Relicensing Study 3.3.12

EVALUATION OF EMERGENCY GATE AND BYPASS FLUME DISCHARGES

Study Report

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

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EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for the Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018. This report documents the results of Study No. 3.3.12 *Evaluation of Emergency Gate and Bypass Flume Discharges*.

The historical upriver extent of the federally endangered Shortnose Sturgeon (*Acipenser brevirostrum*) populations on the Connecticut River is the Turners Falls Dam. A population of sturgeon resides in the area between Holyoke Dam and Turners Falls Dam, with one of two known spawning locations in close proximity to Cabot Station, the primary generation facility of the Turners Falls Project. Concerns were raised by stakeholders regarding the potential effects of spill events at the Emergency Spillway and the Log Sluice (i.e. Bypass Flume), located adjacent to the Cabot Powerhouse on Shortnose Sturgeon.

A two-phased approach to this study was conducted. First, FirstLight determined the frequency, intensity, and causes of high flow events through the Emergency Spillway and Log Sluice using data from 2005 through 2012 from April 1 through June 30. Though at least one emergency spill gate was open to some degree 60% of the time, most releases were of a small magnitude to sluice debris and/or ice, rather than discrete spill events. Releases greater than 1,500 cubic feet per second (cfs) were uncommon, occurring only 1.1% of the time, and spill events of this magnitude typically occurred when Cabot Station discharge was greater than 7,500 cfs. Spill events with flow greater than 1,500 cfs occurred 120 times during the study period, with a median duration of approximately 0.92 hours. During the study period, the Emergency Spillway released a maximum of approximately 8,233 cfs. Of the highest magnitude spill events from the Emergency Spillway, non-emergency events were the result of operations that are no longer standard procedure at Cabot Station, and have not occurred since 2008. Only six of these events occurred in 2009 and 2010, and none occurred in 2011 and 2012.

The Log Sluice is smaller than the Emergency Spillway, containing only one gate, and released up to approximately 1,720 cfs during the study period. Typical flow for downstream fish passage, occurring most of the time during the sturgeon spawning season, is approximately 219 cfs, with a fish passage weir in place. However, during high river flows or periods of high debris load, the weir may be pulled to pass ice and debris for an extended period, and the gate may be opened further during brief periods for trashrack cleaning at Cabot Station or for sluicing of logs and other debris. Sluicing operations are typically brief, with a median duration of 1.5 hours.

As part of the second phase, in lieu of field data collection, FirstLight used the River2D hydraulic model to simulate changes in velocity due to flow releases from the Emergency Spillway. The purpose of the modeling was to examine the potential effects of spill releases under different water surface elevations (WSELs), and to determine if a potential threshold exists by which velocity changes due to spill would result in high velocities in the sturgeon spawning area, along with sediment mobilization.

The River2D model was calibrated and validated for use with the instream flow study (Study No. 3.3.1) for areas around Cabot Station. The model was calibrated to WSELs collected from 20 water level recorders, including in the sturgeon spawning area, installed from May until October 2014. In addition, the model was calibrated to velocities in key locations as measured by an acoustic Doppler profiler during the summer of 2014 under a wide range of flow conditions. The upstream flow boundary for the model is located about 800 feet above Rawson Island and about 2,100 feet above Rock Dam. Inflow at this location represents discharge from Station No. 1, the Turners Falls Dam, the Fall River, and other smaller inflow sources. Near the middle of the River2D area, inflow was modeled from Cabot Station and the nearby emergency spillway gates. Near the lower part of the River2D model is the confluence of the Deerfield River; the downstream boundary is near the United States Geological Survey (USGS) gage on the Connecticut River at Montague City. During field studies associated with Study No. 3.3.1 (*Instream Flow Study*), substrate classification data were collected in the vicinity of Cabot Station and the sturgeon spawning area.

With River2D, 10 baseline scenarios were modeled including Cabot Station generating without flows from the emergency spillway gates, with varying flows in the bypass reach and from the Deerfield River. To model emergency spillway gate operations, nine scenarios were modeled including flows from the emergency spillway gates and Cabot Station generating or not generating, with varying flows in the bypass reach and from the Deerfield River. These scenarios produced WSELs, velocity, shear stress, and other variables at each of the over 30,000 nodes of the modeled area. The potential for substrate mobilization (relative shear stress) was determined by dividing shear stress by critical stress. Relative shear stress is very sensitive to particle size since smaller particles have a smaller critical stress meaning that higher relative shear stress represents higher substrate mobilization potential. FirstLight analyzed the changes in the velocity and relative shear stress between baseline conditions and emergency spillway gate operations among scenarios with the same total river flow. These analyses indicated that higher velocities and relative shear stress generally occur on the western side of the main channel during operation of the emergency spillway gates. However, the location and magnitude of these values and changes are dependent on the relative amount of flow from the emergency spillway gates, Cabot Station, and the bypass reach.

During all modeling scenarios, suitable velocities were present within the defined sturgeon spawning area, though higher velocities were observed within the spawning area as well, with the largest areas of high velocity present during the greater discharges (i.e. 5,000 and 8,000 cfs) modeled from the emergency spillway. Given the size of the spawning area and the relatively narrow areas affected by increased velocity and suspended sediment resulting from emergency spill events, sturgeon could move relatively short distances to a more suitable area if a spill event occurred during spawning, or wait until the conditions subside.

Flow events from the emergency spillway at Cabot Station have the potential to mobilize sandy substrate at all spill flows modeled, with some variability resulting from different operational conditions. Mobilized substrate has the potential to affect sturgeon eggs and larvae. However, mobilization of sand and fine-grained substrates in the study area may also occur in the absence of discharge from the emergency spillway, with large areas of mobilization predicted during relatively common springtime bypass reach flows. These conditions occur naturally, at comparable magnitudes to conditions modeled over a range of emergency spillway discharges. High bypass flows will also occur over longer time periods than the brief discharge events from the emergency spillway.

During recent years, FirstLight has modified operation of the emergency spillway gates, such that spill events of the greatest magnitude only result from emergencies. In these cases, spill was necessary to ensure station viability and/or public safety. It is anticipated that release of high flows from the emergency spillway in the future will only be due to emergency events.

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cfs	cubic feet per second
CRASC	Connecticut River Atlantic Salmon Commission
ELS	Early Life History Stage
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
ft/s	feet per second
ILP	Integrated Licensing Process
ISR	Initial Study Report
MA	Massachusetts
mm	millimeter
NGVD	National Geodetic Vertical Datum
NH	New Hampshire
NMFS	National Marine Fisheries Service
Northfield Mountain Project	Northfield Mountain Pumped Storage Project
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
RSS	Relative Shear Stress
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
TFI	Turners Falls Impoundment
Turners Falls Project	Turners Falls Hydroelectric Project
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VY	Vermont Yankee Nuclear Power Plant
VT	Vermont
WSEL	Water Surface Elevation

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain Project and Turners Falls Project using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the two Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

On August 27, 2013 Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon Impoundment on the Connecticut River and upstream of the two Projects, will be closing no later than December 29, 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013 regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies on February 21, 2014, approving the RSP for Study No. 3.3.12 with certain modifications. The SPDL required FirstLight to conduct an analysis of historical emergency water releases for the period 2005 through 2012, with regard to effects on federally-listed Shortnose Sturgeon (*Acipenser brevirostrum*). FirstLight was then required to consult with stakeholders to determine the need for fieldwork.

The Initial Study Report (ISR) for this study was filed with FERC in September 2014 and included an analysis of gate operations on a 10-minute time step for years 2005-2012 during the Shortnose Sturgeon spawning period, April through June. The results were presented at the ISR meeting on September 30, 2014. Additional information related to discussions at the ISR meeting was filed with the meeting summary on October 15, 2014. Some stakeholders filed comments and posed additional questions on the data analysis and next steps related to evaluating the impact of emergency gate spill events on Shortnose Sturgeon spawning and rearing habitat downstream of Cabot Station.

On January 22, 2015, FERC issued its Determination on Requests for Study Modifications and New Studies with guidance on how to proceed on this study. FERC recommended that FirstLight complete the historical data analysis and consult with stakeholders by March 31, 2015, so that if fieldwork is necessary, it could be conducted during the 2015 field season. A meeting was held with interested stakeholders on February 4, 2015 to discuss Study No. 3.3.12 and other relicensing studies. During this meeting, FirstLight agreed to re-analyze operations data on 1-minute time steps during selected periods, to confirm the reasons for use of the Cabot Station emergency spillway gates. In addition, FirstLight agreed to investigate and describe, if appropriate, a study approach using the River 2D hydraulic model to evaluate velocity changes in the study area due to emergency spillway gate releases in lieu of field velocity measurements.

On March 18, 2015, FirstLight provided stakeholders with a memo containing additional analysis related to the study. On March 24, 2015, FirstLight held a meeting to discuss Study No. 3.3.12 and other relicensing studies. It was agreed that field data collection would not be performed for this study. Instead, FirstLight agreed to conduct its River2D hydraulic analysis to define the critical flow from the emergency spill gates that would result in sedimentation/scour in sturgeon spawning habitat under different bypass reach flows and tailrace water surface elevations (WSELs). In light of the additional information provided after the ISR was filed, as well as the analyses contained in this report, the ISR for this study should be considered superseded by this report.

1.1 Background

The Shortnose Sturgeon (*Acipenser brevirostrum*) was listed as endangered by the U.S. Fish and Wildlife Service (USFWS) on March 11, 1967, and remains on the endangered species list. Adult sturgeon typically occur in freshwater or freshwater/tidal reaches of rivers, but may undertake spawning migrations between river systems (Fernandes *et al*., 2010). They spawn in freshwater, typically near the most upstream reaches that are accessible to the fish (NMFS, 1998). Part of the Connecticut River population of Shortnose Sturgeon exists between Holyoke Dam and Turners Falls Dam (Kieffer & Kynard, 2012).

One of the two known spawning and rearing areas in the Connecticut River is located within the Cabot Station tailrace. They spawn in the spring, typically in late-April to mid-May, and have only been known to spawn when the total mean daily river discharge was less than ~35,315 cfs. Shortnose Sturgeon spawning habitat in the study area comprises areas of relatively swift flow (1-4 ft/s), depths ranging from 4 to 17 feet, and primarily rubble substrate (Kieffer & Kynard, 2012). Female Shortnose Sturgeon spawn eggs in discrete batches during multiple spawning bouts. Once spawning commences, females will deposit their eggs until completion, which could take 20 hours or more (Kieffer & Kynard, 2012). Eggs are adhesive, and stick to substrate, often in cobble/rubble areas downstream of spawning locations in areas with current, where they incubate for approximately two weeks at 8-12ºC water temperatures. Larval sturgeon will hide in the substrate for 12 days before swimming up and drifting downstream to deeper water areas.

The emergency spillway gates are located adjacent to the Cabot Powerhouse and discharge water into the Connecticut River upstream of the station and fishway. The log sluice discharges water into the river on the downstream side of the station. These structures are in close proximity to the sturgeon spawning area, and upstream of egg incubation and larval sturgeon habitat.

1.2 Study Goals and Objectives

The goal of this study is to determine the frequency of spill events during the sturgeon spawning period, and, if deemed necessary, determine appropriate protocols for operation of the emergency spillway gates and log sluice gate that will be sufficiently protective of sturgeon spawning and nursery areas below Cabot Station from excessive water velocities and exposure to abrasive sediments dislodged and transported across spawning and rearing areas.

The objectives of the study are to:

1. Determine the frequency with which the emergency spillway gates are operated to discharge large quantities of water.

2. Describe the operation of the log sluice gate that results in bypass flume spill events.

3. Evaluate the impact of these events on sediment transport and bottom velocities within known Shortnose Sturgeon spawning and rearing habitat below Cabot Station.

2 PROJECT FACILITIES AND STUDY AREA

The Turners Falls Project is located on the Connecticut River in the towns of Gill and Montague, MA with a project boundary that extends upriver into NH and VT. The principal components of the Turners Falls Project (Figure 2.0-1) include the Turners Falls Dam, bypass reach, gatehouse, power canal, Station No. 1 and Cabot Station, located at the downstream end of the power canal. Water enters the power canal from the Turners Falls Impoundment (TFI) at the gatehouse and can be released via Station No. 1 and Cabot Station generation, through the Cabot emergency spillway gates (upstream of Cabot Station), and from the log sluice gate just downstream from the Cabot Station powerhouse intake. Emphasis of this study is on the emergency spillway gates and log sluice gate. Water can also be released through the fishways at Cabot Station (Cabot fishway) and Turners Falls Dam (spillway fishway), as well as from other water users along the canal. Water not utilized for generation or other releases mentioned is passed over the Turners Falls Dam and flows through the bypass reach from the dam to Cabot Station.

N

0 500 1,000 2,000 Feet

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Figure 2.0-1: Overview of the Turners Falls Project

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2.1 Turners Falls Power Canal Emergency Spillway Gates

The emergency spillway gates (Figures 2.1-1 and 2.1-2), adjacent to and upstream of Cabot Station, comprise 10 vertical, downward-opening slide gates that are 12 feet wide by 12 feet high, with individually driven rack and pinion operators. Eight of the gates are used to discharge canal flows and two of the gates supply attraction water to the Cabot fish ladder. In this report, these eight gates are referred to as the "spill gates."

The discharge capacity of these eight spill gates is approximately 12,000 cubic feet per second (cfs) at the normal canal level of 173.5 feet (NGVD 1929 datum). The maximum Cabot fish ladder attraction water provided through the other two gates is approximately 335 cfs.

The canal level at Cabot Station is constantly monitored. For safety reasons, the spill gates automatically open and the gates at the Turners Falls Gatehouse automatically close in the event an abnormal high or low canal level is detected, or when there is a load rejection at Cabot Station. An abnormally low canal level could indicate a dike breach which could cause inundation of houses along Montague City Road. A load rejection at Cabot Station could cause the canal level to rise and overflow, inundating surrounding areas. During events when the gates are operated automatically, the canal level will drop rapidly and excess water would flow through the spill gates for a short period, just minutes.

The gates are used for operational reasons as well. During periods of high river flows, at least one spill gate will be opened to allow river debris entering the canal to be discharged back to the river to prevent obstructions at the Cabot Station intake racks. Likewise in the winter and spring, when there is excess ice in the canal, gates will be opened to route ice down the spillway. Operators will also routinely open one or more gates when necessary to help remove debris from the trash boom. During these periods, operators may also temporarily reduce generation - the load reduction allows for debris to be moved off the log boom. The gates discharge back to the river just upstream of Cabot Station.

Figure 2.1-1: Locations of the Spillway Gates and Log Sluice at Cabot Station

View of Cabot Station Spillway Area during low water levels and no gates open.

View of Cabot Station Spillway Area during high water levels and one gate open

Figure 2.1-2: Photographs of Cabot Station Spillway

2.2 Log Sluice Gate

Past the Cabot Station intake and trashracks is a gated log sluice that has been enhanced to provide downstream fish passage past Cabot Station. In this report, the gate controlling water passage through this opening is referred to as the "sluice gate", which is a downward-opening slide gate. The sluice has been resurfaced to provide a passage route, and above-water lighting and a fish sampling facility have been added. Although the sluice gate is approximately 16 feet wide, there is an 8 foot wide weir that is inserted in the sluice opening during downstream fish passage periods. The weir has an elliptical floor, and was developed specifically to enhance fish passage. The sluice discharges to the river just downstream of Cabot Station (Figures 2.1-1 and 2.2-1).

The sluice gate is utilized as a downstream fish passage facility at Cabot Station, and operated in accordance with a schedule provided by the Connecticut River Atlantic Salmon Commission (CRASC) during the period of study. The schedule for the downstream fish passage facility at the Turners Falls Project is as follows:

- Atlantic Salmon smolts April 1 – June 15[1]
- Atlantic Salmon adults October 15 – December 15[2]
- American Shad adults April 7 – July 31
- American Shad juveniles August 1 – November 15
- American Eel adults September 1 – November 15

During these times, a continuous flow is maintained through the sluice gate and the fish passage weir is in place, except for brief periods of sampler deployment or rack maintenance and longer periods when high river flow would pose an erosion threat at the sluice discharge if the gate were left open. This opening can also be used to pass debris downstream; the fish passage weir may be removed at times to facilitate clearing the intake racks of debris. Gate openings greater than 7 feet usually indicate a period of intake rack cleaning.

[1] In a letter to FERC from CRASC, dated February 11, 2016, CRASC will no longer be requiring downstream passage for Atlantic Salmon smolts at the main-stem hydroelectric projects.
[2] Downstream passage operation for adult salmon will only be required if 50 or more adults are documented as passing upstream at this facility. For this study, the status of the salmon passage effort is not relevant, because the downstream fish passage facility will be open during the sturgeon spawning period for adult American shad.

View of Sluice Gate discharge during typical operation, from above

Upstream View of Sluice Gate discharge location

Figure 2.2-1: Photographs of Cabot Station Sluice Gate

2.3 Shortnose Sturgeon Spawning and Rearing Habitat

One of the two spawning sites known to exist within the Project boundary is in close proximity to Cabot Station, with shoals downstream available for rearing of early life history stages (ELS) of sturgeon (Figure 2.3-1). The spawning area was identified by Kieffer & Kynard (2012) and the locations of shoals were derived from bathymetry as part of Study No. 3.3.1. Modeling efforts focused on the areas around and including these habitats.

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Figure 2.3-1: Shortnose Sturgeon Spawning Area and Downstream Shoals in the Vicinity of Cabot Station

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3 METHODS

3.1 Frequency Analyses

For the initial analyses, gate opening data from 2005 through 2012 were obtained from FirstLight's operations records on a 10-minute time step, April 1 – June 30 annually. In addition to the gate openings, additional operations data obtained from FirstLight included the canal forebay elevation, Cabot Station generation in megawatts - converted to discharge, and approximate bypass reach discharge calculated from Turners Falls Dam (via gate rating curves) and Station No. 1 (via MW vs cfs relationship).

Flow Calculations

Flow over each spill gate, and through the sluice gate, was calculated based on the head atop each gate using the standard weir equation:

$Q = C*L*H^{1.5}$, where,

Q is discharge (in cfs)

C is the weir coefficient (unitless)

L is the length of each gate (in feet)

H is the head or depth of water atop the gate crest (in feet).

A weir coefficient of 3.3 was used for the spill gates and a coefficient of 3.1 was used for the sluice gate.

Emergency Spill Gates (10-minute data)

The top elevation of the eight spill gates varies between about 174.1 and 174.7 feet when fully closed. When calculating head over the spill gates, an average top of gate elevation of 174.4 feet was used for all the spill gates. FirstLight's system records the gate opening relative to its fully closed position. For example, if the gate is fully closed at elevation 174.4 feet and at a particular time the crest is at 170.4 feet, the system reports the gate level as 4.0 feet. The normal WSEL in the canal is 173.5 feet[3]. A gate was defined as open if the value was > 1.2 feet (this accounts for the difference between the top of gate elevation of 174.7 feet and normal canal level of 173.5 feet).

Histograms were developed with the Statistical Package R (R Core Team, 2015) to evaluate the frequency of spill flows from all data observed on a 10-minute time step. Additionally, discrete spill events were identified, and average flows for high spill events (flow > 1,500 cfs) were compared with average flows through the bypass reach and from Cabot Station to characterize operational conditions during spill events.

The number of Cabot spill gates open at each 10-min interval was computed, and then the frequency of times when 0 through 8 gates were open was calculated. The results were tabulated to show frequency of spill gate and sluice gate openings per year (during the period of interest).

Emergency Spill Gates (1-minute data)

Data related to gate openings were initially analyzed on a 10-minute step. After further discussions with the FirstLight operators, this time step may not have been adequate to fully characterize emergency related

[3] Note that all FirstLight gages which measure the WSEL are based on the Natural Geodetic Vertical Datum (NGVD) of 1929.

events at the spill gates. Therefore, data on a one-minute time step were obtained and analyzed for the periods when more than four gates were open, as identified in the initial report.

Data series were obtained from FirstLight for: canal forebay WSEL; opening of each of the emergency spill gates; Cabot Station generation, Station No. 1 generation, and flow over Turners Falls Dam. Forebay elevation and gate openings were used to calculate total discharge through the gates in cfs, and Cabot Station generation was converted from megawatt output to total discharge in cfs. Also shown in each figure is river flow as measured on the Connecticut River at the United States Geological Survey Gage (USGS) No. 01170500 near Montague City, MA on a 15-minute time step and prorated to remove the Deerfield River[4] flow.

Sluice Gate

The top of the sluice gate is at elevation 175.1 feet (approximately) when the gate is closed, and normal canal forebay elevation equals 173.5 feet, so no water would typically be flowing over the gate at gate openings up to about 1.6 feet due to freeboard. For this analysis, reported gate opening values less than 1.5 feet open indicated that the gate was closed. Spill was calculated if the reported elevation of the gate crest was greater than 1.5 feet below the fully closed position.

Gate openings greater than 7 feet typically indicate that the fish passage weir was removed temporarily to facilitate cleaning the intake racks of debris. During these periods, when the fish weir is removed, the width of the weir is 16 ft.

Histograms were developed with the Statistical Package R (R Core Team, 2015) to evaluate the frequency of spill flows of all data observed on a 10-minute time step. Additionally, discrete events were identified, and average flows for high spill events (flow > 400 cfs) were compared with average flows through the bypass reach and from Cabot Station.

3.2 Selection of Modeling Scenarios

Two different types of scenarios were modeled in River 2D hydraulic model for this study:

- Baseline Conditions: Cabot Station generating without flows from the emergency spillway gates (Scenarios B1a – B7) and varying flows in the bypass reach and from the Deerfield River (Table 3.2-1).
- Emergency Spillway Gate Releases: Flows from the emergency spillway gates and Cabot Station generating or not generating (Scenarios E1a S1500 – E6 S8000[5]) and varying flows in the bypass reach and from the Deerfield River (Table 3.2-2).

Release scenarios were compared with baseline scenarios to describe the potential changes in velocity and sediment mobilization in the vicinity of Cabot Station as a result of different emergency spill gate releases and over a range of typical operational conditions. The baseline scenarios (Table 3.2-1) represent a combination of low (1,500 cfs) to medium (3,000 and 5,000 cfs) to high (14,000 cfs[6]) Cabot Station generation discharges, varying bypass flows, and no discharge from the emergency spillway gates. Under baseline conditions (Scenarios B1a and B1b) during low flow periods, the bypass flow value of approximately 500 cfs is representative of the sum of minimum flows from Turners Falls Dam, leakage from Station No.1, and inflow from Fall River which enters the bypass reach just downstream of Turners Falls Dam. Other scenarios include higher bypass flows of 2,500, 10,000, and 20,000 cfs that are more common during the spring months when Shortnose Sturgeon may be occupying the spawning habitat.

[4] There is also a USGS Gage on the Deerfield River at West Deerfield, MA (Gage No. 01170000)
[5] In this designation, the second number (S8000) specifies the modeled flow through the emergency spillway gates.
[6] Technically, the hydraulic capacity of Cabot Station is 13,728 cfs; however, it was rounded to 14,000 cfs for this analysis.

Modeled flows from the Deerfield River varied in the scenarios from 200 cfs during low flow conditions, to 1,445 cfs during higher flow conditions. These flow values are representative of the minimum flow requirement and maximum generation flow at the Deerfield River Project Station No. 2, the lowermost development on the Deerfield River. Analyses of the modeling results indicated that the Deerfield River flows in this range have a very limited effect on velocities in the sturgeon spawning area. In addition, while not modeled for this analysis, higher Deerfield River flows would tend to create a higher tailwater conditions and lower velocities in the sturgeon spawning area.

The emergency spillway gate release scenarios (Table 3.2-2) include low flow conditions where Cabot Station generation discharges were stopped (a load rejection) and all of the flow was routed through the emergency spillway gates with bypass flows of 500 cfs and 2,500 cfs. Other modeled emergency spillway gate release scenarios included conditions when Cabot generates with either 6,000, 9,000, or 11,000 cfs and flow through the emergency spillway gates were 8,000, 5,000, or 3,000 cfs for a total of 14,000 cfs from both sources and bypass flows of 2,500 and 10,000 cfs.

Table 3.2-1: Baseline River2D Modeling Scenarios

Scenario	Bypass Flows (cfs)	Cabot Flows (cfs)	Deerfield Flows (cfs)	Emergency Spillway Gates (cfs)	Total Flow (cfs)	Downstream Model Boundary WSEL (ft)
B1a	500	1,500	200	0	2,200	32.21
B1b	500	1,500	1,445	0	3,445	32.47
B2a	2,500	1,500	200	0	4,200	32.62
B2b	2,500	1,500	1,445	0	5,445	32.83
B3	2,500	3,000	1,445	0	6,945	33.06
B4	2,500	5,000	1,445	0	8,945	33.30
B5a	500	14,000	1,445	0	15,945	34.11
B5b	2,500	14,000	1,445	0	17,945	34.30
B6	10,000	14,000	1,445	0	25,445	34.88
B7	20,000	14,000	1,445	0	35,445	35.34

Table 3.2-2: Emergency Spillway Releases River2D Modeling Scenarios

Scenario	Bypass Flows (cfs)	Cabot Flows (cfs)	Deerfield Flows (cfs)	Emergency Spillway Gates (cfs)	Total Flow (cfs)	Downstream Model Boundary WSEL (ft)
E1a S1500	500	0	200	1,500	2,200	32.21
E2a S1500	2,500	0	200	1,500	4,200	32.62
E3 S3000	2,500	0	1,445	3,000	6,945	33.06
E4 S5000	2,500	0	1,445	5,000	8,945	33.30
E5b S3000	2,500	11,000	1,445	3,000	17,945	34.30
E5b S5000	2,500	9,000	1,445	5,000	17,945	34.30
E5b 8000	2,500	6,000	1,445	8,000	17,945	34.30
E6 S5000	10,000	9,000	1,445	5,000	25,445	34.88
E6 S8000	10,000	6,000	1,445	8,000	25,445	34.88

3.3 Velocity and Shear Stress Modeling

Velocity and shear stress were modeled to determine the potential effects of emergency spillway gate operation on Shortnose Sturgeon. Velocity data during spill events were compared to suitable spawning conditions based on habitat suitability criteria. The modeling provides average water column velocity, which was used as a surrogate for bottom velocity, though bottom velocities are expected to be lower than average column velocity. Shear stress was also modeled, and relative shear stress was calculated to predict sediment mobilization.

3.3.1 Two-Dimensional Hydraulic Model Summary

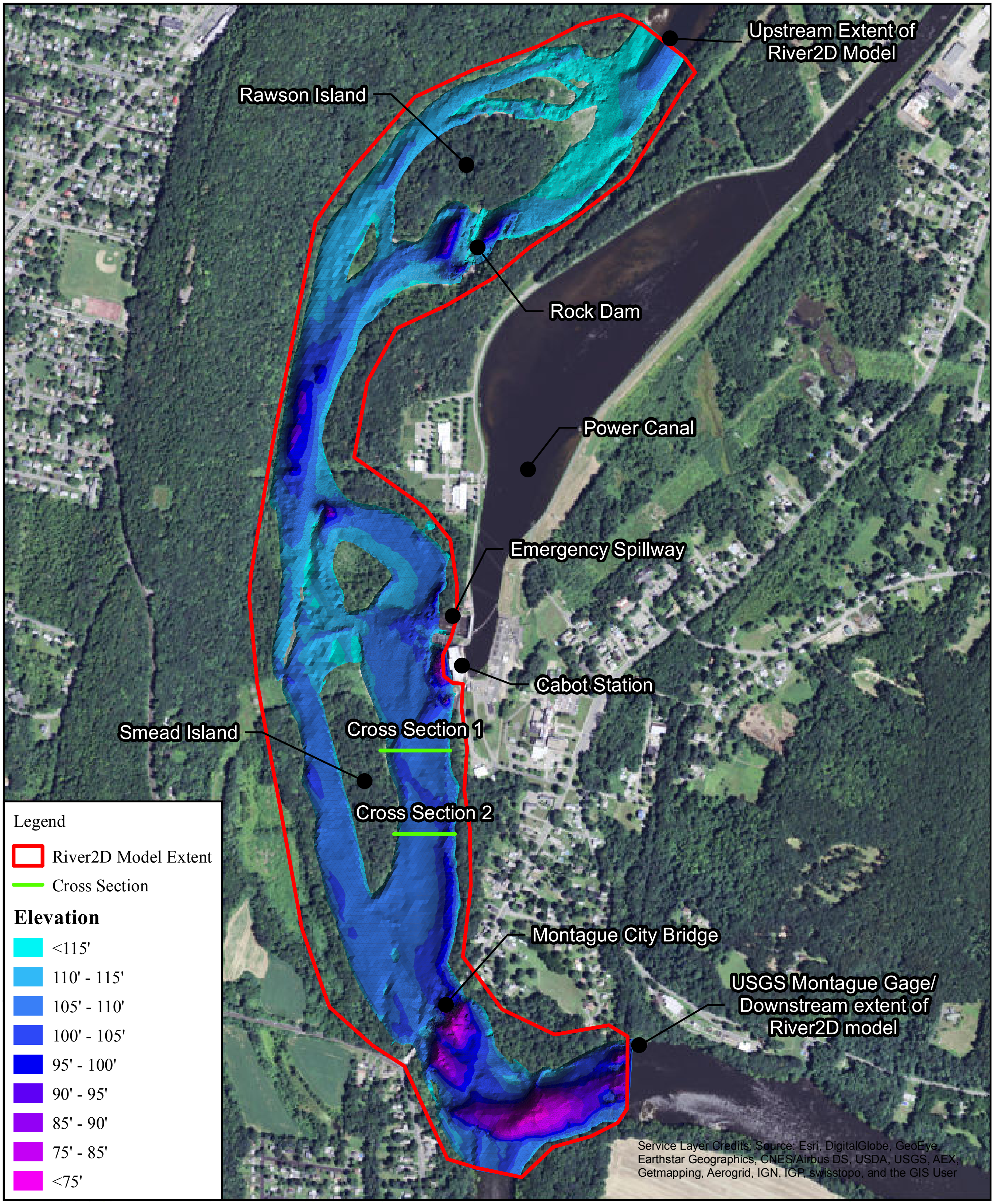
FirstLight used the two-dimensional hydraulic model, River2D that has been developed for use in Reach 3 portion (i.e., from Rock Dam downstream to the Deerfield River confluence) of the Study No. 3.3.1 *Conduct Instream Flow Habitat Assessments in the Bypass Reach and below Cabot Station* to model releases from the emergency spillway gates. River2D was developed at the University of Alberta with funding from the Natural Sciences and Engineering Research Council of Canada, the Department of Fisheries and Oceans, Government of Canada, Alberta Environmental Protection, and the USGS. River2D is a suite of programs, which is publicly available and free-of-charge[7], which includes R2D_Bed and R2D_Mesh. This section provides a brief technical background on the development of a River2D model, which contains technical terms relating to hydraulics and hydrology. Whenever possible, effort has been made to simplify hydraulic concepts presented; however, if further clarification or explanation is desired, the reader is referred to the Users Manuals for each respective program[8].

The River2D model is a two-dimensional finite element depth averaged hydrodynamic and fish habitat model developed for use in natural streams and rivers. River2D solves for mass conservation and momentum balance in two dimensions using the St. Venant flow equations. River2D is designed to perform both steady (flow does not change over time) and unsteady (flow changes over a time) flow routing. The software predicts WSELs, river depths, and depth-averaged velocities at various locations under a range of flows.

The River2D model utilizes a bed topography file and overlays a computational mesh file. R2D_Bed is an interactive and graphical bed topography file editor, which defines points with horizontal and vertical locations as well as an associated roughness value for use in the River2D model. This file is usually comprised of bathymetry, LiDAR, or other observed elevation data. It should be noted that the roughness values in River2D are not the same as the Manning's n values typically used in one-dimensional modeling. This two-dimensional resistance term, roughness, only accounts for the direct bed shear, and represents the height of the bed roughness in meters. Therefore observations of bed material and bedform size are usually sufficient to establish reasonable initial roughness estimates. While the program provides a tool which estimates an appropriate roughness value based on a Manning's n roughness and a hydraulic radius, it is always better to develop roughness values through calibration where possible, as was done for this study (see Section 4, below). R2D_Mesh is an interactive and graphical mesh file editor, which is used to build a finite element mesh in order to generate an input file for River2D. R2D_Mesh defines a set of spatially distributed points or "nodes" throughout the study area, which extract an elevation and roughness value from the underlying bed file. It then creates a linearly-interpolated triangulated mesh from the set of nodes, with each triangle referred to as an "element". The boundary conditions including the computational extents are also defined in R2D_Mesh. Inflow boundaries can be either constant or time-varying, while outflow boundaries can be fixed or time-varying elevations, a stage-total discharge relationship, or a depth-unit discharge relationship. Many of the functions in R2D_Mesh are available within River2D. Transient, or unsteady, boundary conditions must be defined within the River2D user interface, rather than R2D_Mesh.

[7] Main Page of River2D website: http://www.river2d.ca/
[8] River2D User's Manual (Steffler & Blackburn, 2002), R2D_Bed User's Manual (Steffler, 2002), and R2D_Mesh User's Manual (Waddle & Steffler, 2002).

The processes utilized in the development of the bed and mesh files for this study are briefly summarized below, but will be presented in more detail in Study Report No. 3.3.1, when filed with FERC. It should be noted that while the River2D requires the use of the metric system for all inputs (i.e., meters and cubic meters per second), this study uses the U.S. Customary system of units (i.e., ft and cfs). River2D Bed was used to create a seamless bathymetric/topographic surface for the study reach using the bathymetric and LiDAR data (Figure 3.3.1-1). River2D Mesh was used to represent the topography of the bed file, but aims to create mesh elements which are reasonably close to equilateral, as this is a preference of the River2D software.



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AND BYPASS FLUME DISCHARGES

N

0 500 1,000 2,000 Feet

Figure 3.3.1-1:
River2D Model Extent

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3.3.2 Model Calibration and Boundary Conditions

Model calibration requires the use of observed data. The River2D model was calibrated and validated for use with the instream flow study (Study No. 3.3.1) associated with the lower part of Reach 2 and Reach 3; detailed descriptions will be provided in Study Report No. 3.3.1. The model was calibrated to WSELs collected from 20 water level recorders installed from May until October 2014 (Figure 3.3.2-1). In addition, the model was calibrated to velocities in key locations as measured by an acoustic Doppler profiler during the summer of 2014 under a wide range of flow conditions. While flow from Turners Falls Dam and other sources have their own accuracy variation and steady-state conditions rarely exist, calibration to measured WSELs were generally in the 0.25 ft +/- during the calibration periods (close to steady-state conditions) that were used during model development. The model also achieved a calibration to measured velocities generally in the +/- 15% range.

The upstream flow boundary for the model is located about 800 feet above Rawson Island and about 2,100 feet above Rock Dam (Figure 3.3.1-1). Inflow at this location represents discharge from FirstLight's Station No. 1, the Turners Falls Dam, the Fall River, and other smaller inflow sources. Near the middle of the River2D area, inflow was also modeled from FirstLight's Cabot Station and from the nearby Emergency Spillway which consists of 8 gates each about 13.6 feet wide. Near the lower part of the River2D model is the confluence of the Deerfield River. The downstream boundary is near the USGS Montague Gage located close to the Keystone Bridge. The location for the downstream boundary near the USGS gage provides a wide range of accurate and documented flow versus stage conditions that were used for the downstream condition. During field studies associated with Study 3.3.1, substrate classification data was collected in all of Reach 3 including near Cabot Station and the sturgeon spawning area. This field data was processed by GIS and used in the River2D model (Figure 3.3.2-2).

3.3.3 Shear Stress and Relative Shear Stress Calculations

River2D is capable of predicting depth-averaged hydraulic parameters including depth, velocity, shear stress, and other variables. FirstLight used the model's velocity and shear stress output to estimate sediment mobilization potential throughout the area of interest. Three types of stress (shear, critical shear, and relative shear) are commonly used in describing substrate mobilization and general definitions are provided below:

- Shear Stress: A measure of a river's ability to entrain substrate caused by flow acting on the substrate interface;
- Critical Shear Stress: The amount of shear stress required to mobilize bed material and is based partly on the grain size of the substrate; and
- Relative Shear Stress: Shear stress divided by critical shear stress and indicates the potential for mobilization of the substrate.

A common way to determine substrate mobilization potential is by comparing a location's shear stress to the critical shear stress of the substrate found at that location. Critical shear stress is the shear stress at which a particle has a 50% chance of being mobilized from the river channel. For non-cohesive sediments critical shear stress generally increases with particle size, though there are other factors (e.g., particle density) that are also important. The relationship between shear stress and critical shear stress is sometimes expressed as a ratio called relative shear stress (RSS). RSS is calculated as a given location's shear stress at a given flow divided by critical shear stress. Higher relative shear stress values are an indication of a higher mobilization potential of the substrate. General methods for calculating relative shear stress are provided below:

An output variable from River2D is Shear Velocity Magnitude: (U*)

The Shear Velocity Magnitude is related to Shear Stress (τ) (units of Pascals or lbs/ft^2) by: $U^* = (\frac{\tau}{\rho})$

Where: ρ = density of water (1,000 kg/m^3 or 62.4 lbs/ft^3) and

τ = a location's shear stress (N/m$_2$ or psf)

Grain size (Table 3.3.3-1) in mm can be related to the Critical Shear Stress(τ_C) using the equations laid out in Figure 11-11 of NRCS (2007).

For grain size above 10 mm, we used the Colorado Data trendline equation

Where: Stable Particle Diameter (mm) = $152.02(\tau_C)^{0.7355}$

For grain size 10 mm and below, we used the Leopold, Wolman, and Miller trendline equation

Where: Stable Particle Diameter (mm) = $77.966(\tau_C)^{1.42}$

There is no definitive set threshold for which the Colorado data and Leopold, Wolman, and Miller trendlines are applicable. Additionally, there are some areas of overlap in the two datasets for particles sizes between 2 mm and 400 mm. We arbitrarily chose 10 mm as the cutoff point to switch between the two equations.

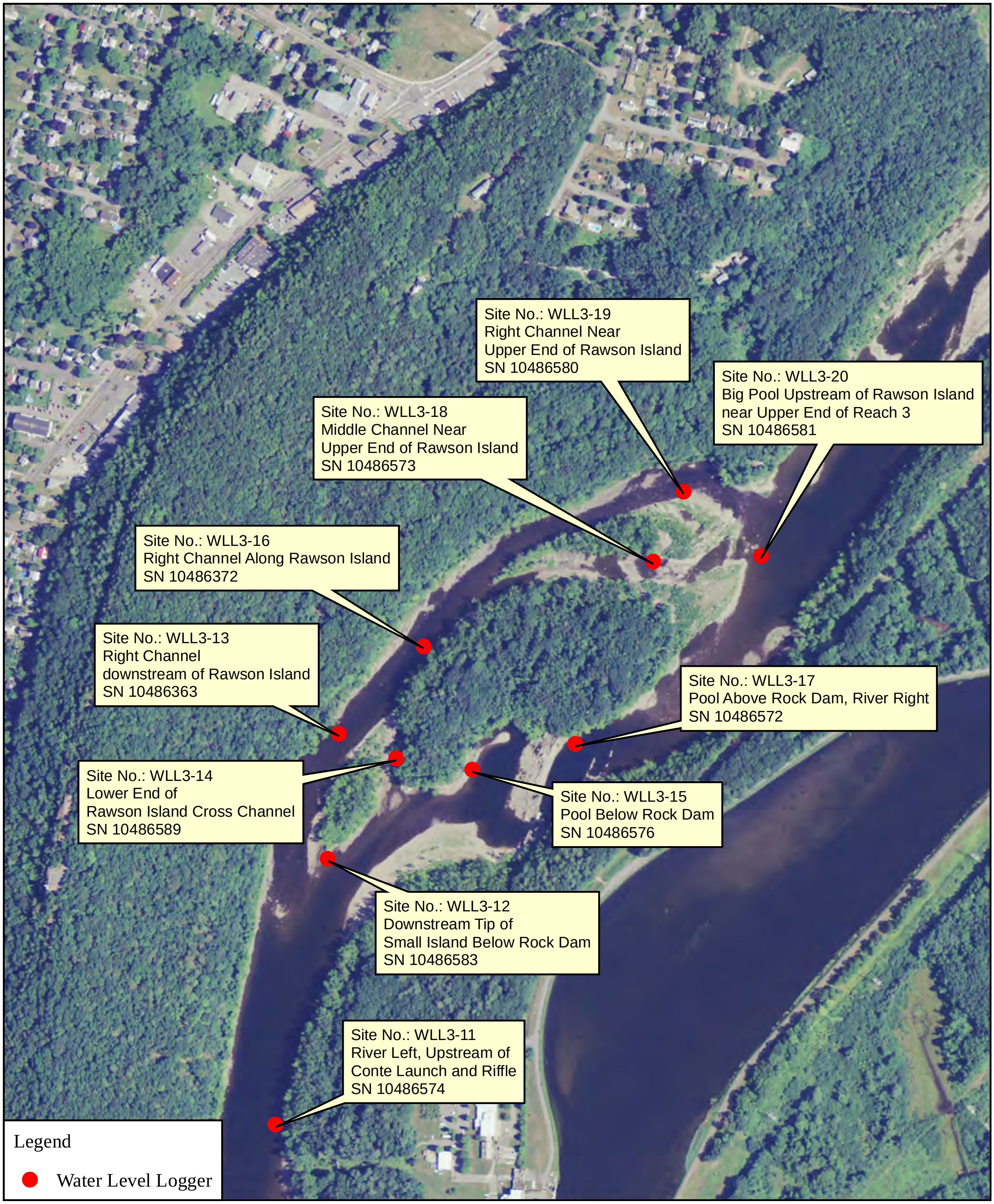
Relative Shear Stress, as the ratio of shear stress to critical shear stress, is defined as: $\tau_R = \tau / \tau_C$.

Where: τ = Shear Stress and

τ_C = Critical Shear Stress

Table 3.3.3-1: Substrate Classification and Grain Size

Substrate	Size (mm)
Silt	<0.062
Sand	0.062 to 2.0
Gravel	2.0 to 64
Cobble/Rubble	64 to 250
Boulder	250 to 4000



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N

0 300 600 1,200 Feet

Figure 3.3.2-1:
Water Level Logger Locations

Map 1

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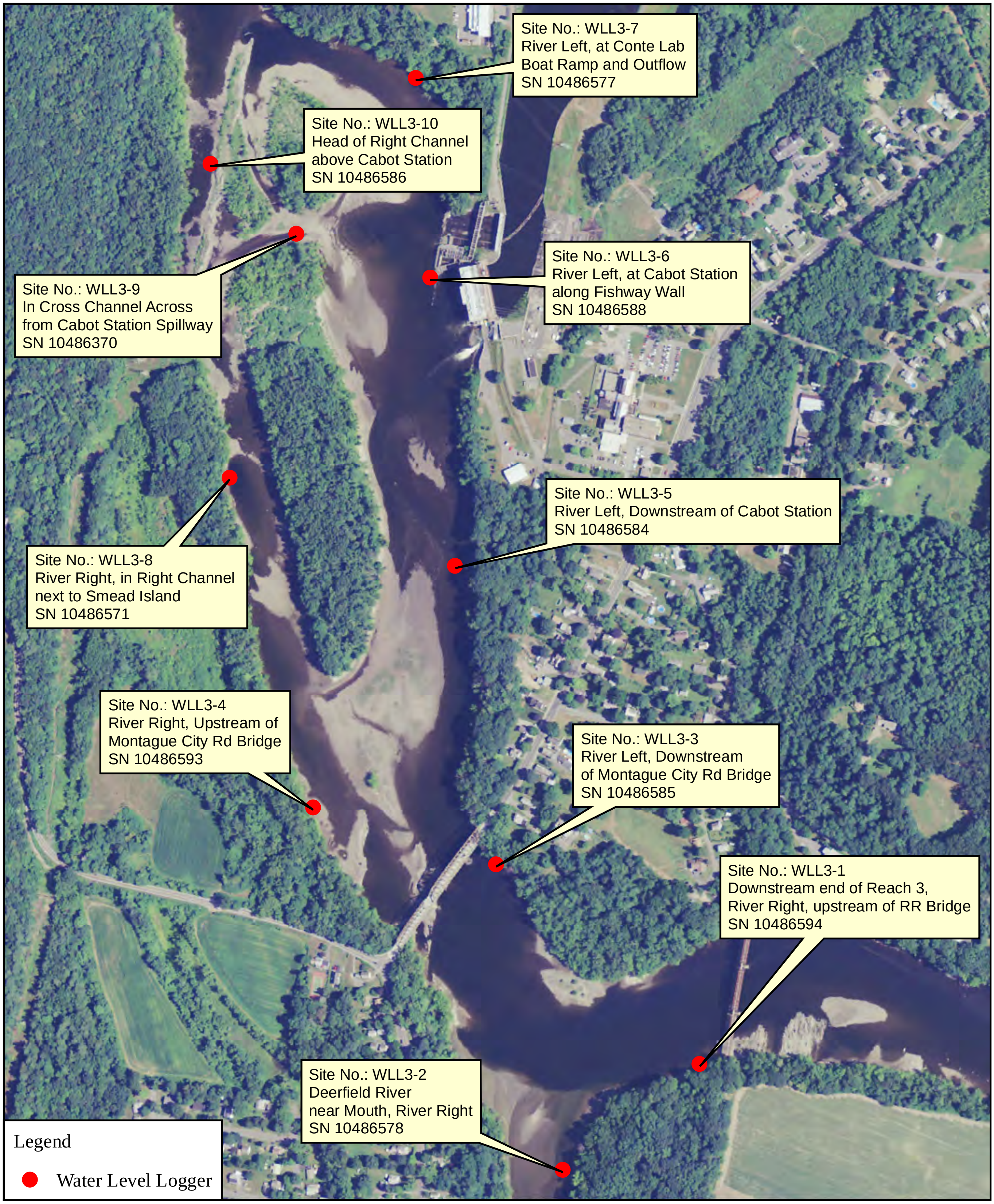

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N

0 300 600 1,200 Feet

Figure 3.3.2-1:
Water Level Logger Locations

Map 2

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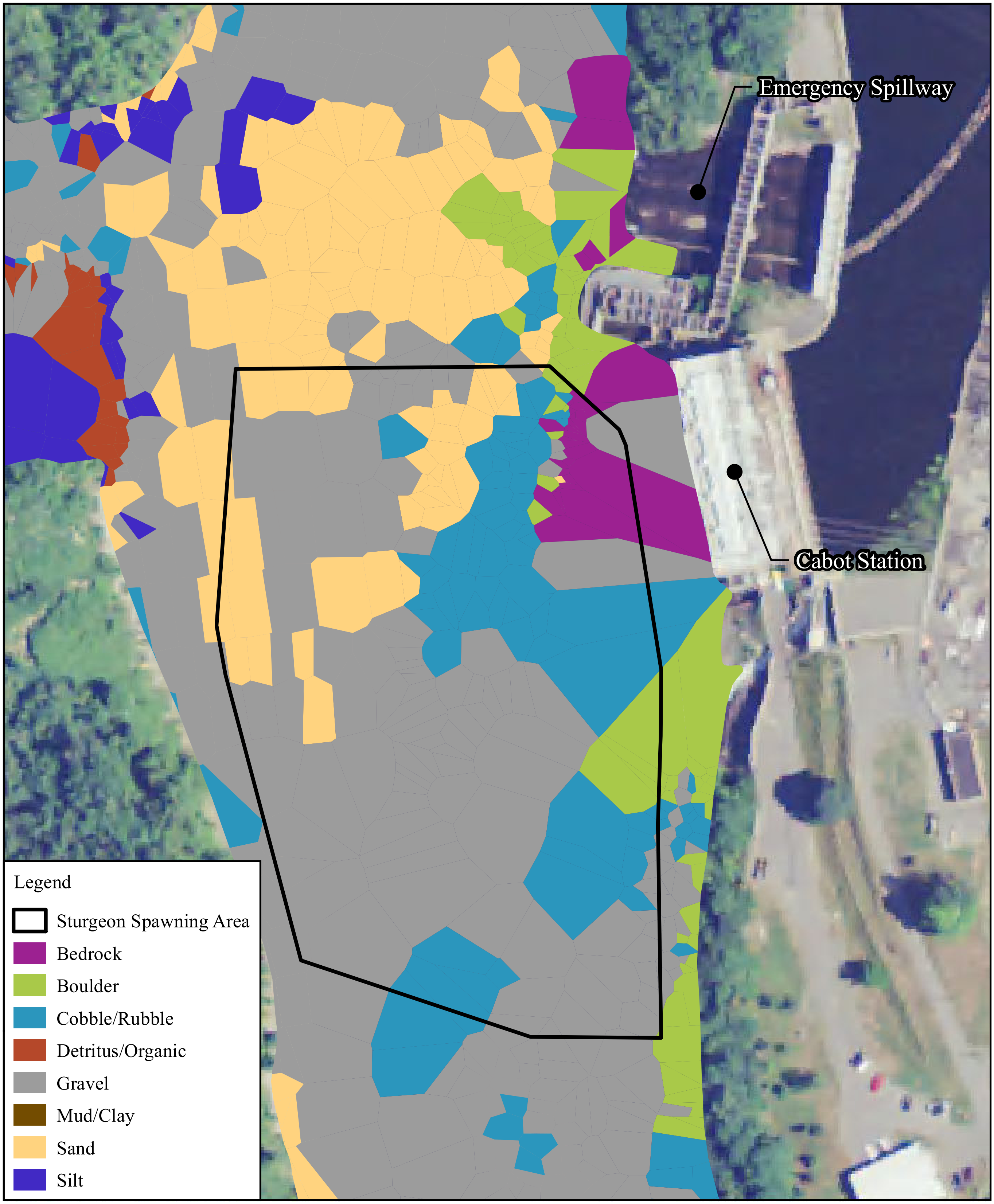

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Figure 3.3.2-2:
Substrate Near Cabot Station

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4 RESULTS

4.1 Emergency Spillway Flow Frequency Analyses

4.1.1 Frequency of Spill Gate Flows (10-minute data)

For the entire dataset, at least one spill gate was open to some degree approximately 60% of the time, and all gates were closed 40% of the time. The frequency of flows from the spill gates, when operating, was multi-modal (Figure 4.1.1-1 and 4.1.1-2), with multiple peaks in frequency, likely due to the usage of multiple gates. Peaks in frequency were largest at lower flows, with progressively smaller peaks at higher flows. The high frequency of operation at lower flows likely resulted from continuous operation of a small number of gates to divert ice and/or debris from the log boom. Additional peaks could be characterized as the typical operation of spill events of varying magnitude. When operating, the frequency distribution showed that flows greater than 1,500 cfs were uncommon (1.1% of the 10-minute time intervals). No clear pattern in frequency was observed by month, though these higher spill flows were more frequent in the earlier years of the dataset (2005-2007) than the later years (2008-2012) (Figure 4.1.1-3).

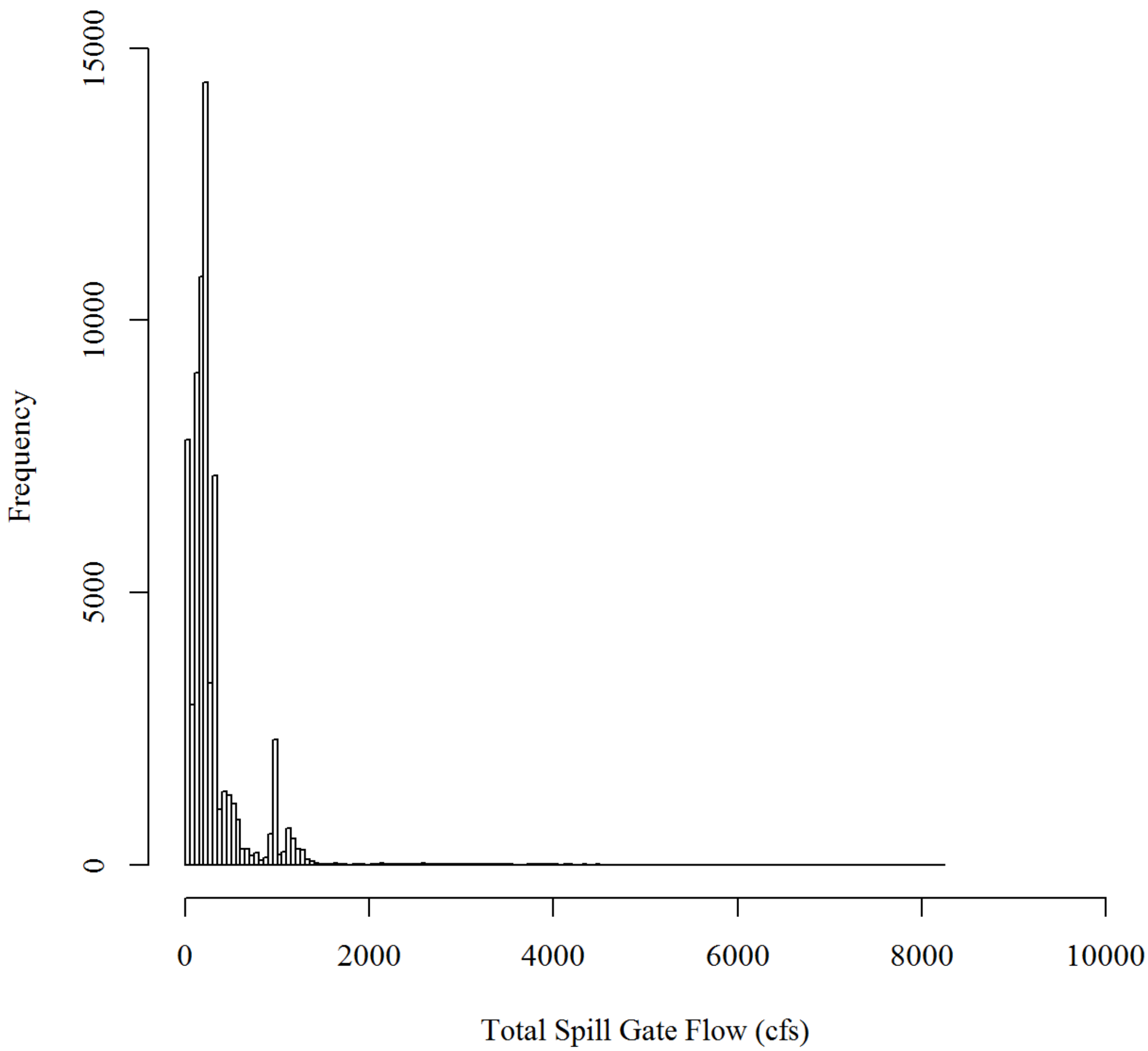


Figure 4.1.1-1: Frequency of Spill Gate Flow during the Sturgeon Spawning Season, 2005-2012.

The y-axis represents the number of data points within a given flow range that occurred within the dataset (10-minute timestep). The plot shows 68,262 data points and does not include data when the gates were closed.

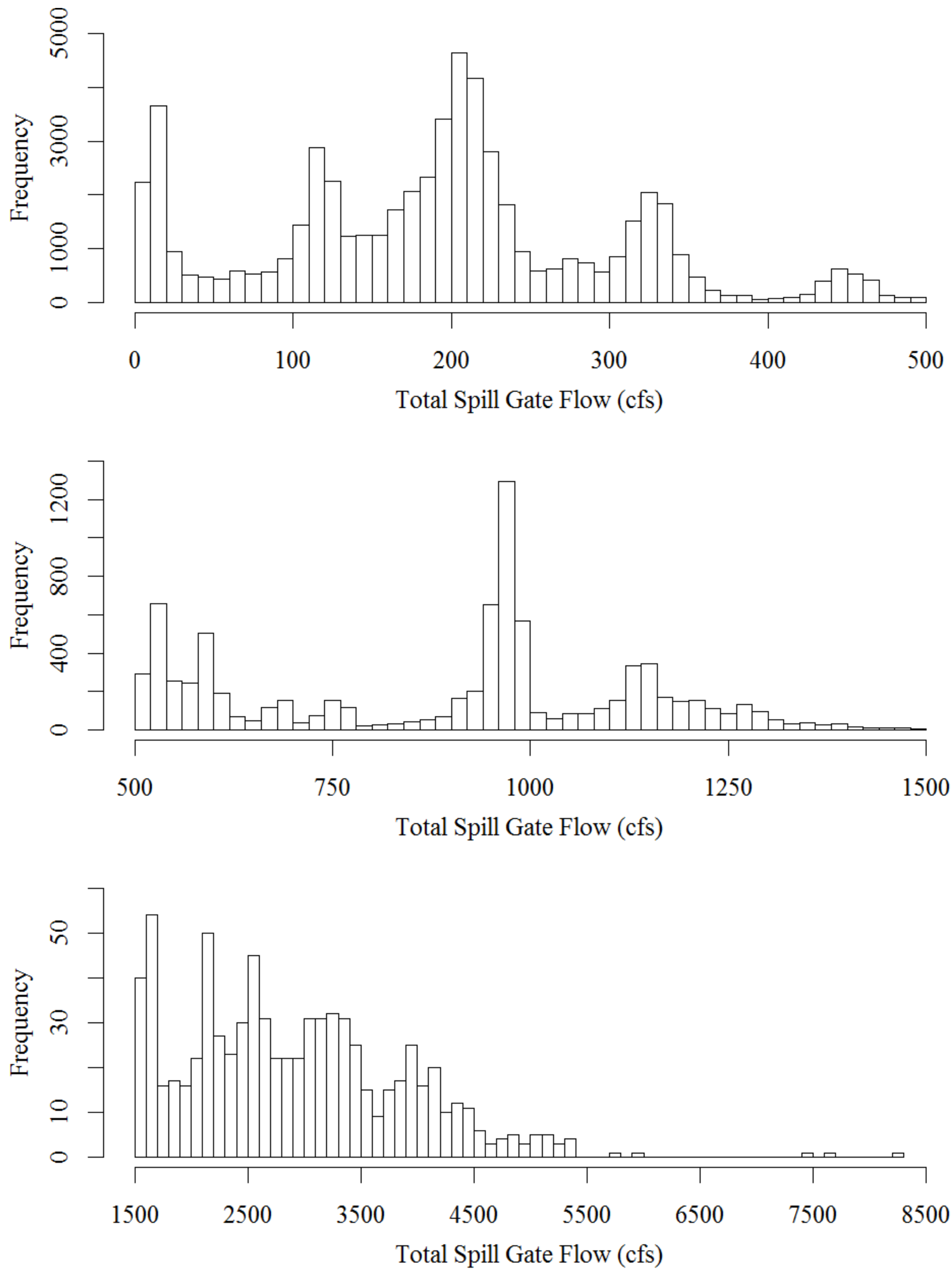


Figure 4.1.1-2: Frequency of Spill Gate Flow During the Sturgeon Spawning Season, 2005-2012.

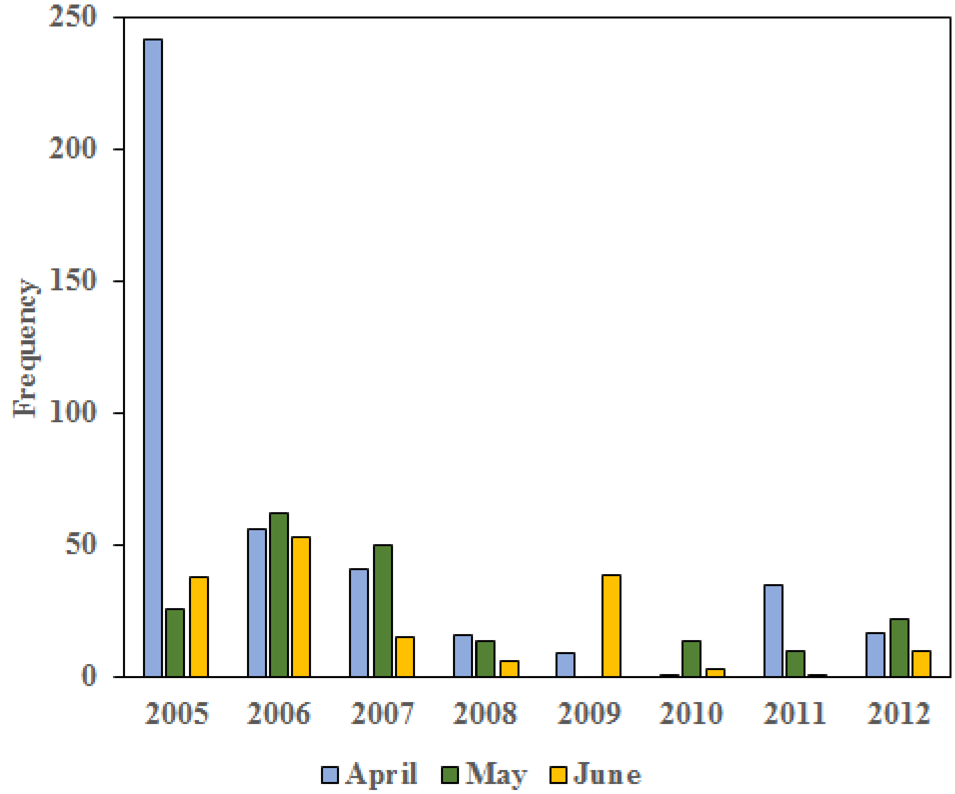


Figure 4.1.1-3: Frequency of Spill Gate Flows > 1,500 cfs by Month and Year

The y-axis represents the number of data points within a given flow range that occurred within the dataset (10-minute timestep).

4.1.2 Bypass Reach and Cabot Station Flow Conditions During Spill Flows > 1,500 CFS

Spill events where flow was greater than 1,500 cfs occurred 120 times during the study period, and under a variety of bypass reach flows, but were most common during Cabot Station generation flows of approximately 7,500 to 13,500 cfs (Figure 4.1.2-1). The spill events were typically brief, with a median of 5.5 10-minute timesteps (~0.92 hours) and a range of 1-79 10-minute timesteps (< 10 minutes to 13.2 hours). Additional summary information of conditions during differing numbers of gates open, are presented in Table 4.1.2-1.

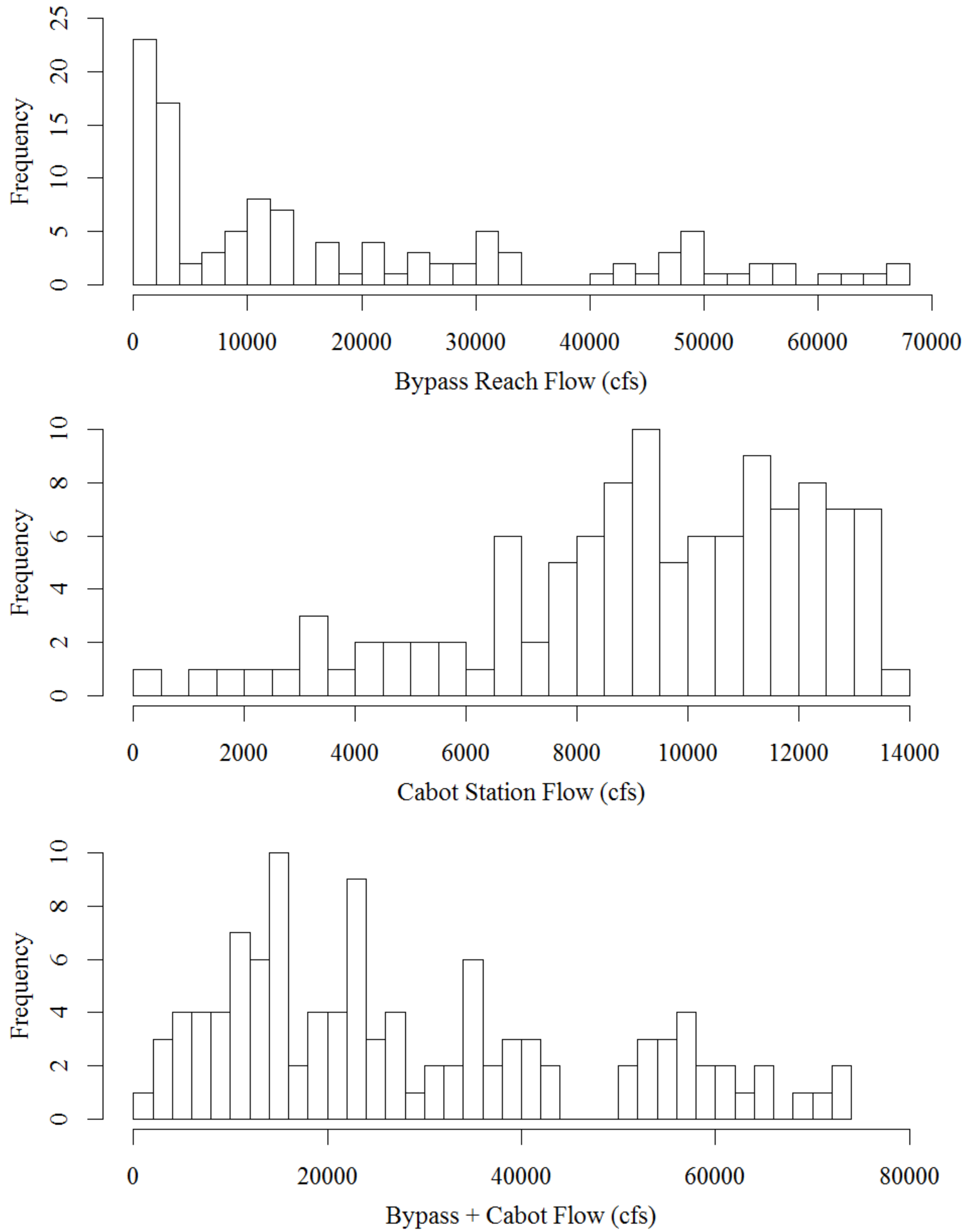


Figure 4.1.2-1: Flow Conditions during High (Flow > 1,500 cfs) Spill Events.
The y-axis shows the number of times that a spill event (flow > 1,500) occurred during conditions on the x-axis.

Table 4.1.2-1: Summary of Conditions Observed and Spill Flows Given the Number of Spill Gates Open (2005-2012).

Data used in this table were analyzed on a 10-minute time step.

Number of gates open	2005						
	2005 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	4742	0	0	0	15,043	2,850	82,000
1	7915	259	2	1,135	35,802	6,690	92,300
2	190	1,286	92	2,233	46,184	10,800	92,000
3	156	2,631	1,532	3,441	63,108	15,300	92,600
4	55	3,335	2,340	4,401	62,647	18,100	92,300
5	42	4,582	3,705	5,399	49,298	21,800	79,800
6	4	4,747	4,155	5,164	55,700	20,700	90,700
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-

Number of gates open	2006						
	2006 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	4121	0	0	0	15,458	5,470	69,400
1	8749	448	0	1,128	31,151	5,840	74,600
2	80	1,388	146	2,259	37,503	11,600	72,600
3	42	2,288	878	3,347	38,852	15,900	69,100
4	80	3,133	128	4,151	39,918	14,400	69,100
5	28	4,220	556	5,196	36,700	14,400	52,900
6	4	5,160	5,086	5,252	21,625	21,600	21,700
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-

Number of gates open	2007						
	2007 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	5437	0	0	0	11,773	2,280	88,500
1	7278	331	1	1,130	35,534	2,610	91,100
2	302	571	113	2,315	40,751	8,150	72,800
3	53	2,787	762	3,334	53,921	15,900	79,400
4	30	4,000	3,362	4,463	28,397	16,500	42,000
5	-	-	-	-	-	-	-
6	2	4,142	2,358	5,927	12,800	12,200	13,400
7	-	-	-	-	-	-	-
8	2	7,541	7,429	7,653	13,200	12,200	14,200

Number of gates open	2008						
	2008 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	6057	0	0	0	12,387	2,660	79,500
1	6981	162	0	1,163	41,359	3,500	82,200
2	31	1,286	282	2,457	29,618	2,910	60,300
3	11	1,761	190	3,340	30,052	3,900	72,700
4	16	3,324	337	4,209	48,303	7,140	63,400
5	8	3,912	1,114	4,400	22,125	7,500	24,500
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-

Number of gates open	2009						
	2009 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	2320	0	0	0	12,528	3,950	56,900
1	9821	269	3	1,235	24,557	4,250	67,900
2	951	1,214	87	2,120	19,656	5,090	49,500
3	3	1,843	713	3,180	14,100	9,800	16,500
4	7	3,063	2,578	3,423	24,457	24,300	24,800
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	2	3,068	2,750	3,385	14,850	13,700	16,000
8	-	-	-	-	-	-	-

Number of gates open	2010						
	2010 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	6145	0	0	0	10,144	3,390	63,200
1	6930	231	0	1,246	25,314	3,410	74,400
2	16	1,474	189	2,309	14,459	5,780	51,800
3	4	2,329	1,262	3,422	18,623	6,160	52,300
4	-	-	-	-	-	-	-
5	1	3,367	3,367	3,367	7,350	7,350	7,350
6	4	4,069	2,416	5,745	9,838	7,170	17,800
7	-	-	-	-	-	-	-
8	4	4,612	2,187	8,223	15,350	11,400	17,800

Number of gates open	2011						
	2011 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	4001	0	0	0	16,143	2,280	73,300
1	9032	303	0	1,194	39,032	3,650	86,600
2	41	1,489	495	2,253	49,682	6,200	84,000
3	29	2,379	352	3,492	59,534	7,400	78,700
4	1	476	476	476	6,460	6,460	6,460
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-

Number of gates open	2012						
	2012 Count	Spill Gate Discharge (cfs)			River Discharge (cfs)		
		Mean	Min	Max	Mean	Min	Max
0	9589	0	0	0	13,614	2,700	42,700
1	3455	215	0	1,132	23,095	2,730	44,700
2	13	1,379	674	2,115	20,345	5,450	34,400
3	32	2,702	1,201	3,461	32,037	5,800	44,100
4	15	3,264	2,594	3,528	28,007	18,800	34,100
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-

River Discharge = Data obtained from USGS Gage: Connecticut River at Montague City, MA (USGS 01170500).

4.1.3 Operations When > 4 Spill Gates Were Open

Within the period of interest, there were a total of 26 occurrences when more than four gates were open to some degree; of these 26 events, 9 were emergency-related (see Table 4.1.3-1 and Figures in Appendix A-1). Based on discussions with the FirstLight Operations Manager, the events were attributed to three main factors (Table 4.1.3-2):

1. Emergency-triggered events. These are triggered when the canal forebay WSEL is at or above 174.3 feet. If this level is reached, the emergency gates open automatically to varying degrees, based on the specific condition. The spill gates will also open automatically if a full station trip occurs at Cabot Station. Gates are closed manually once the operator assesses the situation.

2. Trashrack debris management. These procedures were occasionally used by an operator during periods when river flows were high (>35,000 cfs) for the period 2005-2008. During this procedure, the emergency spill gates were opened during the trashrack raking period to manage excess water in the canal. Cabot units were usually backed-off so trash could be cleaned off the racks and moved downstream through the log sluice. The spill gates were used on occasion to manage excess water. These practices are no longer in place and are considered "Antiquated Operations". From 2008 to the present, the normal practice has been to manage canal elevation during periods of reduced generation at Cabot Station, associated with rack cleaning, by controlling inflow at the canal gatehouse.

3. Log boom debris management or other special maintenance conditions (e.g., on 4/1/2006, an operator needed to move debris off the log boom during a headgate closure, see Appendix A-1).

