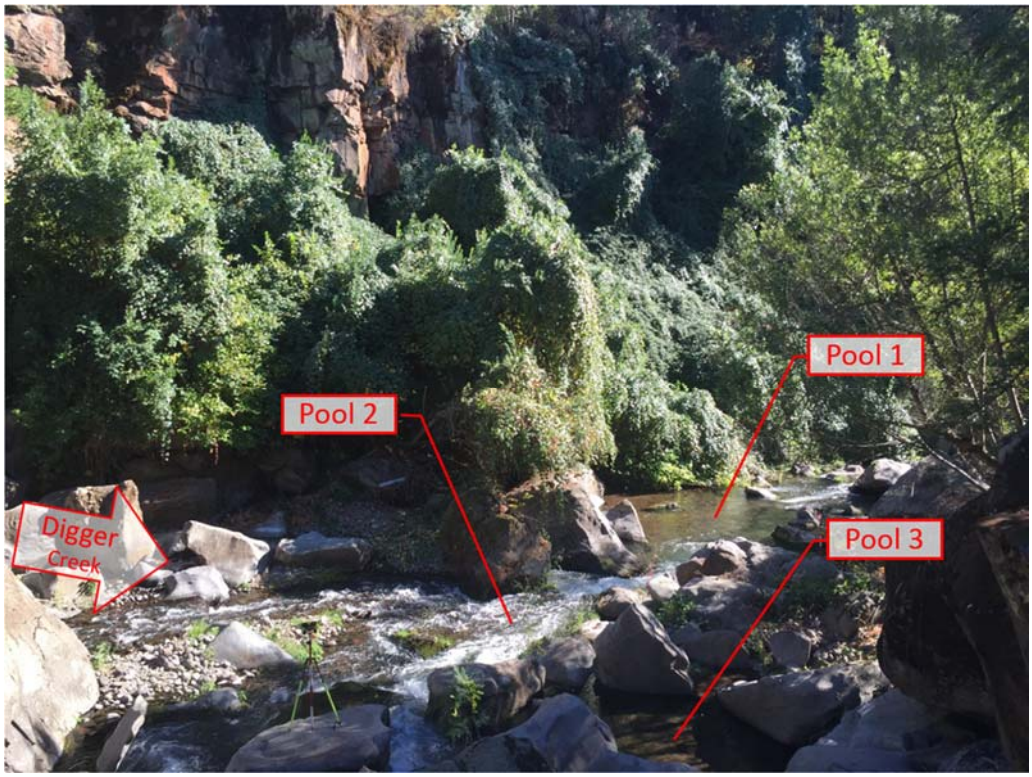



**Figure C-1. UBS looking downstream at Pools 1, 2, and 3. For scale, the prism tripod in bottom center left is 5 feet tall, NFBC flow is 17 cfs and Digger Creek is 5 cfs.**




**Figure C-2. UBS looking upstream from Digger Creek confluence. For scale, the prism tripod in foreground is 5 feet tall, flow is approximately 17 cfs.**

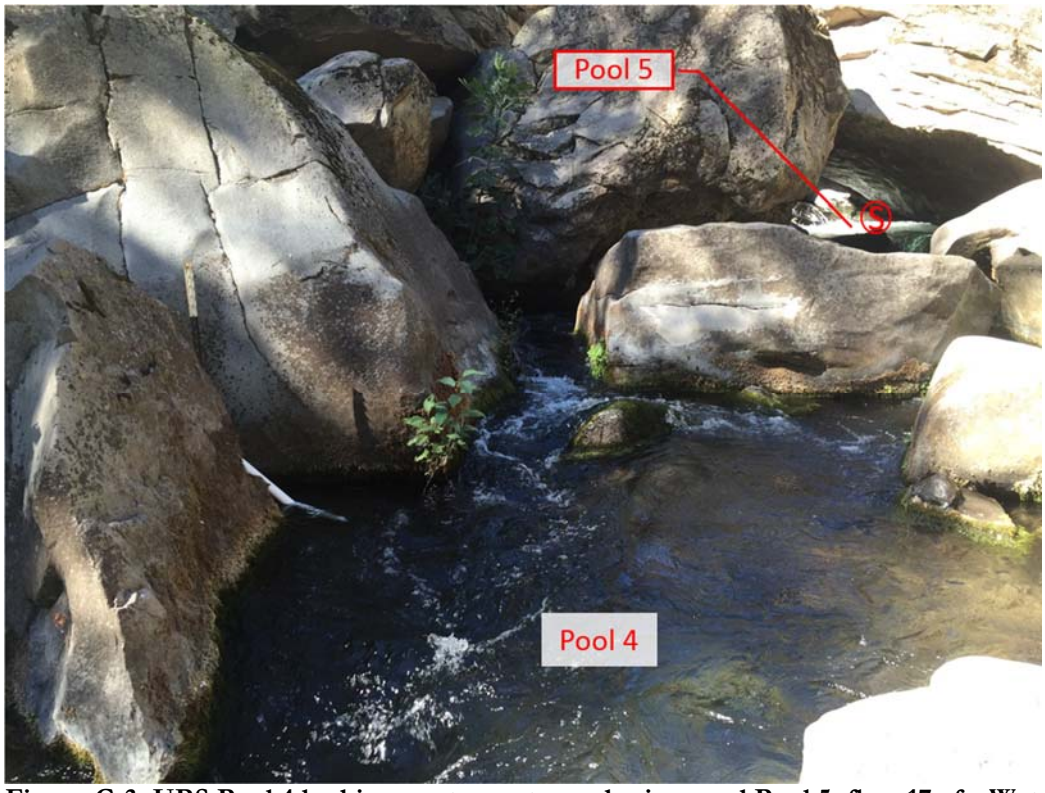



**Figure C-3. UBS Pool 4 looking upstream towards sieve and Pool 5, flow 17 cfs. Water level gage (UB2) located on left of picture will be discussed in Sections** Error! Reference source not found. **and** Error! Reference source not found.**.**

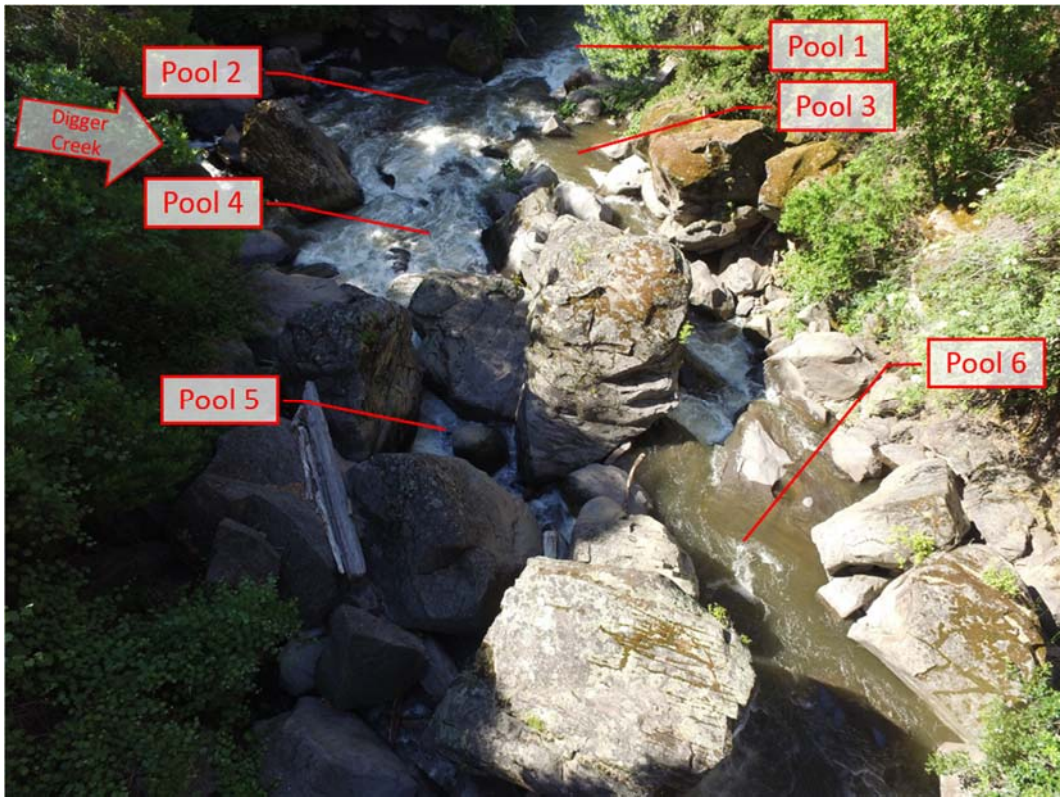


**Figure C-4. UBS Pools 1, 2, 3, 4, 5, and 6 looking downstream under moderate flows, 195 cfs.**



**Figure C-5. UBS primary drop and Pools 7 and 8, looking upstream when flow 87 cfs.**

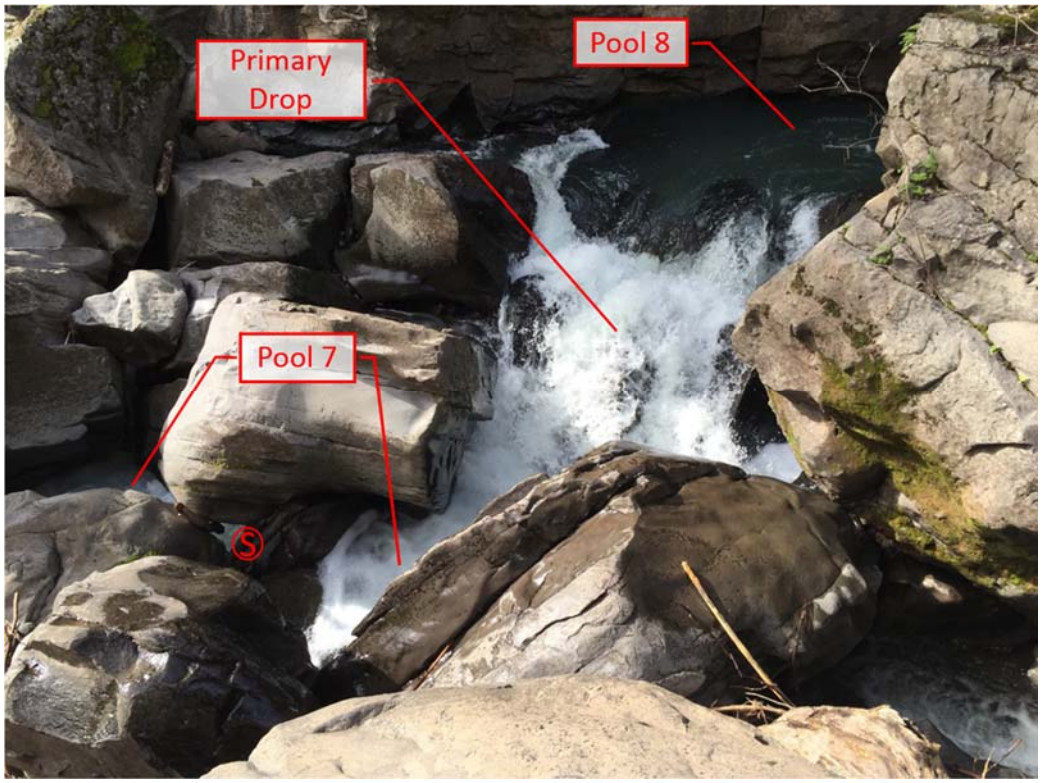



**Figure C-6. UBS primary drop and Pools 7 and 8, looking upstream when flow 87 cfs.**

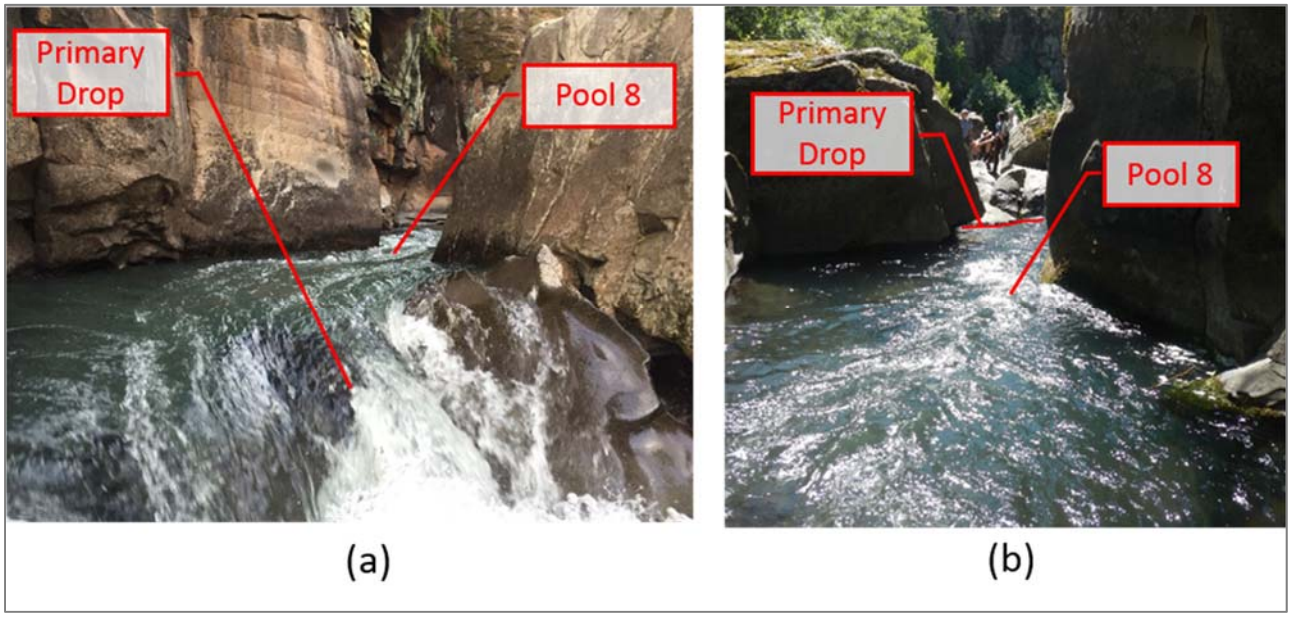



**Figure C-7. UBS at primary drop looking upstream (a) and downstream (b) at channel constriction. Flows 87 cfs (a) and 17 cfs (b). People visible in background of (b) are downstream of the primary drop.**




**Figure C-8. UBS Pool 9 looking upstream (a) and downstream (b) when flow 17 cfs.**

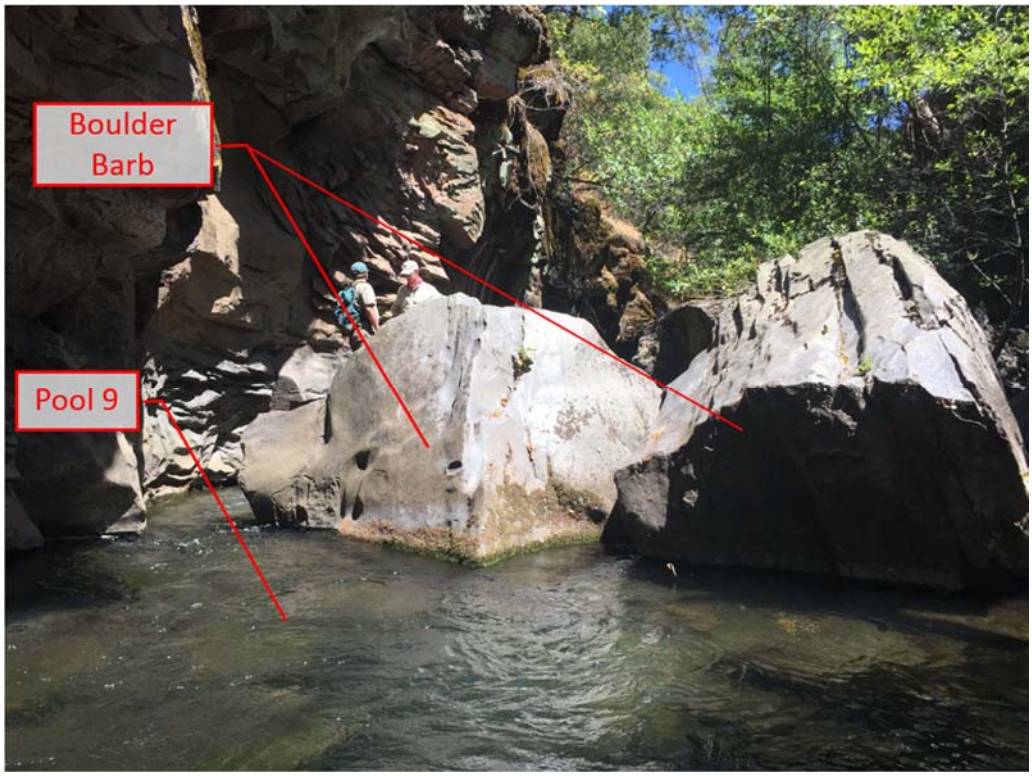



**Figure C-9. UBS two of the three boulders within the boulder barb located at the head of Pool 9. This marks the upstream end of the UBS study area.**

Attachment D **Hydrology Support**

**Estimates of mean monthly flows and diversion rates at the North Battle Creek Feeder (NBCF) diversion dam prior to current instream flow agreement. Data provided by PG&E.**

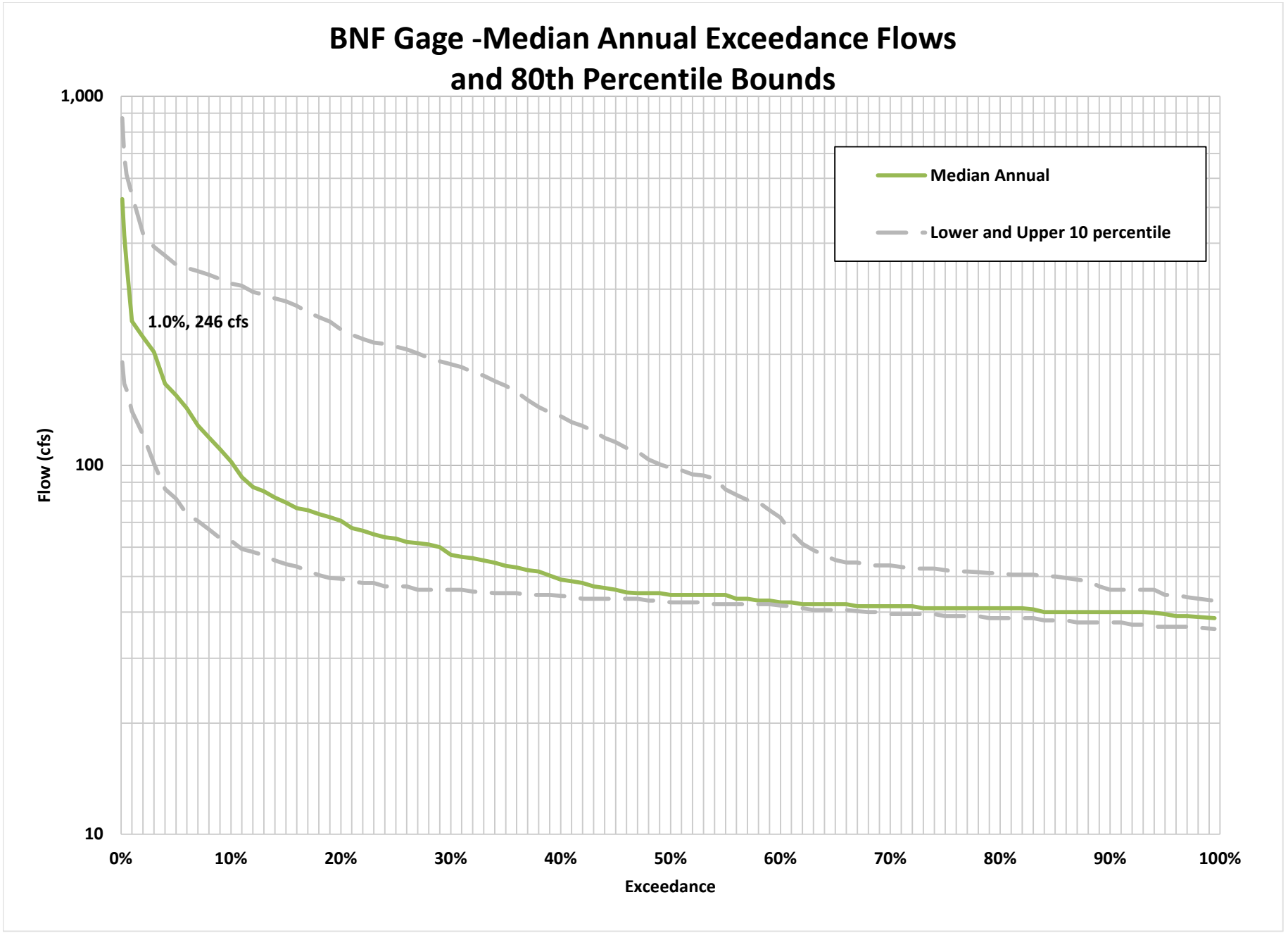
| Water Year (WY) / Location | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| **WY 1989 (Typical Year)** | | | | | | | | | | | | |
| Flow upstream of NBCF | 38 | 51 | 41 | 46 | 54 | 147 | 164 | 89 | 81 | 42 | 34 | 50 |
| Diversion to NBCF Canal | 0 | 4 | 0 | 0 | 0 | 45 | 45 | 42 | 34 | 0 | 0 | 3 |
| **Flow to Downstream Channel** | **38** | **47** | **41** | **46** | **54** | **102** | **119** | **47** | **47** | **42** | **34** | **47** |
| **WY 1983 (Wettest of Record)** | | | | | | | | | | | | |
| Flow upstream of NBCF | 45 | 53 | 91 | 52 | 77 | 387 | 127 | 69 | 98 | 64 | 44 | 28 |
| Diversion to NBCF Canal | 0 | 6 | 3 | 0 | 0 | 45 | 45 | 22 | 45 | 17 | 0 | 0 |
| **Flow to Downstream Channel** | **45** | **47** | **88** | **52** | **77** | **342** | **82** | **47** | **53** | **47** | **44** | **28** |
| **WY 1992 (2nd Driest of Record)** | | | | | | | | | | | | |
| Flow upstream of NBCF | 25 | 25 | 23 | 28 | 58 | 39 | 41 | 33 | 24 | 18 | 18 | 16 |
| Diversion to NBCF Canal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Flow to Downstream Channel** | **25** | **25** | **23** | **28** | **58** | **39** | **41** | **32** | **24** | **18** | **18** | **16** |

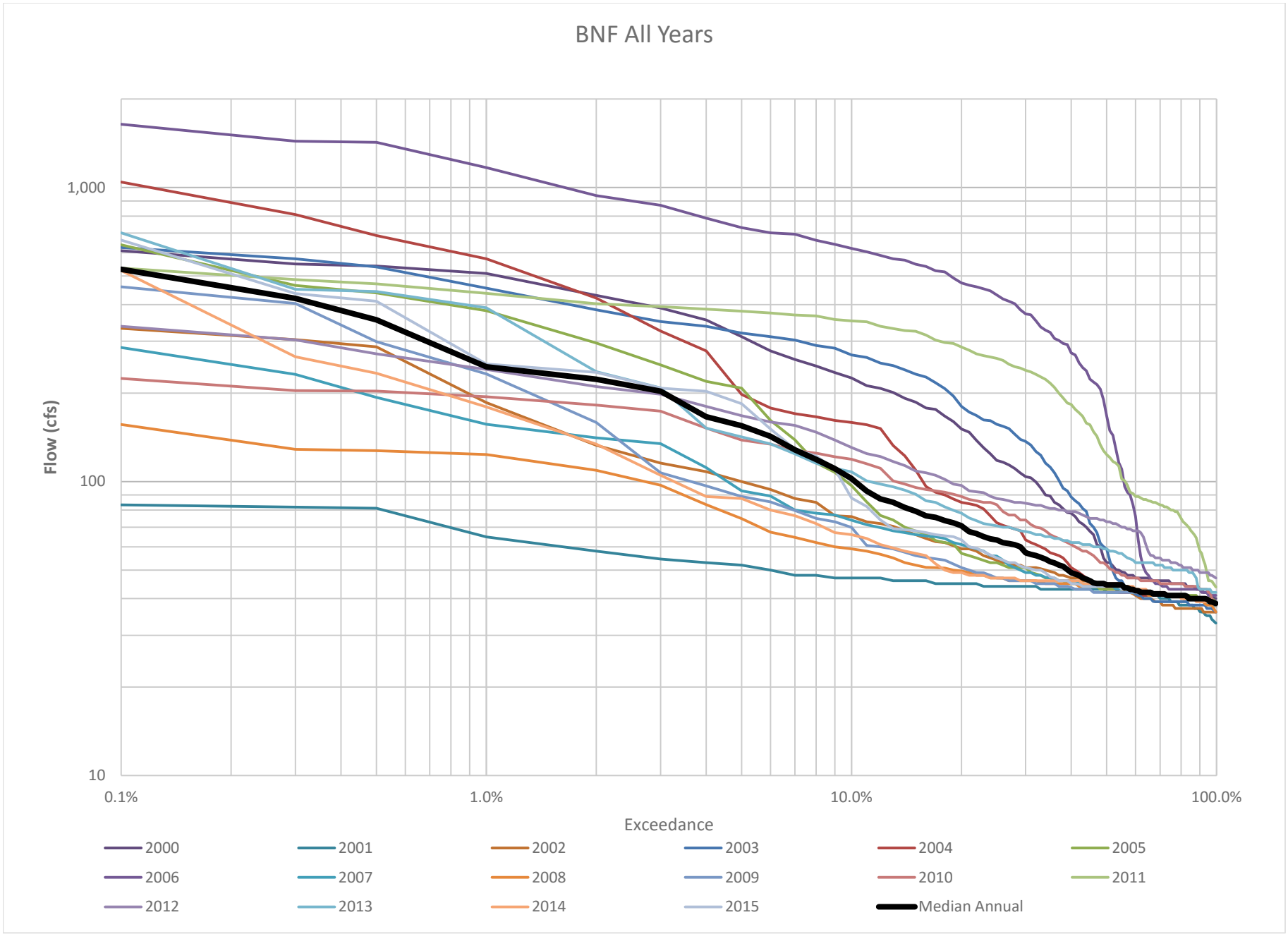
*Period of Record is WY 1962-1994.*

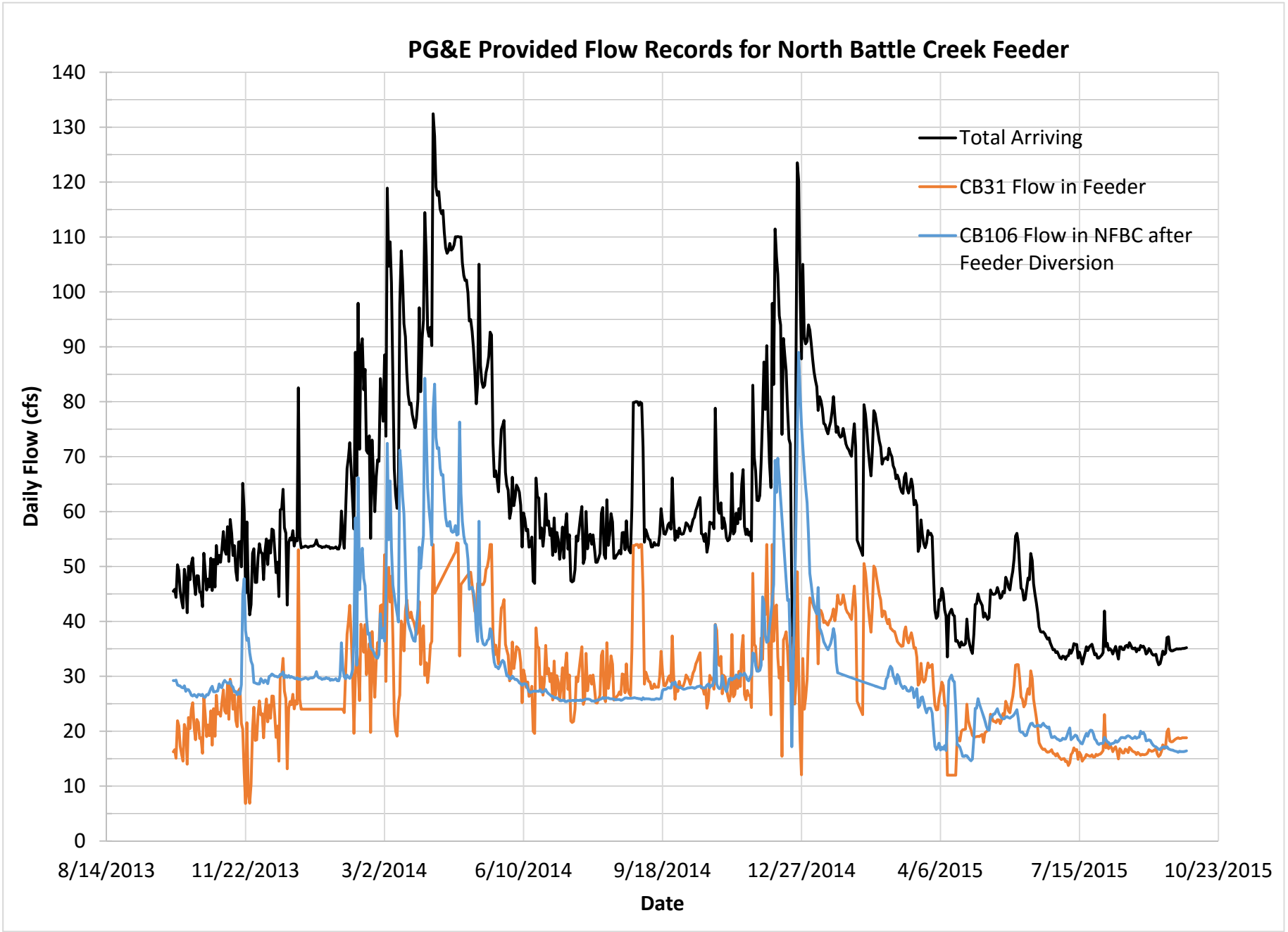
**Estimates of mean monthly flows and diversion rates at the Eagle Canyon Dam prior to current instream flow agreement. Data provided by PG&E.**

| Water Year (WY) Location | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| **WY 1989 (Typical Year)** | | | | | | | | | | | | |
| Flow upstream of Eagle Canyon Div. | 62 | 75 | 70 | 87 | 102 | 364 | 253 | 160 | 138 | 72 | 61 | 74 |
| Diversion to E.C. Canal | 37 | 50 | 34 | 51 | 65 | 65 | 65 | 65 | 65 | 47 | 36 | 49 |
| **Flow to Downstream Channel** | **25** | **25** | **36** | **36** | **37** | **299** | **188** | **95** | **73** | **25** | **25** | **25** |
| **WY 1983 (Wettest of Record)** | | | | | | | | | | | | |
| Flow upstream of Eagle Canyon Div. | 95 | 121 | 168 | 81 | 188 | 301 | 141 | 159 | 216 | 106 | 111 | 98 |
| Diversion to E.C. Canal | 65 | 65 | 65 | 45 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 |
| **Flow to Downstream Channel** | **30** | **56** | **103** | **36** | **123** | **236** | **76** | **94** | **151** | **41** | **46** | **33** |
| **WY 1992 (2nd Driest of Record)** | | | | | | | | | | | | |
| Flow upstream of Eagle Canyon Div. | 60 | 58 | 65 | 63 | 77 | 68 | 77 | 73 | 80 | 69 | 55 | 56 |
| Diversion to E.C. Canal | 35 | 33 | 29 | 27 | 41 | 32 | 41 | 48 | 55 | 44 | 30 | 31 |
| **Flow to Downstream Channel** | **25** | **25** | **36** | **36** | **36** | **36** | **36** | **25** | **25** | **25** | **25** | **25** |

*Period of Record is WY 1962-1994.*


BNF Gage -Median Annual Exceedance Flows
and 80th Percentile Bounds
1,000
100
10
Flow (cfs)
1.0%, 246 cfs
Median Annual
Lower and Upper 10 percentile
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedance


BNF All Years
1,000
100
10
Flow (cfs)
0.1%
1.0%
10.0%
100.0%
Exceedance
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Median Annual


PG&E Provided Flow Records for North Battle Creek Feeder
Daily Flow (cfs)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
8/14/2013
11/22/2013
3/2/2014
6/10/2014
9/18/2014
12/27/2014
4/6/2015
7/15/2015
10/23/2015
Date
Total Arriving
CB31 Flow in Feeder
CB106 Flow in NFBC after Feeder Diversion

Attachment E **Flow Measurement Data Tables**

# Discharge Measurement Computation Sheet - Pygmy Current Meter - 1999 Equation

**Personnel:** G. Matthews
**Date:** 2/12/2016
**Location:**
**Site:** NF Battle Eagle Canyon Upstream Site
**Pygmy Meter #:** GMA 302
**Spin Test (pre-Q):**
**Spin Test (post-Q):**

**Begin Gage Height:** 0 feet
**End Gage Height:** 0 feet
**Begin Time:** 2/12/2016 13:55
**End Time:** 2/12/2016 14:36
**Accuracy Rating:**
**Water Temperature:**
**Air Temperature:**

**0.00** feet - Average Weighted Mean Gauge Height

**87.14** Cubic Feet Per Second

**Measurement No:** 1
**Rating No:**
**Shift Adj:**
**Percent Diff:**

| Vertical | Flow Angle | Angle Coefficent | Station | Width | Depth | Wetted Perimeter | Revolutions | | | 0.2 Time | 0.6 Time | 0.8 Time | Velocity (fps) | | | | Horizontal Angle Adjusment | Area | Flow | % Flow | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Θ | Cosine Θ | (ft) | (ft) | (ft) | (ft) | 0.2 | 0.6 | 0.8 | (sec) | (sec) | (sec) | At Point 0.2 | At point 0.6 | At Point 0.8 | Mean in Vertical | Vel * Cos(Θ) | ($ft^2$) | (cfs) | | |
| Left Edge of Water | | | 1.0 | | | | | | | | | | | | | | | | | | |
| Dead Left Edge of Water | | | 11.5 | | | | | | | | | | | | | | | | | | |
| 1 | | 1.00 | 14.0 | 1.75 | 0.55 | 2.56 | | 28 | | | 40.5 | | 0.00 | 1.54 | 0.00 | 1.54 | 1.54 | 0.96 | 1.48 | 1.70% | |
| 2 | | 1.00 | 15.0 | 1.00 | 1.00 | 1.10 | | 39 | | | 40.3 | | 0.00 | 2.15 | 0.00 | 2.15 | 2.15 | 1.00 | 2.15 | 2.47% | |
| 3 | | 1.00 | 16.0 | 1.00 | 1.00 | 1.00 | | 48 | | | 40.7 | | 0.00 | 2.62 | 0.00 | 2.62 | 2.62 | 1.00 | 2.62 | 3.01% | |
| 4 | | 1.00 | 17.0 | 1.00 | 1.03 | 1.00 | | 50 | | | 40.1 | | 0.00 | 2.77 | 0.00 | 2.77 | 2.77 | 1.03 | 2.85 | 3.27% | |
| 5 | | 1.00 | 18.0 | 1.00 | 1.10 | 1.00 | | 62 | | | 40.3 | | 0.00 | 3.41 | 0.00 | 3.41 | 3.41 | 1.10 | 3.75 | 4.30% | |
| 6 | | 1.00 | 19.0 | 1.00 | 1.30 | 1.02 | | 55 | | | 40.4 | | 0.00 | 3.02 | 0.00 | 3.02 | 3.02 | 1.30 | 3.93 | 4.51% | |
| 7 | | 1.00 | 20.0 | 1.00 | 1.60 | 1.04 | | 57 | | | 40.1 | | 0.00 | 3.15 | 0.00 | 3.15 | 3.15 | 1.60 | 5.04 | 5.78% | |
| 8 | | 1.00 | 21.0 | 1.00 | 1.65 | 1.00 | | 60 | | | 40.0 | | 0.00 | 3.32 | 0.00 | 3.32 | 3.32 | 1.65 | 5.48 | 6.29% | |
| 9 | | 1.00 | 22.0 | 0.75 | 1.77 | 1.01 | | 61 | | | 40.0 | | 0.00 | 3.38 | 0.00 | 3.38 | 3.38 | 1.33 | 4.49 | 5.15% | |
| 10 | | 1.00 | 22.5 | 0.50 | 1.70 | 0.50 | | 61 | | | 40.1 | | 0.00 | 3.37 | 0.00 | 3.37 | 3.37 | 0.85 | 2.86 | 3.29% | |
| 11 | | 1.00 | 23.0 | 0.50 | 1.85 | 0.52 | | 60 | | | 40.5 | | 0.00 | 3.29 | 0.00 | 3.29 | 3.29 | 0.93 | 3.04 | 3.49% | |
| 12 | | 1.00 | 23.5 | 0.50 | 2.13 | 0.57 | | 59 | | | 40.5 | | 0.00 | 3.23 | 0.00 | 3.23 | 3.23 | 1.07 | 3.44 | 3.95% | |
| 13 | | 1.00 | 24.0 | 0.50 | 2.22 | 0.51 | | 60 | | | 40.2 | | 0.00 | 3.31 | 0.00 | 3.31 | 3.31 | 1.11 | 3.67 | 4.22% | |
| 14 | | 1.00 | 24.5 | 0.50 | 2.30 | 0.51 | | 57 | | | 40.2 | | 0.00 | 3.14 | 0.00 | 3.14 | 3.14 | 1.15 | 3.61 | 4.14% | |
| 15 | | 1.00 | 25.0 | 0.50 | 2.28 | 0.50 | | 55 | | | 40.0 | | 0.00 | 3.05 | 0.00 | 3.05 | 3.05 | 1.14 | 3.48 | 3.99% | |
| 16 | | 1.00 | 25.5 | 0.50 | 2.35 | 0.50 | | 54 | | | 40.3 | | 0.00 | 2.97 | 0.00 | 2.97 | 2.97 | 1.18 | 3.49 | 4.00% | |
| 17 | | 1.00 | 26.0 | 0.50 | 2.30 | 0.50 | | 51 | | | 40.8 | | 0.00 | 2.78 | 0.00 | 2.78 | 2.78 | 1.15 | 3.20 | 3.67% | |
| 18 | | 1.00 | 26.5 | 0.50 | 2.38 | 0.51 | | 48 | | | 40.0 | | 0.00 | 2.66 | 0.00 | 2.66 | 2.66 | 1.19 | 3.17 | 3.63% | |
| 19 | | 1.00 | 27.0 | 0.75 | 2.33 | 0.50 | | 44 | | | 40.7 | | 0.00 | 2.40 | 0.00 | 2.40 | 2.40 | 1.75 | 4.19 | 4.81% | |
| 20 | | 1.00 | 28.0 | 1.00 | 2.40 | 1.00 | | 40 | | | 40.1 | | 0.00 | 2.22 | 0.00 | 2.22 | 2.22 | 2.40 | 5.33 | 6.11% | |
| 21 | | 1.00 | 29.0 | 1.00 | 2.35 | 1.00 | | 35 | | | 40.8 | | 0.00 | 1.91 | 0.00 | 1.91 | 1.91 | 2.35 | 4.49 | 5.15% | |
| 22 | | 1.00 | 30.0 | 1.00 | 2.25 | 1.00 | | 33 | | | 40.9 | | 0.00 | 1.80 | 0.00 | 1.80 | 1.80 | 2.25 | 4.05 | 4.65% | |
| 23 | | 1.00 | 31.0 | 1.00 | 2.15 | 1.00 | | 29 | | | 40.4 | | 0.00 | 1.60 | 0.00 | 1.60 | 1.60 | 2.15 | 3.44 | 3.95% | |
| 24 | | 1.00 | 32.0 | 1.00 | 2.08 | 1.00 | | 26 | | | 41.0 | | 0.00 | 1.42 | 0.00 | 1.42 | 1.42 | 2.08 | 2.95 | 3.39% | |
| 25 | | 1.00 | 33.0 | 0.75 | 2.20 | 1.01 | | 10 | | | 40.2 | | 0.00 | 0.57 | 0.00 | 0.57 | 0.57 | 1.65 | 0.94 | 1.08% | |
| Dead Right Edge of Water | | | 33.5 | | | | | | | | | | | | | | | | | | |
| Right Edge of Water | | | 33.5 | | | | | | | | | | | | | | | | | | |
| | | | | | Totals: | 21.89 | | | | | | | | | | | | 35.35 | 87.14 | | |