Table 4.1.3-1: Periods When More Than Four Spill Gates Were Open, April 1-June 30, 2005-2012

Time	Gate Opening (feet)								Gates Open	Spill Gate Discharge (cfs)
	SG03	SG04	SG05	SG06	SG07	SG08	SG09	SG10		
4/2/2005 19:10	0.00	9.31	0.38	0.40	6.12	9.90	10.00	8.50	5	4,368
4/2/2005 19:20	0.00	9.31	0.38	0.40	6.12	9.90	10.00	8.50	5	4,304
4/2/2005 19:30	0.00	9.32	0.38	0.40	6.12	9.90	10.00	8.50	5	4,464
4/2/2005 19:40	0.00	9.32	0.38	0.40	6.12	9.90	10.00	8.50	5	4,446
4/2/2005 19:50	0.00	9.32	0.38	0.40	6.12	9.91	10.00	8.50	5	4,498
4/2/2005 20:00	0.00	9.32	0.38	0.40	6.12	9.91	10.00	8.50	5	4,511
4/2/2005 20:10	0.00	9.32	0.38	0.40	6.13	9.91	10.00	8.50	5	4,399
4/2/2005 20:20	0.00	9.32	0.38	0.40	6.12	9.91	10.00	8.50	5	4,353
4/2/2005 20:30	0.00	9.32	0.38	0.40	6.12	9.91	10.00	8.50	5	4,310
4/3/2005 18:00	0.00	9.32	0.02	4.04	10.00	3.77	10.00	8.49	6	4,786
4/3/2005 18:10	0.00	9.33	0.02	5.21	9.04	2.98	10.00	8.49	6	4,155
4/5/2005 5:30	0.00	9.31	0.02	0.03	4.11	10.00	10.00	8.50	5	4,193
4/7/2005 13:50	0.00	9.34	0.33	7.01	10.00	10.00	10.00	0.09	5	4,954
4/7/2005 14:00	0.00	9.34	0.33	10.00	10.00	10.00	10.00	0.09	5	5,202
4/8/2005 12:40	0.00	9.35	2.64	0.04	10.00	10.00	10.00	0.09	5	4,580
4/8/2005 12:50	0.00	9.35	8.02	0.04	10.00	10.00	10.00	0.09	5	5,143
4/8/2005 13:00	0.00	9.35	6.02	0.04	10.00	10.00	10.00	0.09	5	4,739
4/8/2005 13:10	0.00	9.35	3.94	0.04	10.00	10.00	10.00	0.09	5	4,504
4/8/2005 13:20	0.00	9.35	3.94	0.04	10.00	10.00	10.00	0.09	5	4,584
4/8/2005 13:30	0.00	9.35	3.94	0.04	10.00	10.00	10.00	0.10	5	4,578
4/8/2005 13:40	0.00	9.35	3.94	0.04	10.00	10.00	10.00	0.09	5	4,497
4/17/2005 6:00	0.00	9.31	5.58	4.71	10.00	10.00	10.00	0.09	6	5,164
4/17/2005 6:10	0.00	9.31	5.58	4.71	10.00	10.00	10.00	0.09	6	4,883
4/26/2005 12:40	0.00	5.38	0.00	9.90	4.96	10.00	10.00	0.09	5	3,984
4/26/2005 12:50	0.00	5.38	0.00	9.91	7.01	10.00	10.00	0.09	5	4,314
4/26/2005 13:00	0.00	5.38	0.00	9.91	7.01	10.00	10.00	0.09	5	4,280
4/26/2005 13:10	0.00	5.38	0.00	9.91	7.01	10.00	10.00	0.09	5	4,226
4/26/2005 13:20	0.00	5.38	0.00	9.91	5.86	10.00	10.00	0.09	5	4,029
4/26/2005 13:30	0.00	5.38	0.00	9.91	5.86	10.00	10.00	0.09	5	3,981
4/26/2005 13:40	0.00	5.38	0.00	9.91	5.86	10.00	10.00	0.09	5	3,970
4/26/2005 13:50	0.00	5.38	0.00	9.91	3.88	10.00	10.00	0.09	5	3,705
5/6/2005 13:00	0.00	9.35	9.77	10.00	0.05	10.00	10.00	0.09	5	5,348
5/6/2005 13:10	0.00	9.35	9.77	10.00	0.05	10.00	10.00	0.09	5	5,389
5/6/2005 13:20	0.00	9.35	9.77	10.00	0.05	10.00	10.00	0.09	5	5,390
5/6/2005 13:30	0.00	9.35	9.77	10.00	0.05	10.00	10.00	0.09	5	5,399
5/6/2005 13:40	0.00	9.35	9.77	10.00	0.05	10.00	7.92	0.09	5	4,971
5/6/2005 13:50	0.00	9.35	9.77	10.00	0.05	10.00	7.92	0.09	5	5,154
5/6/2005 14:00	0.00	9.35	9.77	10.00	0.04	10.00	7.92	0.09	5	5,030
5/6/2005 14:10	0.00	9.35	9.77	10.00	0.04	10.00	7.01	0.09	5	4,853

Time	Gate Opening (feet)								Gates Open	Spill Gate Discharge (cfs)
	SG03	SG04	SG05	SG06	SG07	SG08	SG09	SG10		
6/2/2005 12:40	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,677
6/2/2005 12:50	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,658
6/2/2005 13:00	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,612
6/2/2005 13:10	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,535
6/2/2005 13:20	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,498
6/2/2005 13:30	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,429
6/2/2005 13:40	0.00	9.37	4.86	10.00	0.05	10.00	10.00	0.09	5	4,362
4/1/2006 13:30	4.26	2.42	2.23	0.26	0.23	0.18	2.23	2.48	5	556
4/26/2006 7:20	0.00	9.31	9.74	0.04	0.04	2.97	8.77	8.47	5	3,964
4/26/2006 7:30	0.00	9.31	9.74	0.04	0.04	7.09	8.77	8.48	5	4,480
4/26/2006 7:40	0.00	9.31	9.74	0.04	0.04	10.00	8.77	8.48	5	4,788
4/26/2006 7:50	0.00	9.31	9.74	0.04	5.09	10.00	8.80	8.48	6	5,252
4/26/2006 8:00	0.00	9.31	9.74	0.04	5.09	10.00	8.79	8.48	6	5,206
4/26/2006 8:10	0.00	9.31	9.75	0.04	5.09	10.00	8.79	8.48	6	5,086
4/26/2006 8:20	0.00	9.31	9.75	0.04	5.09	10.00	8.80	8.49	6	5,094
4/26/2006 9:00	0.00	9.31	9.75	0.04	0.04	10.00	9.50	8.49	5	5,013
4/26/2006 9:10	0.00	9.31	9.75	0.04	0.04	10.00	9.49	8.49	5	4,937
4/26/2006 9:20	0.00	4.86	9.75	0.04	0.04	10.00	9.49	8.49	5	4,273
5/5/2006 12:50	0.00	8.06	0.03	0.04	5.09	7.71	9.58	8.52	5	3,783
5/5/2006 13:00	0.00	8.06	0.03	0.04	5.09	7.72	9.57	8.52	5	3,720
5/14/2006 11:40	0.00	9.32	0.01	0.04	3.97	10.00	9.60	8.50	5	4,236
5/14/2006 11:50	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,167
5/14/2006 12:00	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,175
5/14/2006 12:10	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,153
5/14/2006 12:20	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,224
5/14/2006 12:30	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,112
5/14/2006 12:40	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,170
5/14/2006 12:50	0.00	9.33	0.01	0.04	3.97	10.00	9.60	8.50	5	4,167
6/11/2006 7:50	0.00	9.13	3.84	0.04	0.00	10.00	9.86	8.51	5	4,006
6/11/2006 8:00	0.00	9.33	2.91	0.04	0.00	10.00	9.86	8.51	5	3,949
6/11/2006 8:10	0.00	9.33	2.91	0.04	0.00	10.00	9.86	8.51	5	3,961
6/11/2006 8:20	0.00	9.33	2.91	0.04	0.00	10.00	9.86	8.51	5	3,937
6/12/2006 3:40	0.00	9.17	9.76	0.04	5.14	10.00	0.00	8.51	5	4,487
6/29/2006 15:20	0.00	9.36	9.79	4.98	0.00	0.02	10.00	8.53	5	4,446
6/29/2006 15:30	0.00	9.36	9.79	7.28	0.00	0.02	10.00	8.53	5	4,802
6/29/2006 15:40	0.00	9.36	9.79	10.00	0.00	0.02	10.00	8.53	5	5,196
6/29/2006 15:50	0.00	9.36	9.79	10.00	0.00	0.02	10.00	8.53	5	4,898
6/29/2006 16:00	0.00	9.36	9.79	10.00	0.00	0.02	10.00	8.53	5	4,829
6/29/2006 16:10	0.00	9.36	9.79	10.00	0.00	0.02	10.00	8.53	5	4,720
6/4/2007 8:00	9.81	9.92	9.74	9.99	10.00	10.00	8.70	8.44	8	7,429

Time	Gate Opening (feet)								Gates Open	Spill Gate Discharge (cfs)
	SG03	SG04	SG05	SG06	SG07	SG08	SG09	SG10		
6/4/2007 8:10	9.81	9.87	9.74	10.00	10.00	10.00	0.00	0.09	6	5,927
6/27/2007 18:20	9.81	9.89	9.76	10.00	10.00	10.00	7.48	6.56	8	7,653
6/27/2007 18:30	3.86	7.03	7.41	10.00	4.86	2.73	0.00	0.09	6	2,358
5/7/2008 4:20	0.0	9.2	1.1	0.0	4.1	10.0	10.0	8.4	5	4,298
5/7/2008 4:30	0.0	9.2	1.1	0.0	4.1	10.0	10.0	8.4	5	4,267
5/7/2008 4:40	0.0	9.3	1.1	0.0	4.1	10.0	10.0	8.4	5	4,339
5/7/2008 4:50	0.0	9.4	1.1	0.0	4.1	10.0	10.0	8.4	5	4,344
5/7/2008 5:00	0.0	9.5	1.1	0.0	4.1	10.0	10.0	8.4	5	4,400
5/7/2008 5:10	0.0	9.3	1.1	0.0	4.1	10.0	10.0	8.4	5	4,346
5/7/2008 5:20	0.0	9.3	1.1	0.0	4.1	10.0	10.0	8.4	5	4,188
6/8/2008 23:40	4.1	2.5	1.1	3.8	3.3	3.4	0.0	0.1	5	1114
6/2/2009 23:00	5.90	7.03	0.01	5.83	5.51	5.83	4.82	5.03	7	3,385
6/15/2009 4:30	5.89	6.19	0.01	5.81	5.49	5.80	4.84	1.92	7	2,750
5/4/2010 2:40	6.57	10.00	6.42	6.46	6.38	6.94	6.14	6.80	8	5,184
5/4/2010 2:50	0.00	4.49	0.00	4.54	5.47	10.00	10.00	3.98	6	3,103
5/4/2010 4:00	2.76	7.58	3.08	3.30	3.20	3.62	3.13	3.87	8	2,187
5/4/2010 4:10	2.76	10.00	5.97	3.30	3.20	3.62	3.13	3.96	8	2,855
5/26/2010 23:20	5.57	5.85	5.42	0.30	5.02	0.27	4.39	3.16	6	2,416
5/26/2010 23:30	9.79	10.00	3.75	0.31	9.83	0.27	9.99	9.81	6	5,745
5/26/2010 23:40	9.79	10.00	3.75	0.31	9.83	0.27	9.99	9.81	6	5,012
5/26/2010 23:50	9.79	10.00	3.75	0.31	9.83	0.27	4.11	0.19	5	3,367
6/14/2010 2:40	9.78	10.00	9.88	10.00	9.88	10.00	10.00	9.83	8	8,223

Note 1: There were no occurrences when >4 spill gates were open during the period April 1-June 30, in 2011 or 2012.

Note 2: Red box indicates emergency-triggered spill events.

Table 4.1.3-2: Reasons for Use of More than Four Spill Gates (April 1-June 30, 2005-2012)

Date	Number of Gates Open	Reason	Emergency Triggered
4/2/2005	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
4/3/2005	6	High Flow, Trashrack Cleaning, Antiquated Operations	No
4/5/2005	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
4/7/2005	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
4/8/2005	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
4/17/2005	6	Trashrack Cleaning, Antiquated Operations	No
4/26/2005	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
5/6/2005	5	Trashrack Cleaning, Antiquated Operations	No
6/2/2005	5	Trashrack Cleaning, Antiquated Operations	No
4/1/2006	5	(Low Magnitude Spill Event) Headgate Maintenance	No
4/26/2006	5-6	Trashrack Cleaning, Antiquated Operations	No
5/5/2006	5	Large log on trashracks, Antiquated Operations	No
5/14/2006	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
6/11/2006	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
6/12/2006	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
6/29/2006	5	High Flow, Trashrack Cleaning, Antiquated Operations	No
6/4/2007	6-8	Unit Trip	Yes
6/27/2007	6-8	Station Trip, Lightning Storm	Yes
5/7/2008	5	Trashrack Cleaning, Antiquated Operations	No
6/8/2008	5	High Canal Level	Yes
6/2/2009	7	High Canal Level	Yes
6/15/2009	7	High Canal Level	Yes
5/4/2010 2:40	8	High Canal Level	Yes
5/4/2010 4:00	8	High Canal Level	Yes
5/26/2010	6	Station Trip, Wind Storm	Yes
6/14/2010	8	High Canal Level	Yes

Summary: *Total Events = 26*

Emergency Triggered = 9

Antiquated Operation = 16

Other = 1

Notes: There were no occurrences when >4 spill gates were open during the period April 1-June 30, in 2011 or 2012 based on the 10-minute time step analyzed.

4.2 Sluice Gate Frequency Analyses

4.2.1 Frequency of Sluice Gate Flows (10-minute data)

The maximum sluice gate flow observed during the study period was nearly 1,720 cfs, though flows this high were extremely rare. The median flow was 218.7 cfs, which could be considered a typical flow through the sluice gate, with the fish passage weir in place (Figure 4.2.1-1). The distribution of flow frequencies was multi-modal, however, and indicated that occasionally the sluice gate was operated at flows between 600-800 cfs and 1000-1400 cfs (Figure 4.2.1-2).

Biweekly plots showing the magnitude of flow through the sluice gate compared to river flow are contained in Appendix A-2.

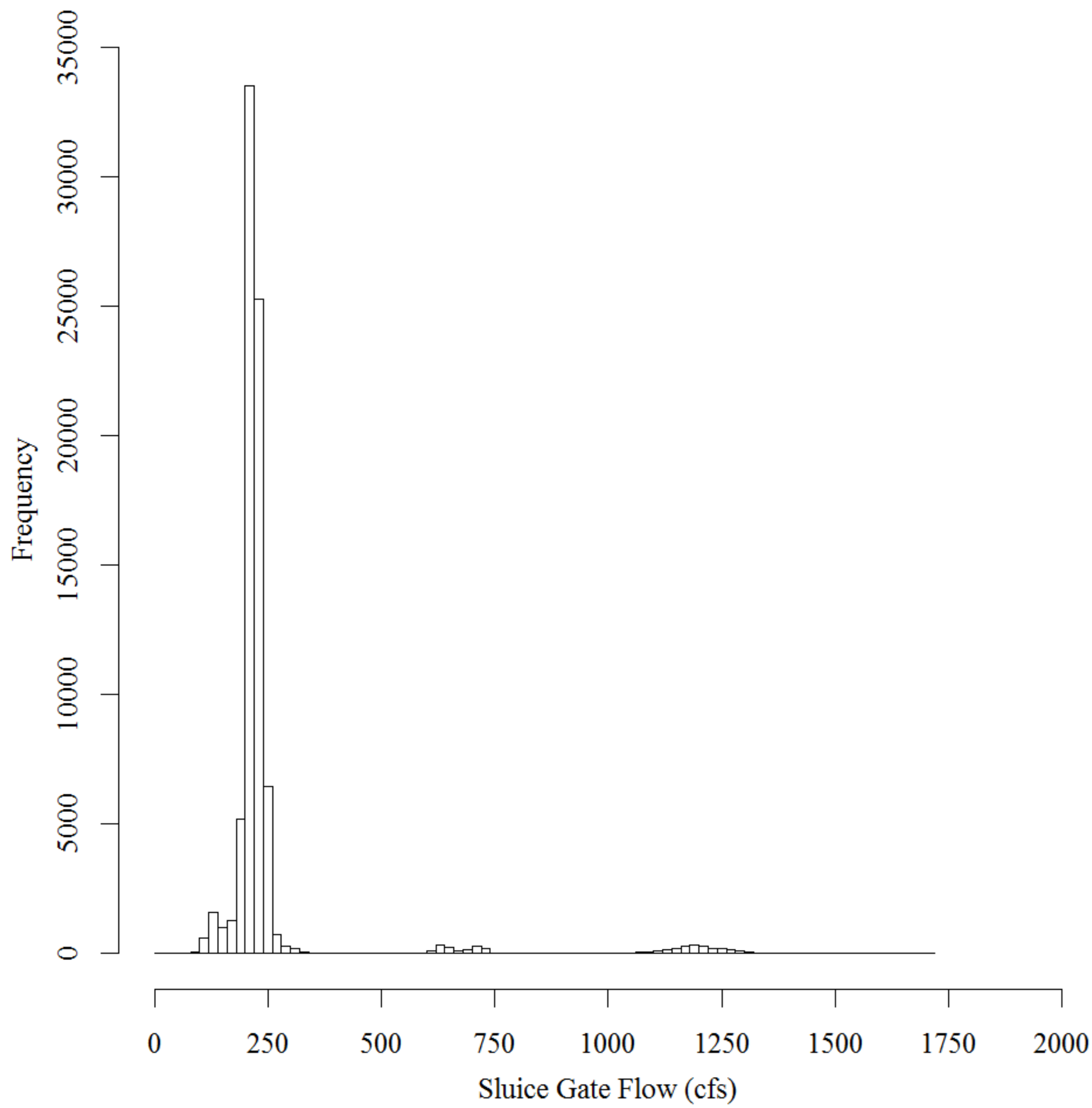


Figure 4.2.1-1: Frequency of Sluice Gate Flow during the Sturgeon Spawning Season, 2005-2012.

The y-axis represents the number of data points within a given flow range that occurred within the dataset (10-minute timestep). The plot shows 80,358 observations and does not include data when the gate was closed.

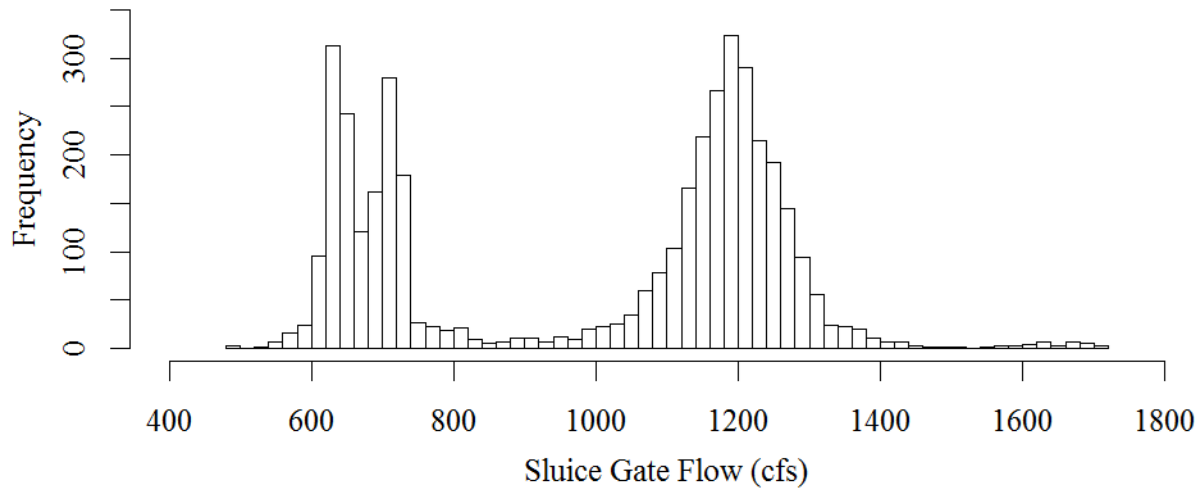


Figure 4.2.1-2: Frequency of Sluice Gate Flow During the Sturgeon Spawning Season, 2005-2012, for Spill Flows Greater than 400 cfs.

The y-axis represents the number of data points within a given flow range that occurred within the dataset (10-minute timestep). The plot shows 4,041 out of the 80,358 observations shown in Figure 4.2.1-1.

4.2.2 Bypass Reach and Cabot Station Flow Conditions During Sluice Flows > 400 cfs

Flow events through the sluice gate greater than 400 cfs were used to sluice debris downstream. These events occurred 277 times during the study period, under a variety of bypass reach flows, but were most common during low bypass reach flows and during Cabot Station generation flows greater than 7,500 cfs (Figure 4.2.2-1). The median duration of these events was 1.5 hours, with a range of 0.17 to 21.5 hours except for one event which was 92.5 hours (3.85 days) long that started on April 9, 2010.

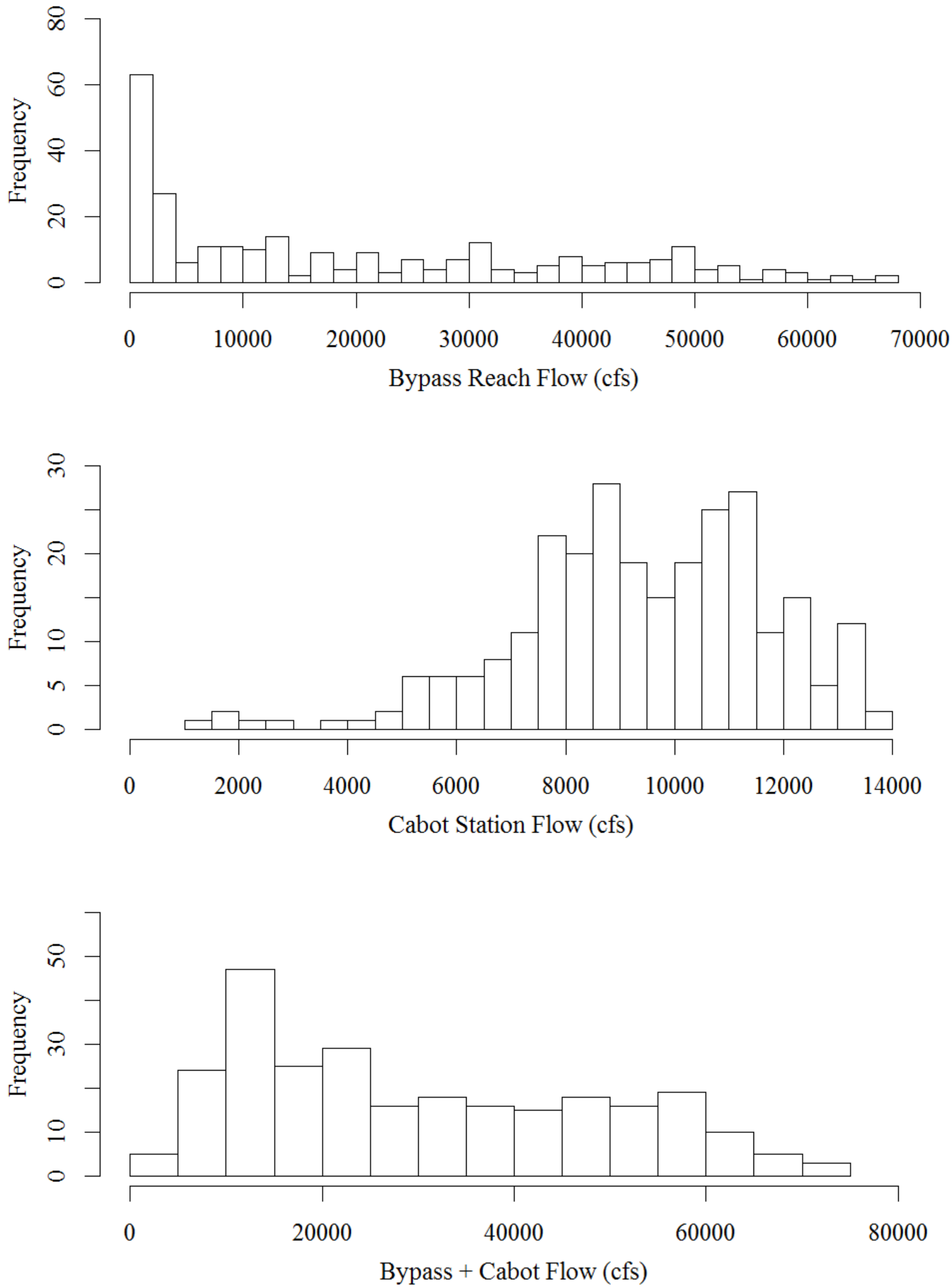


Figure 4.2.2-1: Flow Conditions during High (Flow > 400 cfs) Sluice Gate Events.

4.2.3 Operations of the Sluice Gate

Operation of the sluice gate with the weir installed during the downstream fish passage season results in a flow of ~220 cfs. Even with a constant gate opening, the actual flow through the sluice gate can vary slightly due to changes in forebay water level.

The weir can be lifted out of the water at the sluice gate, allowing flow to be increased for the purposes of:

- Raking debris from the trashracks at Cabot Station and passing the debris through the sluice;
- Passing logs that accumulate at the weir;
- Preventing logs from becoming caught in the weir during high river flows; and
- Passing ice that accumulates at the Cabot trashrack.

Passing debris and logs would typically result in a relatively short-term flow increase on the order of minutes to hours at the sluice gate, except during high flow events when the debris load is high. When river flow is greater than around 30,000 cfs, FirstLight closes the sluice gate to prevent the formation of an eddy downstream of the sluice when it's open under these higher flows. The eddy can cause undermining at the end of the sluice; the bank in this location has been stabilized with rip-rap to prevent erosion. Under lower river flows and tailwater elevation, the relatively low flow input from the sluice and the coarse nature of the substrate in the area likely preclude mobilization of fine sediment.

4.3 Velocity Modeling

4.3.1 Velocities within the Sturgeon Spawning Area

Maps of the velocities from the River2D modeled scenarios are provided in Appendix B. For Scenarios B2b and B3 or B5, there is not a substantial change in the velocity distribution in the majority of the sturgeon spawning area with an increase of 1,500 or 3,500 cfs in the Cabot Station discharge, except in the downstream portion of the sturgeon spawning area. This is partly due to the steeper channel gradient near the downstream portion of the sturgeon spawning area. At full Cabot Station discharges such as shown for Scenarios B5a and B5b7, high velocities occur in the bedrock ledge area in the northeast portion of the sturgeon spawning area near Cabot Station. The velocity in this ledge area decreases as bypass flows increase as modeled in Scenarios B6 and B7 while velocities generally increase with a higher total flow. Velocities, within about 200 feet of the Cabot Station discharge, while modeled with limited accuracy by River2D (since River2D uses a depth averaged velocity) are relatively low due to the depth of water as shown in the depth figures in Appendix C. Deerfield River flows have a limited influence on the model outputs, as seen by the similar velocity distributions of Scenarios B1a and B1b and Scenarios B2a and B2b.

The velocity distribution during discharges from the emergency spillway gates are shown in Scenarios E1a S1500 through E6 S8000 of Appendix B. These figures show that the high velocity field from these discharges has the greatest influence on the western side of the sturgeon spawning area. The influence is more pronounced when either bypass flows are low or when Cabot Station discharges are high.

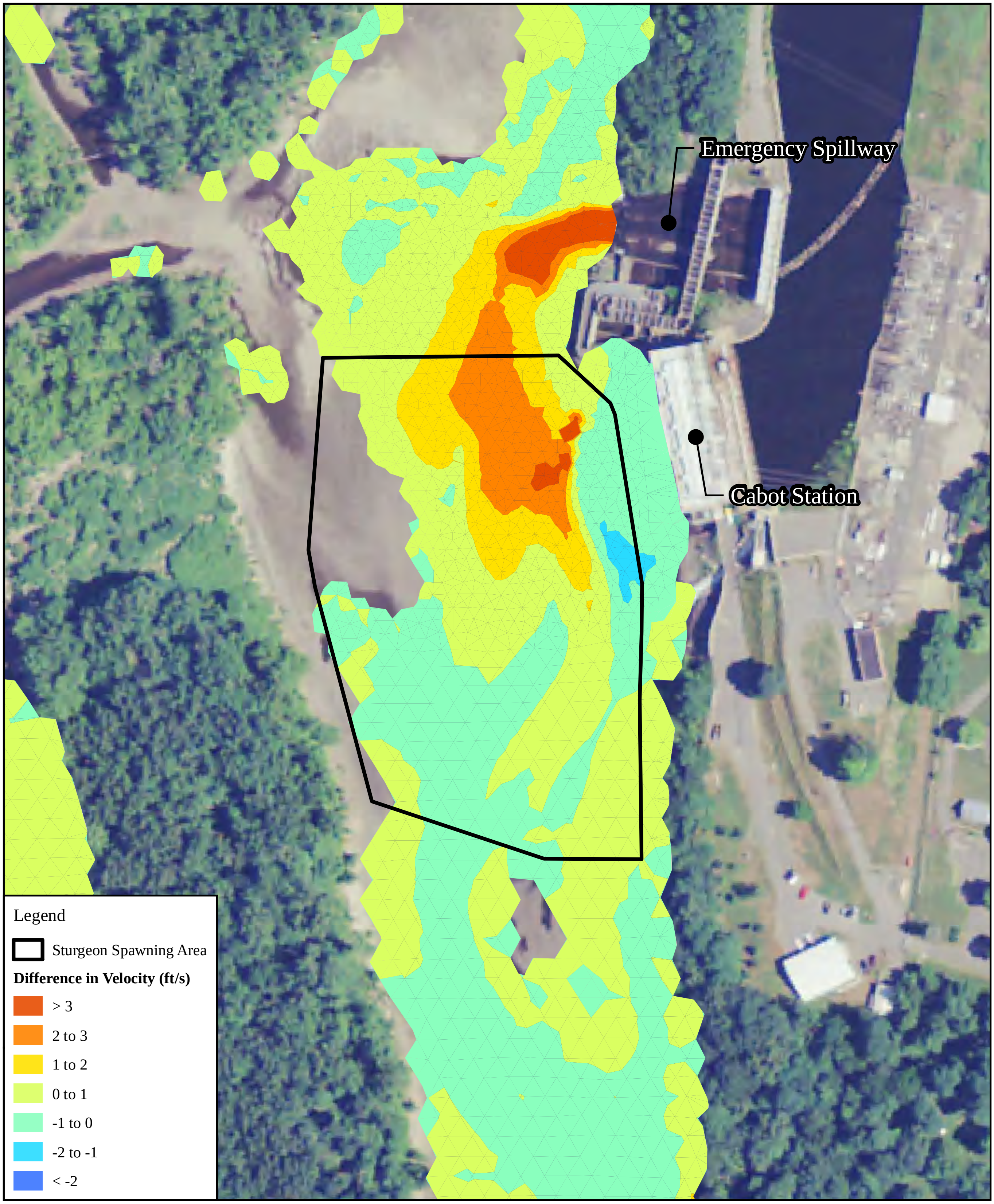
Figures in Section 4.3.1 include velocity difference maps between the baseline scenarios and the appropriate emergency spillway gate release scenarios, including the following comparisons:

- Scenario E1a S1500 (spillway: 1,500 cfs) minus Scenario B1a (Cabot: 1,500 cfs); Bypass flow = 500 cfs;
- Scenario E2a S1500 (spillway: 1,500 cfs) minus Scenario B2a (Cabot: 1,500 cfs); Bypass flow = 2,500 cfs;
- Scenario E3 S3000 (spillway: 3,000 cfs) minus Scenario B3 (Cabot: 3,000 cfs); Bypass flow = 2,500 cfs;

- Scenario E4 S5000 (spillway: 5,000) minus Scenario B4 (Cabot: 5,000 cfs); Bypass flow = 2,500 cfs;
- Scenario E5b S3000 (spillway: 3,000 and Cabot: 11,000 cfs) minus Scenario B5b (Cabot: 14,000 cfs); Bypass flow = 2,500 cfs;
- Scenario E5b S5000 (spillway: 5,000 and Cabot: 9,000 cfs) minus Scenario B5b (Cabot: 14,000 cfs); Bypass flow = 2,500 cfs;
- Scenario E5b S8000 (spillway: 8,000 and Cabot: 6,000 cfs) minus Scenario B5b (Cabot: 14,000 cfs); Bypass flow = 2,500 cfs;
- Scenario E6 S5000 (spillway: 5,000 and Cabot: 9,000 cfs) minus Scenario B6 (Cabot: 14,000 cfs); Bypass flow = 10,000 cfs;
- Scenario E6 S8000 (spillway: 8,000 and Cabot: 6,000 cfs) minus Scenario B6 (Cabot: 14,000 cfs); Bypass flow = 10,000 cfs;

In general, the velocity difference maps and charts in Figures 4.3.1-1 to 4.3.1-9 indicate the following:

- Under Scenarios E1, E2, E3, and E4 when Cabot Station is not generating and flows from the emergency spillway range from 1,500 to 5,000 cfs and bypass flows are 500 or 2,500 cfs, the greatest velocity differences modeled within the sturgeon spawning area were limited to the upstream areas near mid-channel.
- Under Scenarios E5 with Cabot Station generating and flows from the emergency spillway ranging from 3,000 to 8,000 cfs, and bypass flows of 2,500 cfs, the greatest velocity differences were predicted to be near the western side of the sturgeon spawning area as a result of outflow from Cabot Station.
- Under Scenarios E6 with Cabot Station generating and flows from the emergency spillway ranging from 5,000 to 8,000 cfs, and bypass flows of 10,000 cfs, the greatest velocity differences were predicted to be near the center of the sturgeon spawning area as a result of high bypass flows.



FIRSTLIGHT HYDRO GENERATING COMPANY
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Turners Falls Hydroelectric Project No. 1889

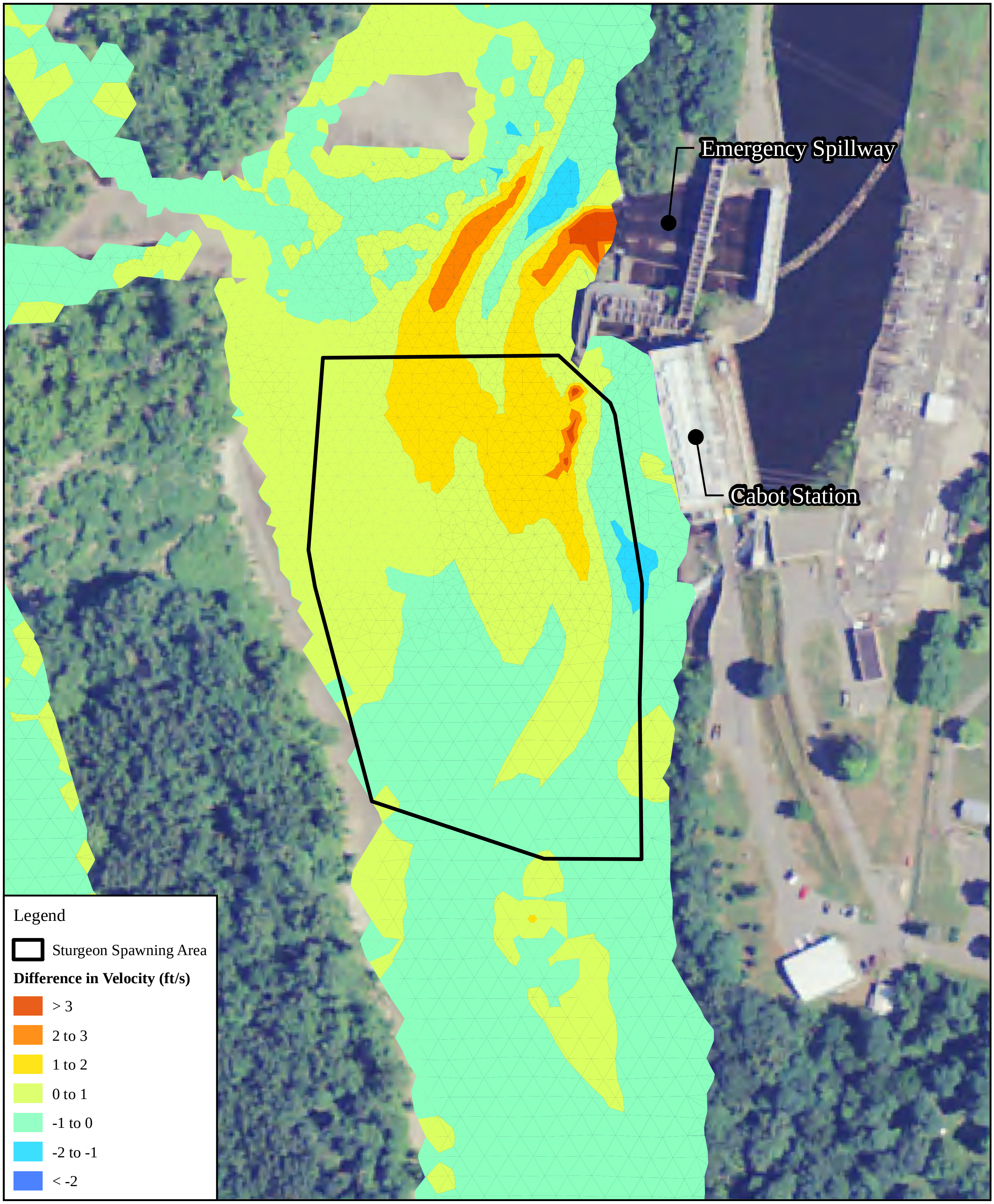
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Figure 4.3.1-1:
Scenario E1a S1500 Minus
Scenario B1a

Path: W:\gis\studies\3_3_12\maps\E1a_S1500_minus_B1a.mxd



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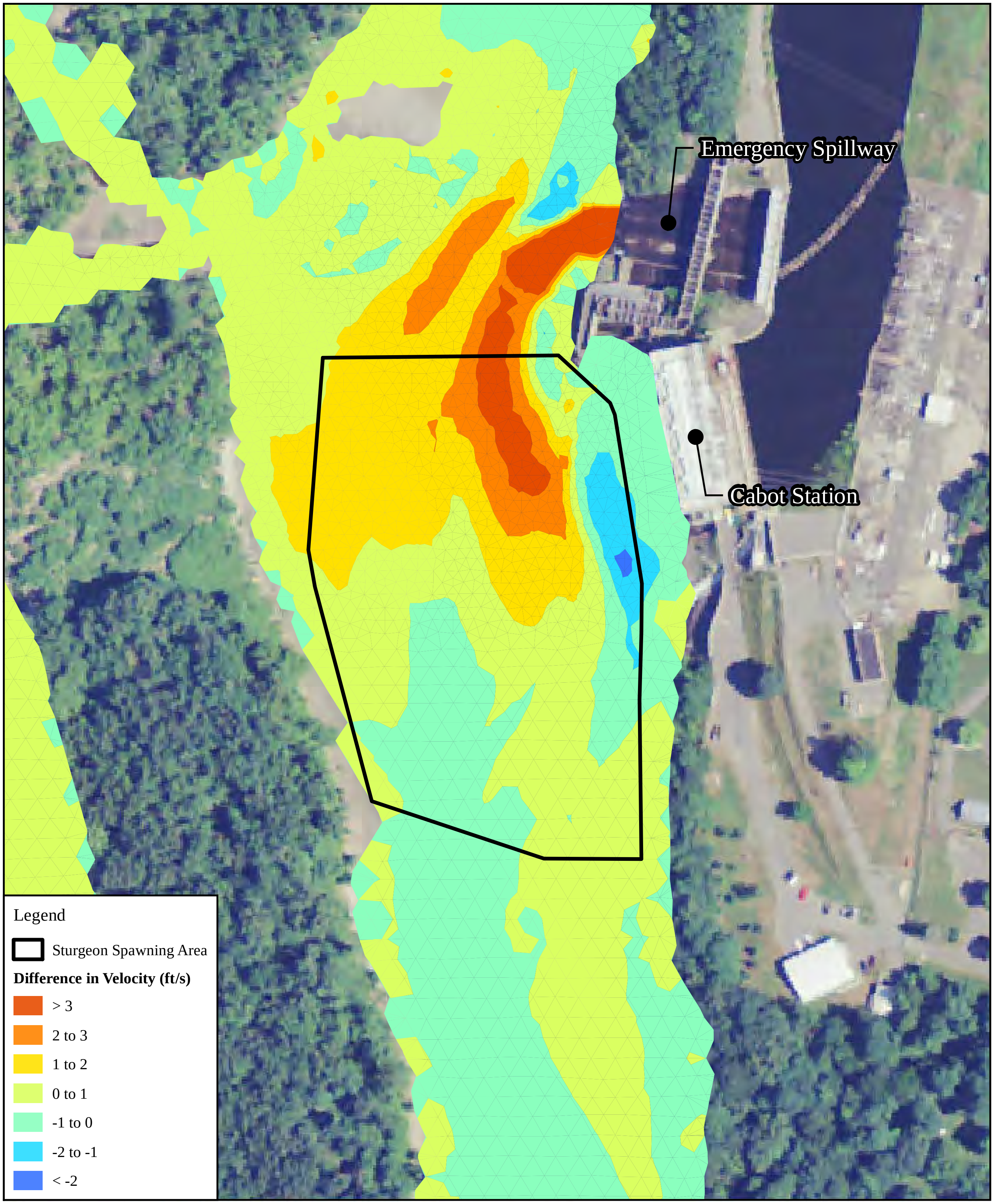
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400
Feet

Figure 4.3.1-2
Scenario E2a S1500 Minus
Scenario B2a

Path: W:\gis\studies\3_3_12\maps\E2a_S1500_minus_B2a.mxd



FirstLight GDF SUEZ

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Turners Falls Hydroelectric Project No. 1889

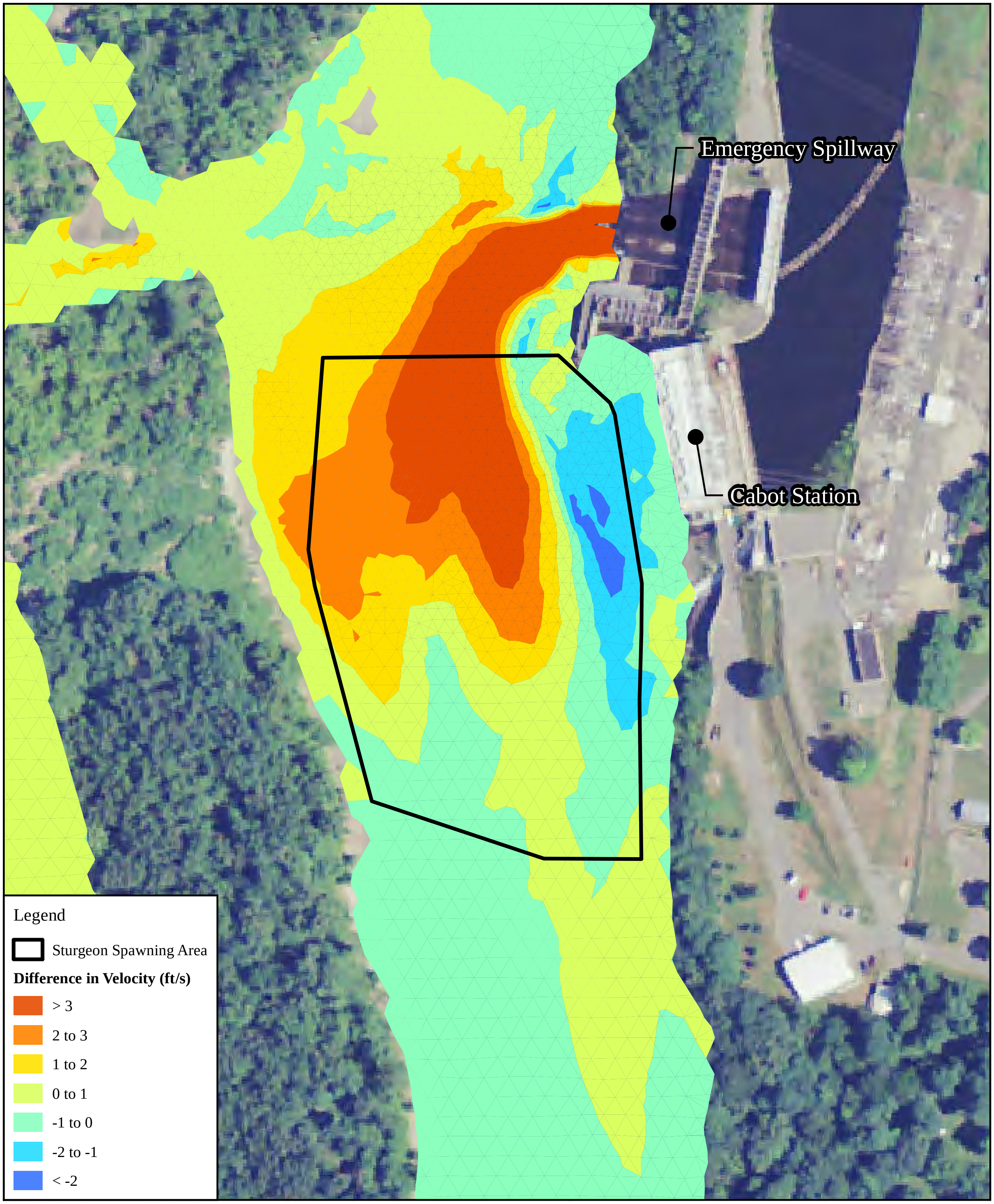
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Figure 4.3.1-3
Scenario E3 S3000 Minus
Scenario B3

Path: W:\gis\studies\3_3_12\maps\E3_S3000_minus_B3.mxd



FirstLight
GDF SUEZ

N

0 100 200 400 Feet

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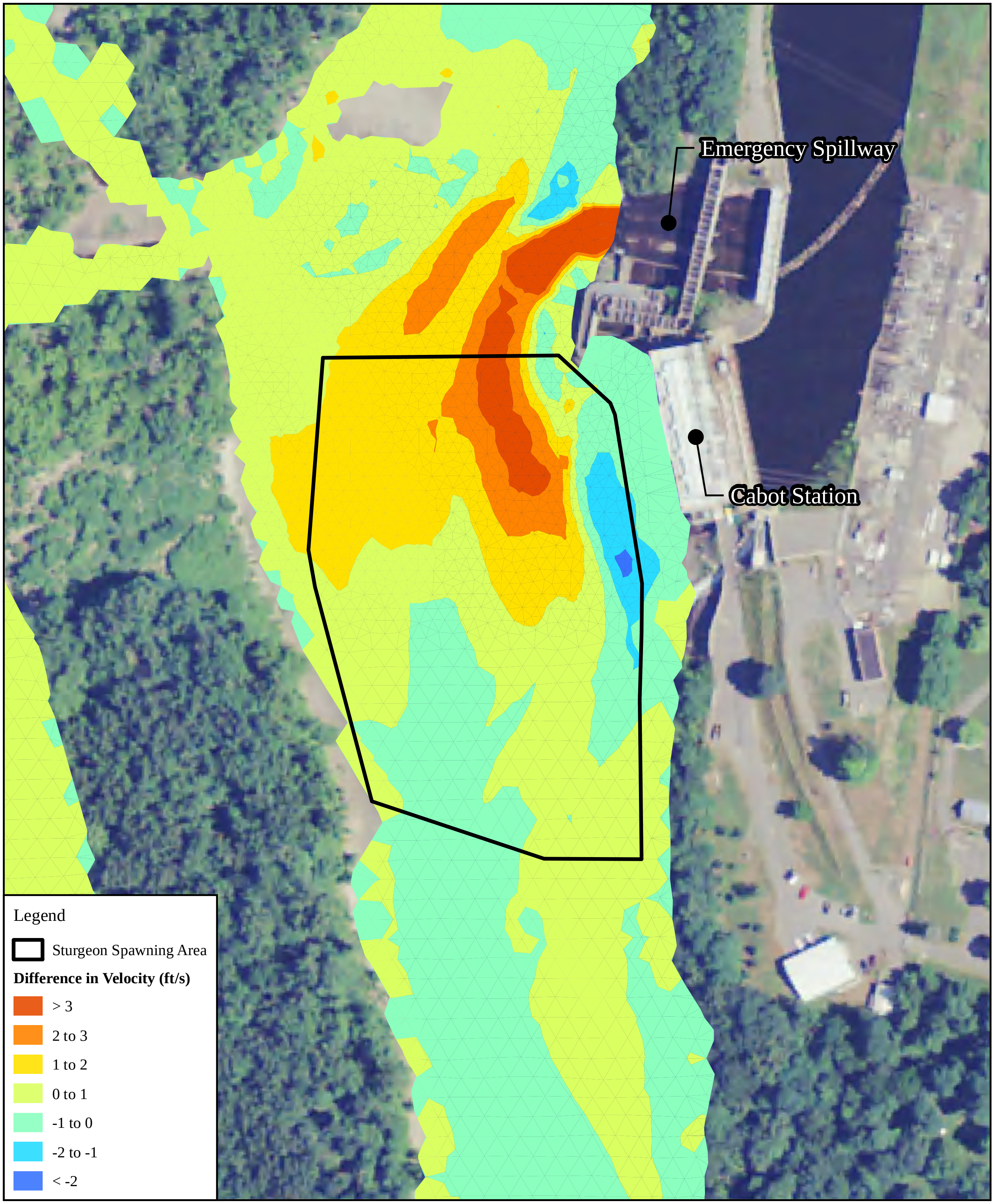
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Figure 4.3.1-4:
Scenario E4 S5000 Minus
Scenario B4

Path: W:\gis\studies\3_3_12\maps\E4_S5000_minus_B4.mxd



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N

0 100 200 400 Feet

Figure 4.3.1-5
Scenario E3 S3000 Minus
Scenario B3

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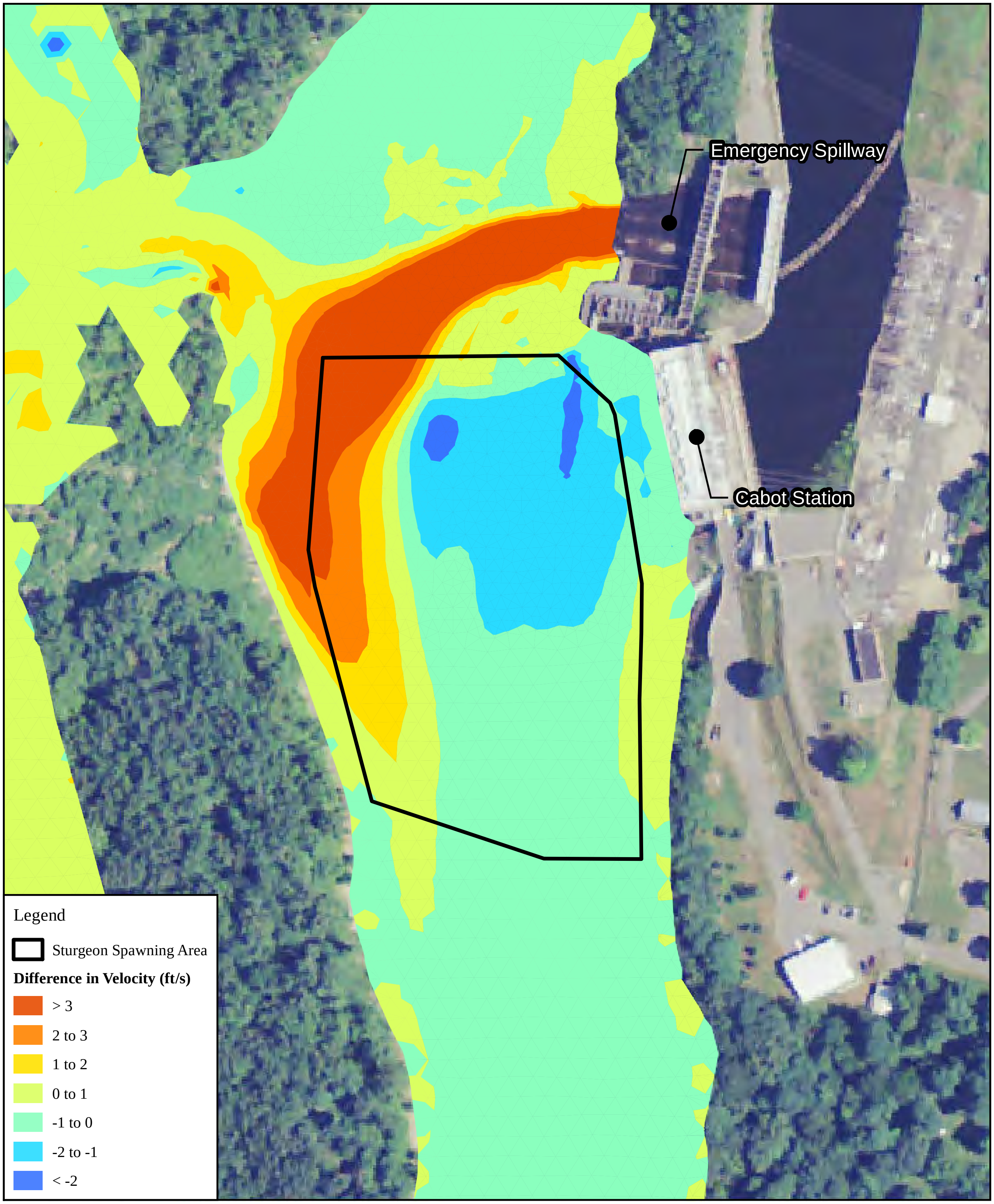

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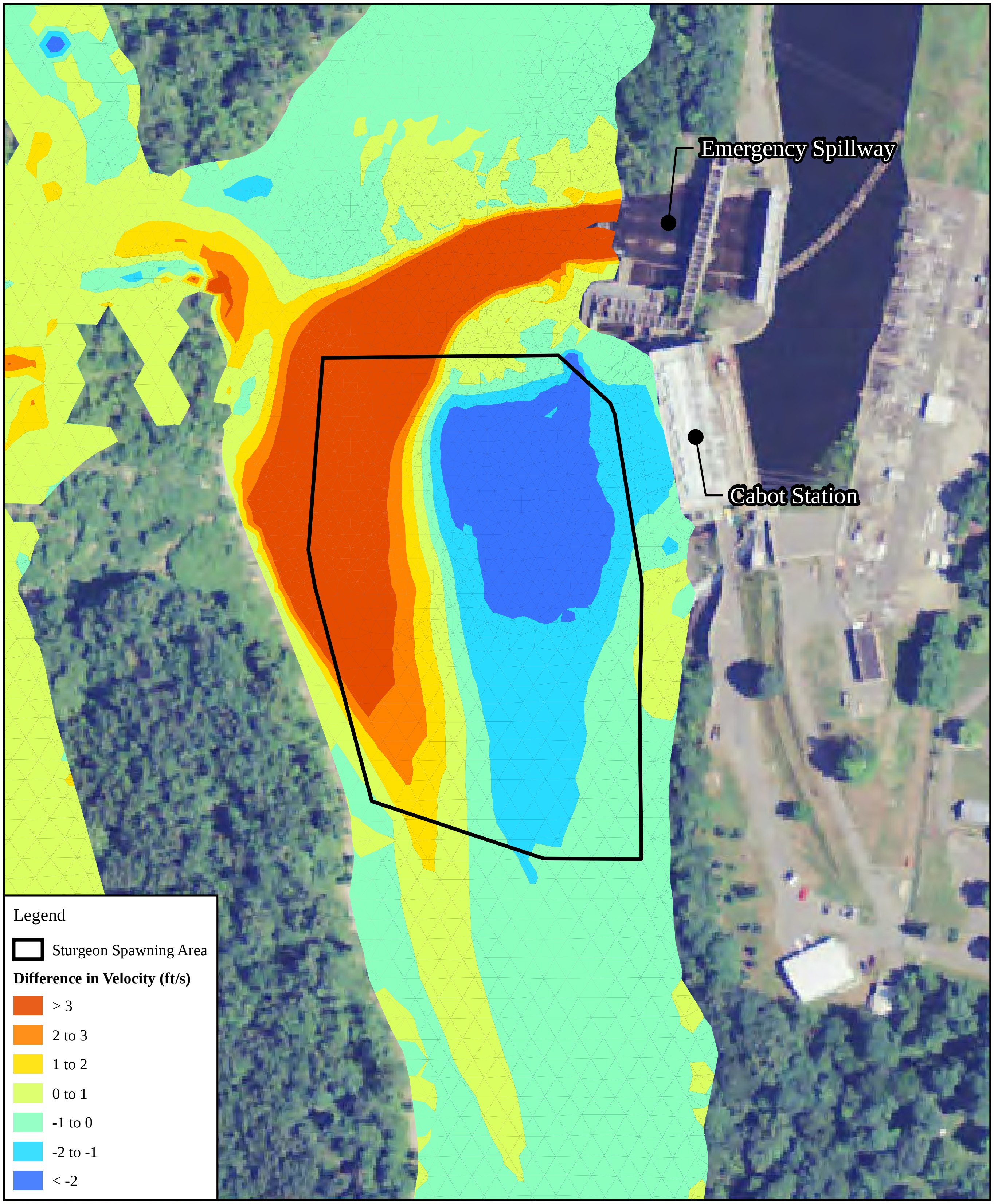
N

0 100 200 400 Feet

Figure 4.3.1-6:
Scenario E5b S5000 Minus
Scenario B5b

Path: W:\gis\studies\3_3_12\maps\E5b_S5000_minus_B5b.mxd



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N

0 100 200 400 Feet

Figure 4.3.1-7:
Scenario E5b S8000 Minus
Scenario B5b

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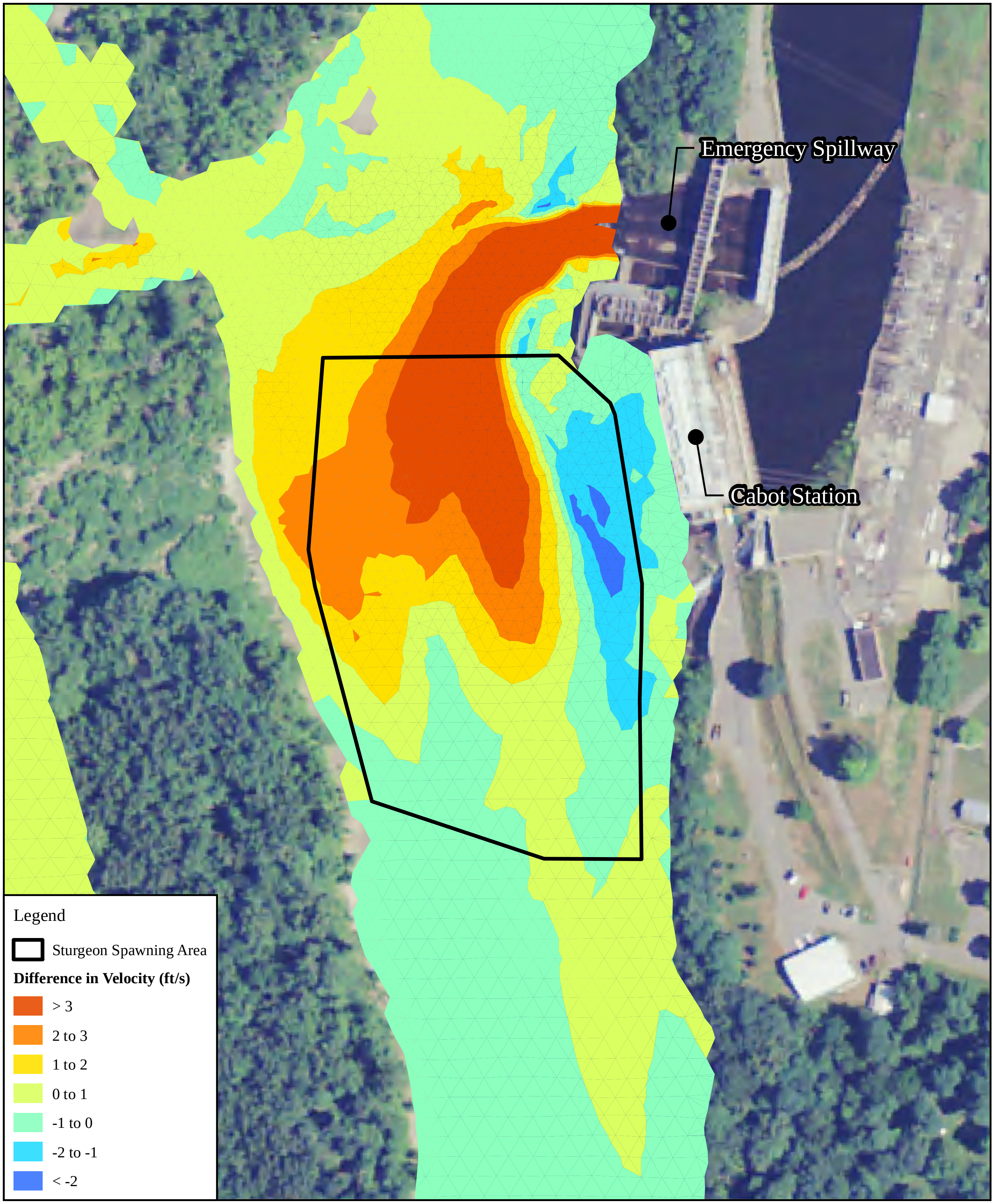

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N

0 100 200 400
Feet

Figure 4.3.1-8:
Scenario E4 S5000 Minus
Scenario B4

Path: W:\gis\studies\3_3_12\maps\E4_S5000_minus_B4.mxd

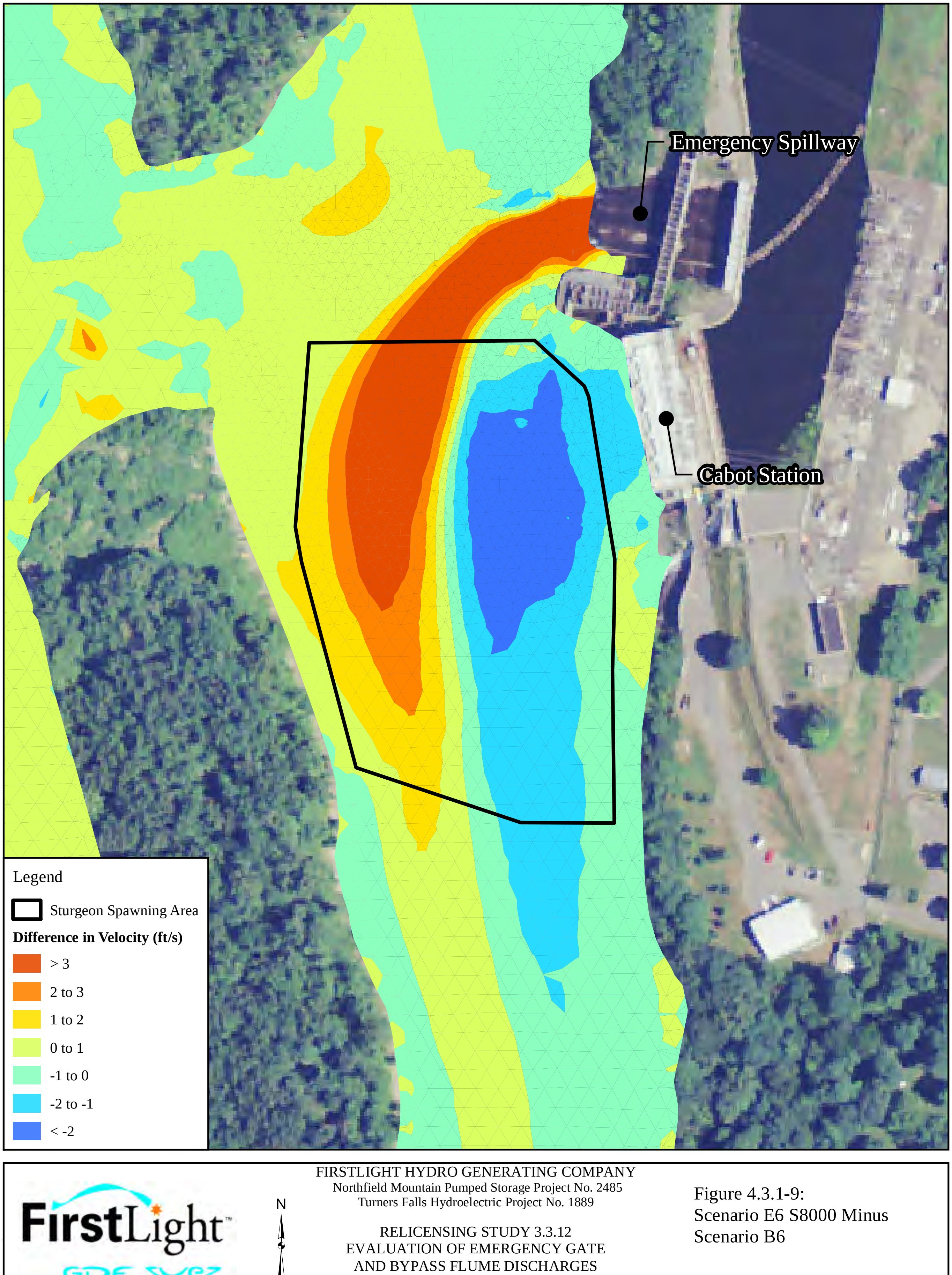

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Figure 4.3.1-9:
Scenario E6 S8000 Minus
Scenario B6

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4.3.2 Velocities Downstream of the Sturgeon Spawning Area

Changes in the velocities at areas downstream of the sturgeon spawning area from emergency spillway gates releases could affect deposition of sturgeon eggs and sediment that was mobilized in the sturgeon spawning area. To determine the velocity changes in key areas downstream of the sturgeon spawning area, we analyzed the velocity at two cross-sections (Figure 3.3.1-1). These locations were selected since it is possible, depending on water column velocities, particle sizes and other variables, that eggs or sediment would be deposited on the gravel bars located immediately downstream of these cross-sections.

Similar to the velocity difference maps, these cross sections were compared in baseline conditions to emergency spillway gate operations scenarios when total river flow near Cabot Station were similar. However, to help show the limited effects of Deerfield River flow, Scenarios B1b and B2b with a Deerfield River flow of 1,445 cfs were added to the comparison;

- Scenario E1a S1500 (spillway: 1,500 cfs) and Scenarios B1a and B1b (Cabot: 1,500 cfs); with bypass flows of 500 cfs;
- Scenario E2a S1500 (spillway: 1,500 cfs) and Scenarios B2a and B2b (Cabot: 1,500 cfs); with bypass flows of 2,500 cfs;
- Scenario E3 S3000 (spillway: 3,000 cfs) and Scenario B3 (Cabot: 3,000 cfs); with bypass flows of 2,500 cfs;
- Scenario E4 S5000 (spillway: 5,000 cfs) and Scenario B4 (Cabot: 5,000 cfs); with bypass flows of 2,500 cfs;
- Scenario E5b S3000 (spillway: 3,000 cfs and Cabot: 11,000 cfs); Scenario E5b S5000 (spillway: 5,000 cfs and Cabot: 9,000 cfs); Scenario E5b S8000 (spillway: 8,000 cfs and Cabot: 6,000 cfs) and Scenario B5b (Cabot: 14,000 cfs); with bypass flows of 2,500 cfs; and
- Scenario E6 S5000 (spillway: 5,000 cfs and Cabot: 9,000 cfs); Scenario E6 S8000 (spillway: 8,000 cfs and Cabot: 6,000 cfs); and B6 (Cabot: 14,000 cfs) with bypass flows of 10,000 cfs.

The cross sectional velocities and bed elevations from River2D are provided in Figures 4.3.2-1 to 4.3.2-6 for cross-section 1 and Figures 4.3.2-8 to 4.3.2-13 for cross-section 2. In this series of charts, Station 0 is on river right, so the charts are viewed as if looking upstream.

Figures 4.3.2-1 to 4.3.2-6 indicate similar velocities between the compared scenarios at the cross-section 1, with some exceptions. For example under higher river flows and releases from the emergency spillway gates as shown in Figures 4.3.2-5 and 4.3.2-6, velocities are generally higher on the western side of the channel and lower on the eastern side of the channel. In addition, the area under the curve, which would be equal if the total flow was the same, is generally smaller for the scenarios with flow from the emergency spillway gates as compared to baseline conditions. The lower amount of flow in the main channel is the result of a higher percentage of flow being forced into the side channel on the western side of Smead Island during releases from the emergency spillway gates. Comparisons in the velocity and vectors for Scenario E5b S8000 and B5b are shown in Figure 4.3.2-7.

Downstream, at cross-section 2 as shown in Figures 4.3.2-8 to 4.3.2-13, velocities are generally slightly lower for the scenarios with flows from the emergency spillway gates as compared to the baseline scenarios. This is due to the velocity field for the emergency spillway gate release scenarios having more of an opportunity to return to baseline conditions. However, the velocities are generally lower in the emergency spillway gate scenarios since the main channel contains a smaller amount of flow due to a higher amount of flow being forced to the side channel on the western side of Smead Island. The effects of higher inflow from the Deerfield River including slightly lower velocities are seen in Figure 4.3.2-8 between Scenarios B1b and B1a and in Figure 4.3.2-9 between Scenarios B2b and B2a. The change in velocities in these two figures from differences in the Deerfield River inflow are slightly larger than the change in velocities that occur when the 1,500 cfs is released from either Cabot Station in baseline conditions or from the emergency spillway gates.

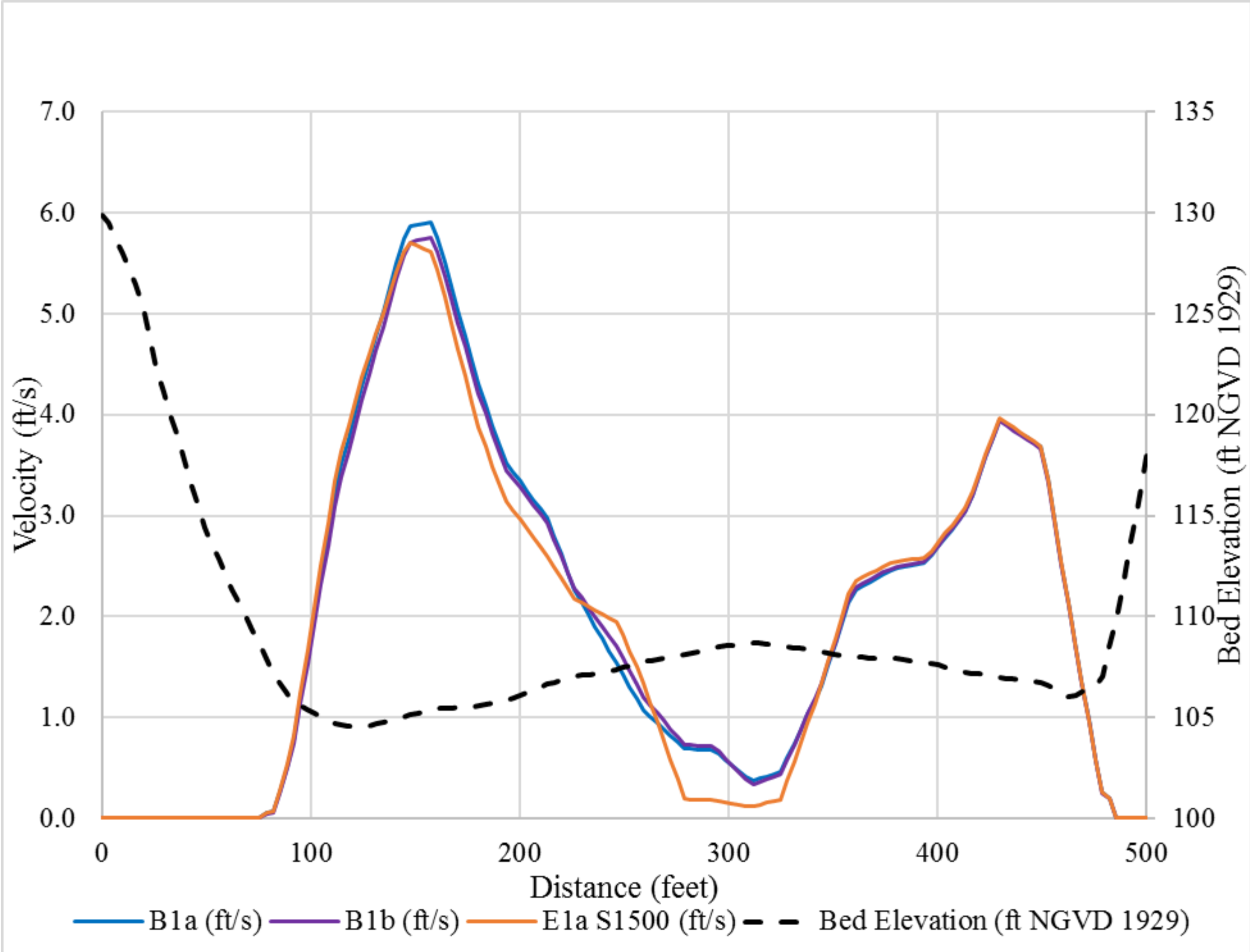


Figure 4.3.2-1: Cross Section 1 at 2,000 cfs

B1a: Bypass Flow-500cfs, Cabot Flow-1,500cfs, Deerfield Flow-200cfs, Emergency Spillway Gates-0cfs
B1b: Bypass Flow-500cfs, Cabot Flow-1,500cfs, Deerfield Flow-1,445cfs, Emergency Spillway Gates-0cfs
E1a:Bypass Flow-500cfs, Cabot Flow-0cfs, Deerfield Flow-200 cfs, Emergency Spillway Gates-1,500cfs

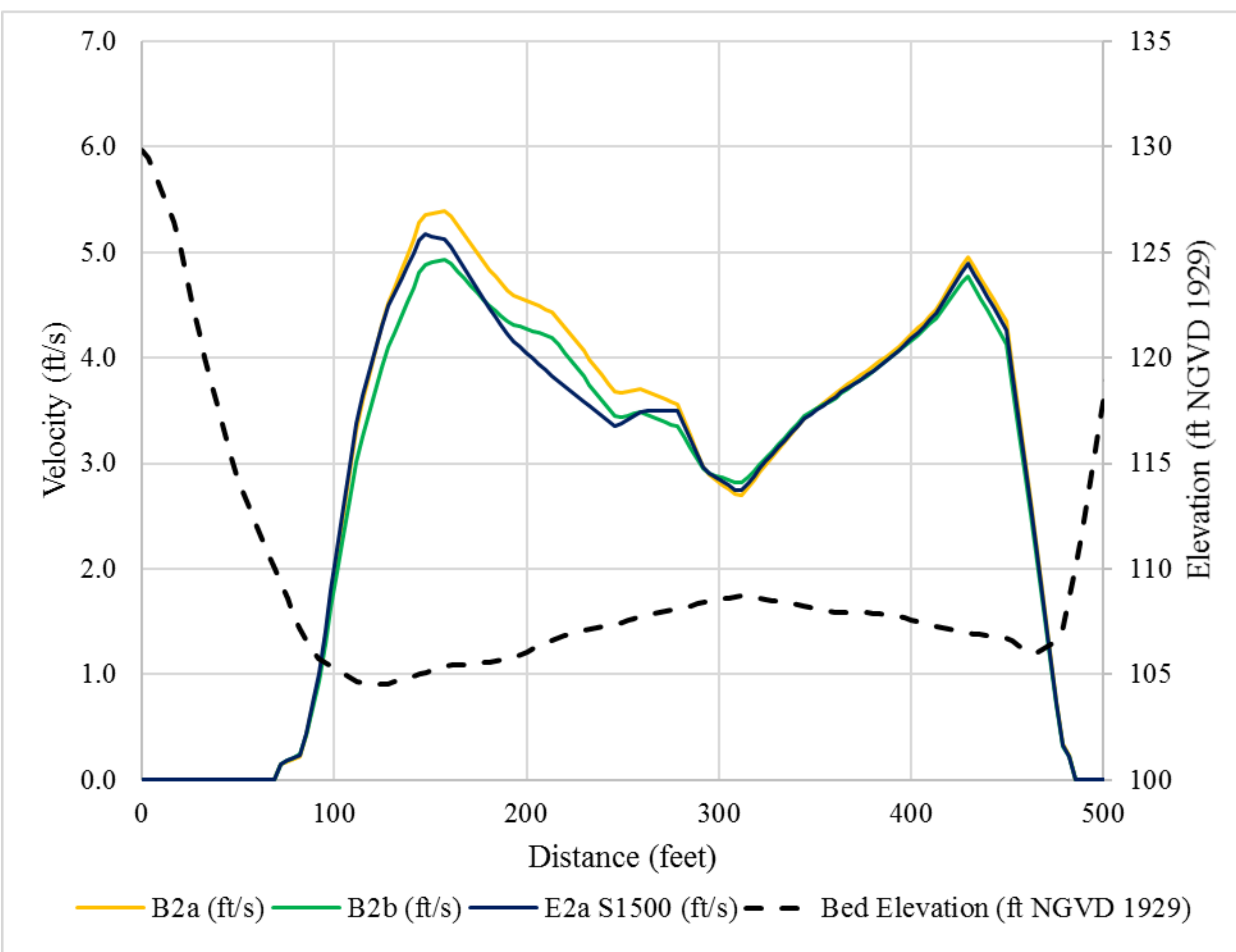


Figure 4.3.2-2: Cross Section 1 at 4,000 cfs

B2a: Bypass Flow-2,500cfs, Cabot Flow-1,500cfs, Deerfield Flow-200cfs, Emergency Spillway Gates-0cfs
B2b: Bypass Flow-2,500cfs, Cabot Flow-1,500cfs, Deerfield Flow-1,445cfs, Emergency Spillway Gates-0cfs
E2a: Bypass Flow-2,500cfs, Cabot Flow-0cfs, Deerfield Flow-200 cfs, Emergency Spillway Gates-1,500cfs

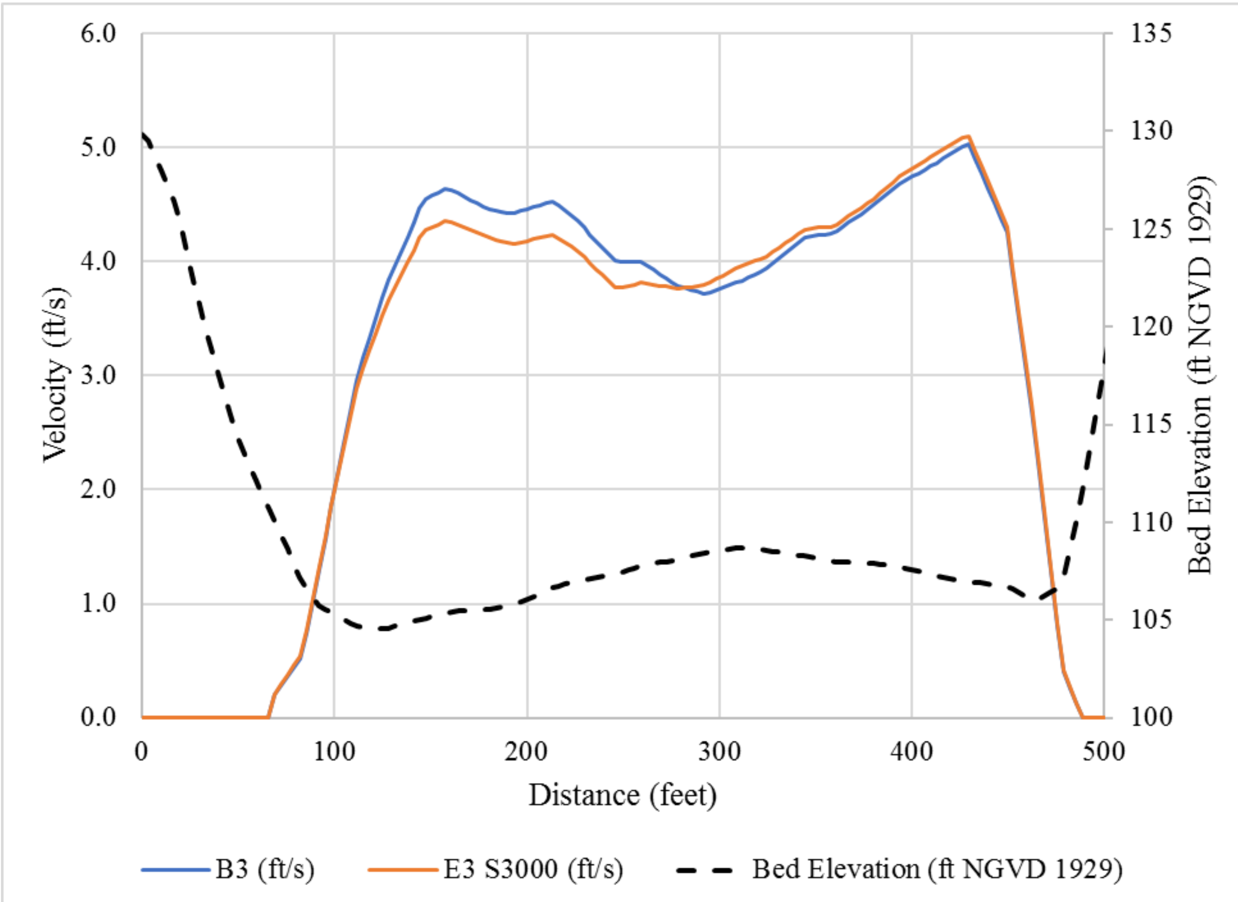


Figure 4.3.2-3: Cross Section 1 at 5,500 cfs

B3: Bypass Flow-2,500cfs, Cabot Flow-3,000cfs, Emergency Spillway Gates-0cfs
E3: Bypass Flow-2,500cfs, Cabot Flow-0cfs, Emergency Spillway Gates-3,000cfs
Deerfield Flow-1,445 cfs for both scenarios

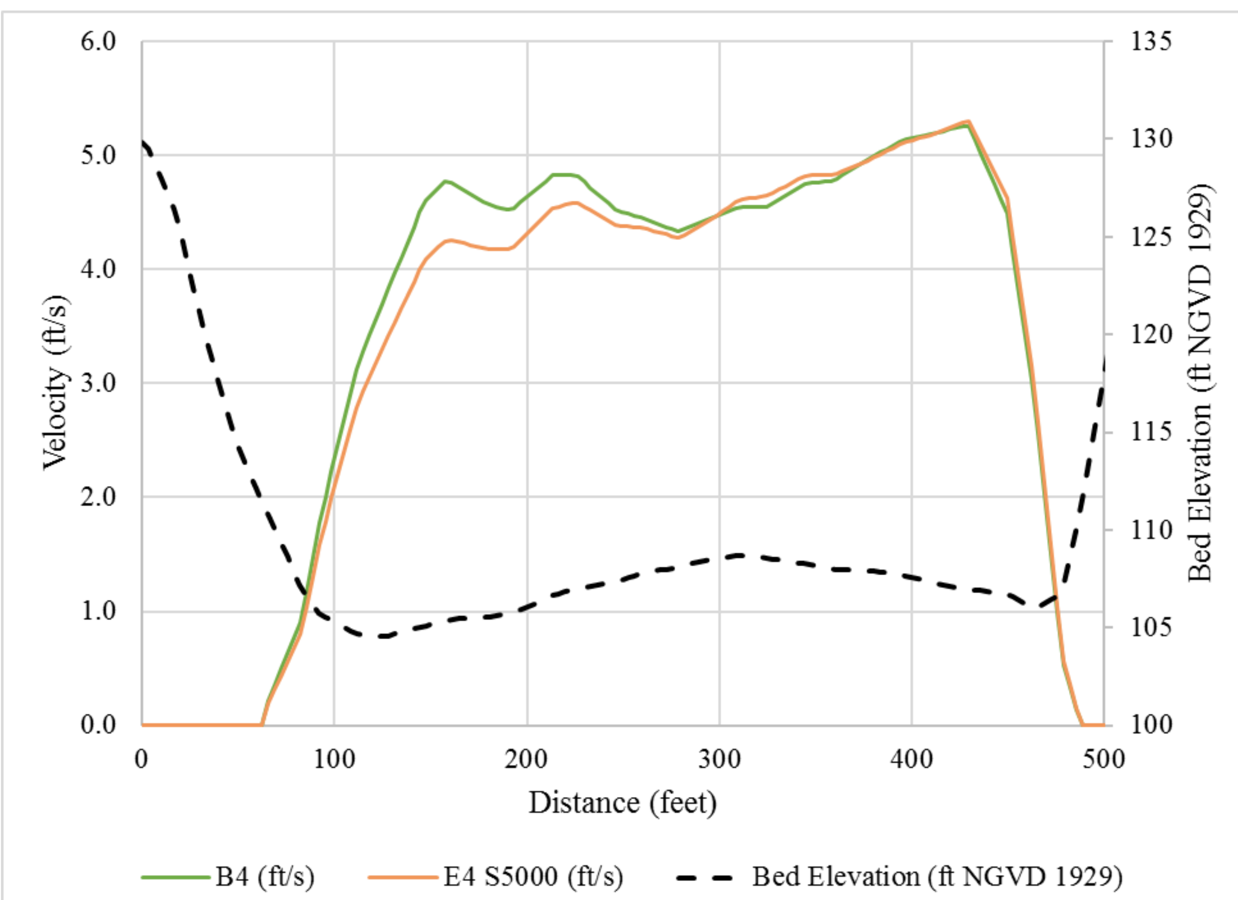


Figure 4.3.2-4: Cross Section 1 at 7,500 cfs

B4: Bypass Flow-2,500cfs, Cabot Flow-5,000cfs, , Emergency Spillway Gates-0cfs
E4: Bypass Flow-2,500cfs, Cabot Flow-0cfs, Emergency Spillway Gates-5,000cfs
Deerfield Flow-1,445 cfs for both scenarios

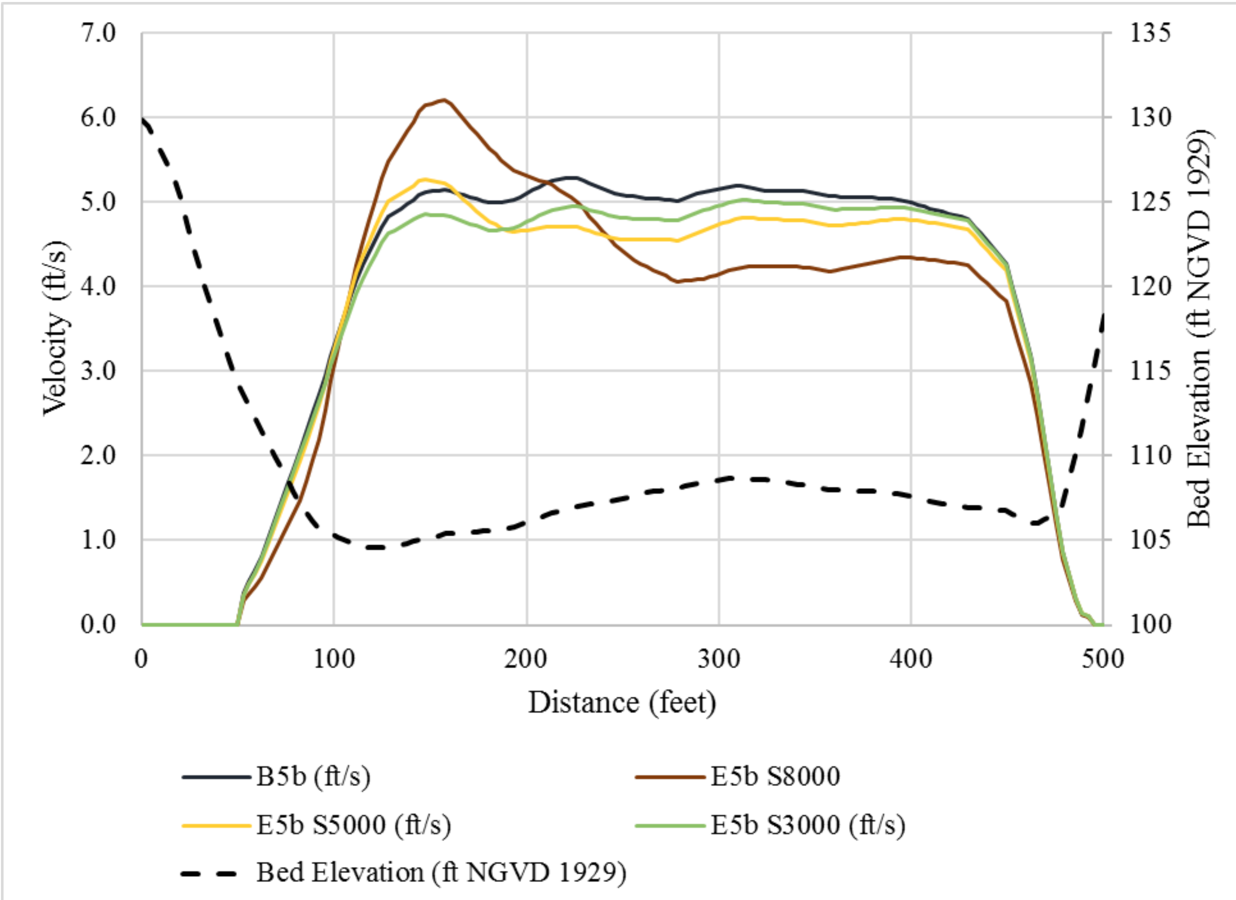


Figure 4.3.2-5: Cross Section 1 at 16,500 cfs

B5b: Bypass Flow-2,500cfs, Cabot Flow-14,000cfs, , Emergency Spillway Gates-0cfs
E5b S3000: Bypass Flow-2,500cfs, Cabot Flow-11,000cfs, Emergency Spillway Gates-3,000cfs
E5b S5000: Bypass Flow-2,500cfs, Cabot Flow-9,000cfs, Emergency Spillway Gates-5,000cfs
E5b S8000: Bypass Flow-2,500cfs, Cabot Flow-6,000cfs, Emergency Spillway Gates-8,000cfs
Deerfield Flow-1,445 cfs for all four scenarios

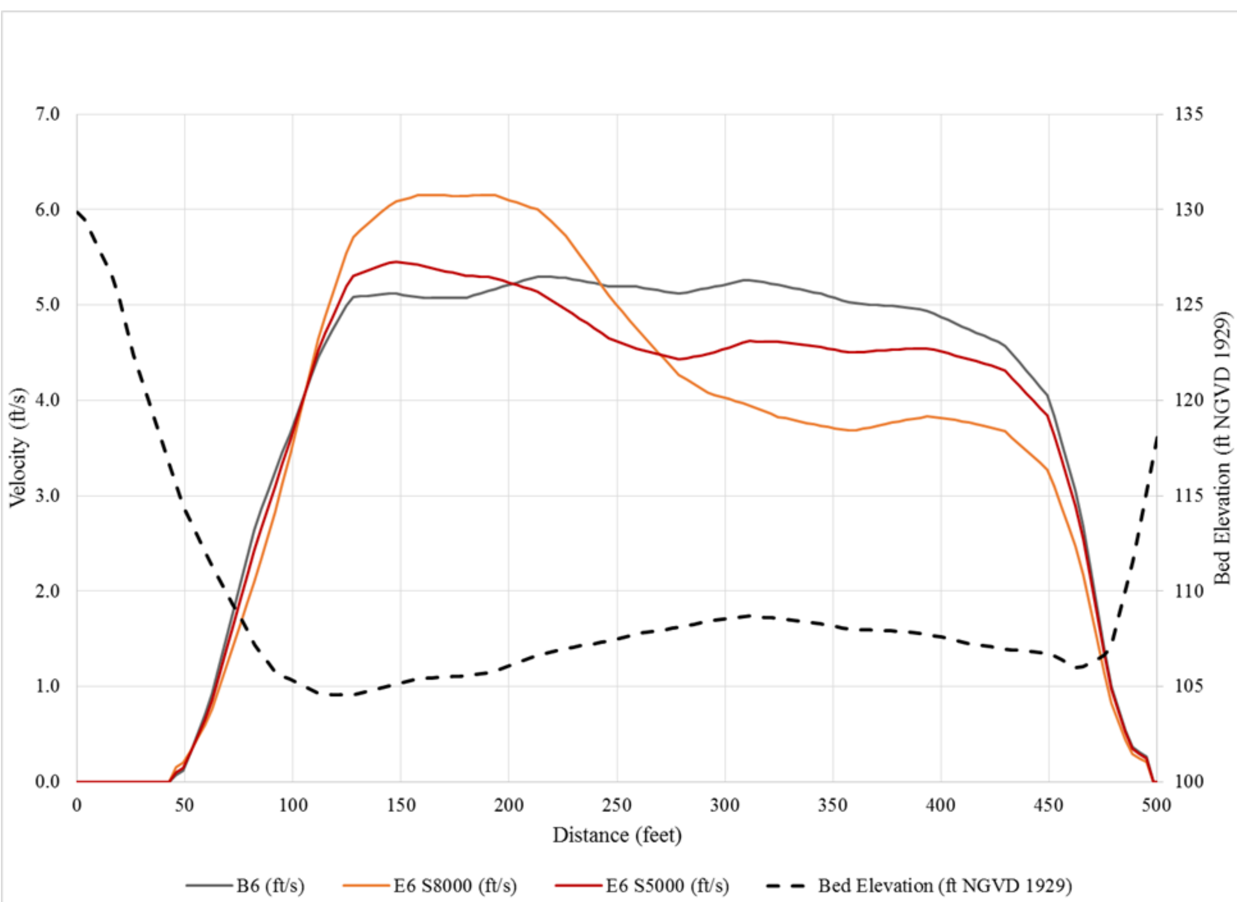
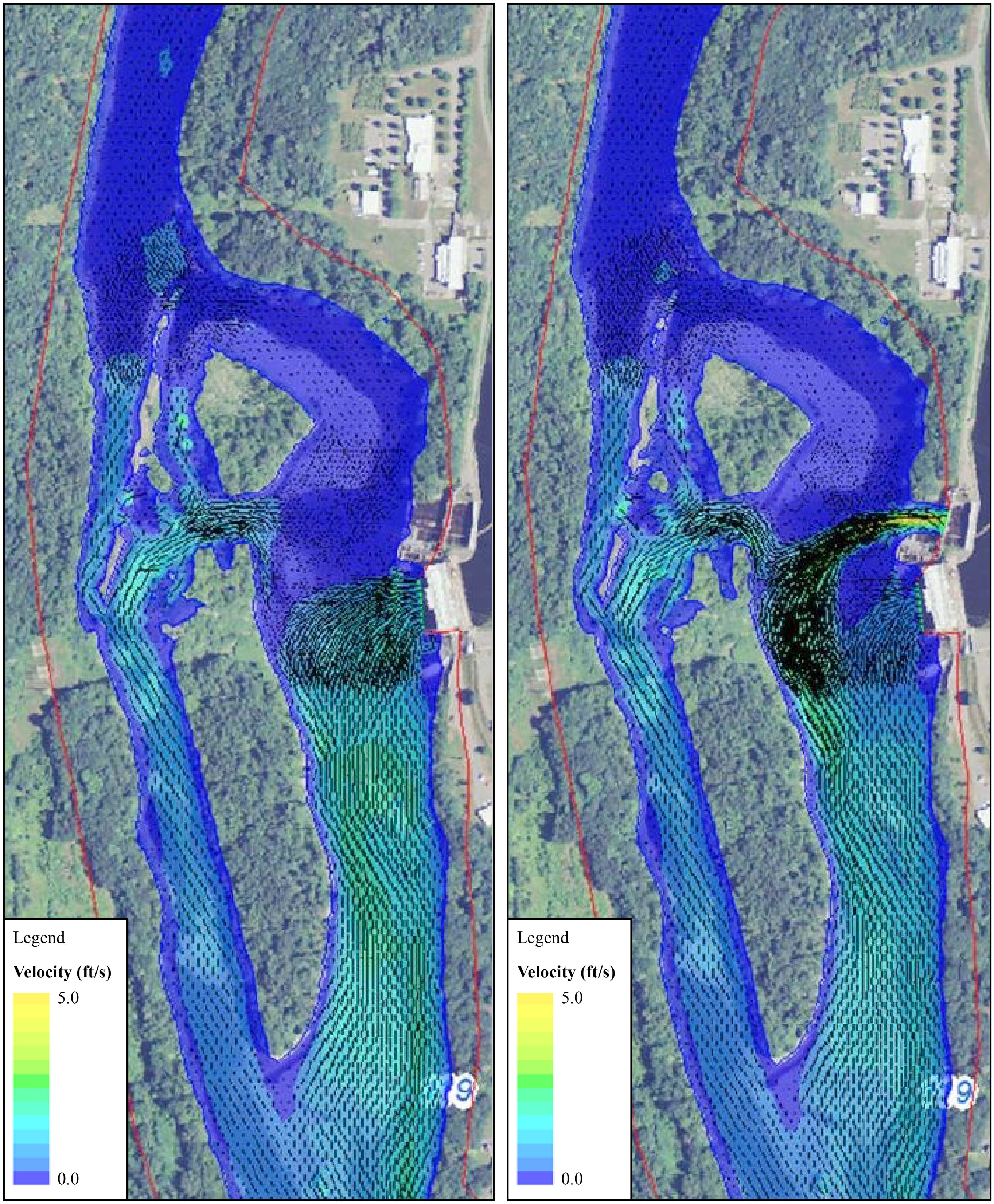


Figure 4.3.2-6: Cross Section 1 at 24,000 cfs

B6: Bypass Flow-10,000cfs, Cabot Flow-14,000cfs, Emergency Spillway Gates-0cfs
E6 S5000: Bypass Flow-10,000cfs, Cabot Flow-9,000cfs, Emergency Spillway Gates-5,000cfs
E6 S8000: Bypass Flow-10,000cfs, Cabot Flow-6,000cfs, Emergency Spillway Gates-8,000cfs
Deerfield Flow-1,445 cfs for all three scenarios



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N

0 250 500 1,000
Feet

Figure 4.3.2-7
Velocity and Vector comparison for Scenario B5b (left) and E5b S8000 (right)

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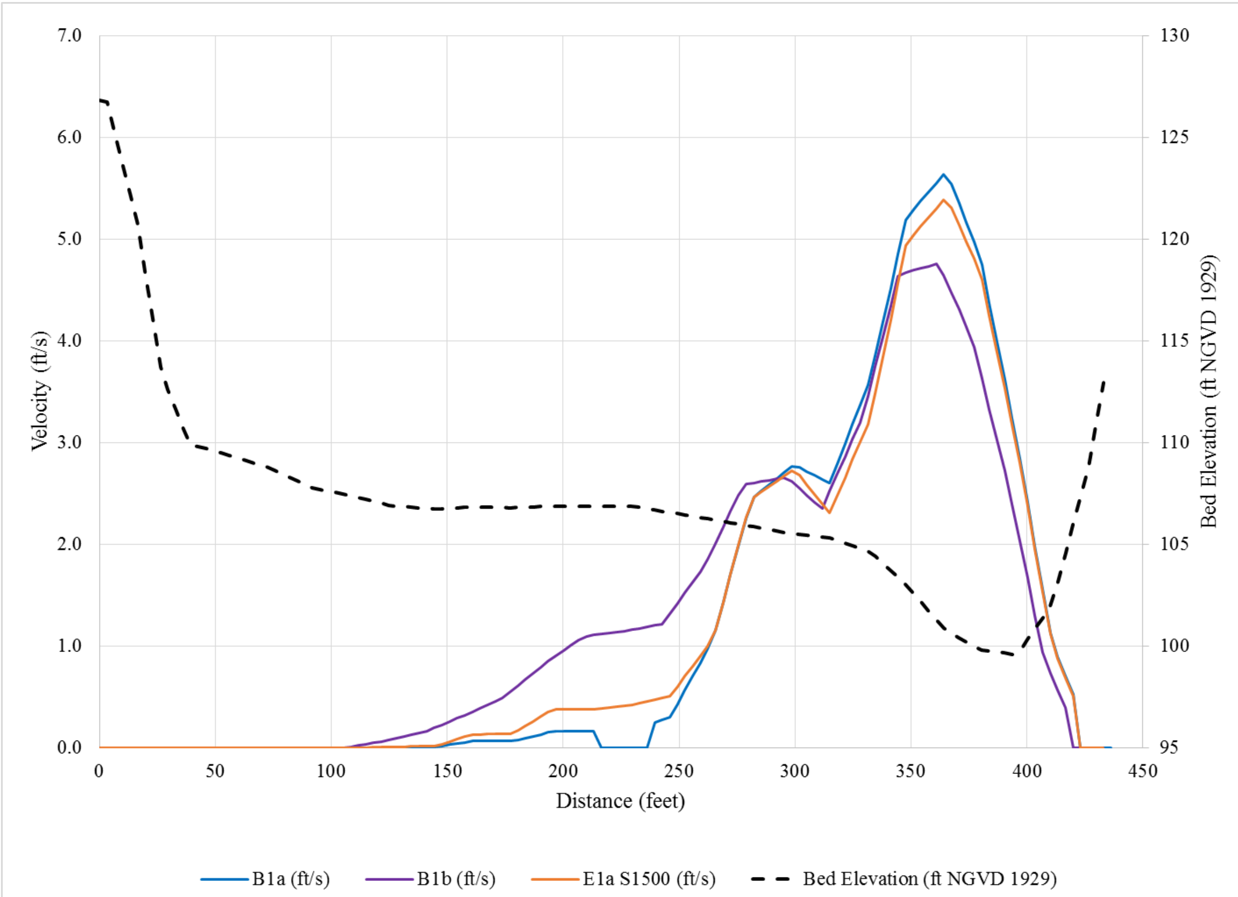


Figure 4.3.2-8: Cross Section 2 at 2,000 cfs

B1a: Bypass Flow-500cfs, Cabot Flow-1,500cfs, Deerfield Flow-200cfs, Emergency Spillway Gates-0cfs
B1b: Bypass Flow-500cfs, Cabot Flow-1,500cfs, Deerfield Flow-1,445cfs, Emergency Spillway Gates-0cfs
E1a:Bypass Flow-500cfs, Cabot Flow-0cfs, Deerfield Flow-200cfs, Emergency Spillway Gates-1,500cfs

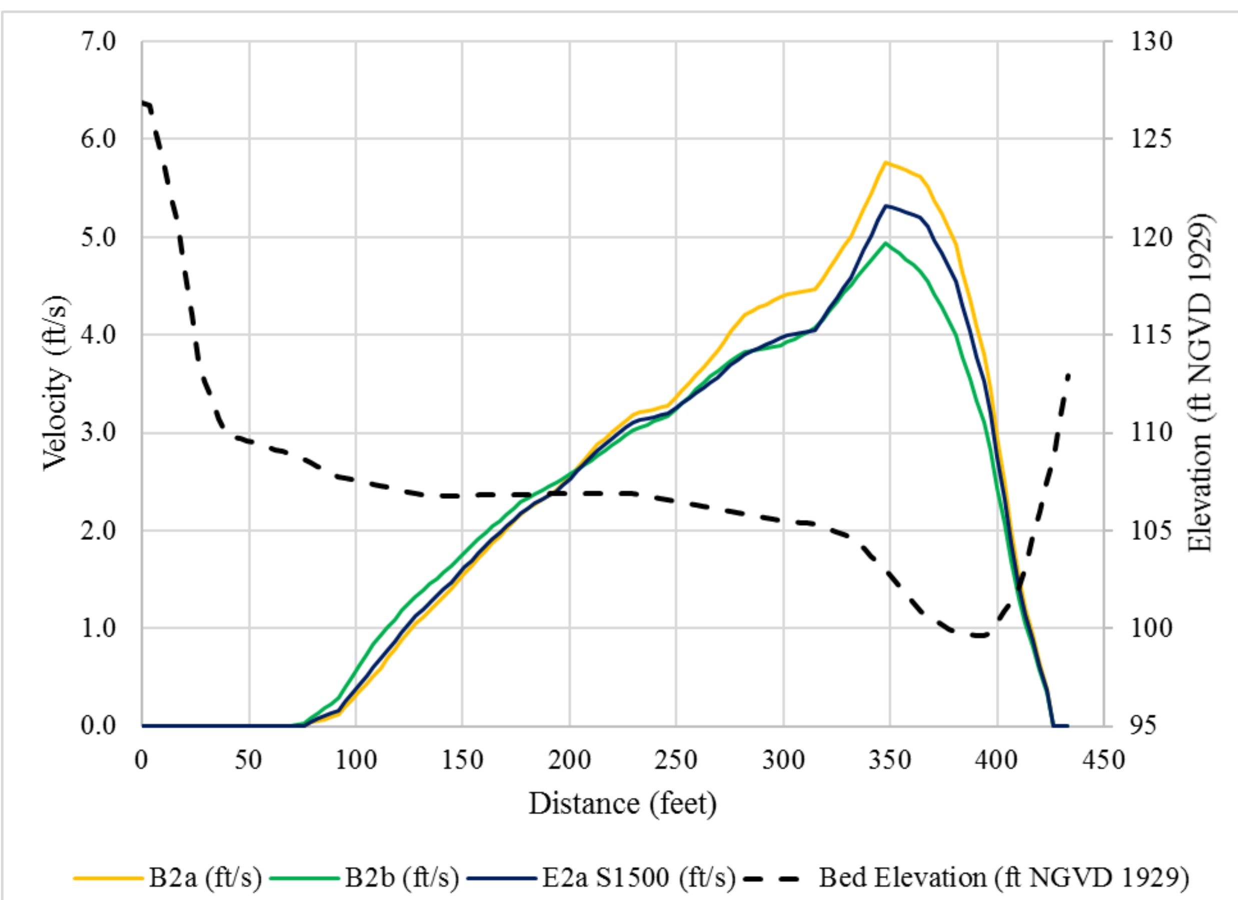


Figure 4.3.2-9: Cross Section 2 at 4,000

B2a: Bypass Flow-2,500cfs, Cabot Flow-1,500cfs, Deerfield Flow-200cfs, Emergency Spillway Gates-0cfs
B2b: Bypass Flow-2,500cfs, Cabot Flow-1,500cfs, Deerfield Flow-1,445cfs, Emergency Spillway Gates-0cfs
E2a: Bypass Flow-2,500cfs, Cabot Flow-0cfs, Deerfield Flow-200cfs, Emergency Spillway Gates-1,500cfs

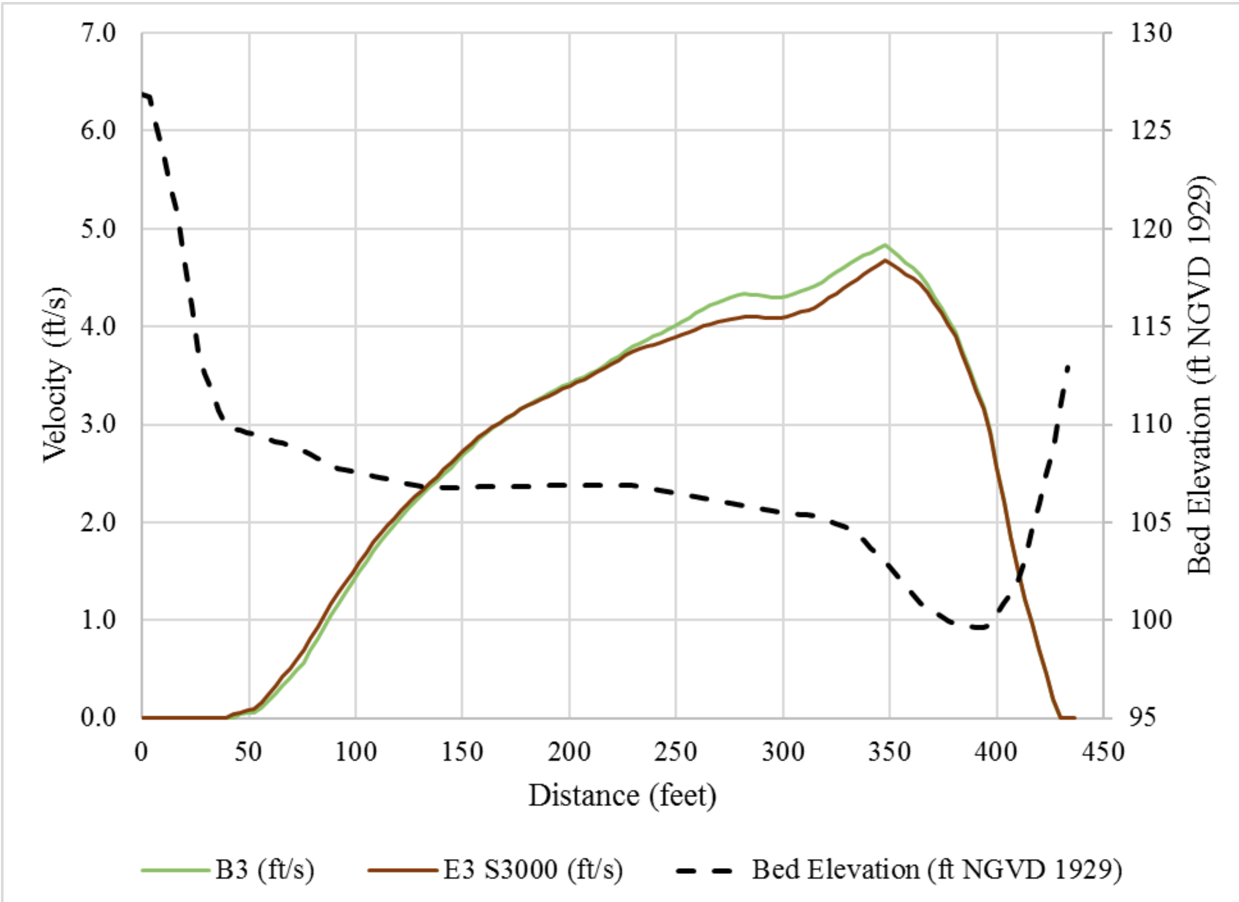


Figure 4.3.2-10: Cross Section 2 at 5,500 cfs

B3: Bypass Flow-2,500cfs, Cabot Flow-3,000cfs, Emergency Spillway Gates-0cfs
E3: Bypass Flow-2,500cfs, Cabot Flow-0cfs, Emergency Spillway Gates-3,000cfs
Deerfield Flow-1,445 cfs for both scenarios

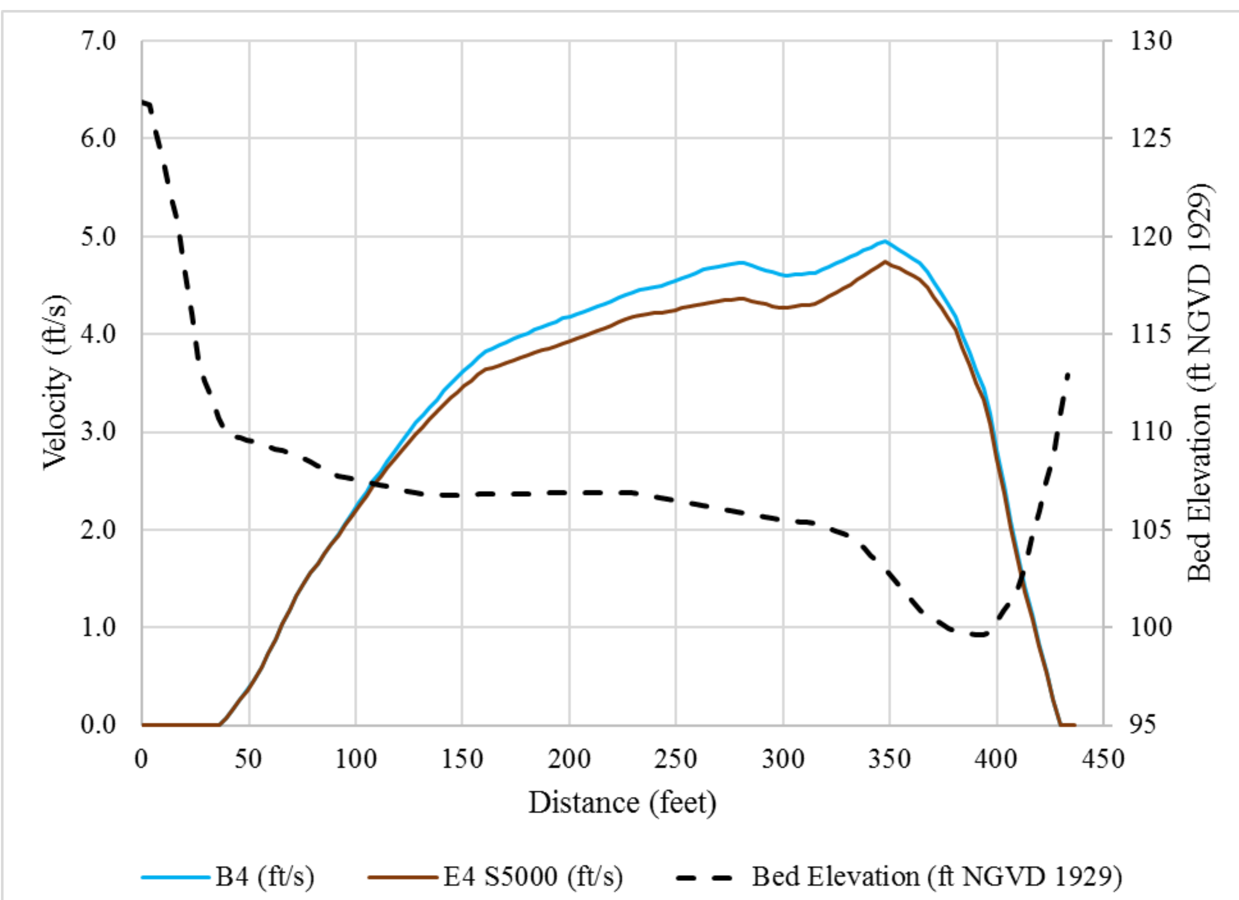


Figure 4.3.2-11: Cross Section 2 at 7,500 cfs

B4: Bypass Flow-2,500cfs, Cabot Flow-5,000cfs, Emergency Spillway Gates-0cfs
E4: Bypass Flow-2,500cfs, Cabot Flow-0cfs, Emergency Spillway Gates-5,000cfs
Deerfield Flow-1,445 cfs for both scenarios

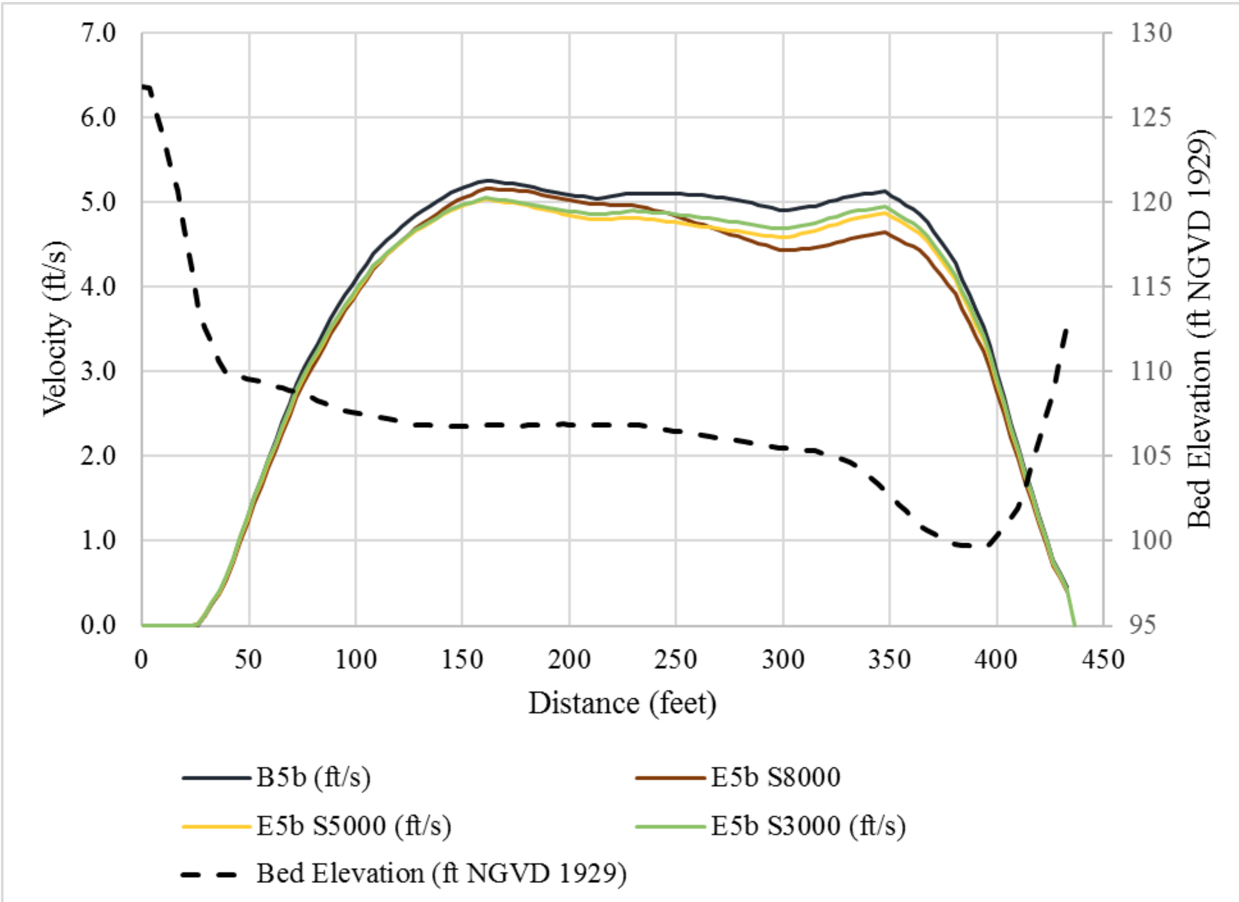


Figure 4.3.2-12: Cross Section 2 at 16,500 cfs

B5b: Bypass Flow-2,500cfs, Cabot Flow-14,000cfs, Emergency Spillway Gates-0cfs
E5b S3000: Bypass Flow-2,500cfs, Cabot Flow-11,000cfs, Emergency Spillway Gates-3,000cfs
E5b S5000: Bypass Flow-2,500cfs, Cabot Flow-9,000cfs, Emergency Spillway Gates-5,000cfs
E5b S8000: Bypass Flow-2,500cfs, Cabot Flow-6,000cfs, Emergency Spillway Gates-8,000cfs
Deerfield Flow-1,445cfs for all four scenarios

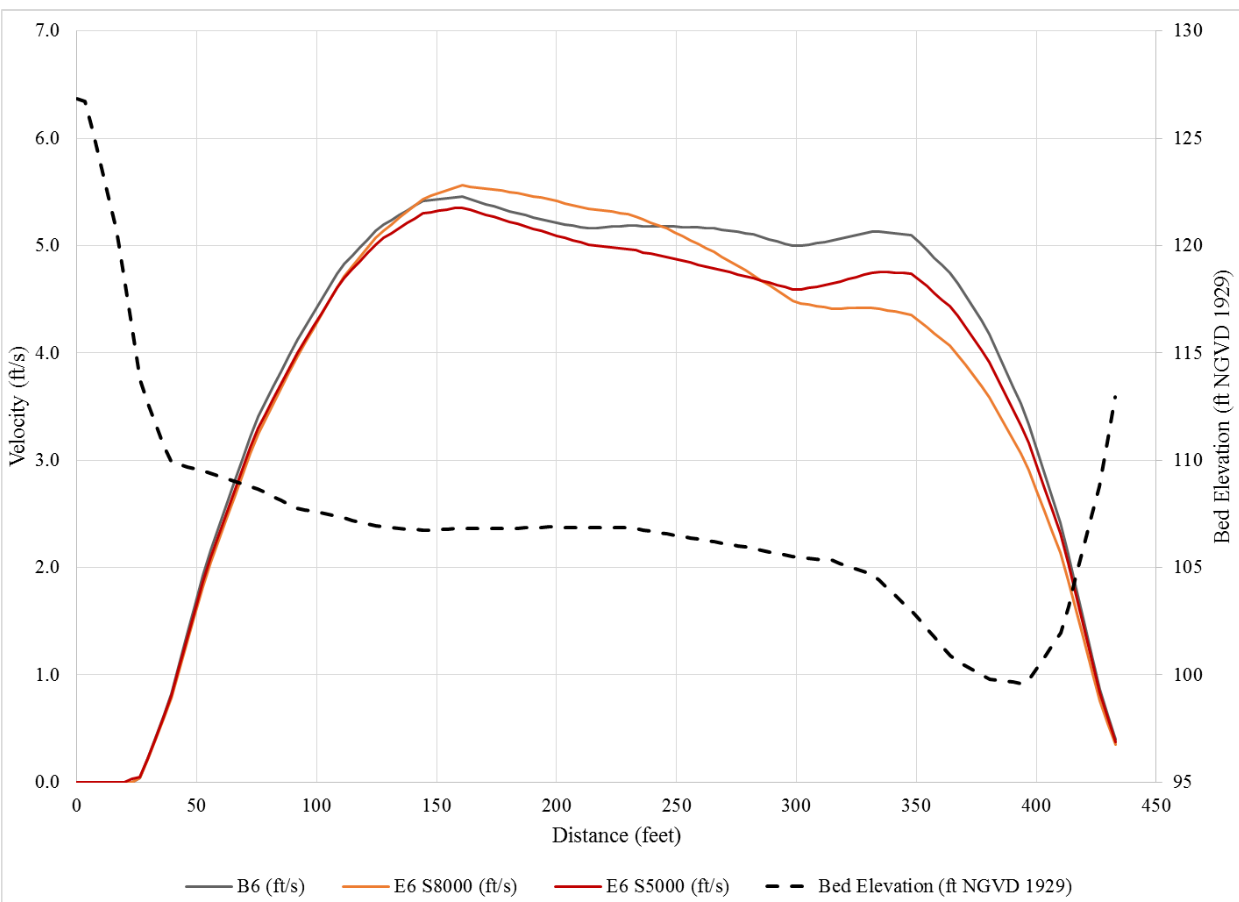


Figure 4.3.2-13: Cross Section 2 at 24,000 cfs

B6: Bypass Flow-10,000cfs, Cabot Flow-14,000cfs, Deerfield Flow-1,445cfs, Emergency Spillway Gates-0cfs
E6 S5000: Bypass Flow-10,000cfs, Cabot Flow-9,000cfs, Emergency Spillway Gates-5,000cfs
E6 S8000: Bypass Flow-10,000cfs, Cabot Flow-6,000cfs, Emergency Spillway Gates-8,000cfs
Deerfield Flow-1,445 cfs for all three scenarios

4.3.3 Evaluation of Shear Stress and Particle Mobilization

River2D is capable of predicting depth-averaged hydraulic parameters including depth, velocity, shear stress, and other variables. Due to the depth-averaged nature of the model, River2D is not capable of predicting vertical flow distributions that can be determined with a three-dimensional model. River2D model results are representative of conditions throughout the modeled area except in areas within 150 feet of the Cabot Station and the emergency spillway gates. However, in this area, the substrate is primarily boulder and bedrock and not subject to mobilization during river flow conditions that are controllable by Cabot Station. We used the model's velocity and shear stress output to estimate sediment mobilization potential throughout the area of interest. The combined sediment mobilization potential and substrate mapping analysis allowed FirstLight to identify what size particles (e.g., silt, sand, gravel) may be transported downstream, potentially affecting the sturgeon spawning area or other areas of concern.

A common way to determine substrate mobilization potential is by determining the relative shear stress which is calculated by shear stress divided by critical stress. Relative shear stress is very sensitive to particle size and since smaller particles have a smaller critical stress. Therefore a higher relative shear stress, above a value of 1, is an indication of the mobilization potential of the substrate. Appendix D contains maps of the relative shear stress in the area in the vicinity of Cabot Station for the 19 scenarios.

Maps of the changes in the particle mobilization potential between baseline and spill conditions for the same total flow values, are shown in Figures 4.3.3-1 to 4.3.3-9. These figures indicate locations where:

- Particle mobilization does not occur in the baseline or spill scenario (relative shear stress below 1);
- Particle mobilization occurs in baseline but not the spill scenario (relative shear stress above 1 for baseline but below 1 for spill);
- Particle mobilization occurs in both the baseline and spill scenario (relative shear stress above 1 for both baseline and spill); and
- Particle mobilization occurs in the spill but not the baseline scenario (relative shear stress above 1 for spill but below 1 for baseline).

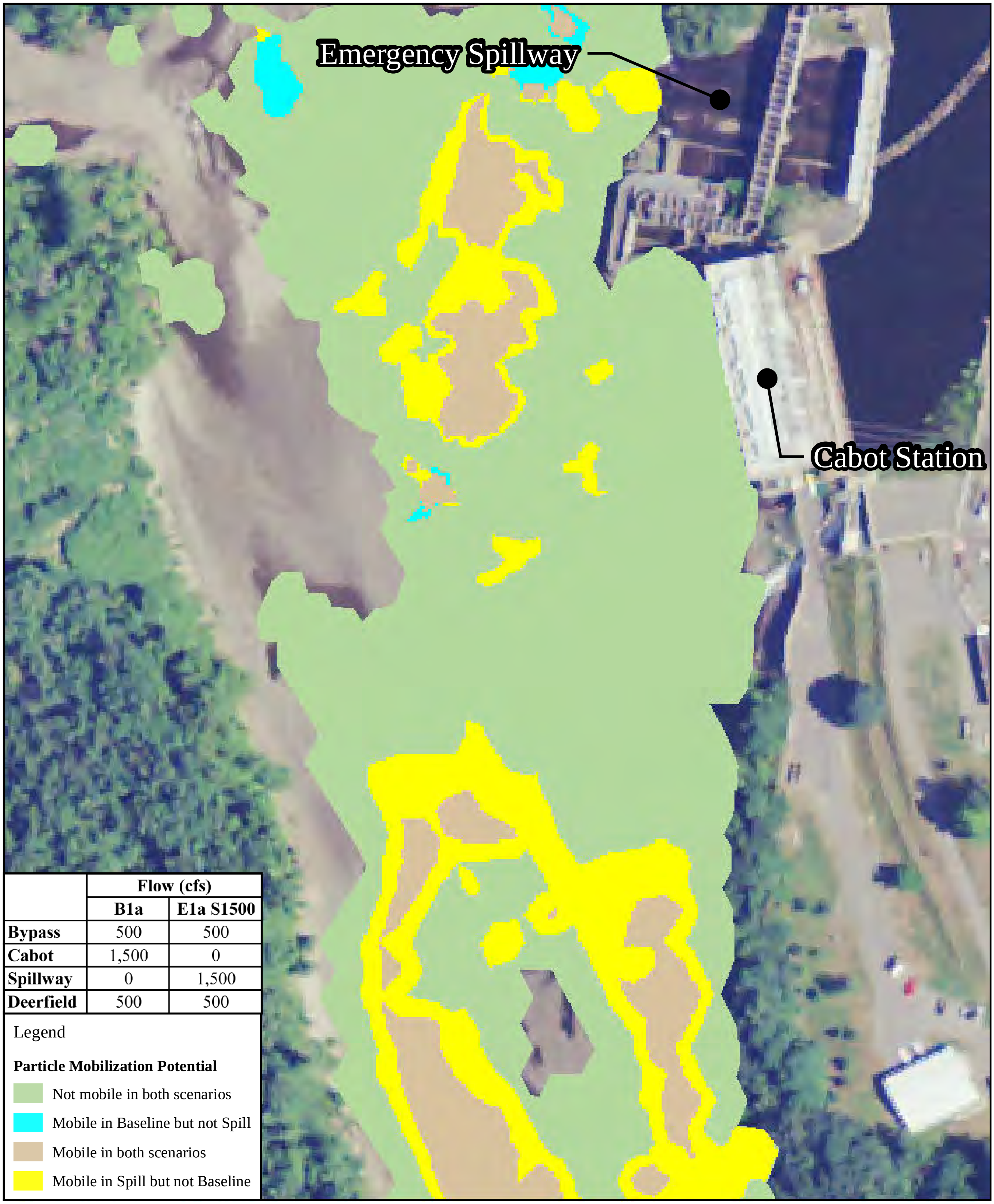
Sediment mobilization potential was observed in every baseline model. Changes in relative shear stress between emergency spill scenarios and comparable baseline flow conditions occurred within all comparisons, though at varying spatial extents. For the purpose of this analysis, areas where relative shear stress was greater than one were considered most important in the vicinity of the spillway and Cabot Station where sand was present. Patterns observed include:

- E1a showed the least amount of change relative to the baseline conditions. Spill flows of 1,500 cfs may not result in considerable differences in sediment mobilization under these operating conditions (i.e. low bypass flow, full station trip, low Deerfield River flow). Mobilization potential for E1a appears to be more comparable to the baseline scenario of B2b, showing similar mobilization potential to moderate (2,500 cfs) bypass flows, low (1,500 cfs) generation at Cabot Station, and high Deerfield River flows in the absence of emergency spillway flow.

- E2a showed slightly less, but similar pattern of, mobilization potential to E3 and E4. The primary similarities between these models is the addition of spill (1,500, 3,000, and 5,000 cfs respectively) to a bypass flow of 2,500 cfs during a full station trip. All of these scenarios showed potential for sediment mobilization most similar to B7 near the emergency spillway and Cabot Station; as such, mobilization potential under these three spill gate scenarios appear to be comparable to times of full capacity generation and a much higher but a still common amount (20,000 cfs) of flow through the bypass reach.

- E6 models with 5,000 cfs and 8,000 cfs, and bypass flows 0f 10,000 cfs, showed very similar patterns of mobilization potential. The most similar baseline model to these emergency scenario models was B7, though with more potential for sediment mobilization in relatively small areas further across the channel from the emergency spillway; as such, mobilization potential appears to be comparable to times of full capacity generation and 20,000 cfs flow through the bypass reach.

- E5b models with 3,000 cfs, 5,000 cfs, and 8,000 cfs, and a bypass flow of 2,500 cfs, represent scenarios where discharge occurred at the emergency spillway but remaining water was still being passed through Cabot Station. These scenarios showed similar patterns, with the greatest changes from the baseline models occurring from the entrance of the spillway, across the channel, and on the far side of the main river channel along the eastern side of Smead Island. Relative to the baseline models, greater flow from the emergency spillway resulted in the greatest increases in mobilization potential toward Smead Island, and decreases in mobilization potential at mid-channel areas near Cabot Station. These scenarios appear to have the greatest potential for mobilization of sediment from areas where mobilization was not predicted during any of the baseline scenarios. However, the total amount of new area for sediment mobilization is not considerably different than those predicted in B7 with the exception of areas further across the channel from the emergency spillway that were not predicted to have the potential for sediment mobilization in any other scenarios.



	Flow (cfs)	
	B1a	E1a S1500
Bypass	500	500
Cabot	1,500	0
Spillway	0	1,500
Deerfield	500	500

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N

0 75 150 300 Feet

Figure 4.3.3-1:
Scenario E1a S1500 minus B1a

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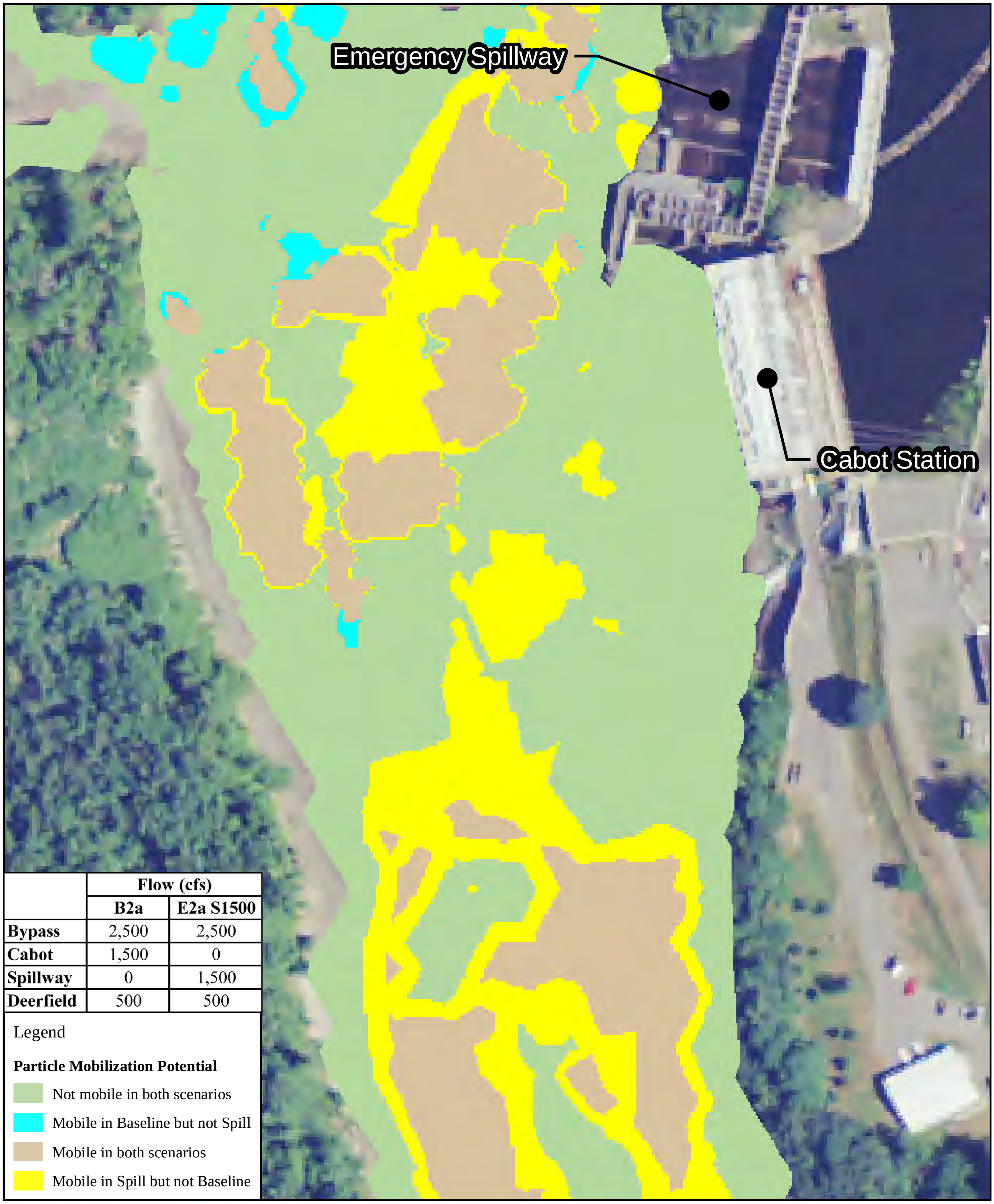

	Flow (cfs)	
	B2a	E2a S1500
Bypass	2,500	2,500
Cabot	1,500	0
Spillway	0	1,500
Deerfield	500	500

Legend

Particle Mobilization Potential

- Not mobile in both scenarios
- Mobile in Baseline but not Spill
- Mobile in both scenarios
- Mobile in Spill but not Baseline

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N

0 75 150 300 Feet

Figure 4.3.3-2:
Scenario E2a S1500 minus B2a

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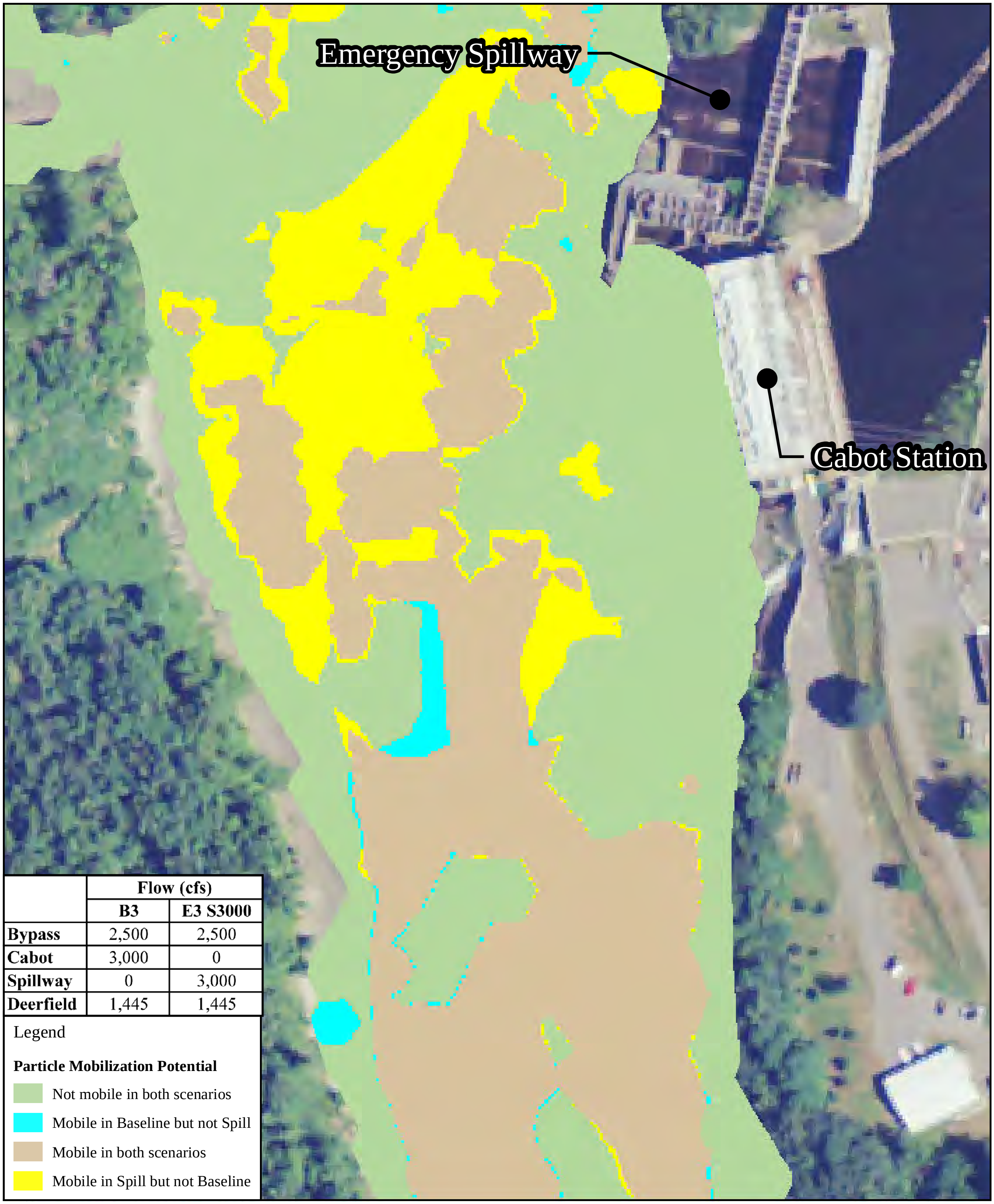

	Flow (cfs)	
	B3	E3 S3000
Bypass	2,500	2,500
Cabot	3,000	0
Spillway	0	3,000
Deerfield	1,445	1,445

Legend

Particle Mobilization Potential

- Not mobile in both scenarios
- Mobile in Baseline but not Spill
- Mobile in both scenarios
- Mobile in Spill but not Baseline

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N

0 75 150 300 Feet

Figure 4.3.3-3:
Scenario E3 S3000 minus B3

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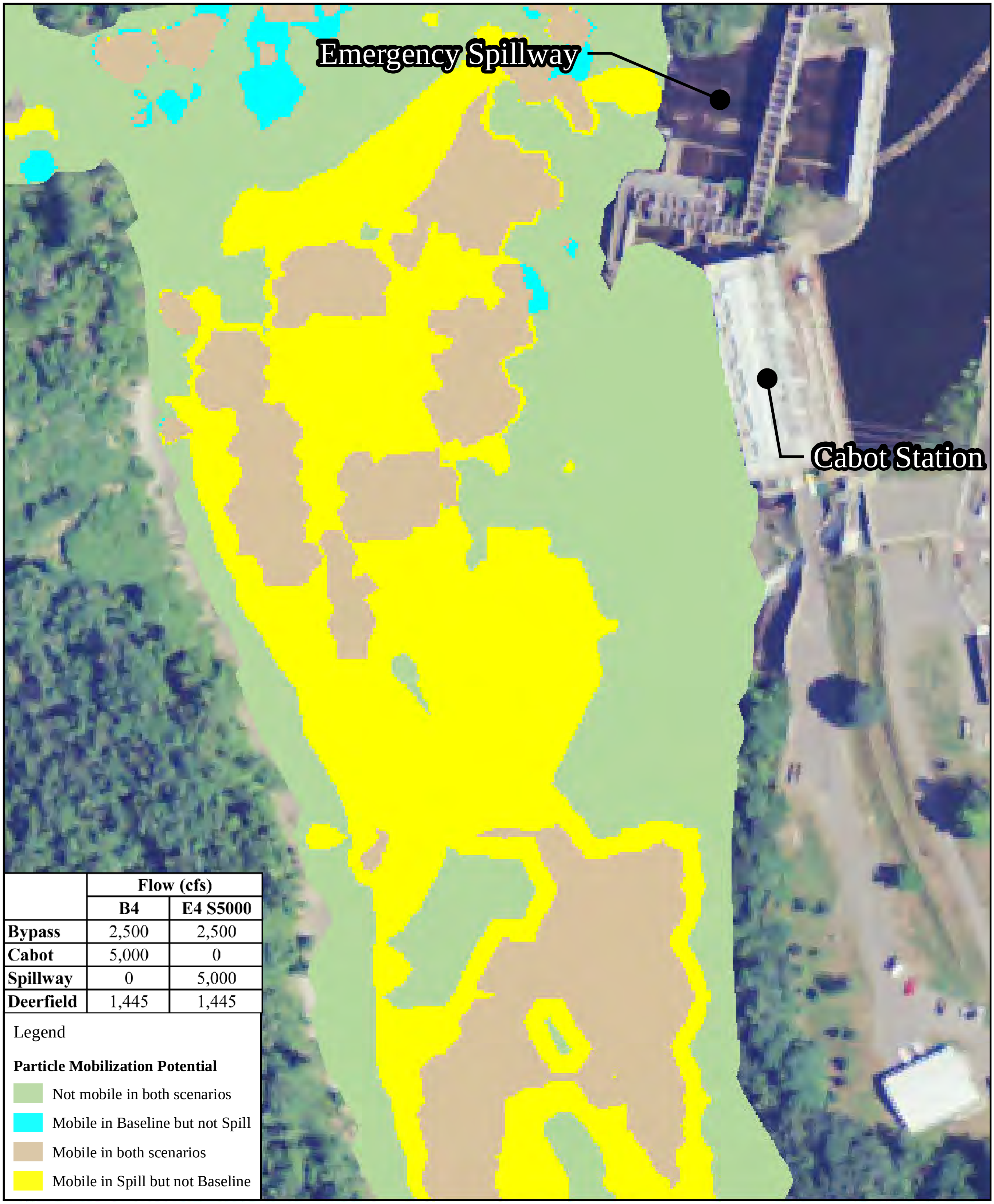

	Flow (cfs)	
	B4	**E4 S5000**
Bypass	2,500	2,500
Cabot	5,000	0
Spillway	0	5,000
Deerfield	1,445	1,445

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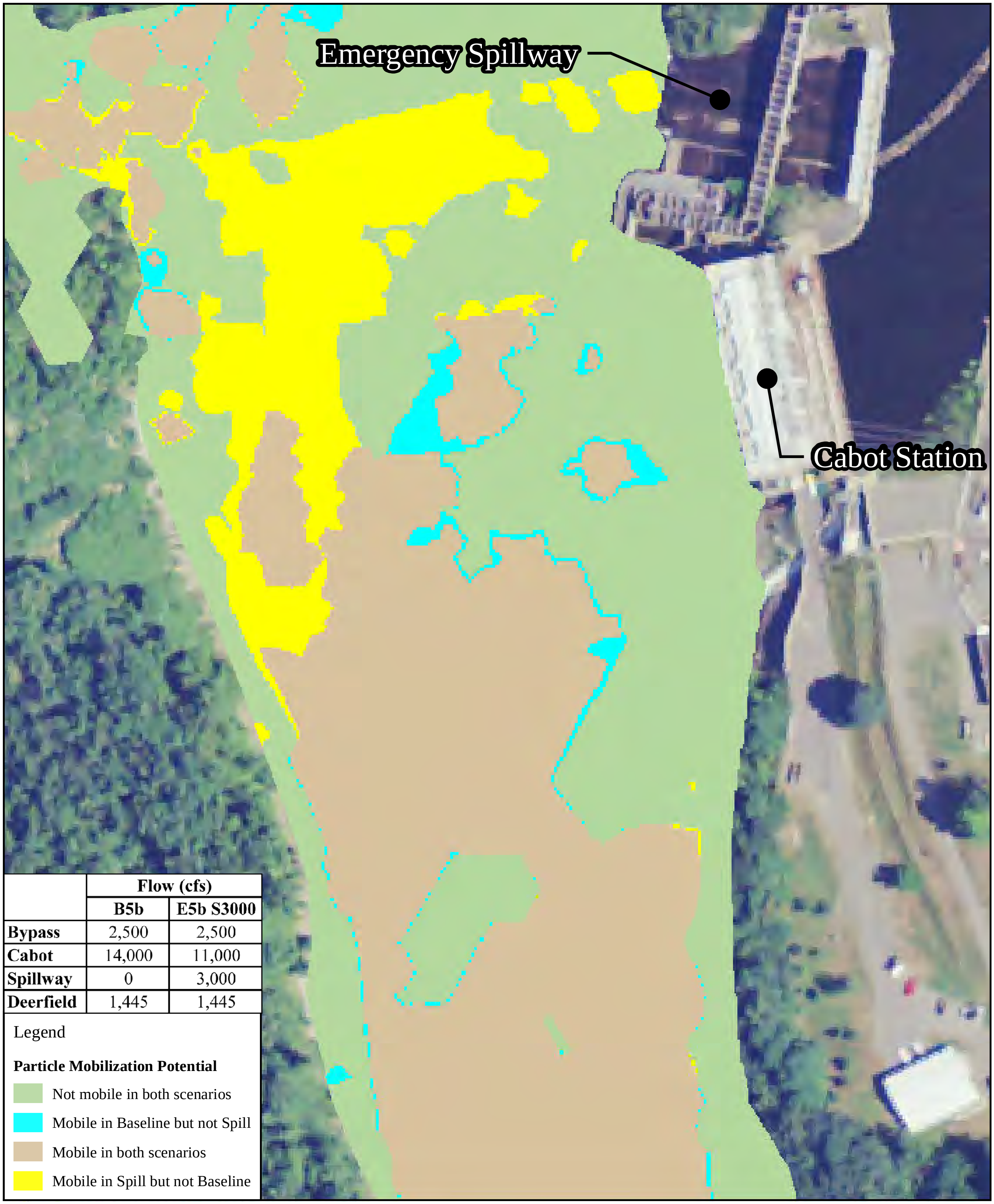
Figure 4.3.3-4:
Scenario E4 S5000 minus B4

Path: W:\gis\studies\3_3_12\maps\E4_S5000_minus_B4_pmp.mxd



	Flow (cfs)	
	B5b	**E5b S3000**
Bypass	2,500	2,500
Cabot	14,000	11,000
Spillway	0	3,000
Deerfield	1,445	1,445

Legend

Particle Mobilization Potential

- Not mobile in both scenarios
- Mobile in Baseline but not Spill
- Mobile in both scenarios
- Mobile in Spill but not Baseline

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Turners Falls Hydroelectric Project No. 1889

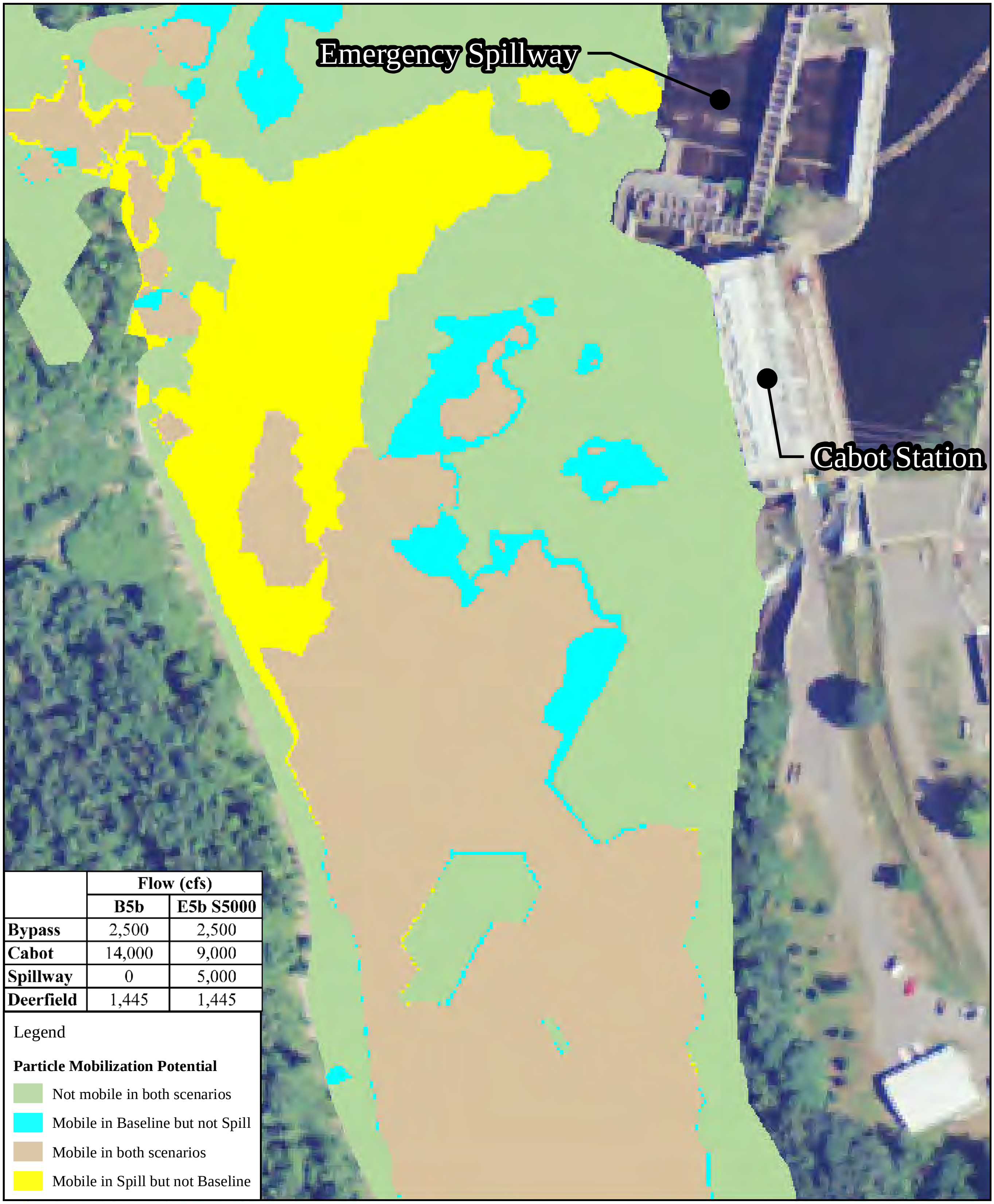
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 75 150 300 Feet

Figure 4.3.3-5:
Scenario E5b S3000 minus B5b

Path: W:\gis\studies\3_3_12\maps\E5b_S3000_minus_B5b_pmp.mxd



	Flow (cfs)	
	B5b	E5b S5000
Bypass	2,500	2,500
Cabot	14,000	9,000
Spillway	0	5,000
Deerfield	1,445	1,445

Legend

Particle Mobilization Potential

- Not mobile in both scenarios
- Mobile in Baseline but not Spill
- Mobile in both scenarios
- Mobile in Spill but not Baseline

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Turners Falls Hydroelectric Project No. 1889

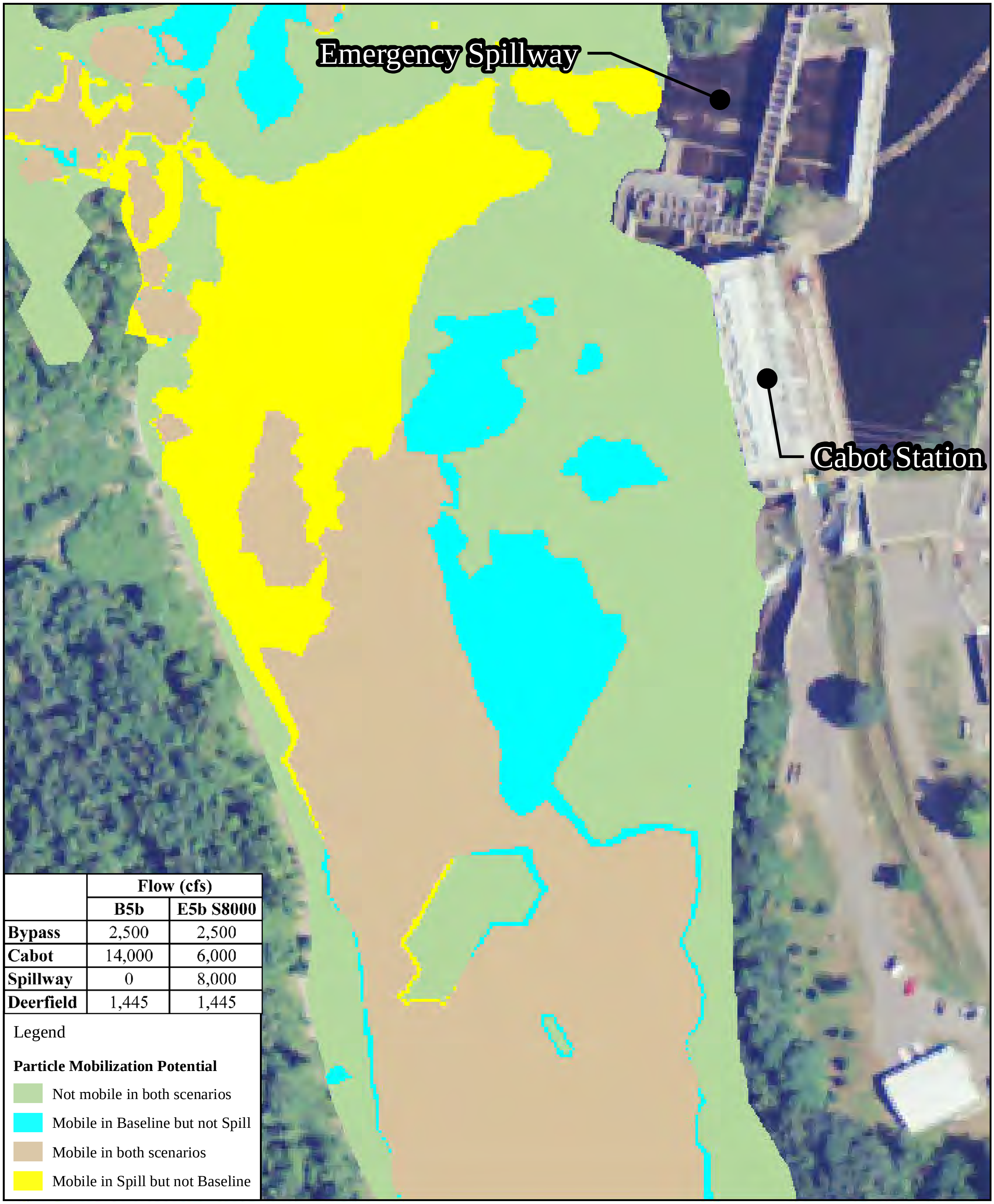
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 75 150 300 Feet

Figure 4.3.3-6:
Scenario E5b S5000 minus B5b

Path: W:\gis\studies\3_3_12\maps\E5b_S5000_minus_B5b_pmp.mxd



	Flow (cfs)	
	B5b	**E5b S8000**
Bypass	2,500	2,500
Cabot	14,000	6,000
Spillway	0	8,000
Deerfield	1,445	1,445

FirstLight GDF SUEZ

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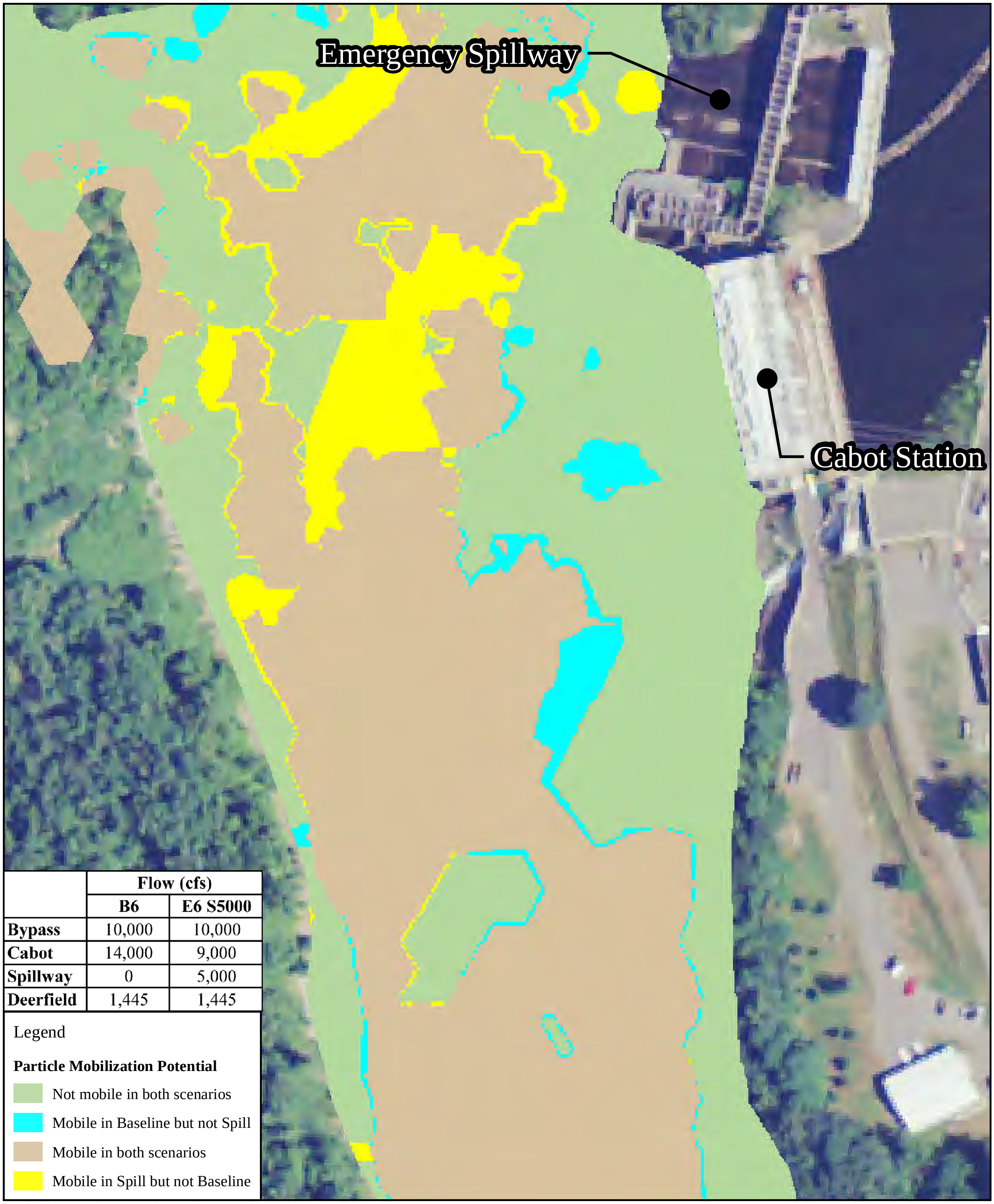
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Figure 4.3.3-7:
Scenario E5b S8000 minus B5b

Path: W:\gis\studies\3_3_12\maps\E5b_S8000_minus_B5b_pmp.mxd



	Flow (cfs)	
	B6	**E6 S5000**
Bypass	10,000	10,000
Cabot	14,000	9,000
Spillway	0	5,000
Deerfield	1,445	1,445

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Turners Falls Hydroelectric Project No. 1889

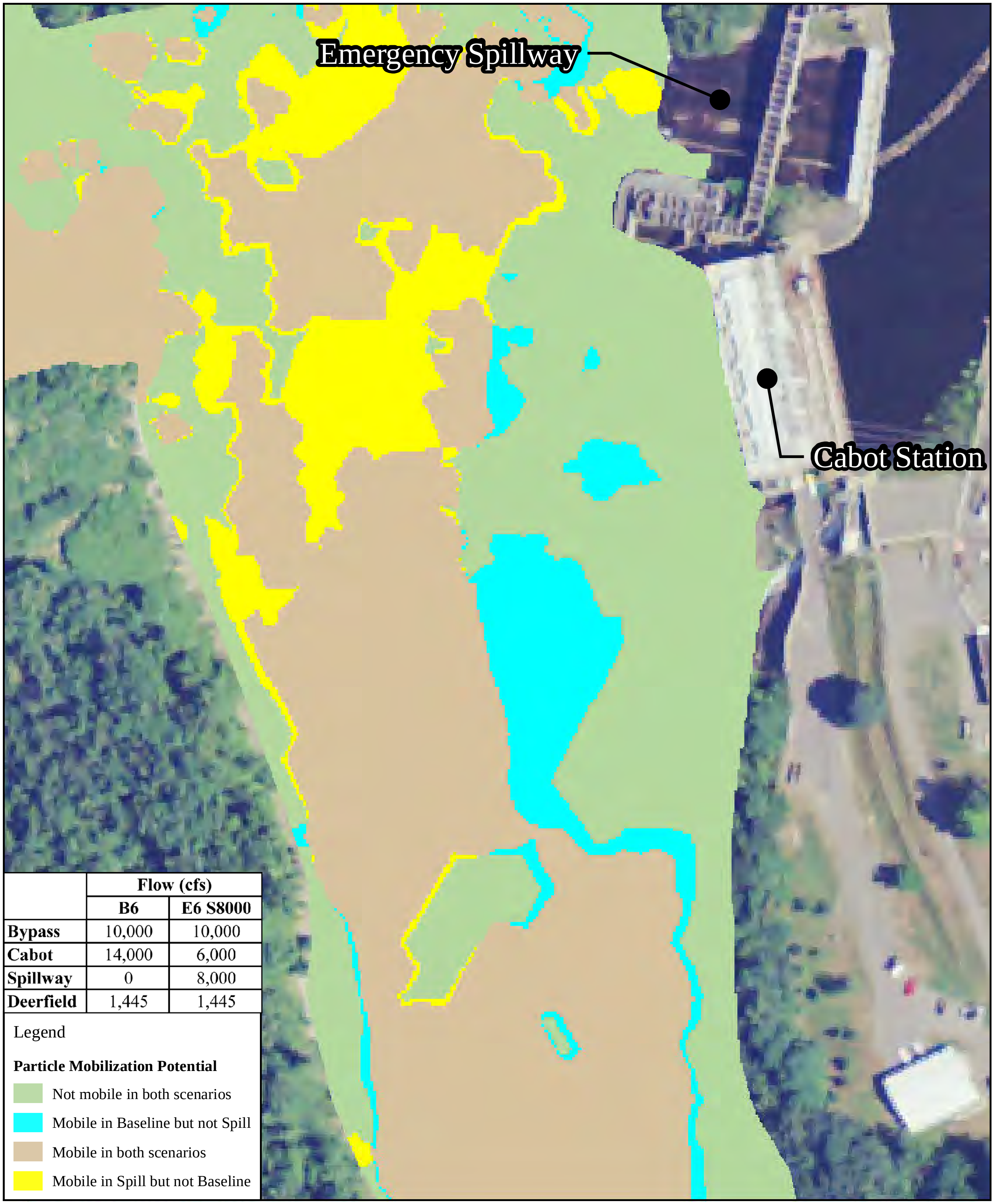
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 75 150 300 Feet

Figure 4.3.3-8:
Scenario E6 S5000 minus B6

Path: W:\gis\studies\3_3_12\maps\E6_S5000_minus_B6_pmp.mxd



	Flow (cfs)	
	B6	**E6 S8000**
Bypass	10,000	10,000
Cabot	14,000	6,000
Spillway	0	8,000
Deerfield	1,445	1,445

FirstLight GDF SUEZ

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Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 75 150 300 Feet

Figure 4.3.3-9:
Scenario E6 S8000 minus B6

Path: W:\gis\studies\3_3_12\maps\E6_S8000_minus_B6_pmp.mxd

5 DISCUSSION

Regardless of the amount of spill from the emergency spillway, changes in velocity and shear stress were observed relative to different baseline conditions in the river. General patterns were found, including:

- Relatively narrow areas of increased velocities resulting from emergency spillway discharge, which increase in intensity and spatial extent at greater spill flow
- Discharges from Cabot Station result in emergency spill discharges flowing toward the west side of the sturgeon spawning area, adjacent to Smead Island, resulting in higher velocities in this area
- Under higher bypass reach flows, high velocity areas from the emergency spill discharge tend to stay in mid-channel, and may result in further increases in magnitude and spatial extent of high velocities compared to baseline conditions
- While the substrate in the vicinity of the emergency spillway is bedrock and other hard substrate, the mid-channel area, across to Smead Island, contains more sandy substrate that could become mobilized

5.1 Potential Effects of Emergency Spillway Flow on Shortnose Sturgeon Spawning

According to habitat suitability indices utilized in Study No. 3.3.1, highly suitable velocities for spawning are in the 1-4 ft/s range. During all modeling scenarios, suitable velocities were present within the defined sturgeon spawning area, though higher velocities were observed within the spawning area as well, with the largest areas of high velocity present during the greater discharges (i.e. 5,000 and 8,000 cfs) modeled from the emergency spillway.