## Summary:

| | | |
|---|---|---|
| **Discharge:** | **87.14** | cfs |
| **Width:** | **22.0** | ft |
| **Area:** | **35.35** | $ft^2$ |
| **Mean Depth:** | **1.61** | ft |
| **Mean Velocity:** | **2.46** | fps |
| **Max % Flow:** | **6.29%** | |
| **Wetted Perimeter** | **21.89** | ft |

## Notes:

**Section:**

**Flow Conditions:**

**Weather:**

**Control:**

**Remarks:**

# Discharge Measurement Computation Sheet - Pygmy Current Meter - 1999 Equation

**Personnel:** G. Matthews
**Date:** 2/12/2016
**Location:** Digger Creek
**Site:**
**Pygmy Meter #:** GMA 302
**Spin Test (pre-Q):**
**Spin Test (post-Q):**

**Begin Gage Height:** 0 feet
**End Gage Height:** 0 feet
**Begin Time:** 2/12/2016 14:58
**End Time:** 2/12/2016 15:24
**Accuracy Rating:**
**Water Temperature:**
**Air Temperature:**

**0.00** feet - Average Weighted Mean Gauge Height

**24.66** Cubic Feet Per Second

**Measurement No:** 2

**Rating No:**

**Shift Adj:**

**Percent Diff:**

| Vertical | Flow Angle | Angle Coefficent | Station | Width | Depth | Wetted Perimeter | Revolutions | | | 0.2 Time | 0.6 Time | 0.8 Time | Velocity (fps) | | | | Horizontal Angle Adjusment | Area | Flow | % Flow | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Θ | Cosine Θ | (ft) | (ft) | (ft) | (ft) | 0.2 | 0.6 | 0.8 | (sec) | (sec) | (sec) | At Point 0.2 | At point 0.6 | At Point 0.8 | Mean in Vertical | Vel * Cos(Θ) | ($ft^2$) | (cfs) | | |
| Left Edge of Water | | | 1.7 | | | | | | | | | | | | | | | | | | |
| Dead Left Edge of Water | | | 1.7 | | | | | | | | | | | | | | | | | | |
| 1 | | 1.00 | 3.0 | 1.15 | 0.35 | 1.35 | | 0 | | | 0.0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00% | |
| 2 | | 1.00 | 4.0 | 1.00 | 0.50 | 1.01 | | 0 | | | 0.0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00% | |
| 3 | | 1.00 | 5.0 | 1.00 | 0.60 | 1.00 | | 9 | | | 44.1 | | 0.00 | 0.47 | 0.00 | 0.47 | 0.47 | 0.60 | 0.28 | 1.14% | |
| 4 | | 1.00 | 6.0 | 1.00 | 0.95 | 1.06 | | 12 | | | 41.9 | | 0.00 | 0.65 | 0.00 | 0.65 | 0.65 | 0.95 | 0.62 | 2.50% | |
| 5 | | 1.00 | 7.0 | 1.00 | 1.22 | 1.04 | | 14 | | | 40.7 | | 0.00 | 0.78 | 0.00 | 0.78 | 0.78 | 1.22 | 0.95 | 3.86% | |
| 6 | | 1.00 | 8.0 | 1.00 | 1.42 | 1.02 | | 15 | | | 43.3 | | 0.00 | 0.78 | 0.00 | 0.78 | 0.78 | 1.42 | 1.11 | 4.49% | |
| 7 | | 1.00 | 9.0 | 1.00 | 1.60 | 1.02 | | 17 | | | 40.4 | | 0.00 | 0.95 | 0.00 | 0.95 | 0.95 | 1.60 | 1.52 | 6.16% | |
| 8 | | 1.00 | 10.0 | 1.00 | 1.68 | 1.00 | | 21 | | | 40.3 | | 0.00 | 1.17 | 0.00 | 1.17 | 1.17 | 1.68 | 1.97 | 7.97% | |
| 9 | | 1.00 | 11.0 | 1.00 | 1.80 | 1.01 | | 37 | | | 40.1 | | 0.00 | 2.05 | 0.00 | 2.05 | 2.05 | 1.80 | 3.69 | 14.96% | |
| 10 | | 1.00 | 12.0 | 1.00 | 1.75 | 1.00 | | 27 | | | 41.4 | | 0.00 | 1.46 | 0.00 | 1.46 | 1.46 | 1.75 | 2.56 | 10.36% | |
| 11 | | 1.00 | 13.0 | 1.00 | 1.68 | 1.00 | | 37 | | | 40.9 | | 0.00 | 2.01 | 0.00 | 2.01 | 2.01 | 1.68 | 3.38 | 13.69% | |
| 12 | | 1.00 | 14.0 | 1.00 | 1.70 | 1.00 | | 38 | | | 40.7 | | 0.00 | 2.08 | 0.00 | 2.08 | 2.08 | 1.70 | 3.54 | 14.34% | |
| 13 | | 1.00 | 15.0 | 1.00 | 1.63 | 1.00 | | 19 | | | 40.2 | | 0.00 | 1.06 | 0.00 | 1.06 | 1.06 | 1.63 | 1.73 | 7.01% | |
| 14 | | 1.00 | 16.0 | 1.00 | 1.60 | 1.00 | | 13 | | | 42.2 | | 0.00 | 0.70 | 0.00 | 0.70 | 0.70 | 1.60 | 1.12 | 4.54% | |
| 15 | | 1.00 | 17.0 | 1.00 | 1.52 | 1.00 | | 14 | | | 41.7 | | 0.00 | 0.76 | 0.00 | 0.76 | 0.76 | 1.52 | 1.16 | 4.68% | |
| 16 | | 1.00 | 18.0 | 1.00 | 1.30 | 1.02 | | 8 | | | 49.2 | | 0.00 | 0.38 | 0.00 | 0.38 | 0.38 | 1.30 | 0.49 | 2.00% | |
| 17 | | 1.00 | 19.0 | 1.00 | 0.97 | 1.05 | | 3 | | | 41.3 | | 0.00 | 0.18 | 0.00 | 0.18 | 0.18 | 0.97 | 0.17 | 0.71% | |
| 19 | | 1.00 | 20.0 | 2.00 | 0.80 | 1.01 | | 4 | | | 40.6 | | 0.00 | 0.24 | 0.00 | 0.24 | 0.24 | 1.60 | 0.38 | 1.56% | |
| Dead Right Edge of Water | | | 23.0 | | | | | | | | | | | | | | | | | | |
| Right Edge of Water | | | 23.0 | | | | | | | | | | | | | | | | | | |
| | | | | | Totals: | 18.61 | | | | | | | | | | | | 23.92 | 24.66 | | |

## Summary:

| | | |
|---|---|---|
| **Discharge:** | **24.66** | cfs |
| **Width:** | **21.3** | ft |
| **Area:** | **23.92** | $ft^2$ |
| **Mean Depth:** | **1.12** | ft |
| **Mean Velocity:** | **1.03** | fps |
| **Max % Flow:** | **14.96%** | |
| **Wetted Perimeter** | **18.61** | ft |

## Notes:

**Section:**

**Flow Conditions:**

**Weather:**

**Control:**

**Remarks:**

# Discharge Measurement Computation Sheet - Pygmy Current Meter - 1999 Equation

**Personnel:** PTJames
**Date:** 6/7/2016
**Location:** Digger Creek
**Site:**
**Pygmy Meter #:** MLA Pigmy 1
**Spin Test (pre-Q):**
**Spin Test (post-Q):**

**Begin Gage Height:** 0 feet
**End Gage Height:** 0 feet
**Begin Time:**
**End Time:**
**Accuracy Rating:**
**Water Temperature:**
**Air Temperature:**

**0.00** feet - Average Weighted Mean Gauge Height

**33.87** Cubic Feet Per Second

**Measurement No:** 3 **Rating No:** **Shift Adj:** **Percent Diff:**

| Vertical | Flow Angle | Angle Coefficent | Station | Width | Depth | Wetted Perimeter | Revolutions | | | 0.2 Time | 0.6 Time | 0.8 Time | Velocity (fps) | | | | Horizontal Angle Adjusment | Area | Flow | % Flow | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Θ | Cosine Θ | (ft) | (ft) | (ft) | (ft) | 0.2 | 0.6 | 0.8 | (sec) | (sec) | (sec) | At Point 0.2 | At point 0.6 | At Point 0.8 | Mean in Vertical | Vel * Cos(Θ) | ($ft^2$) | (cfs) | | |
| Left Edge of Water | | | 0.0 | | | | | | | | | | | | | | | | | | |
| Dead Left Edge of Water | | | 0.0 | | | | | | | | | | | | | | | | | | |
| 1 | | 1.00 | 0.7 | 1.00 | 0.20 | 0.73 | | 16 | | | 42.0 | | 0.00 | 0.40 | 0.00 | 0.40 | 0.40 | 0.20 | 0.08 | 0.23% | |
| 2 | | 1.00 | 2.0 | 1.30 | 0.30 | 1.30 | | 11 | | | 40.8 | | 0.00 | 0.29 | 0.00 | 0.29 | 0.29 | 0.39 | 0.11 | 0.33% | |
| 3 | | 1.00 | 3.3 | 1.30 | 0.63 | 1.34 | | 20 | | | 40.3 | | 0.00 | 0.51 | 0.00 | 0.51 | 0.51 | 0.82 | 0.42 | 1.23% | |
| 4 | | 1.00 | 4.6 | 0.65 | 0.95 | 1.34 | | 35 | | | 40.6 | | 0.00 | 0.86 | 0.00 | 0.86 | 0.86 | 0.62 | 0.53 | 1.57% | |
| 5 | | 1.00 | 4.6 | 0.50 | 0.95 | 0.00 | | 29 | | | 40.1 | | 0.00 | 0.73 | 0.00 | 0.73 | 0.73 | 0.48 | 0.34 | 1.02% | |
| 6 | | 1.00 | 5.6 | 1.00 | 1.20 | 1.03 | | 57 | | | 40.4 | | 0.00 | 1.39 | 0.00 | 1.39 | 1.39 | 1.20 | 1.66 | 4.91% | |
| 7 | | 1.00 | 6.6 | 1.00 | 1.50 | 1.04 | | 54 | | | 40.3 | | 0.00 | 1.32 | 0.00 | 1.32 | 1.32 | 1.50 | 1.98 | 5.84% | |
| 8 | | 1.00 | 7.6 | 1.00 | 1.50 | 1.00 | | 55 | | | 40.5 | | 0.00 | 1.34 | 0.00 | 1.34 | 1.34 | 1.50 | 2.00 | 5.91% | |
| 9 | | 1.00 | 8.6 | 0.50 | 1.60 | 1.00 | | 78 | | | 40.7 | | 0.00 | 1.87 | 0.00 | 1.87 | 1.87 | 0.80 | 1.50 | 4.42% | |
| 10 | | 1.00 | 8.6 | 0.50 | 1.60 | 0.00 | | 49 | | | 40.6 | | 0.00 | 1.19 | 0.00 | 1.19 | 1.19 | 0.80 | 0.95 | 2.81% | |
| 11 | | 1.00 | 9.6 | 0.50 | 1.65 | 1.00 | | 89 | | | 40.1 | | 0.00 | 2.16 | 0.00 | 2.16 | 2.16 | 0.83 | 1.78 | 5.27% | |
| 12 | | 1.00 | 9.6 | 0.50 | 1.65 | 0.00 | | 53 | | | 40.6 | | 0.00 | 1.28 | 0.00 | 1.28 | 1.28 | 0.83 | 1.06 | 3.13% | |
| 13 | | 1.00 | 10.6 | 0.50 | 1.70 | 1.00 | | 82 | | | 40.4 | | 0.00 | 1.98 | 0.00 | 1.98 | 1.98 | 0.85 | 1.68 | 4.97% | |
| 14 | | 1.00 | 10.6 | 0.50 | 1.70 | 0.00 | | 33 | | | 41.0 | | 0.00 | 0.80 | 0.00 | 0.80 | 0.80 | 0.85 | 0.68 | 2.02% | |
| 15 | | 1.00 | 11.6 | 0.50 | 1.95 | 1.03 | | 82 | | | 40.2 | | 0.00 | 1.99 | 0.00 | 1.99 | 1.99 | 0.98 | 1.94 | 5.73% | |
| 16 | | 1.00 | 11.6 | 0.50 | 1.95 | 0.00 | | 21 | | | 41.0 | | 0.00 | 0.52 | 0.00 | 0.52 | 0.52 | 0.98 | 0.51 | 1.51% | |
| 17 | | 1.00 | 12.6 | 0.50 | 2.00 | 1.00 | | 74 | | | 40.2 | | 0.00 | 1.80 | 0.00 | 1.80 | 1.80 | 1.00 | 1.80 | 5.31% | |
| 18 | | 1.00 | 12.6 | 0.50 | 2.00 | 0.00 | | 41 | | | 41.1 | | 0.00 | 0.99 | 0.00 | 0.99 | 0.99 | 1.00 | 0.99 | 2.92% | |
| 19 | | 1.00 | 13.6 | 0.50 | 2.10 | 1.00 | | 44 | | | 40.2 | | 0.00 | 1.08 | 0.00 | 1.08 | 1.08 | 1.05 | 1.14 | 3.36% | |
| 20 | | 1.00 | 13.6 | 0.50 | 2.10 | 0.00 | | 28 | | | 40.9 | | 0.00 | 0.69 | 0.00 | 0.69 | 0.69 | 1.05 | 0.72 | 2.13% | |
| 21 | | 1.00 | 14.6 | 0.50 | 2.10 | 1.00 | | 45 | | | 40.4 | | 0.00 | 1.10 | 0.00 | 1.10 | 1.10 | 1.05 | 1.16 | 3.41% | |
| 22 | | 1.00 | 14.6 | 0.50 | 2.10 | 0.00 | | 22 | | | 41.1 | | 0.00 | 0.55 | 0.00 | 0.55 | 0.55 | 1.05 | 0.57 | 1.69% | |
| 23 | | 1.00 | 15.6 | 0.50 | 2.10 | 8.02 | | 37 | | | 40.6 | | 0.00 | 0.91 | 0.00 | 0.91 | 0.91 | 1.05 | 0.95 | 2.81% | |
| 24 | | 1.00 | 15.6 | 0.50 | 2.10 | 0.00 | | 33 | | | 40.2 | | 0.00 | 0.82 | 0.00 | 0.82 | 0.82 | 1.05 | 0.86 | 2.54% | |
| 25 | | 1.00 | 16.6 | 0.50 | 1.90 | 1.02 | | 41 | | | 40.5 | | 0.00 | 1.00 | 0.00 | 1.00 | 1.00 | 0.95 | 0.95 | 2.81% | |
| 26 | | 1.00 | 16.6 | 0.50 | 1.90 | 0.00 | | 36 | | | 40.0 | | 0.00 | 0.90 | 0.00 | 0.90 | 0.90 | 0.95 | 0.85 | 2.51% | |
| 27 | | 1.00 | 17.6 | 0.50 | 1.80 | 1.00 | | 43 | | | 40.4 | | 0.00 | 1.05 | 0.00 | 1.05 | 1.05 | 0.90 | 0.95 | 2.80% | |
| 28 | | 1.00 | 17.6 | 0.65 | 1.80 | 0.00 | | 36 | | | 40.4 | | 0.00 | 0.89 | 0.00 | 0.89 | 0.89 | 1.17 | 1.04 | 3.06% | |
| 29 | | 1.00 | 18.9 | 1.30 | 1.50 | 1.33 | | 34 | | | 40.6 | | 0.00 | 0.84 | 0.00 | 0.84 | 0.84 | 1.95 | 1.63 | 4.81% | |
| 30 | | 1.00 | 20.2 | 1.30 | 1.30 | 1.32 | | 37 | | | 40.7 | | 0.00 | 0.90 | 0.00 | 0.90 | 0.90 | 1.69 | 1.53 | 4.51% | |
| 31 | | 1.00 | 21.5 | 1.30 | 1.10 | 1.32 | | 25 | | | 40.0 | | 0.00 | 0.63 | 0.00 | 0.63 | 0.63 | 1.43 | 0.90 | 2.67% | |
| 32 | | 1.00 | 22.8 | 1.35 | 0.90 | 1.32 | | 16 | | | 40.8 | | 0.00 | 0.41 | 0.00 | 0.41 | 0.41 | 1.22 | 0.50 | 1.46% | |
| 33 | | 1.00 | 24.2 | 1.35 | 0.40 | 1.49 | | 7 | | | 43.9 | | 0.00 | 0.18 | 0.00 | 0.18 | 0.18 | 0.54 | 0.10 | 0.29% | |
| 34 | | 1.00 | 25.5 | 1.10 | 0.10 | 1.33 | | 0 | | | 0.0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00% | |
| Dead Right Edge of Water | | | 26.4 | | | | | | | | | | | | | | | | | | |
| Right Edge of Water | | | 26.4 | | | | | | | | | | | | | | | | | | |
| | | | | | Totals: | 32.98 | | | | | | | | | | | | 32.81 | 33.87 | | |

## Summary:

| | | |
|---|---|---|
| **Discharge:** | **33.87** | cfs |
| **Width:** | **26.4** | ft |
| **Area:** | **32.81** | $ft^2$ |
| **Mean Depth:** | **1.24** | ft |
| **Mean Velocity:** | **1.03** | fps |
| **Max % Flow:** | **5.91%** | |
| **Wetted Perimeter** | **32.98** | ft |

## Notes:

**Section:**

**Flow Conditions:**

**Weather:**

**Control:**

**Remarks:**

Attachment F **HEC-RAS Plan View Figures**

HEC-RAS ALIGNMENT

PLAN
NOT TO SCALE

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FISH PASSAGE IMPROVEMENT PROJECT
N.F. BATTLE CREEK, EAGLE CANYON

# LOWER BARRIER
# HEC-RAS PLAN

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
F-1

HEC-RAS ALIGNMENT

PLAN

NOT TO SCALE

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# UPPER BARRIER
# HEC-RAS PLAN

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
**F-2**

Attachment G **Discharge Rating Curve Data Tables**

# Lower Barrier Site Discharge Rating Curve Tables

| Pool 2 (LB2 Gage) | | |
|---|---|---|
| Flow (cfs) | WSE (ft) | Notes |
| 37 | 1360.9 | WSME1 |
| 120 | 1362.3 | WSME2 |
| 248 | 1363.1 | WSME4 |
| 2010 | 1367.1 | WSME3 |

| Pool 5 (LB1 Gage) | | |
|---|---|---|
| Flow (cfs) | WSE (ft) | Notes |
| 37 | 1370.1 | WSME1 |
| 120 | 1370.8 | WSME2 |
| 248 | 1371.4 | WSME4 |
| 2010 | 1377.6 | WSME3 |

## Upper Barrier Site Discharge Rating Curve Tables

| Pool 1 | | |
|---|---|---|
| Flow (cfs)[1] | WSE (ft) | Notes |
| 17 | 1472.0 | WSME1 |
| 87 | 1473.0 | WSME2 |
| 195 | 1473.4 | WSME4 |
| 1580 | 1479.6 | WSME3 |

| Pool 4 (UB2 Gage) | | |
|---|---|---|
| Flow (cfs)[1] | WSE (ft) | Notes |
| 17 | 1475.9 | WSME1 |
| 65 | 1476.4 | |
| 80 | 1476.7 | |
| 87 | 1476.8 | WSME2 |
| 195 | 1477.8 | WSME4 |
| 281 | 1478.3 | |
| 371 | 1478.7 | |
| 456 | 1478.9 | |
| 508 | 1479.0 | |
| 797 | 1479.5 | |
| 918 | 1479.8 | |
| 1580 | 1481.0 | WSME3 |

| Pool 6 | | |
|---|---|---|
| Flow (cfs)[1] | WSE (ft) | Notes |
| 17 | 1479.5 | WSME1 |
| 87 | 1482.9 | WSME2 |
| 195 | 1484.4 | WSME4 |
| 1580 | 1493.3 | WSME3 |

| Pool 7 | | |
|---|---|---|
| Flow (cfs)[1] | WSE (ft) | Notes |
| 17 | 1480.0 | WSME1 |
| 65 | 1481.6 | |
| 80 | 1482.3 | |
| 83 | 1482.6 | |
| 87 | 1483.3 | WSME2 |
| 195 | 1485.2 | WSME4 |
| 281 | 1486.5 | |
| 333 | 1486.8 | |
| 428 | 1487.9 | |
| 456 | 1488.4 | |
| 508 | 1489.9 | |
| 797 | 1491.3 | |
| 918 | 1492.0 | |
| 1580 | 1494.2 | WSME3 |

| Pool 9 (UB1 Gage) | | |
|---|---|---|
| Flow (cfs)[1] | WSE (ft) | Notes |
| 17 | 1490.5 | WSME1 |
| 52 | 1490.6 | |
| 82 | 1491.1 | |
| 87 | 1491.6 | WSME2 |
| 143 | 1492.1 | |
| 195 | 1492.4 | WSME4 |
| 207 | 1492.6 | |
| 278 | 1493.1 | |
| 366 | 1493.6 | |
| 429 | 1493.9 | |
| 475 | 1494.1 | |
| 593 | 1494.6 | |
| 748 | 1495.1 | |
| 918 | 1495.6 | |
| 1242 | 1496.1 | |
| 1314 | 1496.6 | |
| 1515 | 1497.1 | |
| 1580 | 1497.8 | WSME3 |

1. Flow within North Fork Battle Creek upstream of Digger Creek.

Attachment H **Lower Barrier Site Water Surface Mapping Results**




WATER SURFACE MAPPING EVENT 1
10/14/2015
37 CFS

TIMELAPSE CAMERA (LB2)
OCT 28, 2015 – FEB 29, 2016

PRIMARY ALIGNMENT

SECONDARY ALIGNMENT

TERTIARY ALIGNMENT

QUATERNARY ALIGNMENT

TIME LAPSE CAMERA (LB1)

TIME LAPSE CAMERA, FEB. 29, 2016 – JUNE 7, 2016

EXTENTS OF INUNDATION

POOL 1

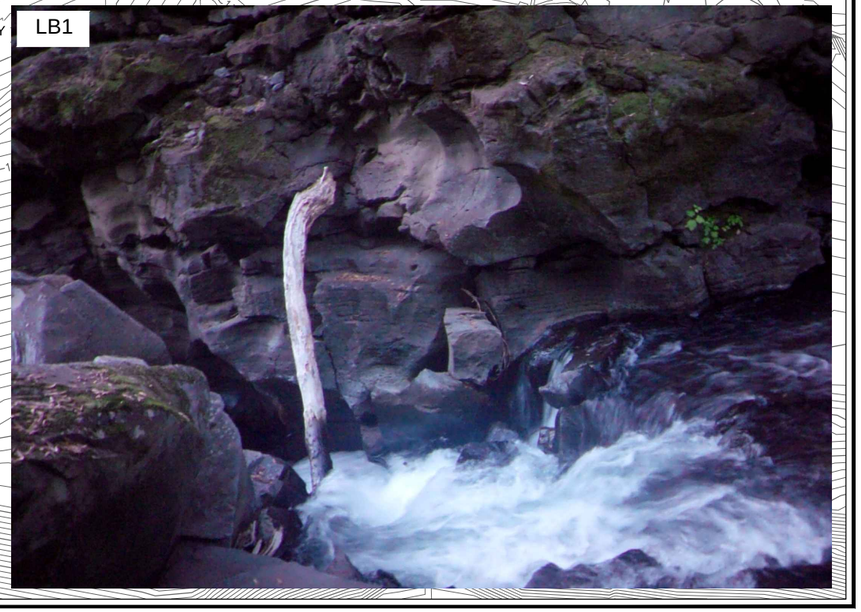
POOL 2

POOL 3

POOL 4

POOL 5

POOL 6




PLAN

0 10' 20'
GRAPHIC SCALE

8/5/2016 12:02:35 PM Q:\Eagle Canyon\05_CAD\Data\LB_WSE1_Profile-20151014.dwg

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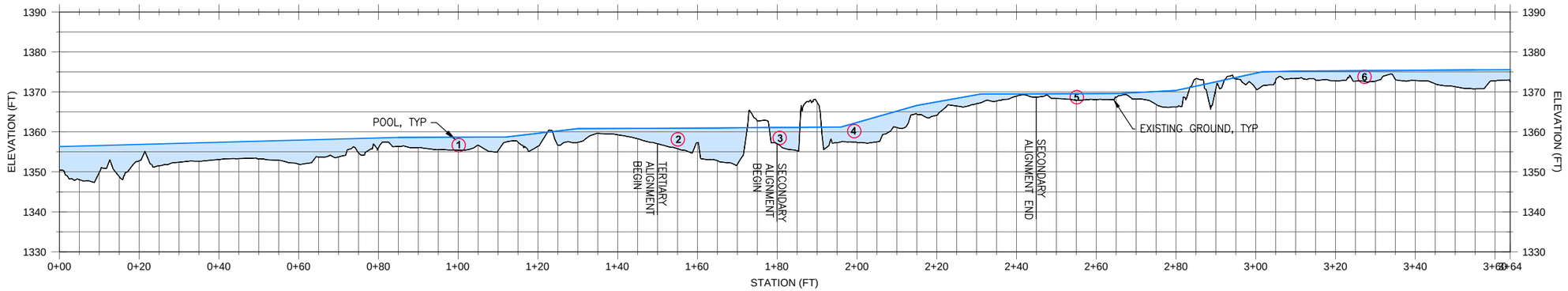
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# LOWER BARRIER
# WATER SURFACE MAPPING EVENT 1 PLAN

DATE
JULY 2016

SUBMITTAL
TASK 4

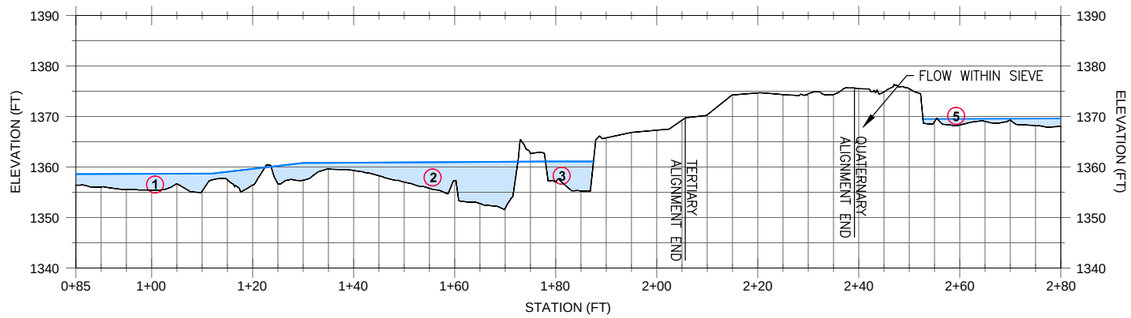
FIGURE
H-1




PRIMARY ALIGNMENT PROFILE

0 15' 30'

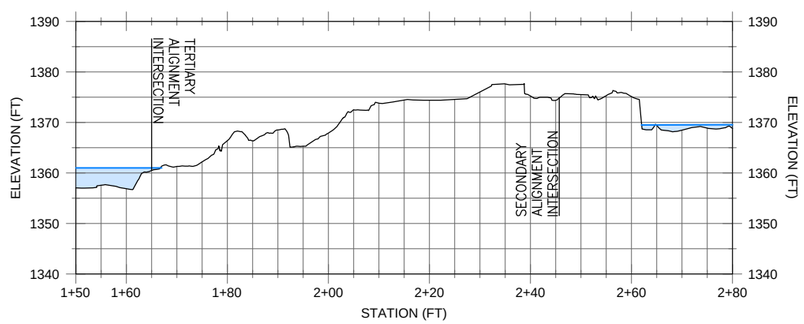
GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE




QUANTERNARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE

8/5/2016 12:02:46 PM Q:\Eagle Canyon\05_CAD\Data\LB_WSE1_Profile-20151014.dwg


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**LOWER BARRIER**

**WATER SURFACE MAPPING EVENT 1 PROFILES**

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
**H-2**




# WATER SURFACE MAPPING EVENT 2

2/29/2016

120 CFS

TIMELAPSE CAMERA (LB2)
OCT 28, 2015 – FEB 29, 2016

PRIMARY ALIGNMENT

SECONDARY ALIGNMENT

TERTIARY ALIGNMENT

QUATERNARY ALIGNMENT

NFBC

POOL 1

POOL 2

POOL 3

POOL 5

POOL 6

TIME LAPSE CAMERA (LB1)

TIME LAPSE CAMERA FEB. 29, 2016 – JUNE 7, 2016

CONTROL POINT, TYP

ELEVATION AT WATER SURFACE (TYPICAL)

EXTENTS OF INUNDATION




PLAN

0 10' 20'

GRAPHIC SCALE

8/5/2016 12:03:20 PM Q:\Eagle Canyon\05_CAD\Data\LB_WSE2_Profile-20160229.dwg

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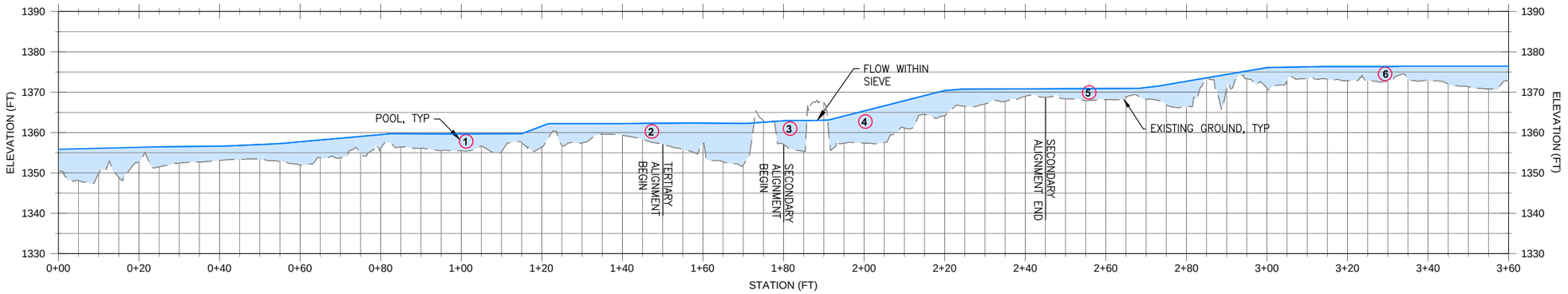
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
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N.F. BATTLE CREEK, EAGLE CANYON

**LOWER BARRIER**
**WATER SURFACE MAPPING EVENT 2 PLAN**

DATE
JULY 2016

SUBMITTAL
TASK 4

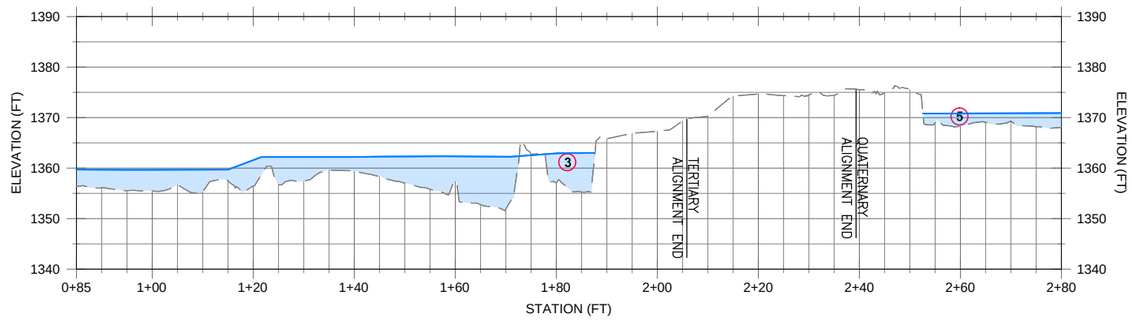
FIGURE
**H-3**




PRIMARY ALIGNMENT PROFILE

0 15' 30'

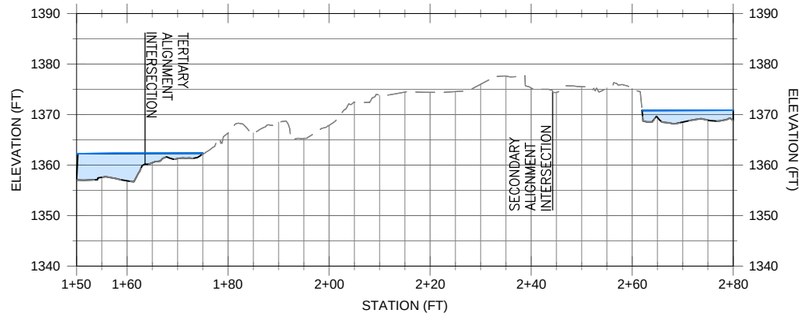
GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE




QUANTERNARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE


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**LOWER BARRIER**

**WATER SURFACE MAPPING EVENT 2 PROFILES**

DATE

JULY 2016

SUBMITTAL

TASK 4

FIGURE

**H-4**




# WATER SURFACE MAPPING EVENT 3
1/29/2016
2,010 CFS

TIMELAPSE CAMERA (LB2)
OCT 28, 2015 - FEB 29, 2016

1368.08

POOL 1

POOL 2

POOL 3

POOL 4

POOL 5

POOL 6

NFBC

PRIMARY ALIGNMENT

TERTIARY ALIGNMENT

SECONDARY ALIGNMENT

QUATERNARY ALIGNMENT

1384.72

1376.85

1376.08

1373.61

1372.10

1369.47

1368.74

1368.70

1368.60

1367.97

1367.95

1367.96

1364.89

1365.12

TIME LAPSE CAMERA (LB1)

CONTROL POINT, TYP

EXTENTS OF INUNDATION

ELEVATION AT WATER SURFACE (TYPICAL)

TIME LAPSE CAMERA, FEB. 29, 2016 – JUNE 7, 2016




PLAN

0 10' 20'
GRAPHIC SCALE

8/5/2016 12:04:09 PM Q:\Eagle Canyon\05_CAD\Data\LB_WSE3_Profile-20160129.dwg

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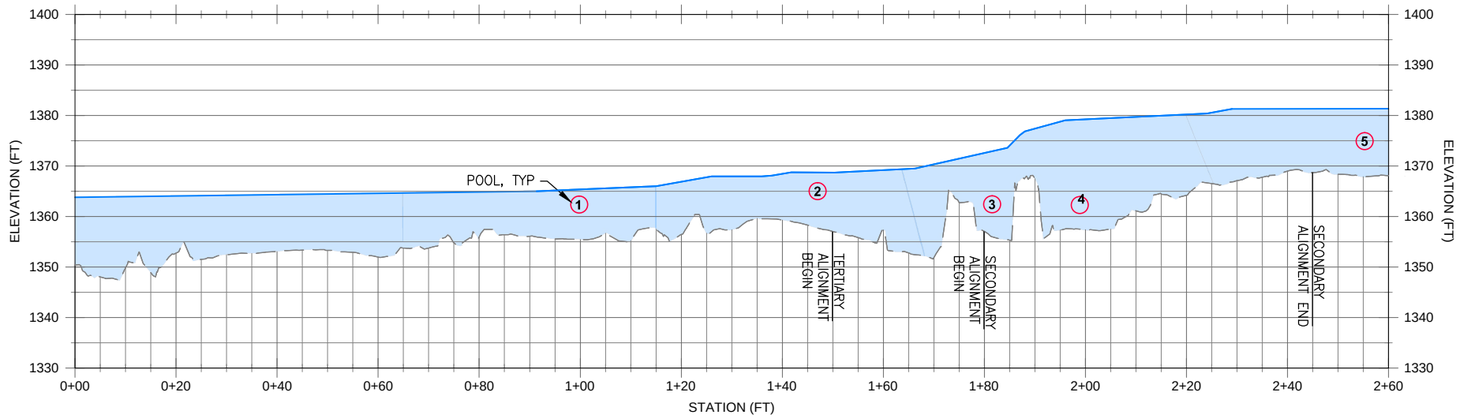
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
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**LOWER BARRIER**
**WATER SURFACE MAPPING EVENT 3 PLAN**

DATE
JULY 2016

SUBMITTAL
TASK 4

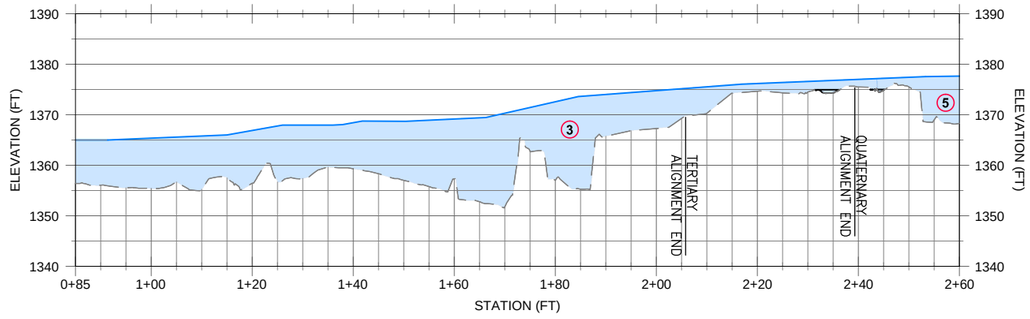
FIGURE
**H-5**




PRIMARY ALIGNMENT PROFILE

0 15' 30'

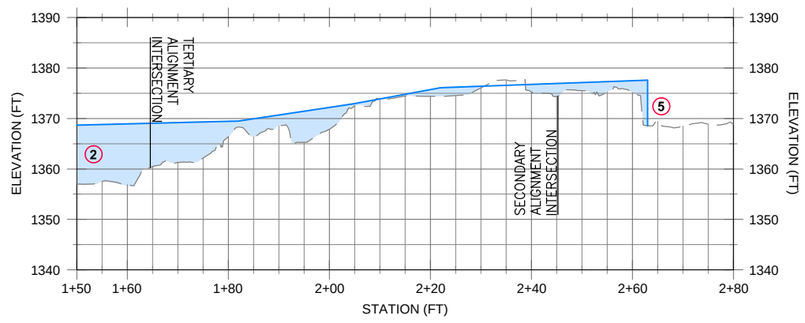
GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE




QUANTERNARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE

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**LOWER BARRIER**

**WATER SURFACE MAPPING EVENT 3 PROFILES**

DATE
JULY 2016

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FIGURE
**H-6**

Attachment I **Lower Barrier HEC-RAS Result Figures and Data Tables**

**Lower Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB_HEC-RAS | 332.29 | Q10 | 5709 | 1370.9 | 1389.67 | 1386.03 | 1391.47 | 0.016481 | 10.89 | 552.55 | 50.53 | 0.56 |
| LB_HEC-RAS | 332.29 | Q25 | 7512 | 1370.9 | 1391.73 | 1387.6 | 1393.96 | 0.016528 | 12.14 | 657.87 | 53.11 | 0.57 |
| LB_HEC-RAS | 332.29 | Q50 | 8914 | 1370.9 | 1393.23 | 1388.73 | 1395.75 | 0.016373 | 12.94 | 742.59 | 58.92 | 0.58 |
| LB_HEC-RAS | 332.29 | Q100 | 10216 | 1370.9 | 1394.53 | 1389.71 | 1397.32 | 0.016337 | 13.65 | 821.87 | 65.42 | 0.59 |
| LB_HEC-RAS | 324.69 | Q10 | 5709 | 1371.03 | 1389.46 | 1386.02 | 1391.31 | 0.023279 | 10.95 | 527.74 | 50.11 | 0.58 |
| LB_HEC-RAS | 324.69 | Q25 | 7512 | 1371.03 | 1391.56 | 1387.64 | 1393.81 | 0.022465 | 12.07 | 634.79 | 51.51 | 0.59 |
| LB_HEC-RAS | 324.69 | Q50 | 8914 | 1371.03 | 1393.07 | 1388.75 | 1395.6 | 0.021946 | 12.83 | 713.21 | 52.70 | 0.59 |
| LB_HEC-RAS | 324.69 | Q100 | 10216 | 1371.03 | 1394.39 | 1389.76 | 1397.17 | 0.021536 | 13.46 | 784.79 | 55.84 | 0.59 |
| LB_HEC-RAS | 322.25 | Q10 | 5709 | 1371.33 | 1389.32 | 1386.1 | 1391.25 | 0.021909 | 11.17 | 522.27 | 50.70 | 0.60 |
| LB_HEC-RAS | 322.25 | Q25 | 7512 | 1371.33 | 1391.43 | 1387.72 | 1393.75 | 0.020901 | 12.27 | 631.09 | 52.52 | 0.60 |
| LB_HEC-RAS | 322.25 | Q50 | 8914 | 1371.33 | 1392.95 | 1388.84 | 1395.55 | 0.020238 | 13.00 | 711.68 | 53.61 | 0.60 |
| LB_HEC-RAS | 322.25 | Q100 | 10216 | 1371.33 | 1394.28 | 1389.86 | 1397.12 | 0.01973 | 13.61 | 784.34 | 55.66 | 0.60 |
| LB_HEC-RAS | 319.07 | Q10 | 5709 | 1371.92 | 1389.49 | 1385.06 | 1391.1 | 0.014577 | 10.33 | 583.18 | 53.54 | 0.51 |
| LB_HEC-RAS | 319.07 | Q25 | 7512 | 1371.92 | 1391.62 | 1386.74 | 1393.59 | 0.014657 | 11.49 | 699.61 | 55.72 | 0.52 |
| LB_HEC-RAS | 319.07 | Q50 | 8914 | 1371.92 | 1393.16 | 1387.95 | 1395.38 | 0.014591 | 12.24 | 787.04 | 58.21 | 0.53 |
| LB_HEC-RAS | 319.07 | Q100 | 10216 | 1371.92 | 1394.52 | 1388.98 | 1396.94 | 0.014422 | 12.83 | 867.21 | 59.66 | 0.54 |
| LB_HEC-RAS | 312.22 | Q10 | 5709 | 1371.29 | 1389.68 | 1383.71 | 1390.89 | 0.012072 | 8.83 | 649.47 | 55.42 | 0.45 |
| LB_HEC-RAS | 312.22 | Q25 | 7512 | 1371.29 | 1391.87 | 1385.61 | 1393.35 | 0.012452 | 9.78 | 774.24 | 60.85 | 0.47 |
| LB_HEC-RAS | 312.22 | Q50 | 8914 | 1371.29 | 1393.46 | 1386.77 | 1395.12 | 0.012452 | 10.34 | 880.16 | 70.81 | 0.47 |
| LB_HEC-RAS | 312.22 | Q100 | 10216 | 1371.29 | 1394.89 | 1387.83 | 1396.65 | 0.01202 | 10.73 | 985.43 | 76.52 | 0.47 |
| LB_HEC-RAS | 308.84 | Q10 | 5709 | 1371.69 | 1389.44 | 1384.9 | 1390.82 | 0.018882 | 9.46 | 610.65 | 61.96 | 0.53 |
| LB_HEC-RAS | 308.84 | Q25 | 7512 | 1371.69 | 1391.71 | 1386.54 | 1393.29 | 0.016949 | 10.12 | 753.56 | 64.75 | 0.51 |
| LB_HEC-RAS | 308.84 | Q50 | 8914 | 1371.69 | 1393.35 | 1387.68 | 1395.06 | 0.015583 | 10.55 | 866.38 | 73.78 | 0.50 |
| LB_HEC-RAS | 308.84 | Q100 | 10216 | 1371.69 | 1394.8 | 1388.94 | 1396.6 | 0.014437 | 10.85 | 978.77 | 79.89 | 0.49 |
| LB_HEC-RAS | 302.18 | Q10 | 5709 | 1372.7 | 1389.38 | 1383.79 | 1390.69 | 0.014061 | 9.20 | 620.52 | 52.82 | 0.47 |
| LB_HEC-RAS | 302.18 | Q25 | 7512 | 1372.7 | 1391.58 | 1385.86 | 1393.19 | 0.014378 | 10.17 | 739.97 | 55.37 | 0.49 |
| LB_HEC-RAS | 302.18 | Q50 | 8914 | 1372.7 | 1393.14 | 1386.97 | 1394.95 | 0.014577 | 10.81 | 827.61 | 57.33 | 0.50 |
| LB_HEC-RAS | 302.18 | Q100 | 10216 | 1372.7 | 1394.5 | 1387.98 | 1396.49 | 0.014907 | 11.31 | 907.41 | 60.27 | 0.51 |
| LB_HEC-RAS | 299.97 | Q10 | 5709 | 1372.64 | 1389.18 | 1383.88 | 1390.64 | 0.020139 | 9.71 | 589.02 | 49.35 | 0.49 |
| LB_HEC-RAS | 299.97 | Q25 | 7512 | 1372.64 | 1391.31 | 1385.83 | 1393.13 | 0.022377 | 10.81 | 697.42 | 52.11 | 0.52 |
| LB_HEC-RAS | 299.97 | Q50 | 8914 | 1372.64 | 1392.83 | 1387.02 | 1394.89 | 0.023685 | 11.53 | 777.56 | 53.78 | 0.53 |
| LB_HEC-RAS | 299.97 | Q100 | 10216 | 1372.64 | 1394.14 | 1388.06 | 1396.42 | 0.024724 | 12.11 | 849.34 | 55.24 | 0.54 |
| LB_HEC-RAS | 292.96 | Q10 | 5709 | 1372.88 | 1388.67 | 1384.43 | 1390.47 | 0.020134 | 10.79 | 541.69 | 49.59 | 0.54 |
| LB_HEC-RAS | 292.96 | Q25 | 7512 | 1372.88 | 1390.72 | 1386.21 | 1392.94 | 0.020572 | 12.06 | 644.68 | 51.10 | 0.56 |
| LB_HEC-RAS | 292.96 | Q50 | 8914 | 1372.88 | 1392.16 | 1387.51 | 1394.68 | 0.020833 | 12.92 | 718.78 | 52.15 | 0.57 |
| LB_HEC-RAS | 292.96 | Q100 | 10216 | 1372.88 | 1393.4 | 1388.67 | 1396.2 | 0.021034 | 13.65 | 784.12 | 53.06 | 0.58 |
| LB_HEC-RAS | 289.76 | Q10 | 5709 | 1373.05 | 1387.46 | 1385.53 | 1390.28 | 0.039227 | 13.53 | 432.44 | 46.49 | 0.73 |
| LB_HEC-RAS | 289.76 | Q25 | 7512 | 1373.05 | 1389.32 | 1387.45 | 1392.73 | 0.038674 | 14.95 | 521.01 | 48.56 | 0.74 |
| LB_HEC-RAS | 289.76 | Q50 | 8914 | 1373.05 | 1390.65 | 1388.72 | 1394.47 | 0.03807 | 15.87 | 586.80 | 50.04 | 0.75 |
| LB_HEC-RAS | 289.76 | Q100 | 10216 | 1373.05 | 1391.83 | 1389.84 | 1395.98 | 0.037413 | 16.61 | 646.40 | 51.35 | 0.75 |
| LB_HEC-RAS | 286 | Q10 | 5709 | 1373.19 | 1387.26 | 1385.71 | 1390.12 | 0.046713 | 13.59 | 425.88 | 46.47 | 0.77 |
| LB_HEC-RAS | 286 | Q25 | 7512 | 1373.19 | 1389.17 | 1387.38 | 1392.57 | 0.043899 | 14.86 | 516.82 | 48.62 | 0.77 |
| LB_HEC-RAS | 286 | Q50 | 8914 | 1373.19 | 1390.51 | 1388.63 | 1394.31 | 0.042474 | 15.73 | 583.12 | 50.12 | 0.77 |
| LB_HEC-RAS | 286 | Q100 | 10216 | 1373.19 | 1391.7 | 1389.7 | 1395.82 | 0.041222 | 16.43 | 643.34 | 51.45 | 0.77 |
| LB_HEC-RAS | 282.94 | Q10 | 5709 | 1368.94 | 1387.5 | 1384.74 | 1389.82 | 0.038404 | 12.27 | 473.90 | 47.02 | 0.65 |
| LB_HEC-RAS | 282.94 | Q25 | 7512 | 1368.94 | 1389.44 | 1386.55 | 1392.28 | 0.038164 | 13.62 | 567.37 | 49.48 | 0.67 |
| LB_HEC-RAS | 282.94 | Q50 | 8914 | 1368.94 | 1390.81 | 1387.75 | 1394.01 | 0.037953 | 14.51 | 636.07 | 51.21 | 0.67 |
| LB_HEC-RAS | 282.94 | Q100 | 10216 | 1368.94 | 1392 | 1388.87 | 1395.52 | 0.037616 | 15.24 | 698.28 | 52.67 | 0.68 |

**Lower Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB_HEC-RAS | 274.97 | Q10 | 5709 | 1361.49 | 1386.11 | 1384.97 | 1389.29 | 0.089837 | 14.34 | 403.85 | 45.25 | 0.82 |
| LB_HEC-RAS | 274.97 | Q25 | 7512 | 1361.49 | 1388.02 | 1386.61 | 1391.76 | 0.083414 | 15.60 | 491.86 | 47.20 | 0.81 |
| LB_HEC-RAS | 274.97 | Q50 | 8914 | 1361.49 | 1389.34 | 1387.95 | 1393.49 | 0.08049 | 16.49 | 555.02 | 48.55 | 0.81 |
| LB_HEC-RAS | 274.97 | Q100 | 10216 | 1361.49 | 1390.51 | 1389.03 | 1395 | 0.077721 | 17.18 | 612.79 | 49.79 | 0.81 |
| LB_HEC-RAS | 272.92 | Q10 | 5709 | 1361.42 | 1385.11 | 1384.75 | 1389.01 | 0.110815 | 15.96 | 368.84 | 44.77 | 0.96 |
| LB_HEC-RAS | 272.92 | Q25 | 7512 | 1361.42 | 1386.56 | 1386.56 | 1391.45 | 0.112715 | 17.88 | 435.25 | 46.26 | 1.00 |
| LB_HEC-RAS | 272.92 | Q50 | 8914 | 1361.42 | 1387.83 | 1387.83 | 1393.19 | 0.105885 | 18.76 | 494.45 | 47.55 | 0.99 |
| LB_HEC-RAS | 272.92 | Q100 | 10216 | 1361.42 | 1388.89 | 1388.89 | 1394.7 | 0.101922 | 19.55 | 545.76 | 48.64 | 0.98 |
| LB_HEC-RAS | 271.17 | Q10 | 5709 | 1361.36 | 1384.62 | 1384.62 | 1388.77 | 0.126801 | 16.37 | 353.14 | 44.75 | 1.01 |
| LB_HEC-RAS | 271.17 | Q25 | 7512 | 1361.36 | 1386.01 | 1386.38 | 1391.21 | 0.129443 | 18.36 | 416.19 | 46.14 | 1.05 |
| LB_HEC-RAS | 271.17 | Q50 | 8914 | 1361.36 | 1387.12 | 1387.62 | 1392.95 | 0.125414 | 19.45 | 468.13 | 47.24 | 1.05 |
| LB_HEC-RAS | 271.17 | Q100 | 10216 | 1361.36 | 1388.1 | 1388.61 | 1394.45 | 0.122131 | 20.35 | 514.70 | 48.21 | 1.05 |
| LB_HEC-RAS | 262.9 | Q10 | 5709 | 1364.35 | 1385.33 | 1379.69 | 1386.74 | 0.019698 | 9.54 | 602.49 | 46.62 | 0.46 |
| LB_HEC-RAS | 262.9 | Q25 | 7512 | 1364.35 | 1387.1 | 1381.34 | 1389 | 0.022588 | 11.08 | 687.48 | 49.47 | 0.50 |
| LB_HEC-RAS | 262.9 | Q50 | 8914 | 1364.35 | 1388.3 | 1382.56 | 1390.58 | 0.024594 | 12.15 | 748.05 | 51.35 | 0.53 |
| LB_HEC-RAS | 262.9 | Q100 | 10216 | 1364.35 | 1389.33 | 1383.59 | 1391.95 | 0.026251 | 13.07 | 801.53 | 52.95 | 0.55 |
| LB_HEC-RAS | 253.26 | Q10 | 5709 | 1367.28 | 1385.31 | 1378.87 | 1386.51 | 0.015701 | 8.81 | 648.72 | 48.28 | 0.42 |
| LB_HEC-RAS | 253.26 | Q25 | 7512 | 1367.28 | 1387.1 | 1380.5 | 1388.72 | 0.018633 | 10.19 | 738.37 | 52.21 | 0.47 |
| LB_HEC-RAS | 253.26 | Q50 | 8914 | 1367.28 | 1388.34 | 1381.66 | 1390.26 | 0.019949 | 11.13 | 804.23 | 54.58 | 0.50 |
| LB_HEC-RAS | 253.26 | Q100 | 10216 | 1367.28 | 1389.39 | 1382.72 | 1391.6 | 0.021028 | 11.94 | 862.98 | 56.62 | 0.51 |
| LB_HEC-RAS | 244.1 | Q10 | 5709 | 1363.95 | 1384.95 | 1378.57 | 1386.33 | 0.02113 | 9.43 | 605.32 | 50.86 | 0.48 |
| LB_HEC-RAS | 244.1 | Q25 | 7512 | 1363.95 | 1386.68 | 1380.38 | 1388.5 | 0.024404 | 10.82 | 694.23 | 51.82 | 0.52 |
| LB_HEC-RAS | 244.1 | Q50 | 8914 | 1363.95 | 1387.87 | 1381.59 | 1390.03 | 0.02642 | 11.78 | 756.52 | 52.91 | 0.55 |
| LB_HEC-RAS | 244.1 | Q100 | 10216 | 1363.95 | 1388.9 | 1383.8 | 1391.35 | 0.029703 | 12.57 | 813.22 | 58.37 | 0.59 |
| LB_HEC-RAS | 228.89 | Q10 | 5709 | 1367.31 | 1385.05 | 1377.55 | 1385.86 | 0.009381 | 7.22 | 793.32 | 67.41 | 0.36 |
| LB_HEC-RAS | 228.89 | Q25 | 7512 | 1367.31 | 1386.89 | 1379.59 | 1387.94 | 0.010171 | 8.25 | 920.14 | 70.65 | 0.39 |
| LB_HEC-RAS | 228.89 | Q50 | 8914 | 1367.31 | 1388.17 | 1380.71 | 1389.4 | 0.010668 | 8.95 | 1011.95 | 72.97 | 0.40 |
| LB_HEC-RAS | 228.89 | Q100 | 10216 | 1367.31 | 1389.26 | 1381.66 | 1390.66 | 0.011075 | 9.54 | 1092.78 | 74.96 | 0.41 |
| LB_HEC-RAS | 222.06 | Q10 | 5709 | 1367.1 | 1384.79 | 1377.81 | 1385.78 | 0.009543 | 8.04 | 736.97 | 68.74 | 0.40 |
| LB_HEC-RAS | 222.06 | Q25 | 7512 | 1367.1 | 1386.6 | 1379.82 | 1387.85 | 0.010225 | 9.11 | 862.54 | 70.72 | 0.43 |
| LB_HEC-RAS | 222.06 | Q50 | 8914 | 1367.1 | 1387.85 | 1381.57 | 1389.3 | 0.010679 | 9.85 | 952.04 | 72.61 | 0.44 |
| LB_HEC-RAS | 222.06 | Q100 | 10216 | 1367.1 | 1388.91 | 1382.62 | 1390.56 | 0.011064 | 10.49 | 1030.47 | 74.49 | 0.46 |
| LB_HEC-RAS | 212.06 | Q10 | 5709 | 1364.61 | 1384.08 | 1380.05 | 1385.58 | 0.026677 | 9.82 | 582.20 | 61.99 | 0.56 |
| LB_HEC-RAS | 212.06 | Q25 | 7512 | 1364.61 | 1385.78 | 1382.09 | 1387.63 | 0.027447 | 10.93 | 689.20 | 64.47 | 0.59 |
| LB_HEC-RAS | 212.06 | Q50 | 8914 | 1364.61 | 1386.97 | 1383.17 | 1389.08 | 0.028004 | 11.66 | 767.15 | 66.83 | 0.60 |
| LB_HEC-RAS | 212.06 | Q100 | 10216 | 1364.61 | 1387.98 | 1384.09 | 1390.32 | 0.028427 | 12.27 | 836.17 | 68.85 | 0.62 |
| LB_HEC-RAS | 208.06 | Q10 | 5709 | 1363.23 | 1381.65 | 1381.65 | 1385.19 | 0.090225 | 15.12 | 381.27 | 55.79 | 1.02 |
| LB_HEC-RAS | 208.06 | Q25 | 7512 | 1363.23 | 1383.2 | 1383.2 | 1387.24 | 0.082487 | 16.14 | 470.22 | 59.13 | 1.01 |
| LB_HEC-RAS | 208.06 | Q50 | 8914 | 1363.23 | 1384.26 | 1384.26 | 1388.67 | 0.078628 | 16.88 | 533.61 | 60.92 | 1.00 |
| LB_HEC-RAS | 208.06 | Q100 | 10216 | 1363.23 | 1385.12 | 1385.12 | 1389.9 | 0.078582 | 17.56 | 587.76 | 63.84 | 1.02 |
| LB_HEC-RAS | 202.06 | Q10 | 5709 | 1359.55 | 1381.91 | 1377.75 | 1383.44 | 0.043236 | 9.92 | 575.91 | 58.76 | 0.56 |
| LB_HEC-RAS | 202.06 | Q25 | 7512 | 1359.55 | 1383.7 | 1379.38 | 1385.58 | 0.043322 | 11.01 | 684.30 | 62.25 | 0.58 |
| LB_HEC-RAS | 202.06 | Q50 | 8914 | 1359.55 | 1384.78 | 1380.68 | 1386.98 | 0.044942 | 11.91 | 753.17 | 65.11 | 0.59 |
| LB_HEC-RAS | 202.06 | Q100 | 10216 | 1359.55 | 1385.73 | 1381.85 | 1388.2 | 0.04596 | 12.65 | 815.48 | 66.44 | 0.61 |
| LB_HEC-RAS | 195.06 | Q10 | 5709 | 1357.03 | 1378.96 | 1378.96 | 1382.93 | 0.033028 | 15.99 | 358.36 | 44.95 | 0.99 |
| LB_HEC-RAS | 195.06 | Q25 | 7512 | 1357.03 | 1380.97 | 1380.97 | 1385.11 | 0.029215 | 16.34 | 461.98 | 55.46 | 0.99 |
| LB_HEC-RAS | 195.06 | Q50 | 8914 | 1357.03 | 1382.22 | 1382.22 | 1386.52 | 0.027639 | 16.66 | 538.05 | 63.85 | 1.01 |
| LB_HEC-RAS | 195.06 | Q100 | 10216 | 1357.03 | 1382.98 | 1382.98 | 1387.72 | 0.027693 | 17.49 | 587.51 | 65.50 | 1.03 |

**Lower Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

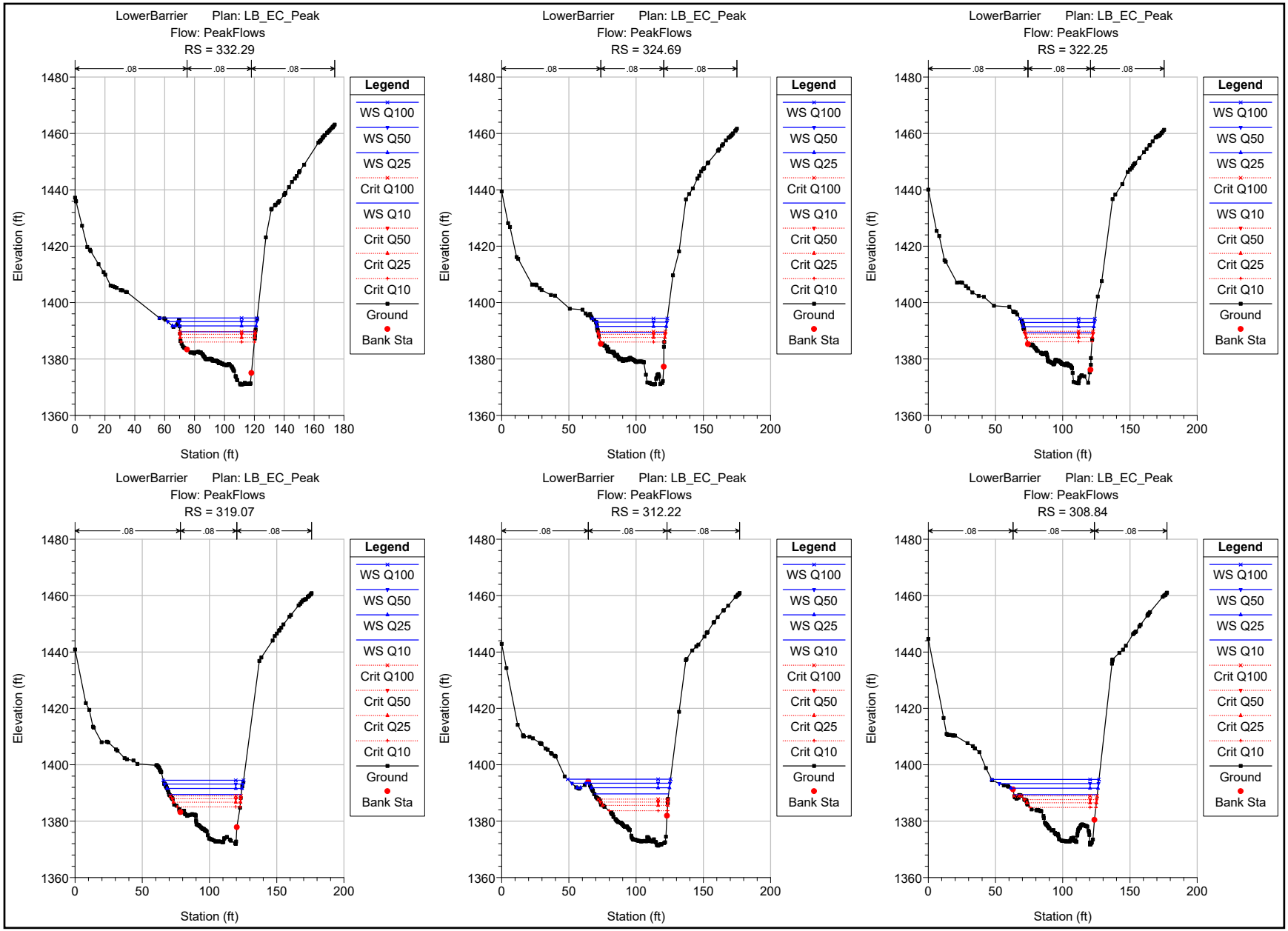
| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB_HEC-RAS | 189.06 | Q10 | 5709 | 1357.13 | 1373.15 | 1376.17 | 1382.09 | 0.120181 | 23.99 | 237.98 | 36.66 | 1.66 |
| LB_HEC-RAS | 189.06 | Q25 | 7512 | 1357.13 | 1374.72 | 1377.7 | 1384.25 | 0.118427 | 24.78 | 303.13 | 48.83 | 1.75 |
| LB_HEC-RAS | 189.06 | Q50 | 8914 | 1357.13 | 1375.65 | 1378.63 | 1385.66 | 0.111479 | 25.38 | 351.20 | 53.34 | 1.74 |
| LB_HEC-RAS | 189.06 | Q100 | 10216 | 1357.13 | 1376.45 | 1379.62 | 1386.87 | 0.103789 | 25.90 | 394.42 | 55.00 | 1.70 |
| LB_HEC-RAS | 182.06 | Q10 | 5709 | 1355.21 | 1376.91 | 1376.91 | 1380.25 | 0.035787 | 14.65 | 389.58 | 59.76 | 1.01 |
| LB_HEC-RAS | 182.06 | Q25 | 7512 | 1355.21 | 1377.84 | 1378.3 | 1382.26 | 0.040573 | 16.87 | 445.32 | 60.61 | 1.10 |
| LB_HEC-RAS | 182.06 | Q50 | 8914 | 1355.21 | 1378.2 | 1379.24 | 1383.85 | 0.049013 | 19.07 | 467.49 | 60.95 | 1.21 |
| LB_HEC-RAS | 182.06 | Q100 | 10216 | 1355.21 | 1378.88 | 1380.22 | 1385.13 | 0.049293 | 20.07 | 508.93 | 61.60 | 1.23 |
| LB_HEC-RAS | 177.06 | Q10 | 5709 | 1355.31 | 1374.57 | 1375.92 | 1379.83 | 0.057718 | 18.41 | 310.11 | 58.04 | 1.40 |
| LB_HEC-RAS | 177.06 | Q25 | 7512 | 1355.31 | 1375.72 | 1377.2 | 1381.85 | 0.053061 | 19.88 | 378.66 | 59.99 | 1.38 |
| LB_HEC-RAS | 177.06 | Q50 | 8914 | 1355.31 | 1376.4 | 1378.28 | 1383.45 | 0.053921 | 21.33 | 419.46 | 60.76 | 1.41 |
| LB_HEC-RAS | 177.06 | Q100 | 10216 | 1355.31 | 1377.1 | 1379.11 | 1384.74 | 0.052041 | 22.21 | 462.40 | 61.57 | 1.40 |
| LB_HEC-RAS | 172.06 | Q10 | 5709 | 1354.84 | 1376.83 | 1373.25 | 1378.49 | 0.011857 | 10.32 | 553.16 | 56.88 | 0.58 |
| LB_HEC-RAS | 172.06 | Q25 | 7512 | 1354.84 | 1379.29 | 1374.83 | 1381.05 | 0.010704 | 10.66 | 704.90 | 68.45 | 0.59 |
| LB_HEC-RAS | 172.06 | Q50 | 8914 | 1354.84 | 1380.82 | 1376.09 | 1382.69 | 0.009669 | 10.99 | 811.20 | 70.87 | 0.57 |
| LB_HEC-RAS | 172.06 | Q100 | 10216 | 1354.84 | 1381.89 | 1377.15 | 1383.95 | 0.009438 | 11.52 | 888.52 | 72.73 | 0.57 |
| LB_HEC-RAS | 167.06 | Q10 | 5709 | 1354.23 | 1373.57 | 1373.57 | 1378.1 | 0.037573 | 17.09 | 333.99 | 37.45 | 1.01 |
| LB_HEC-RAS | 167.06 | Q25 | 7512 | 1354.23 | 1375.97 | 1375.97 | 1380.67 | 0.034658 | 17.40 | 431.72 | 46.68 | 1.01 |
| LB_HEC-RAS | 167.06 | Q50 | 8914 | 1354.23 | 1377.37 | 1377.37 | 1382.31 | 0.032466 | 17.82 | 500.34 | 51.00 | 1.00 |
| LB_HEC-RAS | 167.06 | Q100 | 10216 | 1354.23 | 1379.1 | 1379.1 | 1383.63 | 0.026854 | 17.10 | 602.11 | 67.26 | 0.96 |
| LB_HEC-RAS | 162.05 | Q10 | 5709 | 1351.67 | 1372.22 | 1373.29 | 1377.77 | 0.054792 | 18.91 | 301.99 | 38.64 | 1.19 |
| LB_HEC-RAS | 162.05 | Q25 | 7512 | 1351.67 | 1373.94 | 1375.34 | 1380.3 | 0.050813 | 20.26 | 372.72 | 43.32 | 1.18 |
| LB_HEC-RAS | 162.05 | Q50 | 8914 | 1351.67 | 1375.29 | 1376.78 | 1381.95 | 0.046422 | 20.79 | 433.97 | 47.97 | 1.14 |
| LB_HEC-RAS | 162.05 | Q100 | 10216 | 1351.67 | 1376.53 | 1378.53 | 1383.25 | 0.042202 | 20.97 | 498.48 | 55.57 | 1.11 |
| LB_HEC-RAS | 156.05 | Q10 | 5709 | 1352.22 | 1366.06 | 1369.82 | 1376.84 | 0.088326 | 26.35 | 216.68 | 30.31 | 1.74 |
| LB_HEC-RAS | 156.05 | Q25 | 7512 | 1352.22 | 1367.76 | 1371.52 | 1379.36 | 0.093005 | 27.34 | 274.76 | 38.84 | 1.81 |
| LB_HEC-RAS | 156.05 | Q50 | 8914 | 1352.22 | 1368.73 | 1372.64 | 1381 | 0.098602 | 28.11 | 317.16 | 47.03 | 1.91 |
| LB_HEC-RAS | 156.05 | Q100 | 10216 | 1352.22 | 1369.55 | 1373.5 | 1382.28 | 0.094623 | 28.63 | 356.82 | 50.59 | 1.90 |
| LB_HEC-RAS | 152.05 | Q10 | 5709 | 1354.34 | 1369.13 | 1370.9 | 1375.12 | 0.05934 | 19.65 | 290.56 | 55.32 | 1.51 |
| LB_HEC-RAS | 152.05 | Q25 | 7512 | 1354.34 | 1369.74 | 1372.28 | 1378.03 | 0.075432 | 23.12 | 324.95 | 57.51 | 1.71 |
| LB_HEC-RAS | 152.05 | Q50 | 8914 | 1354.34 | 1370.37 | 1373.19 | 1379.78 | 0.077422 | 24.62 | 362.07 | 59.31 | 1.76 |
| LB_HEC-RAS | 152.05 | Q100 | 10216 | 1354.34 | 1370.97 | 1374.1 | 1381.19 | 0.076899 | 25.65 | 398.36 | 61.04 | 1.77 |
| LB_HEC-RAS | 142.05 | Q10 | 5709 | 1356.79 | 1371.61 | 1370.68 | 1374.26 | 0.015349 | 13.08 | 441.00 | 66.50 | 0.84 |
| LB_HEC-RAS | 142.05 | Q25 | 7512 | 1356.79 | 1370.34 | 1372.36 | 1376.96 | 0.044748 | 20.65 | 364.03 | 56.03 | 1.41 |
| LB_HEC-RAS | 142.05 | Q50 | 8914 | 1356.79 | 1371.01 | 1373.33 | 1378.67 | 0.04681 | 22.23 | 402.69 | 60.35 | 1.46 |
| LB_HEC-RAS | 142.05 | Q100 | 10216 | 1356.79 | 1371.64 | 1374.19 | 1380.04 | 0.048542 | 23.31 | 442.93 | 66.68 | 1.50 |
| LB_HEC-RAS | 133.93 | Q10 | 5709 | 1357.13 | 1372.13 | 1369.91 | 1373.9 | 0.008541 | 10.68 | 534.49 | 68.96 | 0.67 |
| LB_HEC-RAS | 133.93 | Q25 | 7512 | 1357.13 | 1369.12 | 1371.44 | 1376.5 | 0.051242 | 21.79 | 344.72 | 55.80 | 1.55 |
| LB_HEC-RAS | 133.93 | Q50 | 8914 | 1357.13 | 1369.79 | 1372.4 | 1378.19 | 0.053819 | 23.26 | 383.19 | 59.17 | 1.61 |
| LB_HEC-RAS | 133.93 | Q100 | 10216 | 1357.13 | 1370.42 | 1373.21 | 1379.56 | 0.05438 | 24.26 | 421.12 | 62.20 | 1.64 |
| LB_HEC-RAS | 125.75 | Q10 | 5709 | 1357.64 | 1372.09 | 1369.22 | 1373.52 | 0.005879 | 9.60 | 595.72 | 71.53 | 0.58 |
| LB_HEC-RAS | 125.75 | Q25 | 7512 | 1357.64 | 1373.44 | 1370.71 | 1375.28 | 0.006221 | 10.90 | 692.66 | 72.65 | 0.61 |
| LB_HEC-RAS | 125.75 | Q50 | 8914 | 1357.64 | 1374.37 | 1371.51 | 1376.53 | 0.00646 | 11.80 | 760.91 | 73.58 | 0.63 |
| LB_HEC-RAS | 125.75 | Q100 | 10216 | 1357.64 | 1375.17 | 1372.34 | 1377.62 | 0.00667 | 12.57 | 820.00 | 74.47 | 0.65 |
| LB_HEC-RAS | 119.65 | Q10 | 5709 | 1358.7 | 1370.32 | 1370.32 | 1373.31 | 0.02235 | 13.88 | 411.37 | 70.74 | 1.01 |
| LB_HEC-RAS | 119.65 | Q25 | 7512 | 1358.7 | 1371.59 | 1371.59 | 1375.06 | 0.020354 | 14.93 | 503.50 | 73.26 | 1.00 |
| LB_HEC-RAS | 119.65 | Q50 | 8914 | 1358.7 | 1372.45 | 1372.45 | 1376.3 | 0.019854 | 15.75 | 567.26 | 75.66 | 1.00 |
| LB_HEC-RAS | 119.65 | Q100 | 10216 | 1358.7 | 1373.19 | 1373.19 | 1377.38 | 0.019161 | 16.45 | 623.16 | 76.30 | 1.00 |