Based on changes in relative shear stress, there is also the potential for sediment mobilization to occur upstream of the sturgeon spawning area, which could affect spawning behavior. This could result from relatively high spill events, during which high velocity water from the emergency spillway flows over sand substrates in the main channel and toward Smead Island.

The boundary of the sturgeon spawning area was developed by Kieffer and Kynard (2012) by circumscribing all locations recorded for tracked female sturgeon believed to have been spawning in that area over the course of multiple years. While this is likely a good representation of the spawning area, individual fish likely choose different spawning locations within the area under different conditions. Given the size of the spawning area and the relatively narrow areas affected by increased velocity and suspended sediment resulting from emergency spill events, sturgeon could move relatively short distances to a more suitable area if a spill event occurred during spawning, or wait until the conditions subside.

5.2 Potential Effects of Emergency Spillway Flow on Shortnose Sturgeon ELS

Downstream of the spawning area are locations identified as potential ELS habitat for sturgeon. Relative changes in velocity along transects in these areas during emergency spillway operation, when compared with the baseline conditions, are not expected to negatively affect sturgeon eggs and larvae in these areas. The greatest concern, based on the modeling, for these areas is the potential for scour from the emergency spillway operation that could result in deposition of sediment and higher suspended sediment concentrations in ELS rearing areas. While changes in sediment mobilization relative to baseline scenarios varied spatially given different operational conditions, all scenarios modeled, with the exception of E1a which had little effect, have the potential to mobilize sediment at a comparable magnitude to sediment mobilization predicted during high bypass flow (i.e. 20,000 cfs) and full capacity generation at Cabot Station in the absence of spill. These potential impacts could be most severe when the spill flow is high, bypass flows are moderate, and Cabot Station continues generation during the spill event. Such an event results in water from the emergency spillway rushing across the channel, toward Smead Island, where it encounters greater amounts of sand, which could then become mobilized and transported downstream.

Sturgeon eggs are adhesive, such that they attach to substrates downstream of spawning areas. Deposition of sediments that cover sturgeon eggs can greatly reduce embryo survival, delay hatch timing, and decrease larvae length, weight, and survival (Kock, 2004). Mobilization of substrate was predicted in areas near Cabot Station during every scenario modeled, indicating that sand could be mobilized during both emergency spill and baseline conditions. However, water velocities at the ELS shoals did not change considerably due to emergency spillway operation, and were relatively swift under most conditions, likely preventing deposition. As such, there is no indication that sturgeon eggs will become smothered by sand mobilized near Cabot Station during discharges from the emergency spillway. Additionally, even during the scenario with the greatest potential impact (E5b 8000), predicted sediment mobilization did not appear to be considerably different than what could be encountered naturally during high (flow > 20,000) bypass reach flow. Flows of this magnitude and sometimes much greater occur naturally nearly every spring, and can occur prior to and/or during the sturgeon spawning period. It is also possible that high flow in the bypass reach would mobilize sediment and move it out of the study area prior to discharge events from the emergency spillway, resulting in less sediment that could become mobile due to emergency spill; given that substrate surveys were not performed during the sturgeon spawning season, it is not known whether the areas with sand substrate, as observed in the summer of 2014, would have been present during discharge events evaluated from the emergency spillway in April through June of 2005-2012.

5.3 Conclusion

Flow events from the emergency spillway at Cabot Station have the potential to mobilize sandy substrate at all spill flows modeled, with some variability resulting from different operational conditions. However, mobilization of sand and fine-grained substrates in the study area may also occur in the absence of discharge from the emergency spillway, with larger areas of mobilization predicted during relatively common springtime bypass reach flows. These conditions occur naturally and over much longer time periods than the brief discharge events from the emergency spillway.

During recent years, FirstLight has modified operation of the emergency spillway gates, such that spill events of the greatest magnitude only result from emergencies. In these cases, spill was necessary to ensure station viability and/or public safety. It is anticipated that release of high flows from the emergency spillway in the future will only be due to emergency events.

6 LITERATURE CITED

Fernandes, S.J., Zydlewski, G.B., Zydlewski, J.D., Wippelhauser, G.S., & Kinnison ,M.T. (2010). Seasonal distribution and movements of shorenose sturgeon and Atlantic sturgeon in the Penobscot River Estuary, Maine. Transactions of the American Fisheries Society 139: 1436-1449.

Kieffer, M. & Kynard, B. (2012). Spawning and non-spawning migrations, spawning, and the effect of river regulation on spawning success of Connecticut River Shortnose Sturgeon. In B. Kynard, P. Bronzi, & H. Rosenthal (Eds.), *Life History and Behaviour of Connecticut River Shotnose and Other Sturgeons*. Norderstedt, Germany: World Sturgeon Conservation Society Special Publication No. 4, 2012.

Kock, T.J. (2004). Effects of sedimentation and water velocity on white sturgeon (*Acipenser transmontanus*) embryo survival. M.S. Thesis. University of Idaho.

National Marine Fisheries Service (NMFS). (1998). Final Recovery Plan for the Shortnose Sturgeon, *Acipenser brevirostrum*. U.S. Department of Commerce – National Oceanic and Atmospheric Administration. December 1998.

Natural Resources Conservation Service (NRCS). (2007). Chapter 11 Rosgen Geomorphic Channel Design: Figure 11-11. In Part 654 Stream Restoration Design National Engineering Handbook. U.S. Department of Agriculture. Retrieved February, 2016 from http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17771.wba.

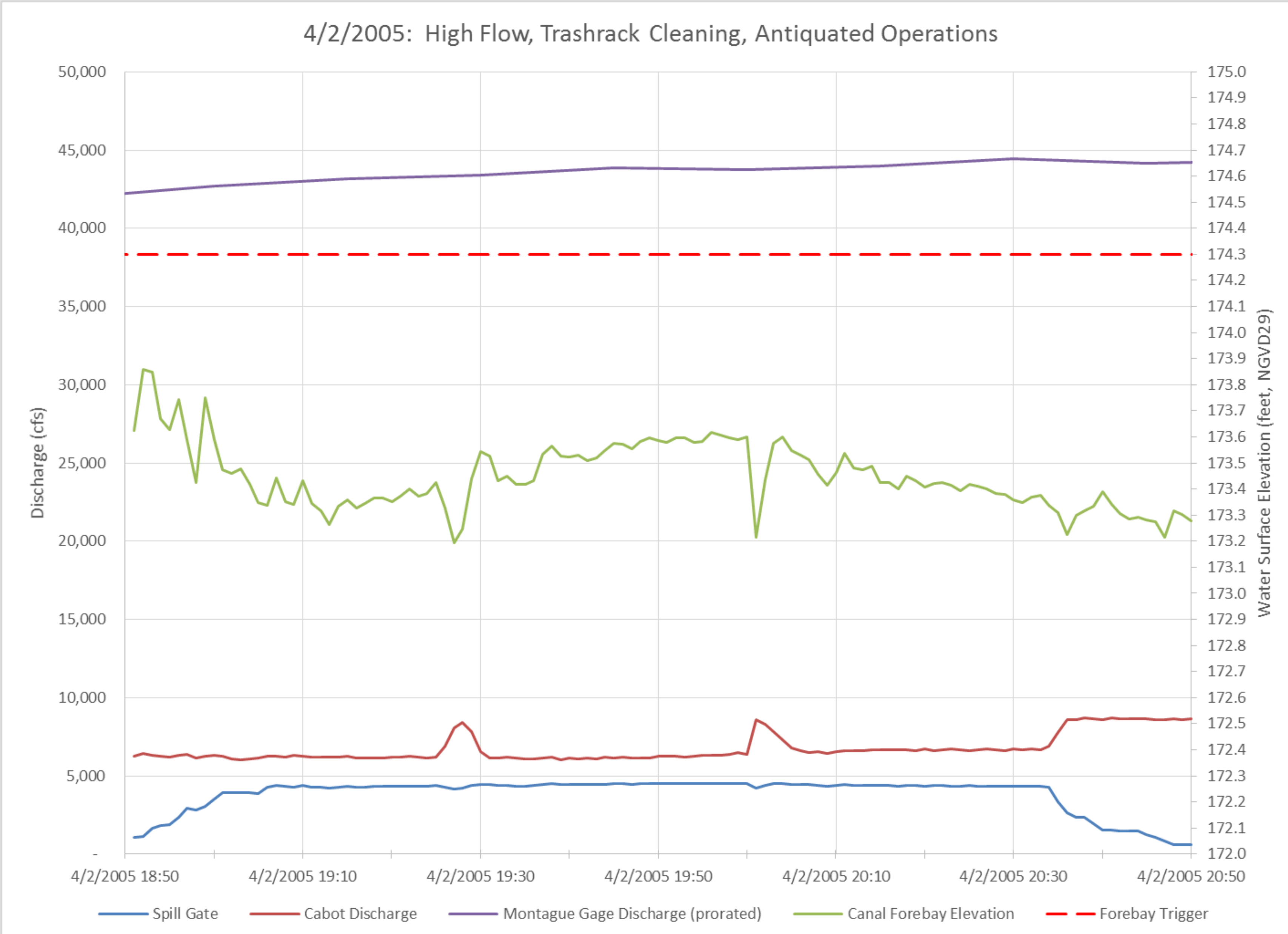
R Core Team. (2015). R: A language and environmental for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved December, 2015 from. https://www.R-project.org/

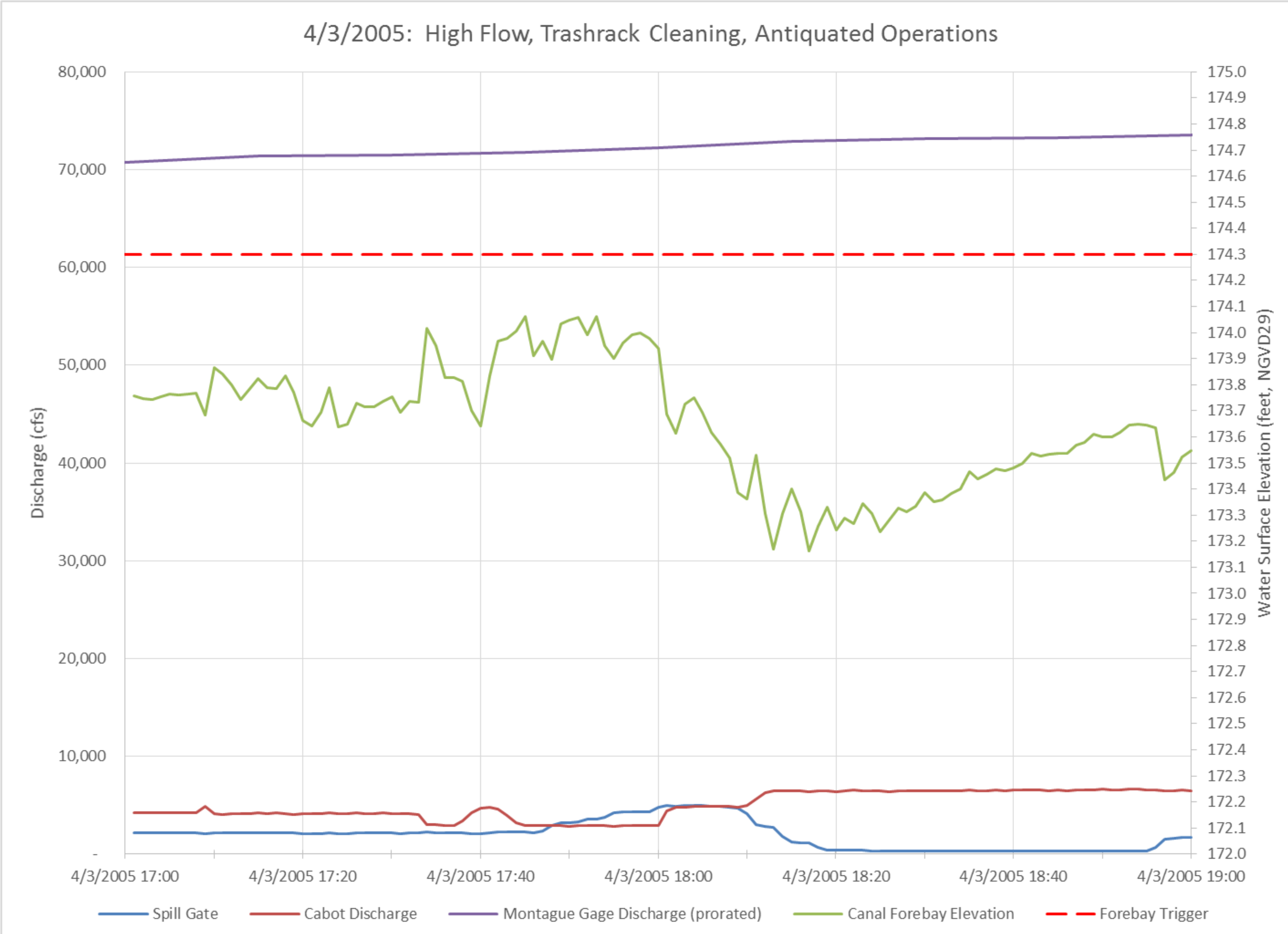
Steffler, T. & Blackburn, J. (2002). River2D: Two-Dimensional Depth Averaged Model of River Hydrodynamics and Fish Habitat, Introduction to Depth Averaged Modeling and User's Manual. University of Alberta. Retrieved December 23, 2014 from http://www.river2d.ca/Downloads/documentation/River2D.pdf

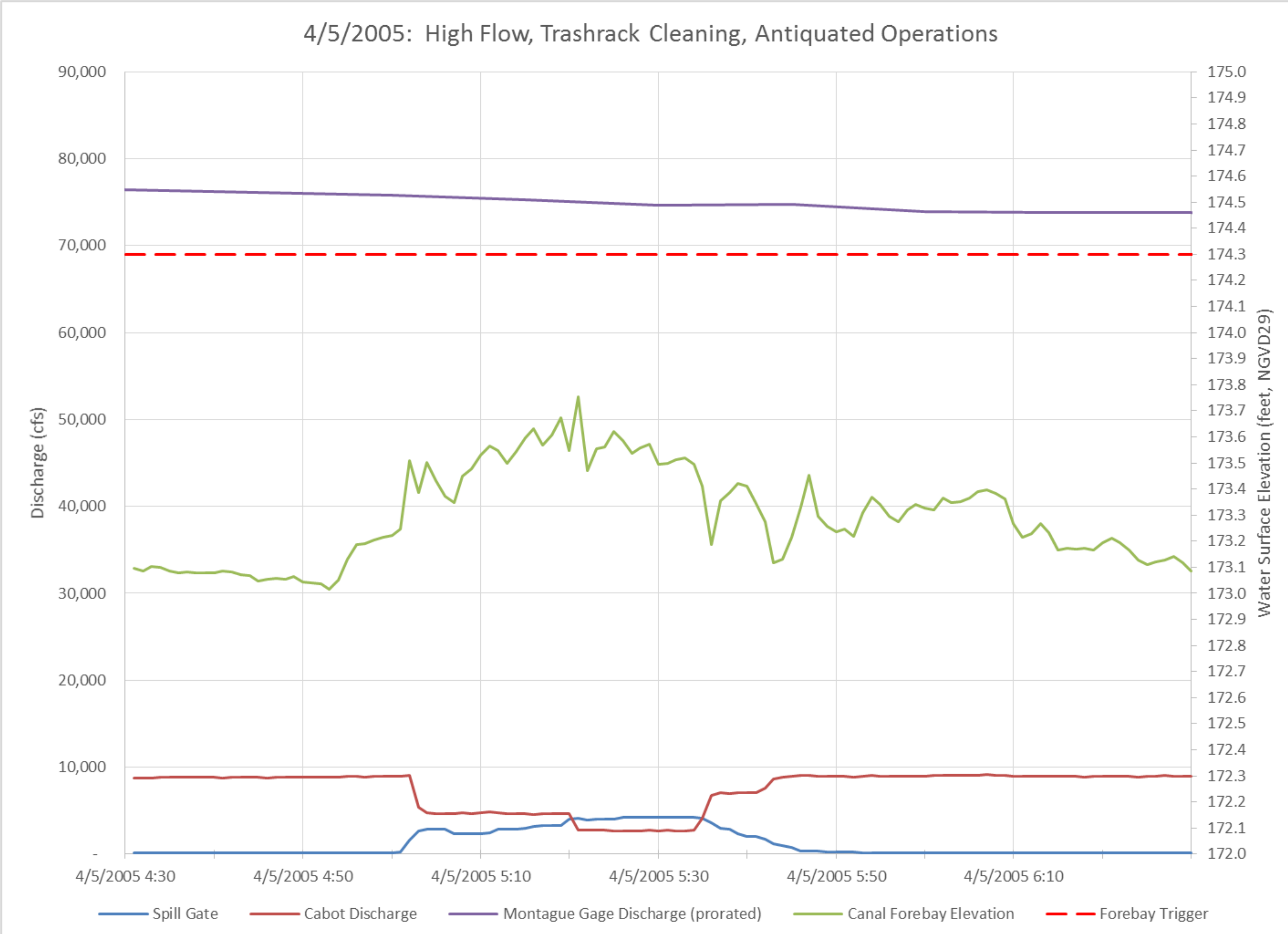
Steffler, T. (2002). R2D_Bed: Bed Topography File Editor User Manual for River2D. University of Alberta. Retrieved December 23, 2014 from http://www.river2d.ca/Downloads/documentation/River2D.pdf

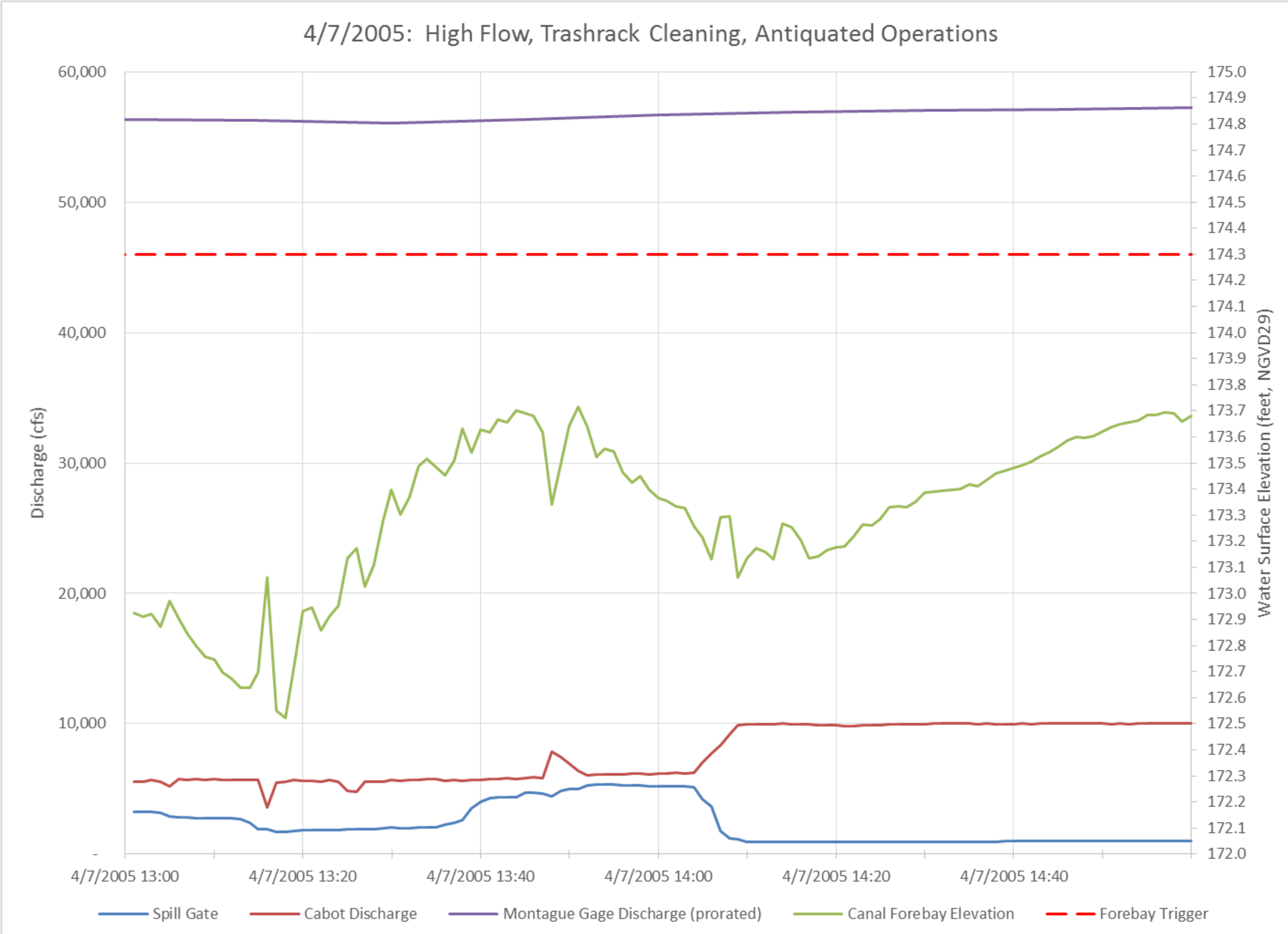
Waddle, T. & Steffler, P. (2002). R2D_Mesh: Mesh Generation Program for River2D Two Dimensional Depth Averaged Finite Element, Introduction to Mesh Generation and User's Manual. U.S. Geological Survey. Retrieved December 23, 2014 from http://www.river2d.ca/Downloads/documentation/R2d_Mesh.pdf

APPENDIX A-1 – OPERATIONAL PARAMETERS AT THE EMERGENCY SPILLWAY DURING EVENTS WHEN MORE THAN FOUR GATES WERE OPEN


4/2/2005: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
Water Surface Elevation (feet, NGVD29)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/2/2005 18:50
4/2/2005 19:10
4/2/2005 19:30
4/2/2005 19:50
4/2/2005 20:10
4/2/2005 20:30
4/2/2005 20:50
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger


4/3/2005: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/3/2005 17:00
4/3/2005 17:20
4/3/2005 17:40
4/3/2005 18:00
4/3/2005 18:20
4/3/2005 18:40
4/3/2005 19:00
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger


4/5/2005: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/5/2005 4:30
4/5/2005 4:50
4/5/2005 5:10
4/5/2005 5:30
4/5/2005 5:50
4/5/2005 6:10
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger


4/7/2005: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
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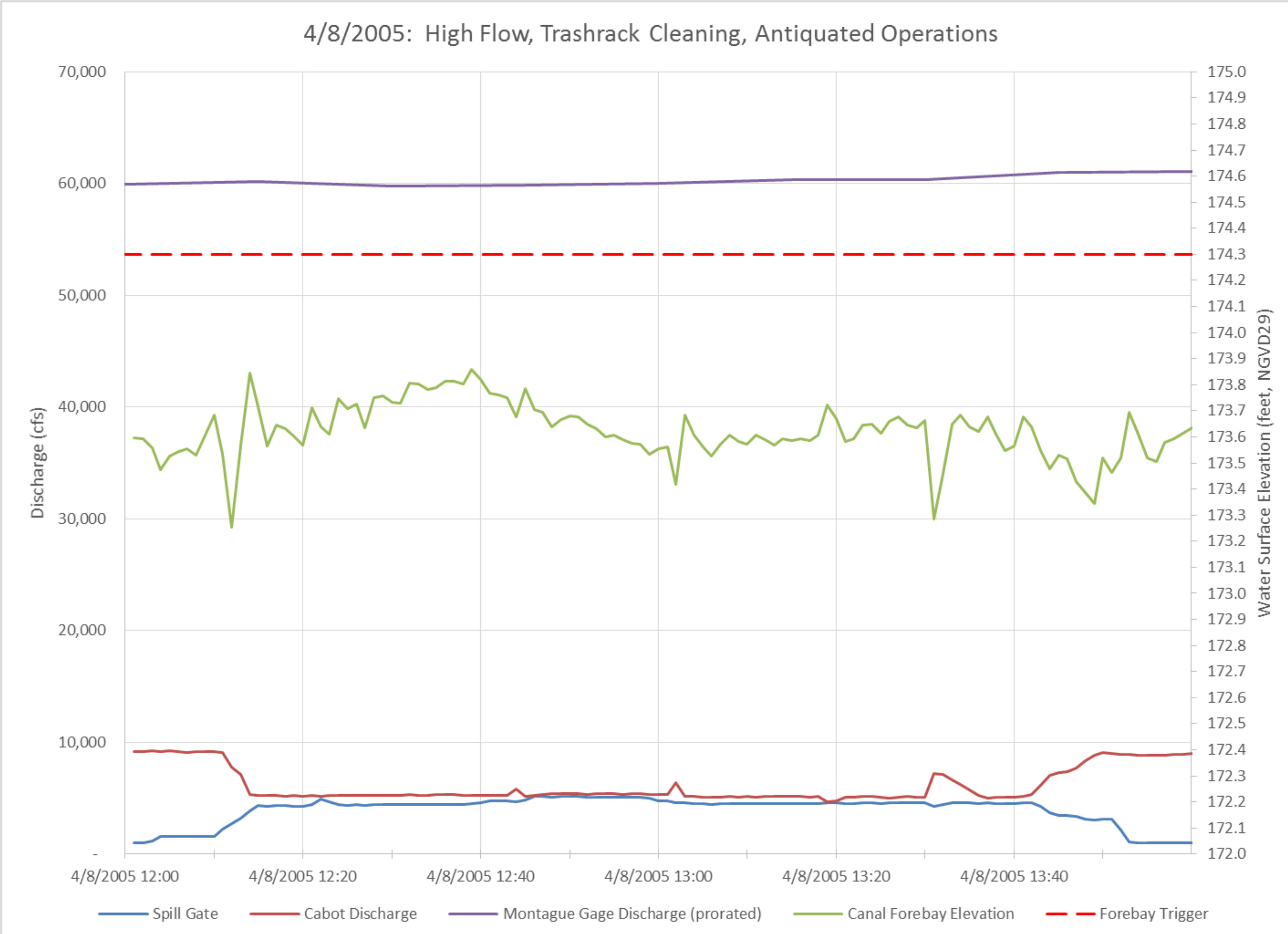
50,000
40,000
30,000
20,000
10,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/7/2005 13:00
4/7/2005 13:20
4/7/2005 13:40
4/7/2005 14:00
4/7/2005 14:20
4/7/2005 14:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger


4/8/2005: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
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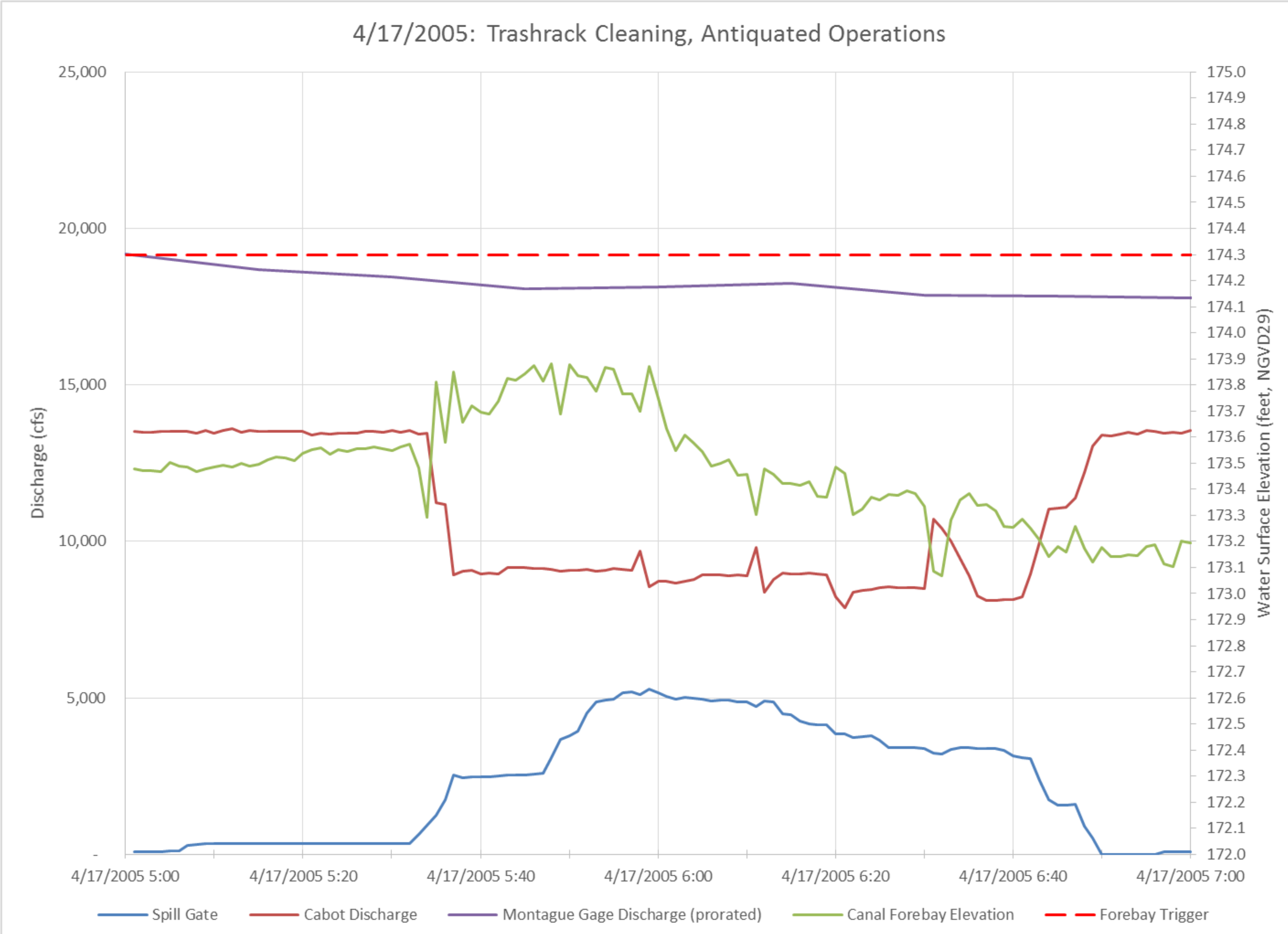
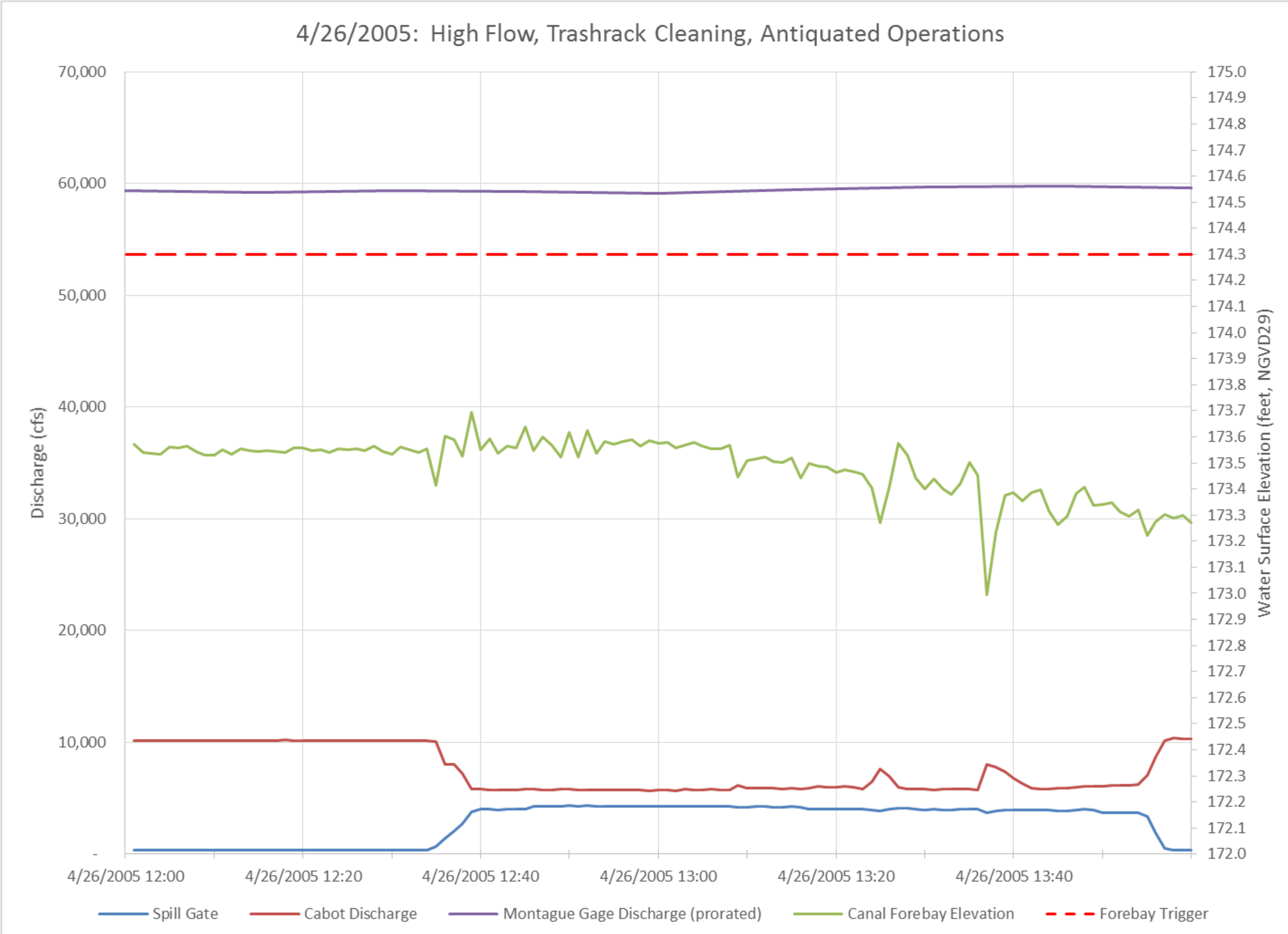
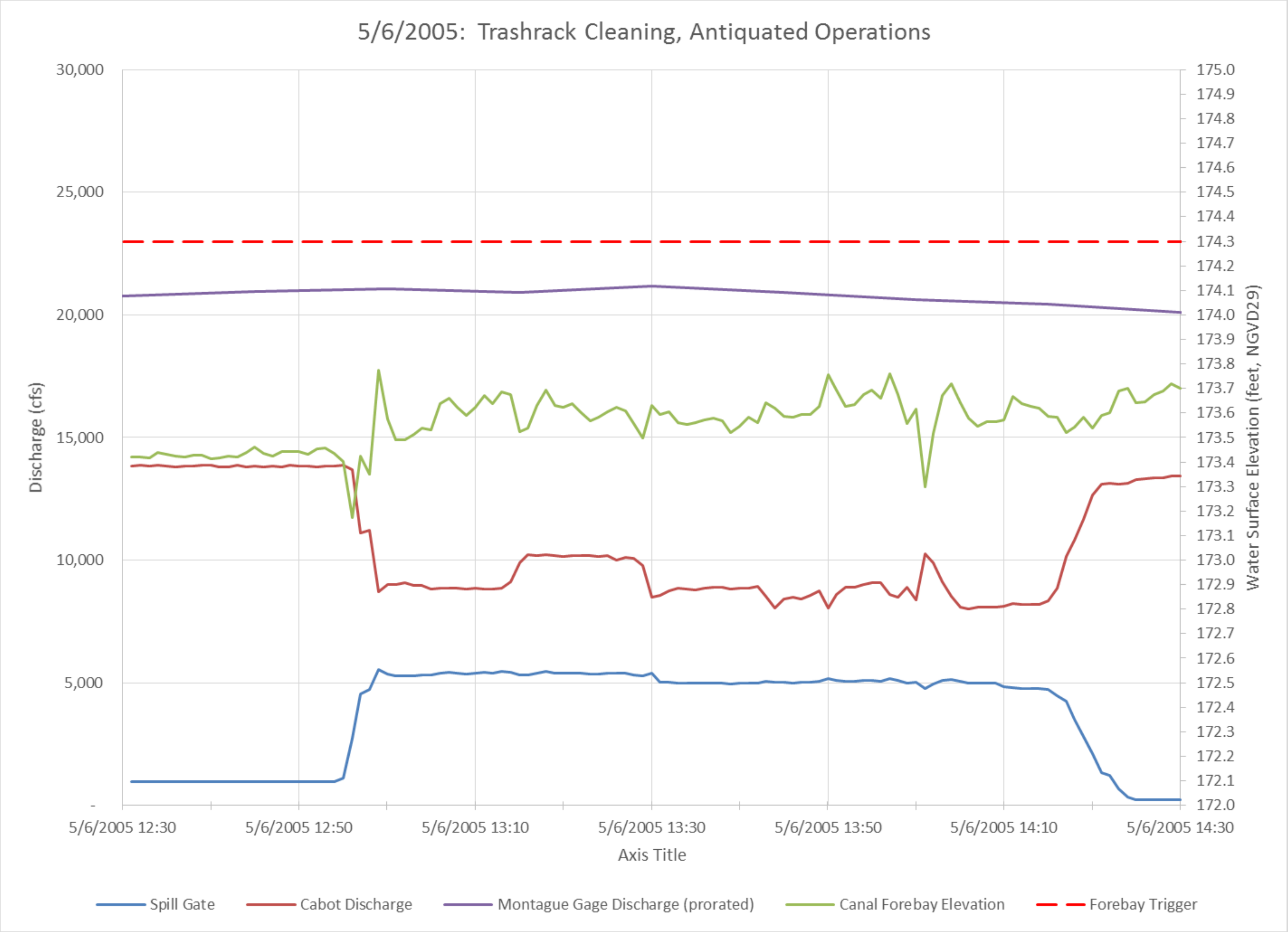
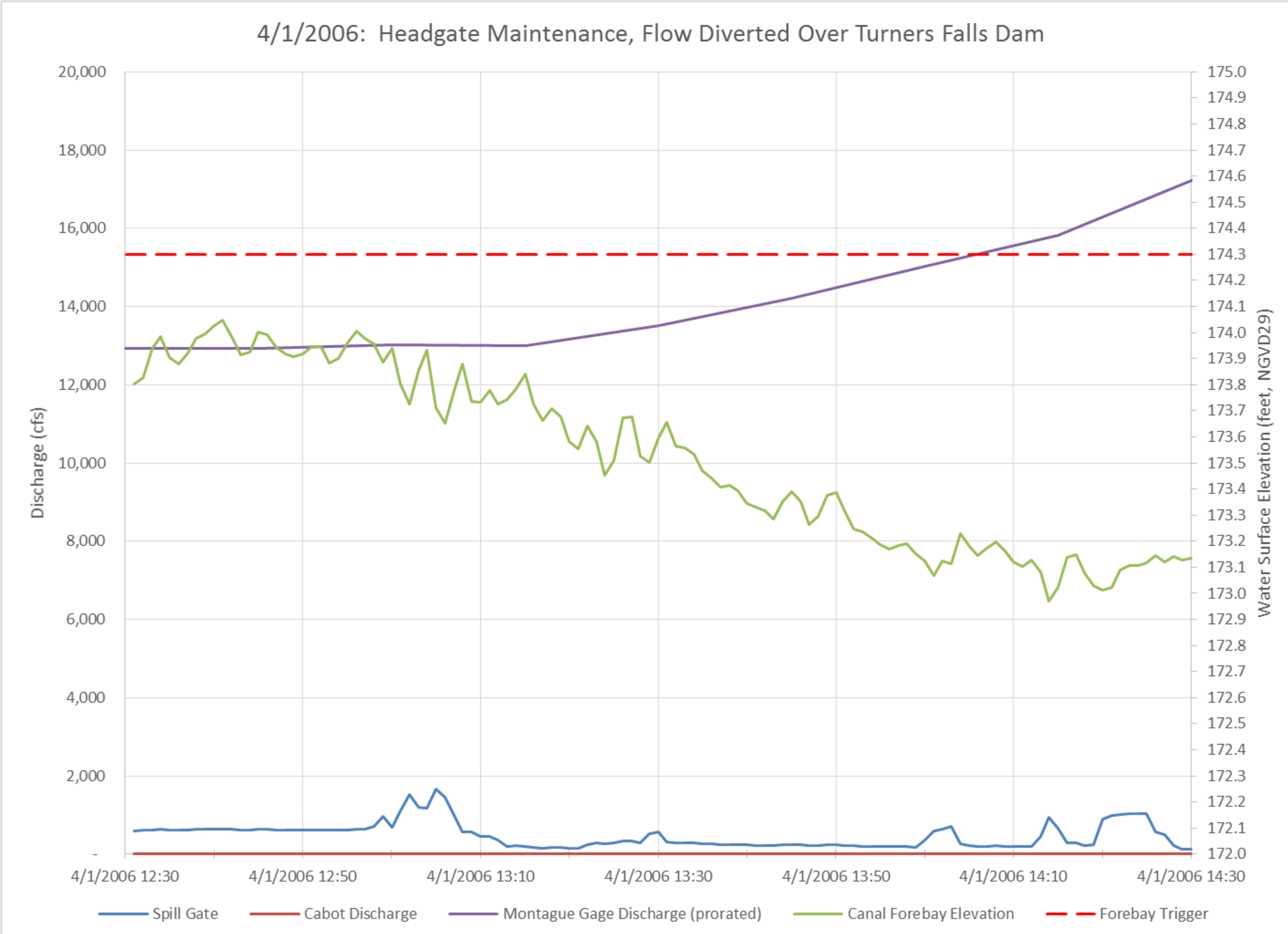
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/8/2005 12:00
4/8/2005 12:20
4/8/2005 12:40
4/8/2005 13:00
4/8/2005 13:20
4/8/2005 13:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger


4/17/2005: Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/17/2005 5:00
4/17/2005 5:20
4/17/2005 5:40
4/17/2005 6:00
4/17/2005 6:20
4/17/2005 6:40
4/17/2005 7:00
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

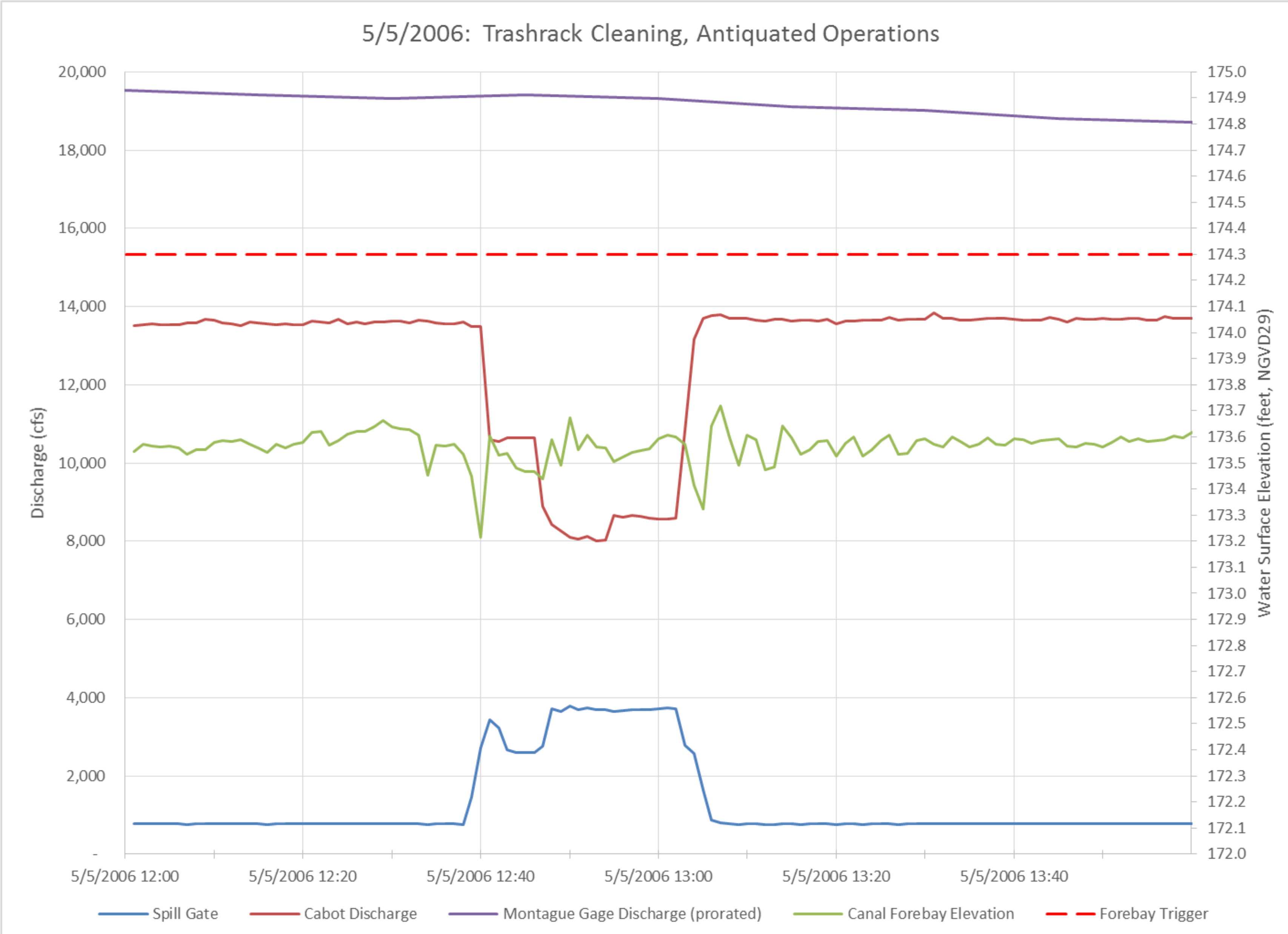

4/26/2005: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
Water Surface Elevation (feet, NGVD29)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/26/2005 12:00
4/26/2005 12:20
4/26/2005 12:40
4/26/2005 13:00
4/26/2005 13:20
4/26/2005 13:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

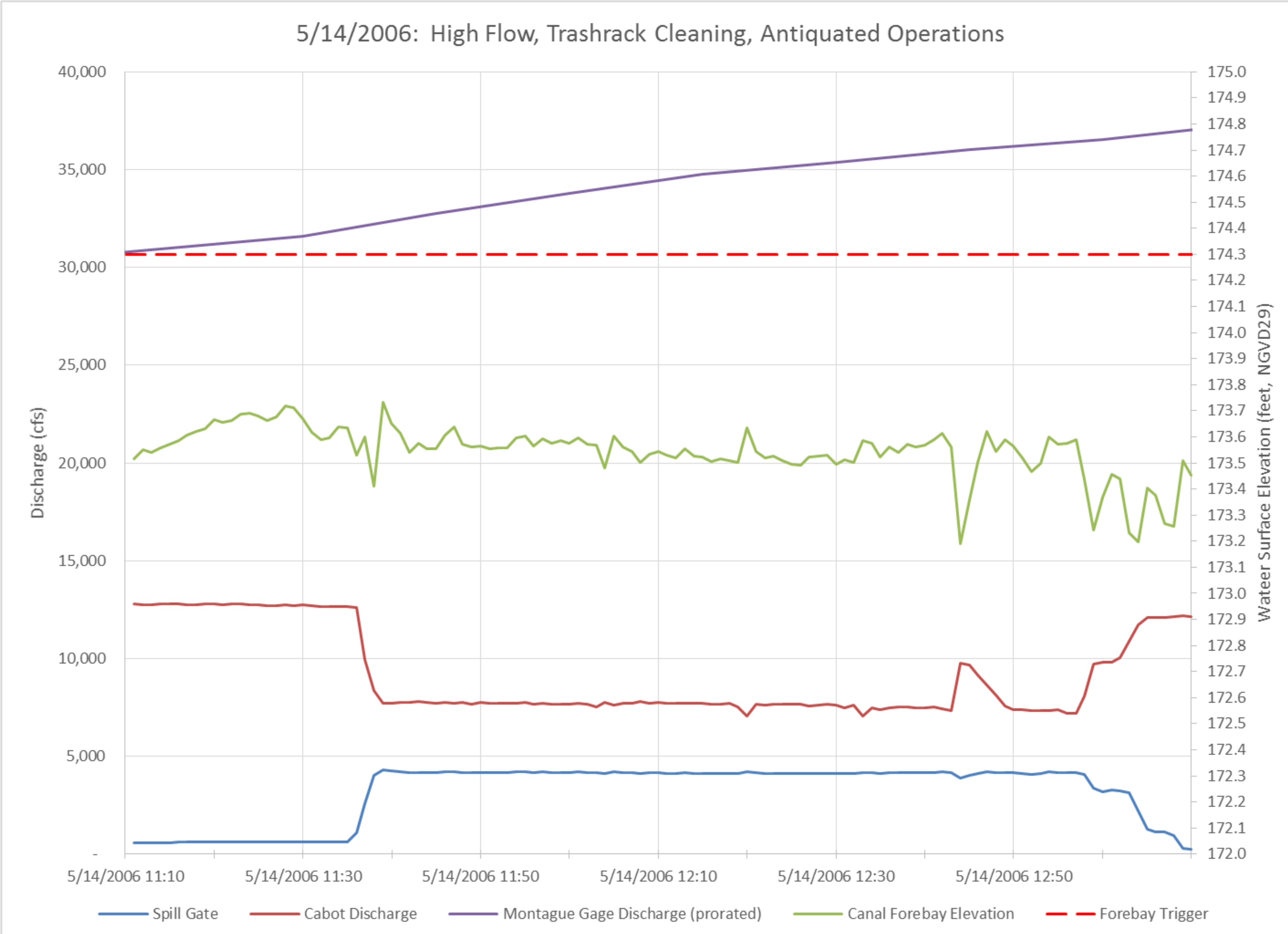

5/6/2005: Trashrack Cleaning, Antiquated Operations
30,000
25,000
20,000
15,000
10,000
5,000
-
Discharge (cfs)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
Water Surface Elevation (feet, NGVD29)
5/6/2005 12:30
5/6/2005 12:50
5/6/2005 13:10
5/6/2005 13:30
5/6/2005 13:50
5/6/2005 14:10
5/6/2005 14:30
Axis Title
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

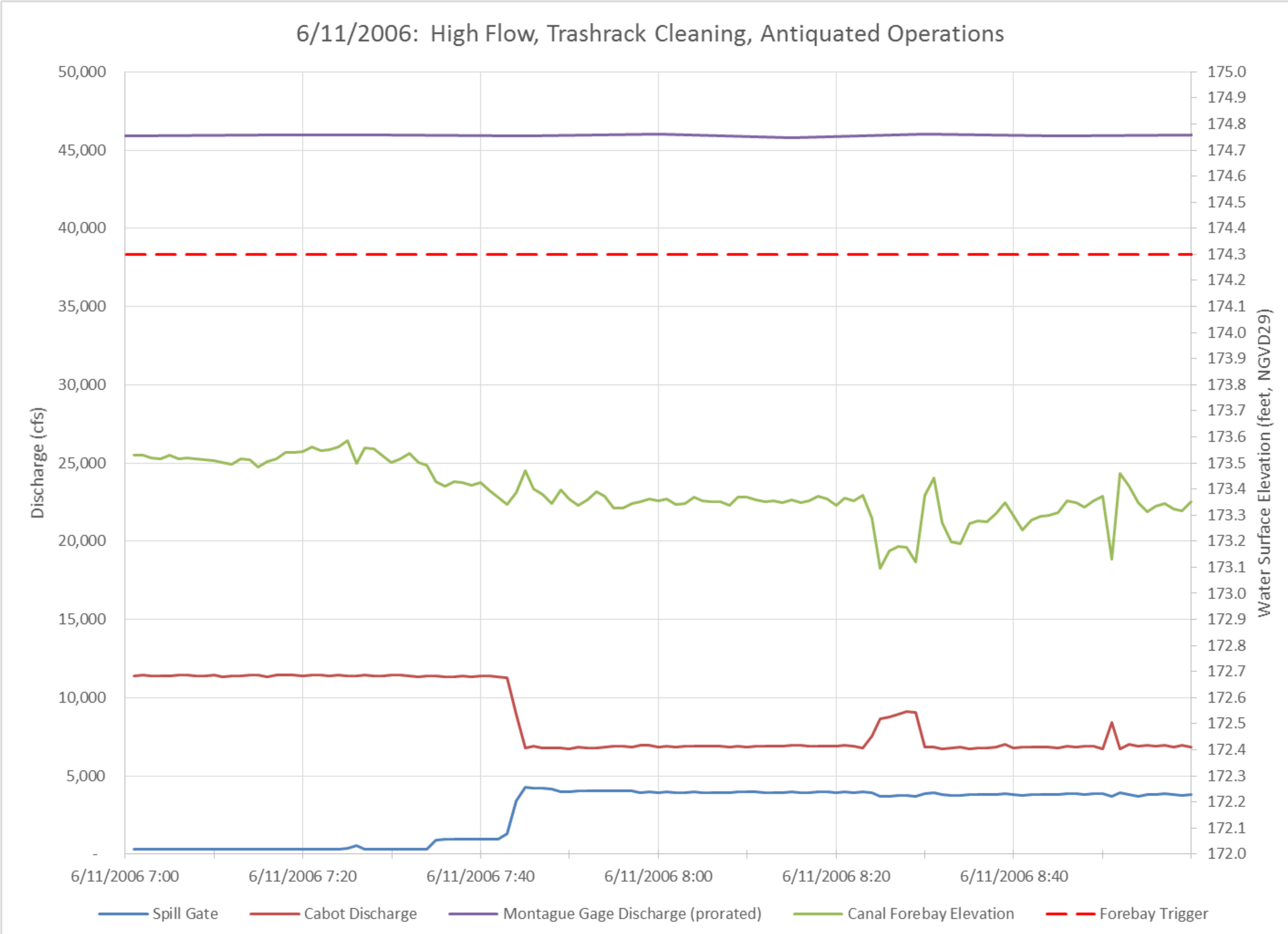

6/2/2005: Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/2/2005 12:00
6/2/2005 12:20
6/2/2005 12:40
6/2/2005 13:00
6/2/2005 13:20
6/2/2005 13:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

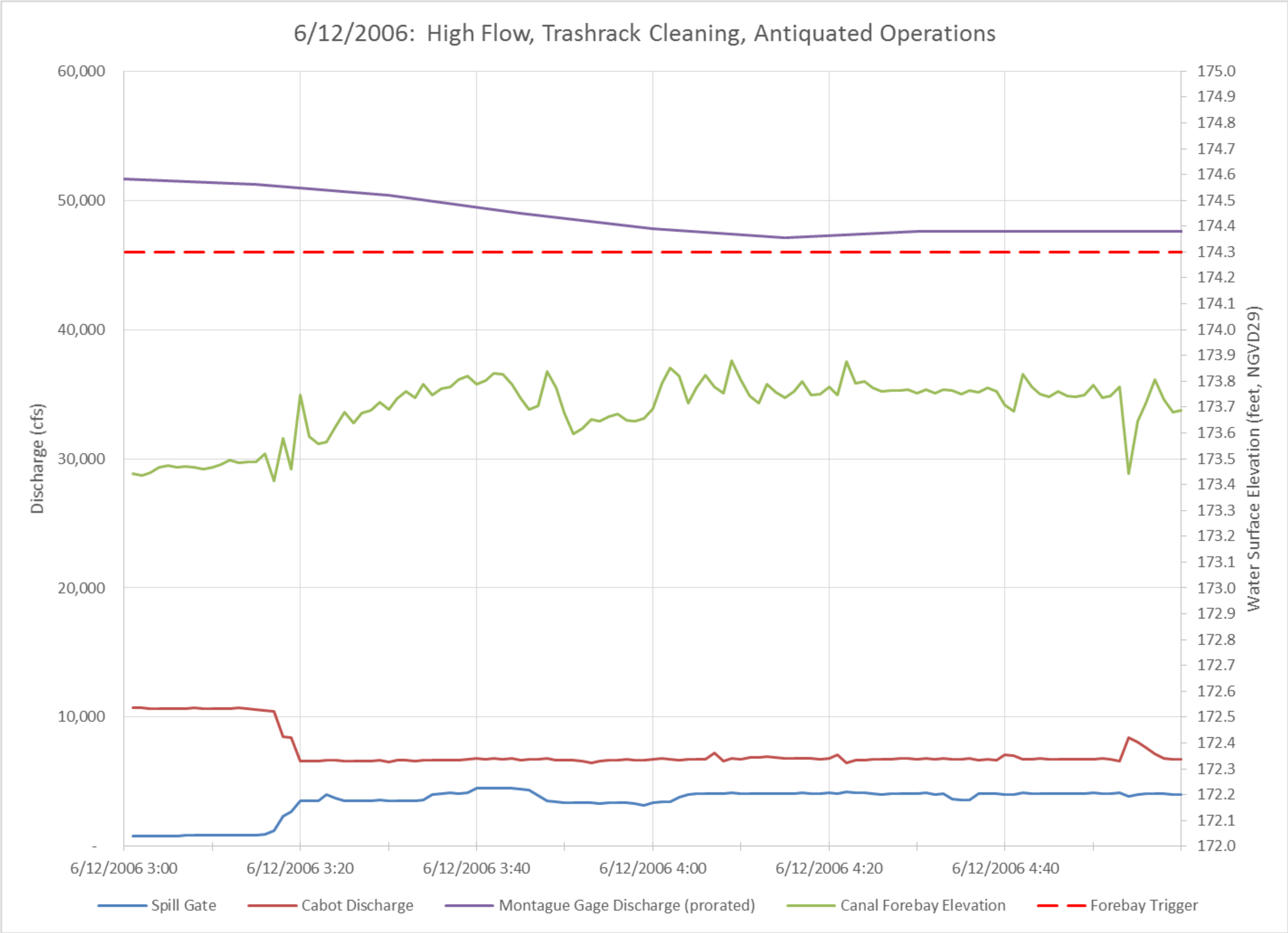

4/1/2006: Headgate Maintenance, Flow Diverted Over Turners Falls Dam
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/1/2006 12:30
4/1/2006 12:50
4/1/2006 13:10
4/1/2006 13:30
4/1/2006 13:50
4/1/2006 14:10
4/1/2006 14:30
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

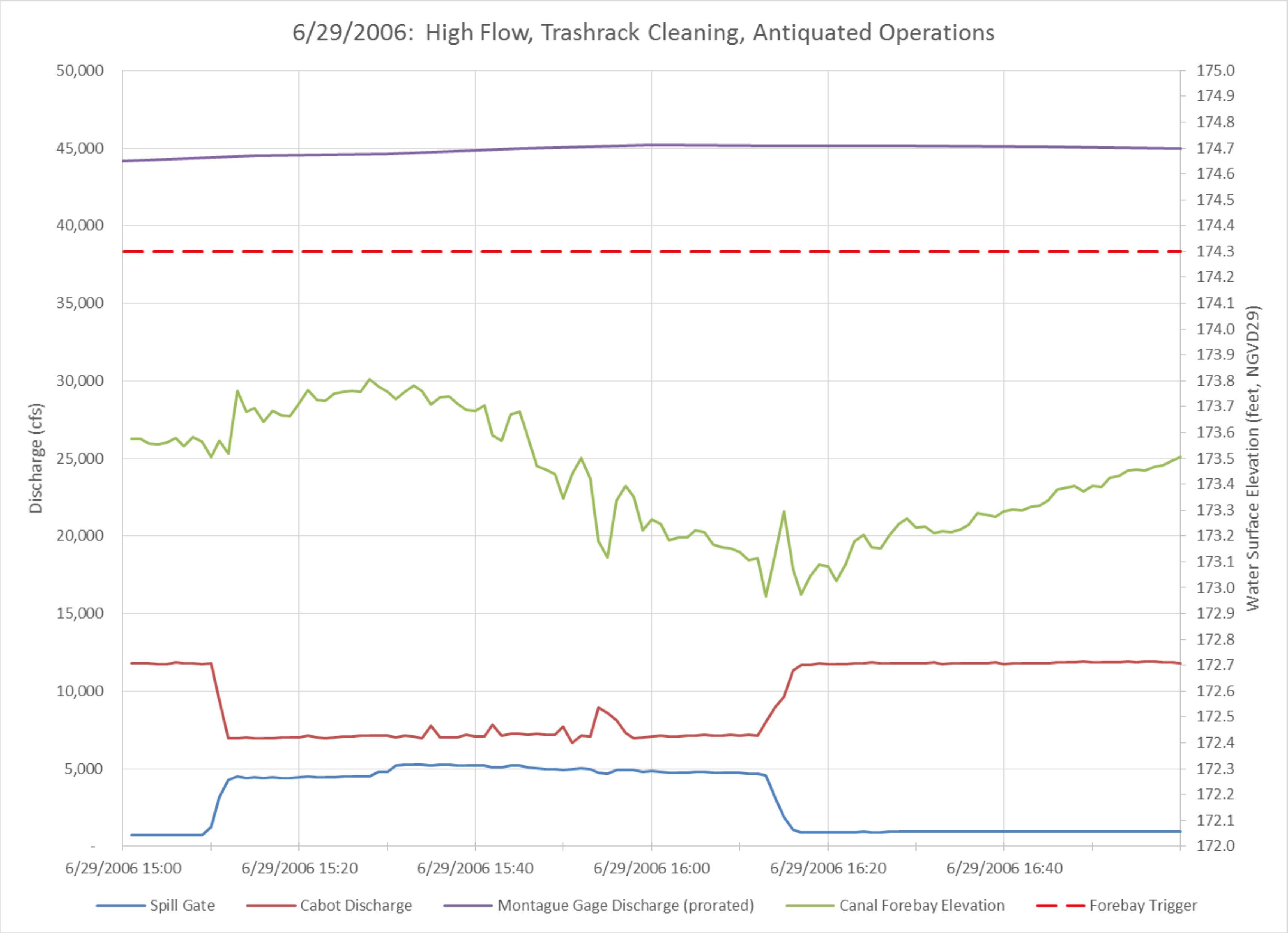

4/26/2006: Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
4/26/2006 6:50
4/26/2006 7:10
4/26/2006 7:30
4/26/2006 7:50
4/26/2006 8:10
4/26/2006 8:30
4/26/2006 8:50
4/26/2006 9:10
4/26/2006 9:30
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

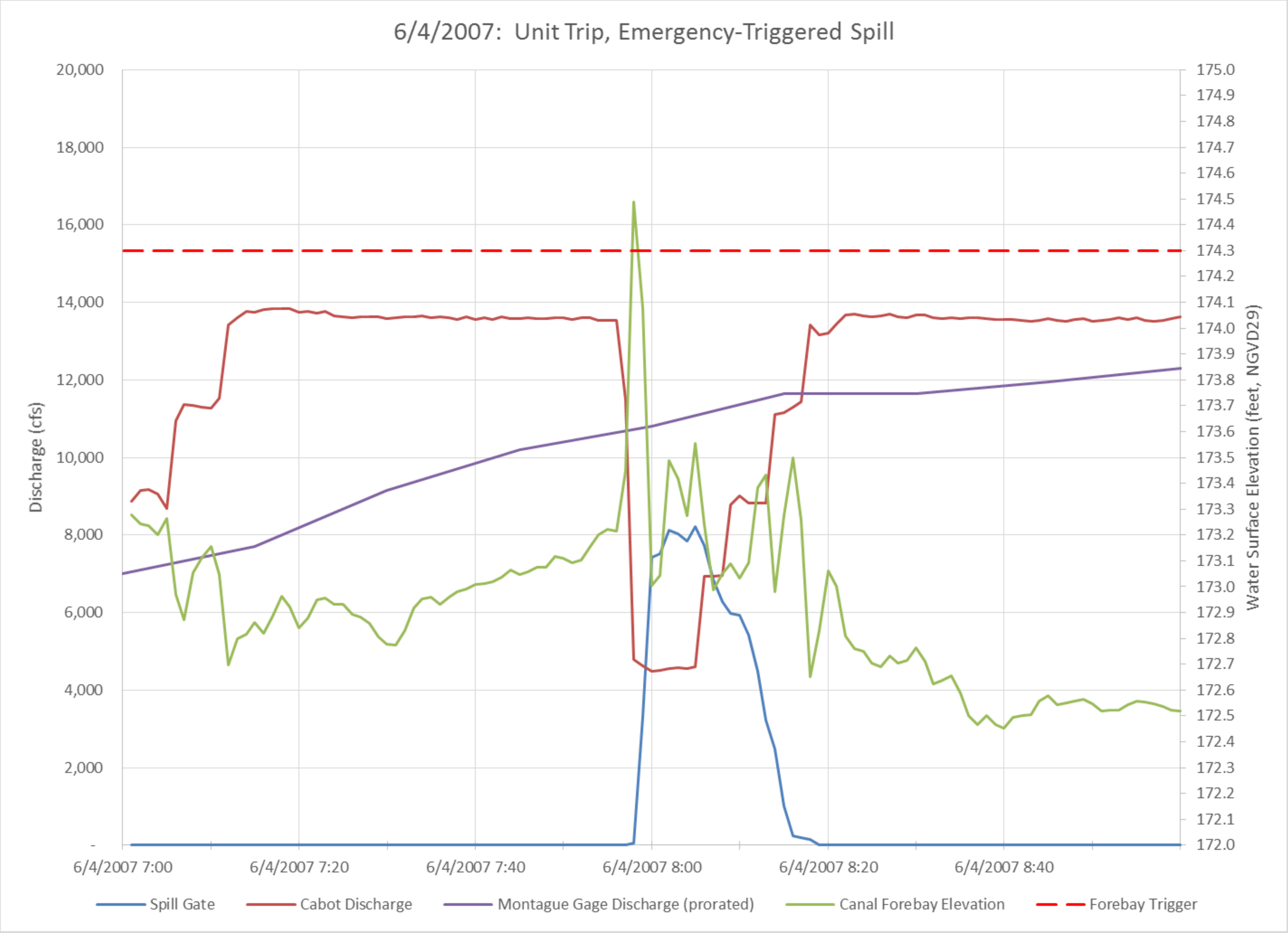

5/5/2006: Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
5/5/2006 12:00
5/5/2006 12:20
5/5/2006 12:40
5/5/2006 13:00
5/5/2006 13:20
5/5/2006 13:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

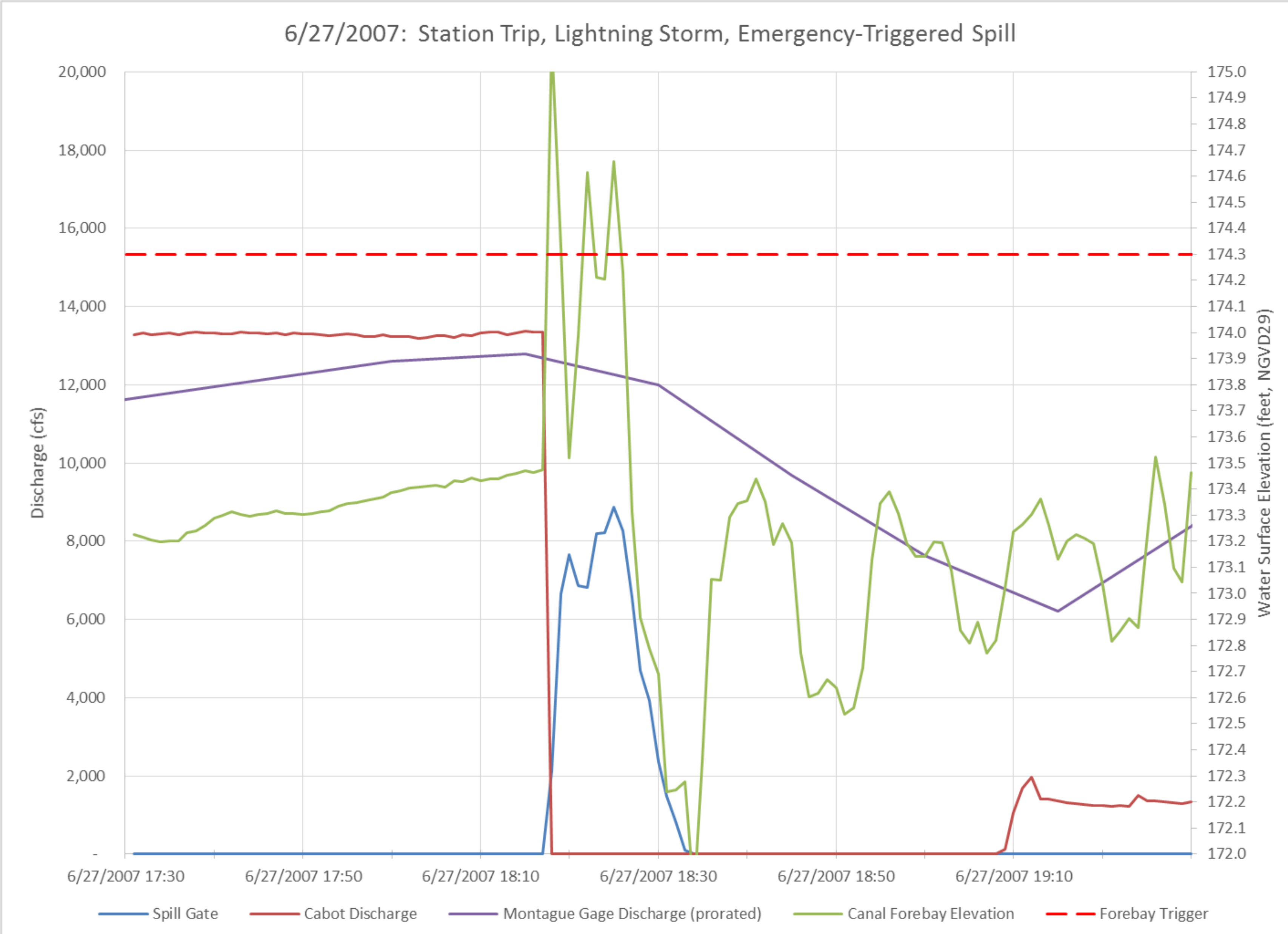

5/14/2006: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
Wateer Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
5/14/2006 11:10
5/14/2006 11:30
5/14/2006 11:50
5/14/2006 12:10
5/14/2006 12:30
5/14/2006 12:50
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