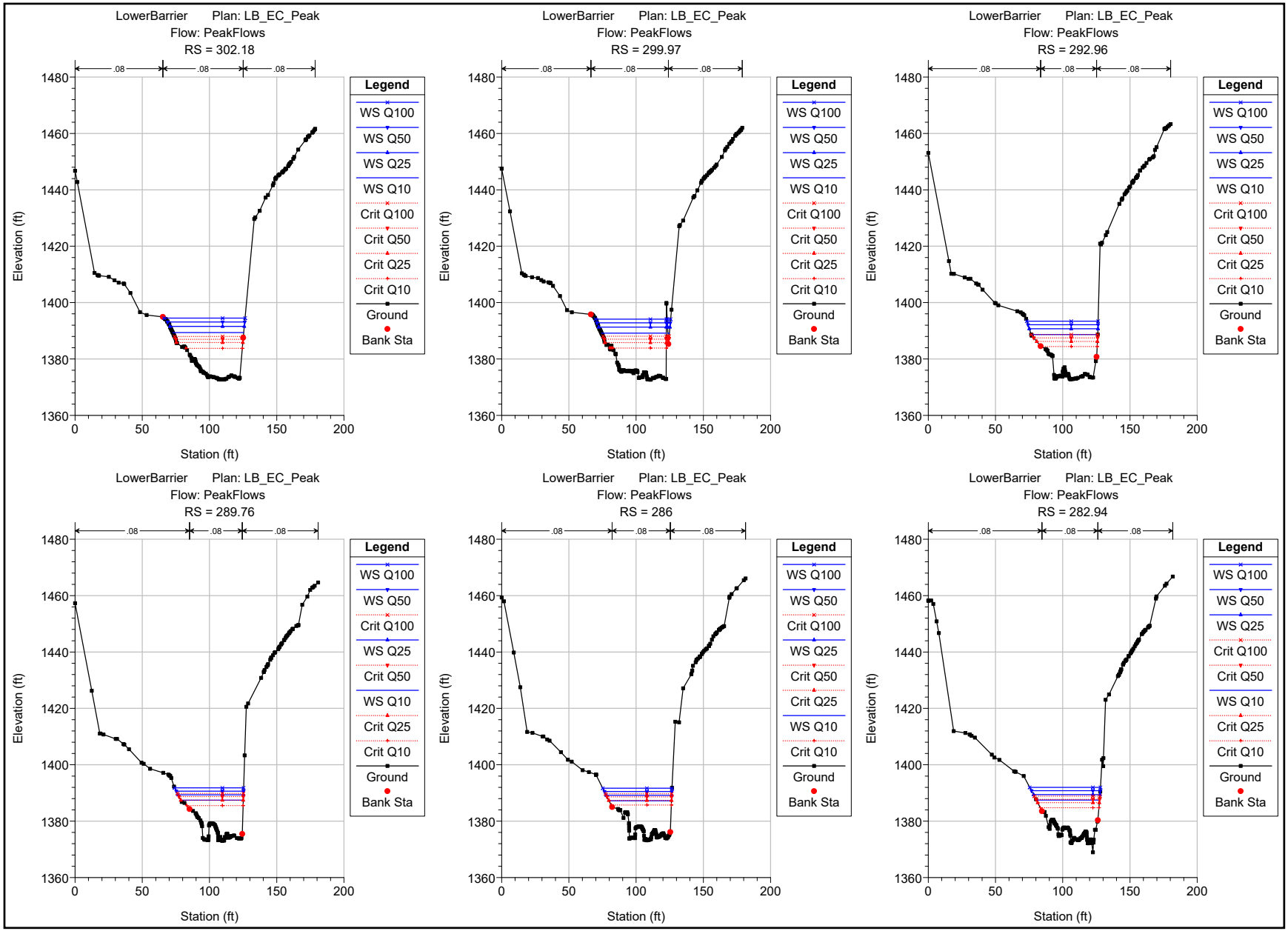
**Lower Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

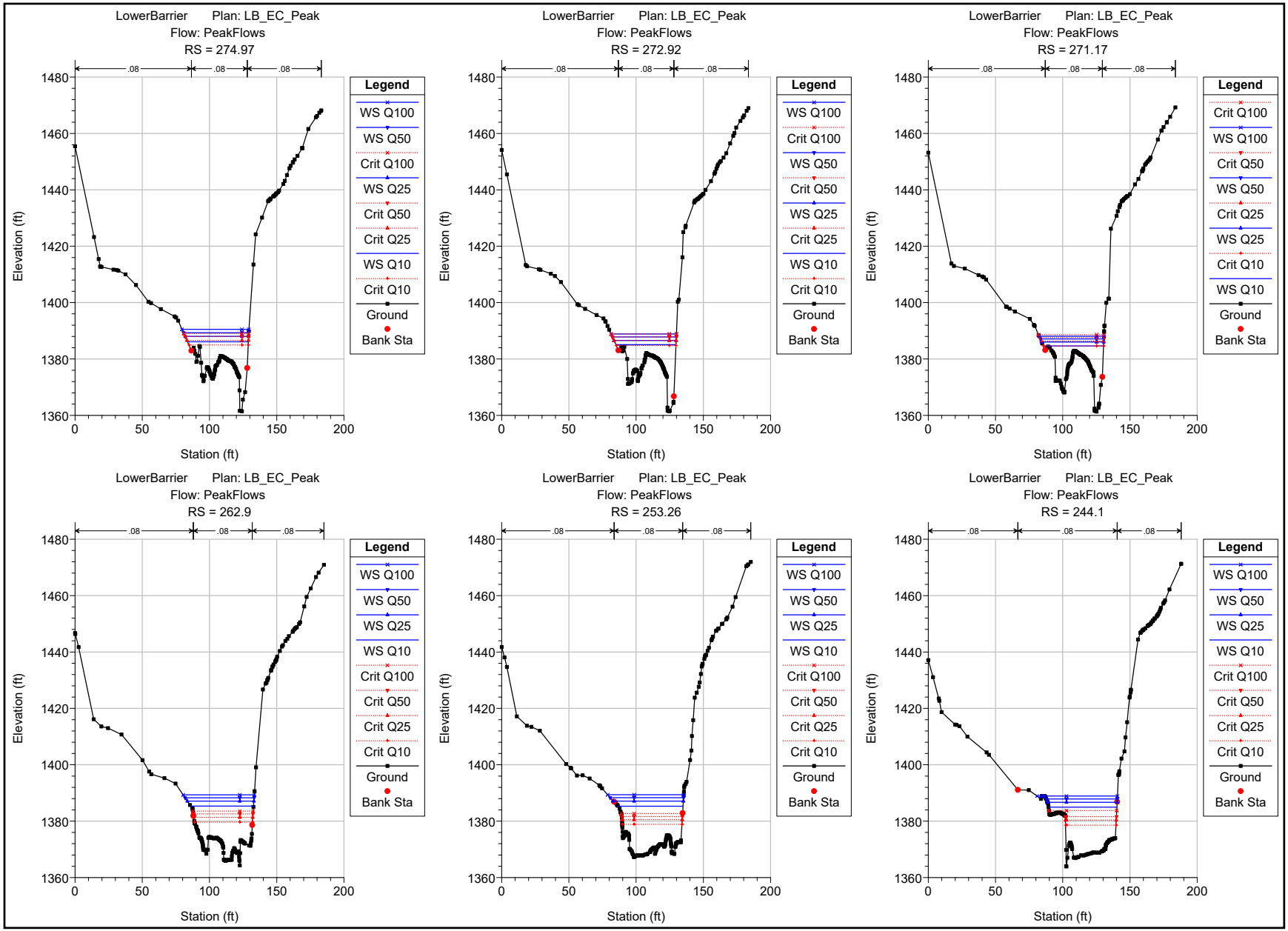
| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB_HEC-RAS | 111 | Q10 | 5709 | 1353.31 | 1370.61 | 1368.13 | 1372.11 | 0.009758 | 9.84 | 581.87 | 77.40 | 0.63 |
| LB_HEC-RAS | 111 | Q25 | 7512 | 1353.31 | 1372.34 | 1369.62 | 1374.06 | 0.008506 | 10.53 | 717.91 | 79.05 | 0.61 |
| LB_HEC-RAS | 111 | Q50 | 8914 | 1353.31 | 1373.55 | 1370.49 | 1375.44 | 0.00797 | 11.05 | 814.17 | 80.16 | 0.60 |
| LB_HEC-RAS | 111 | Q100 | 10216 | 1353.31 | 1374.57 | 1371.2 | 1376.63 | 0.007693 | 11.54 | 895.88 | 81.03 | 0.60 |
| LB_HEC-RAS | 102.31 | Q10 | 5709 | 1354.77 | 1370.89 | 1365.76 | 1371.91 | 0.003748 | 8.13 | 702.82 | 72.43 | 0.46 |
| LB_HEC-RAS | 102.31 | Q25 | 7512 | 1354.77 | 1372.6 | 1367.44 | 1373.89 | 0.003798 | 9.10 | 829.04 | 75.06 | 0.47 |
| LB_HEC-RAS | 102.31 | Q50 | 8914 | 1354.77 | 1373.79 | 1368.54 | 1375.27 | 0.00384 | 9.77 | 919.80 | 76.89 | 0.48 |
| LB_HEC-RAS | 102.31 | Q100 | 10216 | 1354.77 | 1374.8 | 1369.55 | 1376.46 | 0.003899 | 10.36 | 997.93 | 78.44 | 0.49 |
| LB_HEC-RAS | 94.49 | Q10 | 5709 | 1354.45 | 1370.77 | 1365.75 | 1371.88 | 0.00394 | 8.44 | 682.23 | 70.10 | 0.45 |
| LB_HEC-RAS | 94.49 | Q25 | 7512 | 1354.45 | 1372.45 | 1367.29 | 1373.84 | 0.004149 | 9.53 | 802.14 | 73.35 | 0.48 |
| LB_HEC-RAS | 94.49 | Q50 | 8914 | 1354.45 | 1373.62 | 1368.35 | 1375.23 | 0.004262 | 10.26 | 889.59 | 75.55 | 0.49 |
| LB_HEC-RAS | 94.49 | Q100 | 10216 | 1354.45 | 1374.61 | 1369.28 | 1376.41 | 0.004366 | 10.88 | 965.21 | 77.00 | 0.50 |
| LB_HEC-RAS | 89.42 | Q10 | 5709 | 1354.08 | 1370.52 | 1366.65 | 1371.83 | 0.004853 | 9.30 | 630.03 | 66.42 | 0.50 |
| LB_HEC-RAS | 89.42 | Q25 | 7512 | 1354.08 | 1372.13 | 1368.09 | 1373.79 | 0.005141 | 10.50 | 739.76 | 69.60 | 0.52 |
| LB_HEC-RAS | 89.42 | Q50 | 8914 | 1354.08 | 1373.26 | 1369.1 | 1375.17 | 0.00531 | 11.31 | 819.38 | 71.82 | 0.54 |
| LB_HEC-RAS | 89.42 | Q100 | 10216 | 1354.08 | 1374.22 | 1370 | 1376.36 | 0.005451 | 11.99 | 890.91 | 77.89 | 0.55 |
| LB_HEC-RAS | 84.48 | Q10 | 5709 | 1354 | 1370.53 | 1366.66 | 1371.8 | 0.004214 | 9.02 | 634.89 | 66.28 | 0.50 |
| LB_HEC-RAS | 84.48 | Q25 | 7512 | 1354 | 1372.15 | 1368.07 | 1373.75 | 0.004393 | 10.18 | 743.99 | 68.80 | 0.53 |
| LB_HEC-RAS | 84.48 | Q50 | 8914 | 1354 | 1373.27 | 1369.03 | 1375.13 | 0.004514 | 10.98 | 822.22 | 70.58 | 0.54 |
| LB_HEC-RAS | 84.48 | Q100 | 10216 | 1354 | 1374.24 | 1369.89 | 1376.33 | 0.004616 | 11.65 | 890.97 | 72.11 | 0.56 |
| LB_HEC-RAS | 74.47 | Q10 | 5709 | 1354.57 | 1367.66 | 1367.66 | 1371.46 | 0.026665 | 15.63 | 365.17 | 48.86 | 1.01 |
| LB_HEC-RAS | 74.47 | Q25 | 7512 | 1354.57 | 1369.68 | 1369.68 | 1373.45 | 0.023718 | 15.57 | 482.37 | 64.80 | 1.00 |
| LB_HEC-RAS | 74.47 | Q50 | 8914 | 1354.57 | 1370.55 | 1370.55 | 1374.81 | 0.023378 | 16.55 | 539.13 | 65.81 | 1.01 |
| LB_HEC-RAS | 74.47 | Q100 | 10216 | 1354.57 | 1371.42 | 1371.42 | 1375.99 | 0.022244 | 17.16 | 596.91 | 66.82 | 1.00 |
| LB_HEC-RAS | 70.46 | Q10 | 5709 | 1353.88 | 1363.04 | 1365.87 | 1370.9 | 0.055765 | 22.50 | 253.76 | 41.05 | 1.59 |
| LB_HEC-RAS | 70.46 | Q25 | 7512 | 1353.88 | 1364.71 | 1367.33 | 1372.88 | 0.048348 | 22.93 | 327.54 | 46.87 | 1.53 |
| LB_HEC-RAS | 70.46 | Q50 | 8914 | 1353.88 | 1365.71 | 1368.33 | 1374.24 | 0.052541 | 23.44 | 380.33 | 59.02 | 1.63 |
| LB_HEC-RAS | 70.46 | Q100 | 10216 | 1353.88 | 1366.47 | 1369.18 | 1375.43 | 0.049153 | 24.02 | 425.31 | 60.22 | 1.59 |
| LB_HEC-RAS | 64.45 | Q10 | 5709 | 1352.86 | 1361.72 | 1364.49 | 1370.4 | 0.090135 | 23.64 | 241.54 | 46.16 | 1.82 |
| LB_HEC-RAS | 64.45 | Q25 | 7512 | 1352.86 | 1363.09 | 1365.97 | 1372.4 | 0.078673 | 24.49 | 306.76 | 49.55 | 1.73 |
| LB_HEC-RAS | 64.45 | Q50 | 8914 | 1352.86 | 1364.05 | 1367 | 1373.75 | 0.073874 | 24.99 | 356.75 | 54.18 | 1.72 |
| LB_HEC-RAS | 64.45 | Q100 | 10216 | 1352.86 | 1364.85 | 1368.02 | 1374.97 | 0.068319 | 25.53 | 400.14 | 55.45 | 1.67 |
| LB_HEC-RAS | 54.44 | Q10 | 5709 | 1352.39 | 1360.86 | 1363.55 | 1369.56 | 0.078 | 23.67 | 241.20 | 43.55 | 1.77 |
| LB_HEC-RAS | 54.44 | Q25 | 7512 | 1352.39 | 1362.34 | 1365.23 | 1371.67 | 0.066539 | 24.51 | 306.54 | 45.02 | 1.65 |
| LB_HEC-RAS | 54.44 | Q50 | 8914 | 1352.39 | 1363.49 | 1366.37 | 1373.04 | 0.060299 | 24.80 | 359.47 | 46.96 | 1.58 |
| LB_HEC-RAS | 54.44 | Q100 | 10216 | 1352.39 | 1364.53 | 1367.39 | 1374.22 | 0.055787 | 24.99 | 408.81 | 48.76 | 1.52 |
| LB_HEC-RAS | 50.44 | Q10 | 5709 | 1351.9 | 1362.11 | 1363.96 | 1368.65 | 0.056009 | 20.53 | 278.09 | 45.03 | 1.46 |
| LB_HEC-RAS | 50.44 | Q25 | 7512 | 1351.9 | 1363.7 | 1365.6 | 1370.77 | 0.048727 | 21.33 | 352.16 | 47.74 | 1.38 |
| LB_HEC-RAS | 50.44 | Q50 | 8914 | 1351.9 | 1365.09 | 1366.8 | 1372.09 | 0.041231 | 21.23 | 420.01 | 50.14 | 1.29 |
| LB_HEC-RAS | 50.44 | Q100 | 10216 | 1351.9 | 1366.63 | 1367.65 | 1373.13 | 0.033017 | 20.45 | 499.94 | 53.08 | 1.17 |
| LB_HEC-RAS | 44.43 | Q10 | 5709 | 1351.42 | 1361.69 | 1363.57 | 1368.32 | 0.050032 | 20.66 | 276.31 | 45.22 | 1.47 |
| LB_HEC-RAS | 44.43 | Q25 | 7512 | 1351.42 | 1363.23 | 1365.18 | 1370.46 | 0.045338 | 21.58 | 348.16 | 47.75 | 1.41 |
| LB_HEC-RAS | 44.43 | Q50 | 8914 | 1351.42 | 1364.53 | 1366.31 | 1371.82 | 0.038902 | 21.66 | 411.63 | 49.87 | 1.33 |
| LB_HEC-RAS | 44.43 | Q100 | 10216 | 1351.42 | 1365.93 | 1367.28 | 1372.89 | 0.031868 | 21.18 | 482.44 | 51.50 | 1.22 |
| LB_HEC-RAS | 34.42 | Q10 | 5709 | 1351.85 | 1360.82 | 1362.84 | 1367.77 | 0.054129 | 21.16 | 269.86 | 50.92 | 1.62 |
| LB_HEC-RAS | 34.42 | Q25 | 7512 | 1351.85 | 1362.07 | 1364.33 | 1369.93 | 0.048378 | 22.49 | 334.06 | 51.75 | 1.56 |
| LB_HEC-RAS | 34.42 | Q50 | 8914 | 1351.85 | 1363.1 | 1365.39 | 1371.32 | 0.04326 | 23.01 | 387.40 | 52.42 | 1.49 |
| LB_HEC-RAS | 34.42 | Q100 | 10216 | 1351.85 | 1364.15 | 1366.33 | 1372.41 | 0.037879 | 23.07 | 442.74 | 53.11 | 1.41 |

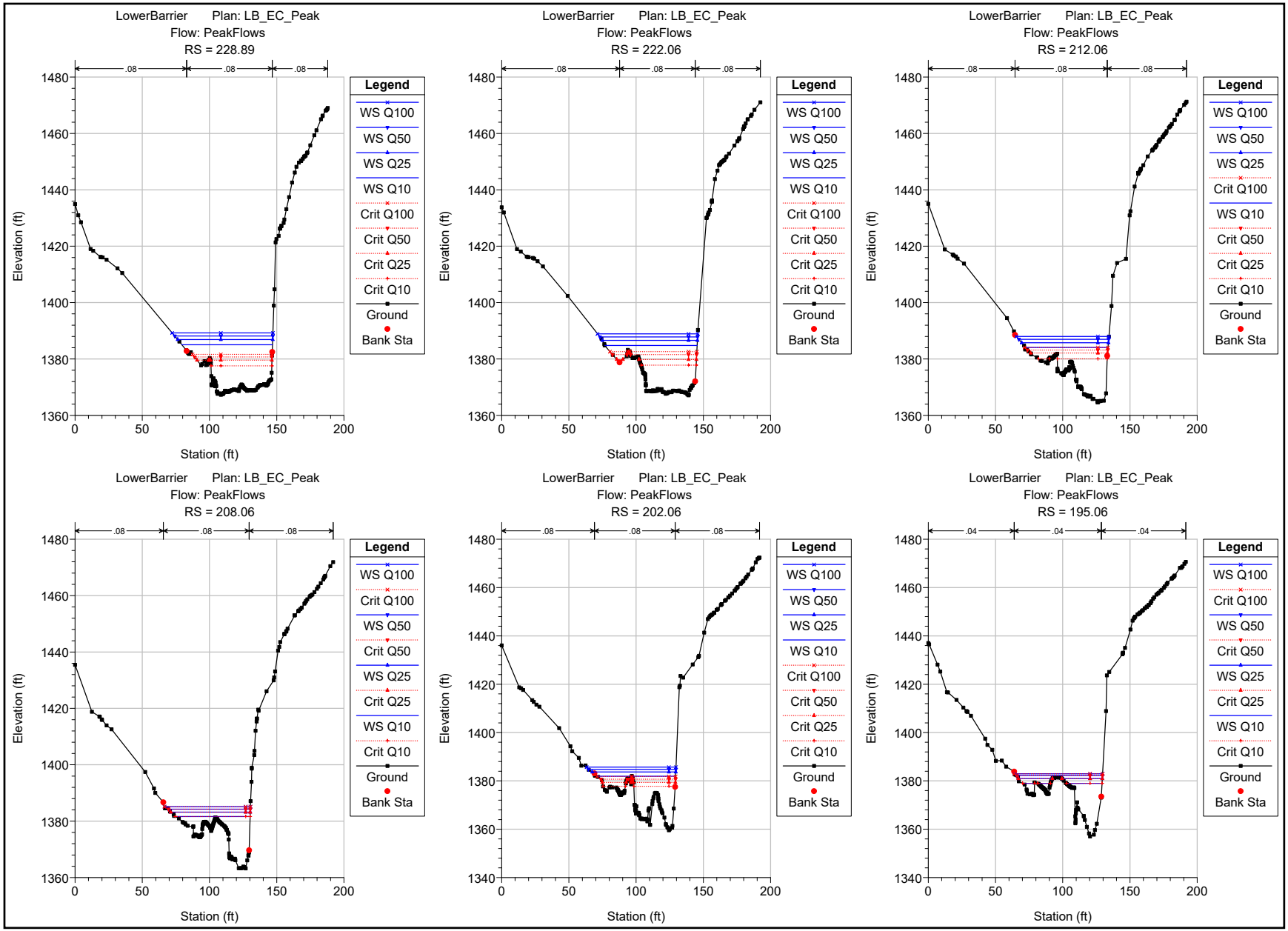
**Lower Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

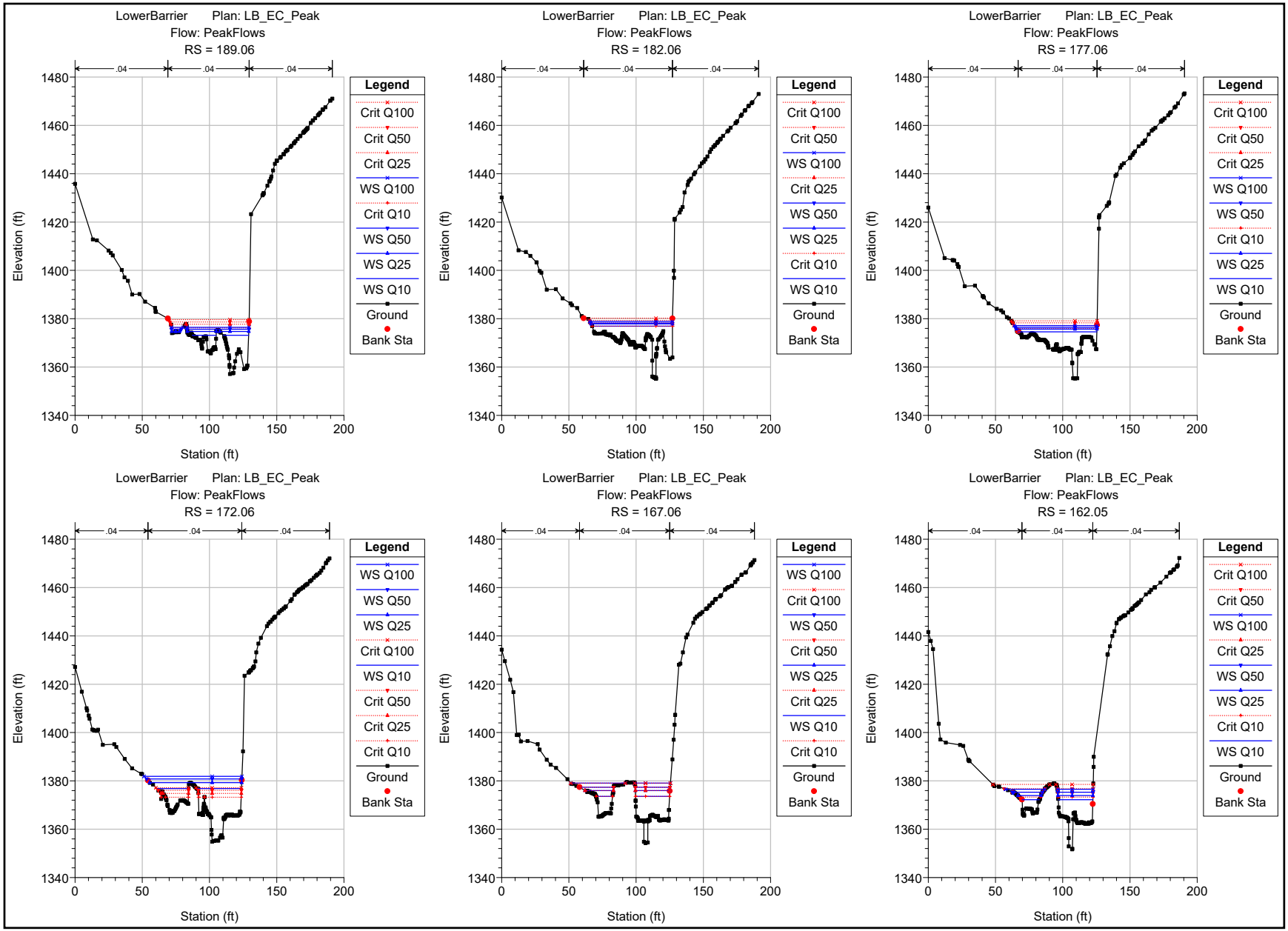
| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LB_HEC-RAS | 24.41 | Q10 | 5709 | 1351.12 | 1358.67 | 1361.15 | 1366.95 | 0.089173 | 23.10 | 247.16 | 54.81 | 1.92 |
| LB_HEC-RAS | 24.41 | Q25 | 7512 | 1351.12 | 1359.71 | 1362.55 | 1369.15 | 0.080029 | 24.66 | 304.59 | 55.85 | 1.86 |
| LB_HEC-RAS | 24.41 | Q50 | 8914 | 1351.12 | 1360.52 | 1363.55 | 1370.58 | 0.072966 | 25.46 | 350.12 | 56.66 | 1.80 |
| LB_HEC-RAS | 24.41 | Q100 | 10216 | 1351.12 | 1361.29 | 1364.43 | 1371.71 | 0.066231 | 25.90 | 394.47 | 57.43 | 1.74 |
| | | | | | | | | | | | | |
| LB_HEC-RAS | 14.4 | Q10 | 5709 | 1348.93 | 1357.44 | 1360.01 | 1365.96 | 0.103385 | 23.43 | 243.65 | 51.26 | 1.89 |
| LB_HEC-RAS | 14.4 | Q25 | 7512 | 1348.93 | 1358.51 | 1361.55 | 1368.24 | 0.096673 | 25.03 | 300.11 | 53.73 | 1.87 |
| LB_HEC-RAS | 14.4 | Q50 | 8914 | 1348.93 | 1359.32 | 1362.51 | 1369.73 | 0.090677 | 25.89 | 344.35 | 55.19 | 1.83 |
| LB_HEC-RAS | 14.4 | Q100 | 10216 | 1348.93 | 1360.08 | 1363.31 | 1370.92 | 0.084734 | 26.42 | 386.72 | 56.50 | 1.78 |
| | | | | | | | | | | | | |
| LB_HEC-RAS | 4.39 | Q10 | 5709 | 1347.77 | 1355.35 | 1358.15 | 1364.89 | 0.091331 | 24.78 | 230.38 | 51.84 | 2.07 |
| LB_HEC-RAS | 4.39 | Q25 | 7512 | 1347.77 | 1356.38 | 1359.6 | 1367.24 | 0.082017 | 26.45 | 284.03 | 52.53 | 2.00 |
| LB_HEC-RAS | 4.39 | Q50 | 8914 | 1347.77 | 1357.17 | 1360.62 | 1368.79 | 0.075272 | 27.35 | 325.98 | 53.07 | 1.94 |
| LB_HEC-RAS | 4.39 | Q100 | 10216 | 1347.77 | 1357.92 | 1361.57 | 1370.03 | 0.069227 | 27.92 | 365.90 | 53.58 | 1.88 |

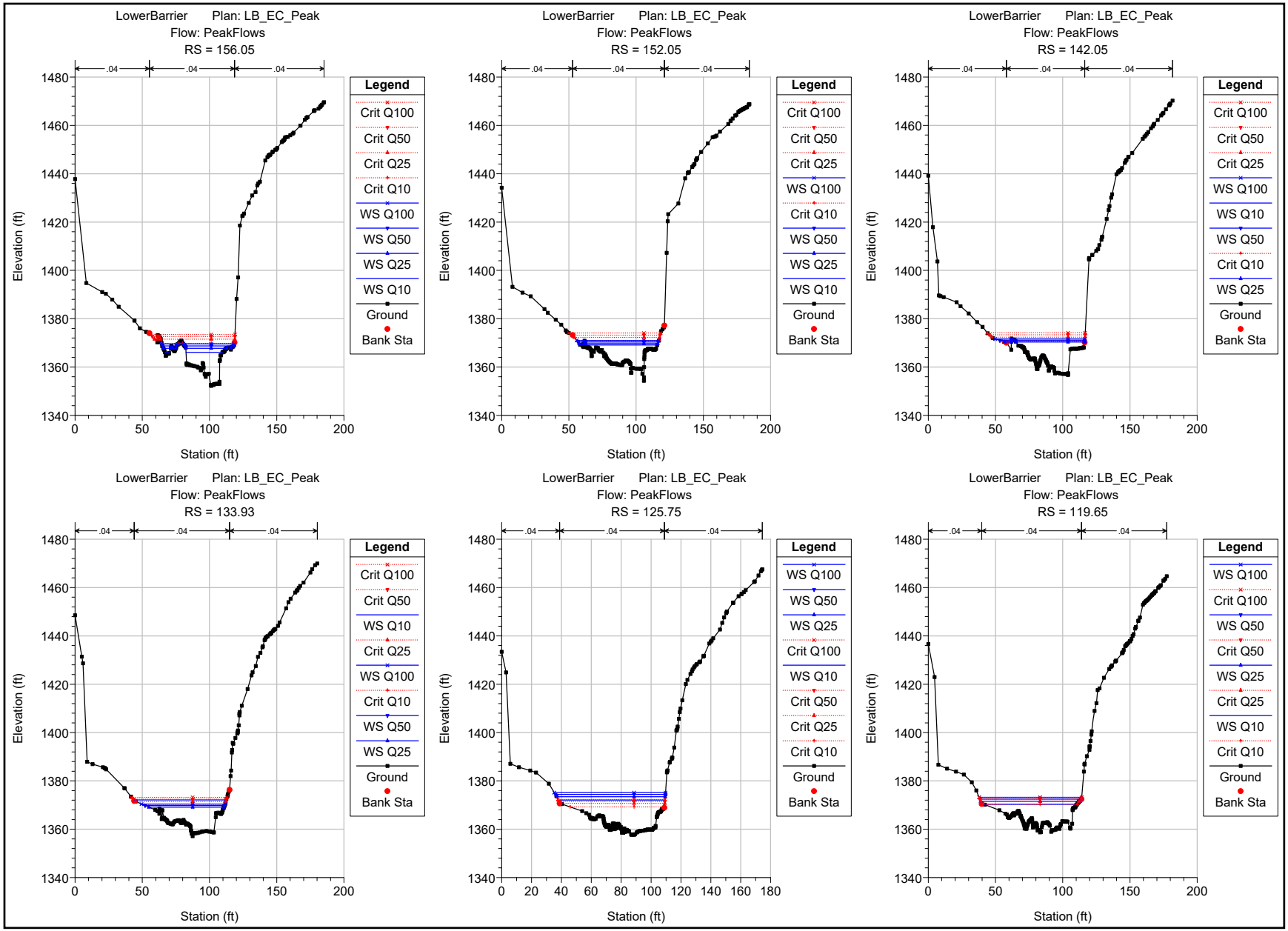

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 332.29
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 324.69
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 322.25
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 319.07
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 312.22
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 308.84
.08
.08
.08
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
WS Q25
WS Q10
Crit Q100
Crit Q50
Crit Q25
Crit Q10
Ground
Bank Sta

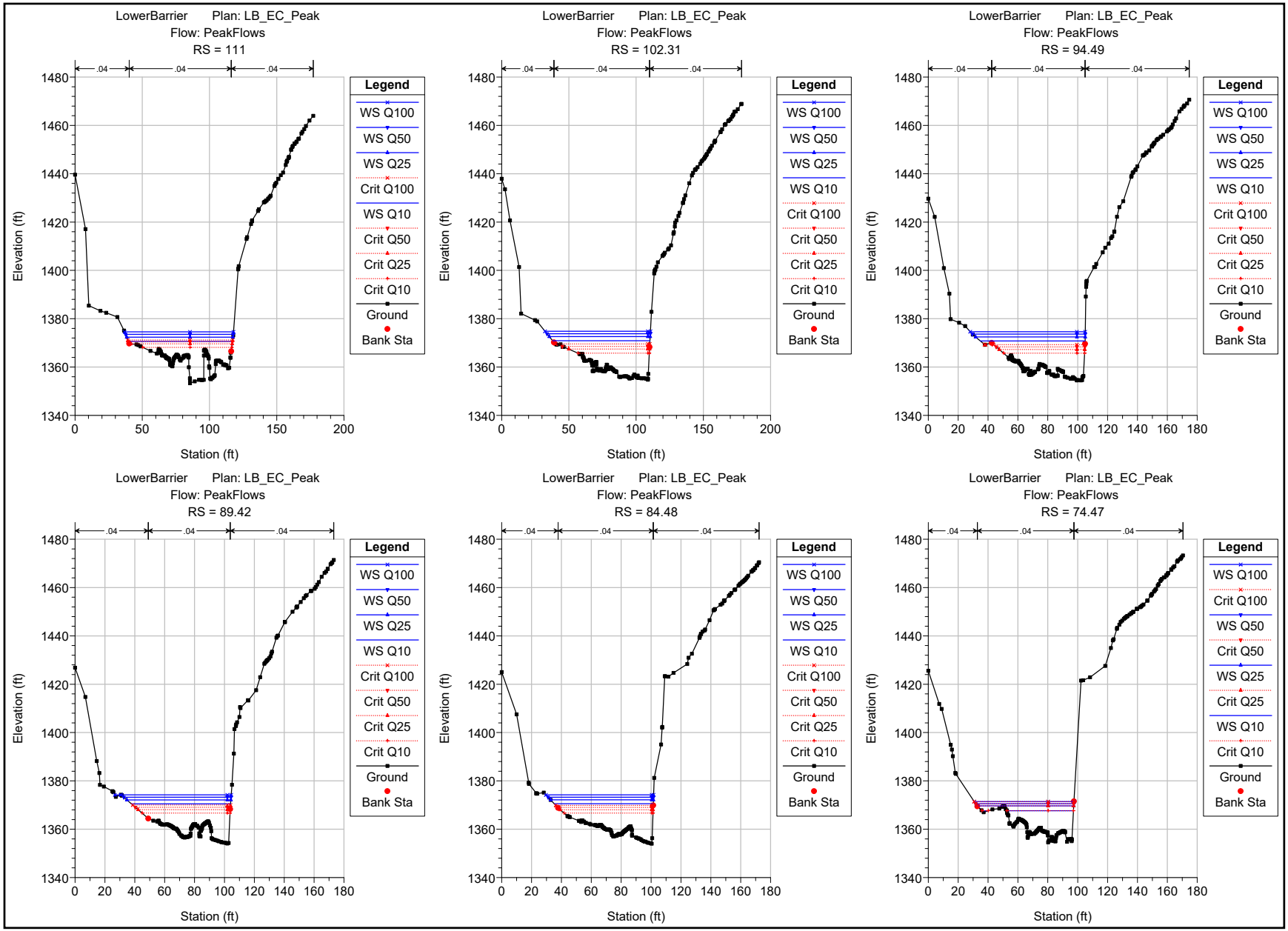

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 302.18
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 299.97
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 292.96
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 289.76
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 286
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 282.94
.08
.08
.08
Legend
WS Q100
WS Q50
WS Q25
WS Q10
Crit Q100
Crit Q50
Crit Q25
Crit Q10
Ground
Bank Sta
Elevation (ft)
Station (ft)
1360
1380
1400
1420
1440
1460
1480
0
50
100
150
200

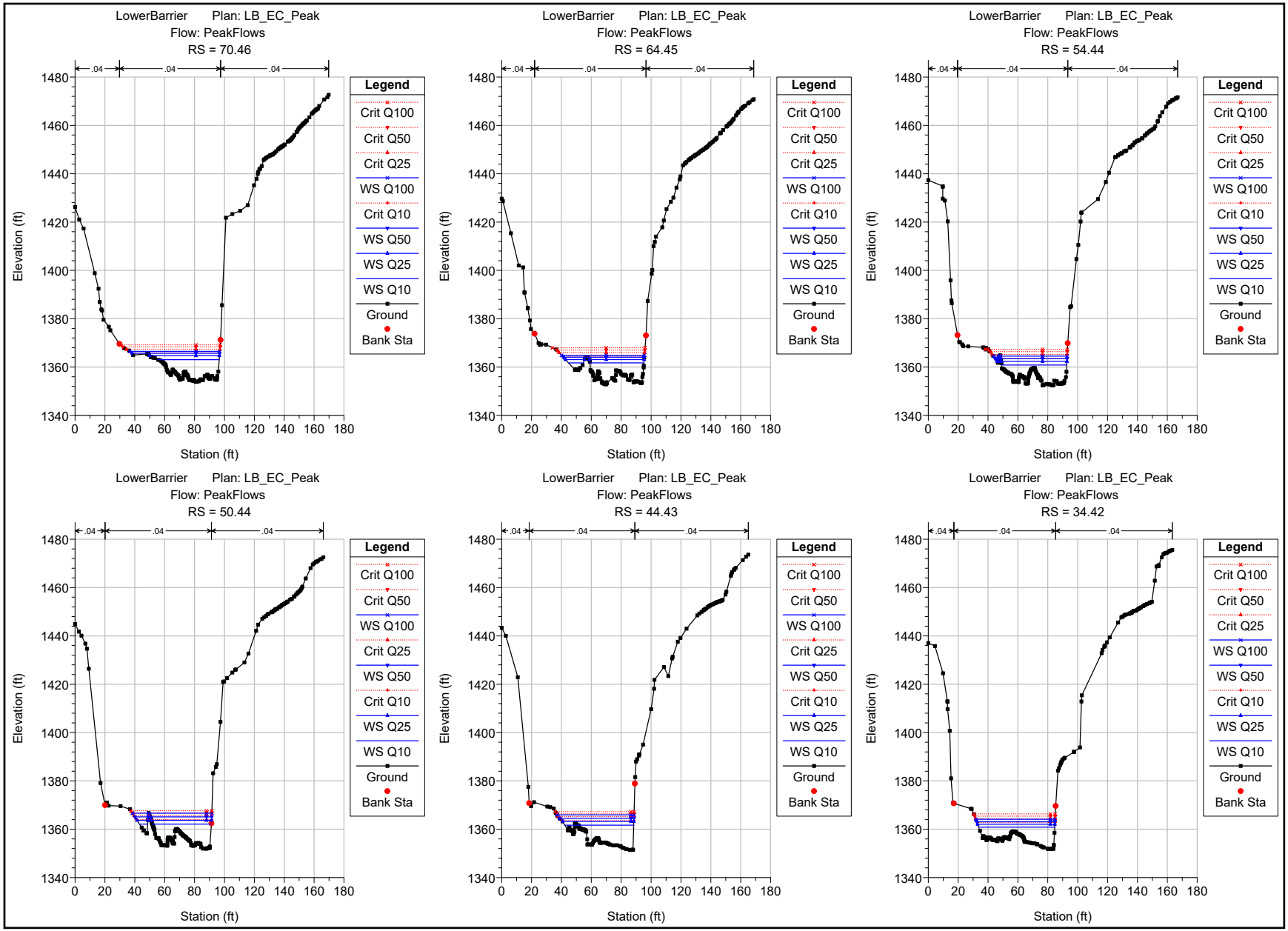

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 274.97
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 272.92
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 271.17
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 262.9
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 253.26
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 244.1
.08
.08
.08
Elevation (ft)
Station (ft)
1360
1380
1400
1420
1440
1460
1480
0
50
100
150
200
Legend
WS Q100
WS Q50
Crit Q100
WS Q25
Crit Q50
Crit Q25
WS Q10
Crit Q10
Ground
Bank Sta

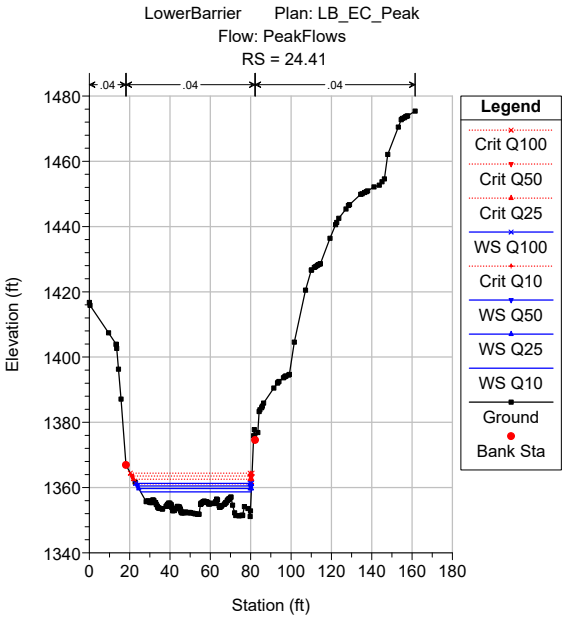

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 228.89
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 222.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 212.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 208.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 202.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 195.06
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
WS Q25
WS Q10
Crit Q100
Crit Q50
Crit Q25
Crit Q10
Ground
Bank Sta

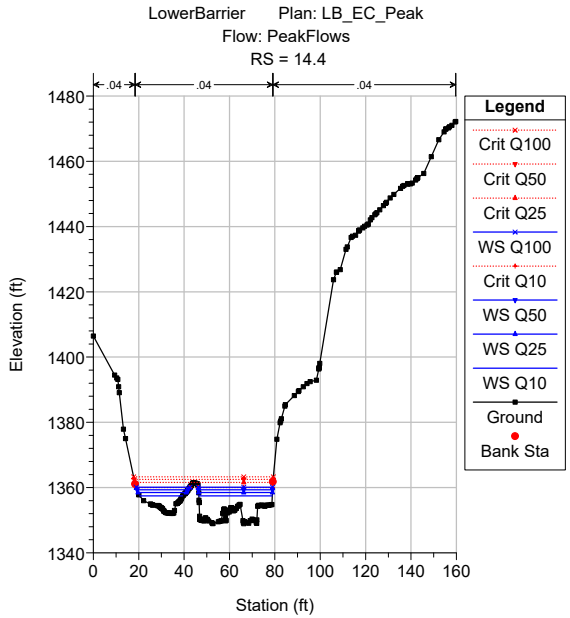

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 189.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 182.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 177.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 172.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 167.06
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 162.05
.04
.04
.04
Elevation (ft)
1340
1360
1380
1400
1420
1440
1460
1480
0
50
100
150
200
Station (ft)
Legend
Crit Q100
Crit Q50
Crit Q25
WS Q100
Crit Q10
WS Q50
WS Q25
WS Q10
Ground
Bank Sta

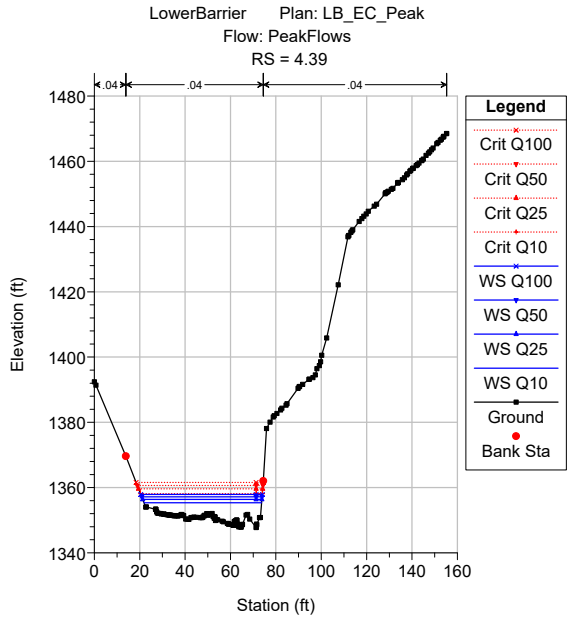

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 156.05
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 152.05
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 142.05
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 133.93
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 125.75
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 119.65
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
Crit Q100
Crit Q50
Crit Q25
Crit Q10
WS Q100
WS Q50
WS Q25
WS Q10
Ground
Bank Sta


LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 111
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 102.31
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 94.49
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 89.42
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 84.48
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 74.47
.04
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
WS Q25
WS Q10
Crit Q100
Crit Q50
Crit Q25
Crit Q10
Ground
Bank Sta

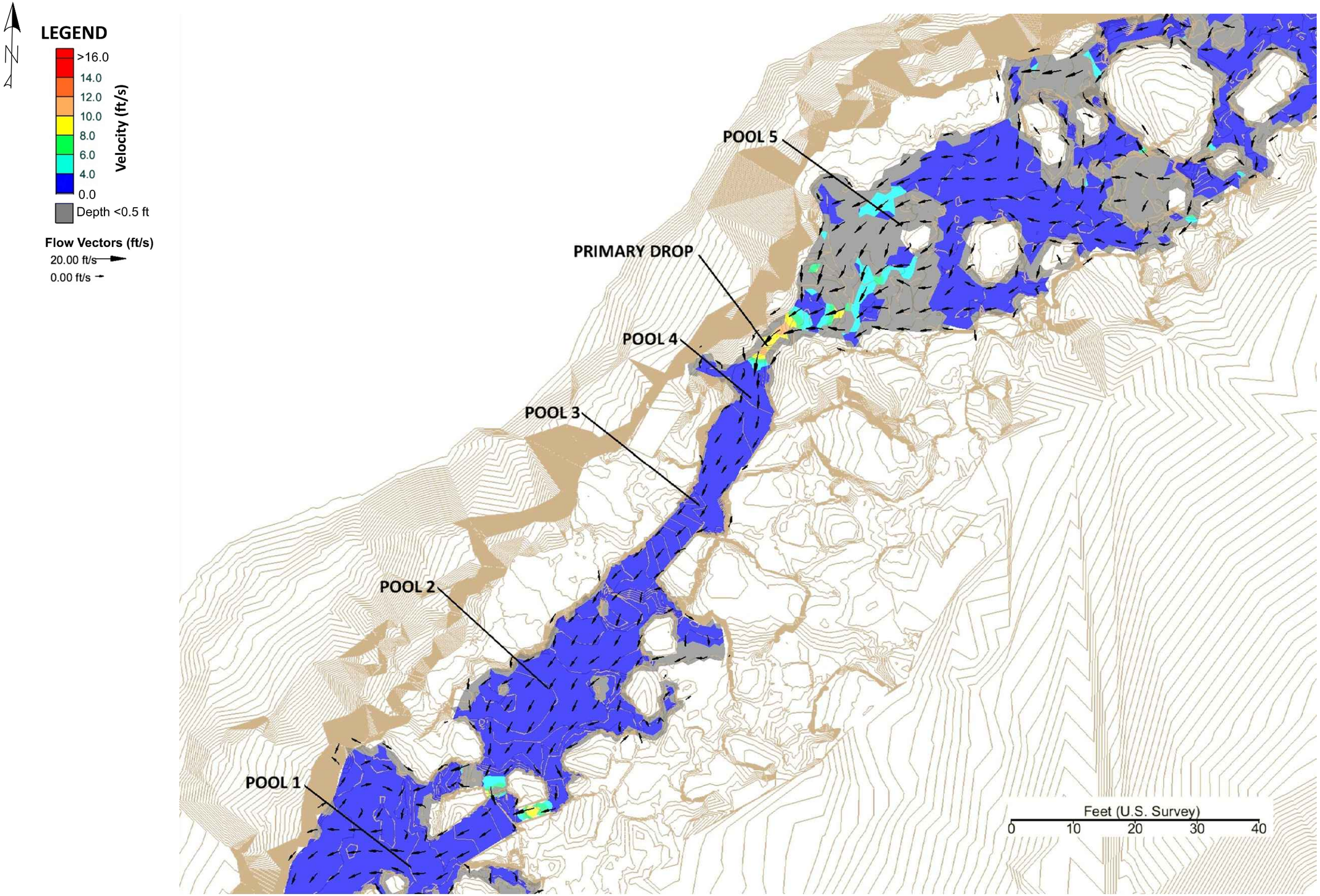

LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 70.46
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 64.45
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 54.44
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 50.44
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 44.43
LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 34.42
.04
.04
.04
Elevation (ft)
1340
1360
1380
1400
1420
1440
1460
1480
0
20
40
60
80
100
120
140
160
180
Station (ft)
Legend
Crit Q100
Crit Q50
Crit Q25
WS Q100
Crit Q10
WS Q50
WS Q25
WS Q10
Ground
Bank Sta


LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 24.41
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
Crit Q100
Crit Q50
Crit Q25
WS Q100
Crit Q10
WS Q50
WS Q25
WS Q10
Ground
Bank Sta


LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 14.4
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
Crit Q100
Crit Q50
Crit Q25
WS Q100
Crit Q10
WS Q50
WS Q25
WS Q10
Ground
Bank Sta


LowerBarrier Plan: LB_EC_Peak
Flow: PeakFlows
RS = 4.39
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
Crit Q100
Crit Q50
Crit Q25
Crit Q10
WS Q100
WS Q50
WS Q25
WS Q10
Ground
Bank Sta

Attachment J **Lower Barrier SRH-2D Result Figures**




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VERIFY SCALE
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FISH PASSAGE IMPROVEMENT PROJECT
N.F. BATTLE CREEK, EAGLE CANYON

**LOWER BARRIER**

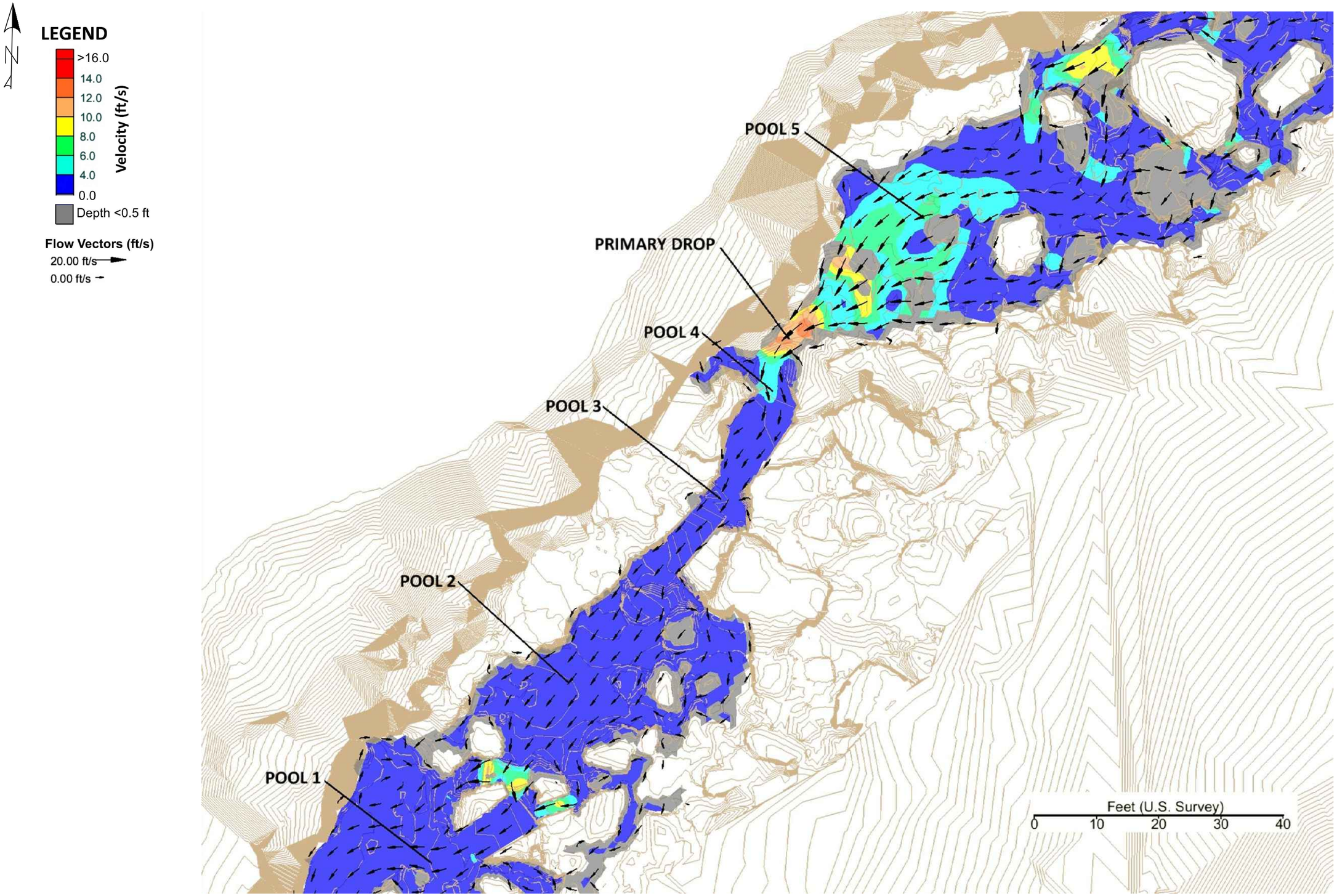
**SRH 2D MODEL RESULTS - 37 CFS**

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
**J-1**

8/4/2016 11:55:18 AM Q:\Eagle Canyon\05_CAD\Sheets\LB_FishPassageFigures.dwg




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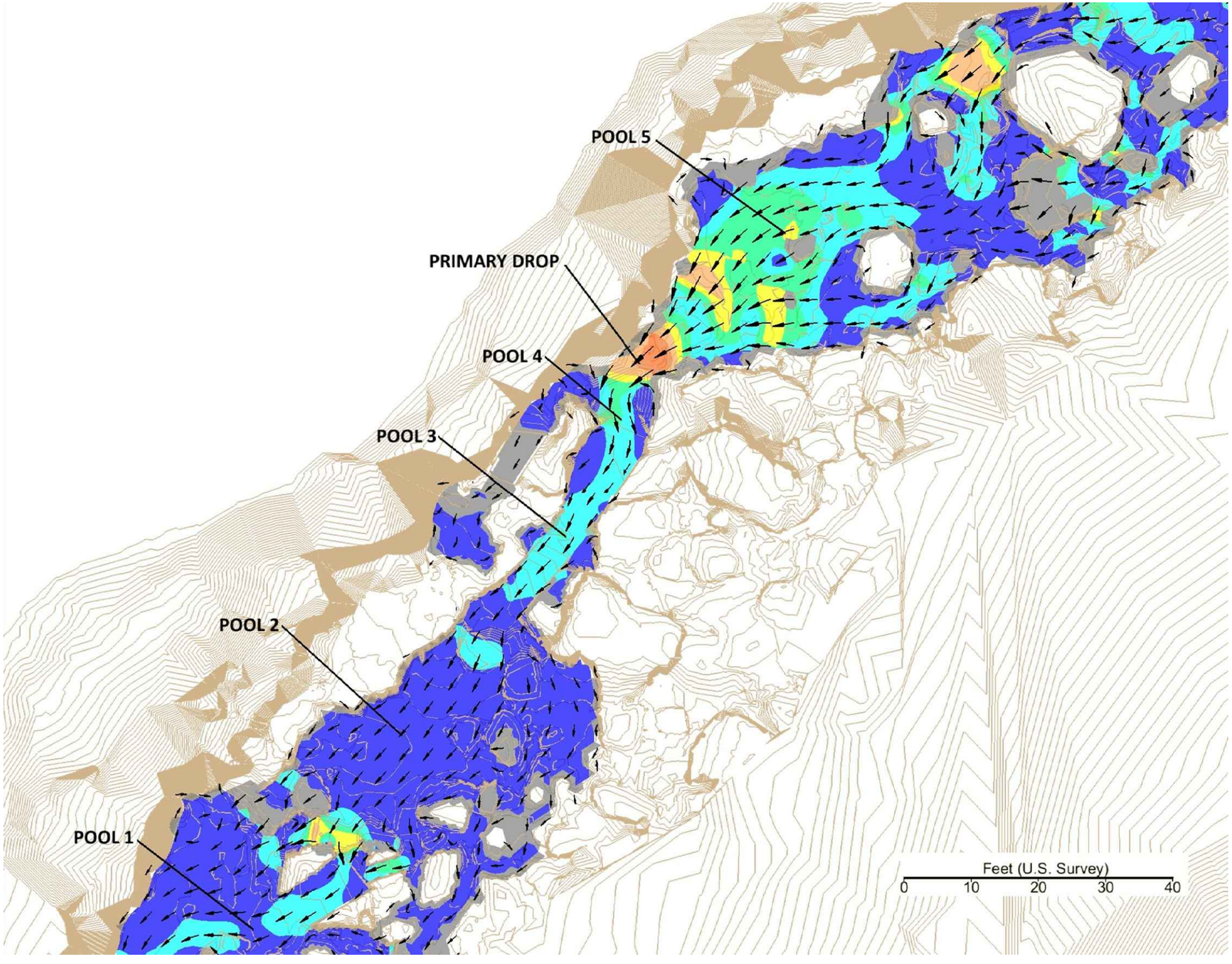
**LOWER BARRIER**

**SRH 2D MODEL RESULTS - 120 CFS**

DATE
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FIGURE
**J-2**




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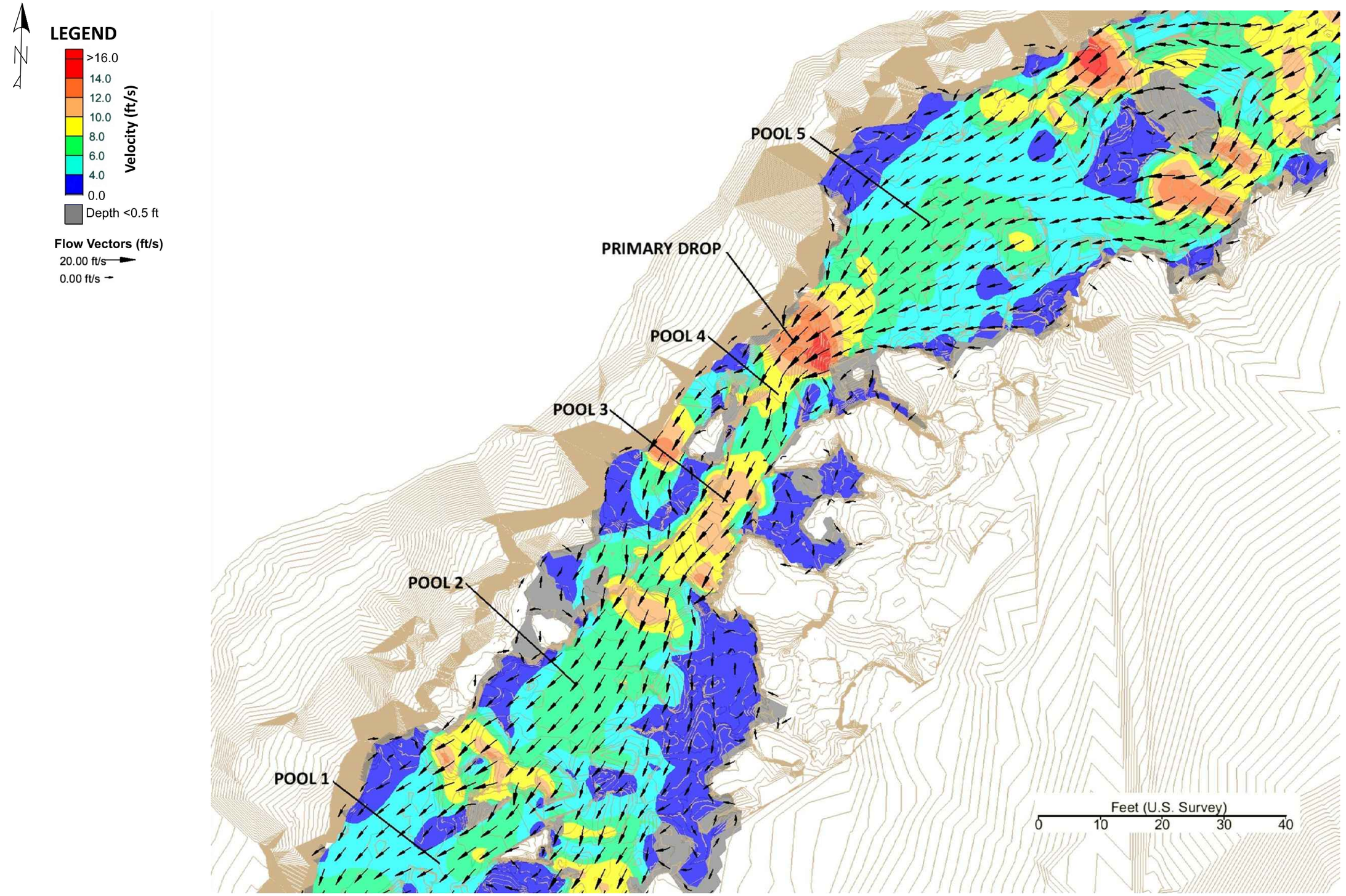
**LOWER BARRIER**

# SRH 2D MODEL RESULTS - 250 CFS

DATE
JULY 2016

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FIGURE
**J-3**




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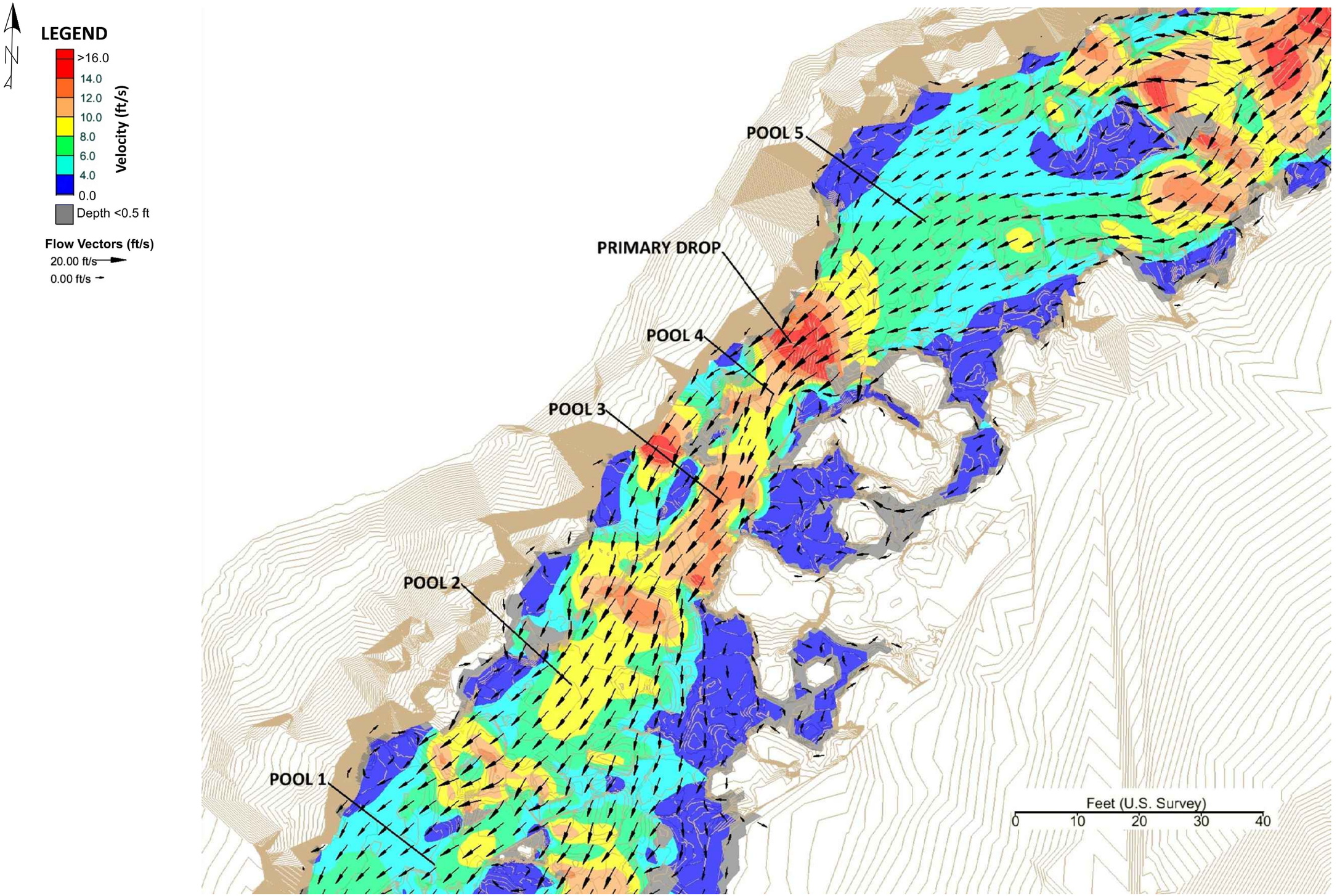
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FISH PASSAGE IMPROVEMENT PROJECT
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**LOWER BARRIER**
**SRH 2D MODEL RESULTS - 1,100 CFS**

DATE
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FIGURE
**J-4**




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**LOWER BARRIER**

**SRH 2D MODEL RESULTS - 1,600 CFS**

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
**J-5**

N

**LEGEND**

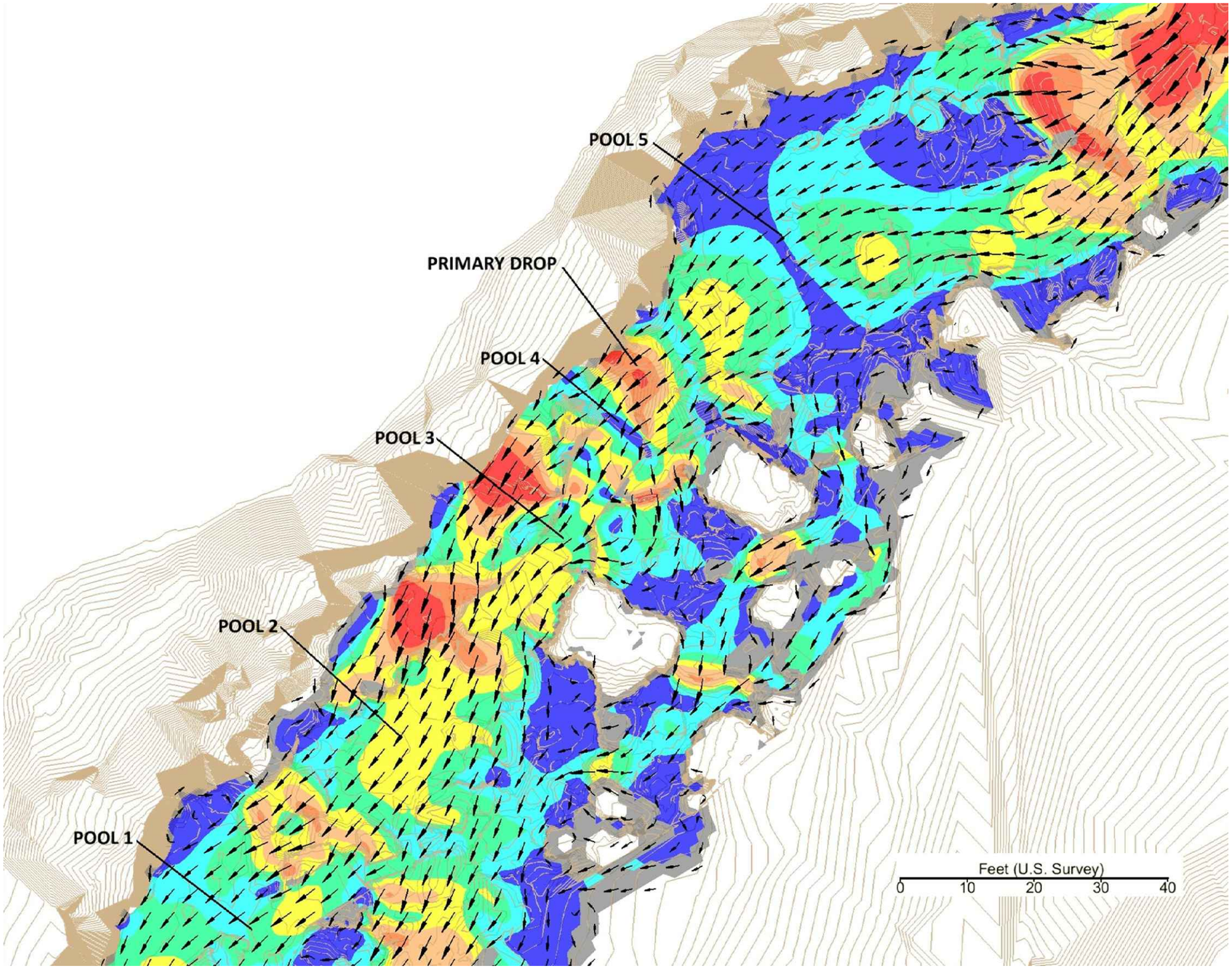
Velocity (ft/s)
- >16.0
- 14.0
- 12.0
- 10.0
- 8.0
- 6.0
- 4.0
- 0.0

Depth <0.5 ft

**Flow Vectors (ft/s)**

20.00 ft/s

0.00 ft/s





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**LOWER BARRIER**

**SRH 2D MODEL RESULTS - 2,010 CFS**

DATE
JULY 2016

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TASK 4

FIGURE
**J-6**

Attachment K **Upper Barrier Site Water Surface Mapping Results**

WATER SURFACE MAPPING EVENT 1
9/22/2015
NFBC
17 CFS
DIGGER CREEK
5 CFS

NFBC

DC

POOL 9

POOL 8

POOL 7

POOL 6

POOL 5

POOL 4

POOL 3

POOL 2

POOL 1

CONTROL POINT, TYP

TIME LAPSE CAMERA (UB1)

APPROXIMATE SIEVE FLOW PATH (TYPICAL)

ELEVATION AT WATER SURFACE (TYPICAL)

(E) PRIMARY DROP

EXTENTS OF INUNDATION

ALIGNMENTS CONVERGE, STA 1+95.58

PRIMARY ALIGNMENT

SECONDARY ALIGNMENT

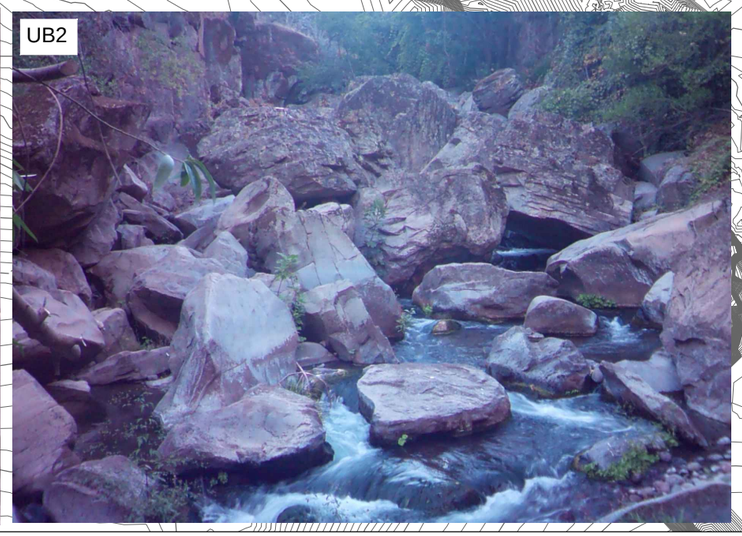
TIME LAPSE CAMERA (UB2)

1491.00
1491.01
1490.19
1490.40
1490.46
1490.19
1489.58
1489.79
1488.96
1479.96
1479.98
1479.48
1479.18
1479.01
1478.08
1478.12
1476.39
1476.32
1476.44
1475.74
1489.75
1475.83
1475.66
1474.80
1475.00
1473.60
1472.07
1472.07
1471.99
1471.35

UB1



UB2



PLAN

0 10' 20'
GRAPHIC SCALE

8/4/2016 11:48:51 AM Q:\Eagle Canyon\05_CAD\Data\UB_WSE1_Profile-20150925.dwg

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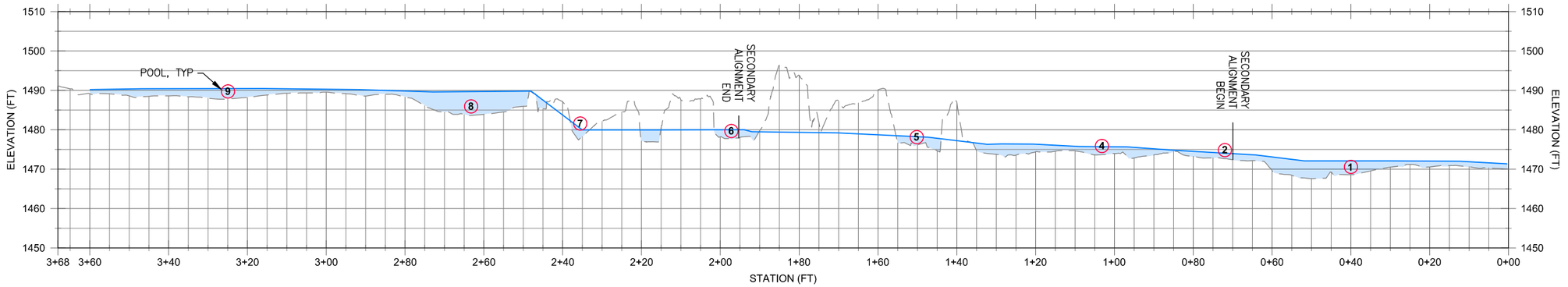
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N.F. BATTLE CREEK, EAGLE CANYON