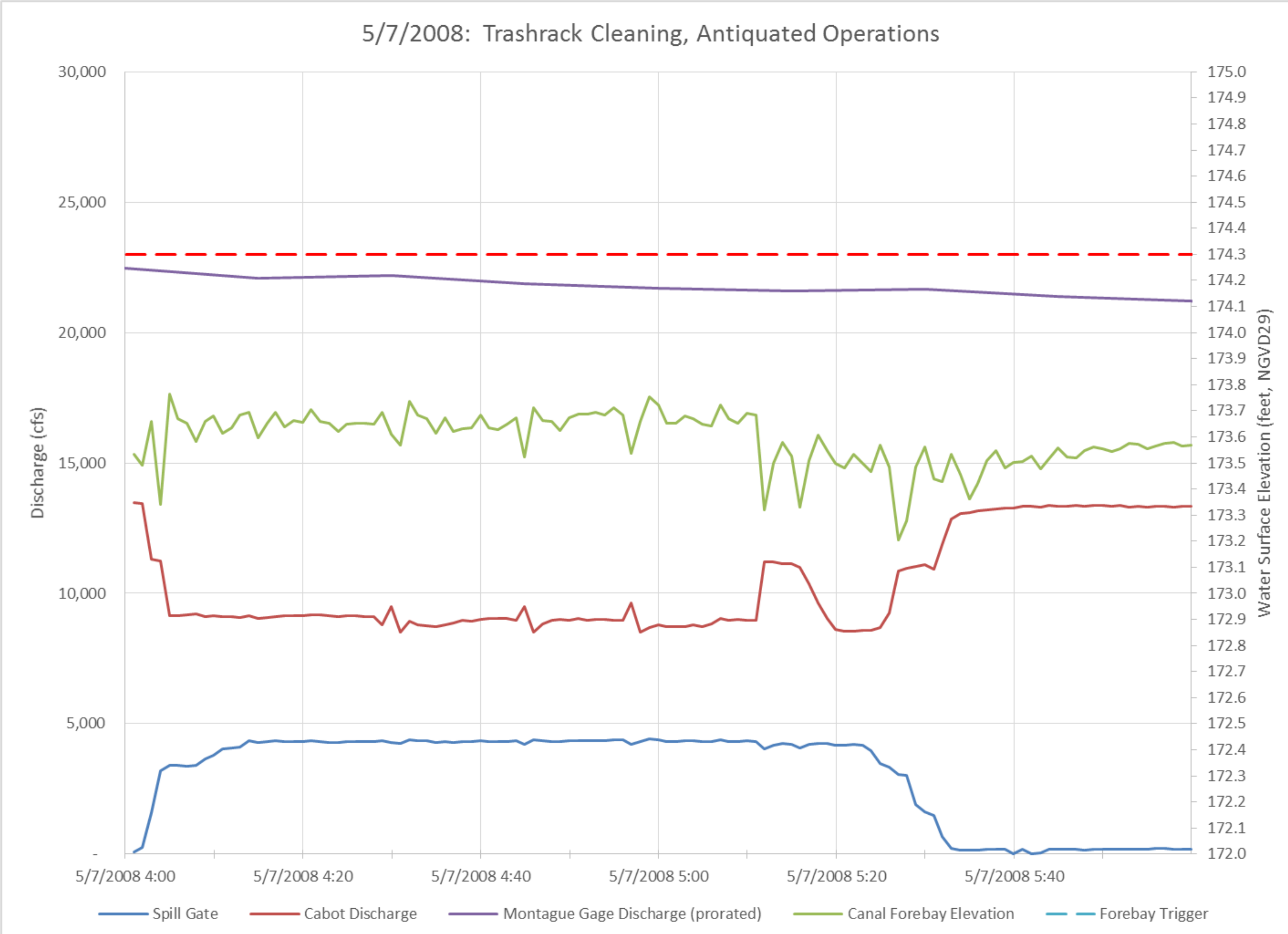

6/11/2006: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/11/2006 7:00
6/11/2006 7:20
6/11/2006 7:40
6/11/2006 8:00
6/11/2006 8:20
6/11/2006 8:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

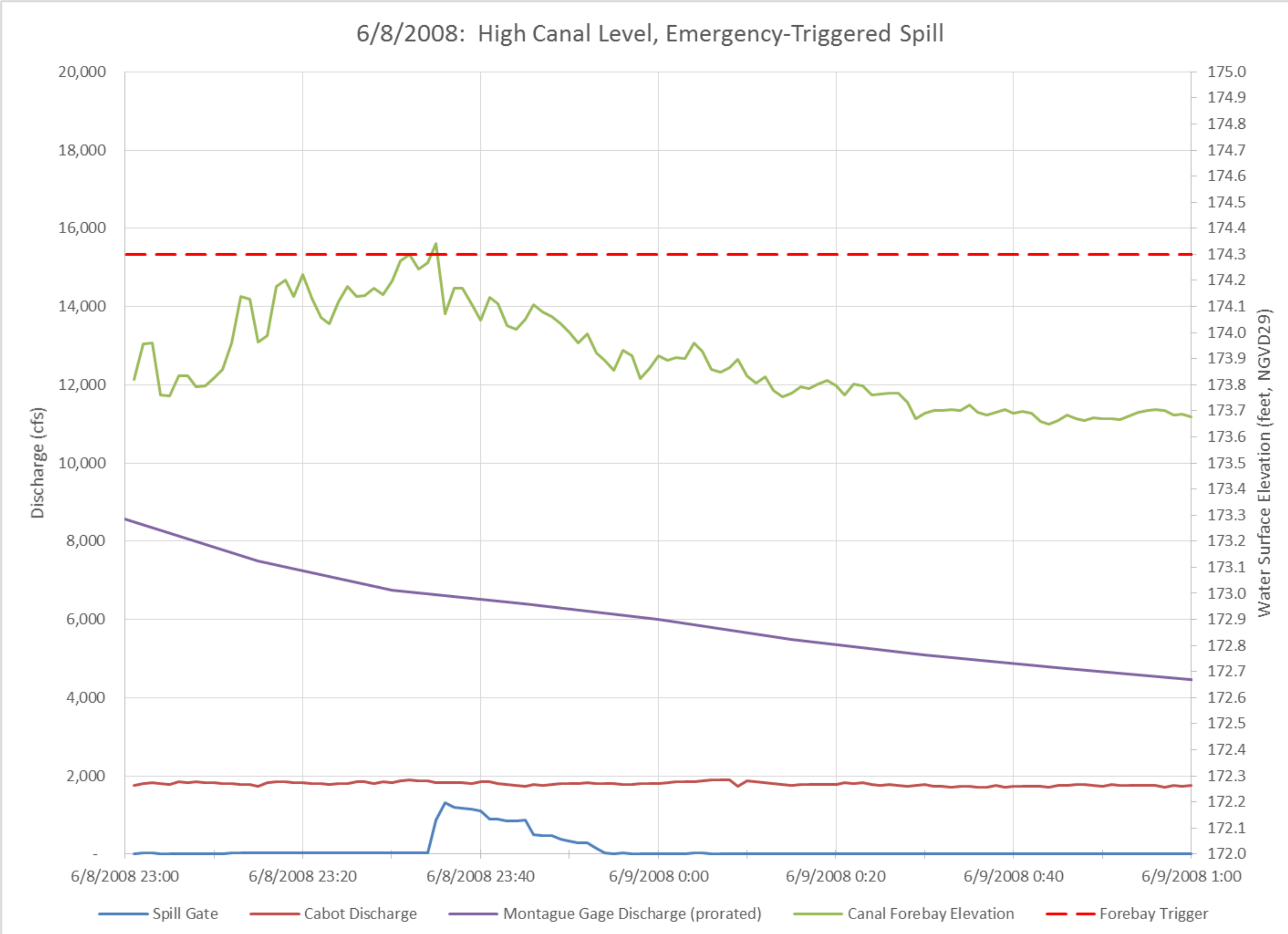

6/12/2006: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
60,000
50,000
40,000
30,000
20,000
10,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/12/2006 3:00
6/12/2006 3:20
6/12/2006 3:40
6/12/2006 4:00
6/12/2006 4:20
6/12/2006 4:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

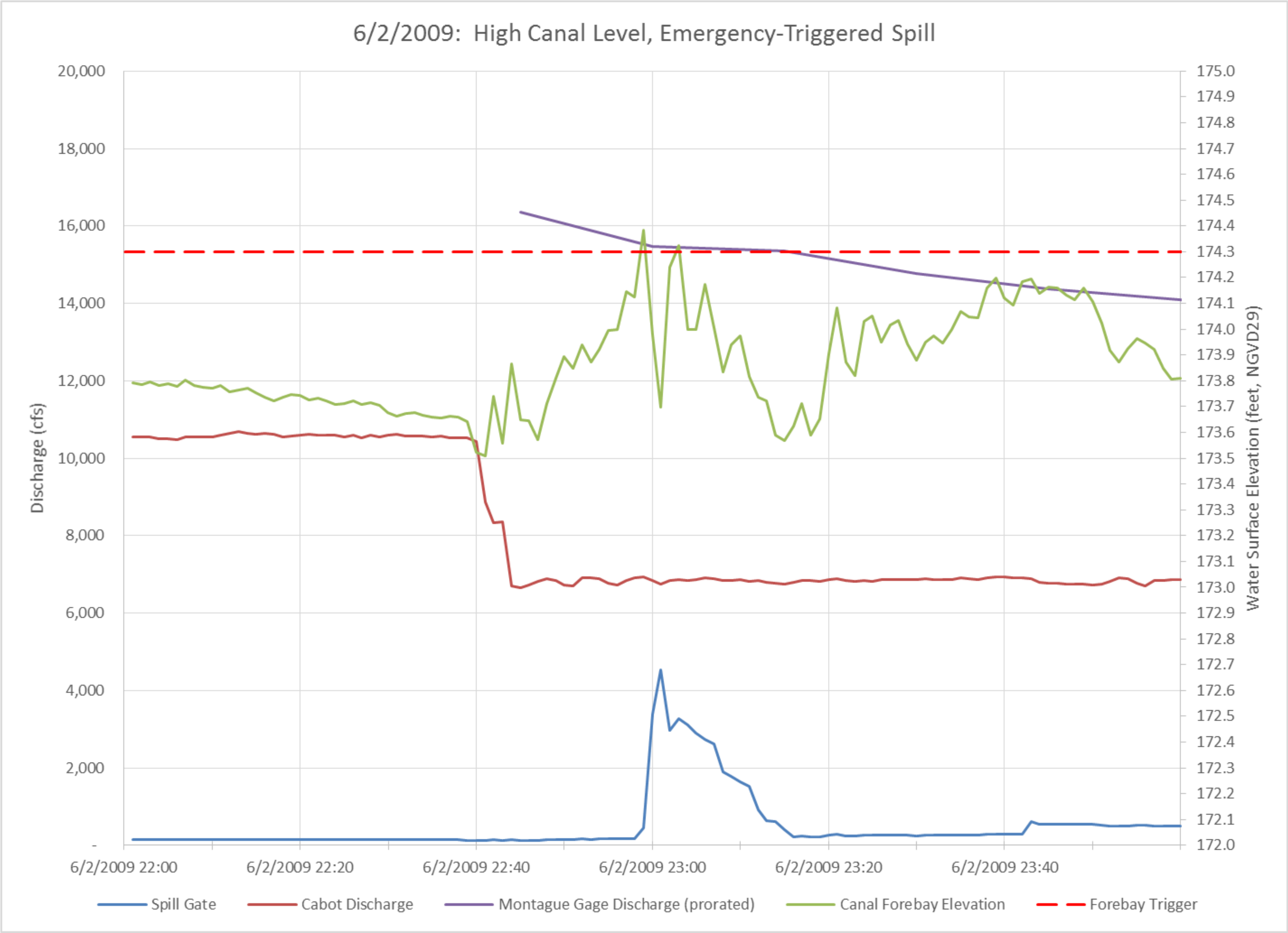

6/29/2006: High Flow, Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/29/2006 15:00
6/29/2006 15:20
6/29/2006 15:40
6/29/2006 16:00
6/29/2006 16:20
6/29/2006 16:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

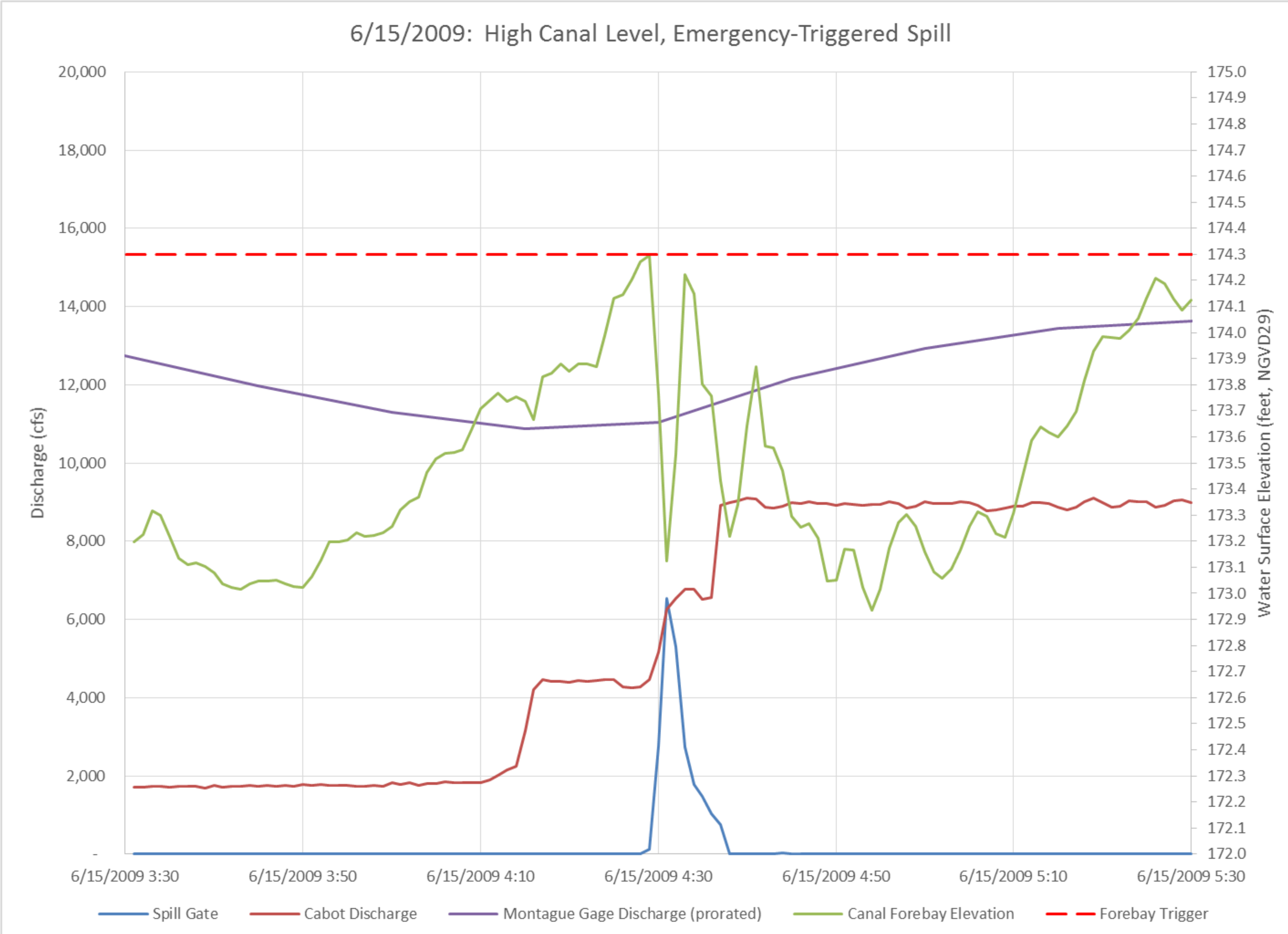

6/4/2007: Unit Trip, Emergency-Triggered Spill
Discharge (cfs)
Water Surface Elevation (feet, NGVD29)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/4/2007 7:00
6/4/2007 7:20
6/4/2007 7:40
6/4/2007 8:00
6/4/2007 8:20
6/4/2007 8:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

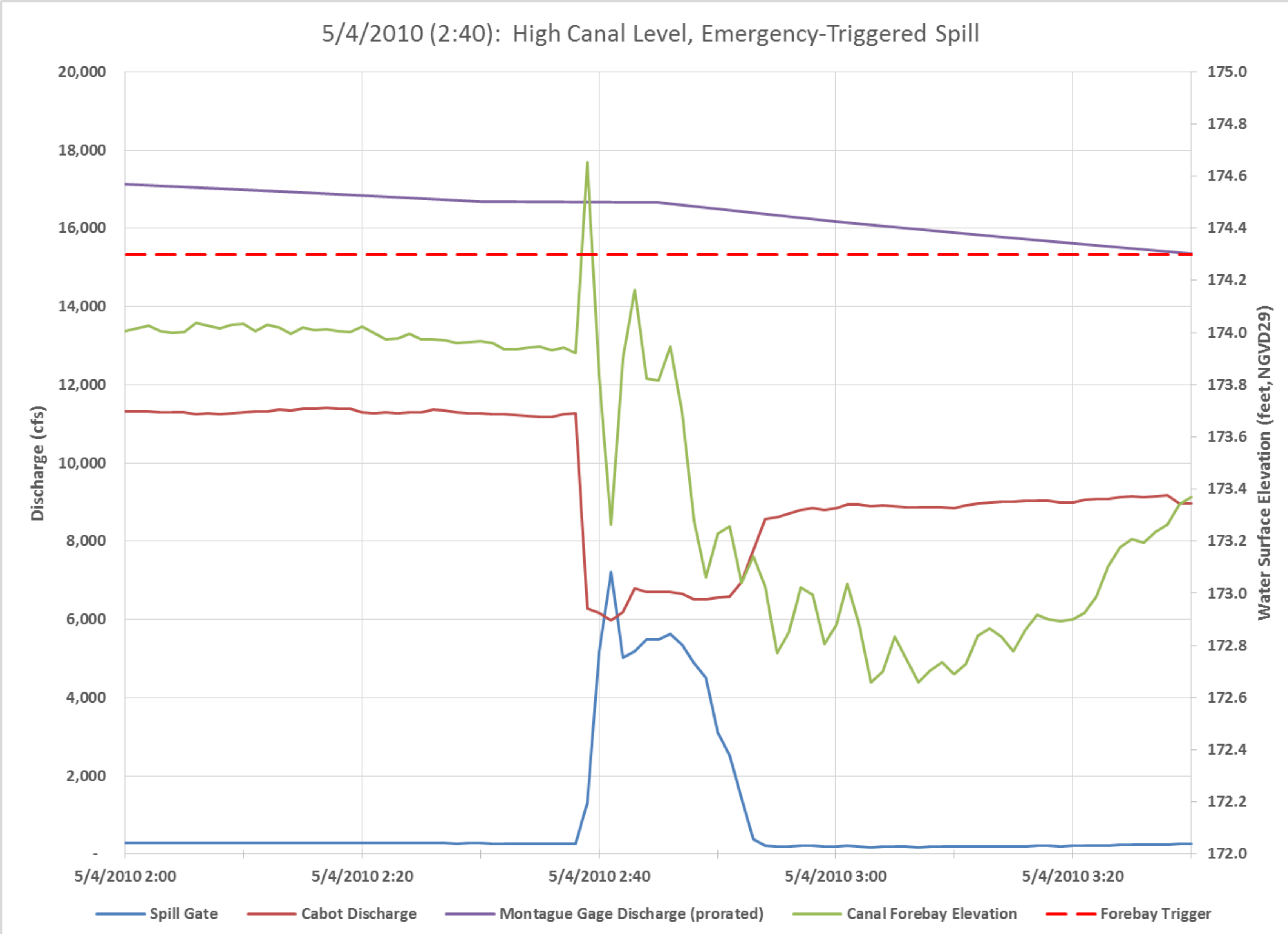

6/27/2007: Station Trip, Lightning Storm, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/27/2007 17:30
6/27/2007 17:50
6/27/2007 18:10
6/27/2007 18:30
6/27/2007 18:50
6/27/2007 19:10
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

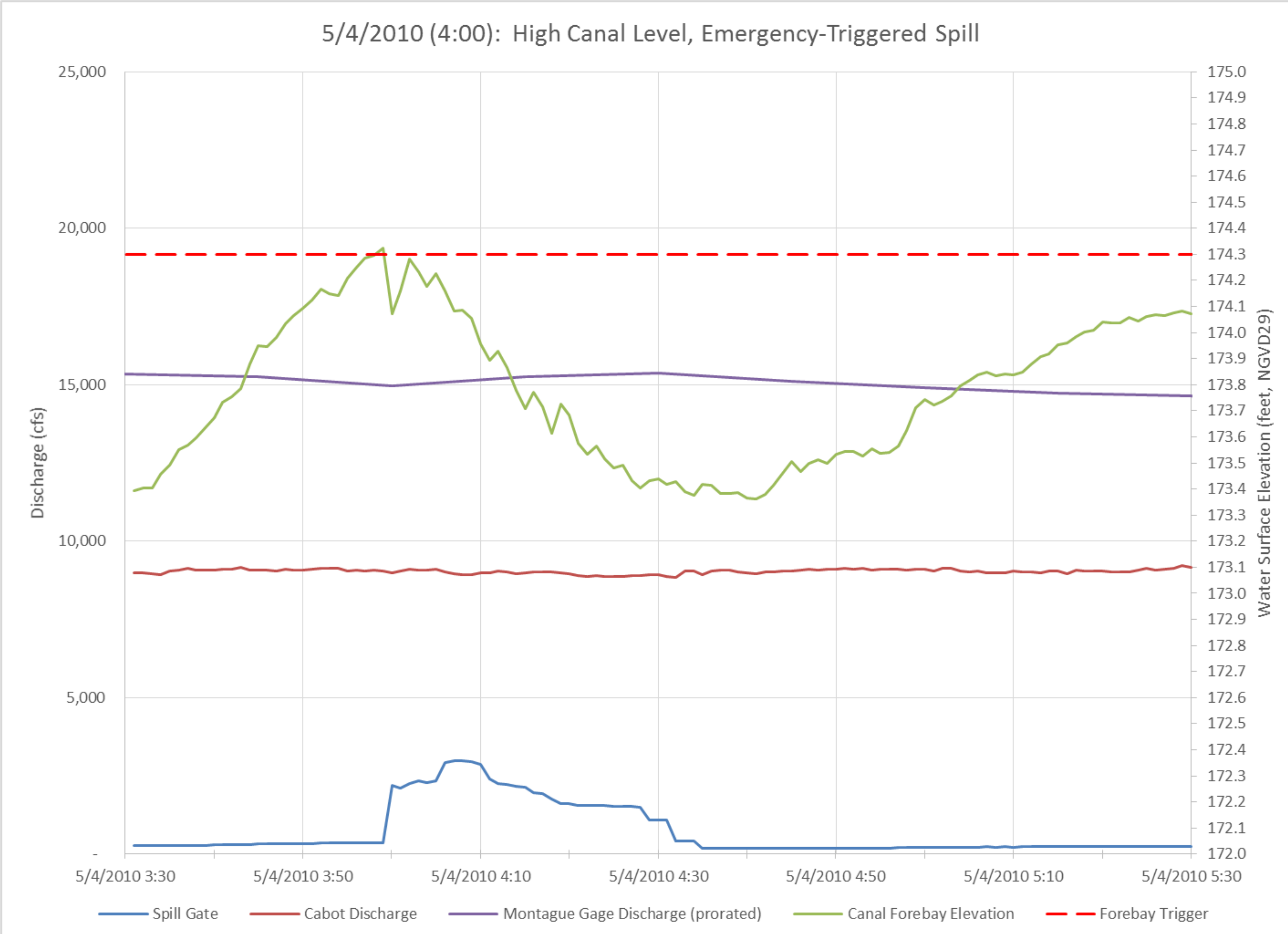

5/7/2008: Trashrack Cleaning, Antiquated Operations
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
5/7/2008 4:00
5/7/2008 4:20
5/7/2008 4:40
5/7/2008 5:00
5/7/2008 5:20
5/7/2008 5:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

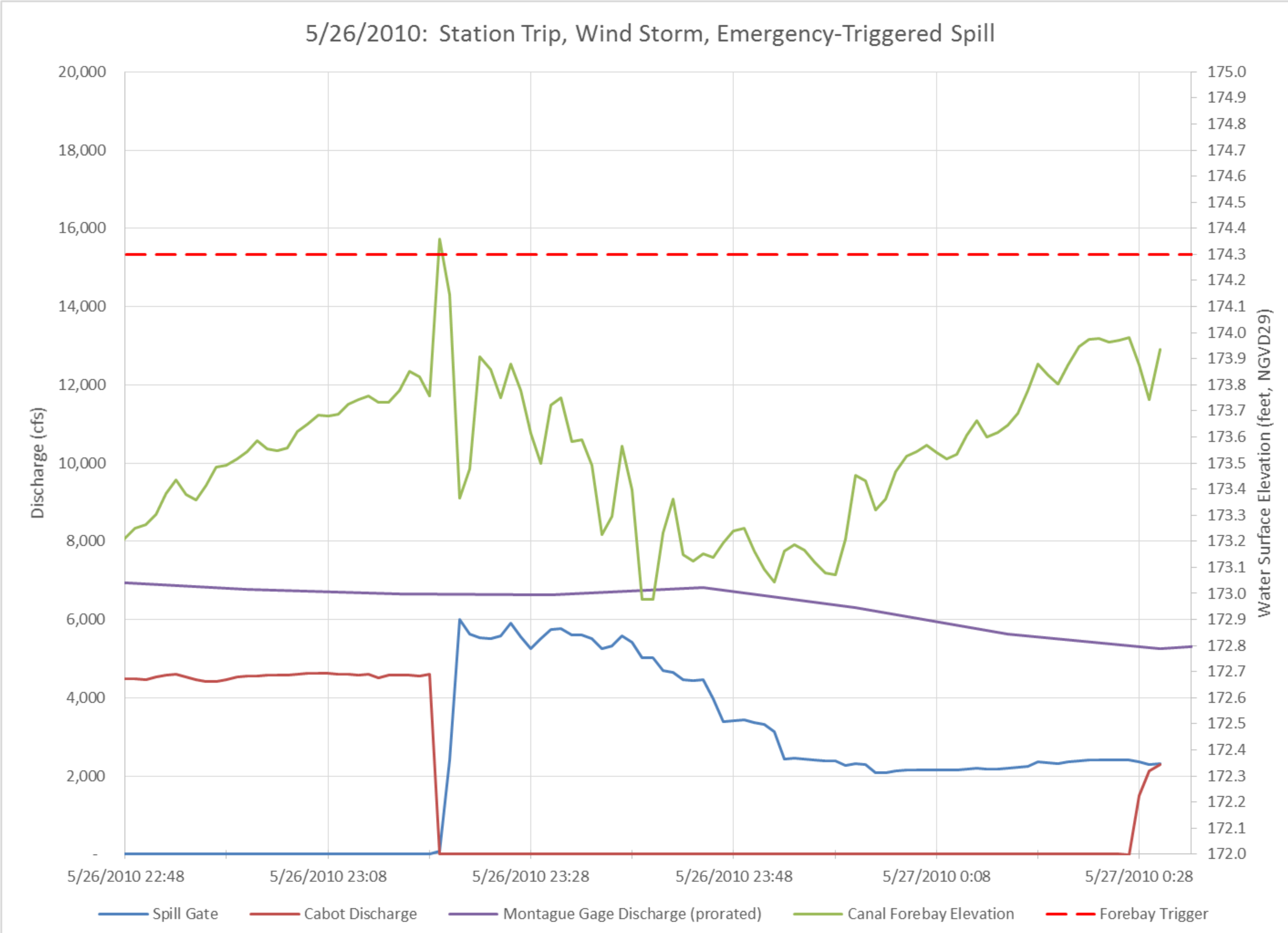

6/8/2008: High Canal Level, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/8/2008 23:00
6/8/2008 23:20
6/8/2008 23:40
6/9/2008 0:00
6/9/2008 0:20
6/9/2008 0:40
6/9/2008 1:00
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

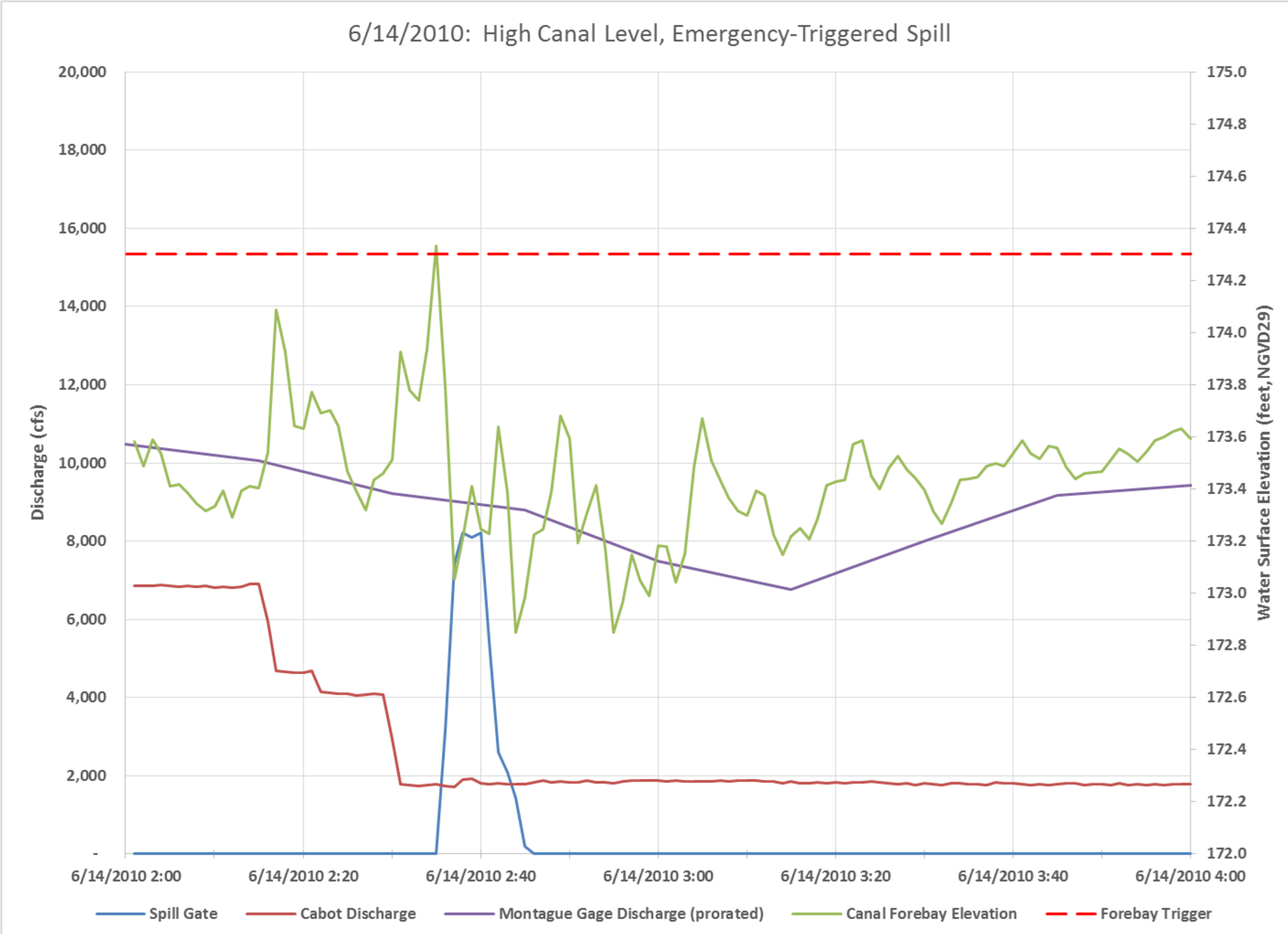

6/2/2009: High Canal Level, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/2/2009 22:00
6/2/2009 22:20
6/2/2009 22:40
6/2/2009 23:00
6/2/2009 23:20
6/2/2009 23:40
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger


6/15/2009: High Canal Level, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
6/15/2009 3:30
6/15/2009 3:50
6/15/2009 4:10
6/15/2009 4:30
6/15/2009 4:50
6/15/2009 5:10
6/15/2009 5:30
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

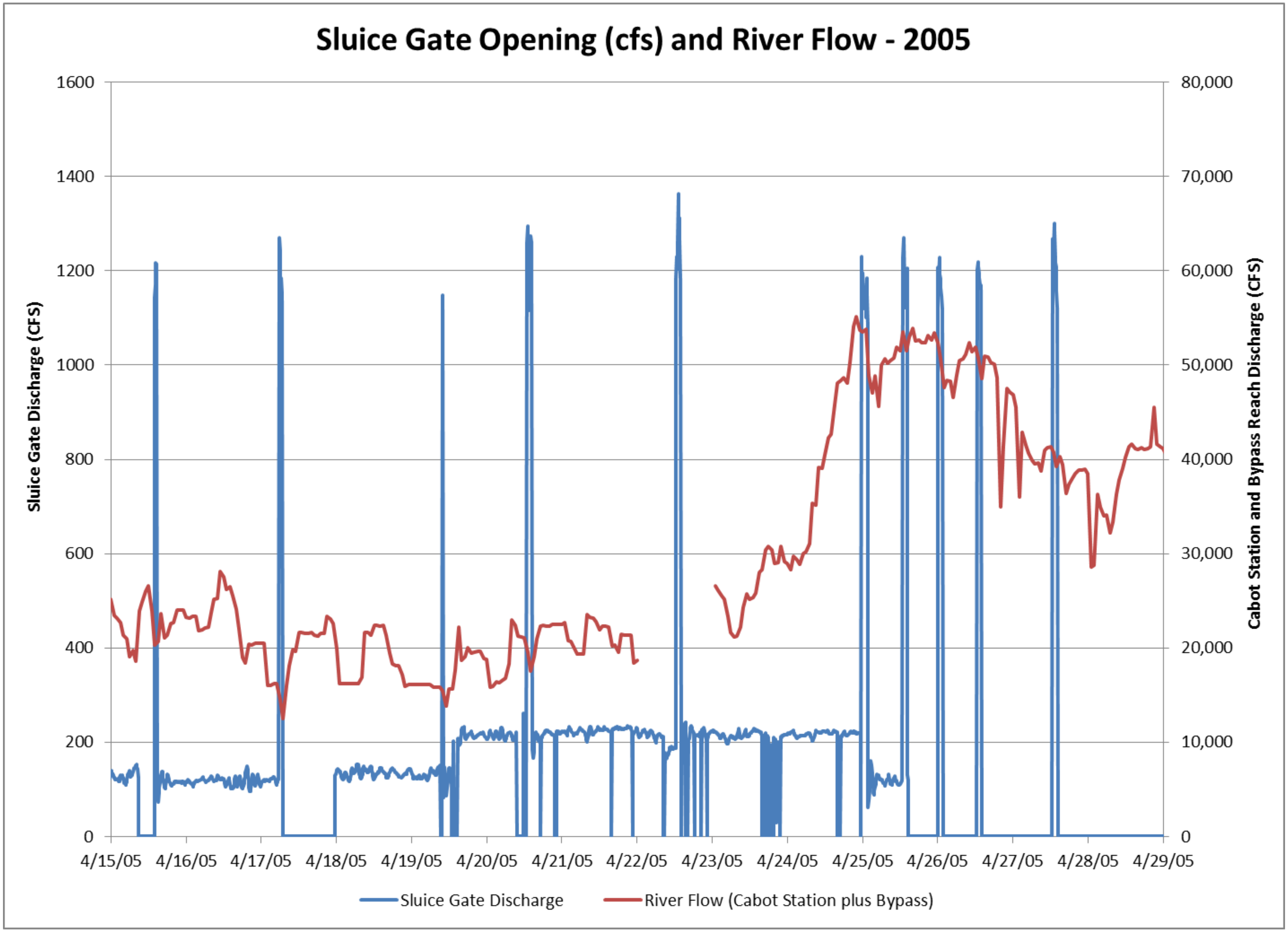

5/4/2010 (2:40): High Canal Level, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.8
174.6
174.4
174.2
174.0
173.8
173.6
173.4
173.2
173.0
172.8
172.6
172.4
172.2
172.0
5/4/2010 2:00
5/4/2010 2:20
5/4/2010 2:40
5/4/2010 3:00
5/4/2010 3:20
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

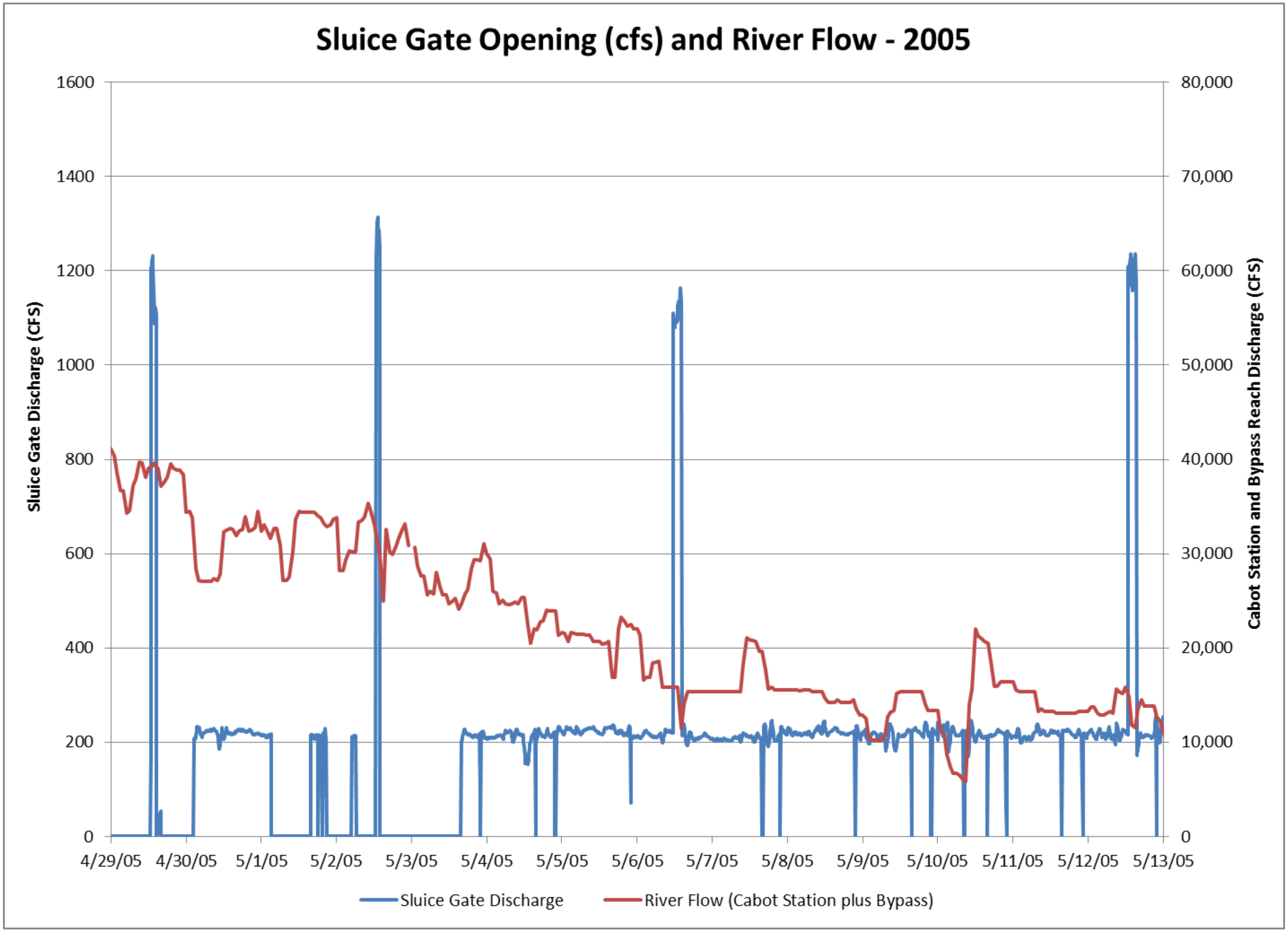

5/4/2010 (4:00): High Canal Level, Emergency-Triggered Spill
Discharge (cfs)
Water Surface Elevation (feet, NGVD29)
25,000
20,000
15,000
10,000
5,000
-
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
5/4/2010 3:30
5/4/2010 3:50
5/4/2010 4:10
5/4/2010 4:30
5/4/2010 4:50
5/4/2010 5:10
5/4/2010 5:30
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

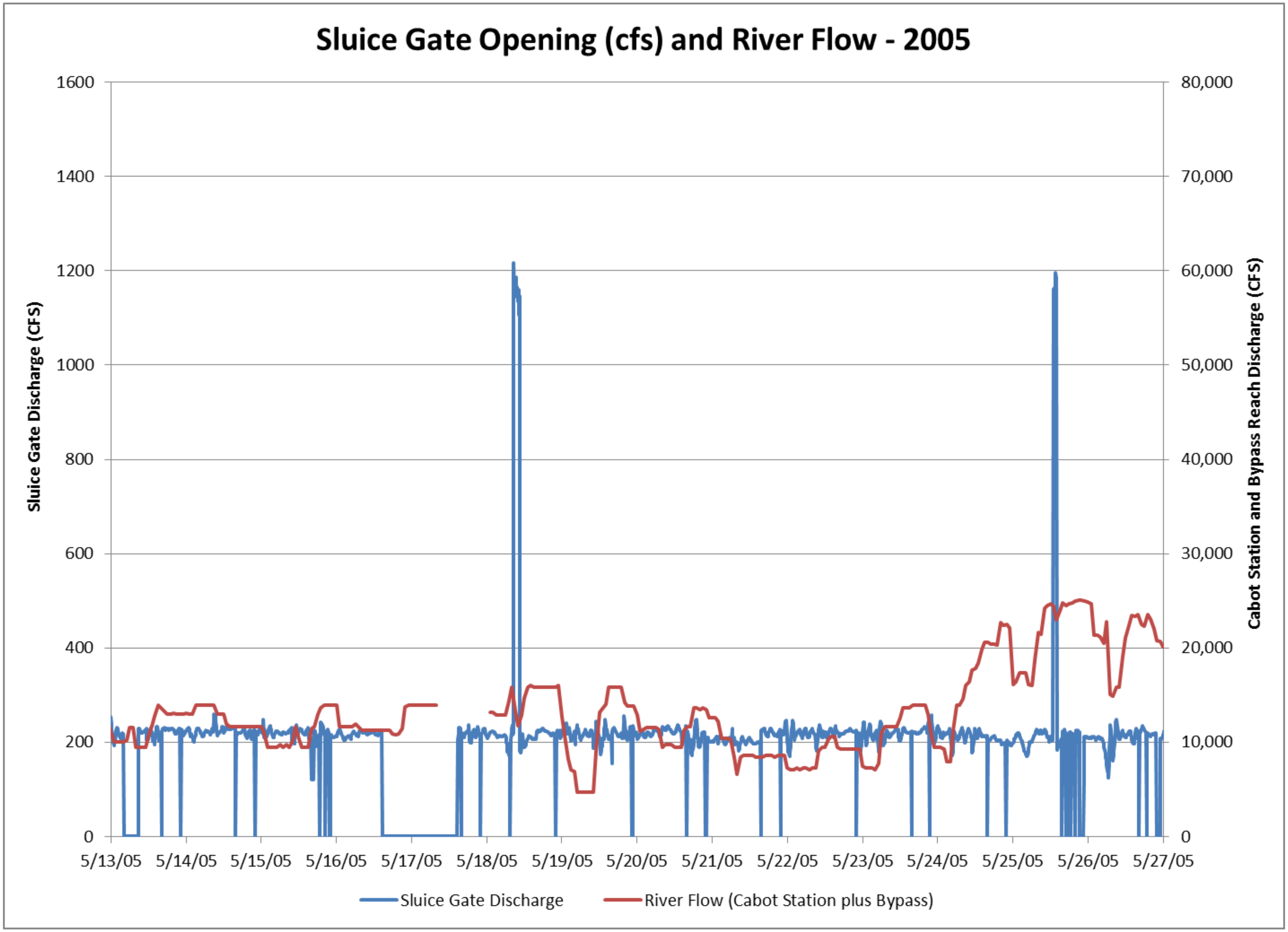

5/26/2010: Station Trip, Wind Storm, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.9
174.8
174.7
174.6
174.5
174.4
174.3
174.2
174.1
174.0
173.9
173.8
173.7
173.6
173.5
173.4
173.3
173.2
173.1
173.0
172.9
172.8
172.7
172.6
172.5
172.4
172.3
172.2
172.1
172.0
5/26/2010 22:48
5/26/2010 23:08
5/26/2010 23:28
5/26/2010 23:48
5/27/2010 0:08
5/27/2010 0:28
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

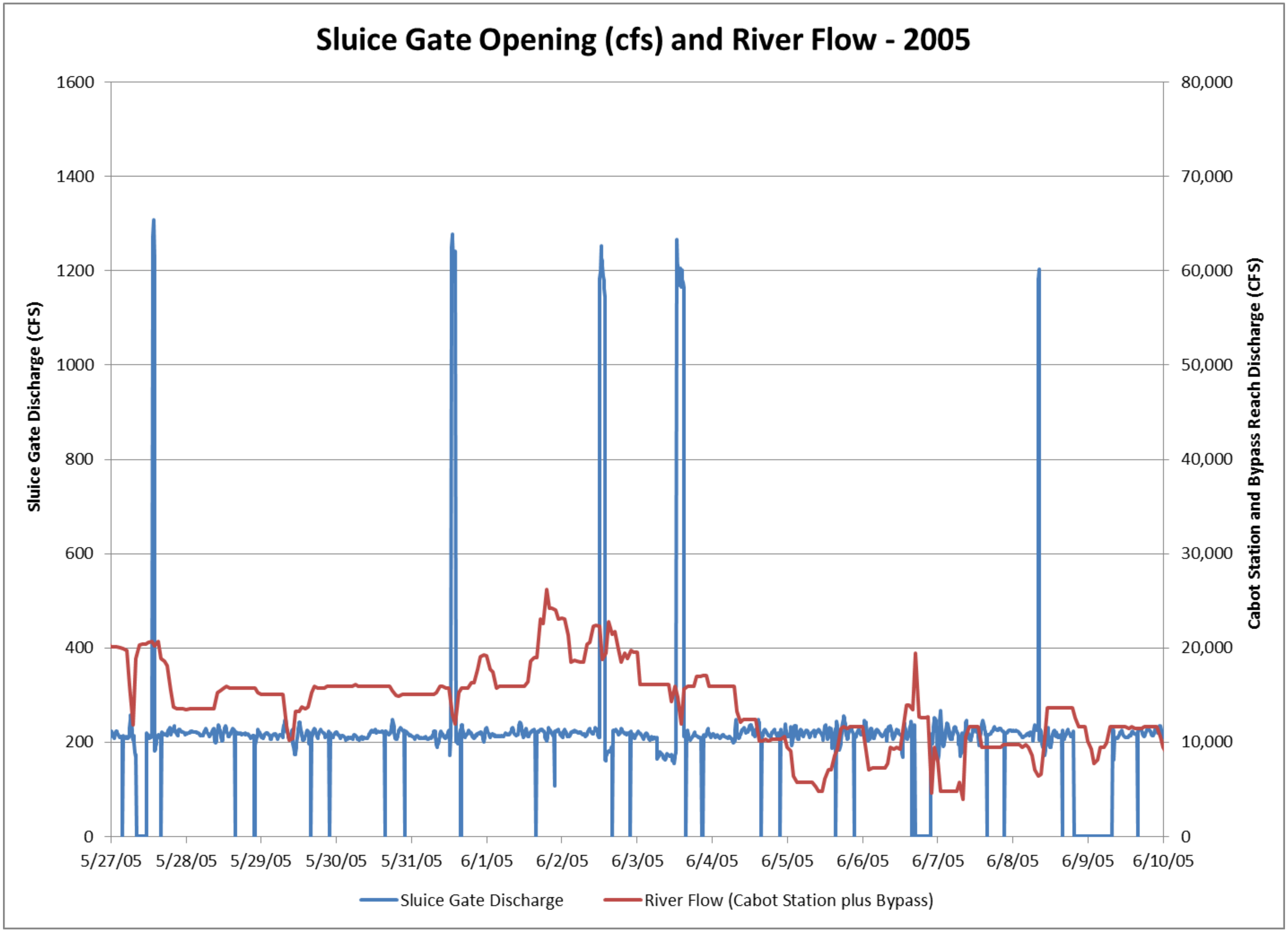

6/14/2010: High Canal Level, Emergency-Triggered Spill
Discharge (cfs)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Water Surface Elevation (feet, NGVD29)
175.0
174.8
174.6
174.4
174.2
174.0
173.8
173.6
173.4
173.2
173.0
172.8
172.6
172.4
172.2
172.0
6/14/2010 2:00
6/14/2010 2:20
6/14/2010 2:40
6/14/2010 3:00
6/14/2010 3:20
6/14/2010 3:40
6/14/2010 4:00
Spill Gate
Cabot Discharge
Montague Gage Discharge (prorated)
Canal Forebay Elevation
Forebay Trigger