# UPPER BARRIER
# WATER SURFACE MAPPING EVENT 1 PLAN

DATE
JULY 2016

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TASK 4

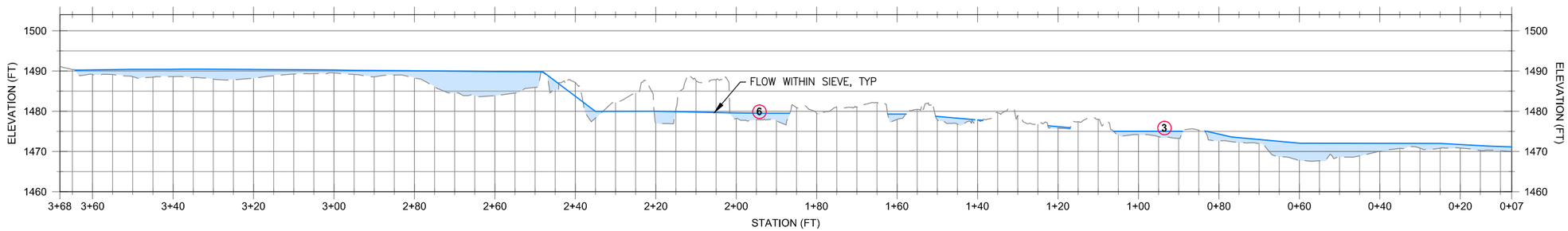
FIGURE
K-1




PRIMARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE


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# UPPER BARRIER
# WATER SURFACE MAPPING EVENT 1 PROFILES

DATE
JULY 2016

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FIGURE
**K-2**

WATER SURFACE MAPPING EVENT 2
2/10/2016
NFBC
87 CFS
DIGGER CREEK
25 CFS

NFBC

DC

POOL 9

POOL 8

POOL 7

POOL 6

POOL 5

POOL 4

POOL 3

POOL 2

POOL 1

ELEVATION AT WATER SURFACE (TYPICAL)

EXTENTS OF INUNDATION

(E) PRIMARY DROP

ALIGNMENTS CONVERGE, STA 1+95.58

TIME LAPSE CAMERA (UB1)

APPROXIMATE SIEVE FLOW PATH (TYPICAL)

PRIMARY ALIGNMENT

SECONDARY ALIGNMENT

TIME LAPSE CAMERA (UB2)

UB1



UB2



PLAN

0 10' 20'
GRAPHIC SCALE

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VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

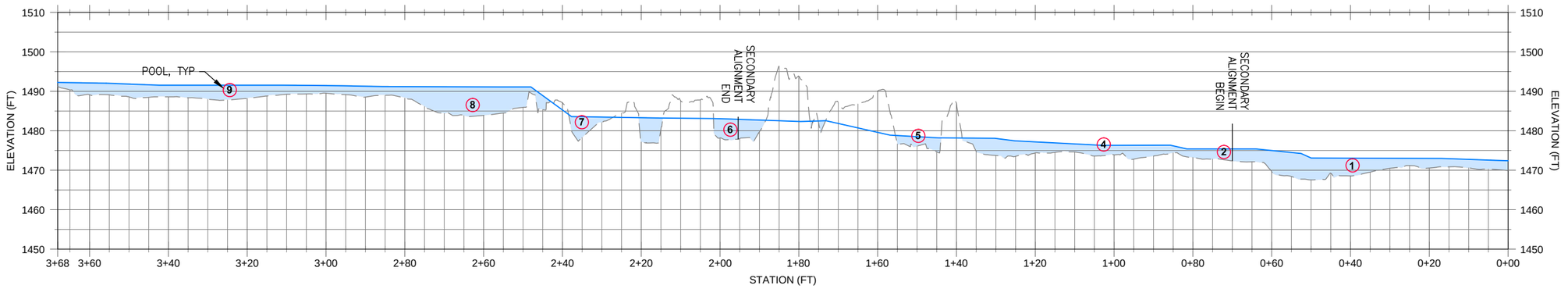
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# UPPER BARRIER
# WATER SURFACE MAPPING EVENT 2 PLAN

DATE
JULY 2016

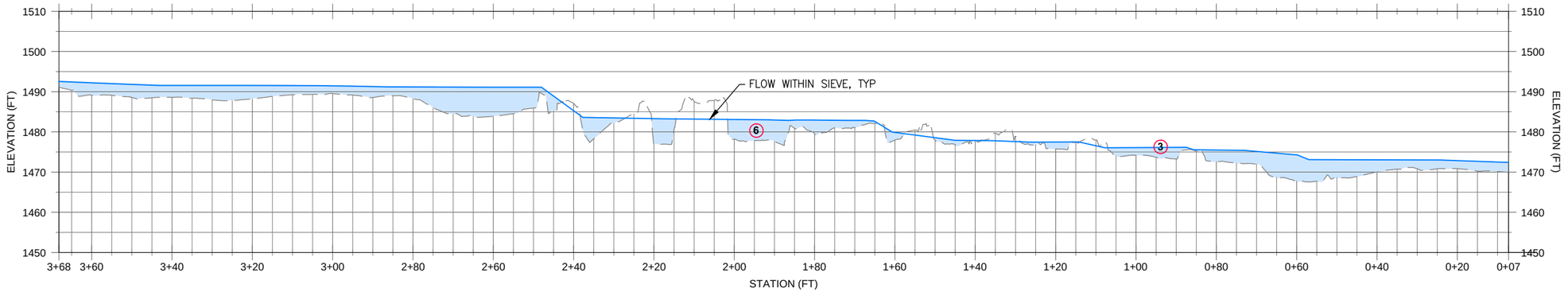
SUBMITTAL
TASK 4

FIGURE
K-3




PRIMARY ALIGNMENT PROFILE

0 15' 30'
GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'
GRAPHIC SCALE

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# UPPER BARRIER
# WATER SURFACE MAPPING EVENT 2 PROFILES

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
**K-4**

WATER SURFACE MAPPING EVENT 3
1/29/2016
NFBC
1,580 CFS
DIGGER CREEK
427 CFS

NFBC
DC
POOL 9
POOL 8
POOL 7
POOL 6
POOL 5
POOL 4
POOL 3
POOL 2
POOL 1
EXTENTS OF INUNDATION
(E) PRIMARY DROP
TIME LAPSE CAMERA (UB1)
LIGNMENTS CONVERGE, STA 1+95.58
PRIMARY ALIGNMENT
SECONDARY ALIGNMENT
TIME LAPSE CAMERA (UB2)
ELEVATION AT WATER SURFACE (TYPICAL)

1497.55
1497.19
1497.75
1497.50
1496.20
1496.90
1498.44
1495.04
1493.27
1492.32
1491.07
1491.08
1488.06
1488.07
1486.85
1493.41
1495.11
1490.00
1488.90
1484.82
1484.23
1483.31
1487.95
1481.57
1481.25
1481.14
1479.60

UB1




PLAN
0 10' 20'
GRAPHIC SCALE

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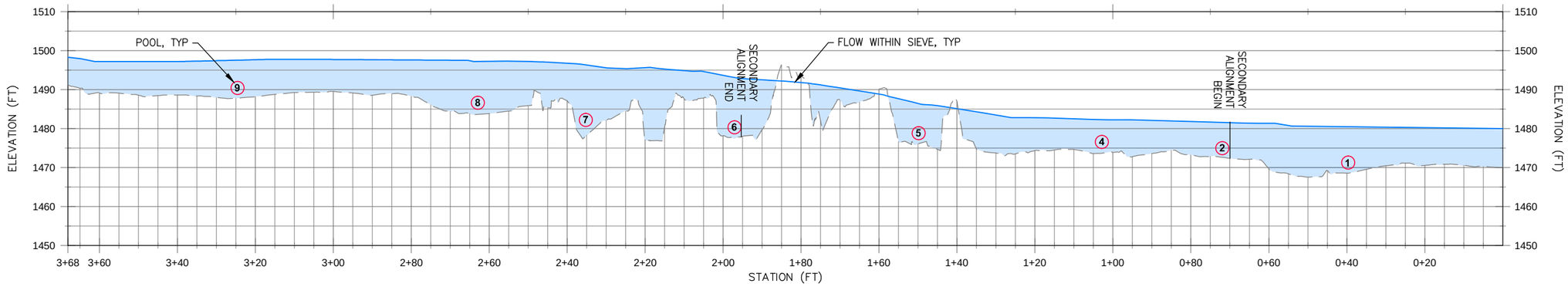
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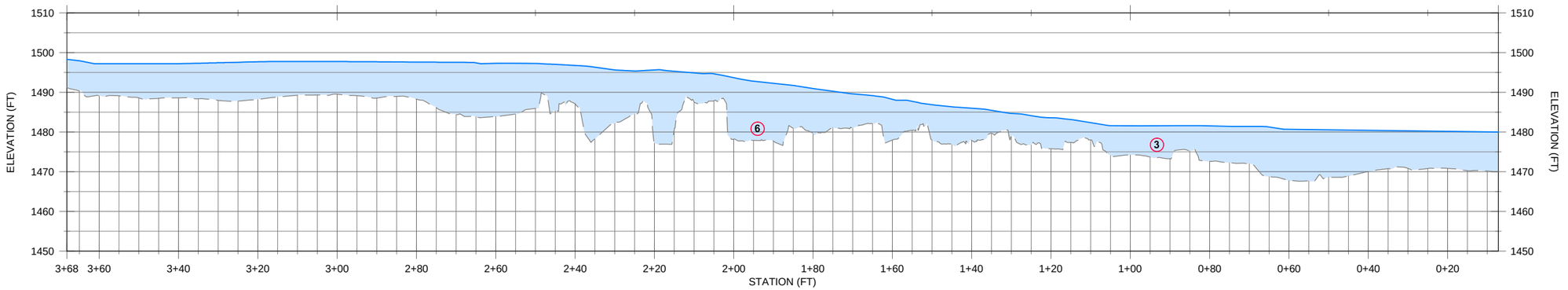
# UPPER BARRIER
# WATER SURFACE MAPPING EVENT 3 PLAN

DATE
JULY 2016
SUBMITTAL
TASK 4
FIGURE
K-5




SECONDARY ALIGNMENT PROFILE

0 15' 30'
GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'
GRAPHIC SCALE

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**UPPER BARRIER**
**WATER SURFACE MAPPING EVENT 3 PROFILES**

DATE
JULY 2016

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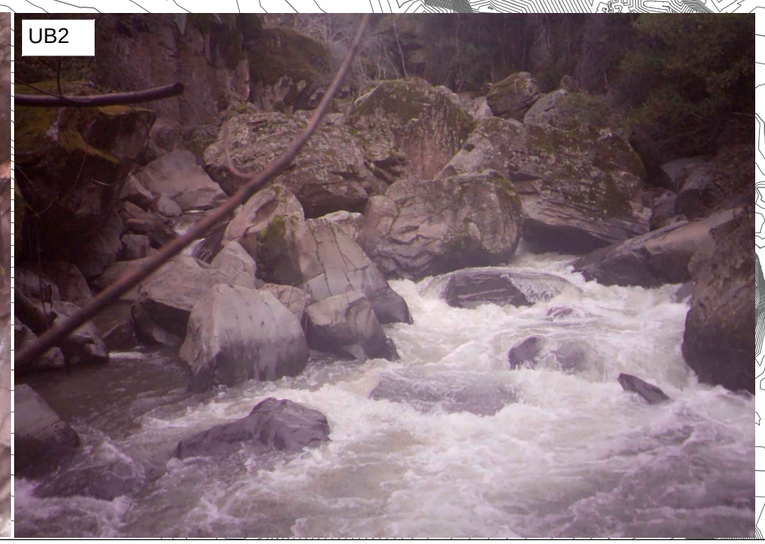
FIGURE
**K-6**

# WATER SURFACE MAPPING EVENT 4

6/7/2016
NFBC
195 CFS
DIGGER CREEK
32 CFS

NFBC
DC
CONTROL POINT, TYP
POOL 9
POOL 8
POOL 7
POOL 6
POOL 5
POOL 4
POOL 3
POOL 2
POOL 1
1492.34
1491.84
491.91
1492.24
1492.08
1491.32
1484.36
1483.88
1483.65
1483.38
1479.58
1478.69
1476.93
1476.99
1477.63
1476.59
1476.77
1476.31
1476.67
1473.42
EXTENTS OF INUNDATION
(E) PRIMARY DROP
ALIGNMENTS CONVERGE, STA 1+95.58
ELEVATION AT WATER SURFACE (TYPICAL)
SECONDARY ALIGNMENT
PRIMARY ALIGNMENT
TIME LAPSE CAMERA (UB1)
APPROXIMATE SIEVE FLOW PATH (TYPICAL)
TIME LAPSE CAMERA (UB2)
PLAN
0' 10' 20'
GRAPHIC SCALE

UB1



UB2

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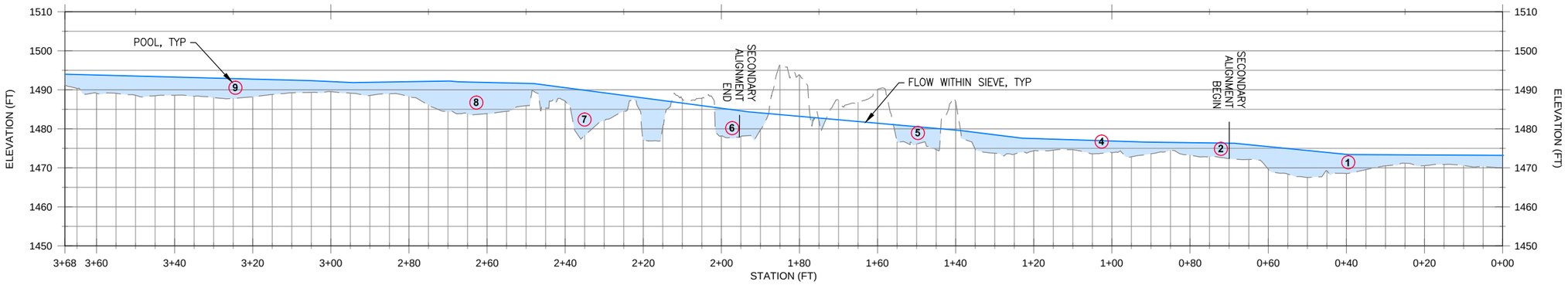
**UPPER BARRIER**
**WATER SURFACE MAPPING EVENT 4 PLAN**

DATE
JULY 2016

SUBMITTAL
TASK 4

FIGURE
**K-7**

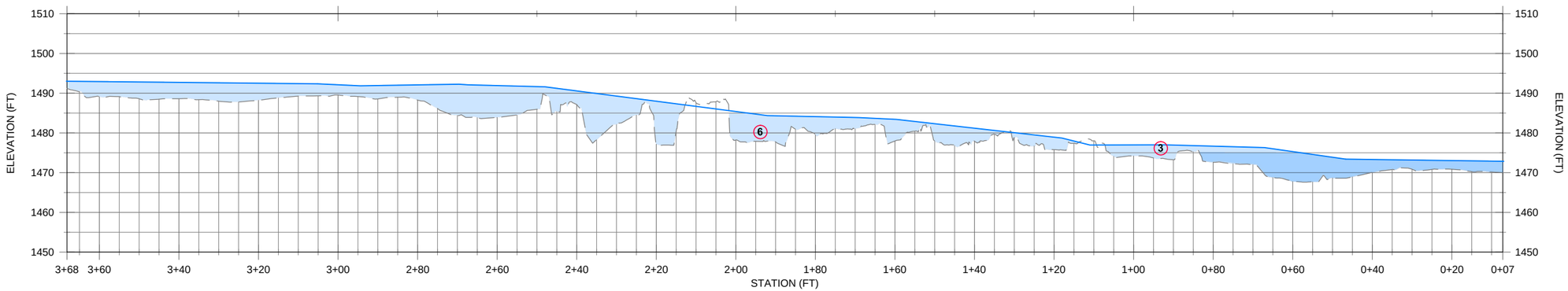
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PRIMARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE




SECONDARY ALIGNMENT PROFILE

0 15' 30'

GRAPHIC SCALE


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# UPPER BARRIER
# WATER SURFACE MAPPING EVENT 4 PROFILES

DATE
JULY 2016

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FIGURE
**K-8**

Attachment L **Upper Barrier HEC-RAS Result Figures and Data Tables**

**Upper Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UB_HEC-RAS | 326.63 | 10-yr | 5331 | 1489.15 | 1505.94 | 1498.52 | 1507.02 | 0.002199 | 8.32 | 644.28 | 43.19 | 0.37 |
| UB_HEC-RAS | 326.63 | 25-yr | 6996 | 1489.15 | 1508.09 | 1500.11 | 1509.51 | 0.002443 | 9.57 | 738.04 | 44.07 | 0.4 |
| UB_HEC-RAS | 326.63 | 50-yr | 8329 | 1489.15 | 1509.86 | 1501.31 | 1511.51 | 0.002505 | 10.33 | 817.61 | 45.69 | 0.41 |
| UB_HEC-RAS | 326.63 | 100-yr | 9551 | 1489.15 | 1511.44 | 1502.31 | 1513.28 | 0.002528 | 10.93 | 889.77 | 46.08 | 0.42 |
| UB_HEC-RAS | 314.91 | 10-yr | 5331 | 1486.85 | 1504.68 | 1501.97 | 1506.68 | 0.0148 | 11.37 | 469.22 | 46.81 | 0.63 |
| UB_HEC-RAS | 314.91 | 25-yr | 6996 | 1486.85 | 1506.83 | 1503.48 | 1509.18 | 0.01335 | 12.29 | 570.58 | 47.13 | 0.62 |
| UB_HEC-RAS | 314.91 | 50-yr | 8329 | 1486.85 | 1508.71 | 1504.56 | 1511.2 | 0.01176 | 12.68 | 659.23 | 47.4 | 0.59 |
| UB_HEC-RAS | 314.91 | 100-yr | 9551 | 1486.85 | 1510.38 | 1505.45 | 1513 | 0.010651 | 13 | 738.88 | 48.05 | 0.58 |
| UB_HEC-RAS | 307.13 | 10-yr | 5331 | 1487.43 | 1504.62 | 1500.57 | 1506.56 | 0.009095 | 11.2 | 477.09 | 38.58 | 0.56 |
| UB_HEC-RAS | 307.13 | 25-yr | 6996 | 1487.43 | 1506.5 | 1502.23 | 1509.03 | 0.009803 | 12.77 | 549.94 | 38.76 | 0.59 |
| UB_HEC-RAS | 307.13 | 50-yr | 8329 | 1487.43 | 1508.1 | 1503.54 | 1511 | 0.009781 | 13.68 | 611.85 | 38.92 | 0.6 |
| UB_HEC-RAS | 307.13 | 100-yr | 9551 | 1487.43 | 1509.53 | 1504.59 | 1512.74 | 0.009656 | 14.39 | 667.66 | 39.05 | 0.61 |
| UB_HEC-RAS | 300.08 | 10-yr | 5331 | 1487.53 | 1504.61 | 1499.08 | 1506.48 | 0.004758 | 10.96 | 488.43 | 33.49 | 0.5 |
| UB_HEC-RAS | 300.08 | 25-yr | 6996 | 1487.53 | 1506.43 | 1500.97 | 1508.98 | 0.005575 | 12.81 | 549.56 | 33.75 | 0.55 |
| UB_HEC-RAS | 300.08 | 50-yr | 8329 | 1487.53 | 1507.82 | 1502.33 | 1510.89 | 0.006054 | 14.08 | 596.45 | 33.94 | 0.58 |
| UB_HEC-RAS | 300.08 | 100-yr | 9551 | 1487.53 | 1509.04 | 1503.56 | 1512.58 | 0.006401 | 15.12 | 637.94 | 34.11 | 0.61 |
| UB_HEC-RAS | 291.48 | 10-yr | 5331 | 1487.61 | 1504.77 | 1498.61 | 1506.25 | 0.00349 | 9.77 | 546.36 | 37.44 | 0.45 |
| UB_HEC-RAS | 291.48 | 25-yr | 6996 | 1487.61 | 1506.66 | 1500.35 | 1508.67 | 0.004015 | 11.36 | 617.5 | 37.7 | 0.49 |
| UB_HEC-RAS | 291.48 | 50-yr | 8329 | 1487.61 | 1508.11 | 1501.64 | 1510.51 | 0.004308 | 12.44 | 672.2 | 37.89 | 0.52 |
| UB_HEC-RAS | 291.48 | 100-yr | 9551 | 1487.61 | 1509.39 | 1502.73 | 1512.14 | 0.00451 | 13.32 | 720.67 | 38.06 | 0.53 |
| UB_HEC-RAS | 283.72 | 10-yr | 5331 | 1488.33 | 1504.89 | 1498.42 | 1506.08 | 0.002986 | 8.75 | 609.55 | 43.35 | 0.41 |
| UB_HEC-RAS | 283.72 | 25-yr | 6996 | 1488.33 | 1506.85 | 1500 | 1508.42 | 0.003387 | 10.07 | 694.73 | 43.7 | 0.44 |
| UB_HEC-RAS | 283.72 | 50-yr | 8329 | 1488.33 | 1508.35 | 1501.18 | 1510.21 | 0.003561 | 10.96 | 760.43 | 43.95 | 0.46 |
| UB_HEC-RAS | 283.72 | 100-yr | 9551 | 1488.33 | 1509.67 | 1502.2 | 1511.79 | 0.003671 | 11.69 | 818.72 | 44.06 | 0.47 |
| UB_HEC-RAS | 272.89 | 10-yr | 5331 | 1488.94 | 1504.98 | 1498.16 | 1505.93 | 0.002054 | 7.83 | 682.4 | 49.27 | 0.37 |
| UB_HEC-RAS | 272.89 | 25-yr | 6996 | 1488.94 | 1506.98 | 1499.6 | 1508.23 | 0.002268 | 8.99 | 780.99 | 49.53 | 0.4 |
| UB_HEC-RAS | 272.89 | 50-yr | 8329 | 1488.94 | 1508.51 | 1500.67 | 1509.99 | 0.00237 | 9.77 | 856.95 | 49.73 | 0.41 |
| UB_HEC-RAS | 272.89 | 100-yr | 9551 | 1488.94 | 1509.86 | 1501.59 | 1511.54 | 0.002432 | 10.4 | 924.3 | 49.91 | 0.42 |
| UB_HEC-RAS | 261.34 | 10-yr | 5331 | 1488.43 | 1504.41 | 1499.24 | 1505.78 | 0.00387 | 9.39 | 568.57 | 44.84 | 0.46 |
| UB_HEC-RAS | 261.34 | 25-yr | 6996 | 1488.43 | 1506.23 | 1500.74 | 1508.03 | 0.004292 | 10.78 | 650.45 | 45.08 | 0.5 |
| UB_HEC-RAS | 261.34 | 50-yr | 8329 | 1488.43 | 1507.63 | 1501.9 | 1509.76 | 0.004475 | 11.7 | 713.85 | 45.27 | 0.52 |
| UB_HEC-RAS | 261.34 | 100-yr | 9551 | 1488.43 | 1508.88 | 1502.89 | 1511.28 | 0.004582 | 12.45 | 770.24 | 45.44 | 0.53 |
| UB_HEC-RAS | 247.04 | 10-yr | 5331 | 1486.61 | 1504.37 | 1498.98 | 1505.71 | 0.003585 | 9.28 | 575.73 | 44.65 | 0.45 |
| UB_HEC-RAS | 247.04 | 25-yr | 6996 | 1486.61 | 1506.19 | 1500.52 | 1507.96 | 0.003996 | 10.68 | 657 | 44.91 | 0.49 |
| UB_HEC-RAS | 247.04 | 50-yr | 8329 | 1486.61 | 1507.59 | 1501.66 | 1509.68 | 0.004194 | 11.62 | 720.01 | 45.1 | 0.51 |
| UB_HEC-RAS | 247.04 | 100-yr | 9551 | 1486.61 | 1508.83 | 1502.62 | 1511.21 | 0.004313 | 12.38 | 776.09 | 45.28 | 0.52 |
| UB_HEC-RAS | 236.44 | 10-yr | 5331 | 1483.79 | 1503.64 | 1499.26 | 1505.5 | 0.005963 | 10.97 | 490.76 | 39.34 | 0.54 |
| UB_HEC-RAS | 236.44 | 25-yr | 6996 | 1483.79 | 1505.05 | 1500.94 | 1507.65 | 0.007247 | 12.96 | 546.77 | 39.76 | 0.6 |
| UB_HEC-RAS | 236.44 | 50-yr | 8329 | 1483.79 | 1506.1 | 1502.24 | 1509.29 | 0.008114 | 14.37 | 588.42 | 40.07 | 0.65 |
| UB_HEC-RAS | 236.44 | 100-yr | 9551 | 1483.79 | 1506.98 | 1503.33 | 1510.73 | 0.008847 | 15.57 | 623.99 | 40.61 | 0.68 |
| UB_HEC-RAS | 229.65 | 10-yr | 5331 | 1484.17 | 1503.73 | 1499.61 | 1505.33 | 0.0058 | 10.17 | 534.47 | 47.77 | 0.52 |
| UB_HEC-RAS | 229.65 | 25-yr | 6996 | 1484.17 | 1505.23 | 1501.17 | 1507.38 | 0.006647 | 11.8 | 606.78 | 48.43 | 0.57 |
| UB_HEC-RAS | 229.65 | 50-yr | 8329 | 1484.17 | 1506.36 | 1502.3 | 1508.93 | 0.007148 | 12.92 | 661.55 | 48.93 | 0.6 |
| UB_HEC-RAS | 229.65 | 100-yr | 9551 | 1484.17 | 1507.32 | 1503.29 | 1510.27 | 0.00754 | 13.86 | 708.97 | 49.34 | 0.62 |
| UB_HEC-RAS | 227.18 | 10-yr | 5331 | 1485.36 | 1503.72 | 1500.24 | 1505.3 | 0.007191 | 10.12 | 533.06 | 52.48 | 0.55 |
| UB_HEC-RAS | 227.18 | 25-yr | 6996 | 1485.36 | 1505.26 | 1501.63 | 1507.32 | 0.007825 | 11.56 | 614.23 | 53.1 | 0.59 |
| UB_HEC-RAS | 227.18 | 50-yr | 8329 | 1485.36 | 1506.41 | 1502.74 | 1508.83 | 0.008146 | 12.53 | 675.85 | 53.47 | 0.61 |
| UB_HEC-RAS | 227.18 | 100-yr | 9551 | 1485.36 | 1507.41 | 1503.66 | 1510.15 | 0.008386 | 13.35 | 729.09 | 53.6 | 0.62 |
| UB_HEC-RAS | 224.72 | 10-yr | 5331 | 1485.7 | 1503.77 | 1499.93 | 1505.22 | 0.00837 | 9.67 | 552.22 | 51.63 | 0.52 |
| UB_HEC-RAS | 224.72 | 25-yr | 6996 | 1485.7 | 1505.31 | 1501.32 | 1507.22 | 0.009222 | 11.1 | 632.1 | 51.78 | 0.56 |
| UB_HEC-RAS | 224.72 | 50-yr | 8329 | 1485.7 | 1506.47 | 1502.35 | 1508.73 | 0.009684 | 12.08 | 692.18 | 51.92 | 0.58 |
| UB_HEC-RAS | 224.72 | 100-yr | 9551 | 1485.7 | 1507.47 | 1503.24 | 1510.05 | 0.010038 | 12.9 | 743.97 | 52.05 | 0.6 |

**Upper Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UB_HEC-RAS | 222.62 | 10-yr | 5331 | 1482.35 | 1503.78 | 1499.51 | 1505.17 | 0.007188 | 9.47 | 564.09 | 50.92 | 0.5 |
| UB_HEC-RAS | 222.62 | 25-yr | 6996 | 1482.35 | 1505.32 | 1501 | 1507.17 | 0.008047 | 10.92 | 643.05 | 51.35 | 0.54 |
| UB_HEC-RAS | 222.62 | 50-yr | 8329 | 1482.35 | 1506.48 | 1502.02 | 1508.68 | 0.008533 | 11.92 | 702.68 | 51.68 | 0.56 |
| UB_HEC-RAS | 222.62 | 100-yr | 9551 | 1482.35 | 1507.48 | 1502.93 | 1510 | 0.008907 | 12.75 | 754.22 | 51.96 | 0.58 |
| UB_HEC-RAS | 220.14 | 10-yr | 5331 | 1481.35 | 1503.81 | 1498.59 | 1505.11 | 0.007327 | 9.15 | 584.06 | 51.59 | 0.47 |
| UB_HEC-RAS | 220.14 | 25-yr | 6996 | 1481.35 | 1505.36 | 1500.63 | 1507.1 | 0.008375 | 10.58 | 664.7 | 52.23 | 0.52 |
| UB_HEC-RAS | 220.14 | 50-yr | 8329 | 1481.35 | 1506.53 | 1501.69 | 1508.59 | 0.008913 | 11.55 | 725.88 | 52.71 | 0.54 |
| UB_HEC-RAS | 220.14 | 100-yr | 9551 | 1481.35 | 1507.53 | 1502.61 | 1509.9 | 0.009325 | 12.36 | 778.96 | 53.13 | 0.56 |
| UB_HEC-RAS | 217.97 | 10-yr | 5331 | 1479.28 | 1503.96 | 1497.25 | 1504.93 | 0.004844 | 7.93 | 675.04 | 51.83 | 0.38 |
| UB_HEC-RAS | 217.97 | 25-yr | 6996 | 1479.28 | 1505.55 | 1498.95 | 1506.88 | 0.005724 | 9.29 | 757.74 | 52.38 | 0.42 |
| UB_HEC-RAS | 217.97 | 50-yr | 8329 | 1479.28 | 1506.73 | 1500.03 | 1508.36 | 0.006275 | 10.23 | 820.25 | 52.79 | 0.45 |
| UB_HEC-RAS | 217.97 | 100-yr | 9551 | 1479.28 | 1507.76 | 1500.97 | 1509.64 | 0.006713 | 11.03 | 874.29 | 53 | 0.47 |
| UB_HEC-RAS | 215.11 | 10-yr | 5331 | 1477.4 | 1504.02 | 1496.06 | 1504.85 | 0.002871 | 7.29 | 733.71 | 51.79 | 0.34 |
| UB_HEC-RAS | 215.11 | 25-yr | 6996 | 1477.4 | 1505.63 | 1497.7 | 1506.78 | 0.003471 | 8.6 | 817.04 | 52.05 | 0.38 |
| UB_HEC-RAS | 215.11 | 50-yr | 8329 | 1477.4 | 1506.83 | 1498.96 | 1508.23 | 0.003862 | 9.52 | 879.65 | 52.24 | 0.4 |
| UB_HEC-RAS | 215.11 | 100-yr | 9551 | 1477.4 | 1507.86 | 1499.97 | 1509.5 | 0.004179 | 10.29 | 933.59 | 52.41 | 0.43 |
| UB_HEC-RAS | 210.12 | 10-yr | 5331 | 1480.56 | 1503.03 | 1499.66 | 1504.6 | 0.00994 | 10.06 | 530.71 | 52.29 | 0.55 |
| UB_HEC-RAS | 210.12 | 25-yr | 6996 | 1480.56 | 1504.32 | 1501.06 | 1506.45 | 0.011496 | 11.71 | 598.51 | 52.43 | 0.61 |
| UB_HEC-RAS | 210.12 | 50-yr | 8329 | 1480.56 | 1505.28 | 1502.06 | 1507.85 | 0.012469 | 12.87 | 648.94 | 52.54 | 0.64 |
| UB_HEC-RAS | 210.12 | 100-yr | 9551 | 1480.56 | 1506.08 | 1502.93 | 1509.07 | 0.013317 | 13.86 | 691.11 | 52.62 | 0.67 |
| UB_HEC-RAS | 206.28 | 10-yr | 5331 | 1480.58 | 1503.05 | 1499.43 | 1504.52 | 0.006427 | 9.77 | 555.65 | 56.03 | 0.53 |
| UB_HEC-RAS | 206.28 | 25-yr | 6996 | 1480.58 | 1504.36 | 1500.8 | 1506.34 | 0.007444 | 11.36 | 629.33 | 56.23 | 0.58 |
| UB_HEC-RAS | 206.28 | 50-yr | 8329 | 1480.58 | 1505.34 | 1501.85 | 1507.72 | 0.008076 | 12.47 | 684.34 | 56.37 | 0.61 |
| UB_HEC-RAS | 206.28 | 100-yr | 9551 | 1480.58 | 1506.16 | 1502.76 | 1508.92 | 0.008623 | 13.43 | 730.48 | 56.44 | 0.64 |
| UB_HEC-RAS | 204.1 | 10-yr | 5331 | 1482.32 | 1502.84 | 1499.87 | 1504.46 | 0.008744 | 10.22 | 527.05 | 57.07 | 0.58 |
| UB_HEC-RAS | 204.1 | 25-yr | 6996 | 1482.32 | 1504.13 | 1501.24 | 1506.28 | 0.009874 | 11.8 | 601.24 | 57.68 | 0.63 |
| UB_HEC-RAS | 204.1 | 50-yr | 8329 | 1482.32 | 1505.11 | 1502.2 | 1507.65 | 0.01049 | 12.87 | 657.65 | 57.7 | 0.65 |
| UB_HEC-RAS | 204.1 | 100-yr | 9551 | 1482.32 | 1505.94 | 1503.18 | 1508.85 | 0.01102 | 13.78 | 705.15 | 57.72 | 0.68 |
| UB_HEC-RAS | 202.72 | 10-yr | 5331 | 1484.33 | 1502.88 | 1499.75 | 1504.4 | 0.00841 | 9.89 | 539.03 | 58.39 | 0.57 |
| UB_HEC-RAS | 202.72 | 25-yr | 6996 | 1484.33 | 1504.19 | 1501.15 | 1506.19 | 0.009341 | 11.36 | 615.91 | 58.75 | 0.62 |
| UB_HEC-RAS | 202.72 | 50-yr | 8329 | 1484.33 | 1505.18 | 1502.12 | 1507.55 | 0.009793 | 12.36 | 674.34 | 58.79 | 0.64 |
| UB_HEC-RAS | 202.72 | 100-yr | 9551 | 1484.33 | 1506.02 | 1503.02 | 1508.73 | 0.010181 | 13.21 | 723.7 | 58.82 | 0.66 |
| UB_HEC-RAS | 195.69 | 10-yr | 5331 | 1482.89 | 1503.1 | 1497.67 | 1504.1 | 0.003641 | 8.02 | 666.58 | 60.77 | 0.42 |
| UB_HEC-RAS | 195.69 | 25-yr | 6996 | 1482.89 | 1504.47 | 1499.32 | 1505.83 | 0.004261 | 9.37 | 749.57 | 60.86 | 0.47 |
| UB_HEC-RAS | 195.69 | 50-yr | 8329 | 1482.89 | 1505.5 | 1500.27 | 1507.15 | 0.004634 | 10.31 | 812.41 | 60.94 | 0.49 |
| UB_HEC-RAS | 195.69 | 100-yr | 9551 | 1482.89 | 1506.37 | 1501.18 | 1508.28 | 0.004945 | 11.1 | 865.68 | 61 | 0.52 |
| UB_HEC-RAS | 192.07 | 10-yr | 5331 | 1485.06 | 1502.71 | 1499.24 | 1504 | 0.00651 | 9.1 | 585.61 | 65.98 | 0.54 |
| UB_HEC-RAS | 192.07 | 25-yr | 6996 | 1485.06 | 1504.04 | 1500.76 | 1505.72 | 0.007151 | 10.39 | 673.53 | 66.16 | 0.57 |
| UB_HEC-RAS | 192.07 | 50-yr | 8329 | 1485.06 | 1505.08 | 1501.72 | 1507.03 | 0.007433 | 11.23 | 742.04 | 66.31 | 0.59 |
| UB_HEC-RAS | 192.07 | 100-yr | 9551 | 1485.06 | 1505.96 | 1502.48 | 1508.17 | 0.007603 | 11.93 | 800.84 | 66.41 | 0.6 |
| UB_HEC-RAS | 186.86 | 10-yr | 5331 | 1486.95 | 1502.81 | 1498.36 | 1503.85 | 0.003245 | 8.18 | 660.39 | 66.57 | 0.46 |
| UB_HEC-RAS | 186.86 | 25-yr | 6996 | 1486.95 | 1504.16 | 1499.85 | 1505.55 | 0.00367 | 9.47 | 750.37 | 66.97 | 0.49 |
| UB_HEC-RAS | 186.86 | 50-yr | 8329 | 1486.95 | 1505.2 | 1500.73 | 1506.85 | 0.003881 | 10.32 | 820.37 | 67.27 | 0.52 |
| UB_HEC-RAS | 186.86 | 100-yr | 9551 | 1486.95 | 1506.1 | 1501.49 | 1507.98 | 0.004047 | 11.04 | 880.58 | 67.54 | 0.53 |
| UB_HEC-RAS | 182.24 | 10-yr | 5331 | 1487.78 | 1499.85 | 1499.85 | 1503.14 | 0.026102 | 14.59 | 368.98 | 56.47 | 1 |
| UB_HEC-RAS | 182.24 | 25-yr | 6996 | 1487.78 | 1501.49 | 1501.49 | 1504.9 | 0.023232 | 14.86 | 476.06 | 70.56 | 1 |
| UB_HEC-RAS | 182.24 | 50-yr | 8329 | 1487.78 | 1502.33 | 1502.33 | 1506.16 | 0.022332 | 15.75 | 535.54 | 70.96 | 1 |
| UB_HEC-RAS | 182.24 | 100-yr | 9551 | 1487.78 | 1503.07 | 1503.07 | 1507.26 | 0.021641 | 16.47 | 587.63 | 71.29 | 1 |
| UB_HEC-RAS | 178.98 | 10-yr | 5331 | 1477.72 | 1496.78 | 1498.36 | 1502.33 | 0.073402 | 18.91 | 281.92 | 56.08 | 1.49 |
| UB_HEC-RAS | 178.98 | 25-yr | 6996 | 1477.72 | 1498.09 | 1499.7 | 1504.03 | 0.060334 | 19.56 | 357.75 | 59.1 | 1.4 |
| UB_HEC-RAS | 178.98 | 50-yr | 8329 | 1477.72 | 1499.04 | 1500.93 | 1505.32 | 0.053492 | 20.11 | 414.28 | 60.42 | 1.35 |
| UB_HEC-RAS | 178.98 | 100-yr | 9551 | 1477.72 | 1499.84 | 1501.69 | 1506.44 | 0.04962 | 20.6 | 463.88 | 62.71 | 1.33 |

**Upper Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

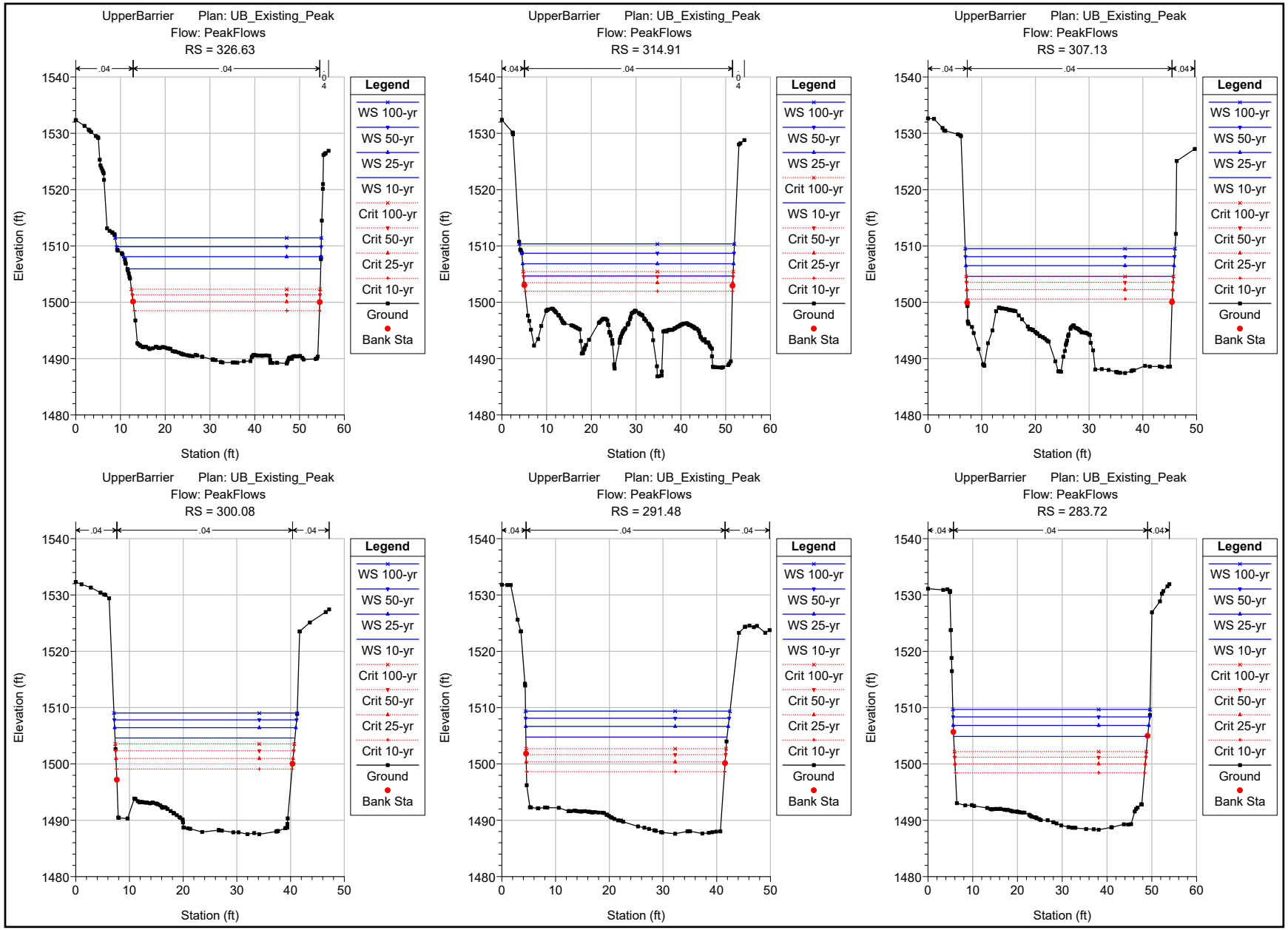
| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UB_HEC-RAS | 176.07 | 10-yr | 5331 | 1476.02 | 1500.45 | 1496.18 | 1501.63 | 0.007914 | 8.74 | 612.39 | 71.4 | 0.52 |
| UB_HEC-RAS | 176.07 | 25-yr | 6996 | 1476.02 | 1501.85 | 1497.75 | 1503.33 | 0.008454 | 9.77 | 719.12 | 77.6 | 0.56 |
| UB_HEC-RAS | 176.07 | 50-yr | 8329 | 1476.02 | 1502.8 | 1498.74 | 1504.53 | 0.008657 | 10.55 | 793.23 | 77.77 | 0.58 |
| UB_HEC-RAS | 176.07 | 100-yr | 9551 | 1476.02 | 1503.69 | 1499.88 | 1505.61 | 0.008641 | 11.14 | 862.11 | 77.92 | 0.59 |
| UB_HEC-RAS | 173.32 | 10-yr | 5331 | 1477.84 | 1500.58 | 1494.07 | 1501.46 | 0.004606 | 7.53 | 712.69 | 77.43 | 0.43 |
| UB_HEC-RAS | 173.32 | 25-yr | 6996 | 1477.84 | 1502 | 1495.69 | 1503.14 | 0.004946 | 8.58 | 822.67 | 77.64 | 0.46 |
| UB_HEC-RAS | 173.32 | 50-yr | 8329 | 1477.84 | 1502.97 | 1497.01 | 1504.33 | 0.005258 | 9.37 | 897.84 | 77.89 | 0.48 |
| UB_HEC-RAS | 173.32 | 100-yr | 9551 | 1477.84 | 1503.86 | 1497.9 | 1505.4 | 0.005411 | 9.98 | 967.42 | 78.14 | 0.5 |
| UB_HEC-RAS | 170.38 | 10-yr | 5331 | 1477.34 | 1500.01 | 1495.67 | 1501.31 | 0.009882 | 9.18 | 584.16 | 77.03 | 0.59 |
| UB_HEC-RAS | 170.38 | 25-yr | 6996 | 1477.34 | 1501.35 | 1498.02 | 1502.97 | 0.00992 | 10.25 | 687.44 | 77.25 | 0.6 |
| UB_HEC-RAS | 170.38 | 50-yr | 8329 | 1477.34 | 1502.23 | 1499.32 | 1504.14 | 0.010285 | 11.11 | 755.54 | 77.4 | 0.62 |
| UB_HEC-RAS | 170.38 | 100-yr | 9551 | 1477.34 | 1503.07 | 1500.22 | 1505.2 | 0.010284 | 11.73 | 820.77 | 77.54 | 0.63 |
| UB_HEC-RAS | 168.25 | 10-yr | 5331 | 1476.32 | 1497.77 | 1497.77 | 1500.77 | 0.038023 | 13.9 | 383.56 | 63.96 | 1 |
| UB_HEC-RAS | 168.25 | 25-yr | 6996 | 1476.32 | 1499.13 | 1499.13 | 1502.43 | 0.035286 | 14.6 | 479.38 | 76.75 | 1.03 |
| UB_HEC-RAS | 168.25 | 50-yr | 8329 | 1476.32 | 1500.03 | 1500.03 | 1503.6 | 0.032 | 15.18 | 549.24 | 77.73 | 1 |
| UB_HEC-RAS | 168.25 | 100-yr | 9551 | 1476.32 | 1500.68 | 1500.68 | 1504.63 | 0.031397 | 15.94 | 600.18 | 78.11 | 1.01 |
| UB_HEC-RAS | 166.43 | 10-yr | 5331 | 1474.44 | 1495.67 | 1496.87 | 1500.22 | 0.057971 | 17.13 | 311.82 | 45.58 | 1.15 |
| UB_HEC-RAS | 166.43 | 25-yr | 6996 | 1474.44 | 1497.43 | 1498.52 | 1501.98 | 0.052332 | 17.13 | 409.42 | 68.96 | 1.24 |
| UB_HEC-RAS | 166.43 | 50-yr | 8329 | 1474.44 | 1498.25 | 1499.25 | 1503.15 | 0.050346 | 17.75 | 470.29 | 76.77 | 1.26 |
| UB_HEC-RAS | 166.43 | 100-yr | 9551 | 1474.44 | 1498.89 | 1499.9 | 1504.16 | 0.048079 | 18.42 | 519.72 | 78.47 | 1.26 |
| UB_HEC-RAS | 163.67 | 10-yr | 5331 | 1477.93 | 1492.41 | 1494.7 | 1499.3 | 0.105917 | 21.07 | 252.97 | 36.48 | 1.41 |
| UB_HEC-RAS | 163.67 | 25-yr | 6996 | 1477.93 | 1494.27 | 1496.59 | 1501.11 | 0.094956 | 20.98 | 333.48 | 49.04 | 1.42 |
| UB_HEC-RAS | 163.67 | 50-yr | 8329 | 1477.93 | 1495.43 | 1497.63 | 1502.35 | 0.089486 | 21.11 | 394.63 | 59.05 | 1.44 |
| UB_HEC-RAS | 163.67 | 100-yr | 9551 | 1477.93 | 1496.22 | 1498.38 | 1503.41 | 0.086235 | 21.52 | 443.88 | 66.79 | 1.47 |
| UB_HEC-RAS | 161.45 | 10-yr | 5331 | 1478.4 | 1491 | 1493.43 | 1498.76 | 0.160084 | 22.35 | 238.56 | 51.41 | 1.83 |
| UB_HEC-RAS | 161.45 | 25-yr | 6996 | 1478.4 | 1492.19 | 1494.86 | 1500.43 | 0.142669 | 23.03 | 303.77 | 57.68 | 1.77 |
| UB_HEC-RAS | 161.45 | 50-yr | 8329 | 1478.4 | 1493.05 | 1495.8 | 1501.62 | 0.129559 | 23.49 | 354.55 | 60.26 | 1.71 |
| UB_HEC-RAS | 161.45 | 100-yr | 9551 | 1478.4 | 1493.78 | 1496.57 | 1502.67 | 0.119818 | 23.92 | 399.23 | 62.03 | 1.66 |
| UB_HEC-RAS | 159.43 | 10-yr | 5331 | 1478.46 | 1492.02 | 1493.53 | 1497.28 | 0.087032 | 18.42 | 289.48 | 66.04 | 1.55 |
| UB_HEC-RAS | 159.43 | 25-yr | 6996 | 1478.46 | 1492.69 | 1494.75 | 1499.49 | 0.093926 | 20.92 | 334.43 | 66.96 | 1.65 |
| UB_HEC-RAS | 159.43 | 50-yr | 8329 | 1478.46 | 1493.29 | 1495.6 | 1500.94 | 0.093103 | 22.2 | 375.27 | 69.06 | 1.68 |
| UB_HEC-RAS | 159.43 | 100-yr | 9551 | 1478.46 | 1493.76 | 1496.25 | 1502.27 | 0.094697 | 23.42 | 407.86 | 70.91 | 1.72 |
| UB_HEC-RAS | 157.42 | 10-yr | 5331 | 1480.71 | 1493.93 | 1493.79 | 1496.59 | 0.01933 | 13.11 | 409.59 | 72.82 | 0.96 |
| UB_HEC-RAS | 157.42 | 25-yr | 6996 | 1480.71 | 1495.02 | 1494.94 | 1498.24 | 0.018619 | 14.44 | 490.44 | 74.67 | 0.97 |
| UB_HEC-RAS | 157.42 | 50-yr | 8329 | 1480.71 | 1495.82 | 1495.76 | 1499.45 | 0.018202 | 15.35 | 550.52 | 75.2 | 0.97 |
| UB_HEC-RAS | 157.42 | 100-yr | 9551 | 1480.71 | 1496.55 | 1496.46 | 1500.51 | 0.017662 | 16.05 | 605.04 | 75.6 | 0.97 |
| UB_HEC-RAS | 155.4 | 10-yr | 5331 | 1480.74 | 1494.3 | 1493.09 | 1496.15 | 0.011609 | 10.92 | 489.23 | 77.08 | 0.76 |
| UB_HEC-RAS | 155.4 | 25-yr | 6996 | 1480.74 | 1495.46 | 1494.24 | 1497.74 | 0.011468 | 12.13 | 578.82 | 77.51 | 0.78 |
| UB_HEC-RAS | 155.4 | 50-yr | 8329 | 1480.74 | 1496.3 | 1495.09 | 1498.92 | 0.011434 | 12.99 | 644.02 | 77.81 | 0.79 |
| UB_HEC-RAS | 155.4 | 100-yr | 9551 | 1480.74 | 1497.05 | 1495.76 | 1499.95 | 0.011308 | 13.67 | 702.29 | 78.08 | 0.8 |
| UB_HEC-RAS | 153.38 | 10-yr | 5331 | 1480.95 | 1494.44 | 1492.62 | 1495.97 | 0.009213 | 9.91 | 538.17 | 78.87 | 0.67 |
| UB_HEC-RAS | 153.38 | 25-yr | 6996 | 1480.95 | 1495.63 | 1493.86 | 1497.53 | 0.009551 | 11.07 | 631.85 | 79.3 | 0.69 |
| UB_HEC-RAS | 153.38 | 50-yr | 8329 | 1480.95 | 1496.49 | 1494.63 | 1498.69 | 0.009801 | 11.89 | 700.24 | 79.62 | 0.71 |
| UB_HEC-RAS | 153.38 | 100-yr | 9551 | 1480.95 | 1497.25 | 1495.3 | 1499.7 | 0.009924 | 12.55 | 761.26 | 79.9 | 0.72 |
| UB_HEC-RAS | 151.36 | 10-yr | 5331 | 1475.9 | 1494.53 | 1492.26 | 1495.85 | 0.010701 | 9.22 | 579.33 | 80.2 | 0.6 |
| UB_HEC-RAS | 151.36 | 25-yr | 6996 | 1475.9 | 1495.72 | 1493.4 | 1497.4 | 0.011193 | 10.38 | 675.85 | 81.02 | 0.63 |
| UB_HEC-RAS | 151.36 | 50-yr | 8329 | 1475.9 | 1496.59 | 1494.21 | 1498.54 | 0.011508 | 11.2 | 746.66 | 81.62 | 0.65 |
| UB_HEC-RAS | 151.36 | 100-yr | 9551 | 1475.9 | 1497.37 | 1494.89 | 1499.54 | 0.01165 | 11.84 | 809.98 | 82.15 | 0.66 |
| UB_HEC-RAS | 149.35 | 10-yr | 5331 | 1475.68 | 1494.7 | 1491.21 | 1495.64 | 0.005589 | 7.78 | 686.77 | 87.06 | 0.48 |
| UB_HEC-RAS | 149.35 | 25-yr | 6996 | 1475.68 | 1495.94 | 1492.39 | 1497.15 | 0.005954 | 8.83 | 795.06 | 87.99 | 0.51 |
| UB_HEC-RAS | 149.35 | 50-yr | 8329 | 1475.68 | 1496.84 | 1493.27 | 1498.26 | 0.006182 | 9.58 | 874.55 | 88.59 | 0.53 |
| UB_HEC-RAS | 149.35 | 100-yr | 9551 | 1475.68 | 1497.64 | 1493.93 | 1499.24 | 0.006308 | 10.18 | 945.39 | 89.12 | 0.54 |

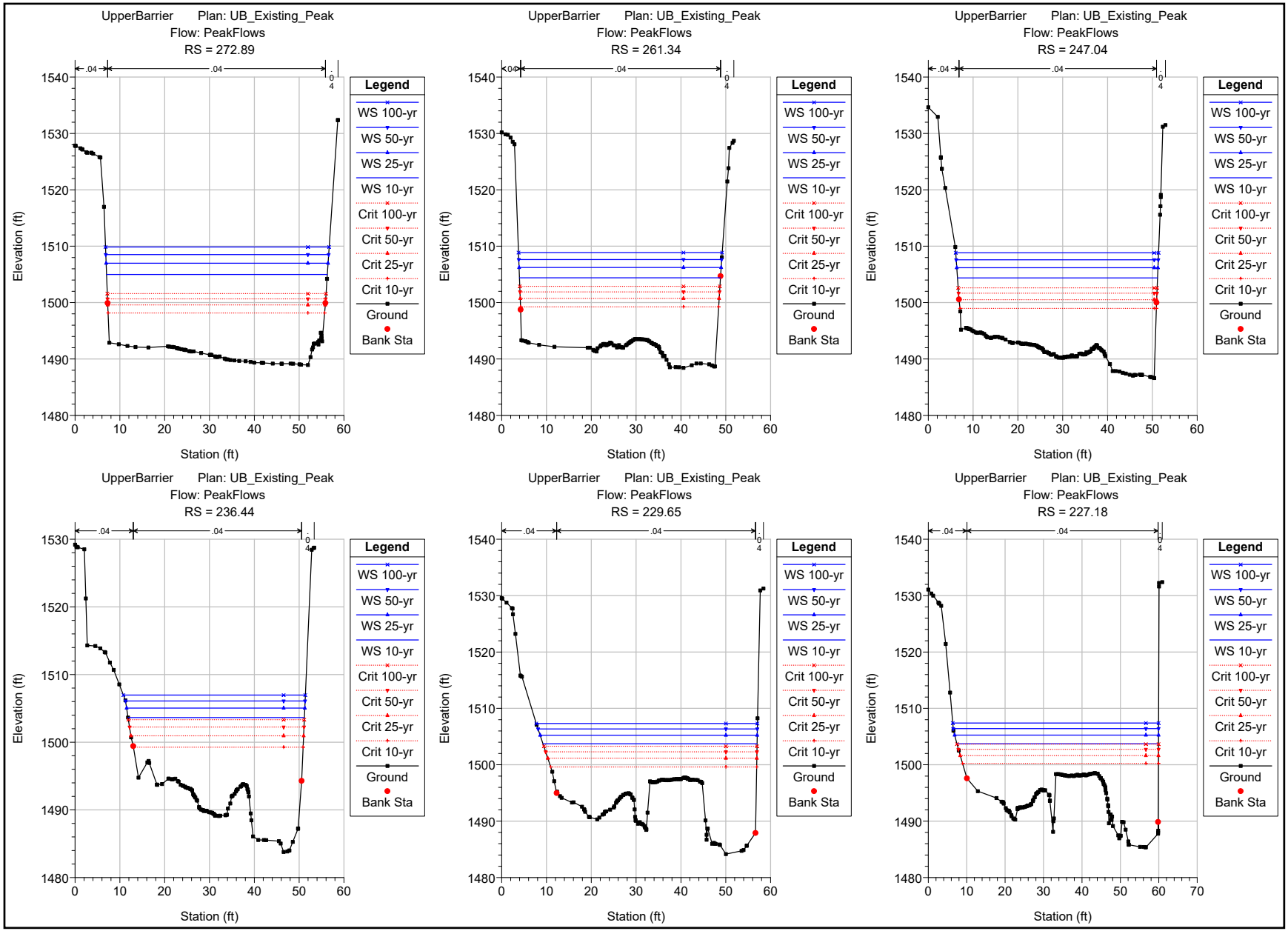
**Upper Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

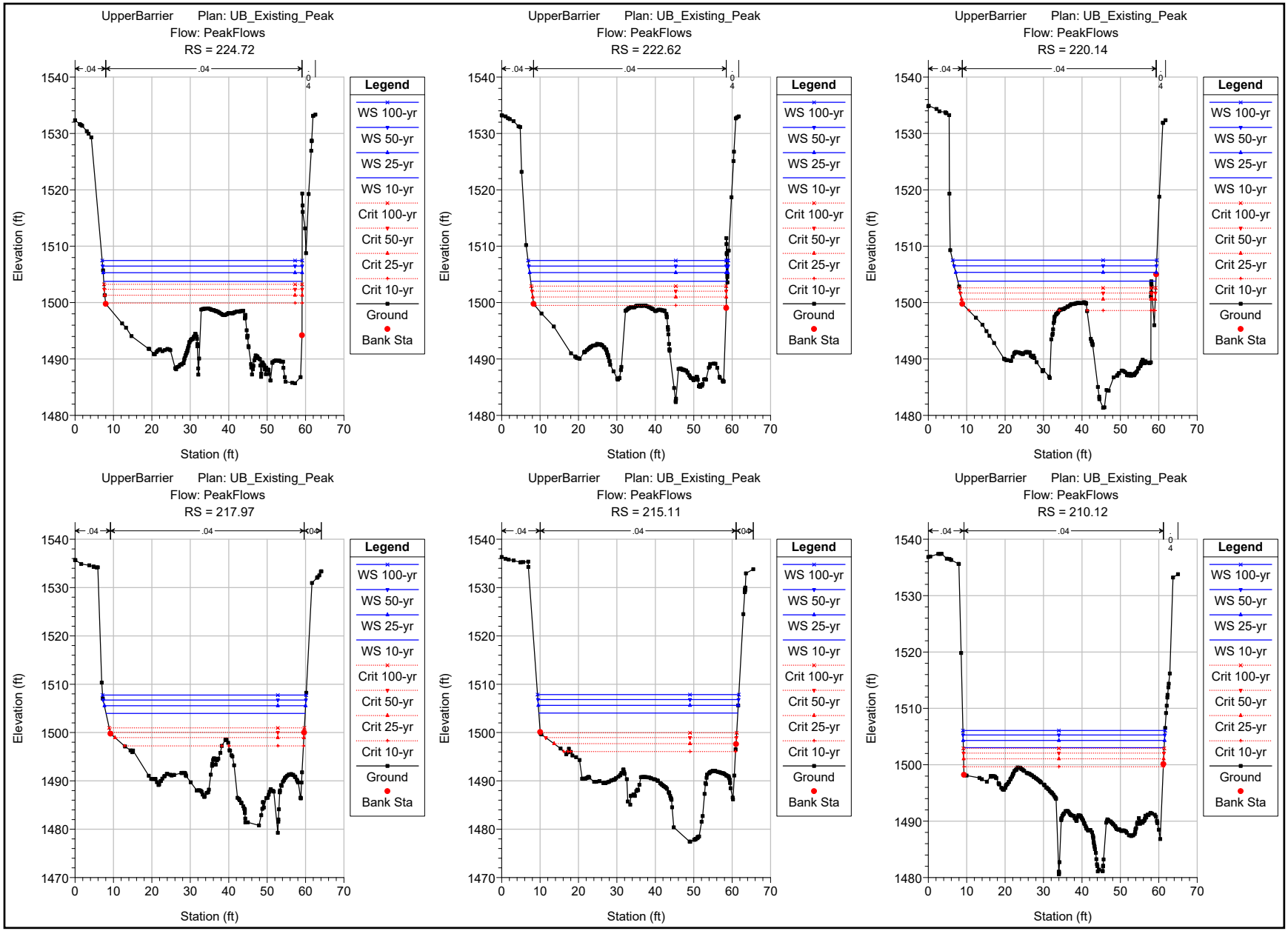
| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UB_HEC-RAS | 147.33 | 10-yr | 5331 | 1476.16 | 1494.78 | 1490.28 | 1495.54 | 0.004148 | 6.97 | 765.58 | 87.3 | 0.41 |
| UB_HEC-RAS | 147.33 | 25-yr | 6996 | 1476.16 | 1496.04 | 1491.67 | 1497.03 | 0.004589 | 8 | 875.49 | 88.31 | 0.44 |
| UB_HEC-RAS | 147.33 | 50-yr | 8329 | 1476.16 | 1496.95 | 1492.46 | 1498.13 | 0.004871 | 8.74 | 956.19 | 88.94 | 0.46 |
| UB_HEC-RAS | 147.33 | 100-yr | 9551 | 1476.16 | 1497.75 | 1493.08 | 1499.1 | 0.005056 | 9.33 | 1028 | 89.47 | 0.48 |
| UB_HEC-RAS | 145.31 | 10-yr | 5331 | 1475.7 | 1494.59 | 1491.21 | 1495.48 | 0.005722 | 7.6 | 701.18 | 86.45 | 0.47 |
| UB_HEC-RAS | 145.31 | 25-yr | 6996 | 1475.7 | 1495.8 | 1492.27 | 1496.97 | 0.006315 | 8.67 | 807.02 | 87.75 | 0.5 |
| UB_HEC-RAS | 145.31 | 50-yr | 8329 | 1475.7 | 1496.69 | 1493.02 | 1498.06 | 0.006684 | 9.41 | 885.1 | 88.47 | 0.52 |
| UB_HEC-RAS | 145.31 | 100-yr | 9551 | 1475.7 | 1497.48 | 1493.64 | 1499.03 | 0.006883 | 10 | 955.1 | 88.98 | 0.54 |
| UB_HEC-RAS | 143.29 | 10-yr | 5331 | 1475.02 | 1494.6 | 1490.77 | 1495.45 | 0.005181 | 7.36 | 724.51 | 85.81 | 0.45 |
| UB_HEC-RAS | 143.29 | 25-yr | 6996 | 1475.02 | 1495.82 | 1491.96 | 1496.93 | 0.005766 | 8.45 | 829.21 | 86.63 | 0.48 |
| UB_HEC-RAS | 143.29 | 50-yr | 8329 | 1475.02 | 1496.7 | 1492.66 | 1498.02 | 0.006142 | 9.21 | 906.16 | 87.23 | 0.5 |
| UB_HEC-RAS | 143.29 | 100-yr | 9551 | 1475.02 | 1497.49 | 1493.36 | 1498.99 | 0.006384 | 9.82 | 975.02 | 87.76 | 0.52 |
| UB_HEC-RAS | 141.27 | 10-yr | 5331 | 1474.26 | 1494.47 | 1491.15 | 1495.41 | 0.006373 | 7.75 | 688.28 | 86.05 | 0.48 |
| UB_HEC-RAS | 141.27 | 25-yr | 6996 | 1474.26 | 1495.67 | 1492.31 | 1496.88 | 0.007038 | 8.84 | 791.44 | 86.99 | 0.52 |
| UB_HEC-RAS | 141.27 | 50-yr | 8329 | 1474.26 | 1496.54 | 1493.02 | 1497.97 | 0.007458 | 9.6 | 867.56 | 87.68 | 0.54 |
| UB_HEC-RAS | 141.27 | 100-yr | 9551 | 1474.26 | 1497.32 | 1493.67 | 1498.93 | 0.007684 | 10.2 | 936.16 | 88.3 | 0.55 |
| UB_HEC-RAS | 139.26 | 10-yr | 5331 | 1474.88 | 1493.94 | 1492.12 | 1495.27 | 0.010292 | 9.25 | 576.31 | 87.72 | 0.64 |
| UB_HEC-RAS | 139.26 | 25-yr | 6996 | 1474.88 | 1495.06 | 1493.12 | 1496.73 | 0.010698 | 10.37 | 674.95 | 88.66 | 0.66 |
| UB_HEC-RAS | 139.26 | 50-yr | 8329 | 1474.88 | 1495.88 | 1493.87 | 1497.8 | 0.010944 | 11.13 | 748.13 | 89.6 | 0.68 |
| UB_HEC-RAS | 139.26 | 100-yr | 9551 | 1474.88 | 1496.64 | 1494.5 | 1498.76 | 0.010914 | 11.7 | 816.65 | 90.47 | 0.69 |
| UB_HEC-RAS | 136.54 | 10-yr | 5331 | 1477.18 | 1492.42 | 1492.42 | 1494.89 | 0.027386 | 12.6 | 423.2 | 87.12 | 1.01 |
| UB_HEC-RAS | 136.54 | 25-yr | 6996 | 1477.18 | 1493.41 | 1493.41 | 1496.32 | 0.02602 | 13.67 | 511.71 | 89.7 | 1.01 |
| UB_HEC-RAS | 136.54 | 50-yr | 8329 | 1477.18 | 1494.17 | 1494.17 | 1497.38 | 0.024675 | 14.37 | 579.8 | 90.26 | 1 |
| UB_HEC-RAS | 136.54 | 100-yr | 9551 | 1477.18 | 1494.75 | 1494.75 | 1498.29 | 0.024556 | 15.1 | 632.45 | 90.7 | 1.01 |
| UB_HEC-RAS | 133.07 | 10-yr | 5331 | 1476.66 | 1490.73 | 1491.3 | 1494.41 | 0.039695 | 15.4 | 346.23 | 62.11 | 1.15 |
| UB_HEC-RAS | 133.07 | 25-yr | 6996 | 1476.66 | 1492.34 | 1492.96 | 1496 | 0.034911 | 15.36 | 455.5 | 79.98 | 1.13 |
| UB_HEC-RAS | 133.07 | 50-yr | 8329 | 1476.66 | 1493.15 | 1493.77 | 1497.07 | 0.034258 | 15.89 | 524.4 | 89.15 | 1.15 |
| UB_HEC-RAS | 133.07 | 100-yr | 9551 | 1476.66 | 1493.73 | 1494.41 | 1497.99 | 0.033961 | 16.56 | 577.09 | 92.61 | 1.16 |
| UB_HEC-RAS | 125.01 | 10-yr | 5331 | 1473.65 | 1484.62 | 1487.07 | 1492.63 | 0.102931 | 22.7 | 234.8 | 46.42 | 1.78 |
| UB_HEC-RAS | 125.01 | 25-yr | 6996 | 1473.65 | 1486.11 | 1488.61 | 1494.25 | 0.082156 | 22.89 | 305.64 | 48.77 | 1.61 |
| UB_HEC-RAS | 125.01 | 50-yr | 8329 | 1473.65 | 1487.27 | 1489.88 | 1495.42 | 0.071674 | 22.9 | 363.74 | 50.95 | 1.51 |
| UB_HEC-RAS | 125.01 | 100-yr | 9551 | 1473.65 | 1488.29 | 1490.98 | 1496.45 | 0.065188 | 22.93 | 416.55 | 53.38 | 1.45 |
| UB_HEC-RAS | 115.23 | 10-yr | 5700 | 1474.17 | 1483.68 | 1486.1 | 1491.72 | 0.083253 | 22.75 | 250.52 | 51.23 | 1.81 |
| UB_HEC-RAS | 115.23 | 25-yr | 7500 | 1474.17 | 1485.07 | 1487.62 | 1493.46 | 0.065375 | 23.25 | 322.62 | 52.44 | 1.65 |
| UB_HEC-RAS | 115.23 | 50-yr | 8900 | 1474.17 | 1486.14 | 1488.72 | 1494.68 | 0.05641 | 23.45 | 379.5 | 53.73 | 1.56 |
| UB_HEC-RAS | 115.23 | 100-yr | 10200 | 1474.17 | 1489.61 | 1490.32 | 1494.43 | 0.022964 | 17.62 | 578.85 | 61.91 | 1.02 |
| UB_HEC-RAS | 83.88 | 10-yr | 5700 | 1473.23 | 1479.05 | 1481.75 | 1488.44 | 0.101073 | 24.6 | 231.74 | 62.79 | 2.26 |
| UB_HEC-RAS | 83.88 | 25-yr | 7500 | 1473.23 | 1479.93 | 1482.96 | 1490.43 | 0.091077 | 25.99 | 288.55 | 65.29 | 2.18 |
| UB_HEC-RAS | 83.88 | 50-yr | 8900 | 1473.23 | 1480.59 | 1483.84 | 1491.74 | 0.085601 | 26.8 | 332.06 | 67.55 | 2.13 |
| UB_HEC-RAS | 83.88 | 100-yr | 10200 | 1473.23 | 1481.57 | 1484.6 | 1491.7 | 0.064884 | 25.55 | 399.24 | 69.02 | 1.87 |
| UB_HEC-RAS | 75.5 | 10-yr | 5700 | 1472.73 | 1484.76 | 1481.76 | 1485.82 | 0.004496 | 8.24 | 691.71 | 89.87 | 0.52 |
| UB_HEC-RAS | 75.5 | 25-yr | 7500 | 1472.73 | 1486.16 | 1482.86 | 1487.45 | 0.004842 | 9.12 | 822.58 | 97.42 | 0.55 |
| UB_HEC-RAS | 75.5 | 50-yr | 8900 | 1472.73 | 1480.95 | 1483.67 | 1490.02 | 0.077291 | 24.17 | 368.17 | 81.2 | 2 |
| UB_HEC-RAS | 75.5 | 100-yr | 10200 | 1472.73 | 1487.88 | 1484.37 | 1489.49 | 0.005287 | 10.19 | 1001.05 | 108.42 | 0.59 |
| UB_HEC-RAS | 70.46 | 10-yr | 5700 | 1472.42 | 1484.75 | 1481.65 | 1485.78 | 0.00398 | 8.13 | 700.76 | 94.05 | 0.53 |
| UB_HEC-RAS | 70.46 | 25-yr | 7500 | 1472.42 | 1486.16 | 1482.94 | 1487.4 | 0.004126 | 8.96 | 837.37 | 100.01 | 0.55 |
| UB_HEC-RAS | 70.46 | 50-yr | 8900 | 1472.42 | 1487.03 | 1483.72 | 1488.46 | 0.004366 | 9.61 | 925.75 | 103.82 | 0.57 |
| UB_HEC-RAS | 70.46 | 100-yr | 10200 | 1472.42 | 1487.88 | 1484.39 | 1489.45 | 0.004348 | 10.05 | 1015.43 | 106.02 | 0.57 |
| UB_HEC-RAS | 66.86 | 10-yr | 5700 | 1472.08 | 1484.53 | 1481.84 | 1485.72 | 0.004962 | 8.73 | 652.84 | 92.26 | 0.58 |
| UB_HEC-RAS | 66.86 | 25-yr | 7500 | 1472.08 | 1485.9 | 1483 | 1487.33 | 0.004959 | 9.62 | 779.98 | 94.53 | 0.59 |
| UB_HEC-RAS | 66.86 | 50-yr | 8900 | 1472.08 | 1486.7 | 1484.01 | 1488.37 | 0.005376 | 10.37 | 857.92 | 99.11 | 0.62 |
| UB_HEC-RAS | 66.86 | 100-yr | 10200 | 1472.08 | 1487.53 | 1484.7 | 1489.36 | 0.005303 | 10.84 | 941.48 | 101.99 | 0.62 |