APPENDIX A-2 - SLUICE GATE OPENING CFS VS RIVER FLOW


Sluice Gate Opening (cfs) and River Flow - 2005
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
0
200
400
600
800
1000
1200
1400
1600
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
4/15/05
4/16/05
4/17/05
4/18/05
4/19/05
4/20/05
4/21/05
4/22/05
4/23/05
4/24/05
4/25/05
4/26/05
4/27/05
4/28/05
4/29/05
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2005
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
1600
1400
1200
1000
800
600
400
200
0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
4/29/05
4/30/05
5/1/05
5/2/05
5/3/05
5/4/05
5/5/05
5/6/05
5/7/05
5/8/05
5/9/05
5/10/05
5/11/05
5/12/05
5/13/05
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2005
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
1600
1400
1200
1000
800
600
400
200
0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/13/05
5/14/05
5/15/05
5/16/05
5/17/05
5/18/05
5/19/05
5/20/05
5/21/05
5/22/05
5/23/05
5/24/05
5/25/05
5/26/05
5/27/05
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2005
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
1600
1400
1200
1000
800
600
400
200
0
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
5/27/05
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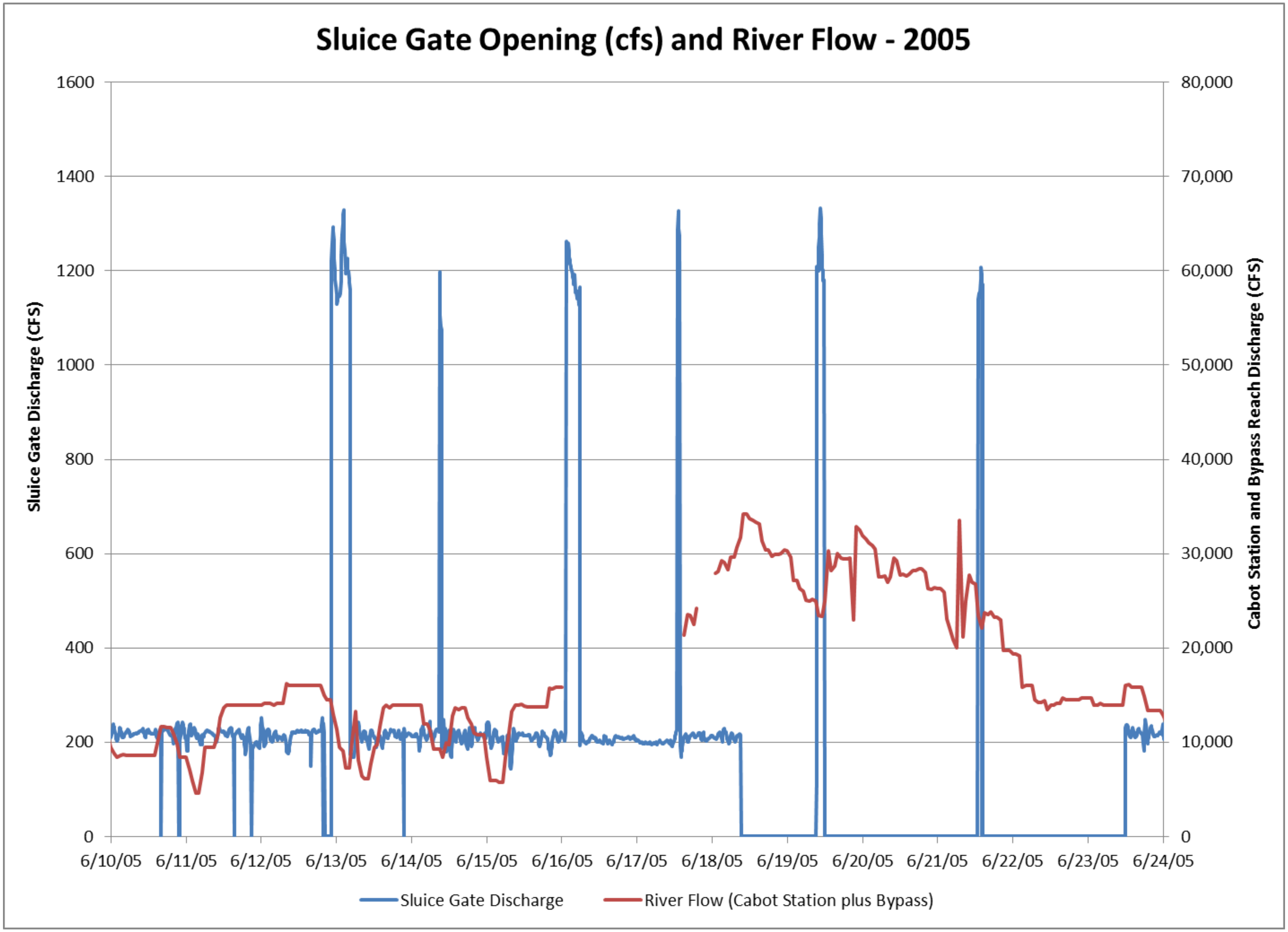
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2005
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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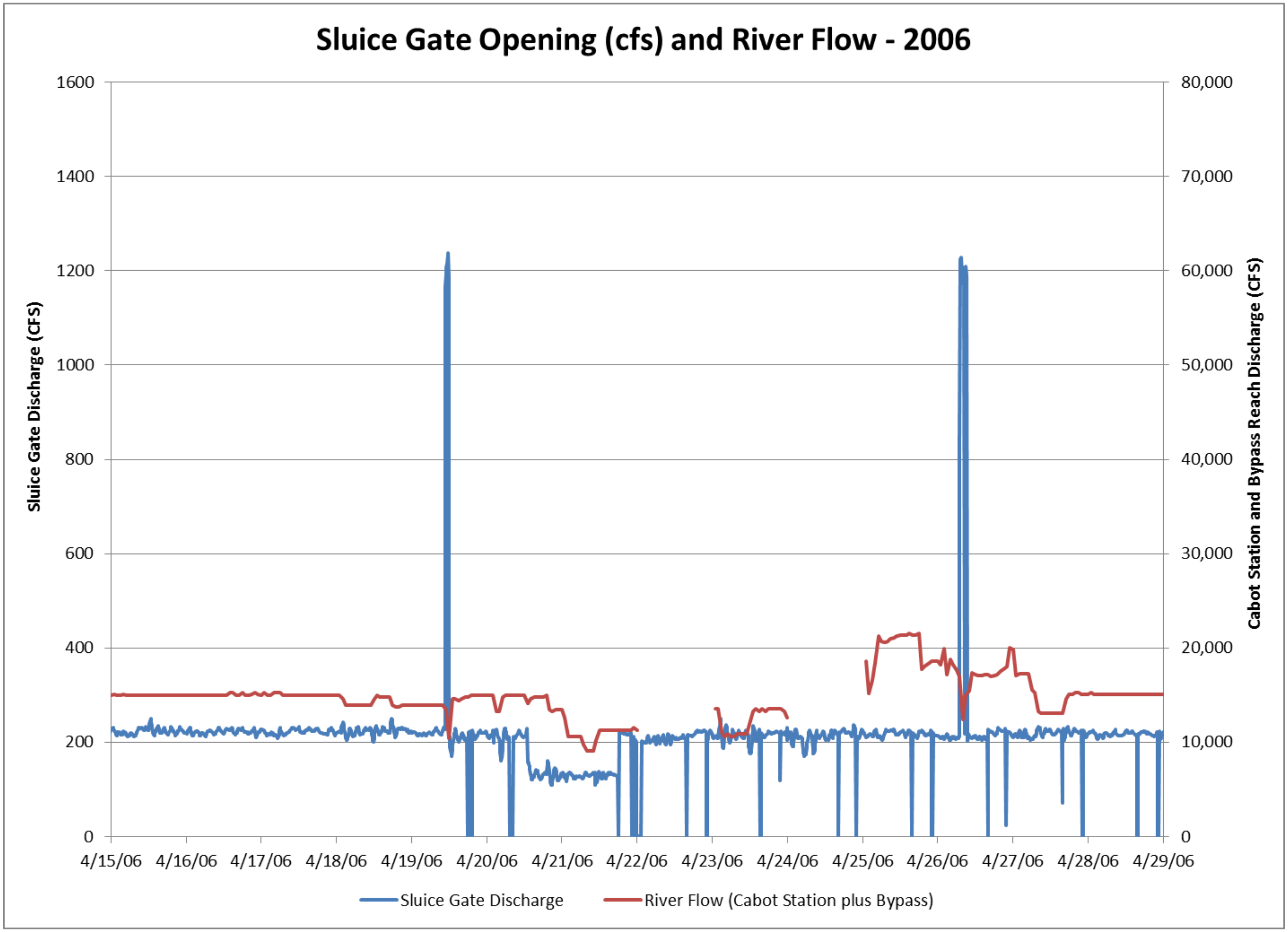
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2006
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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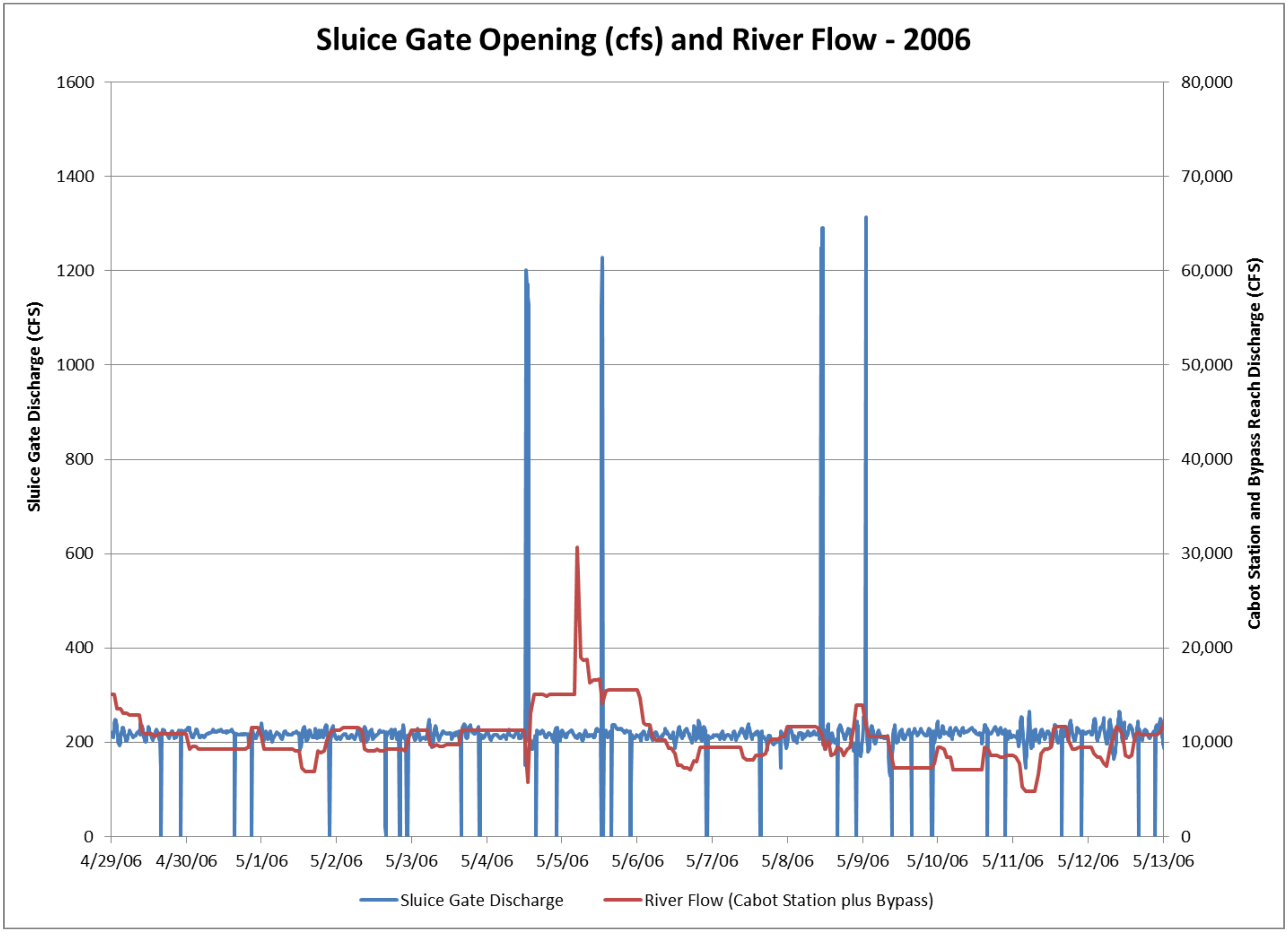
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2006
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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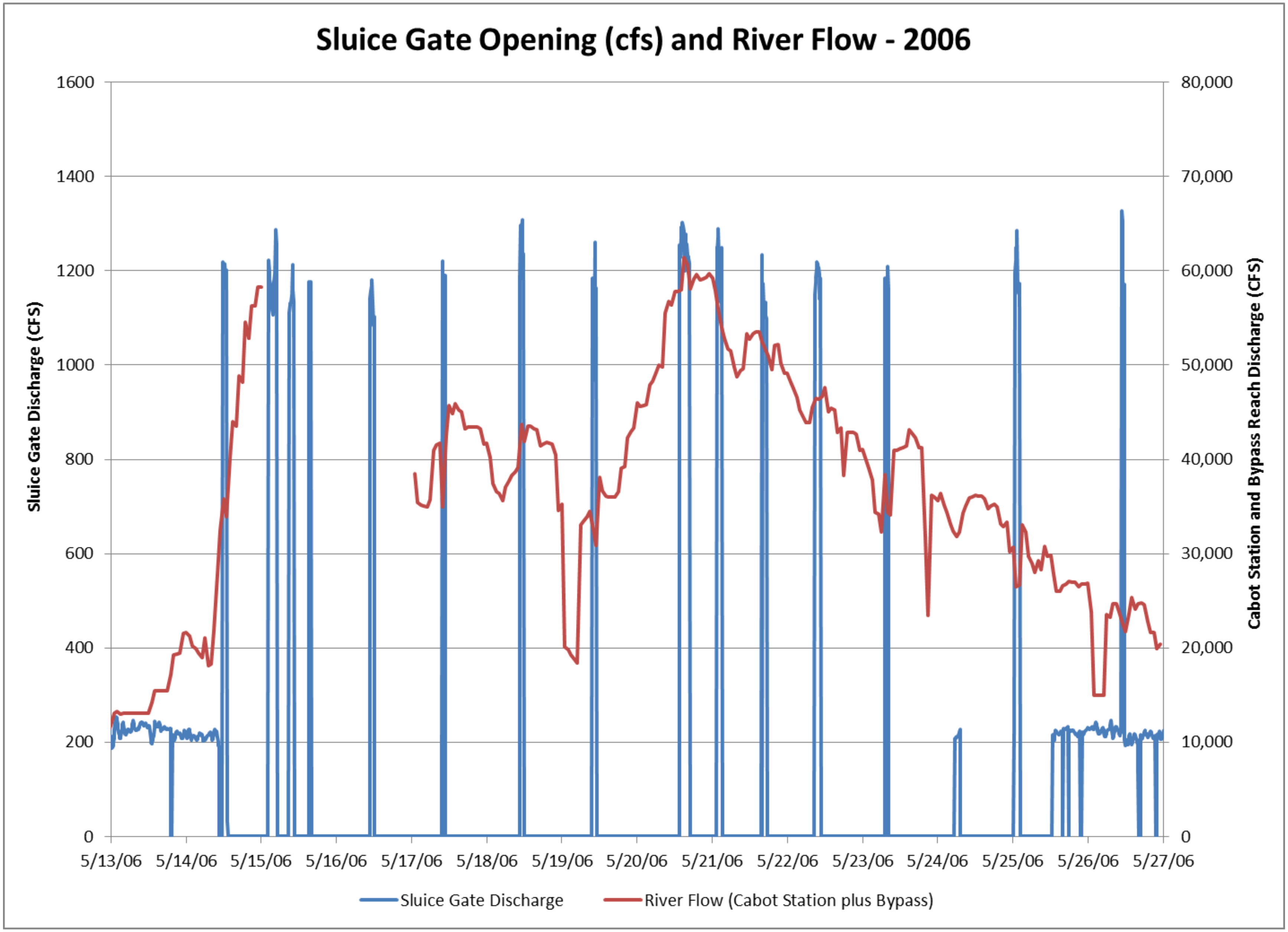
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2006
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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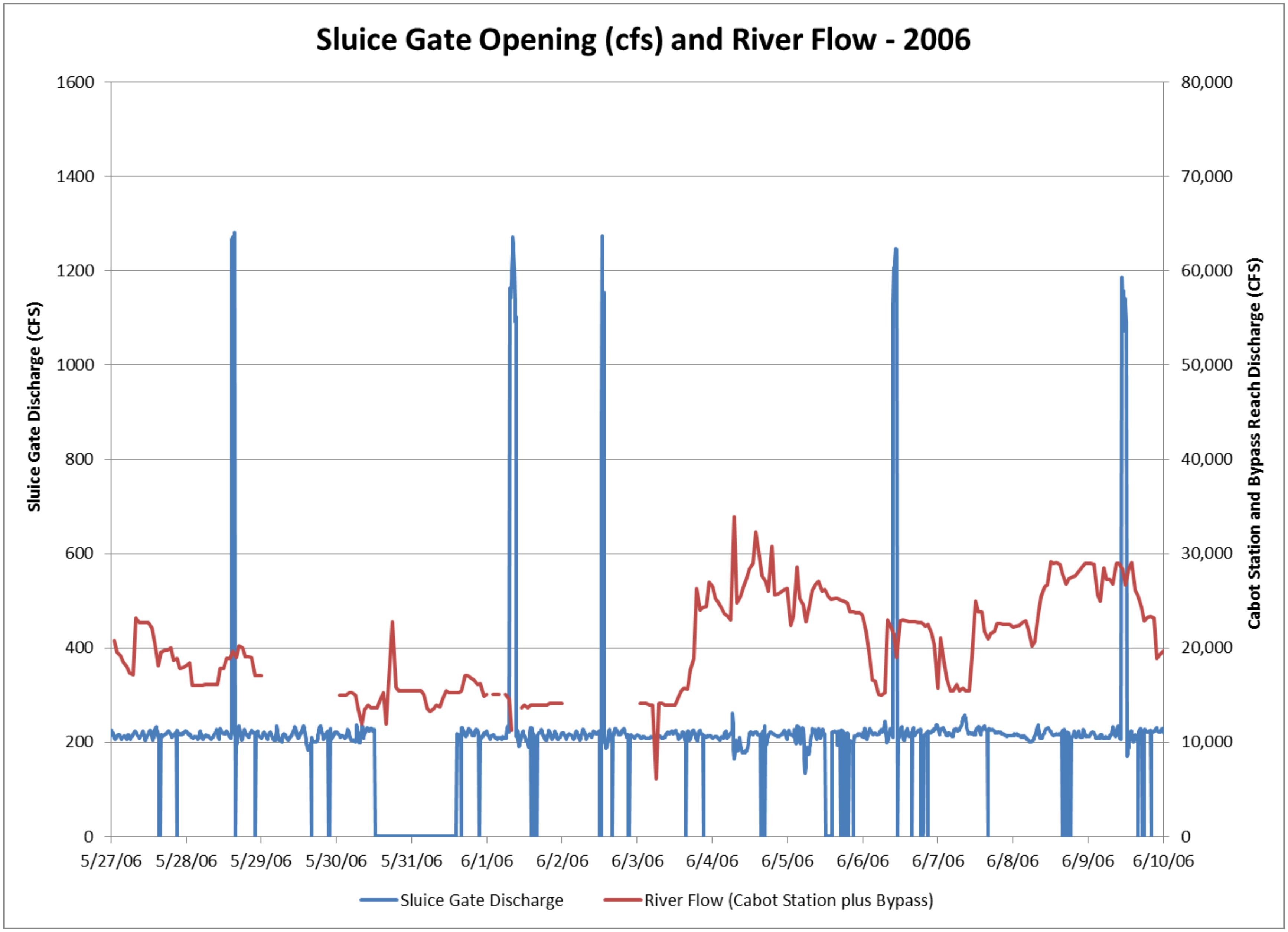
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2006
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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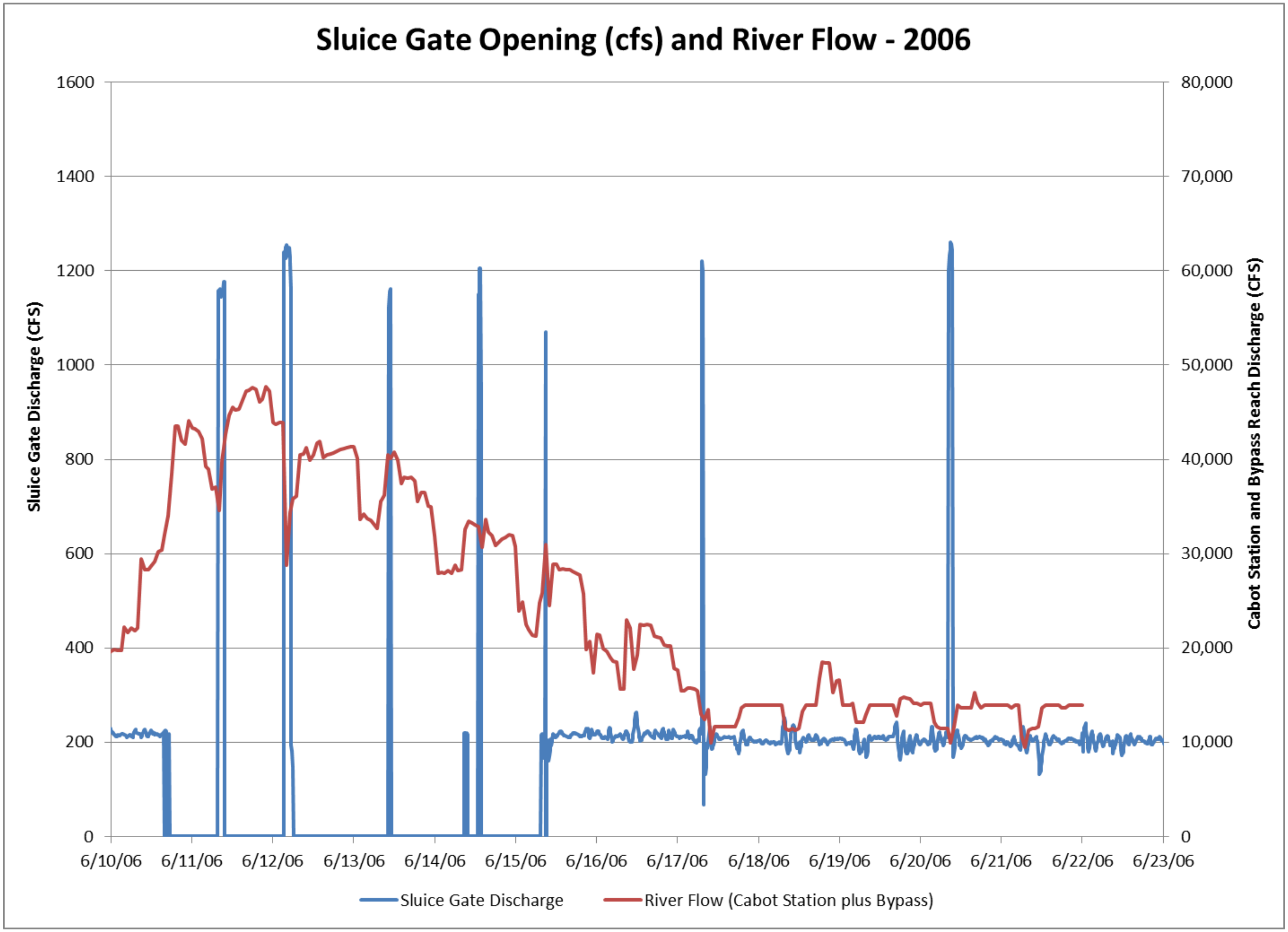
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2006
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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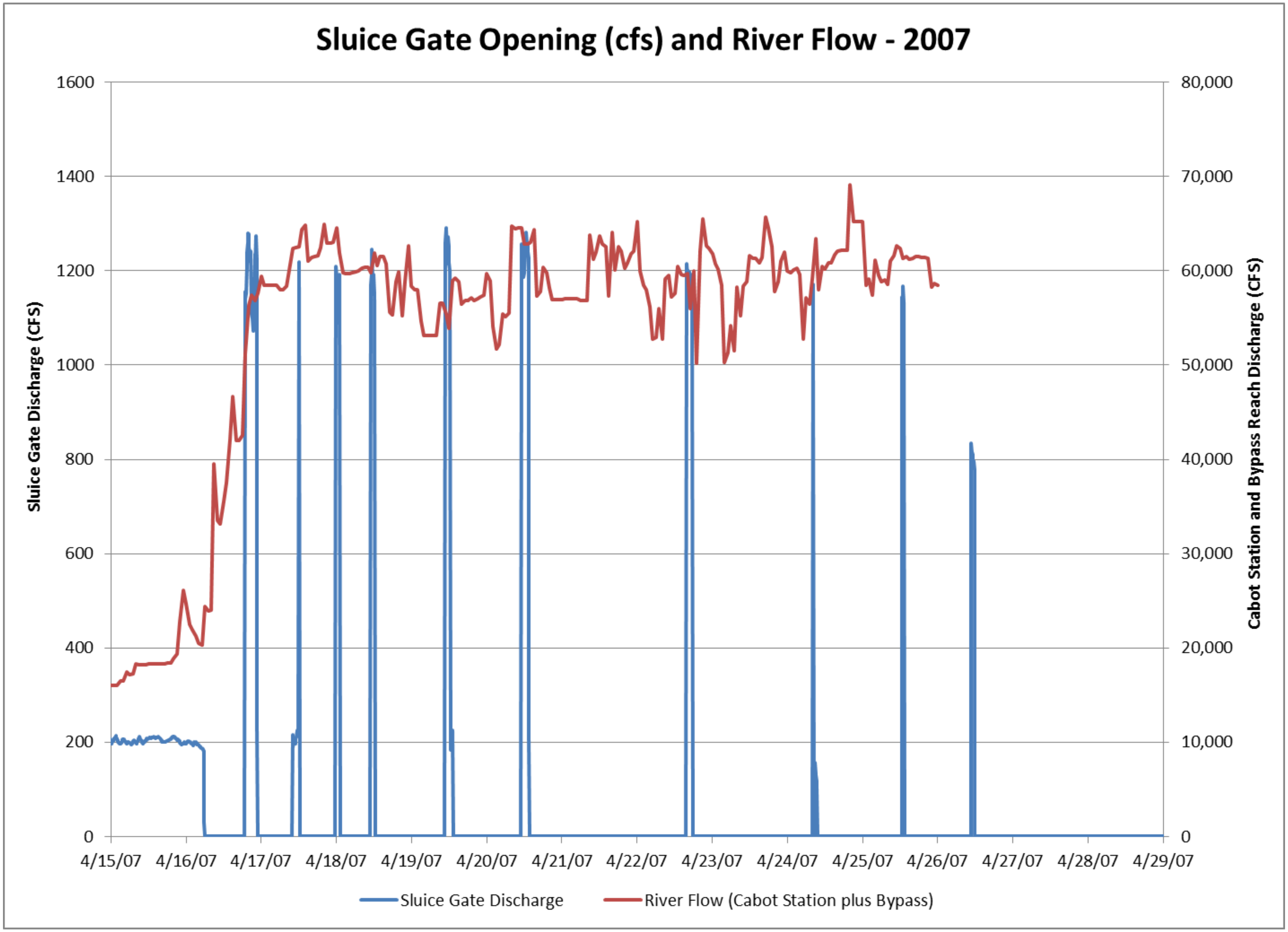
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2007
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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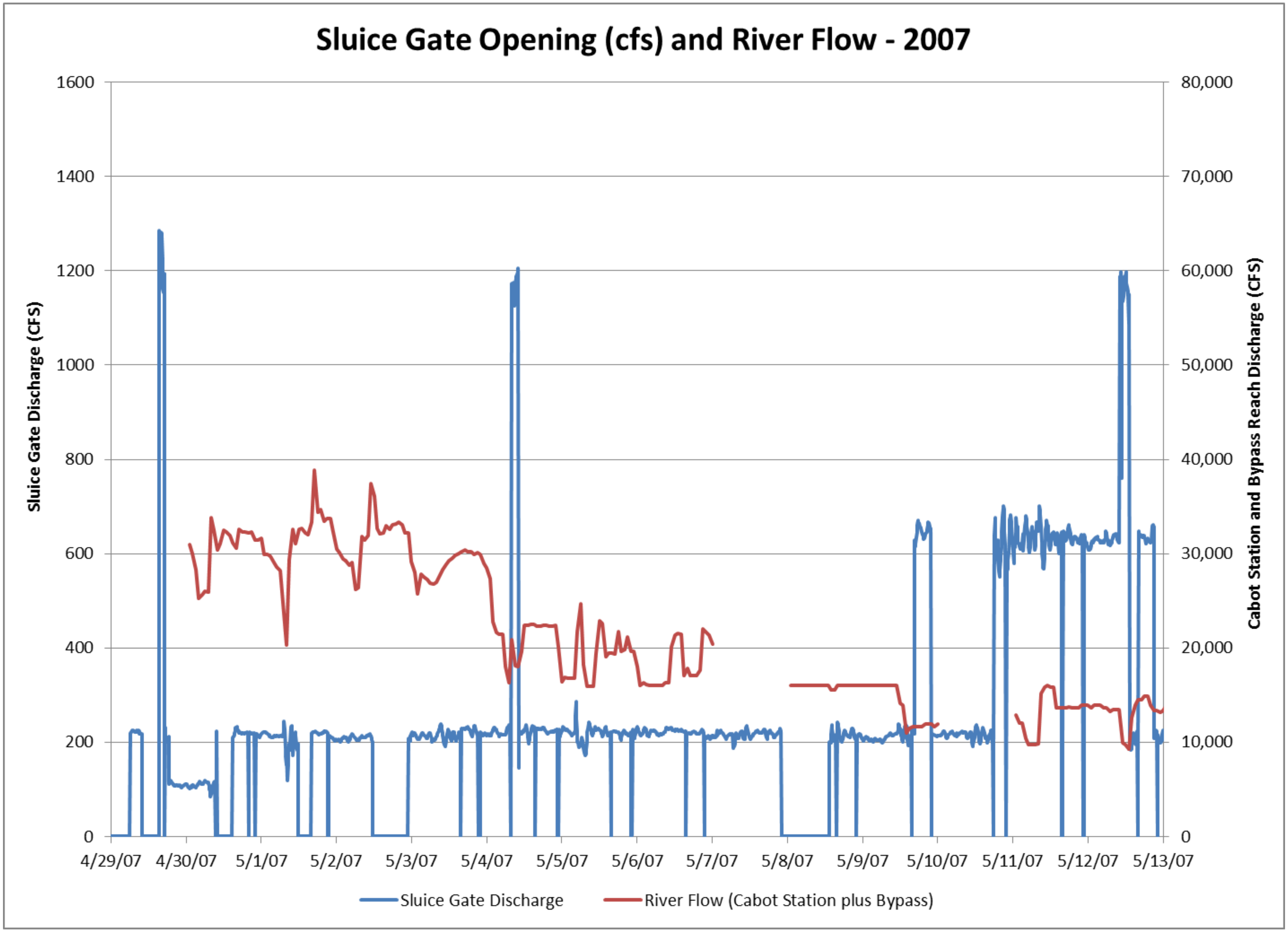
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2007
Sluice Gate Discharge (CFS)
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Cabot Station and Bypass Reach Discharge (CFS)
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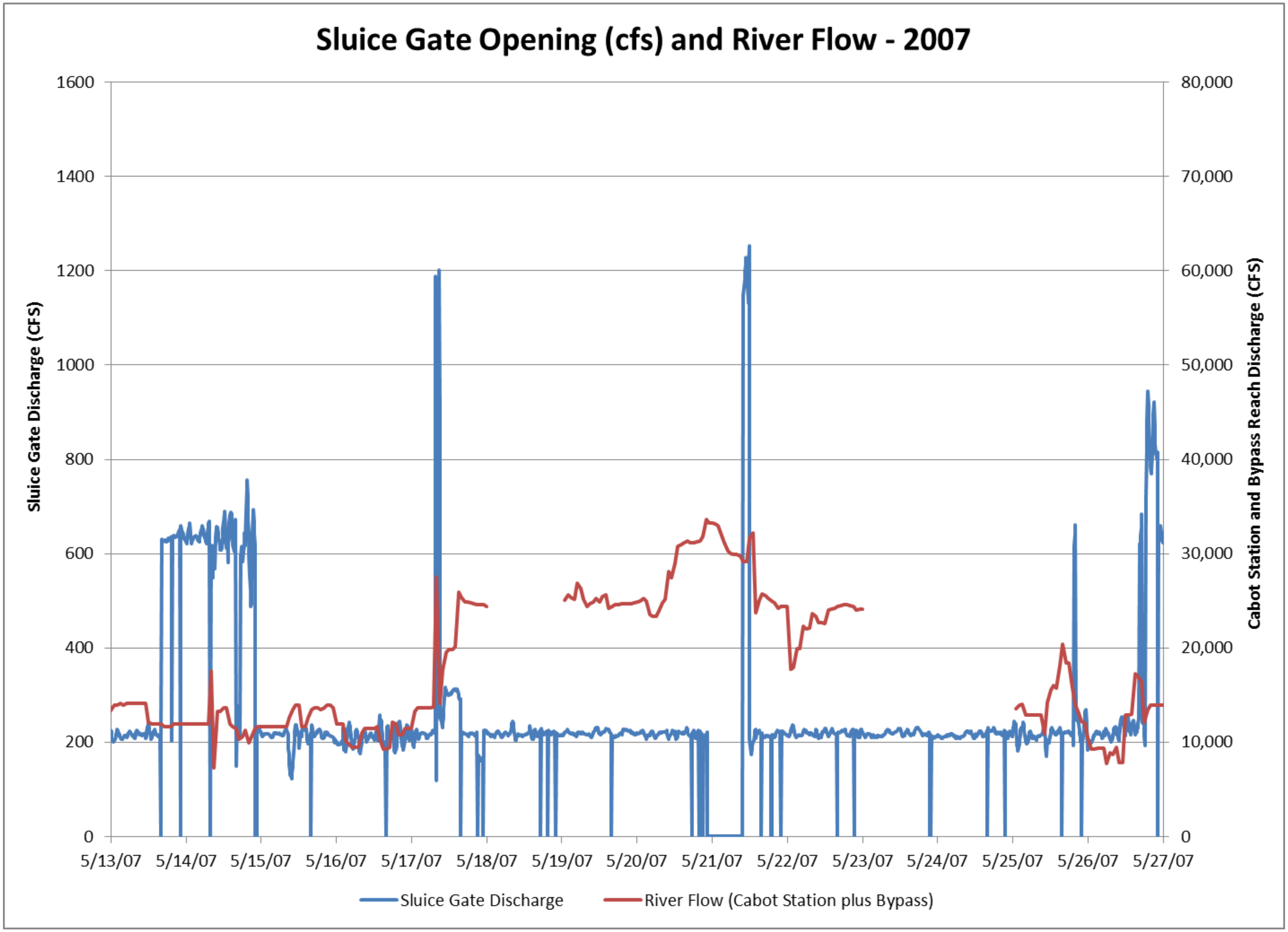
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2007
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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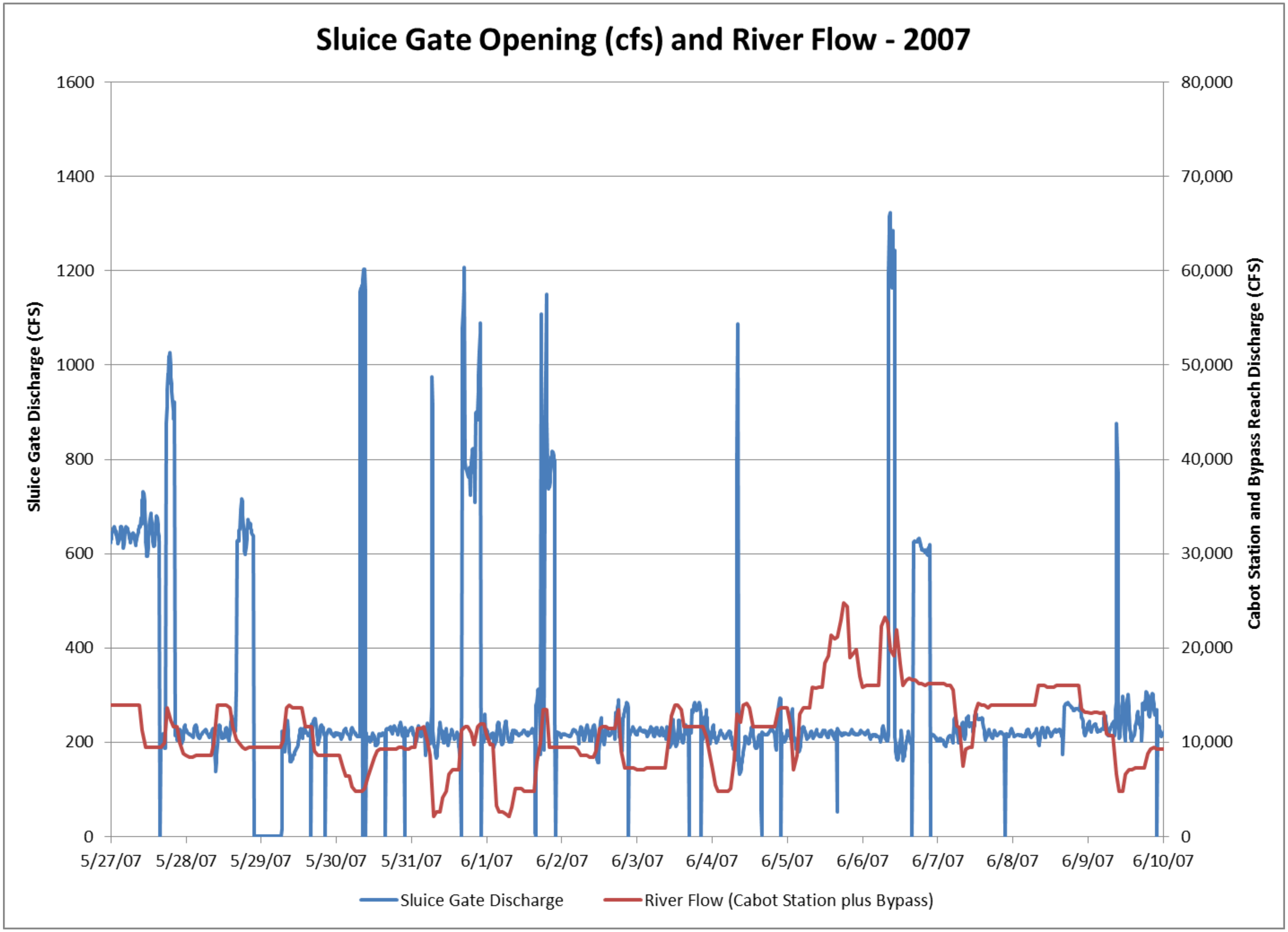
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2007
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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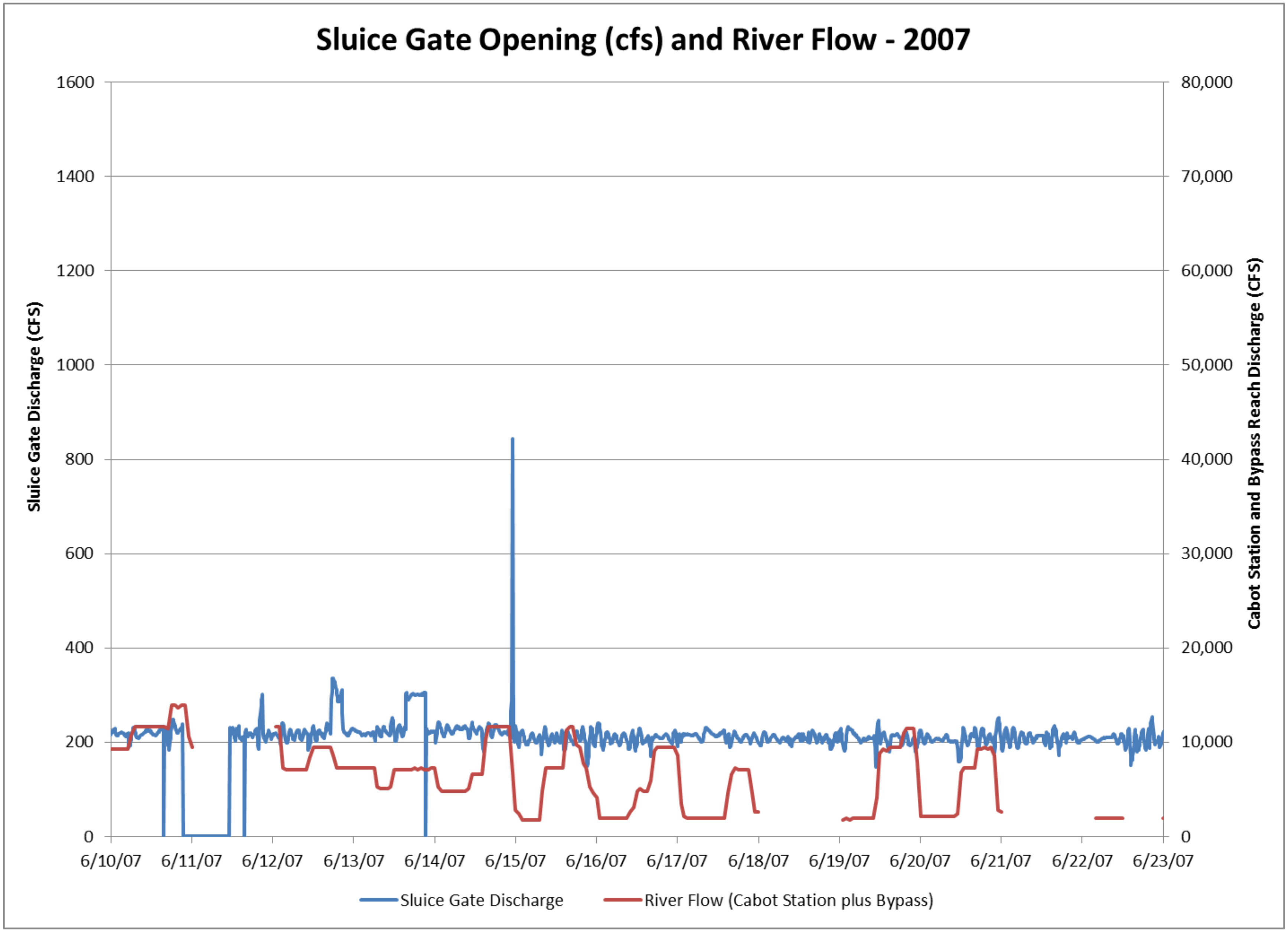
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2007
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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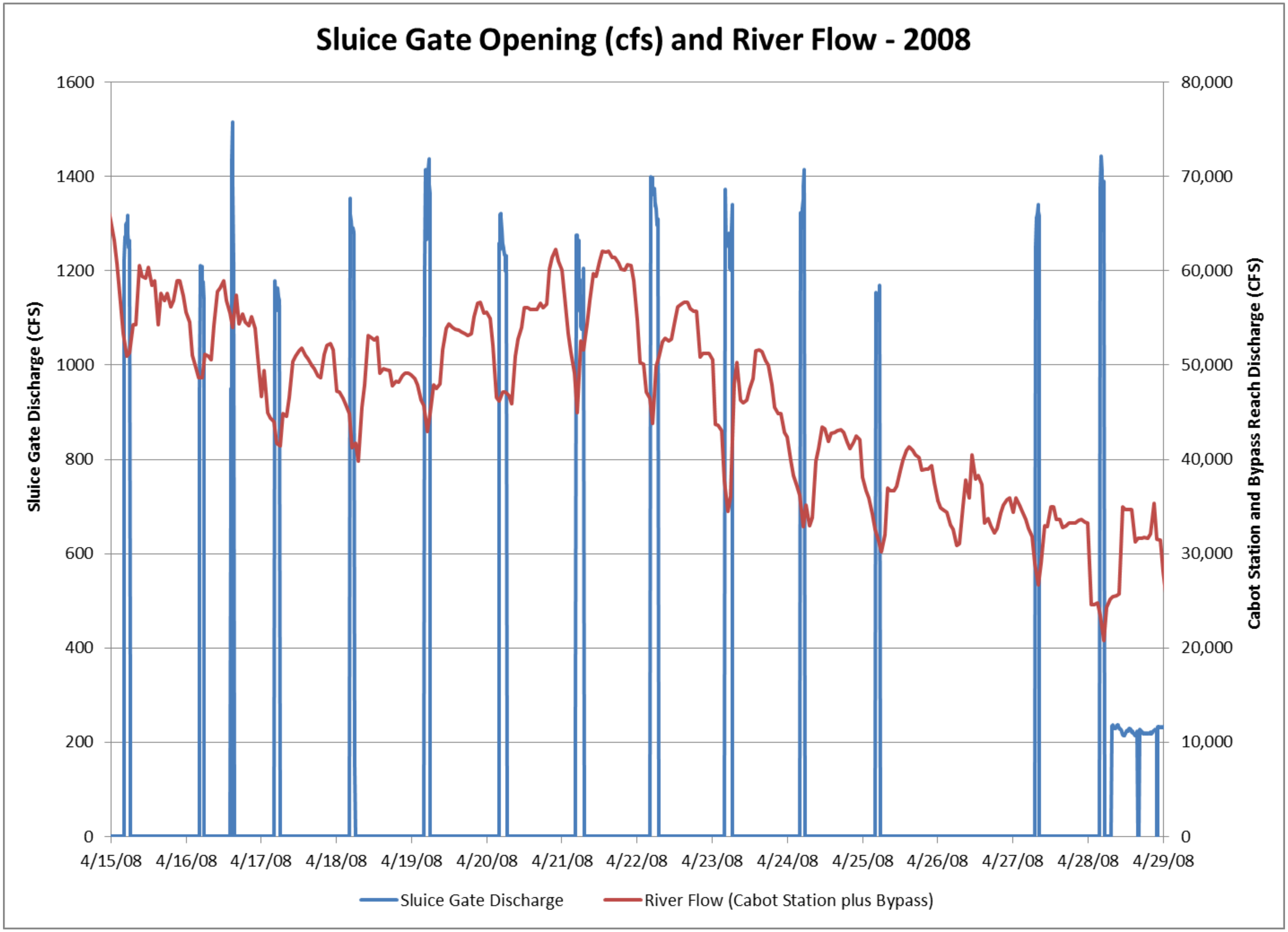
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2008
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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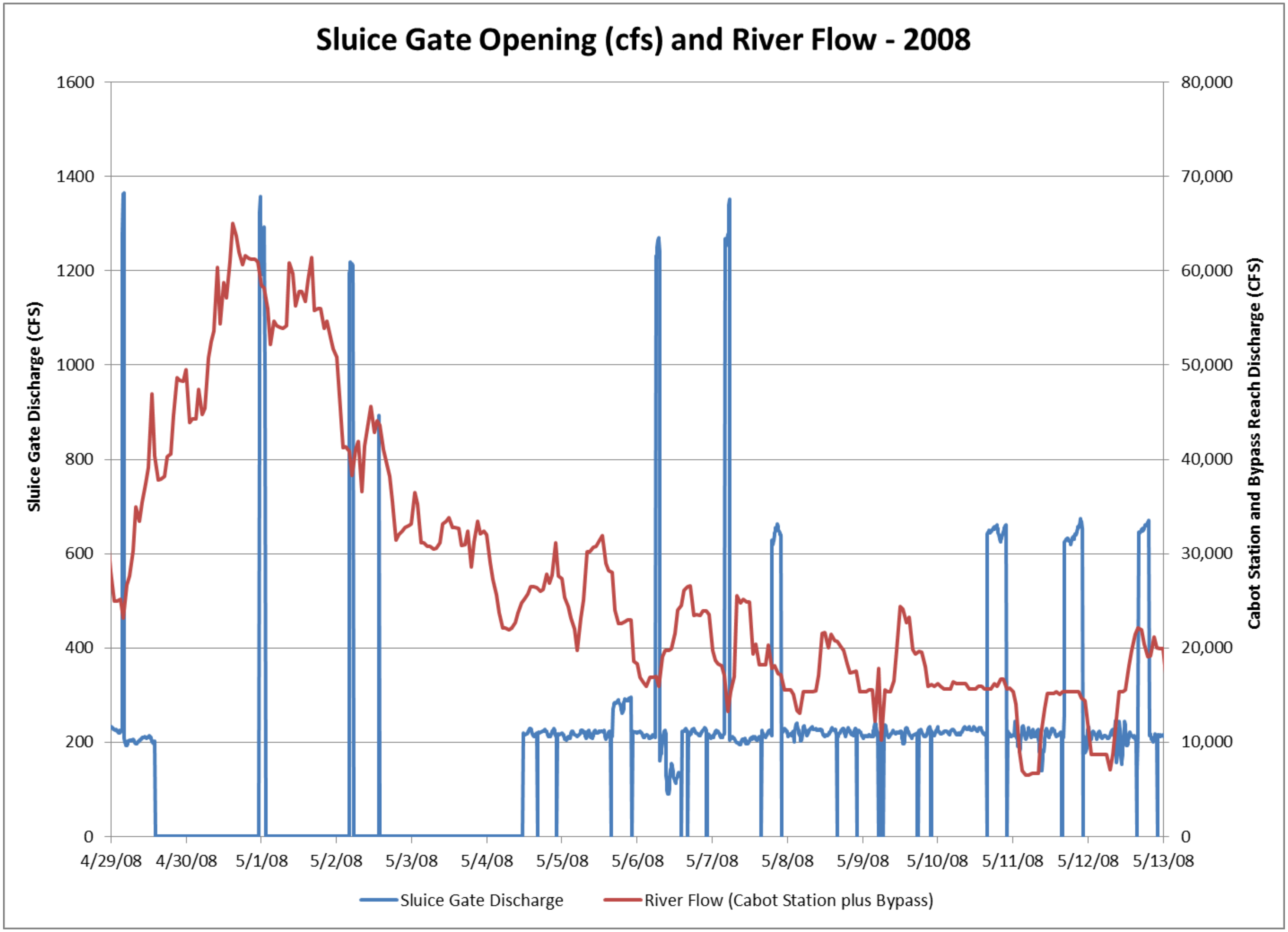
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2008
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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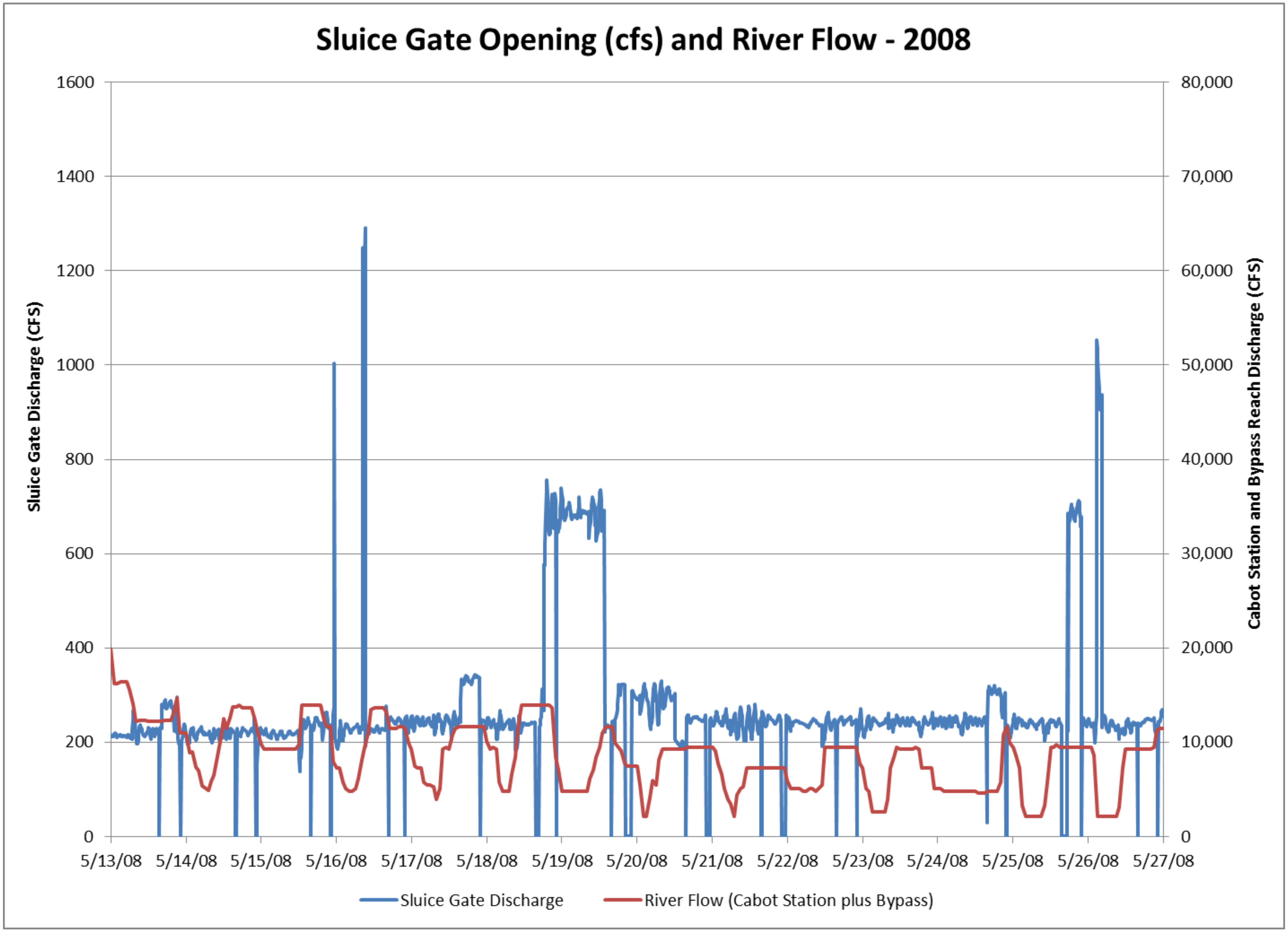
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2008
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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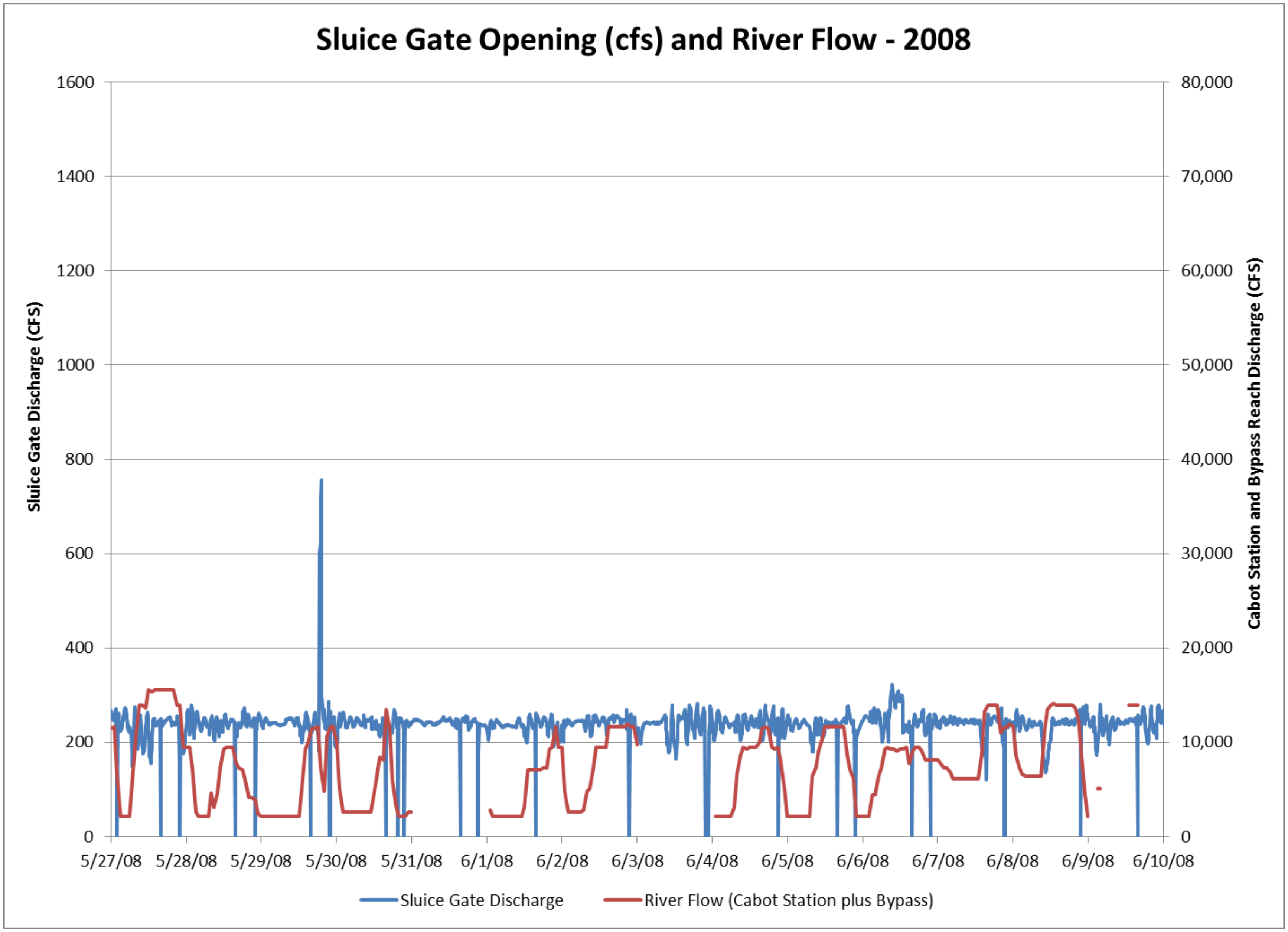
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2008
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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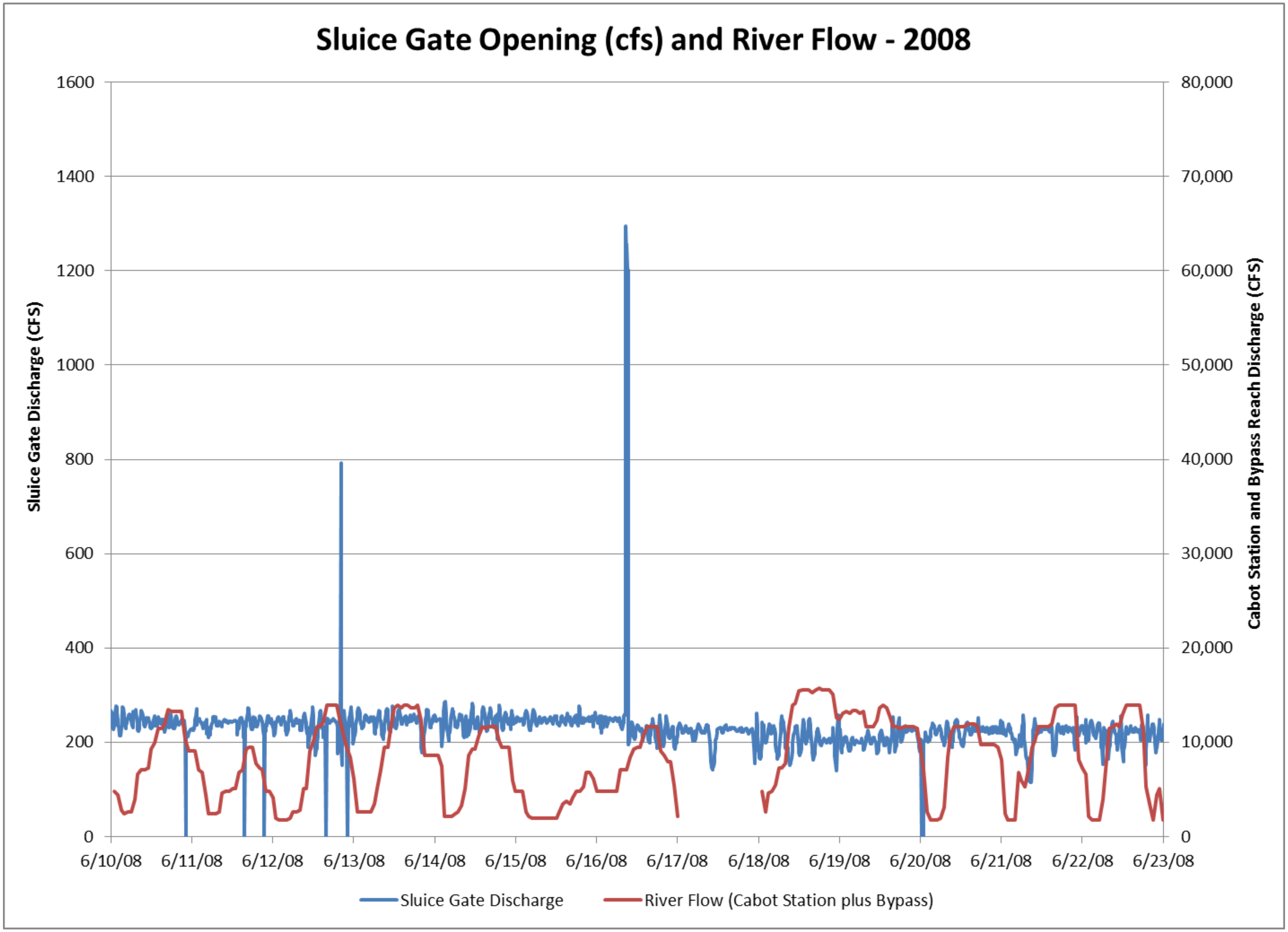
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2008
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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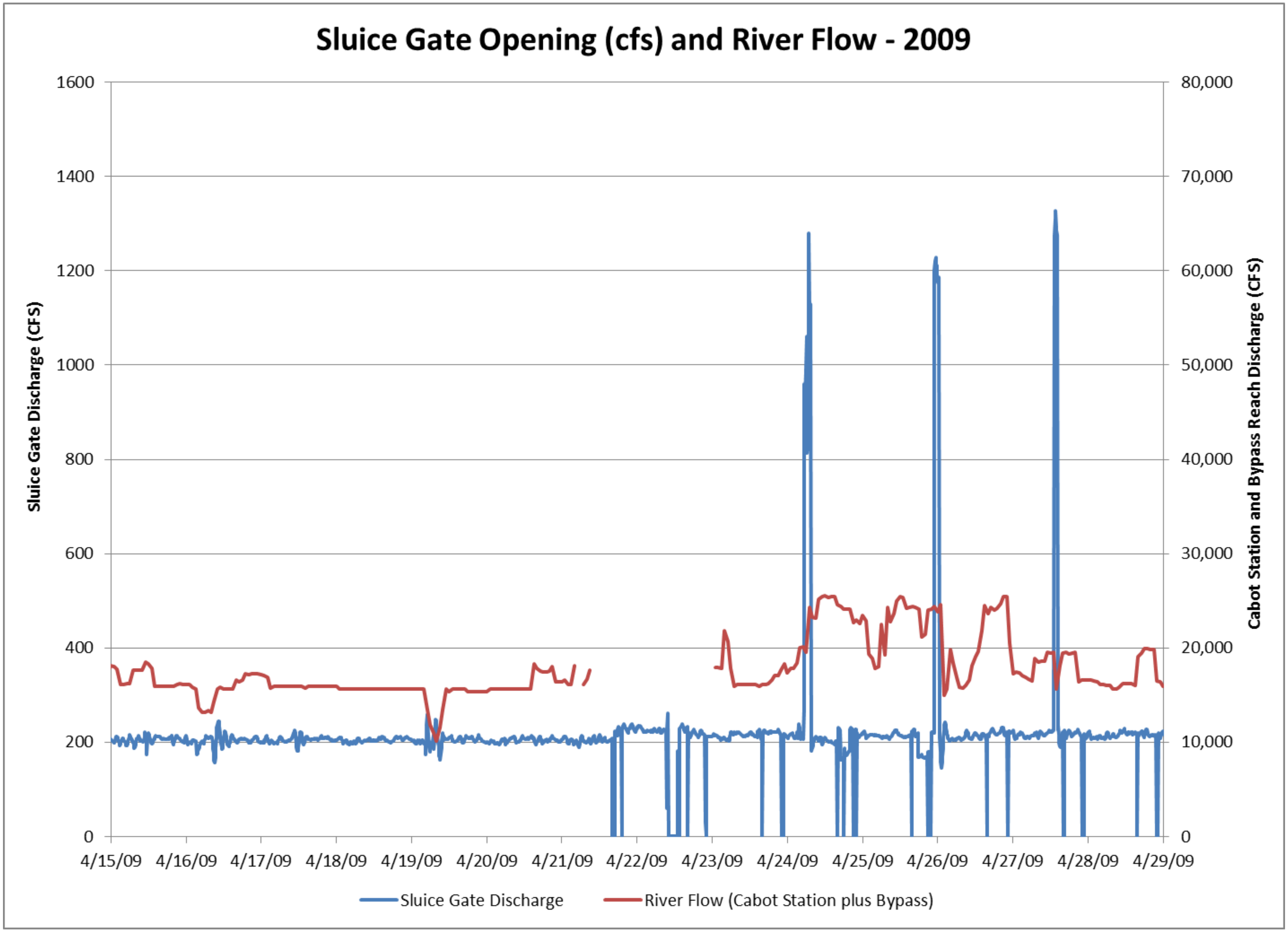
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2009
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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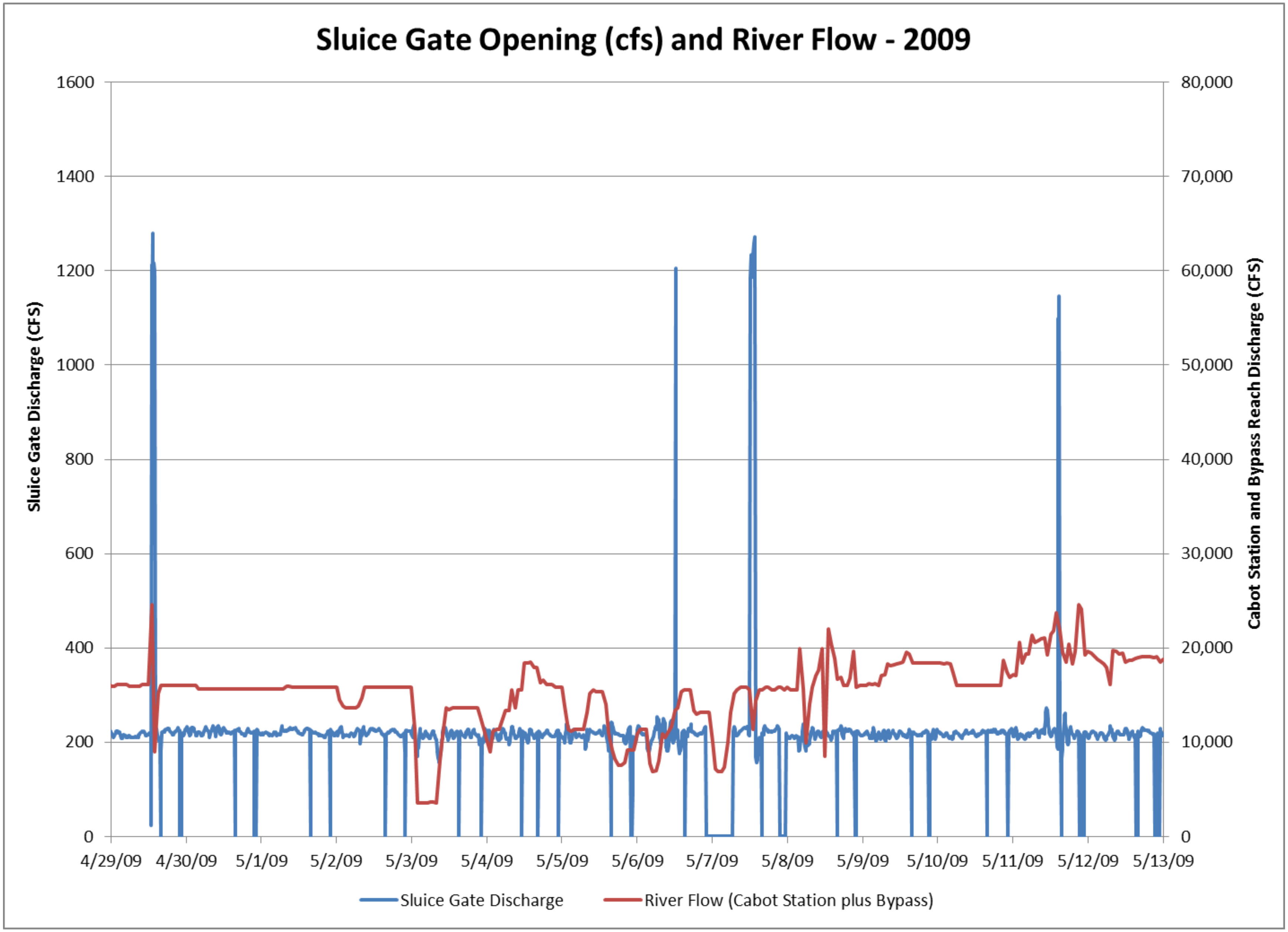
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2009
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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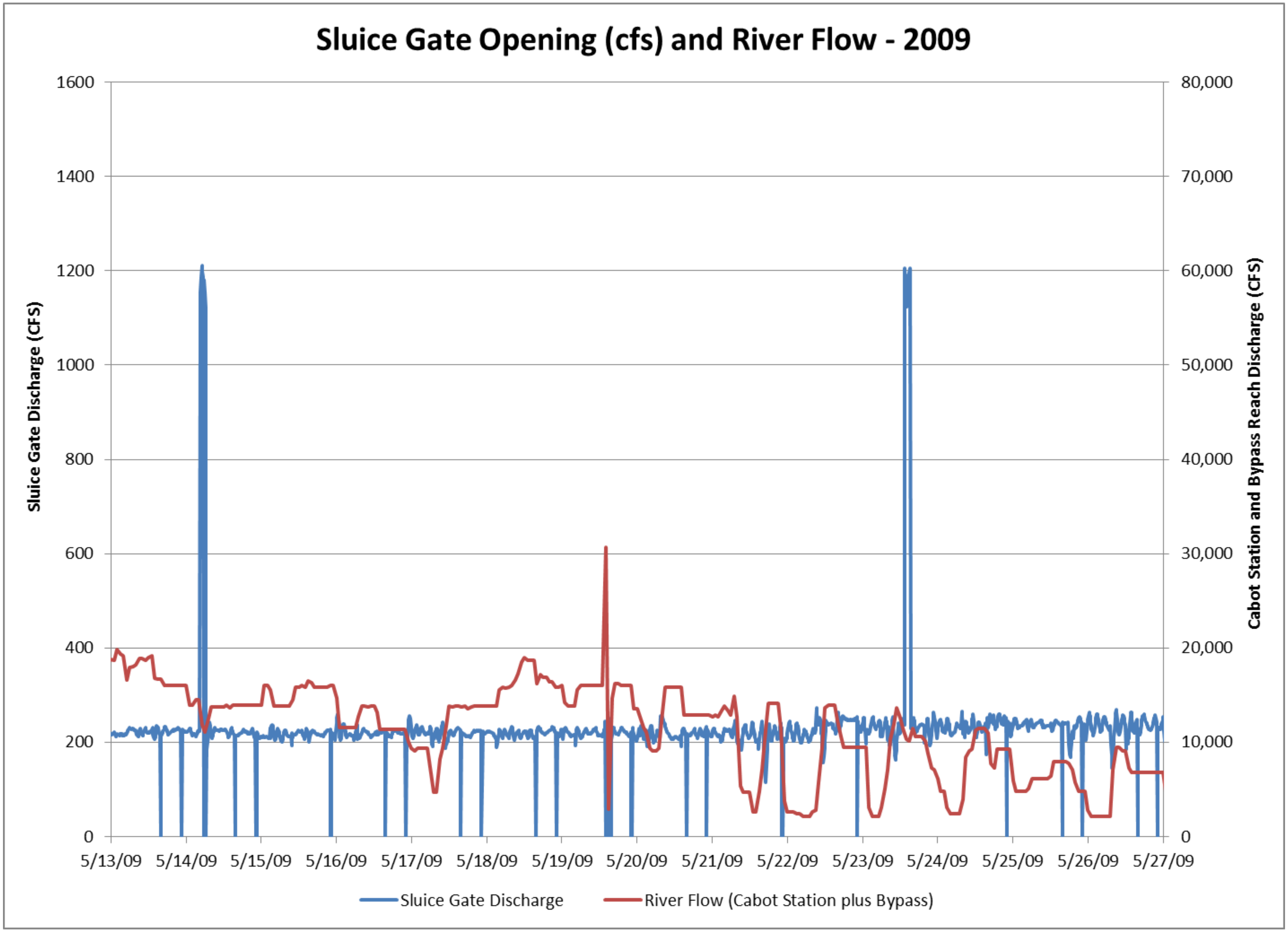
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2009
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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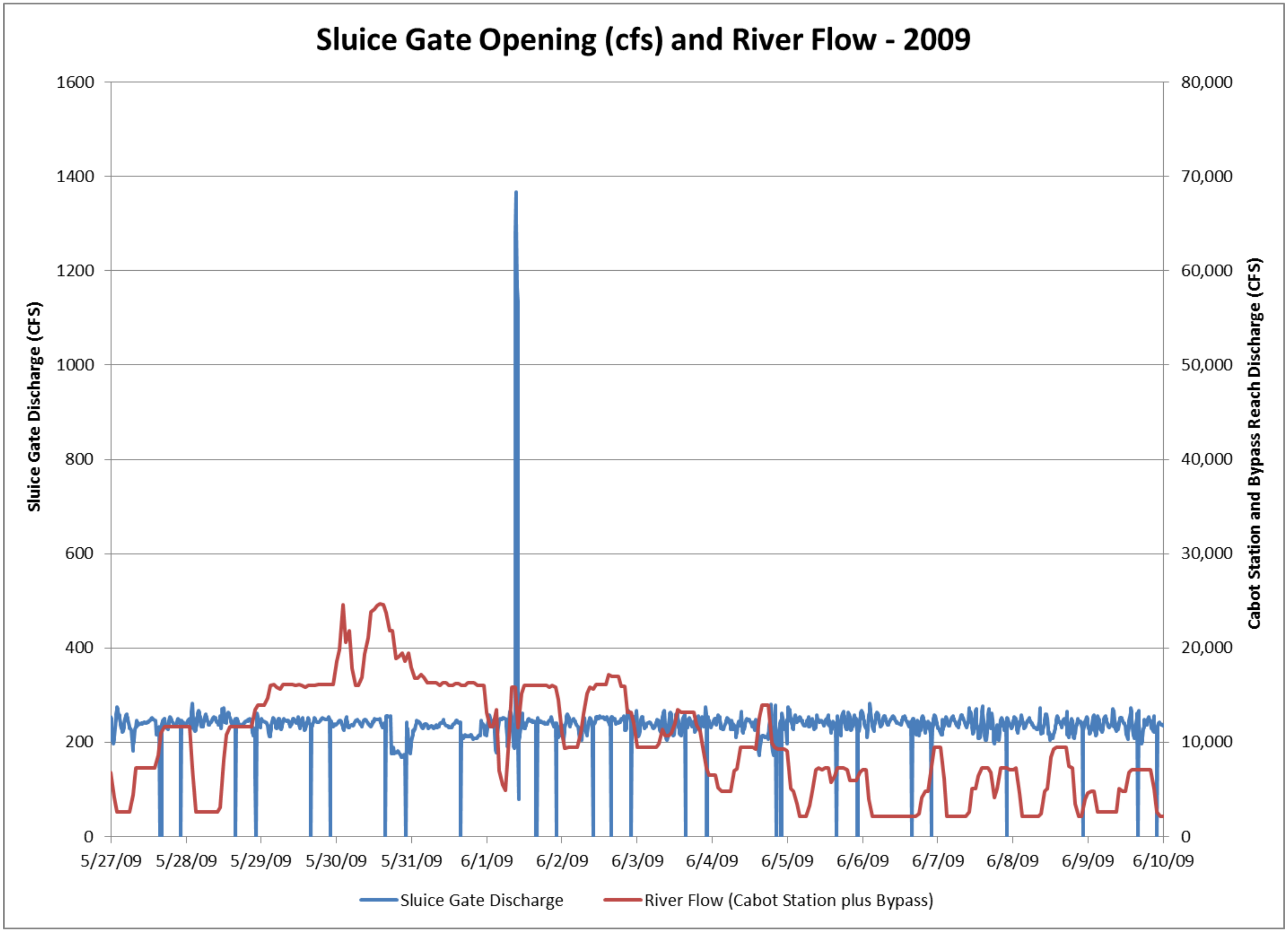
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2009
Sluice Gate Discharge (CFS)
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Cabot Station and Bypass Reach Discharge (CFS)
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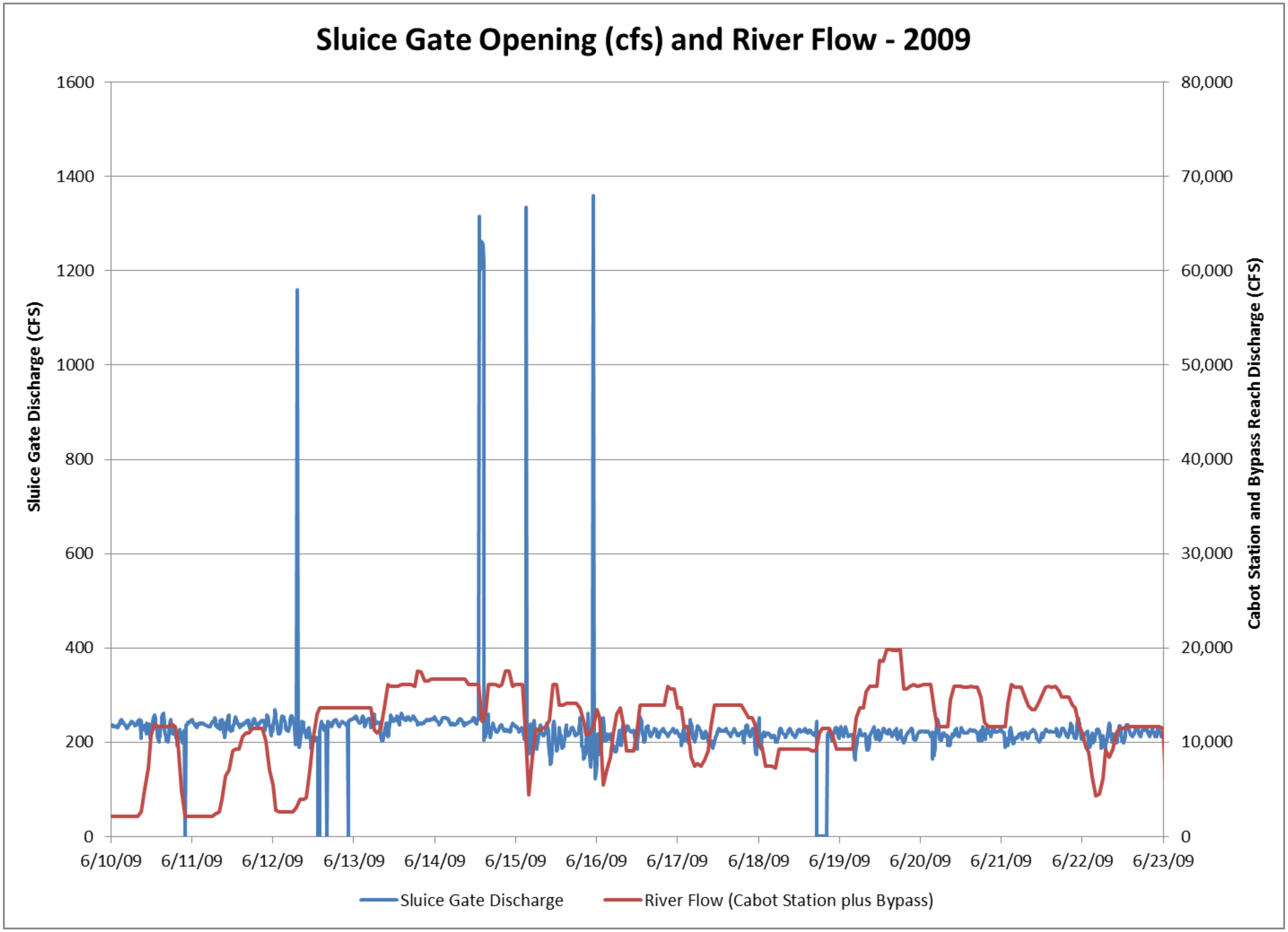
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2009
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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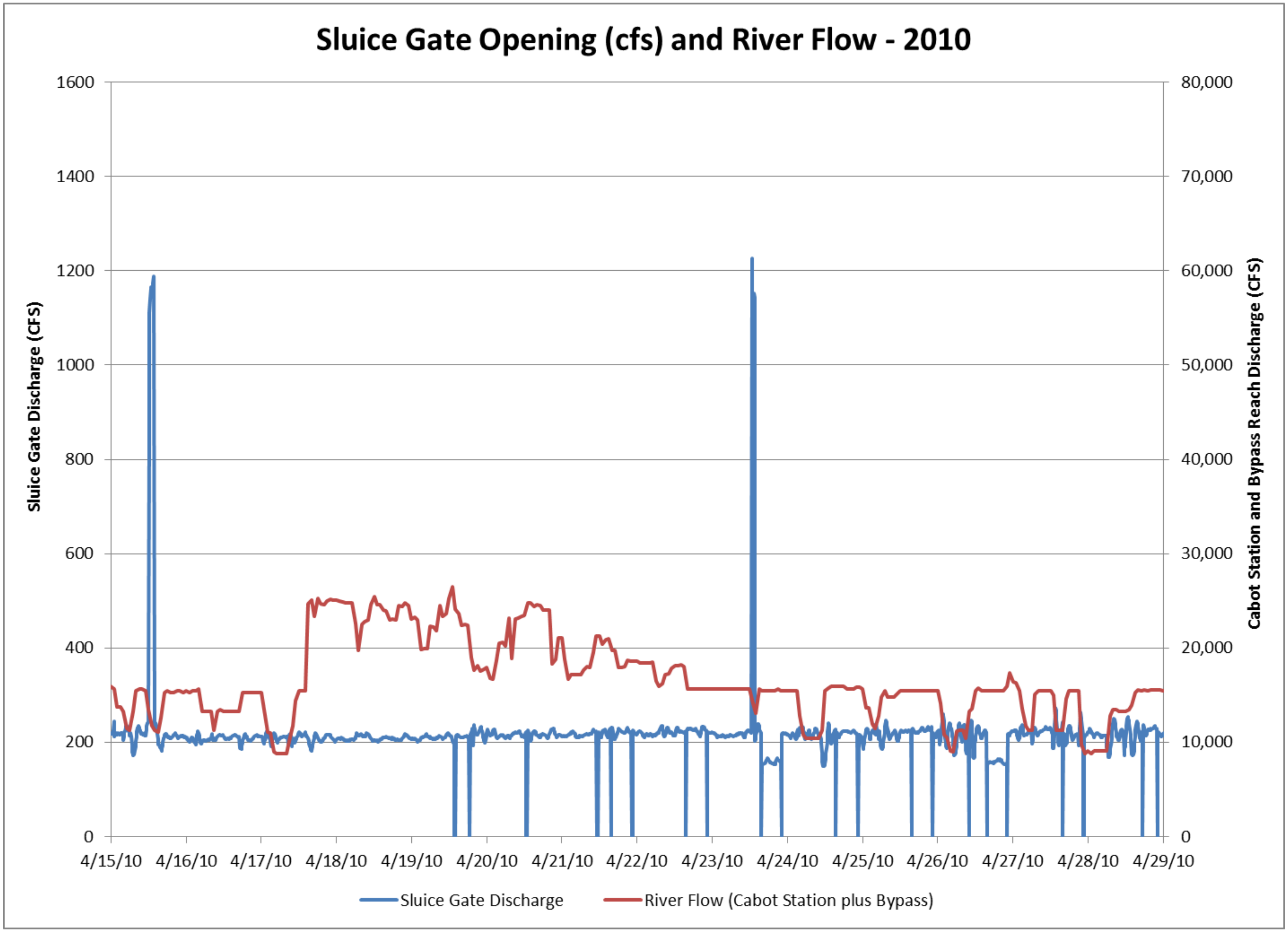
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2010
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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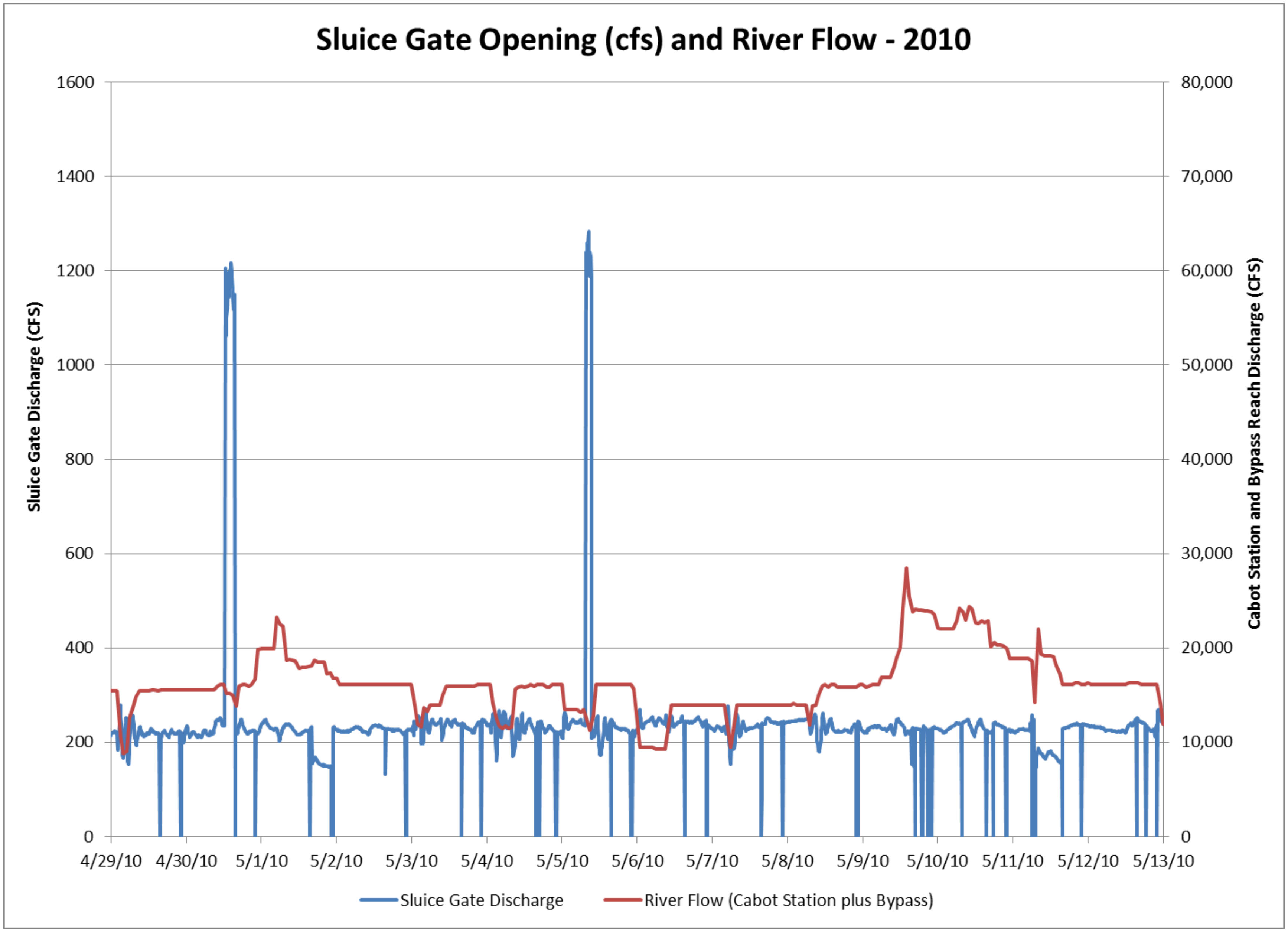
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2010
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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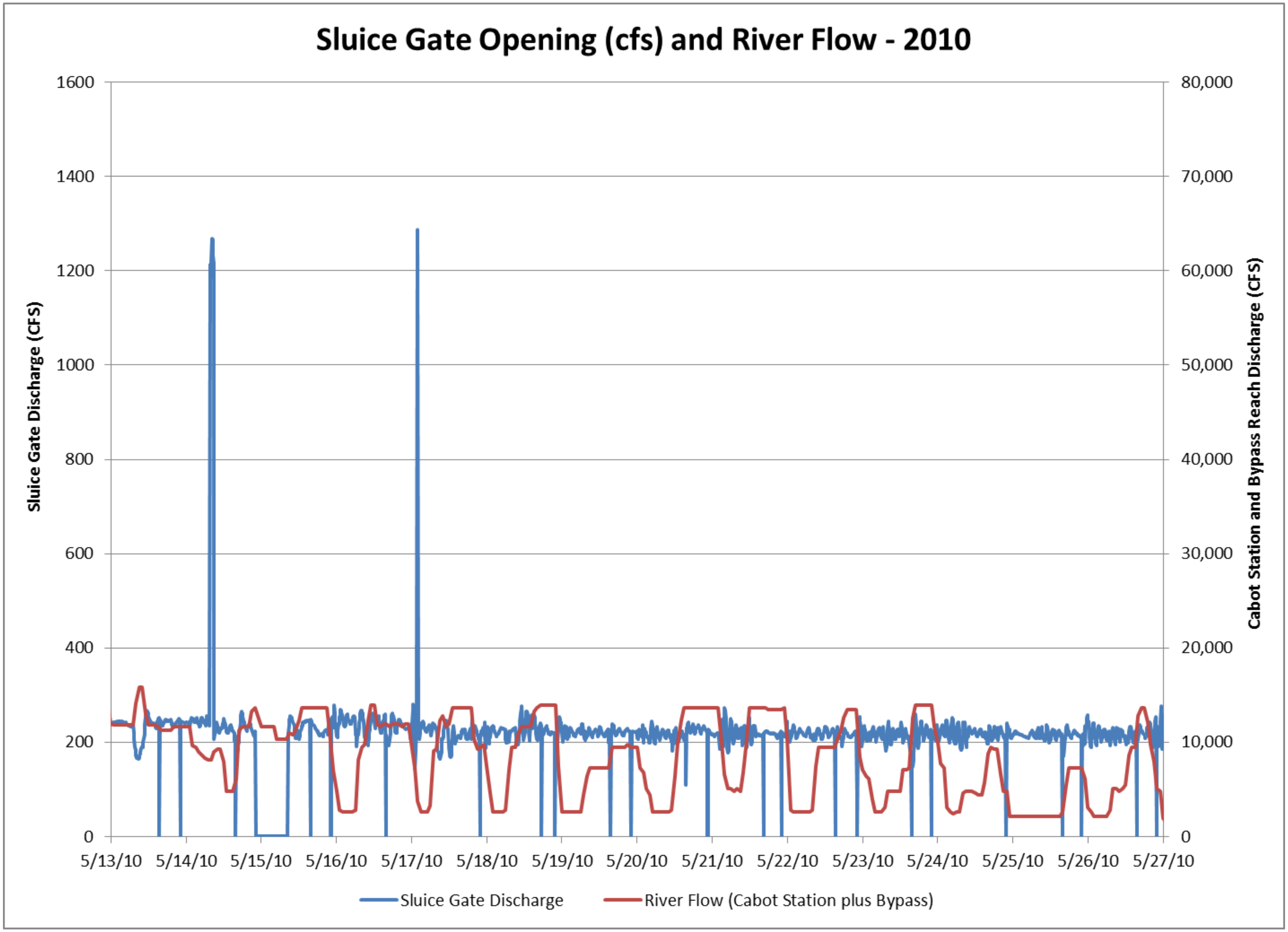
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2010
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
1600
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1200
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800
600
400
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80,000
70,000
60,000
50,000
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20,000
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5/13/10
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5/15/10
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5/17/10
5/18/10
5/19/10
5/20/10
5/21/10
5/22/10
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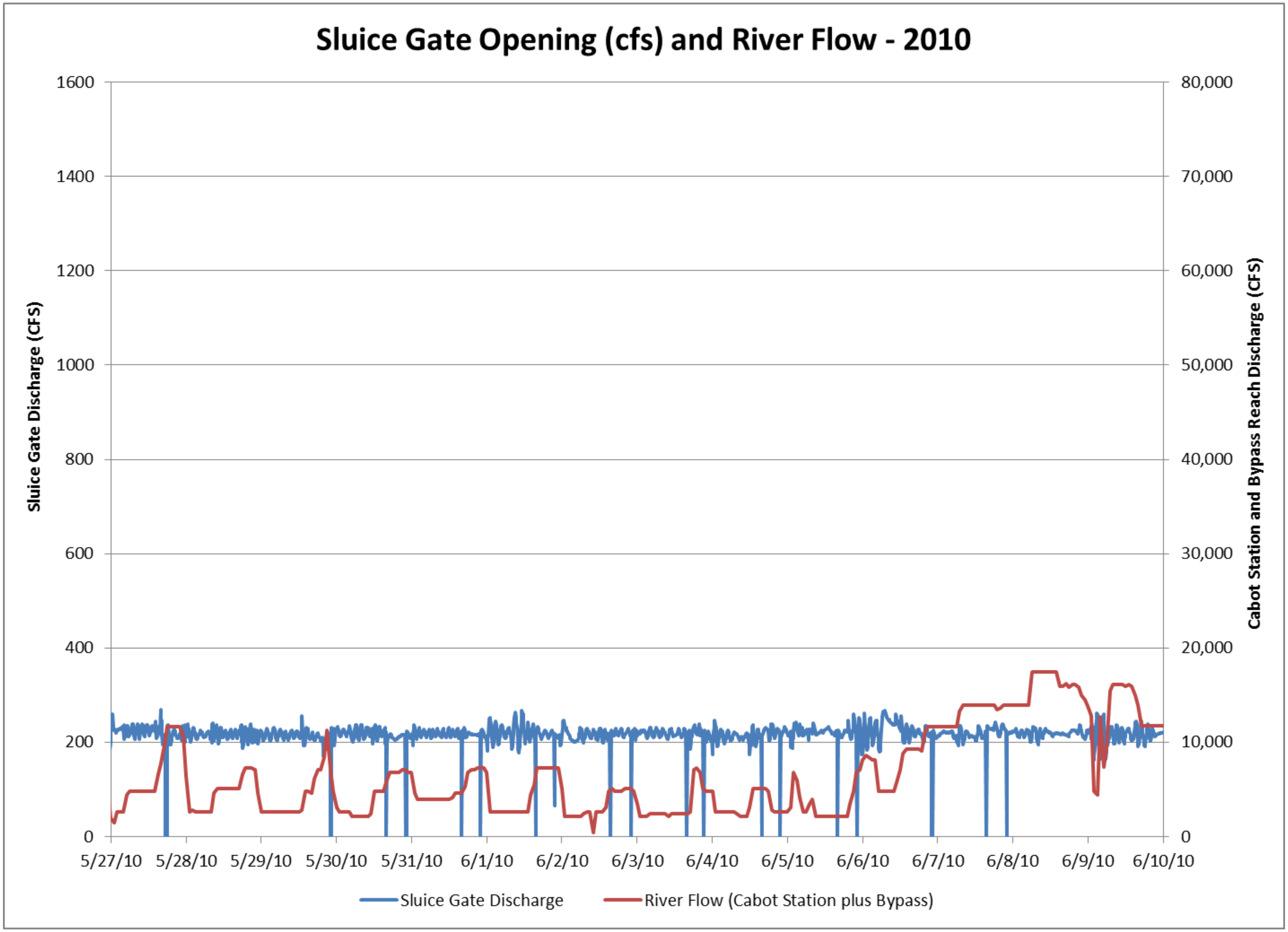
5/24/10
5/25/10
5/26/10
5/27/10
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2010
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
1600
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5/28/10
5/29/10
5/30/10
5/31/10
6/1/10
6/2/10
6/3/10
6/4/10
6/5/10
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6/7/10
6/8/10
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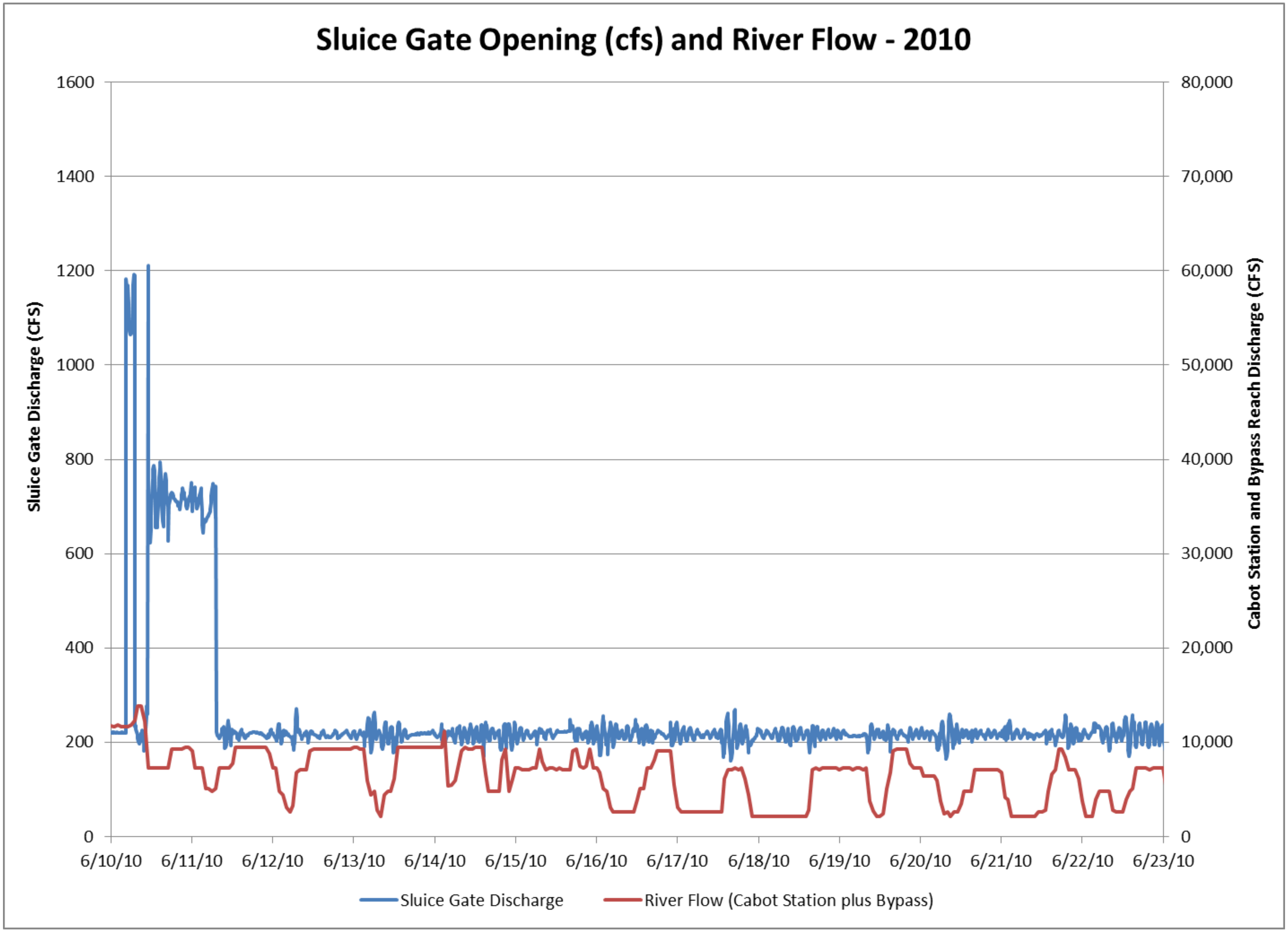
6/10/10
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2010
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
0
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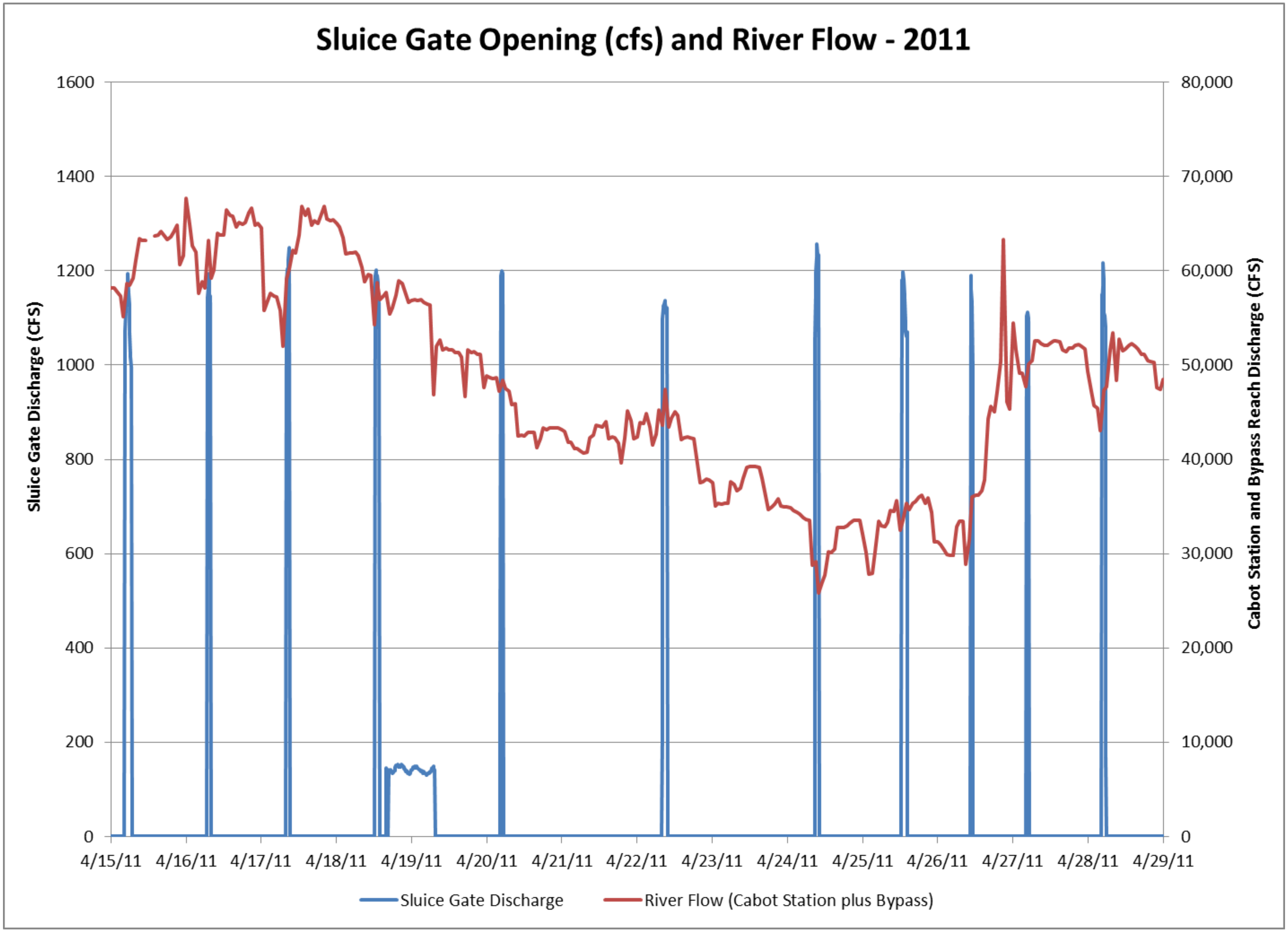
6/23/10
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2011
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
1600
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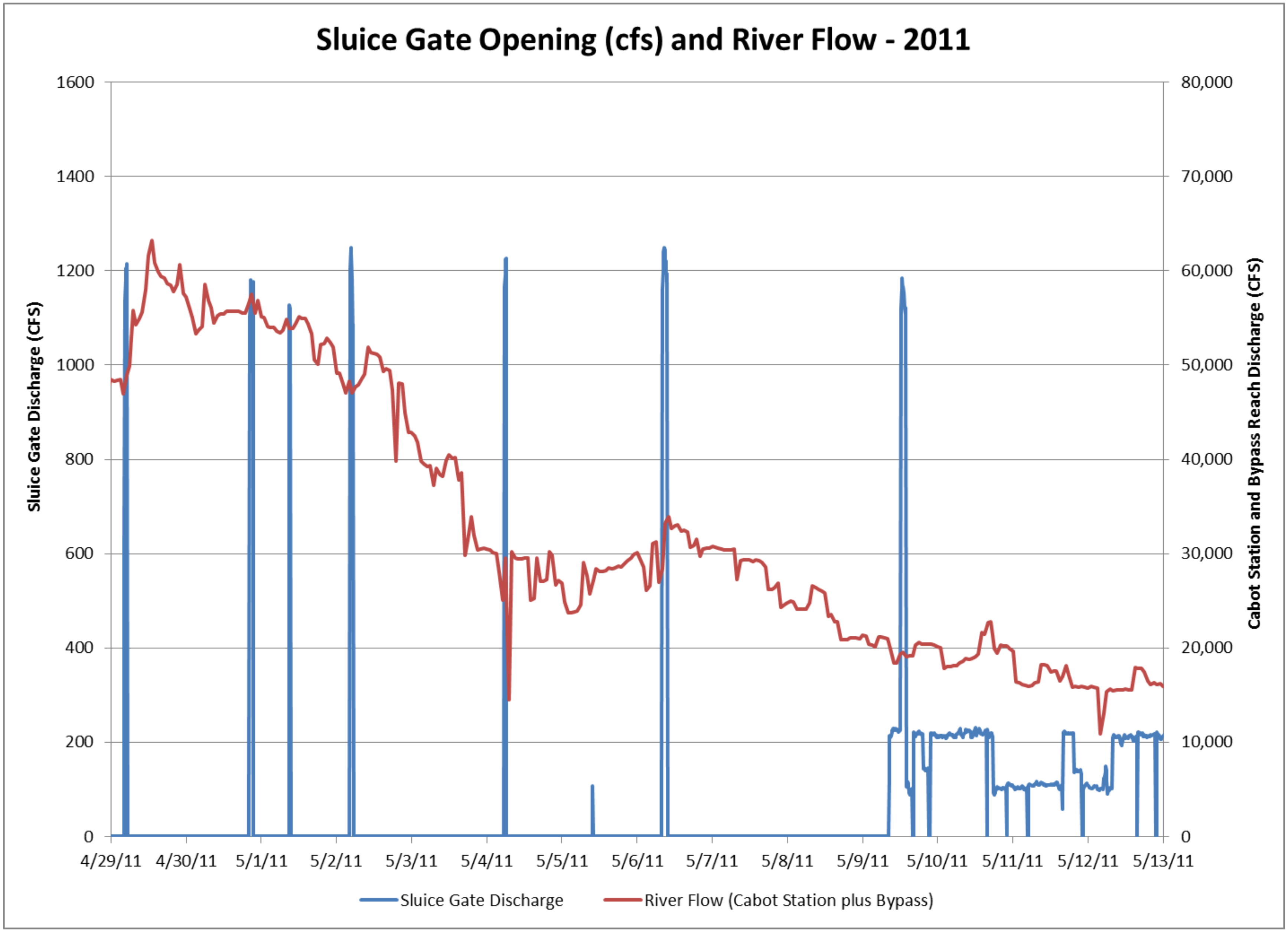
4/28/11
4/29/11
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2011
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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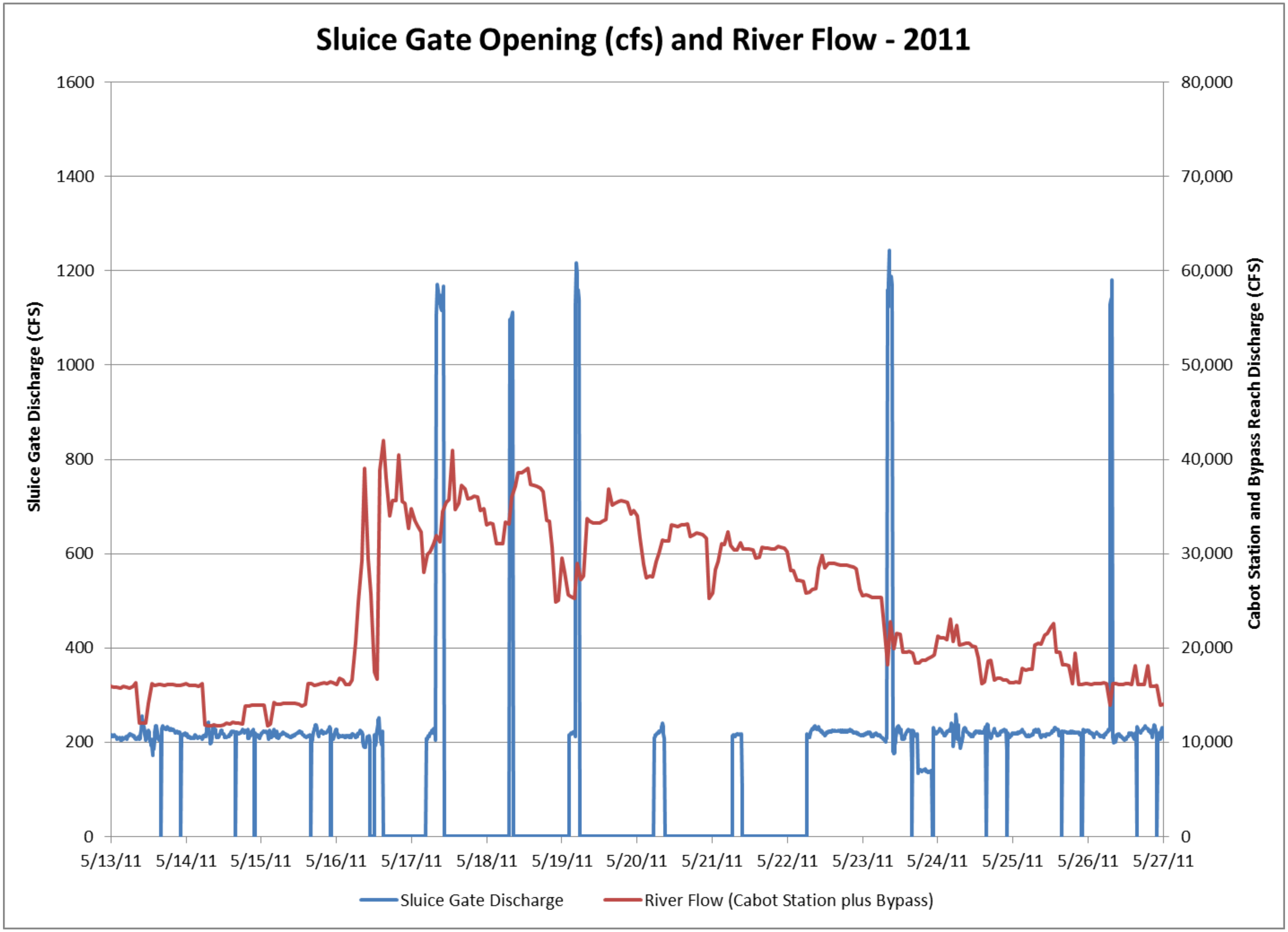
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2011
Sluice Gate Discharge (CFS)
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Cabot Station and Bypass Reach Discharge (CFS)
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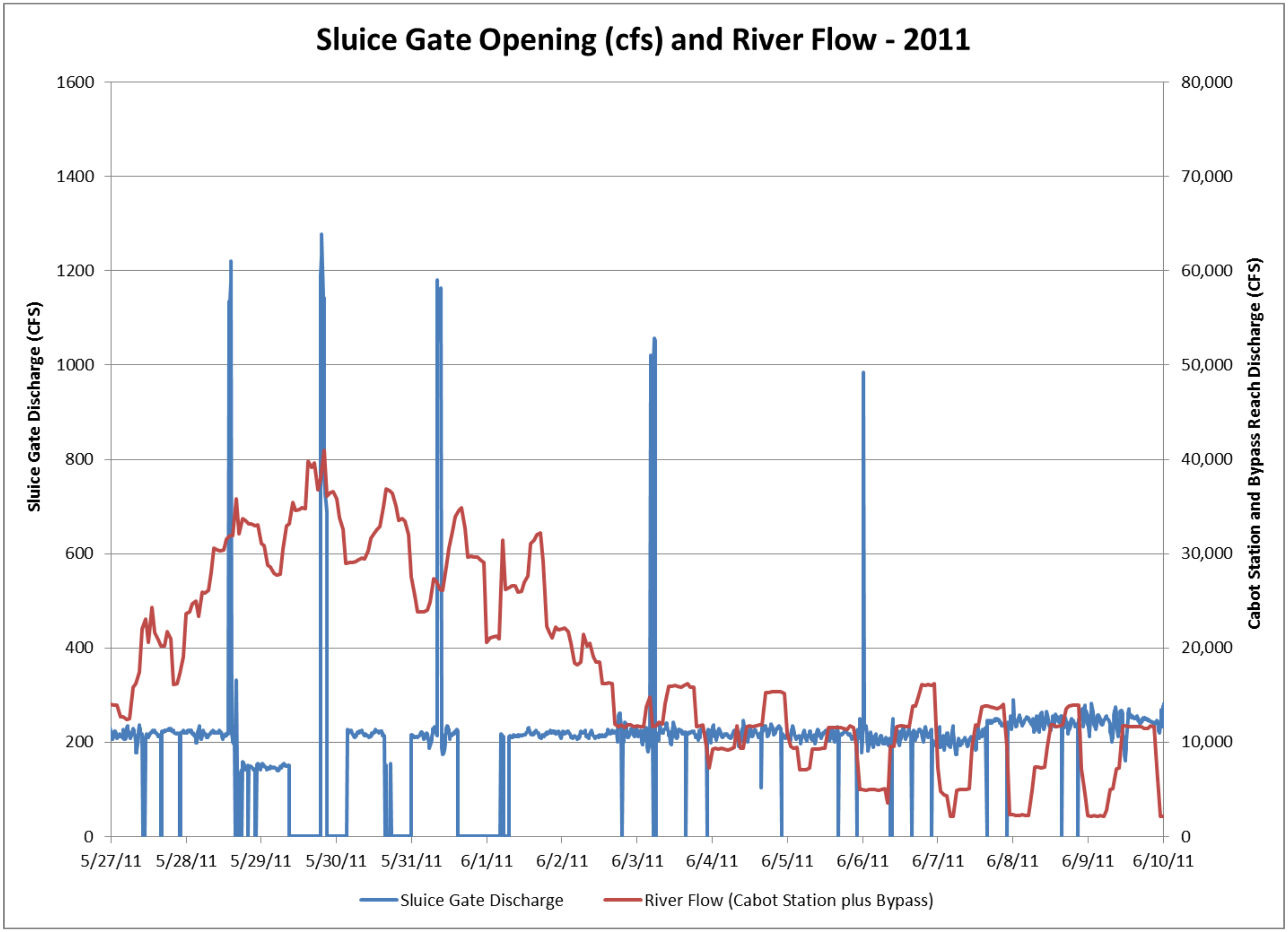
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2011
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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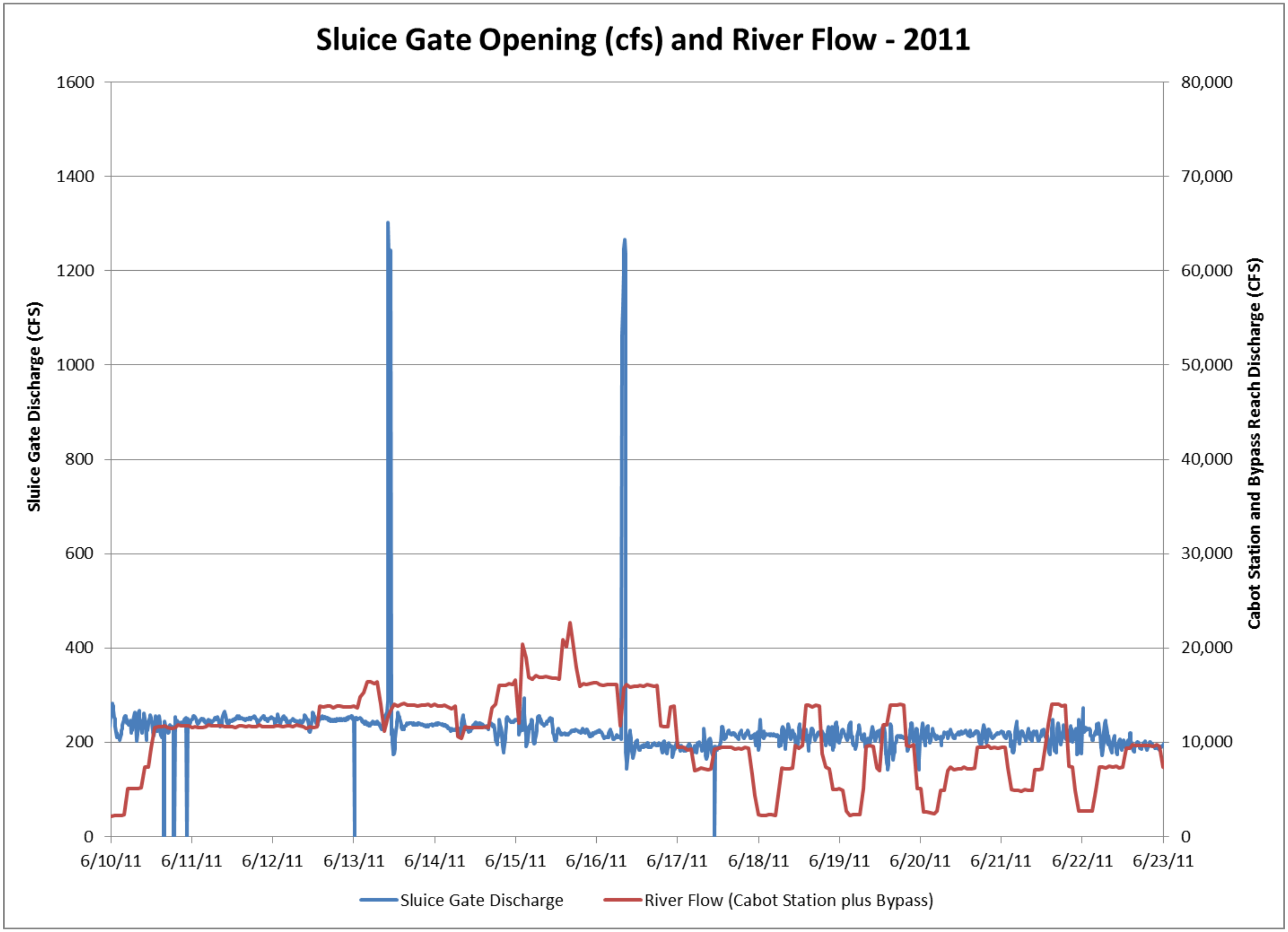
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2011
Sluice Gate Discharge (CFS)
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Cabot Station and Bypass Reach Discharge (CFS)
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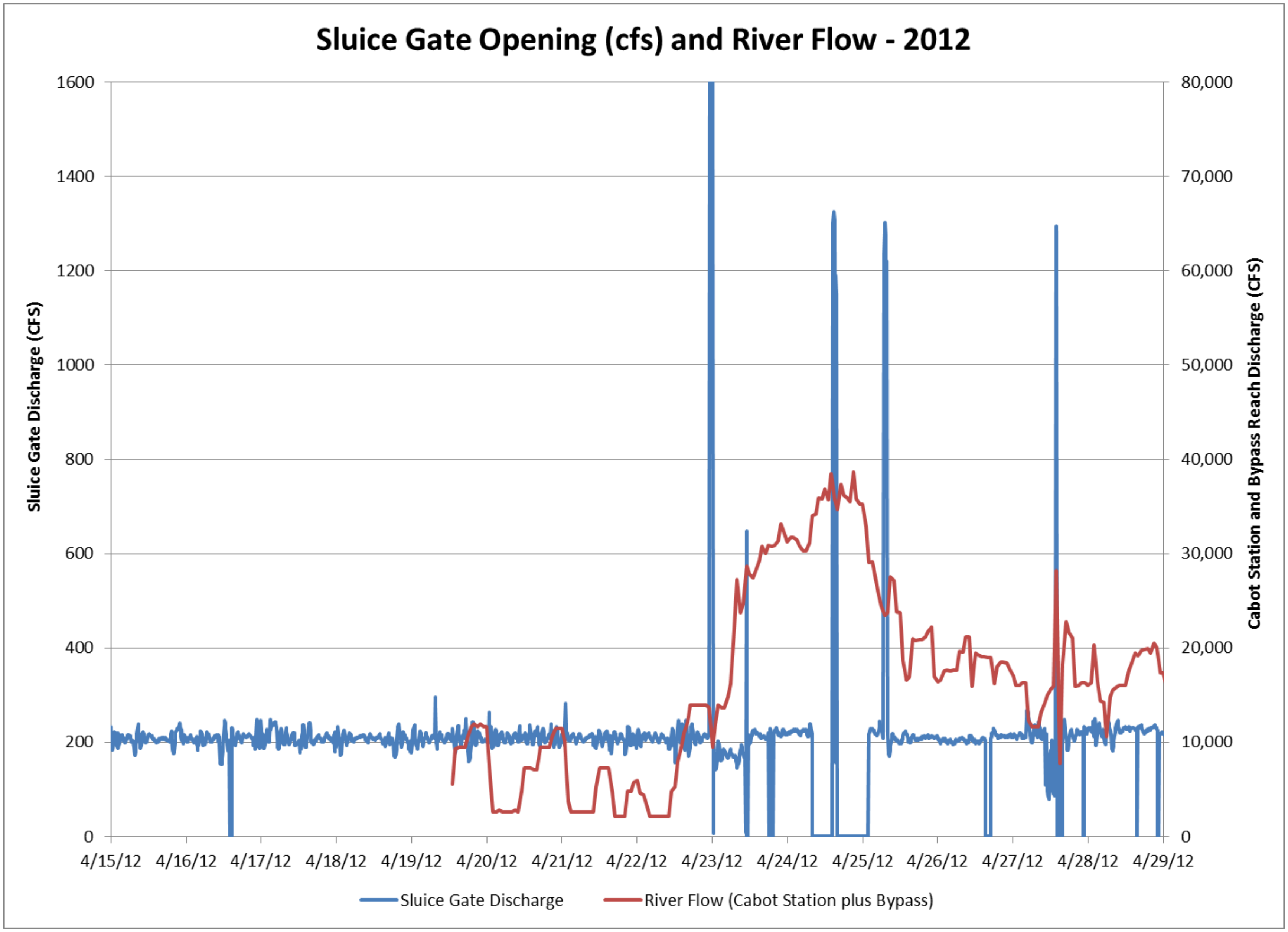
6/23/11
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2012
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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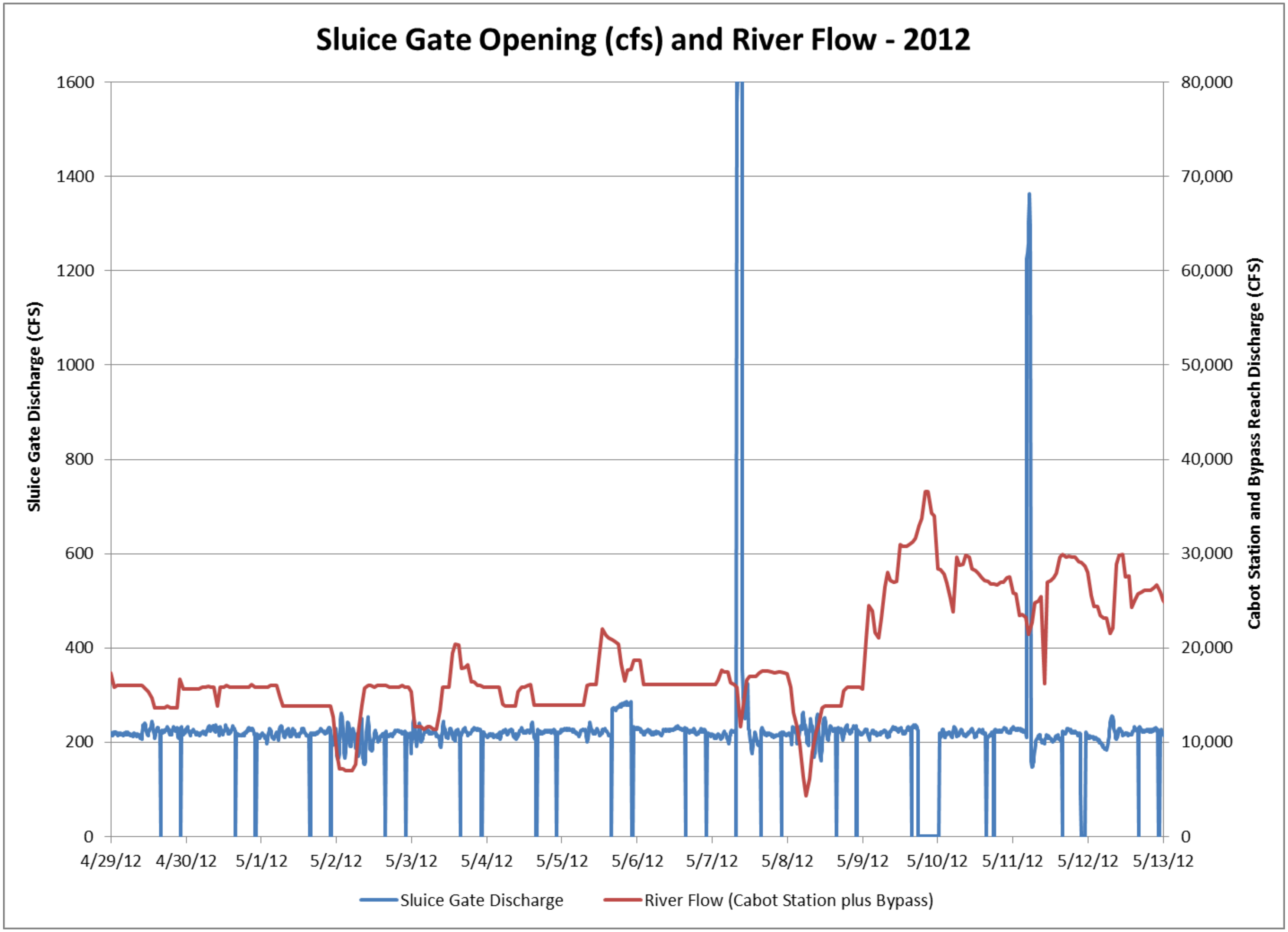
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2012
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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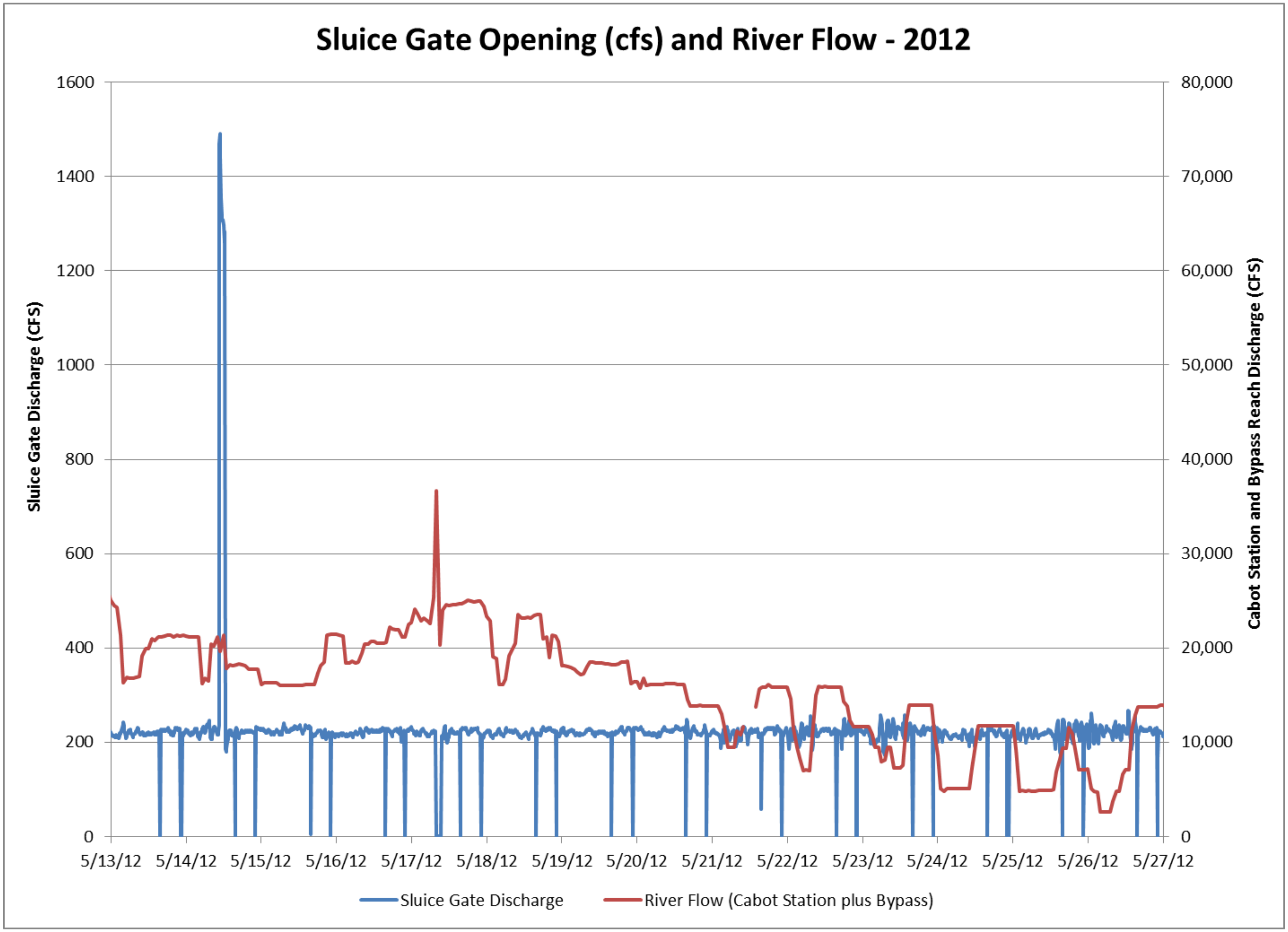
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2012
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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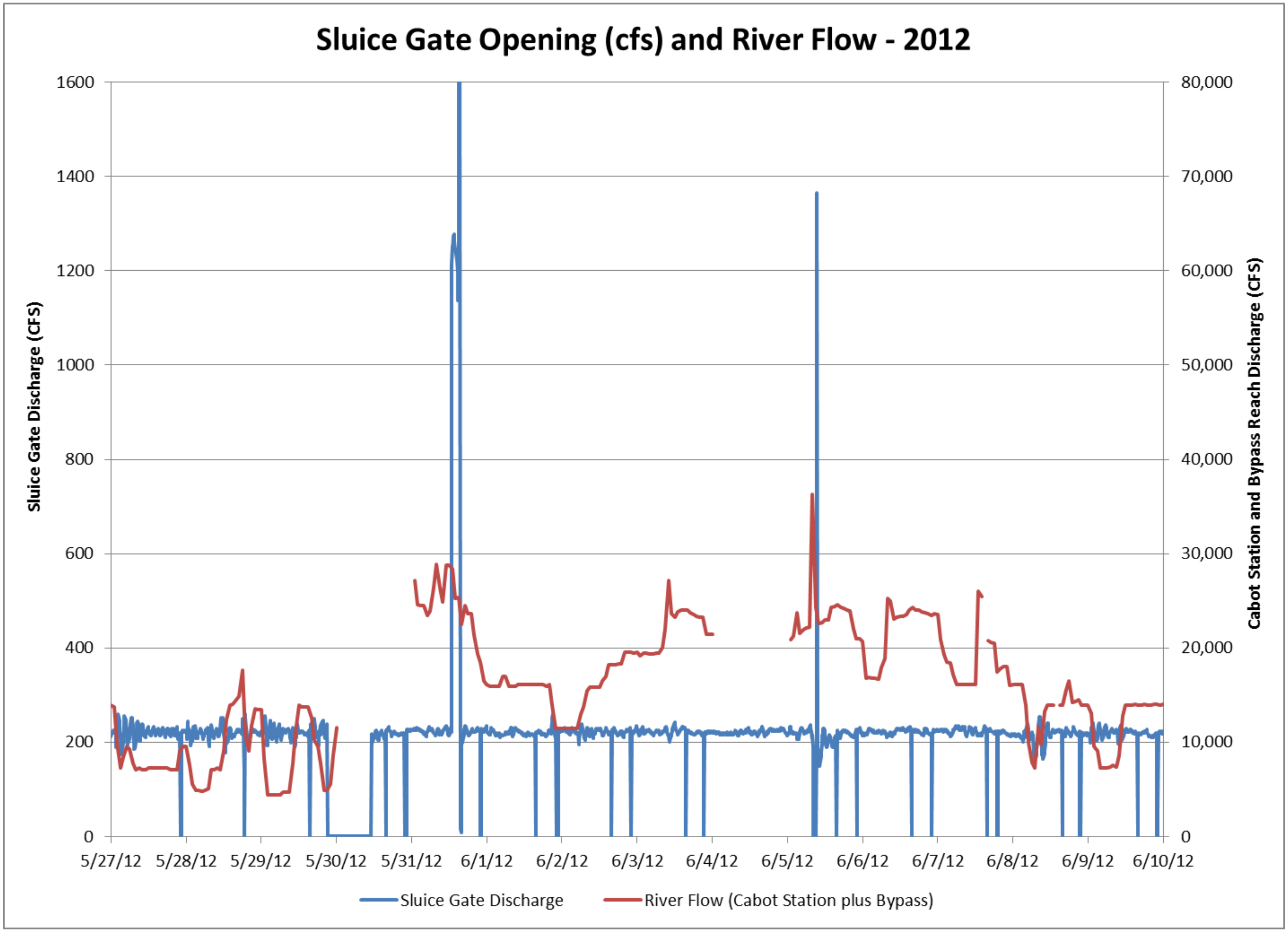
5/27/12
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2012
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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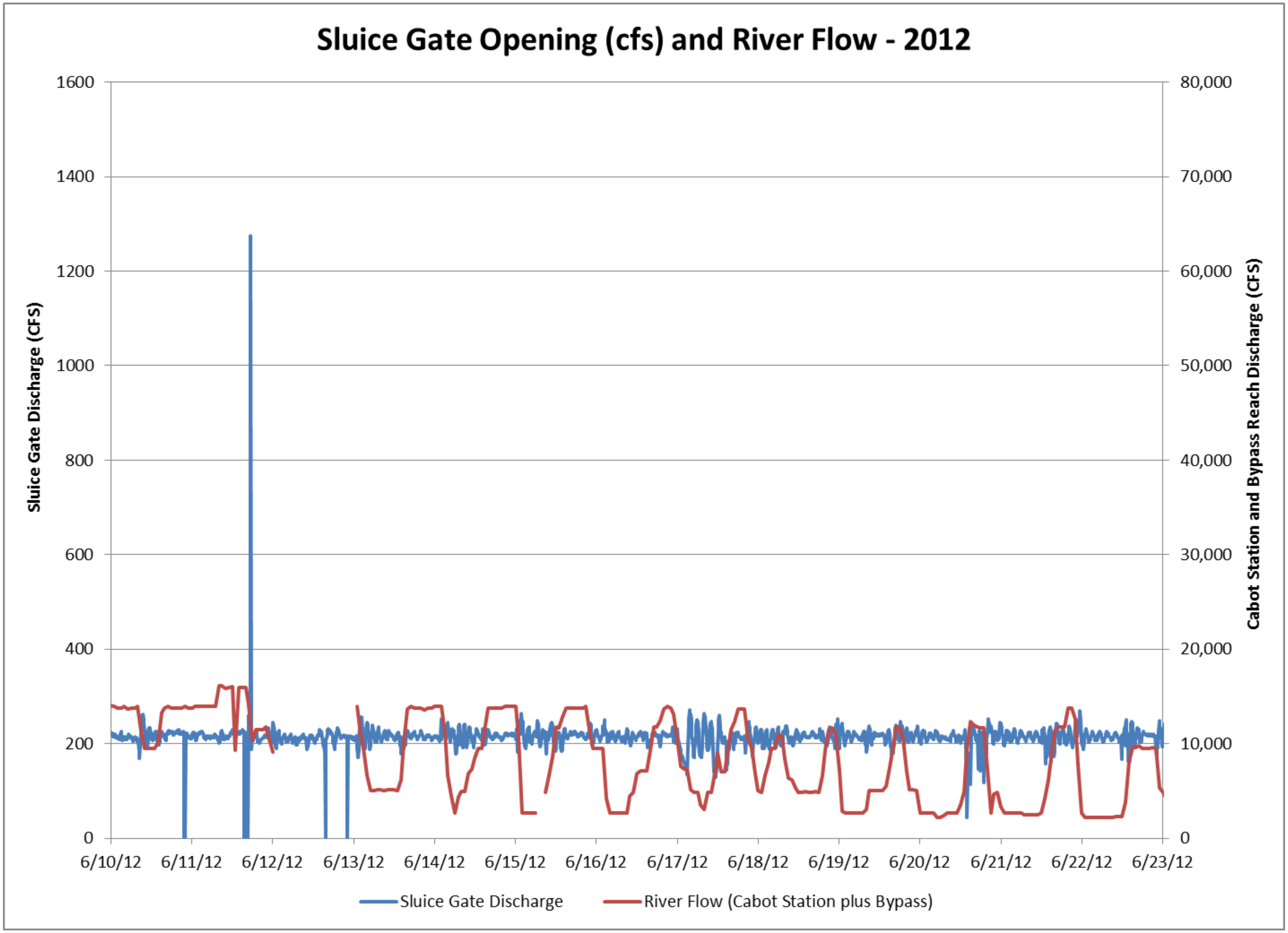
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)