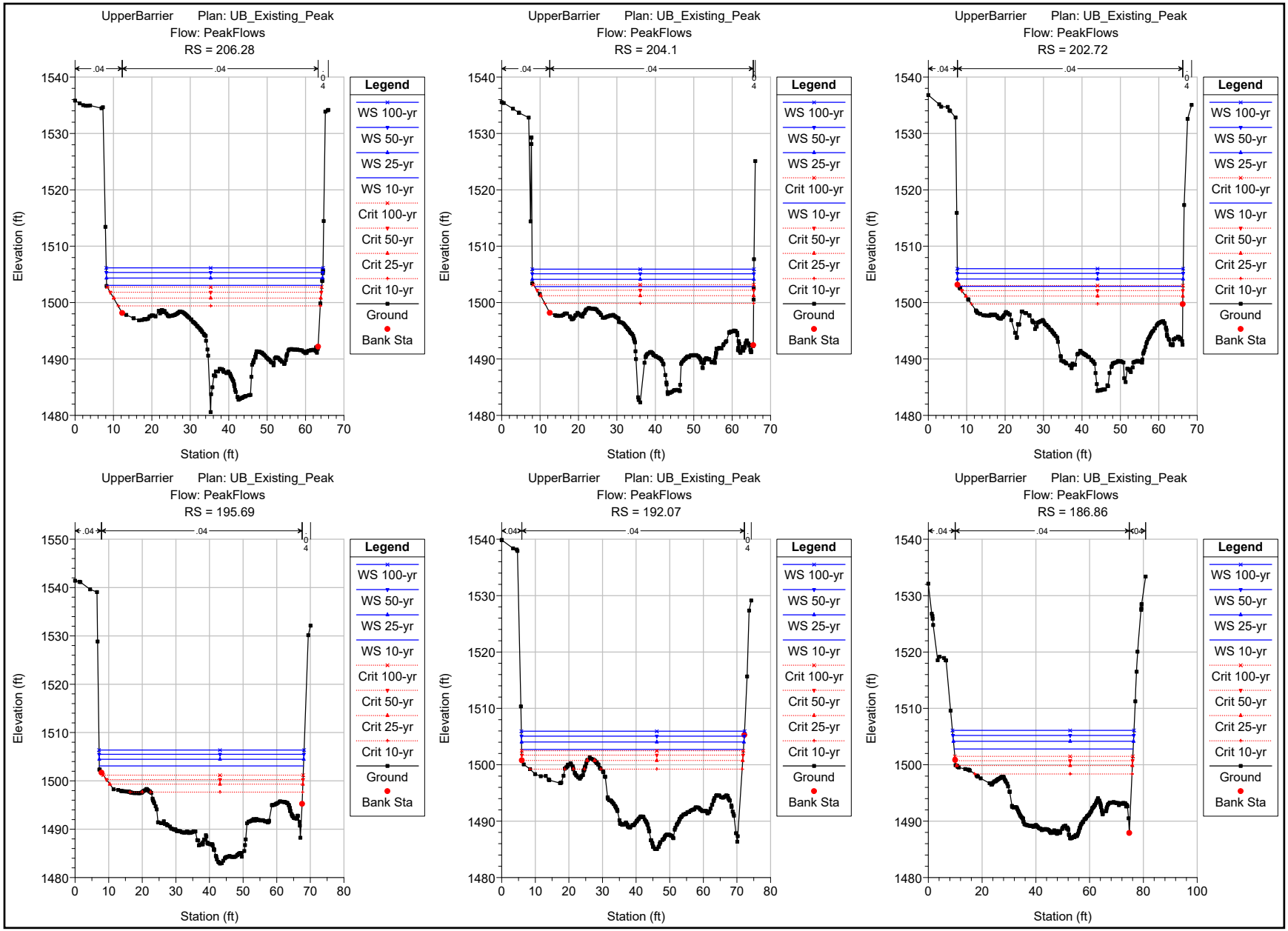
**Upper Barrier Existing Conditions HEC-RAS Modeling Resluts at Peak Flows**

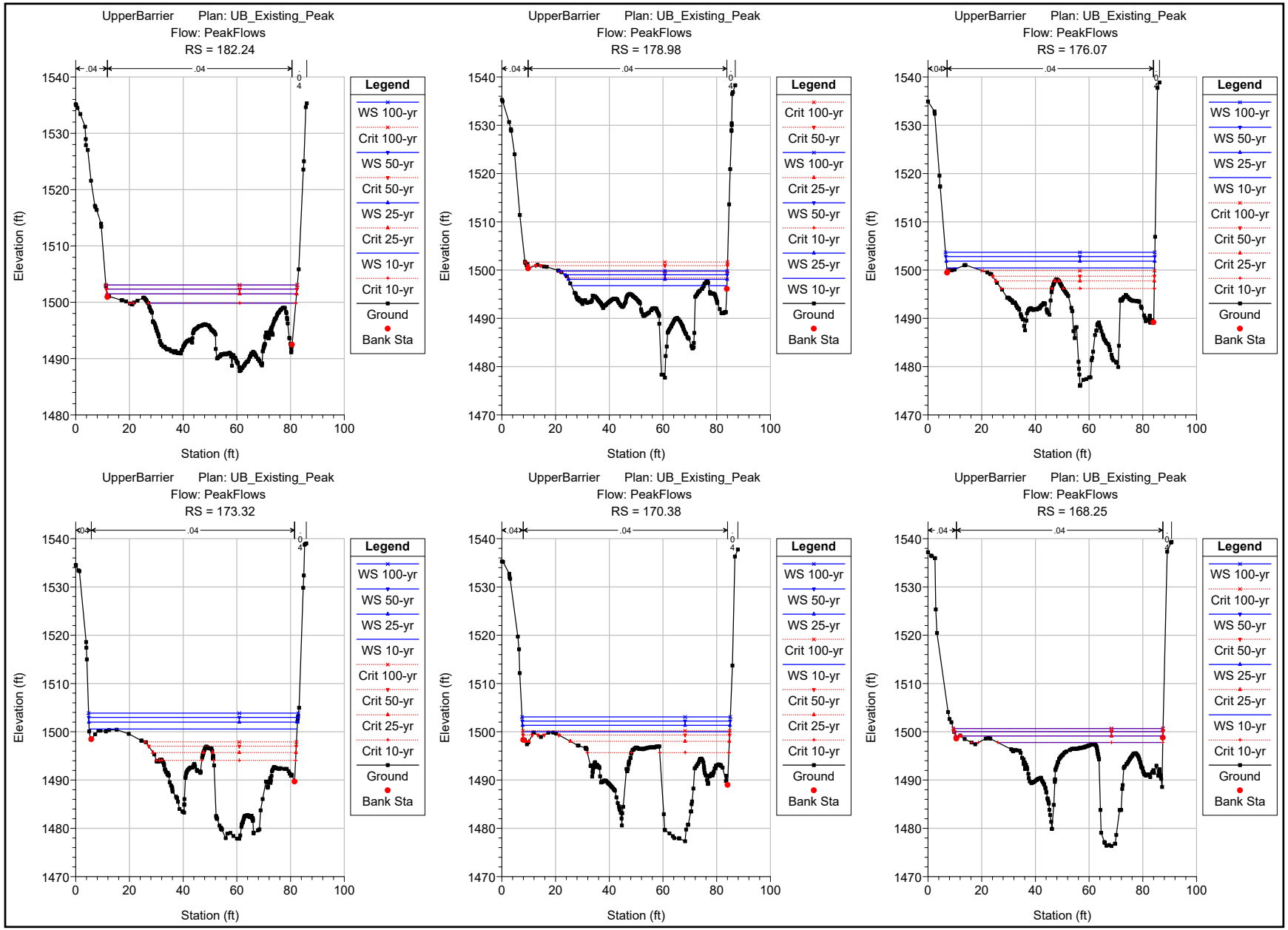
| Reach | River Sta | Profile | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UB_HEC-RAS | 62.05 | 10-yr | 5700 | 1470.87 | 1484.41 | 1482.1 | 1485.67 | 0.006229 | 9 | 633.17 | 92.11 | 0.6 |
| UB_HEC-RAS | 62.05 | 25-yr | 7500 | 1470.87 | 1485.77 | 1483.2 | 1487.28 | 0.006045 | 9.87 | 760.94 | 95.24 | 0.61 |
| UB_HEC-RAS | 62.05 | 50-yr | 8900 | 1470.87 | 1486.54 | 1484.08 | 1488.31 | 0.00639 | 10.68 | 835.35 | 97.34 | 0.64 |
| UB_HEC-RAS | 62.05 | 100-yr | 10200 | 1470.87 | 1487.36 | 1484.79 | 1489.29 | 0.006374 | 11.18 | 915.64 | 100.2 | 0.65 |
| UB_HEC-RAS | 57.03 | 10-yr | 5700 | 1468.31 | 1482.58 | 1482.58 | 1485.2 | 0.020516 | 13 | 438.3 | 83.91 | 1 |
| UB_HEC-RAS | 57.03 | 25-yr | 7500 | 1468.31 | 1483.69 | 1483.69 | 1486.76 | 0.019337 | 14.06 | 533.24 | 87.17 | 1 |
| UB_HEC-RAS | 57.03 | 50-yr | 8900 | 1468.31 | 1484.93 | 1484.44 | 1487.9 | 0.015251 | 13.84 | 642.89 | 90.07 | 0.91 |
| UB_HEC-RAS | 57.03 | 100-yr | 10200 | 1468.31 | 1486.06 | 1485.13 | 1488.96 | 0.012623 | 13.65 | 746.98 | 92.73 | 0.85 |
| UB_HEC-RAS | 50.94 | 10-yr | 5700 | 1467.18 | 1481.44 | 1481.97 | 1484.85 | 0.024006 | 14.82 | 384.72 | 75.47 | 1.16 |
| UB_HEC-RAS | 50.94 | 25-yr | 7500 | 1467.18 | 1483.75 | 1483.12 | 1486.46 | 0.012655 | 13.21 | 567.9 | 82.62 | 0.89 |
| UB_HEC-RAS | 50.94 | 50-yr | 8900 | 1467.18 | 1484.96 | 1483.98 | 1487.71 | 0.010682 | 13.31 | 669.5 | 85.61 | 0.83 |
| UB_HEC-RAS | 50.94 | 100-yr | 10200 | 1467.18 | 1486.06 | 1484.69 | 1488.83 | 0.009306 | 13.37 | 765.01 | 88.26 | 0.79 |
| UB_HEC-RAS | 44.08 | 10-yr | 5700 | 1468.15 | 1482.3 | 1480.44 | 1484.09 | 0.009325 | 10.73 | 531.21 | 71.75 | 0.69 |
| UB_HEC-RAS | 44.08 | 25-yr | 7500 | 1468.15 | 1484.04 | 1481.72 | 1486.04 | 0.008596 | 11.35 | 660.71 | 78.19 | 0.69 |
| UB_HEC-RAS | 44.08 | 50-yr | 8900 | 1468.15 | 1485.19 | 1482.73 | 1487.35 | 0.008359 | 11.78 | 755.21 | 83.77 | 0.69 |
| UB_HEC-RAS | 44.08 | 100-yr | 10200 | 1468.15 | 1486.26 | 1483.57 | 1488.52 | 0.007822 | 12.05 | 846.17 | 86.44 | 0.68 |
| UB_HEC-RAS | 36.02 | 10-yr | 5700 | 1468.83 | 1482.65 | 1478.69 | 1483.65 | 0.003353 | 8.03 | 709.67 | 78.89 | 0.47 |
| UB_HEC-RAS | 36.02 | 25-yr | 7500 | 1468.83 | 1484.39 | 1479.96 | 1485.6 | 0.003409 | 8.81 | 851.48 | 82.81 | 0.48 |
| UB_HEC-RAS | 36.02 | 50-yr | 8900 | 1468.83 | 1485.55 | 1480.84 | 1486.91 | 0.00349 | 9.39 | 948.22 | 84.9 | 0.49 |
| UB_HEC-RAS | 36.02 | 100-yr | 10200 | 1468.83 | 1486.6 | 1481.62 | 1488.1 | 0.003501 | 9.82 | 1038.63 | 86.42 | 0.5 |
| UB_HEC-RAS | 27.68 | 10-yr | 5700 | 1469.27 | 1482.53 | 1478.68 | 1483.6 | 0.003528 | 8.31 | 686.26 | 78.6 | 0.5 |
| UB_HEC-RAS | 27.68 | 25-yr | 7500 | 1469.27 | 1484.27 | 1479.93 | 1485.55 | 0.003553 | 9.07 | 827.27 | 83.11 | 0.51 |
| UB_HEC-RAS | 27.68 | 50-yr | 8900 | 1469.27 | 1485.42 | 1480.91 | 1486.86 | 0.003597 | 9.63 | 924.07 | 84.95 | 0.51 |
| UB_HEC-RAS | 27.68 | 100-yr | 10200 | 1469.27 | 1486.47 | 1481.74 | 1488.04 | 0.003584 | 10.06 | 1014.39 | 86.63 | 0.52 |
| UB_HEC-RAS | 22.63 | 10-yr | 5700 | 1469.25 | 1482.4 | 1478.47 | 1483.56 | 0.004001 | 8.64 | 659.43 | 72.45 | 0.5 |
| UB_HEC-RAS | 22.63 | 25-yr | 7500 | 1469.25 | 1484.06 | 1479.91 | 1485.48 | 0.004355 | 9.58 | 783.03 | 76.37 | 0.53 |
| UB_HEC-RAS | 22.63 | 50-yr | 8900 | 1469.25 | 1485.16 | 1480.88 | 1486.79 | 0.004714 | 10.23 | 870.1 | 81.13 | 0.55 |
| UB_HEC-RAS | 22.63 | 100-yr | 10200 | 1469.25 | 1486.18 | 1481.72 | 1487.96 | 0.004686 | 10.7 | 953.46 | 81.8 | 0.55 |
| UB_HEC-RAS | 19.18 | 10-yr | 5700 | 1469.07 | 1482.08 | 1478.73 | 1483.47 | 0.005413 | 9.46 | 602.45 | 69.36 | 0.57 |
| UB_HEC-RAS | 19.18 | 25-yr | 7500 | 1469.07 | 1483.68 | 1480.28 | 1485.38 | 0.005864 | 10.46 | 716.85 | 73.84 | 0.59 |
| UB_HEC-RAS | 19.18 | 50-yr | 8900 | 1469.07 | 1484.73 | 1481.28 | 1486.67 | 0.006242 | 11.18 | 795.79 | 76.84 | 0.61 |
| UB_HEC-RAS | 19.18 | 100-yr | 10200 | 1469.07 | 1485.74 | 1482.14 | 1487.84 | 0.006367 | 11.63 | 876.71 | 81.09 | 0.62 |
| UB_HEC-RAS | 12.49 | 10-yr | 5700 | 1470.39 | 1479.64 | 1479.64 | 1482.86 | 0.019042 | 14.39 | 396 | 62.15 | 1 |
| UB_HEC-RAS | 12.49 | 25-yr | 7500 | 1470.39 | 1481.07 | 1481.07 | 1484.73 | 0.018206 | 15.35 | 488.53 | 67.91 | 1.01 |
| UB_HEC-RAS | 12.49 | 50-yr | 8900 | 1470.39 | 1482.08 | 1482.08 | 1486.01 | 0.017514 | 15.9 | 559.59 | 71.73 | 1 |
| UB_HEC-RAS | 12.49 | 100-yr | 10200 | 1470.39 | 1482.83 | 1482.83 | 1487.12 | 0.017333 | 16.62 | 613.58 | 72.54 | 1.01 |

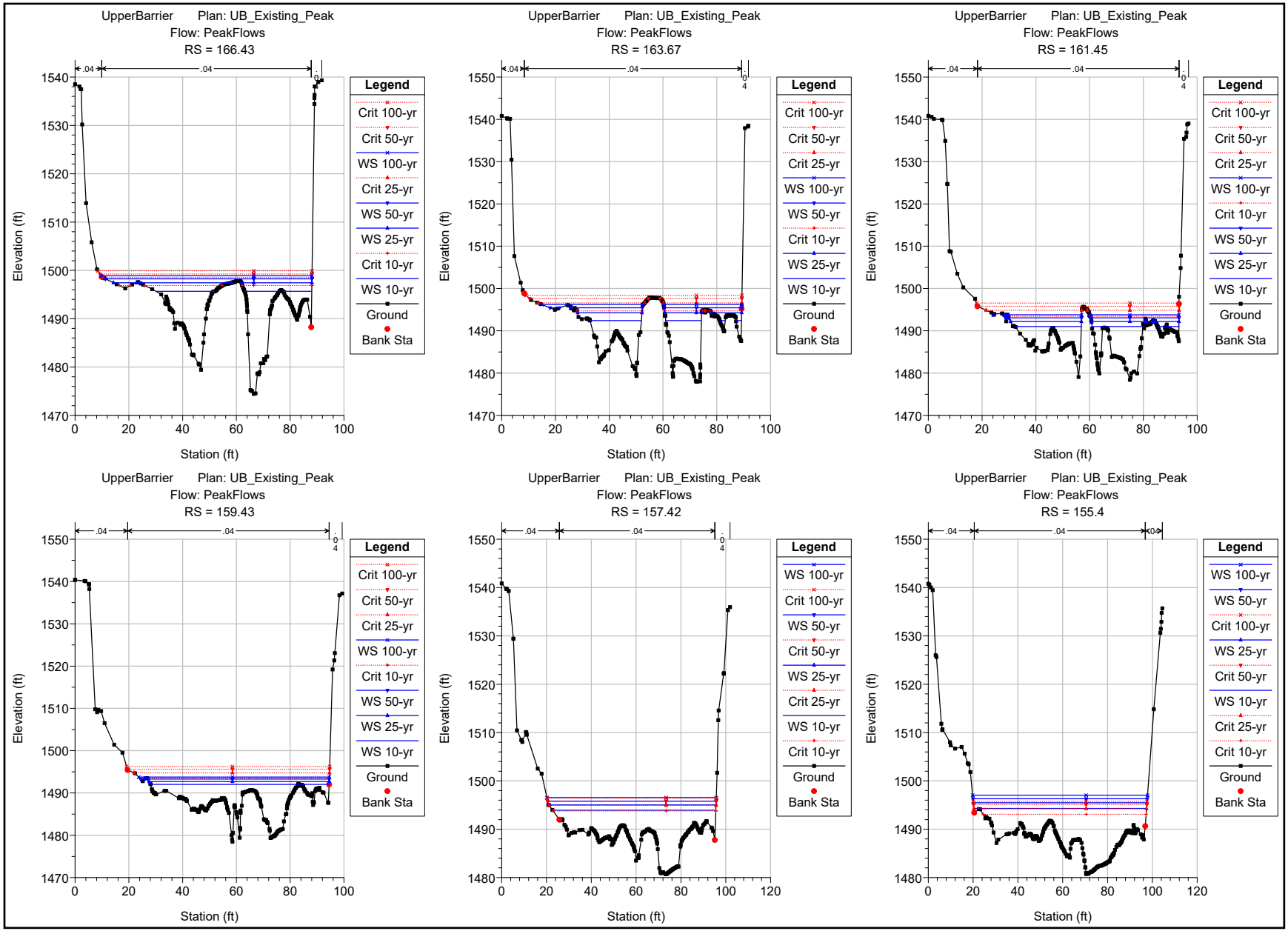

UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 326.63
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 314.91
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 307.13
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 300.08
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 291.48
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 283.72
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)

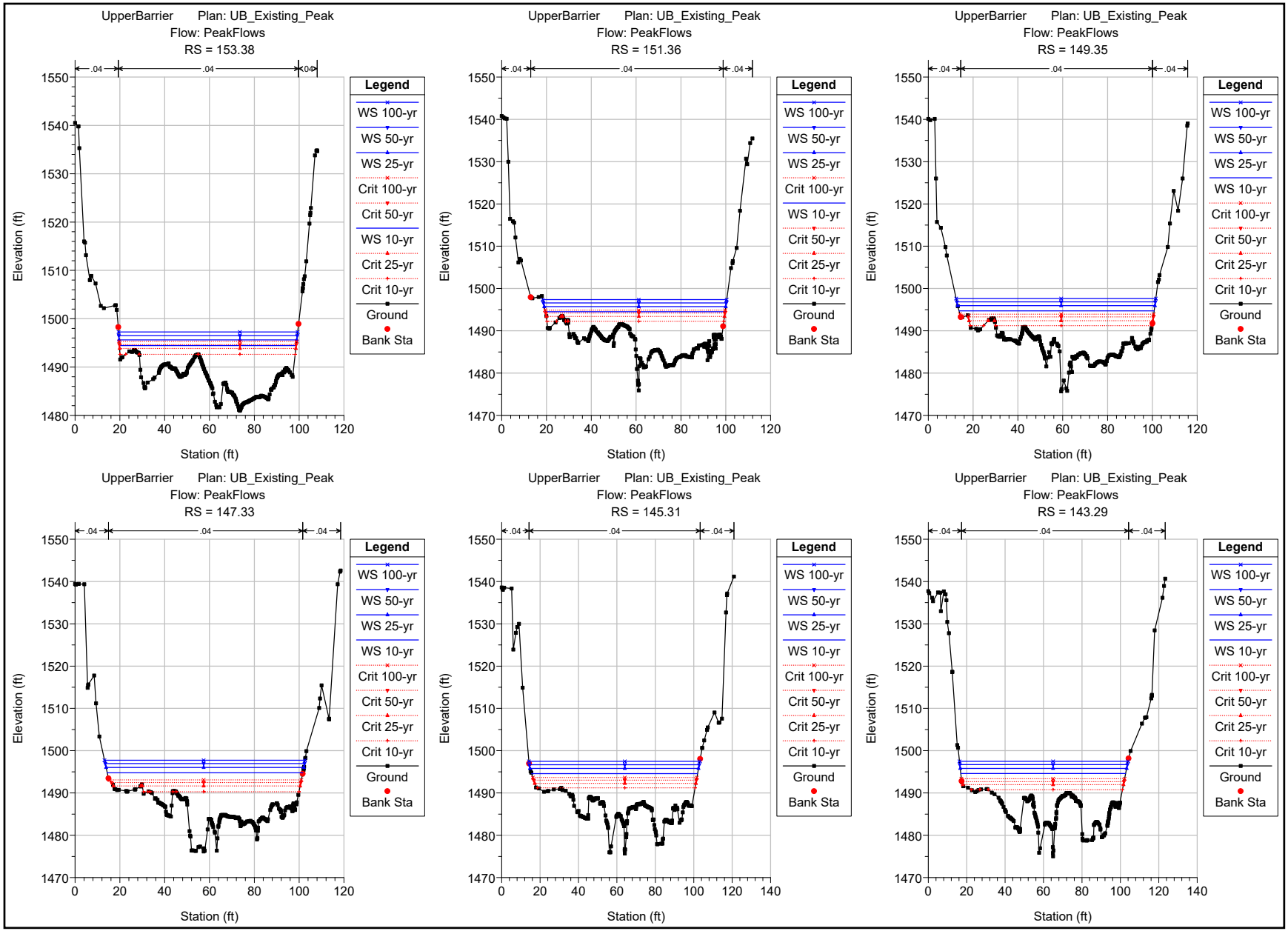

UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 272.89
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 261.34
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 247.04
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 236.44
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 229.65
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 227.18
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)

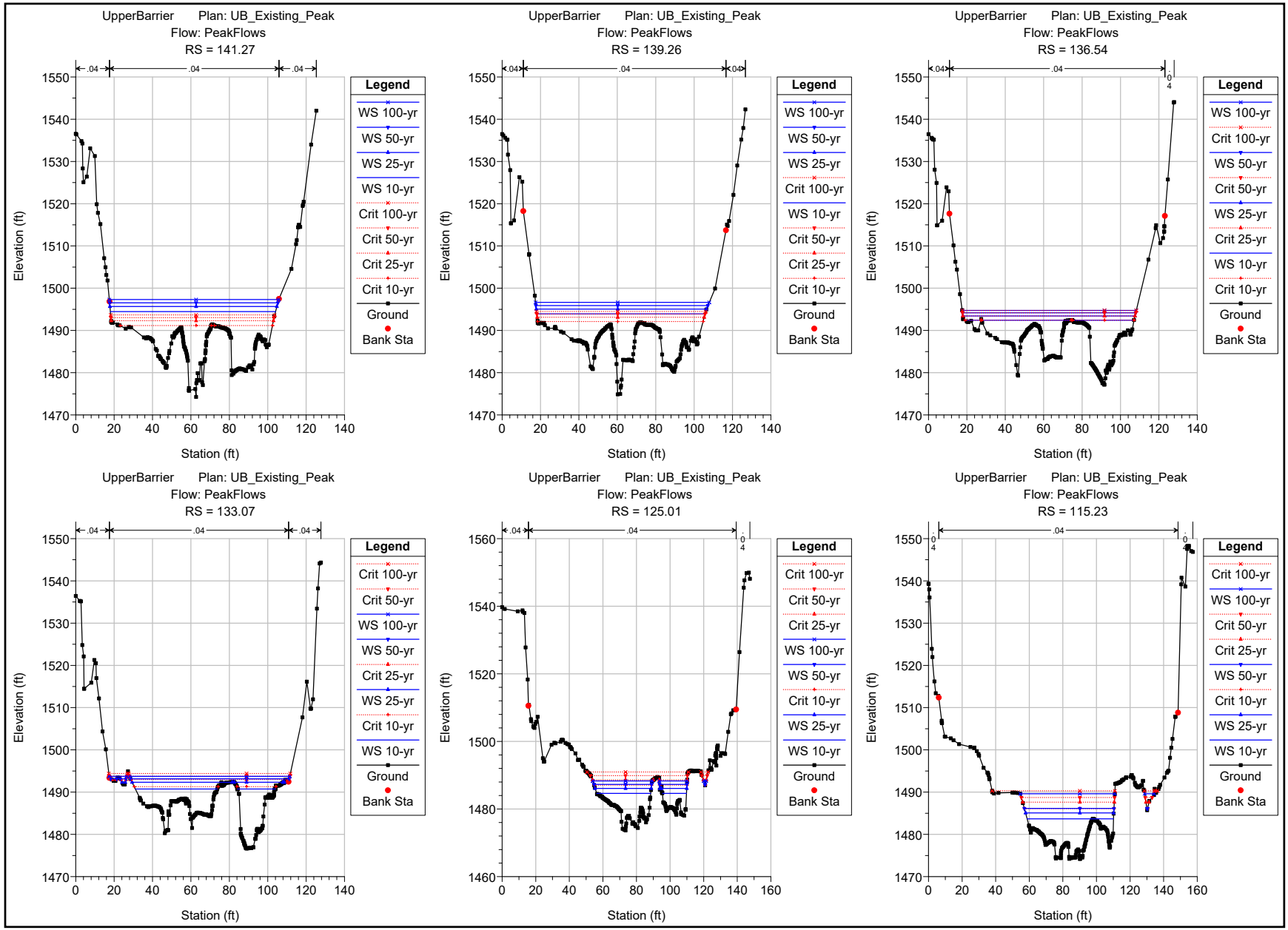

UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 224.72
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 222.62
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 220.14
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 217.97
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 215.11
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 210.12
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta

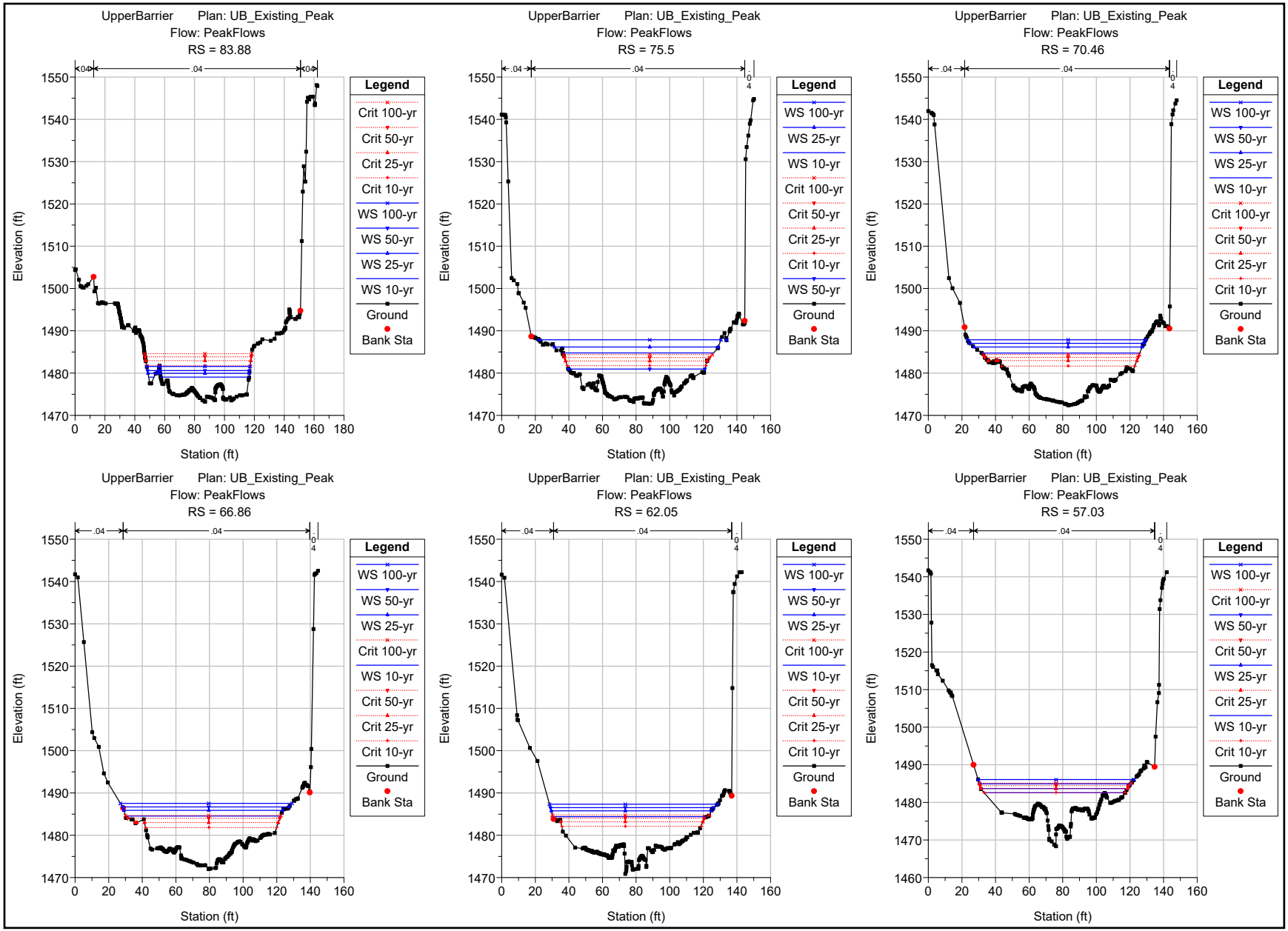

UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 206.28
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 204.1
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 202.72
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 195.69
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 192.07
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 186.86
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta

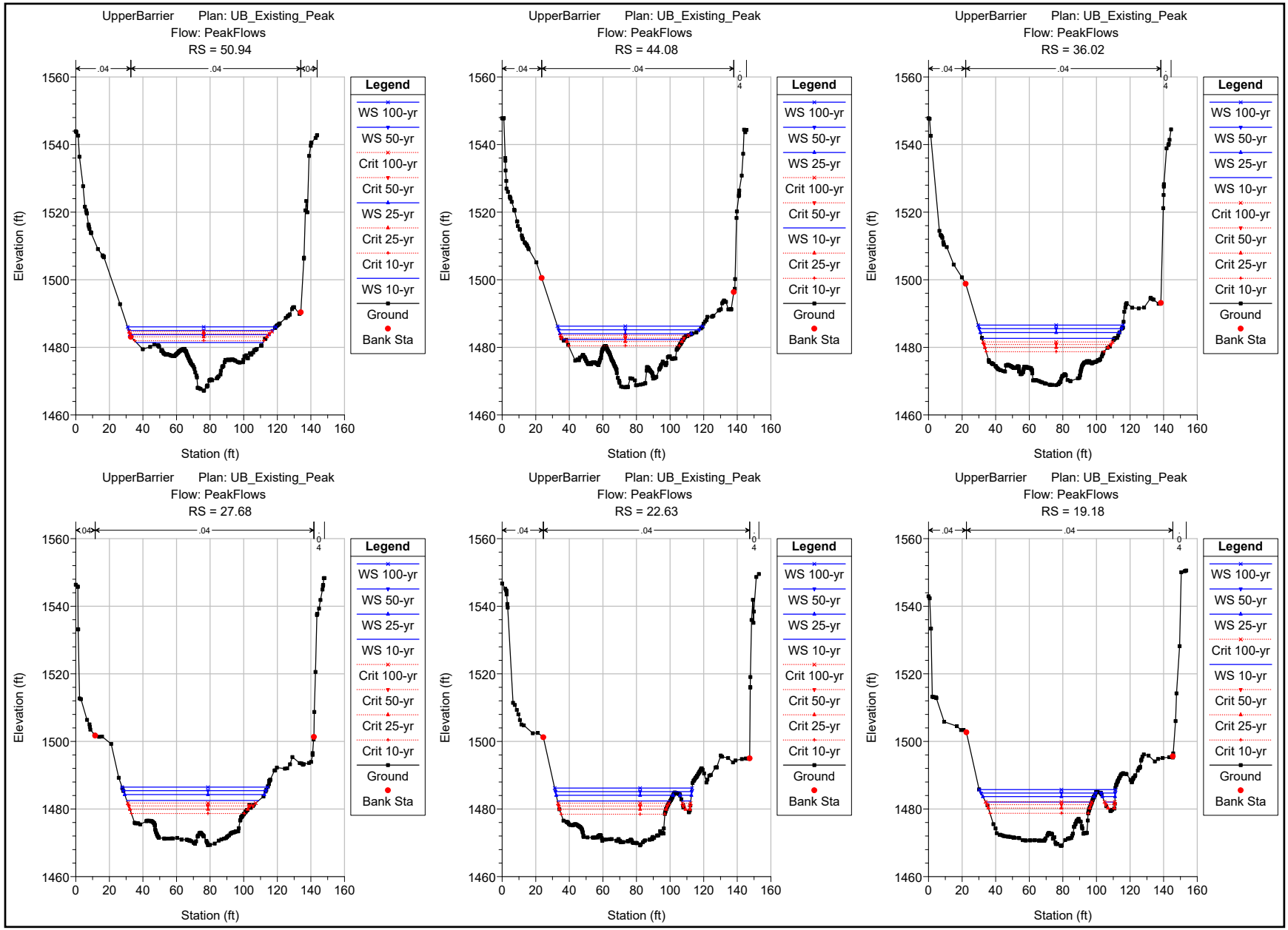

UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 182.24
Legend
WS 100-yr
Crit 100-yr
WS 50-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
WS 10-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 178.98
Legend
Crit 100-yr
Crit 50-yr
WS 100-yr
Crit 25-yr
WS 50-yr
Crit 10-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 176.07
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 173.32
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 170.38
Legend
WS 100-yr
WS 50-yr
WS 25-yr
Crit 100-yr
WS 10-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 168.25
Legend
WS 100-yr
Crit 100-yr
WS 50-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
WS 10-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)

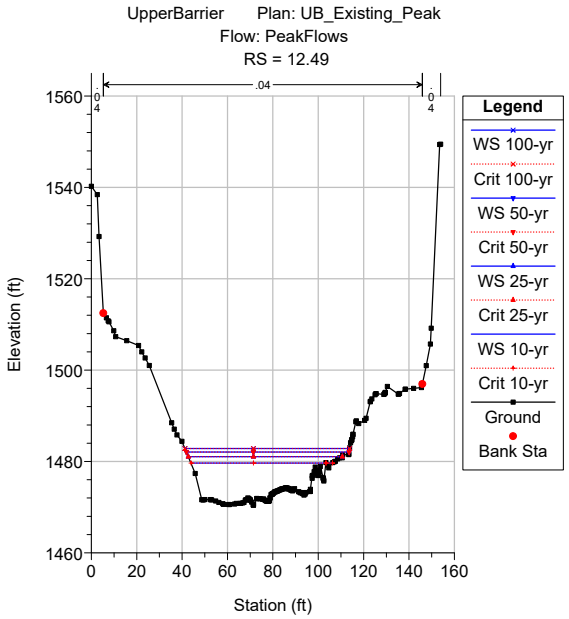

UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 166.43
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
WS 100-yr
Crit 25-yr
WS 50-yr
WS 25-yr
Crit 10-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 163.67
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
Crit 25-yr
WS 100-yr
WS 50-yr
Crit 10-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 161.45
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
Crit 25-yr
WS 100-yr
Crit 10-yr
WS 50-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 159.43
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
Crit 25-yr
WS 100-yr
Crit 10-yr
WS 50-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 157.42
Elevation (ft)
Station (ft)
Legend
WS 100-yr
Crit 100-yr
WS 50-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
WS 10-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 155.4
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
Crit 100-yr
WS 25-yr
Crit 50-yr
WS 10-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta


UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 153.38
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 151.36
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 149.35
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 147.33
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 145.31
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 143.29
Elevation (ft)
Station (ft)
.04
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta


UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 141.27
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 139.26
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
Crit 100-yr
WS 10-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 136.54
Elevation (ft)
Station (ft)
Legend
WS 100-yr
Crit 100-yr
WS 50-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
WS 10-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 133.07
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
WS 100-yr
WS 50-yr
Crit 25-yr
WS 25-yr
Crit 10-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 125.01
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
Crit 25-yr
WS 100-yr
WS 50-yr
Crit 10-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 115.23
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
WS 100-yr
Crit 50-yr
Crit 25-yr
WS 50-yr
Crit 10-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta


UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 83.88
Elevation (ft)
Station (ft)
Legend
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 75.5
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
WS 50-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 70.46
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 66.86
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
Crit 100-yr
WS 10-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 62.05
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
Crit 100-yr
WS 10-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 57.03
Elevation (ft)
Station (ft)
Legend
WS 100-yr
Crit 100-yr
WS 50-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
WS 10-yr
Crit 10-yr
Ground
Bank Sta


UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 50.94
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
Crit 100-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
Crit 10-yr
WS 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 44.08
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
Crit 100-yr
Crit 50-yr
WS 10-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 36.02
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 27.68
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 22.63
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
Crit 100-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta
UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 19.18
Elevation (ft)
Station (ft)
Legend
WS 100-yr
WS 50-yr
WS 25-yr
Crit 100-yr
WS 10-yr
Crit 50-yr
Crit 25-yr
Crit 10-yr
Ground
Bank Sta


UpperBarrier Plan: UB_Existing_Peak
Flow: PeakFlows
RS = 12.49
.04
0
4
0
4
Legend
WS 100-yr
Crit 100-yr
WS 50-yr
Crit 50-yr
WS 25-yr
Crit 25-yr
WS 10-yr
Crit 10-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
1560
1540
1520
1500
1480
1460
0
20
40
60
80
100
120
140
160