Sluice Gate Opening (cfs) and River Flow - 2012
Sluice Gate Discharge (CFS)
Cabot Station and Bypass Reach Discharge (CFS)
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6/19/12
6/20/12
6/21/12
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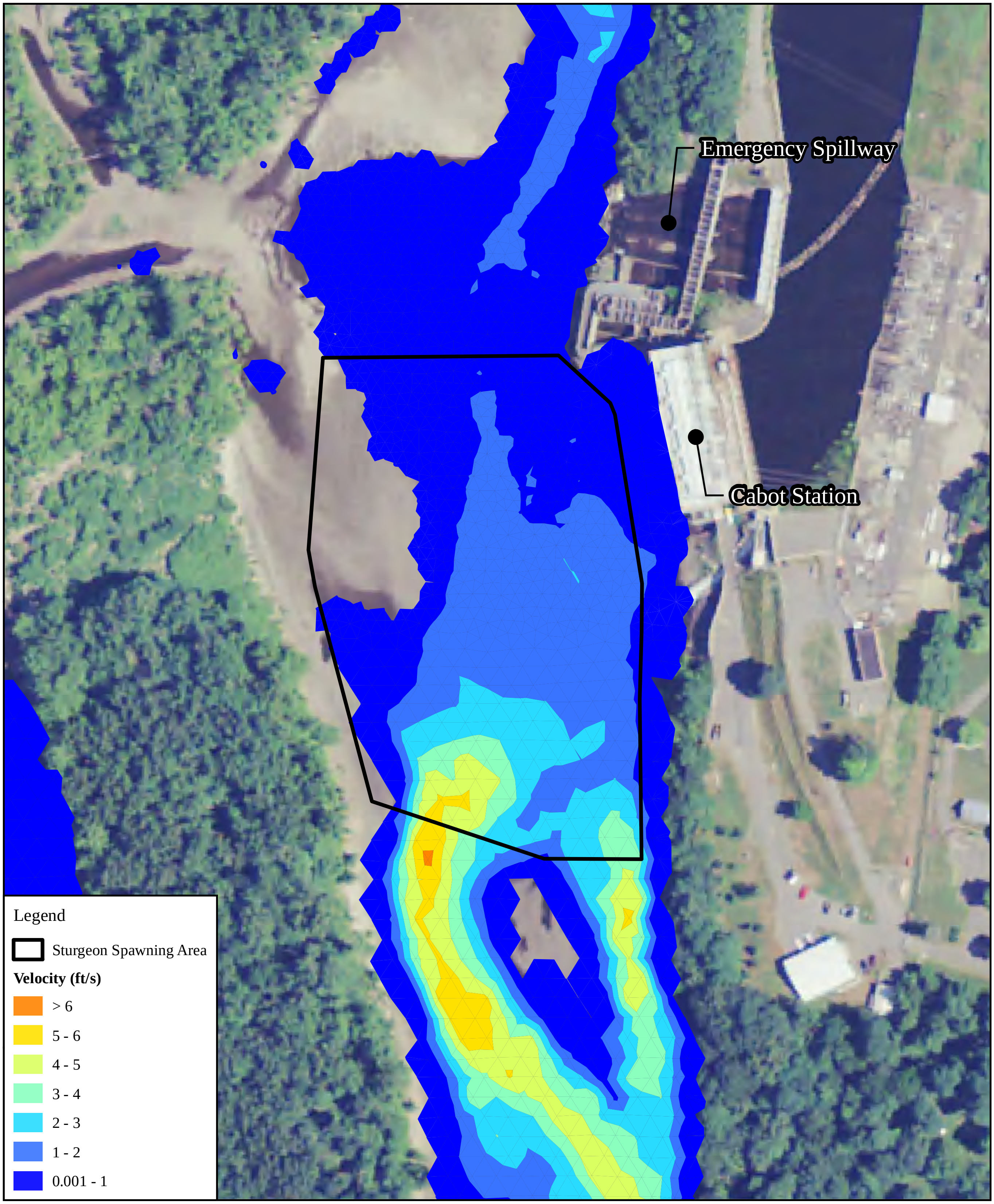
6/23/12
Sluice Gate Discharge
River Flow (Cabot Station plus Bypass)

APPENDIX B – MODELED VELOCITY MAPS



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

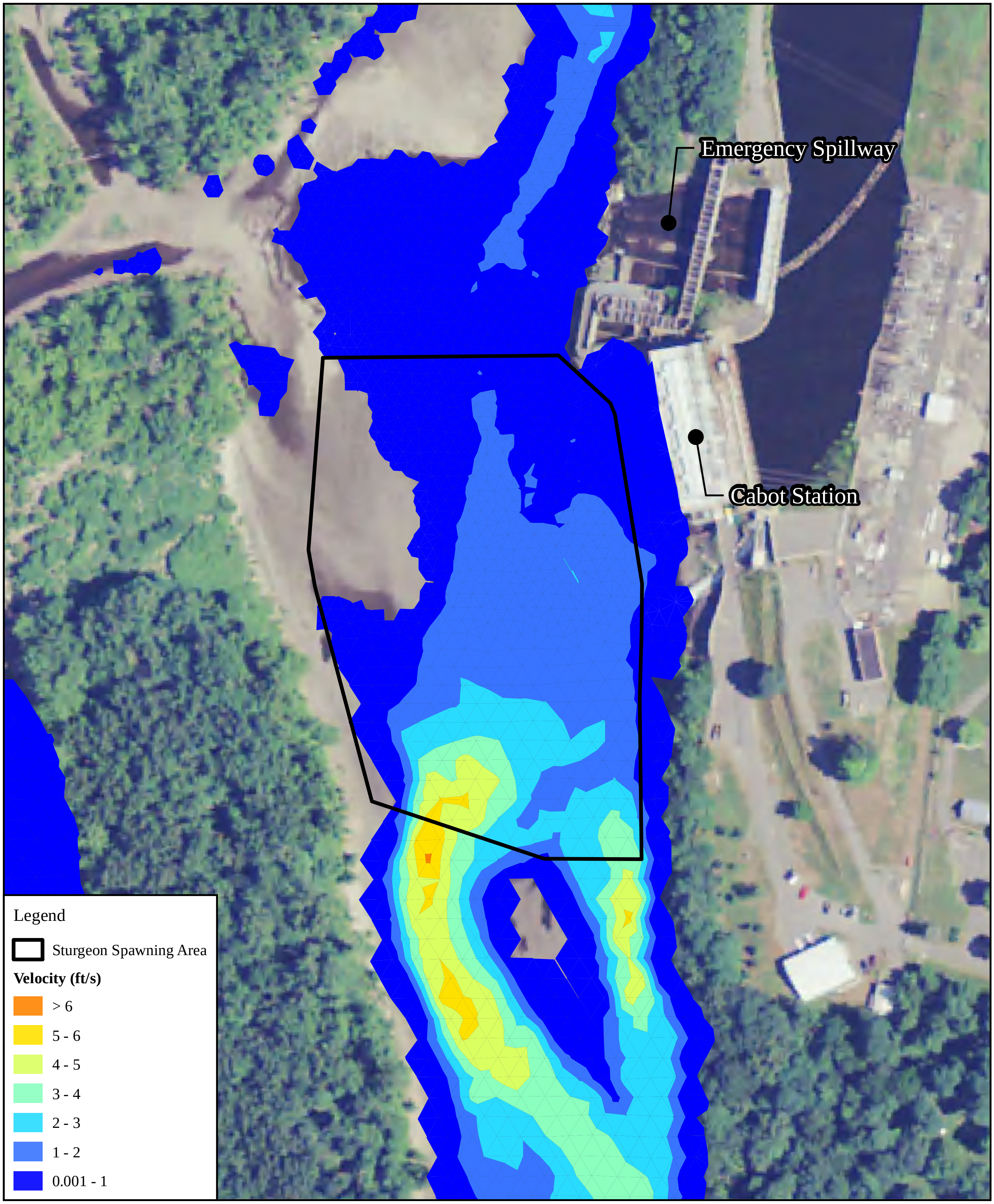
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario B1a:
Bypass Reach 500 cfs
Cabot Station 1,500 cfs
Deerfield River 200 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B1a.mxd



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Turners Falls Hydroelectric Project No. 1889

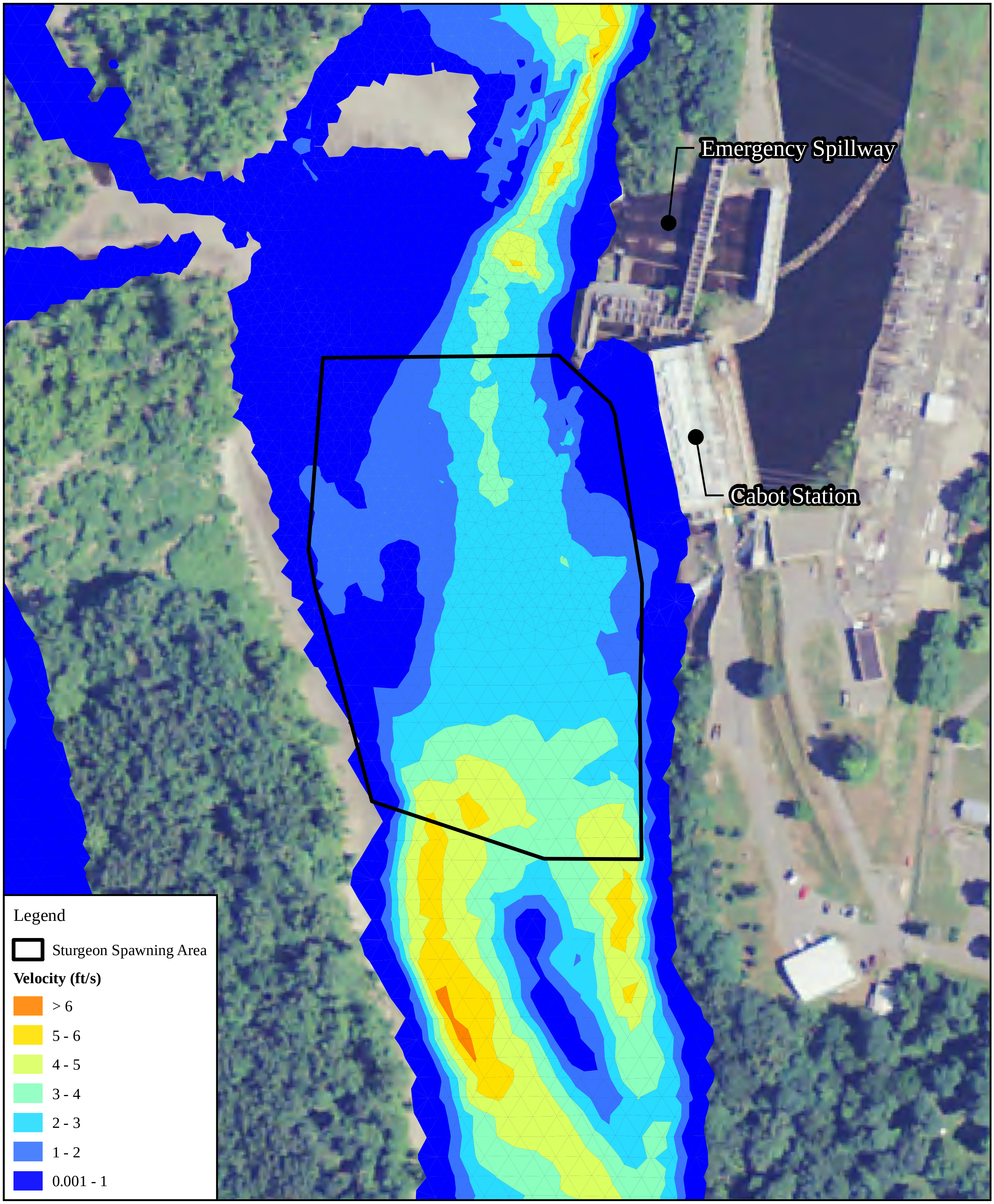
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400
Feet

Appendix B
Velocity Scenario B1b:
Bypass Reach 500 cfs
Cabot Station 1,500 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B1b.mxd



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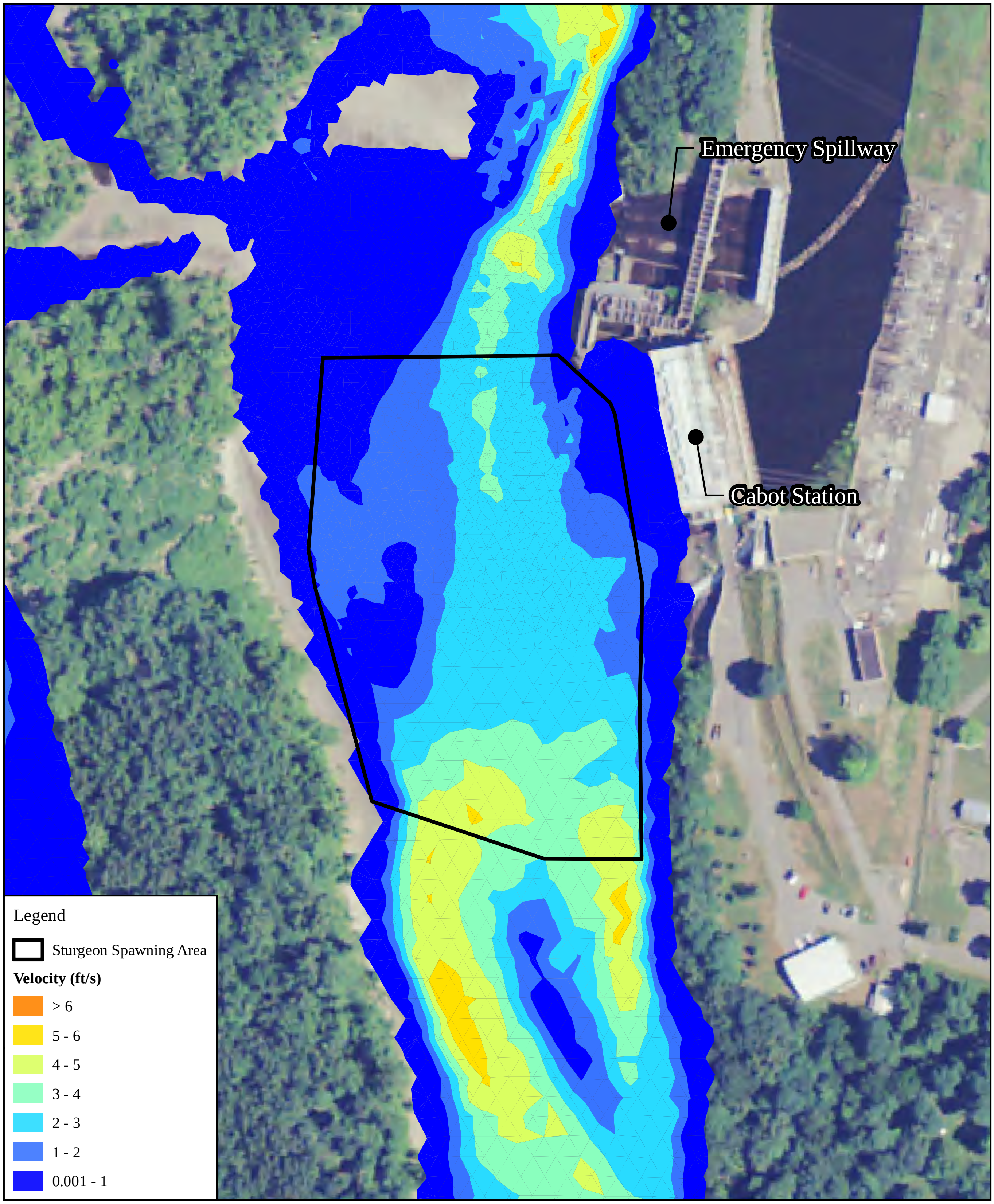
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix B
Velocity Scenario B2a:
Bypass Reach 2,500 cfs
Cabot Station 1,500 cfs
Deerfield River 200 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B2a.mxd



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Turners Falls Hydroelectric Project No. 1889

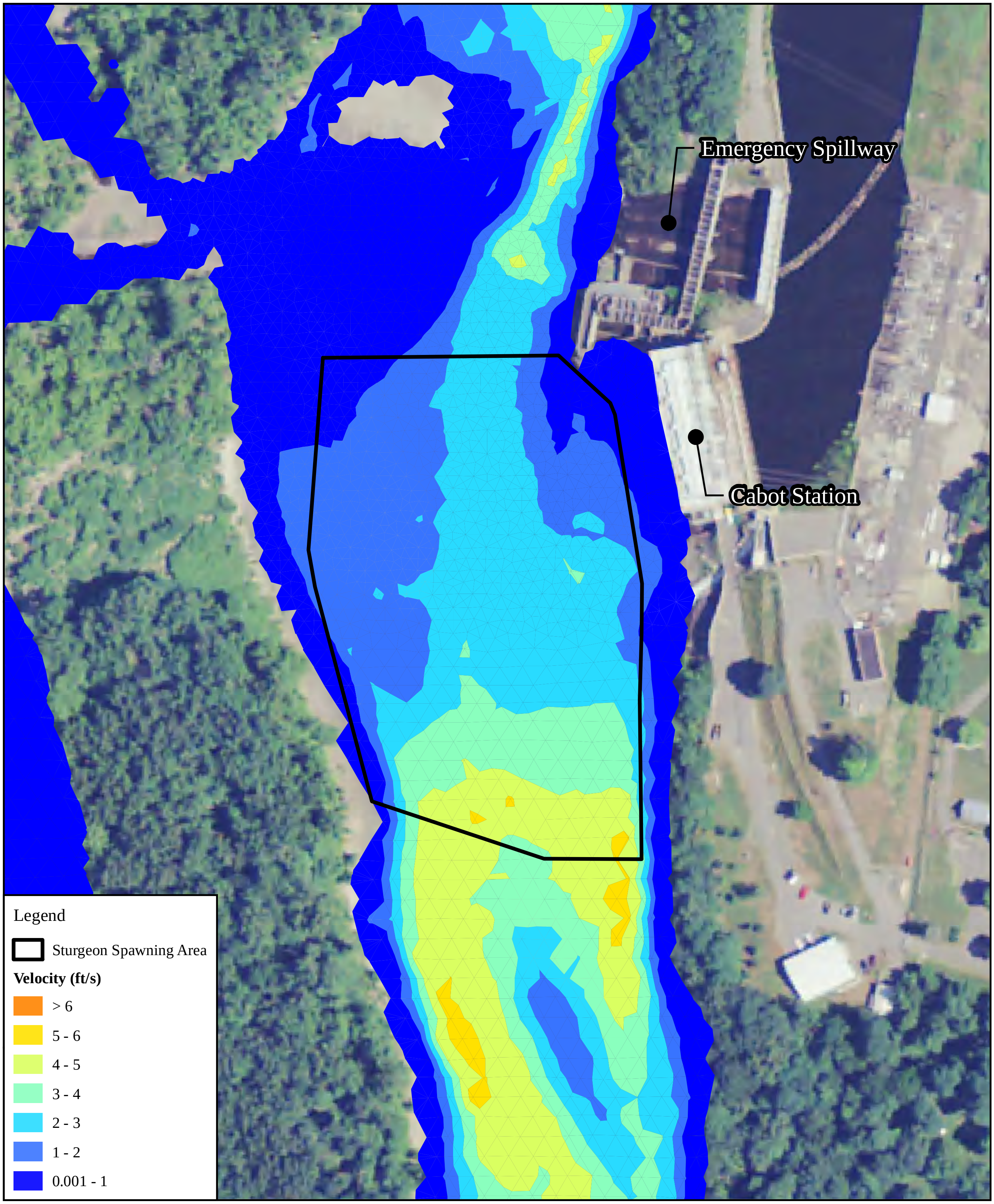
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario B2b:
Bypass Reach 2,500 cfs
Cabot Station 1,500 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B2b.mxd



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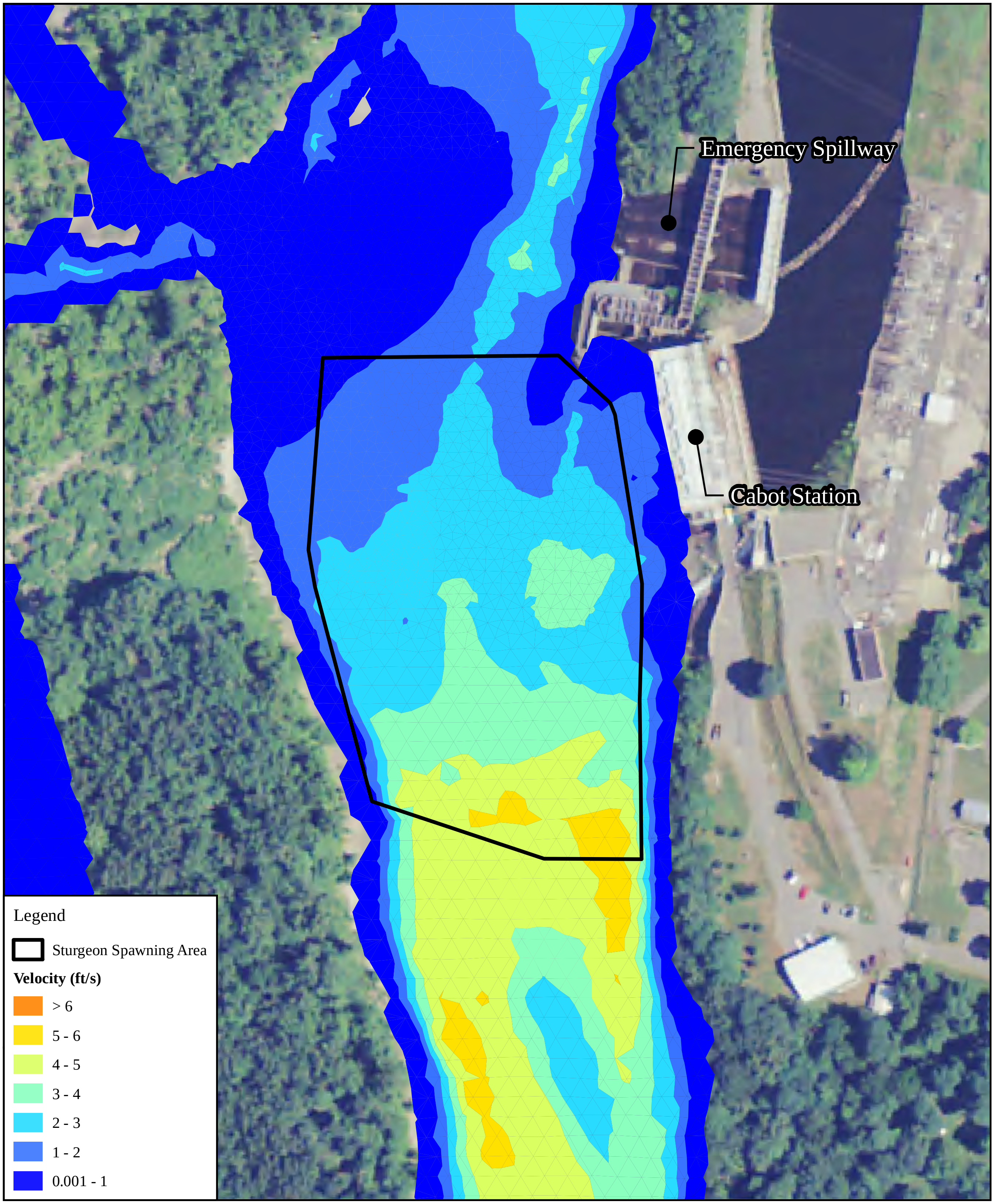
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix B
Velocity Scenario B3:
Bypass Reach 2,500 cfs
Cabot Station 3,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B3.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

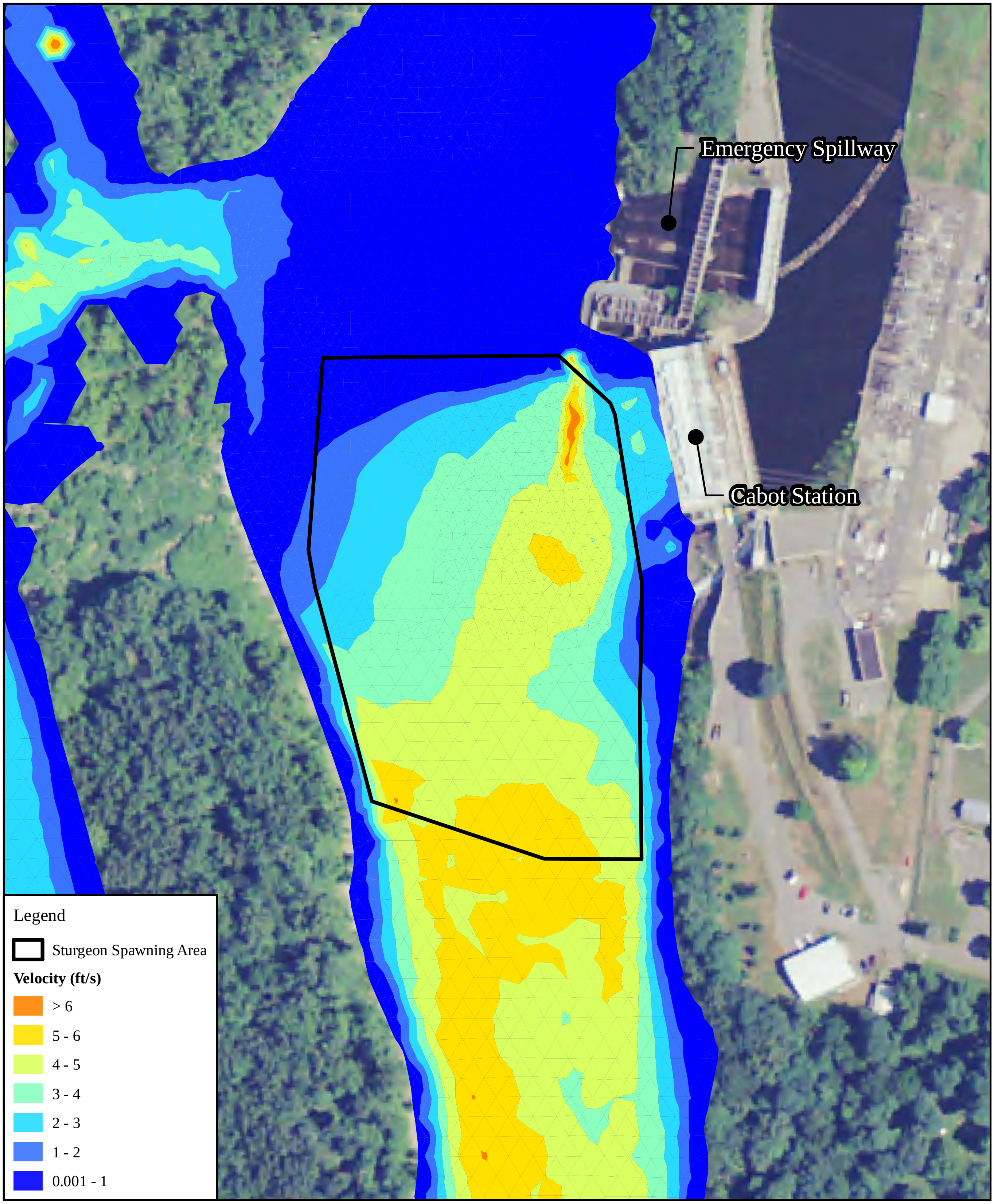
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400
Feet

Appendix B
Velocity Scenario B4:
Bypass Reach 2,500 cfs
Cabot Station 5,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B4.mxd



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Turners Falls Hydroelectric Project No. 1889

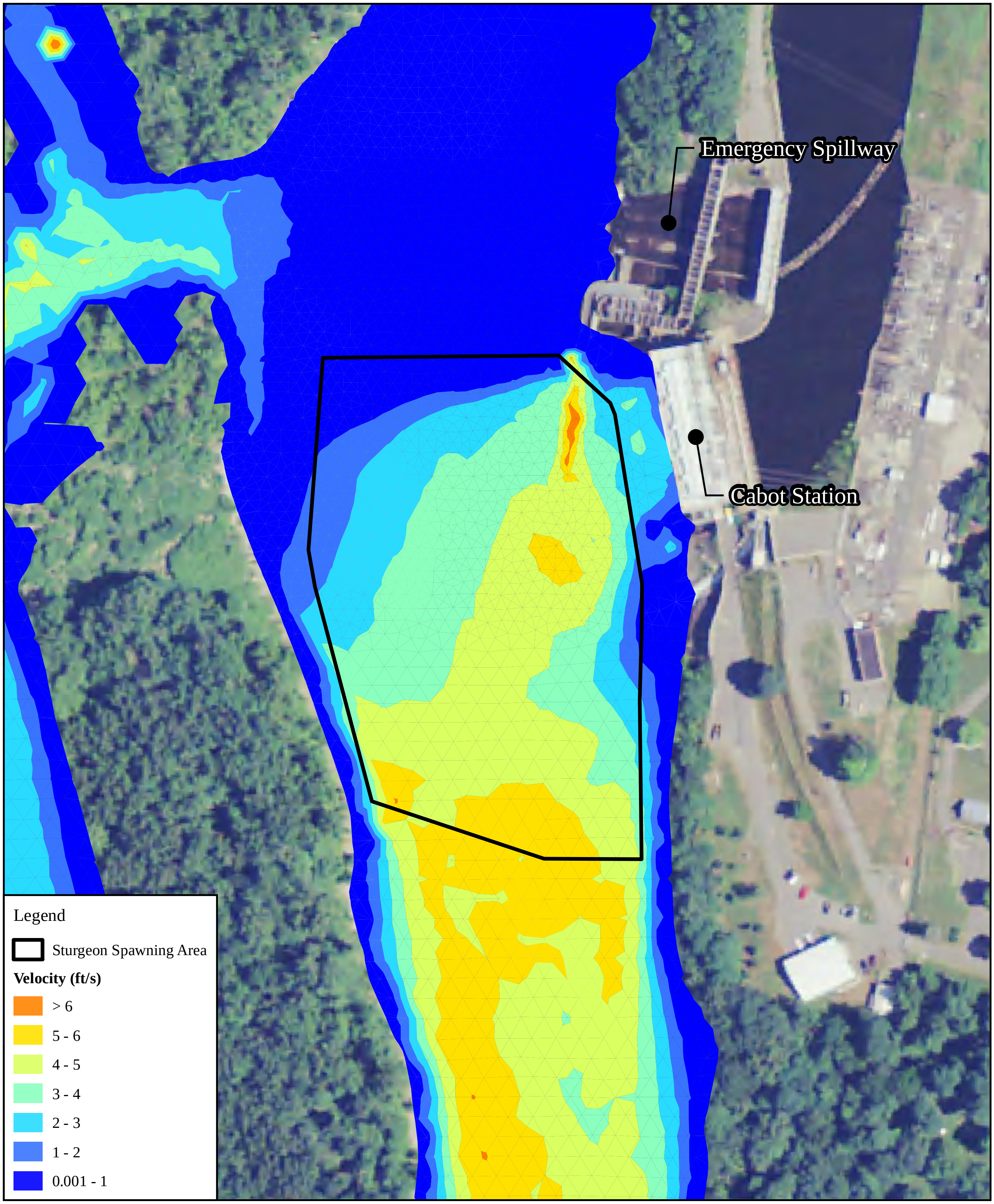
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario B5a:
Bypass Reach 500 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B5a.mxd



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N

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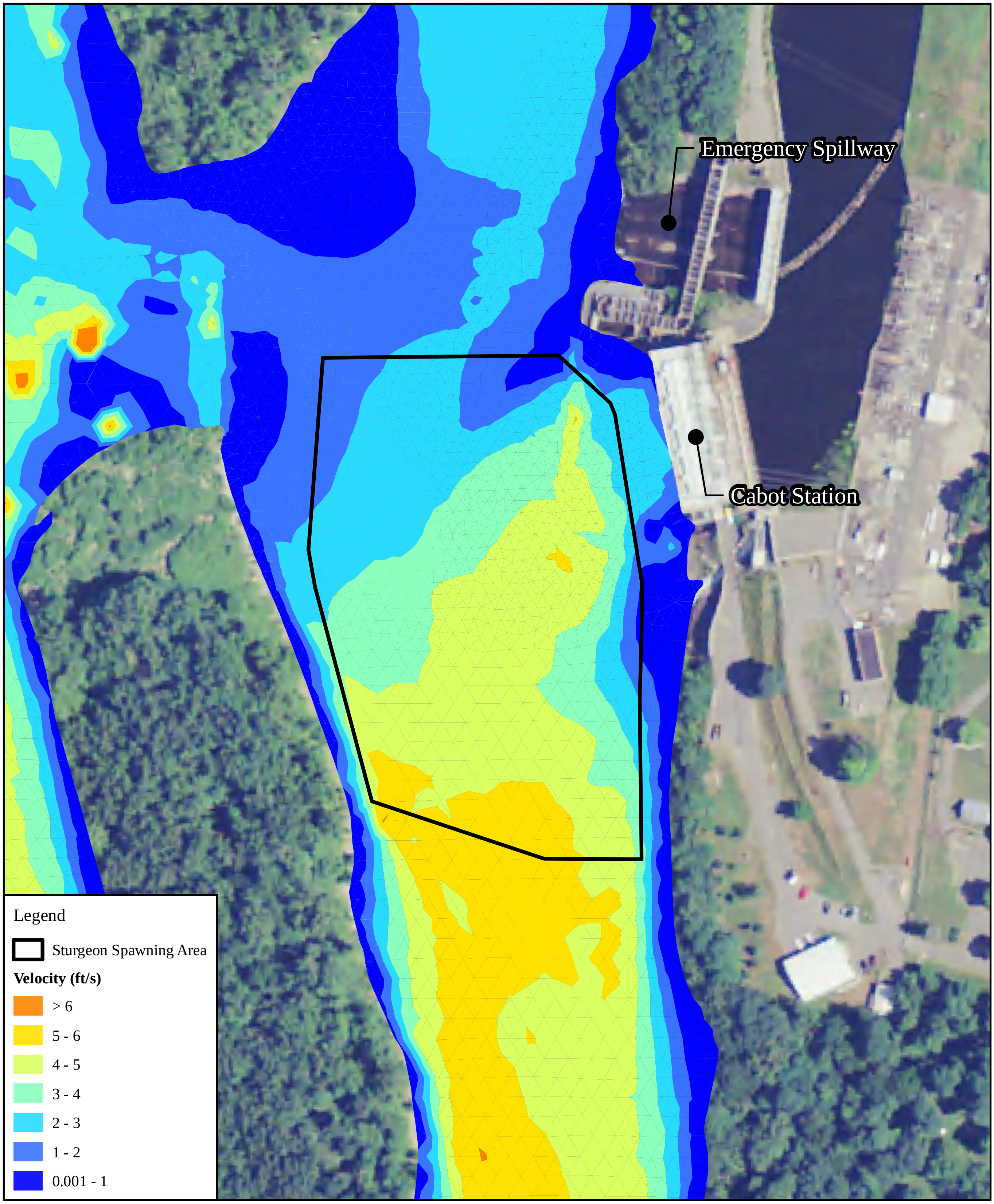
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix B
Velocity Scenario B5b:
Bypass Reach 2,500 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B5b.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

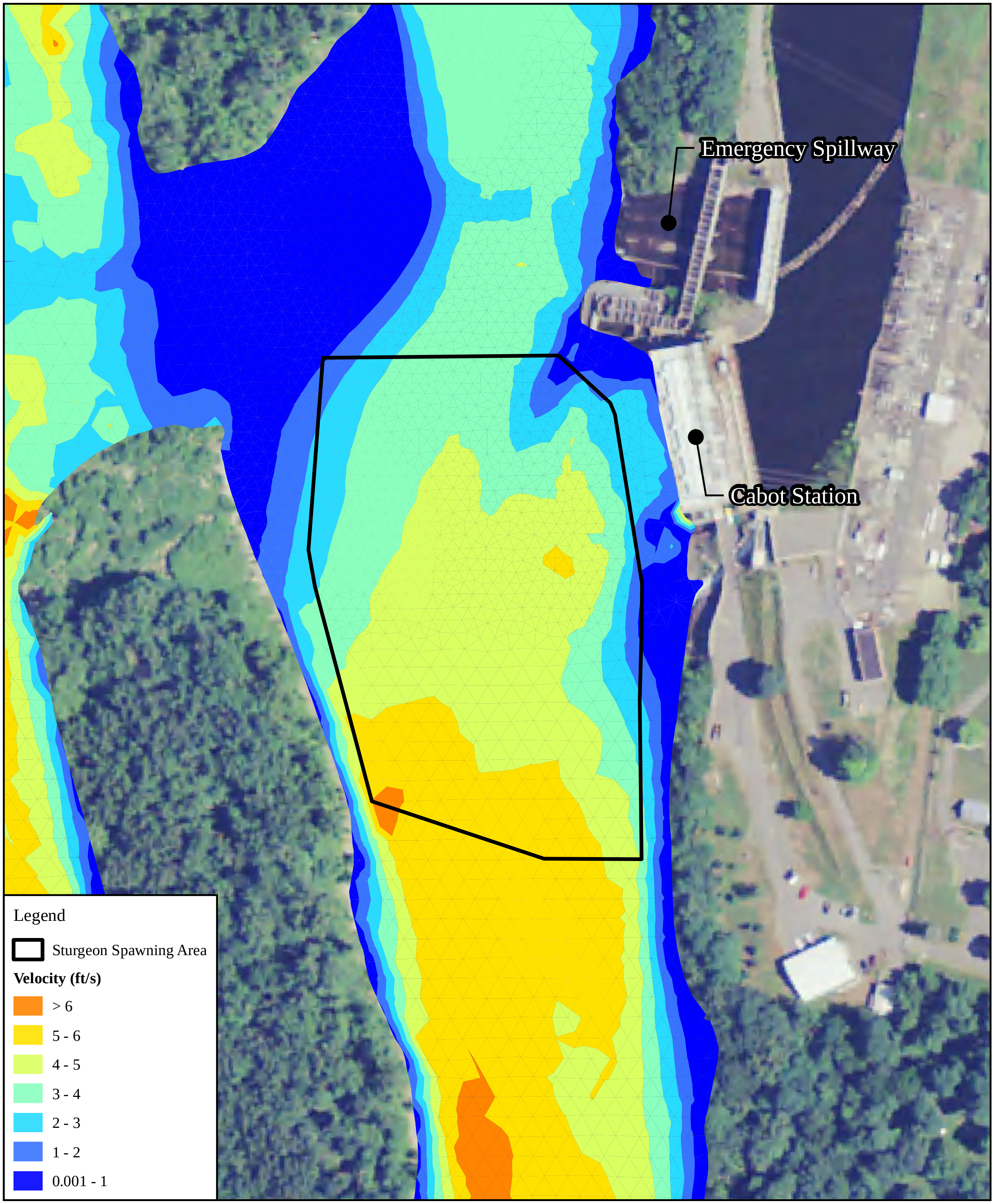
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario B6:
Bypass Reach 10,000 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B6.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

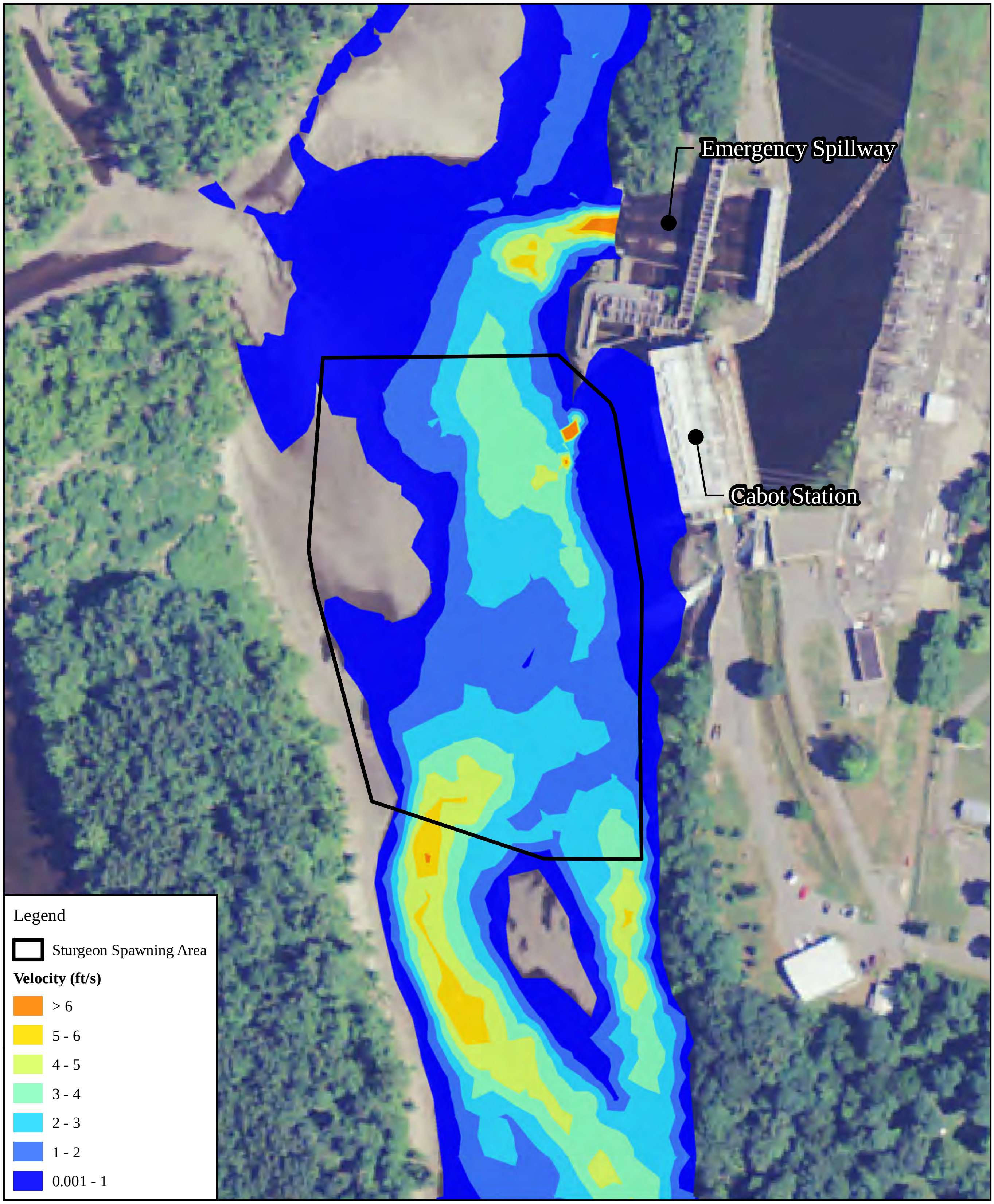
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario B7:
Bypass Reach 20,000 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_B7.mxd



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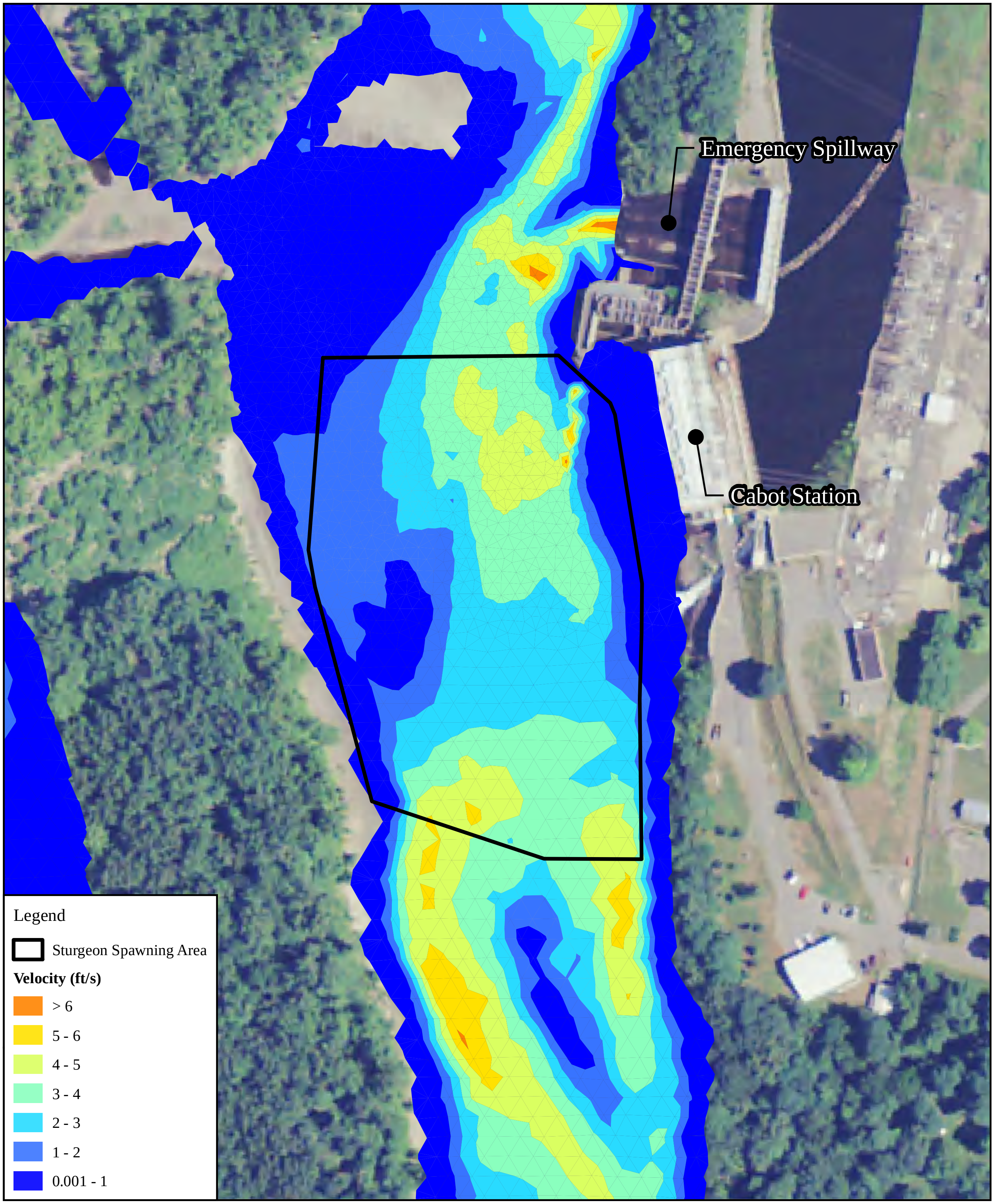
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix B
Velocity Scenario E1a S1500:
Bypass Reach 500 cfs
Cabot Station 0 cfs
Deerfield River 200 cfs
Emergency Spillway 1500 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E1a S1500.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

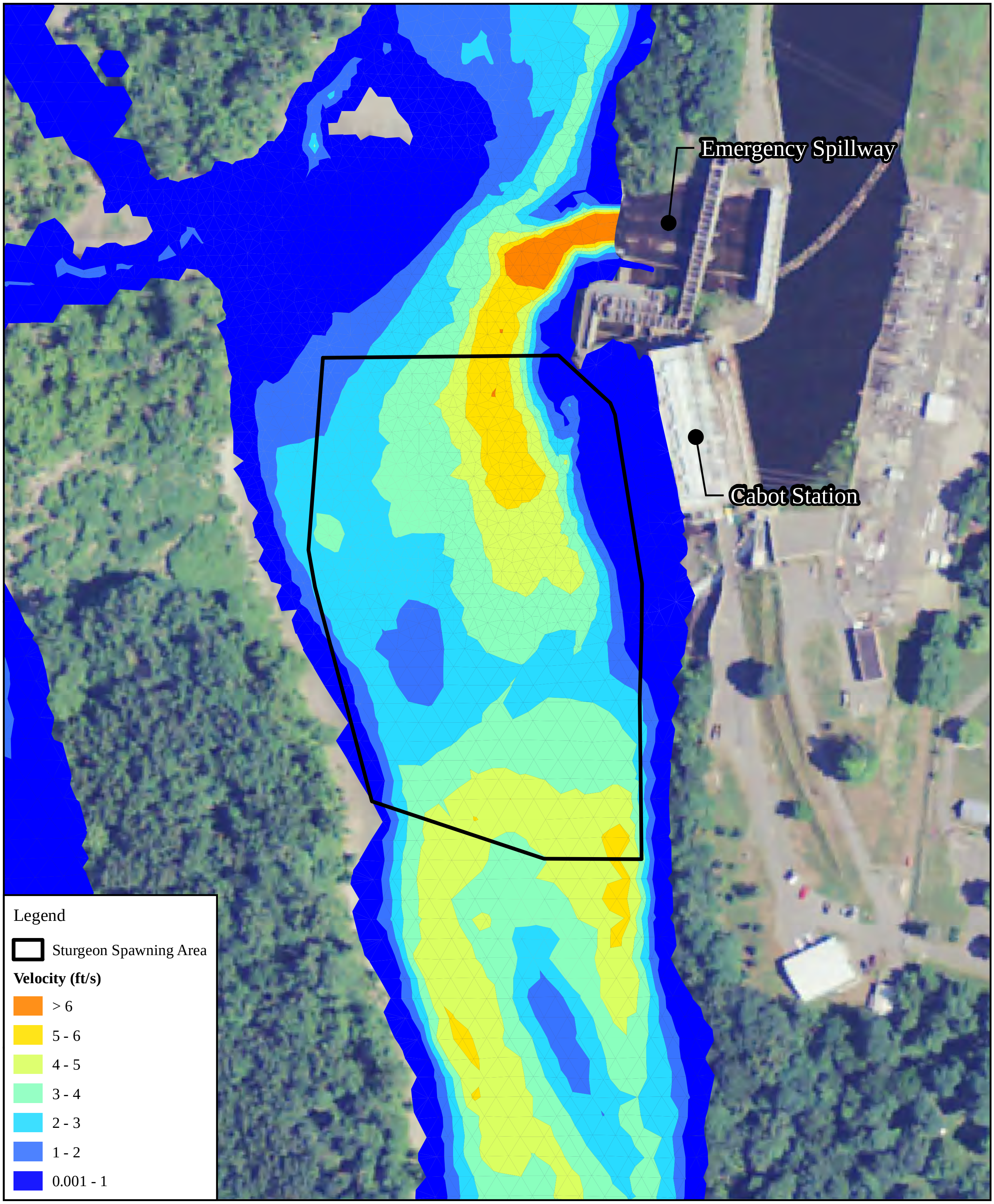
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario E2a S1500:
Bypass Reach 2,500 cfs
Cabot Station 0 cfs
Deerfield River 200 cfs
Emergency Spillway 1,500 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E2a_S1500.mxd



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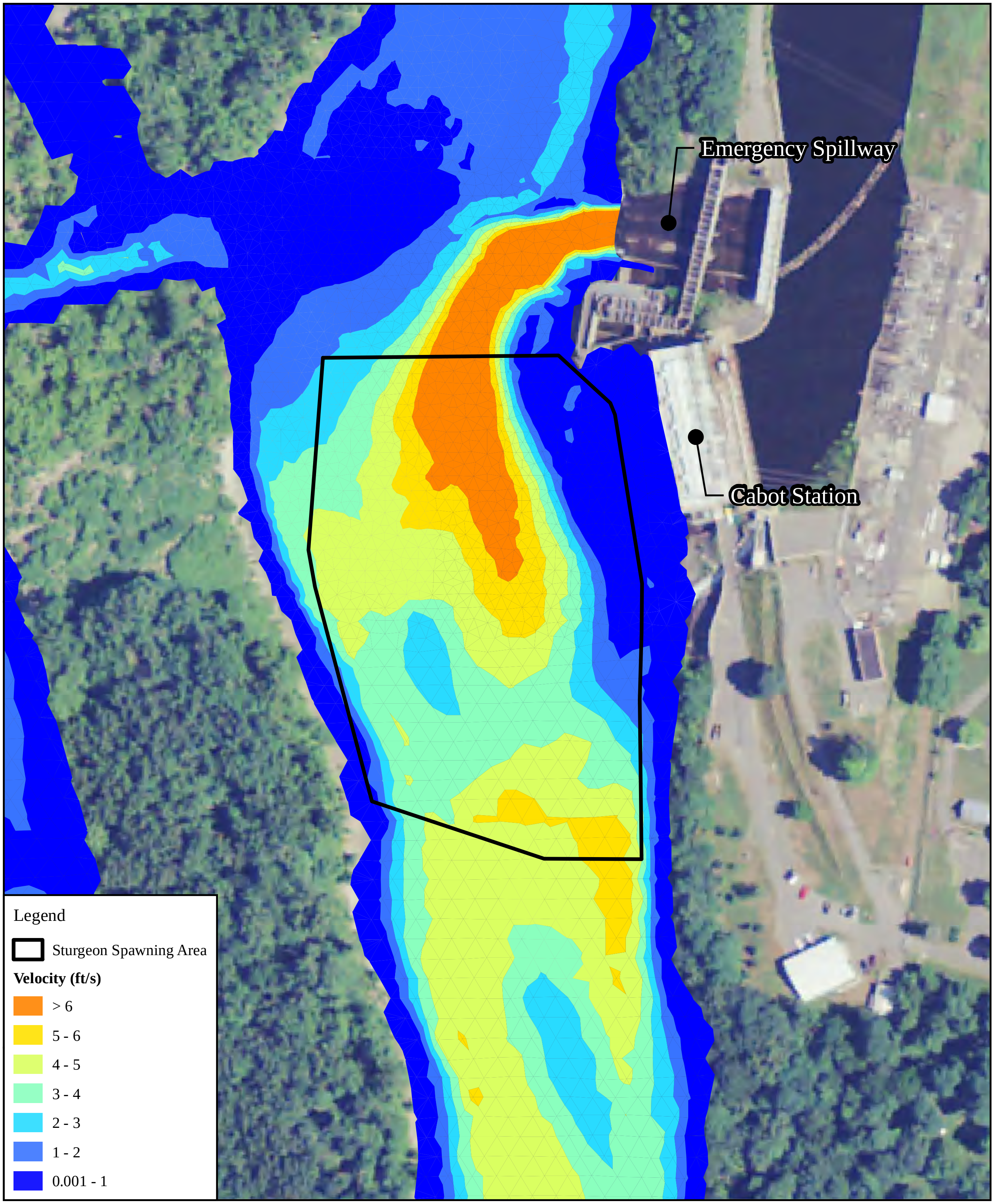
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix B
Velocity Scenario E3 S3000:
Bypass Reach 2,500 cfs
Cabot Station 0 cfs
Deerfield River 1,445 cfs
Emergency Spillway 3,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E3_S3000.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

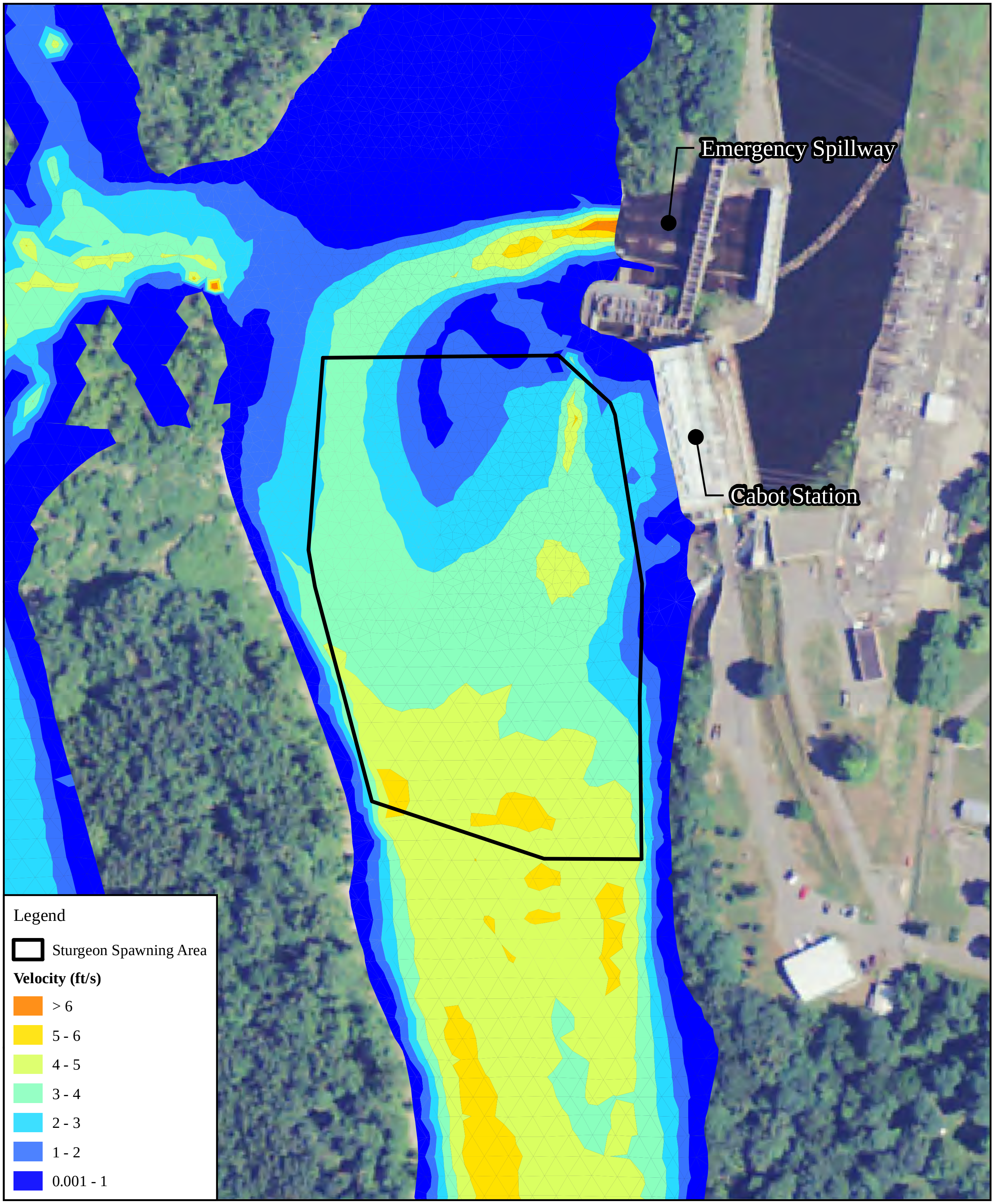
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario E4 S5000:
Bypass Reach 2,500 cfs
Cabot Station 0 cfs
Deerfield River 1,445 cfs
Emergency Spillway 5,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E4_S5000.mxd



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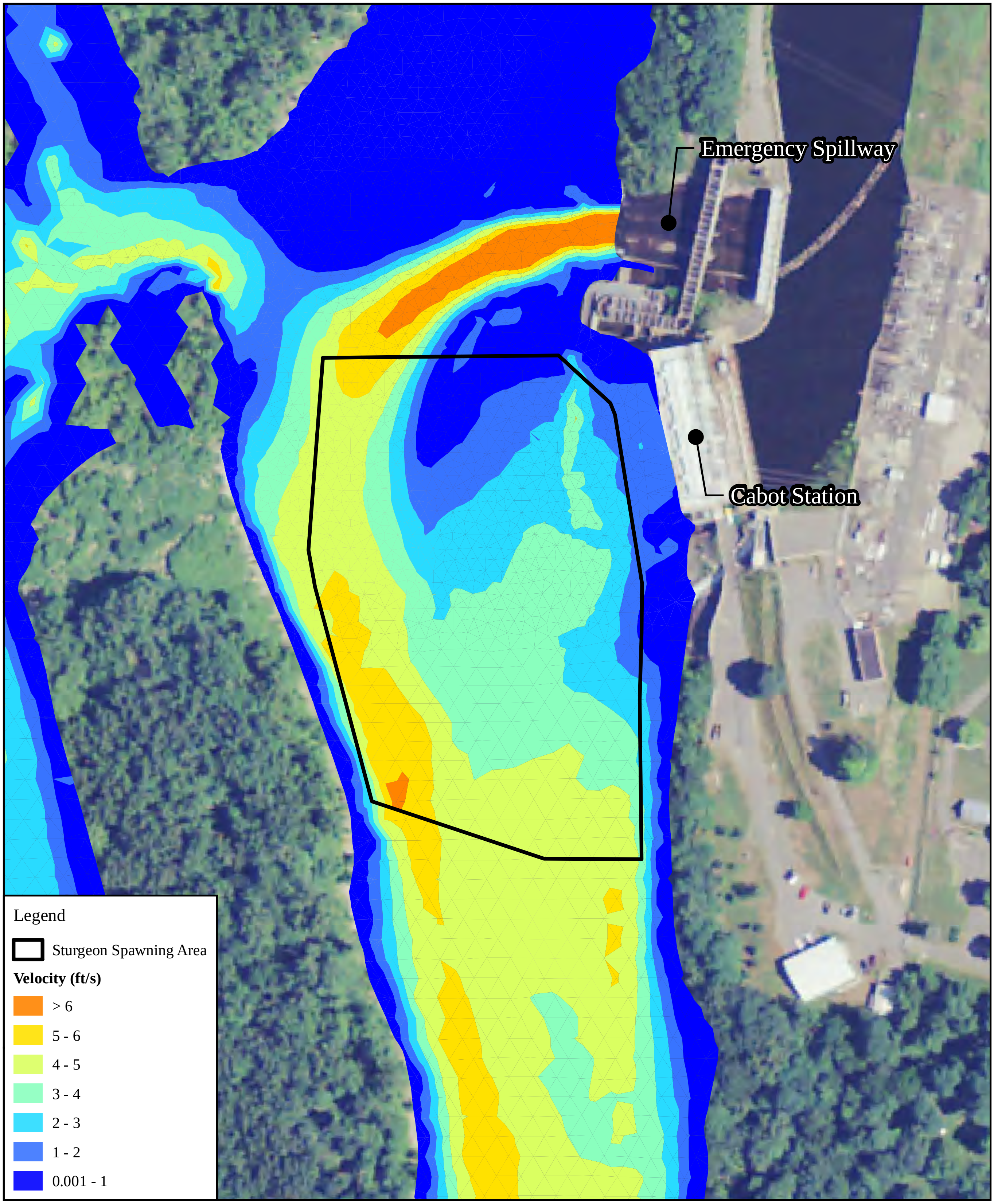
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix B
Velocity Scenario E5b S3000:
Bypass Reach 2,500 cfs
Cabot Station 11,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 3,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E5b_S3000.mxd



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Turners Falls Hydroelectric Project No. 1889

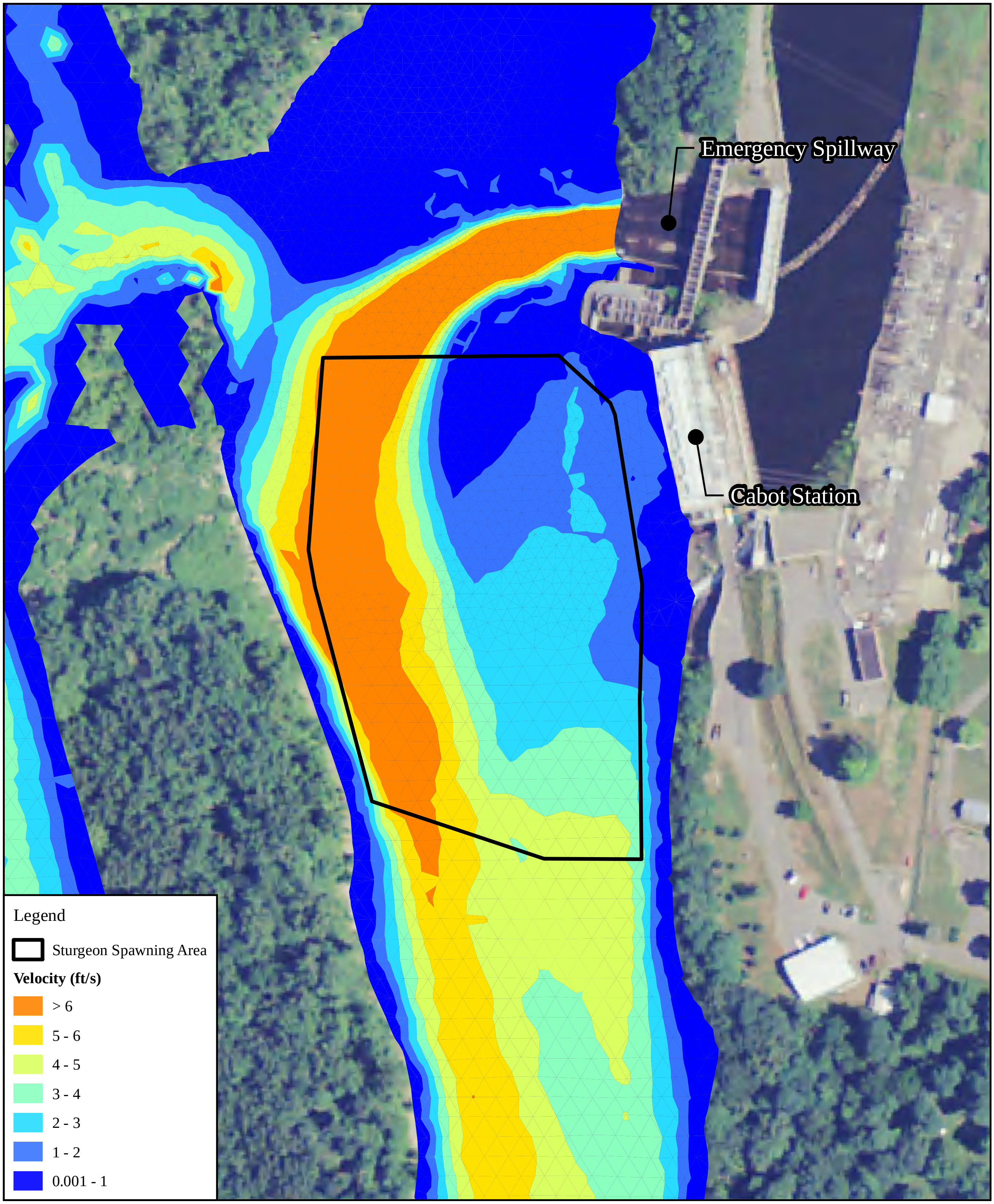
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario E5b S5000:
Bypass Reach 2,500 cfs
Cabot Station 9,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 5,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E5b_S5000.mxd



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Turners Falls Hydroelectric Project No. 1889

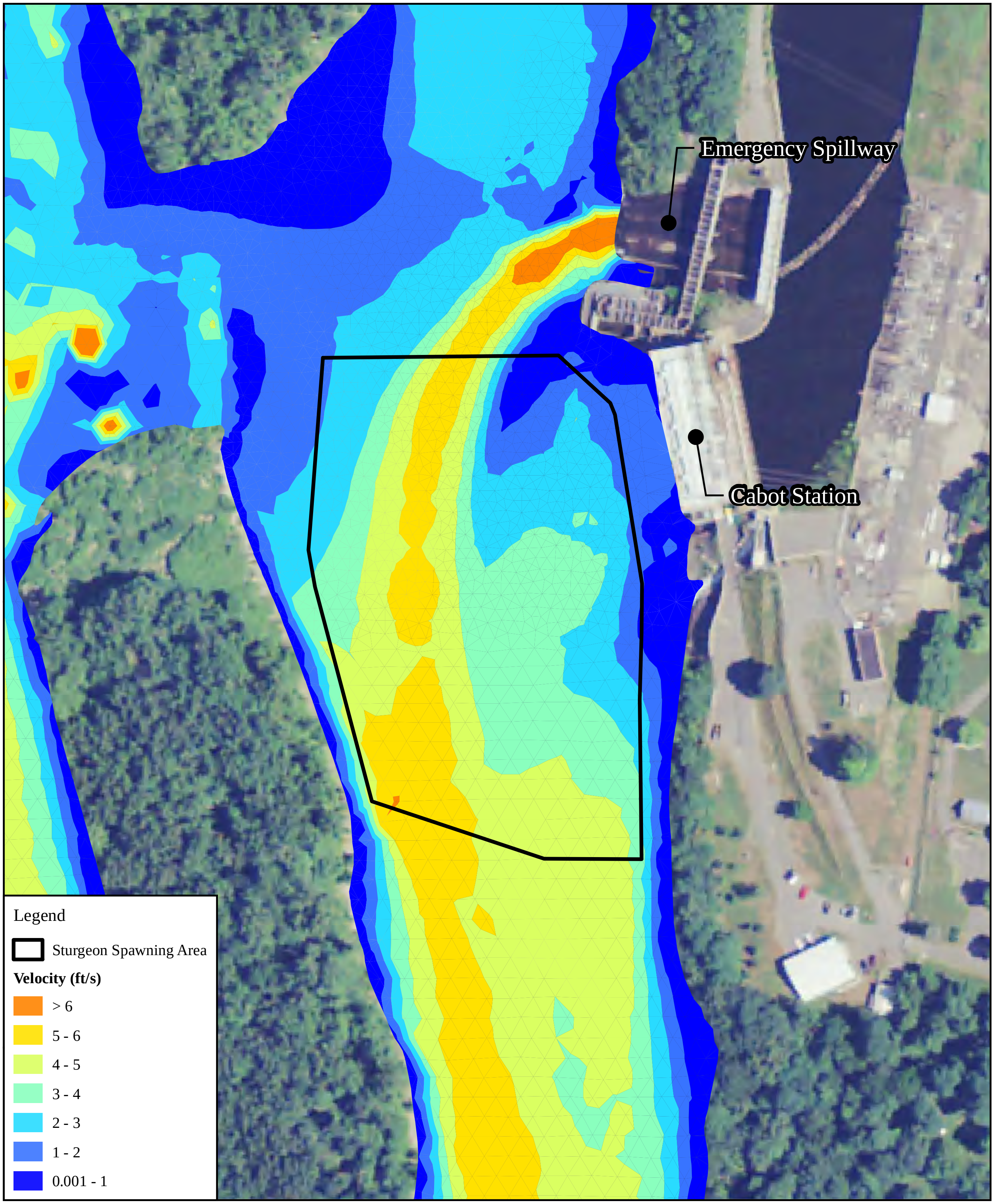
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix B
Velocity Scenario E5b S8000:
Bypass Reach 2,500 cfs
Cabot Station 6,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 8,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E5b_S8000.mxd



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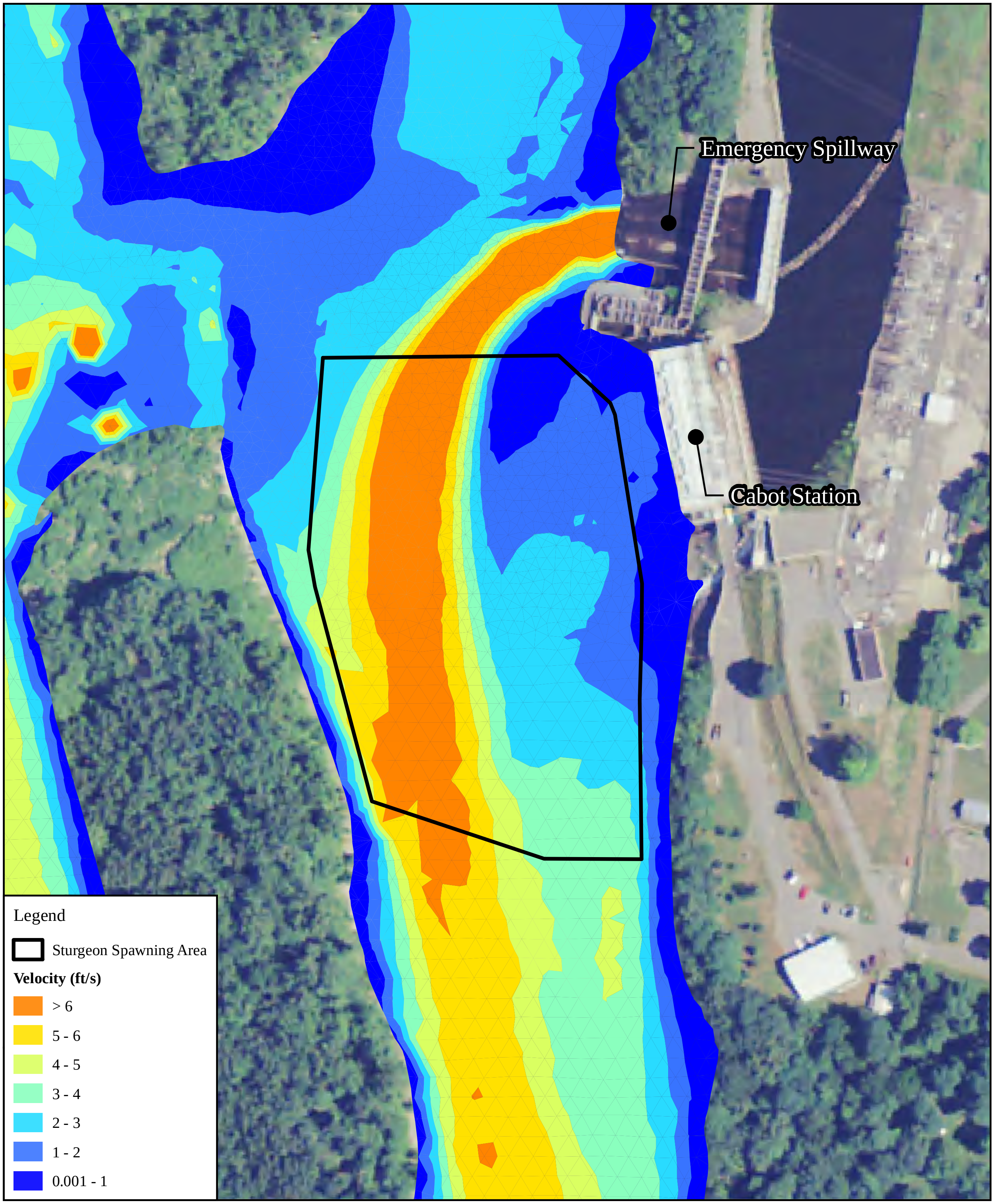
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix B
Velocity Scenario E6 S5000:
Bypass Reach 10,000 cfs
Cabot Station 9,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 5,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E6_S5000.mxd



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Turners Falls Hydroelectric Project No. 1889

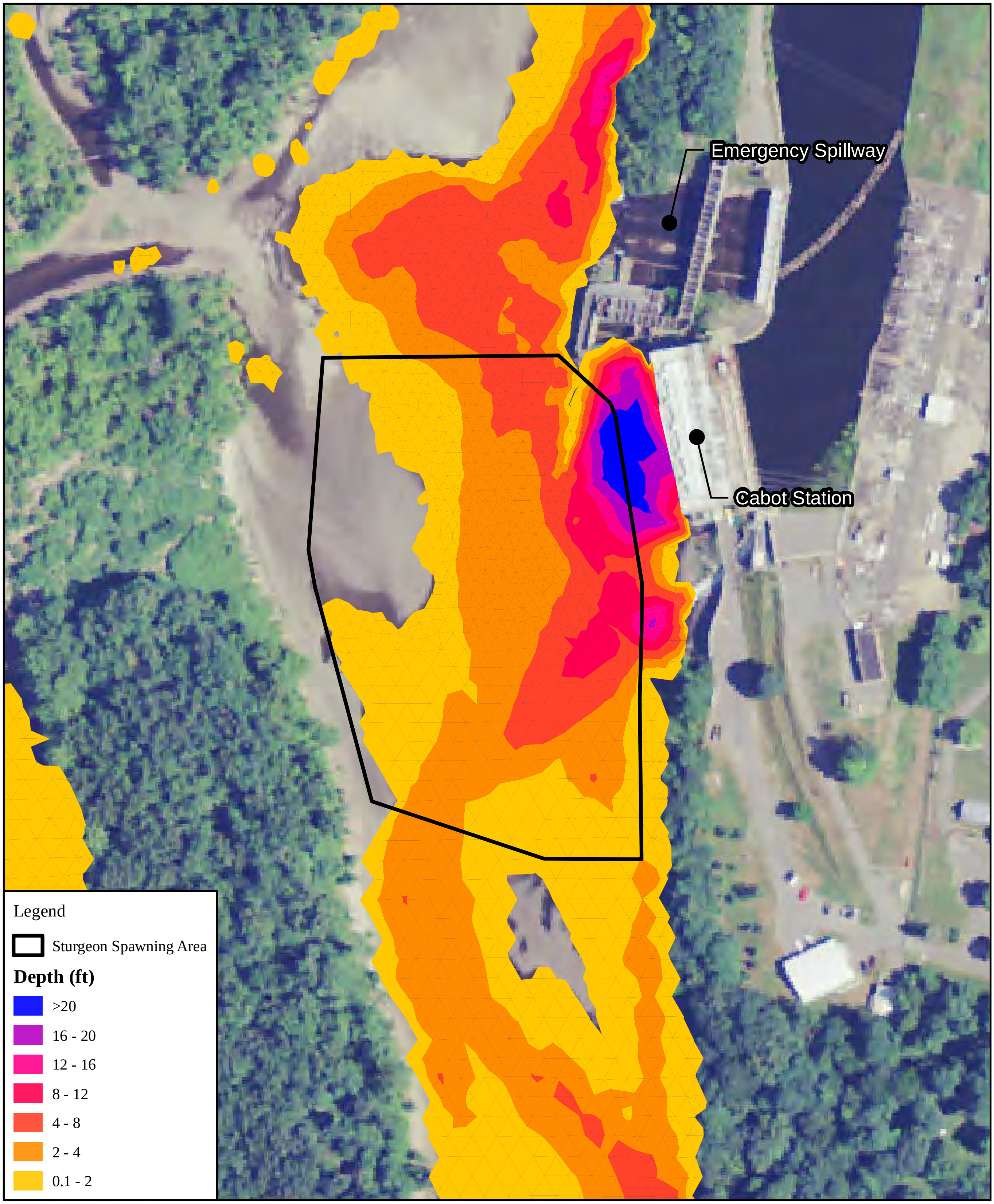
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix B
Velocity Scenario E6 S8000:
Bypass Reach 10,000 cfs
Cabot Station 6,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 8,000 cfs

Path: W:\gis\studies\3_3_12\maps\vel_scenario_E6_S8000.mxd

APPENDIX C – MODELED DEPTH MAPS



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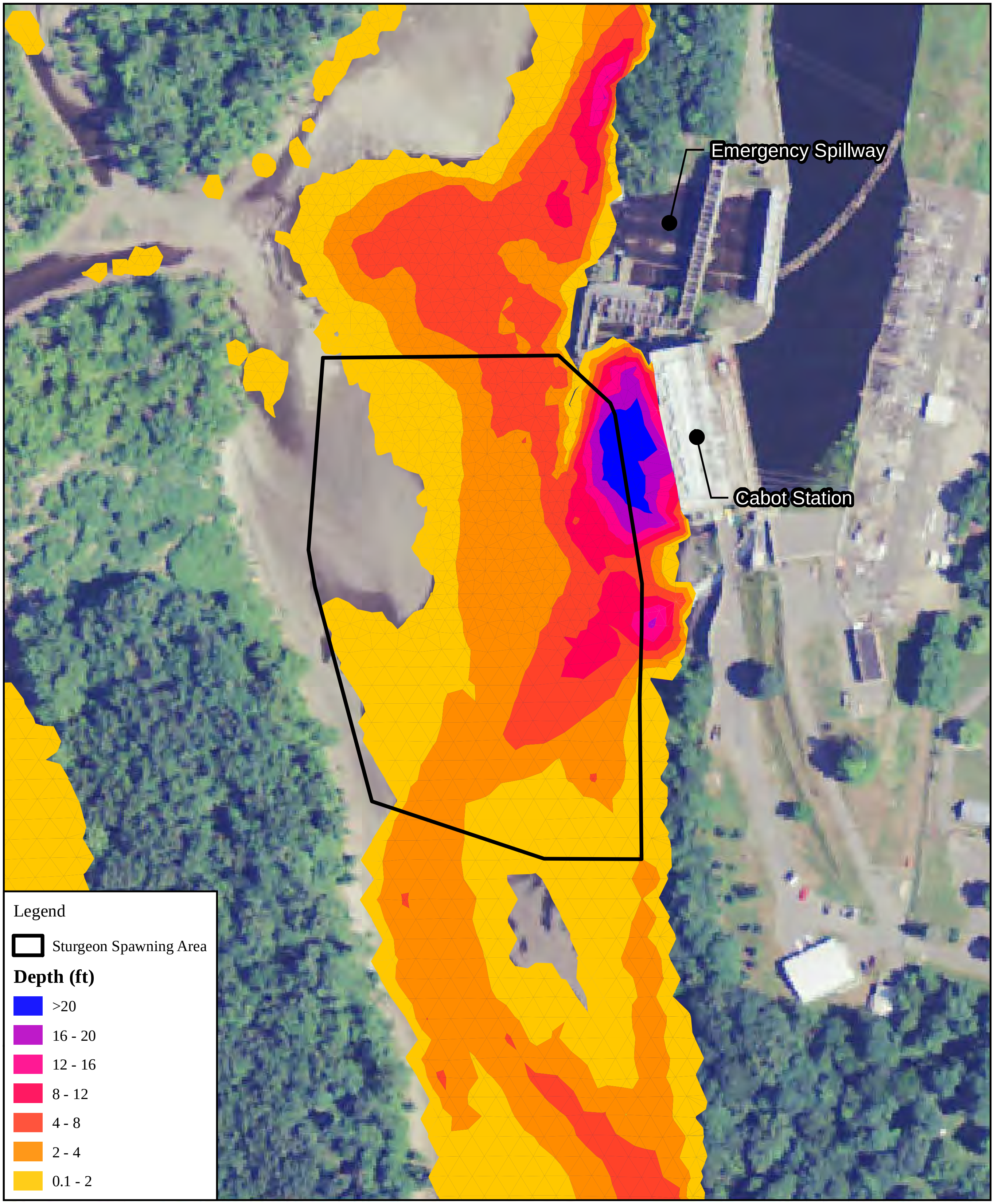
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix C
Depth Scenario B1a:
Bypass Reach 500 cfs
Cabot Station 1,500 cfs
Deerfield River 200 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B1a.mxd



N

0 100 200 400 Feet

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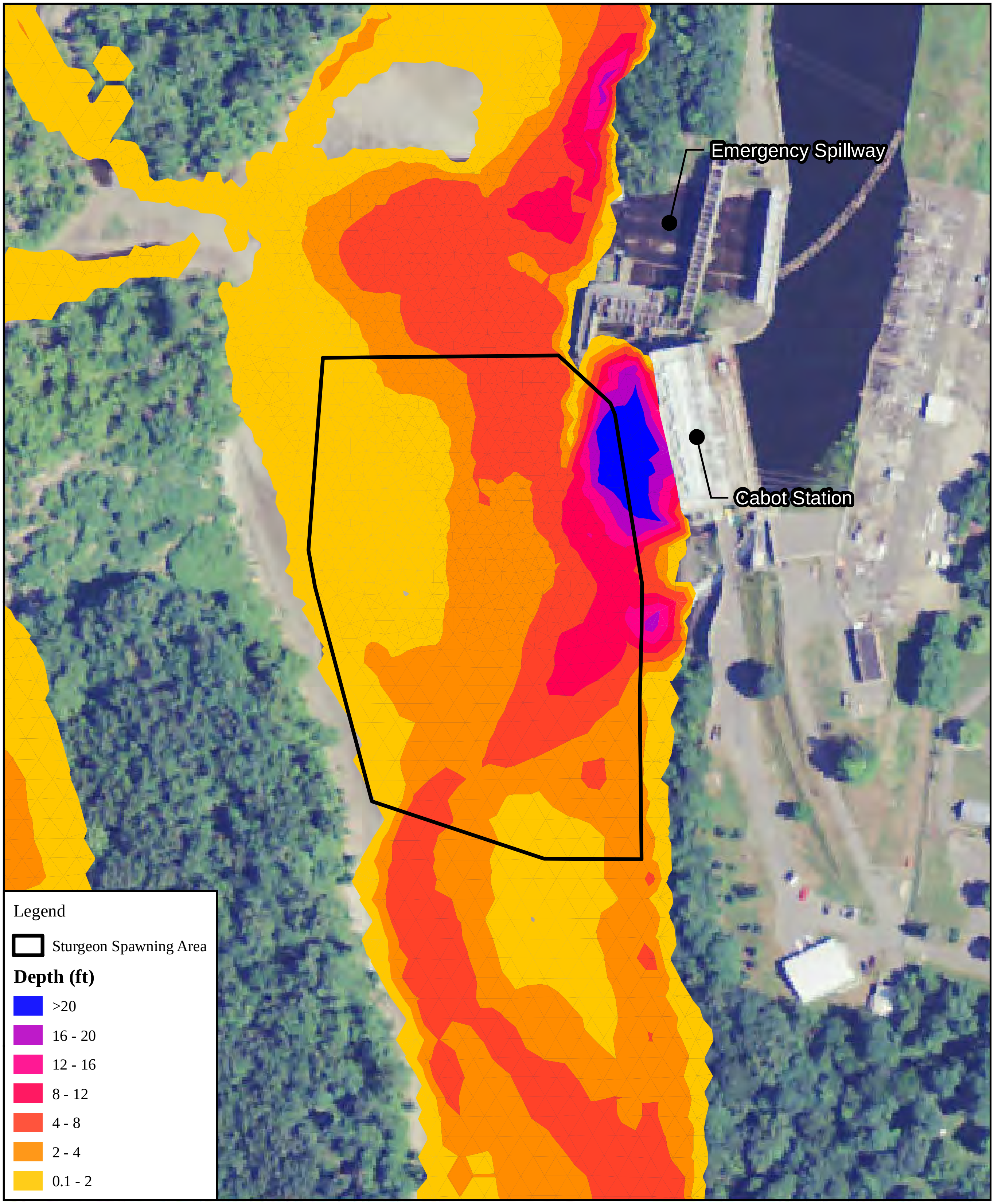
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix C
Depth Scenario B1b:
Bypass Reach 500 cfs
Cabot Station 1,500 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B1b.mxd



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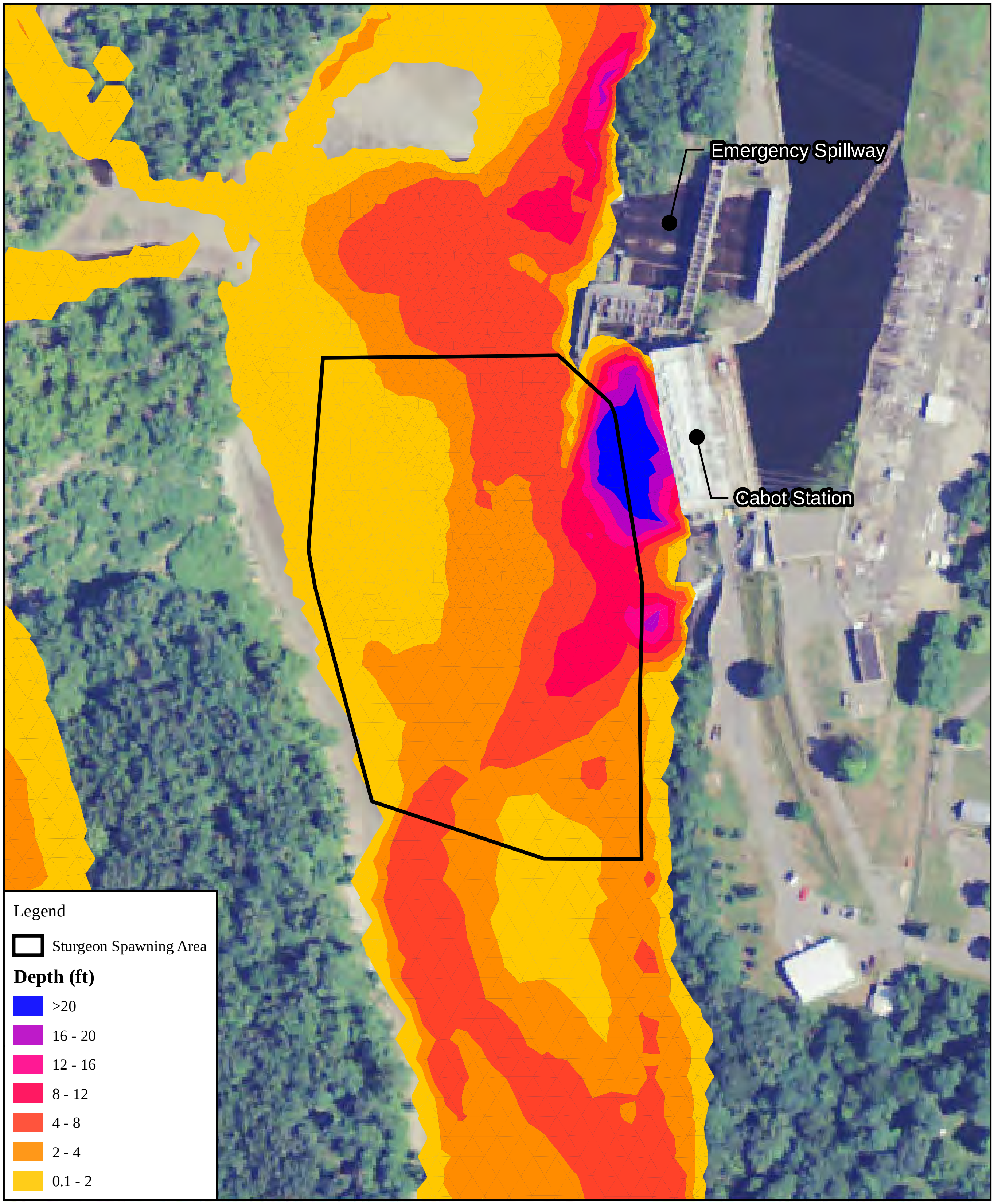
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400
Feet

Appendix C
Depth Scenario B2a:
Bypass Reach 2,500 cfs
Cabot Station 1,500 cfs
Deerfield River 200 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B2a.mxd



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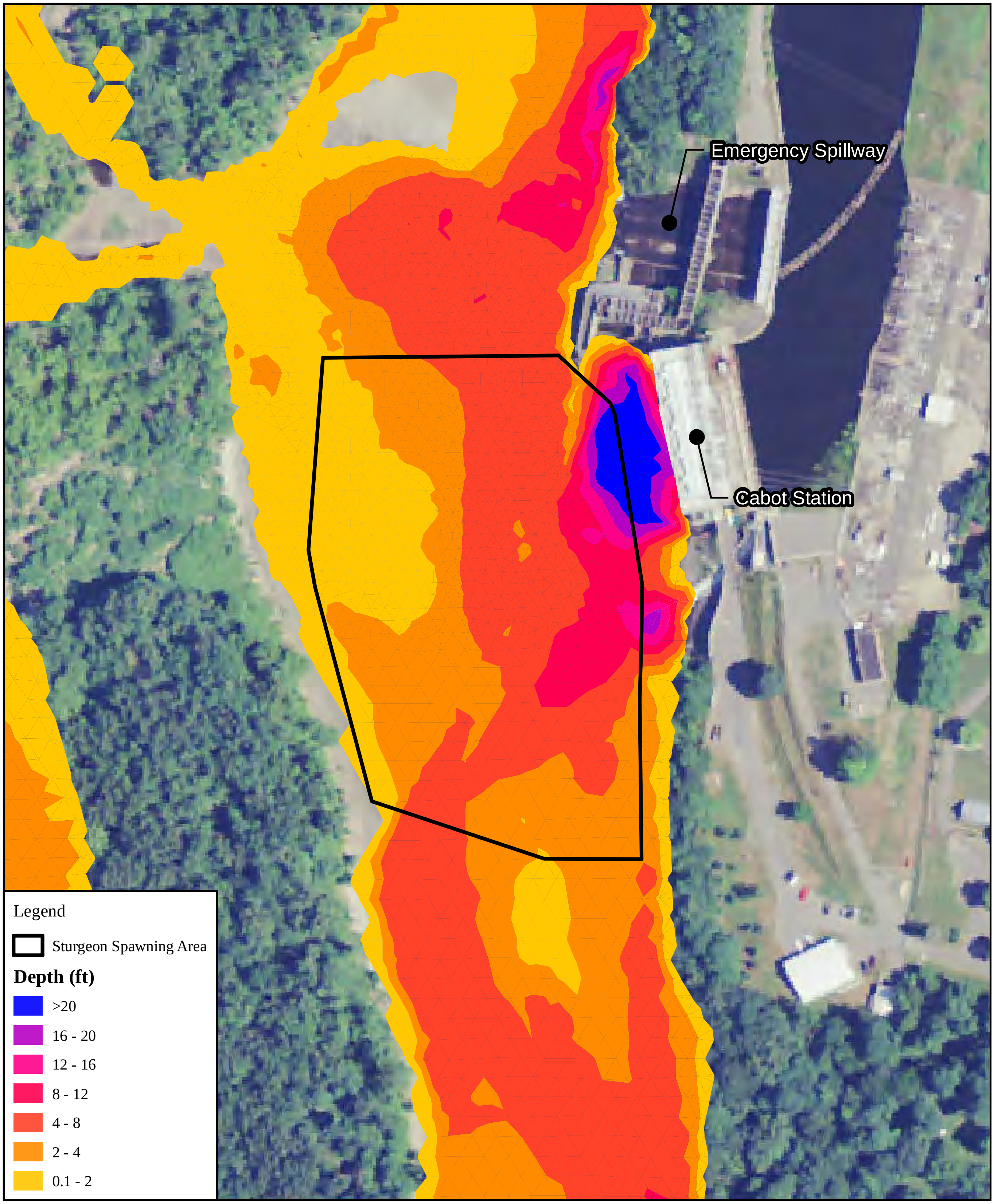
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix C
Depth Scenario B2b:
Bypass Reach 2,500 cfs
Cabot Station 1,500 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B2b.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

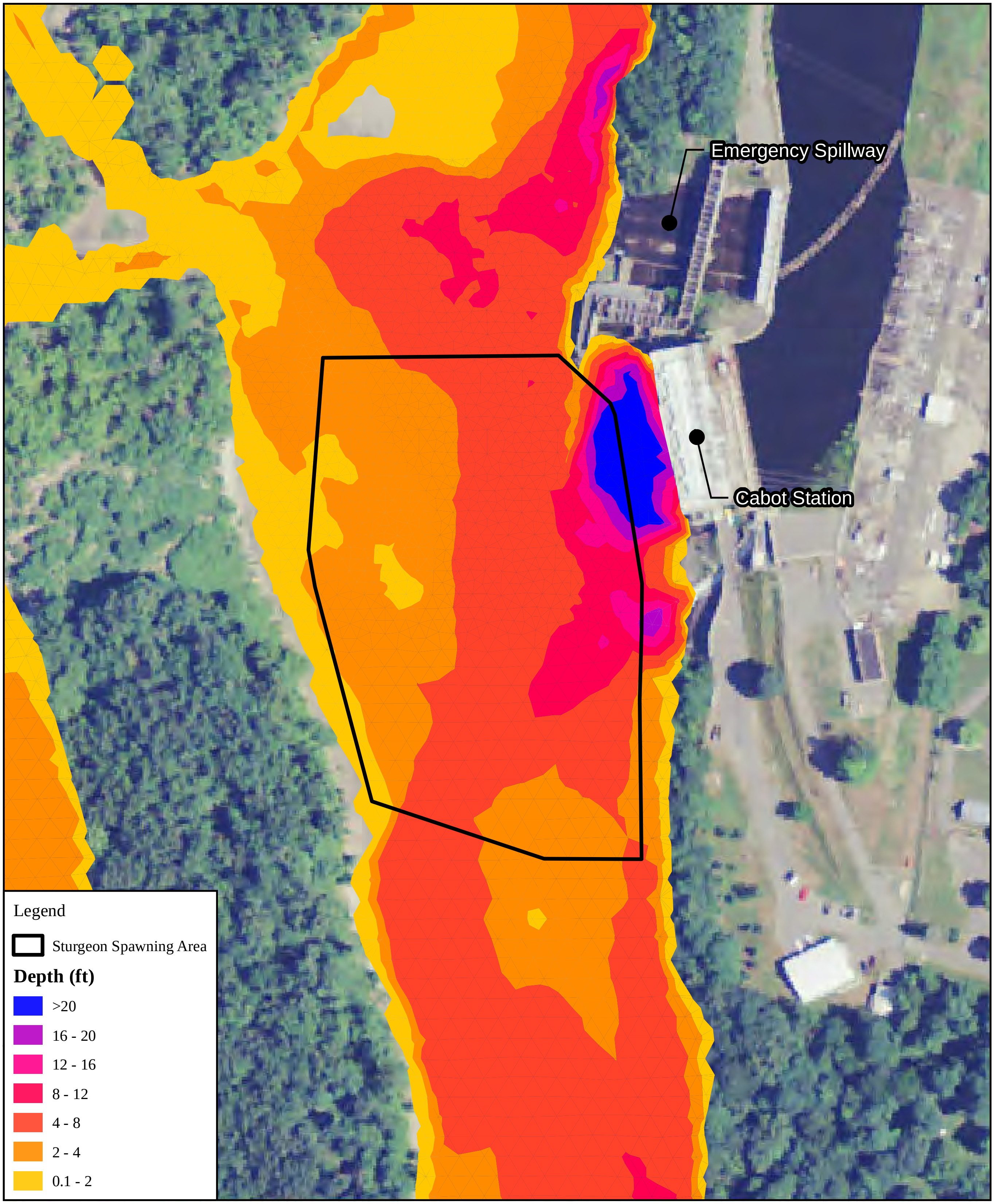
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario B3:
Bypass Reach 2,500 cfs
Cabot Station 3,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B3.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

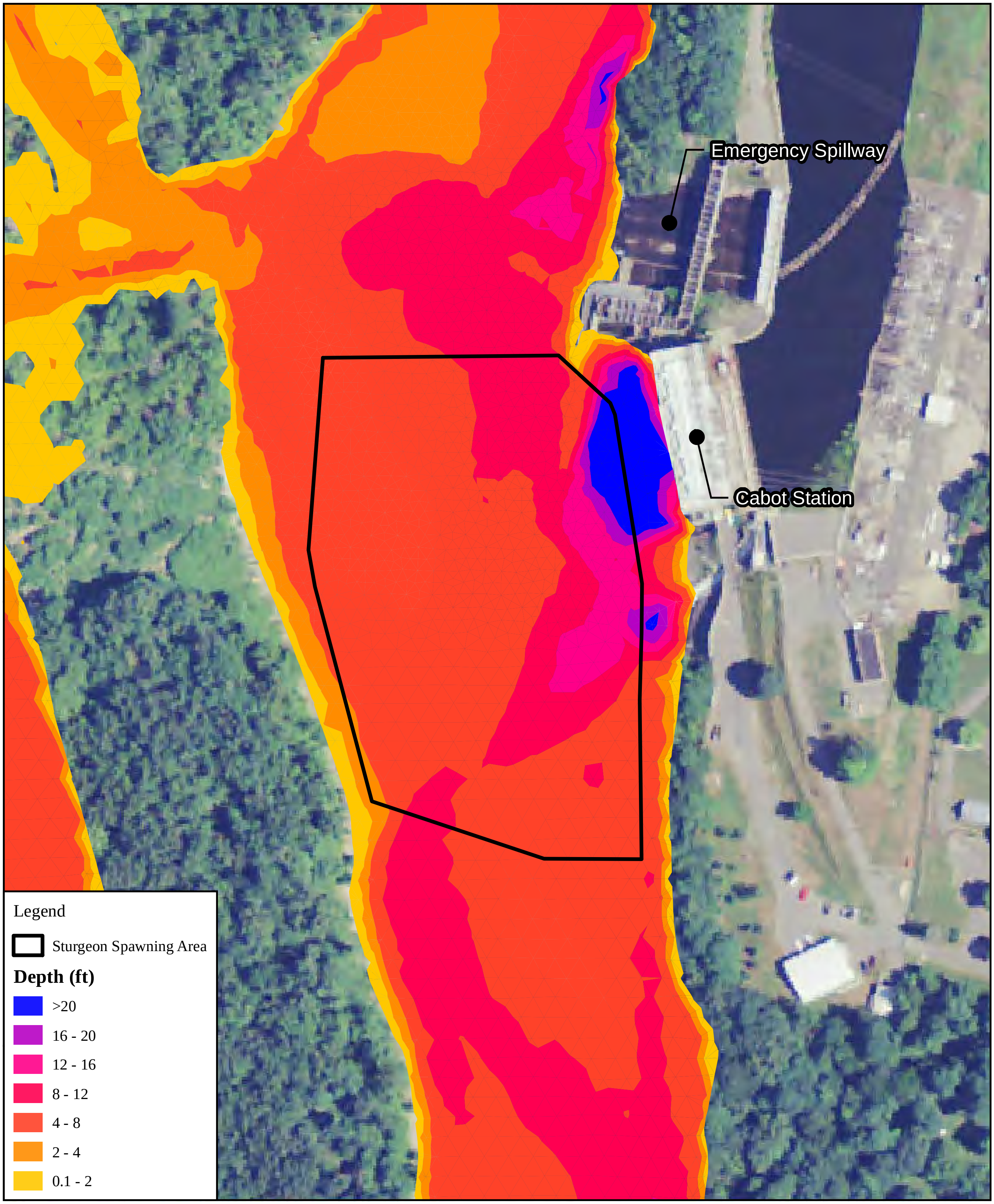
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario B4:
Bypass Reach 2,500 cfs
Cabot Station 5,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B4.mxd



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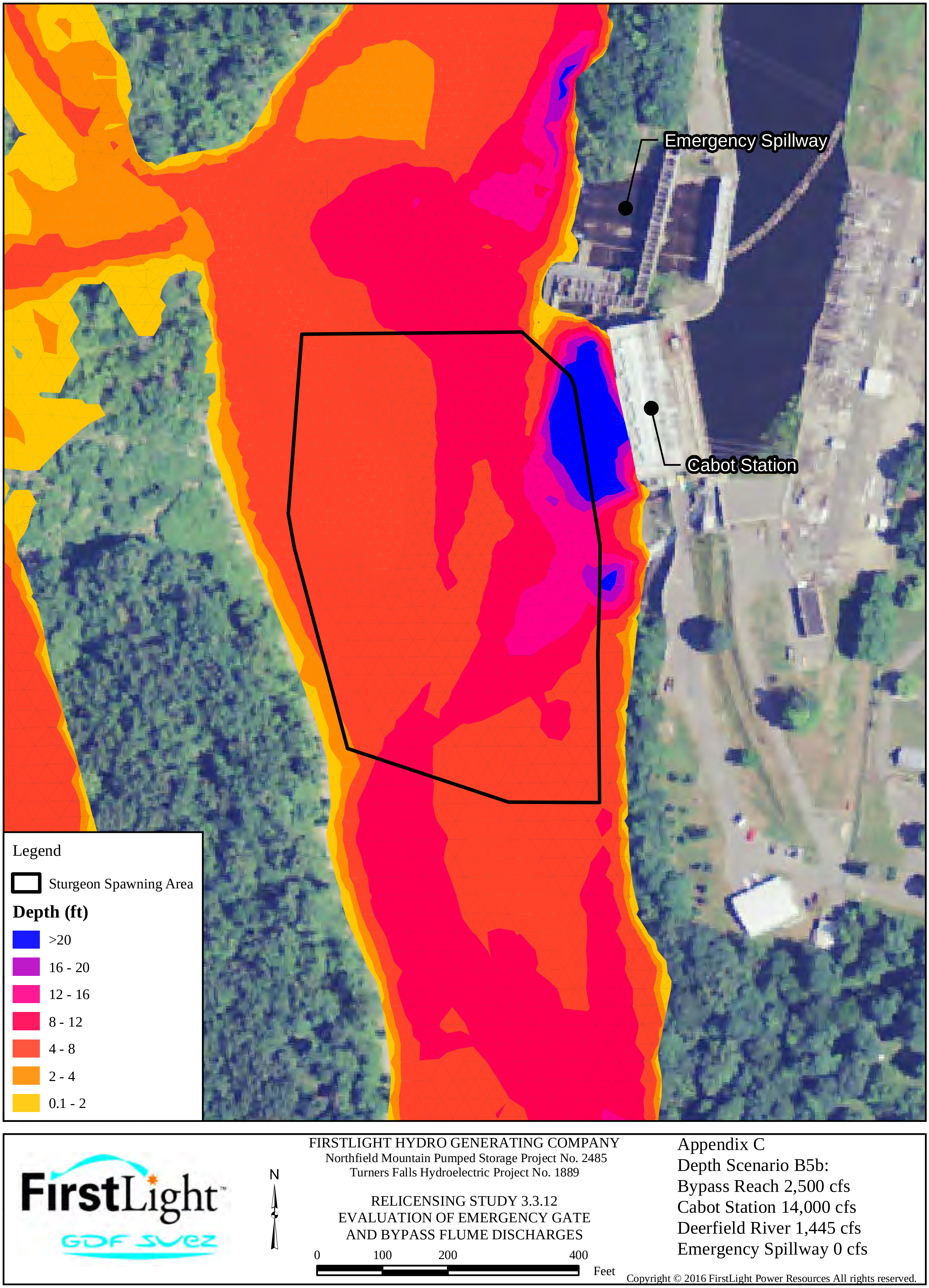
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix C
Depth Scenario B5a:
Bypass Reach 500 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B5a.mxd



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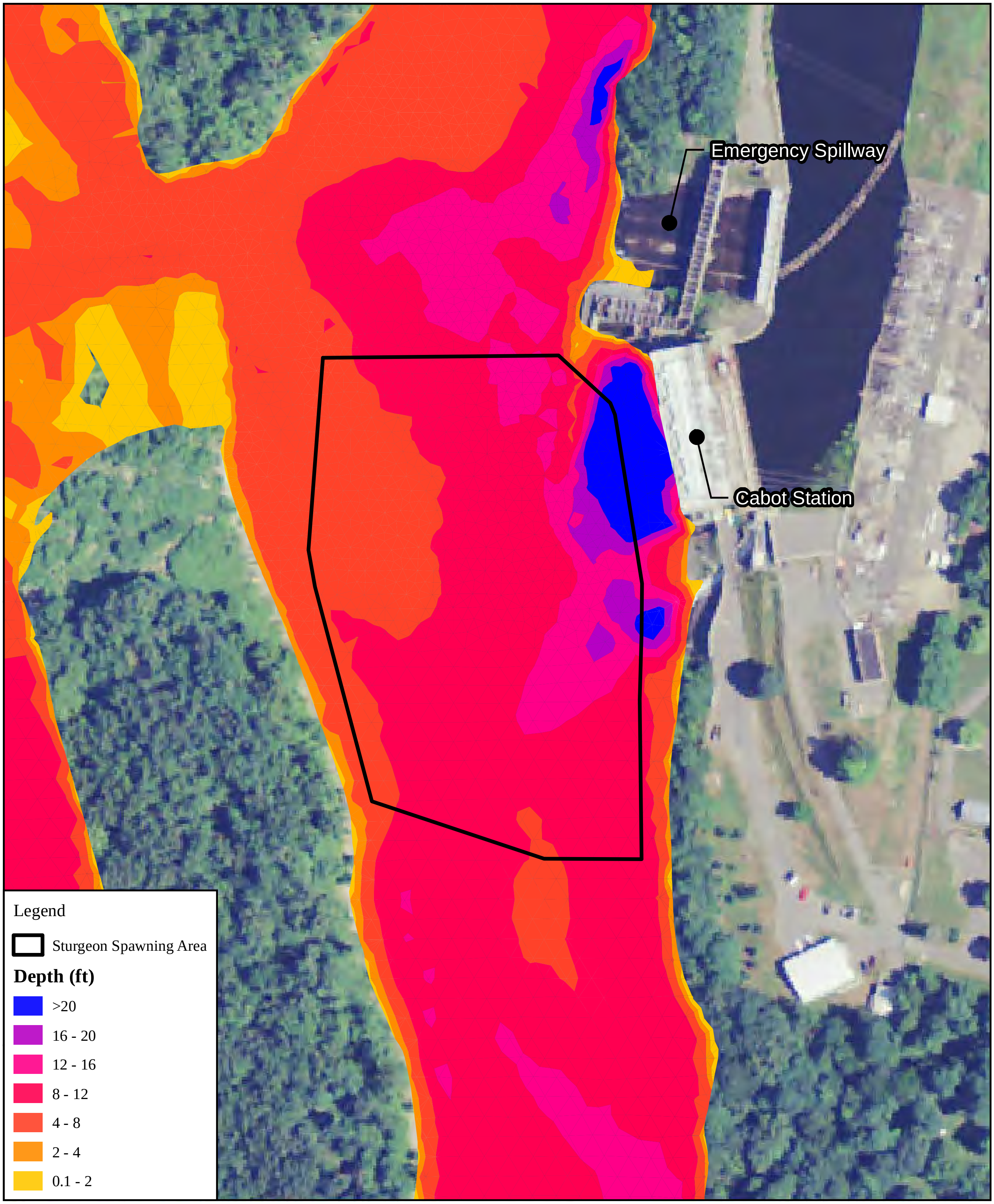
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix C
Depth Scenario B5b:
Bypass Reach 2,500 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B5b.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

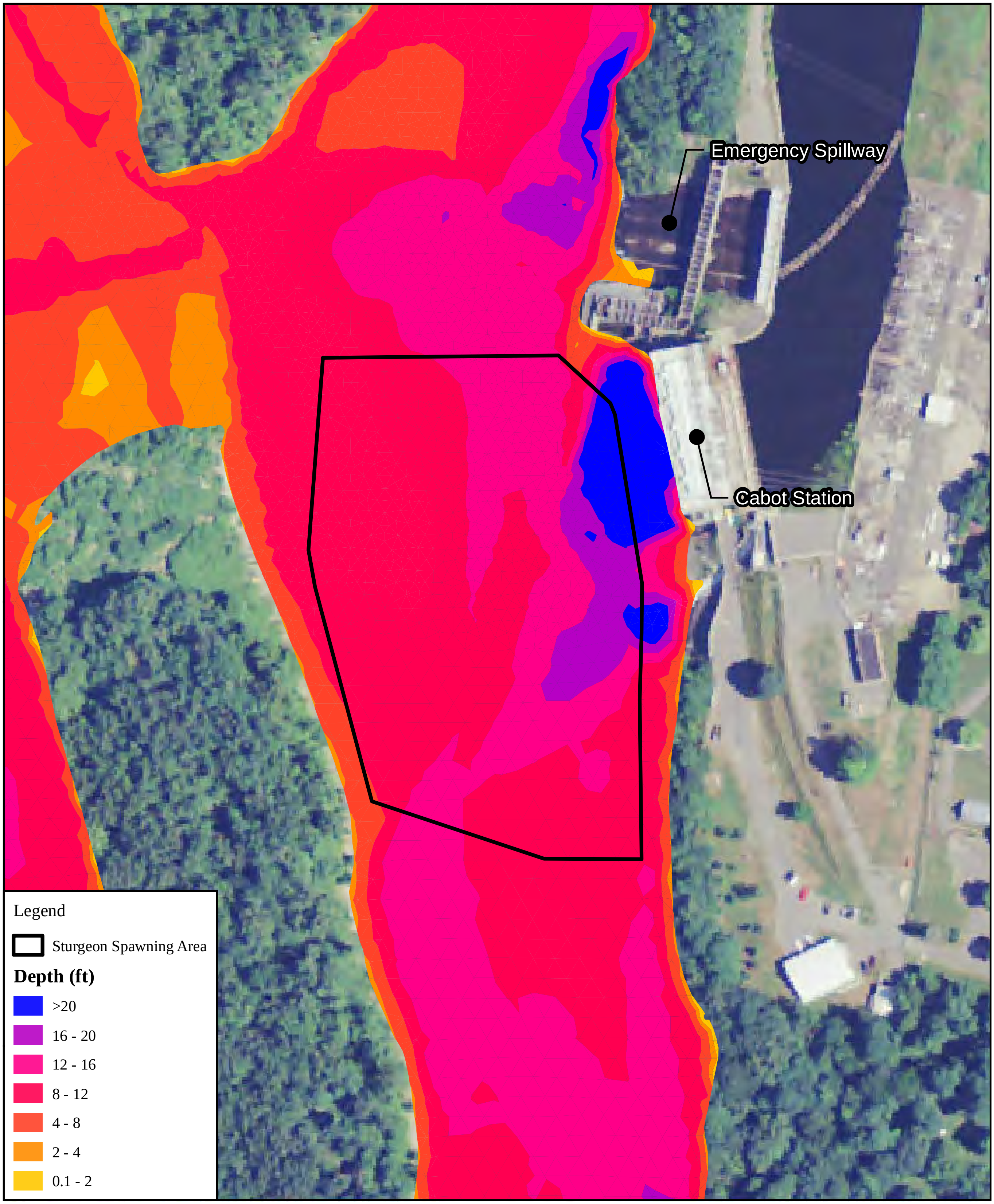
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario B6:
Bypass Reach 10,000 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B6.mxd



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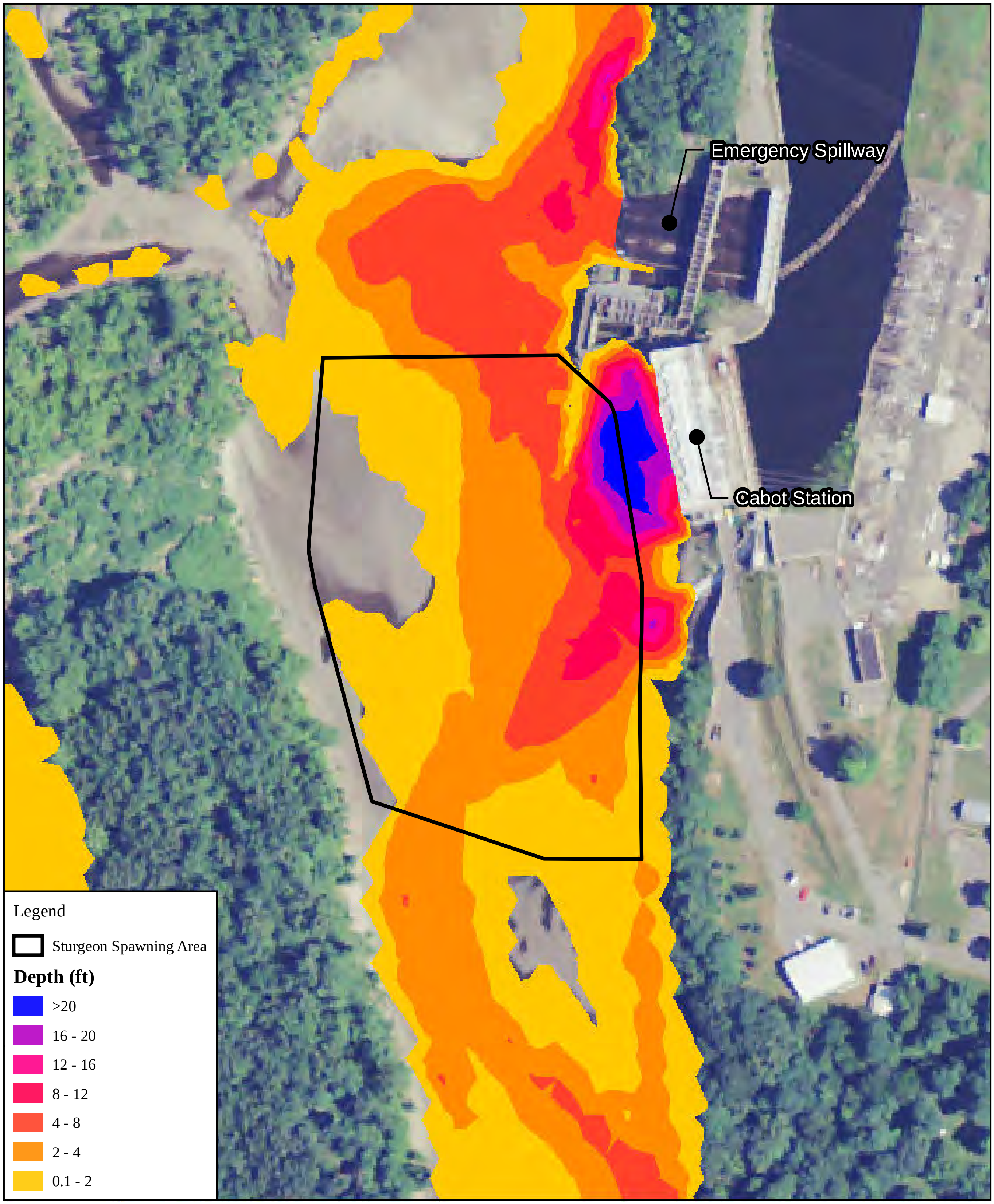
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix C
Depth Scenario B7:
Bypass Reach 20,000 cfs
Cabot Station 14,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 0 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_B7.mxd



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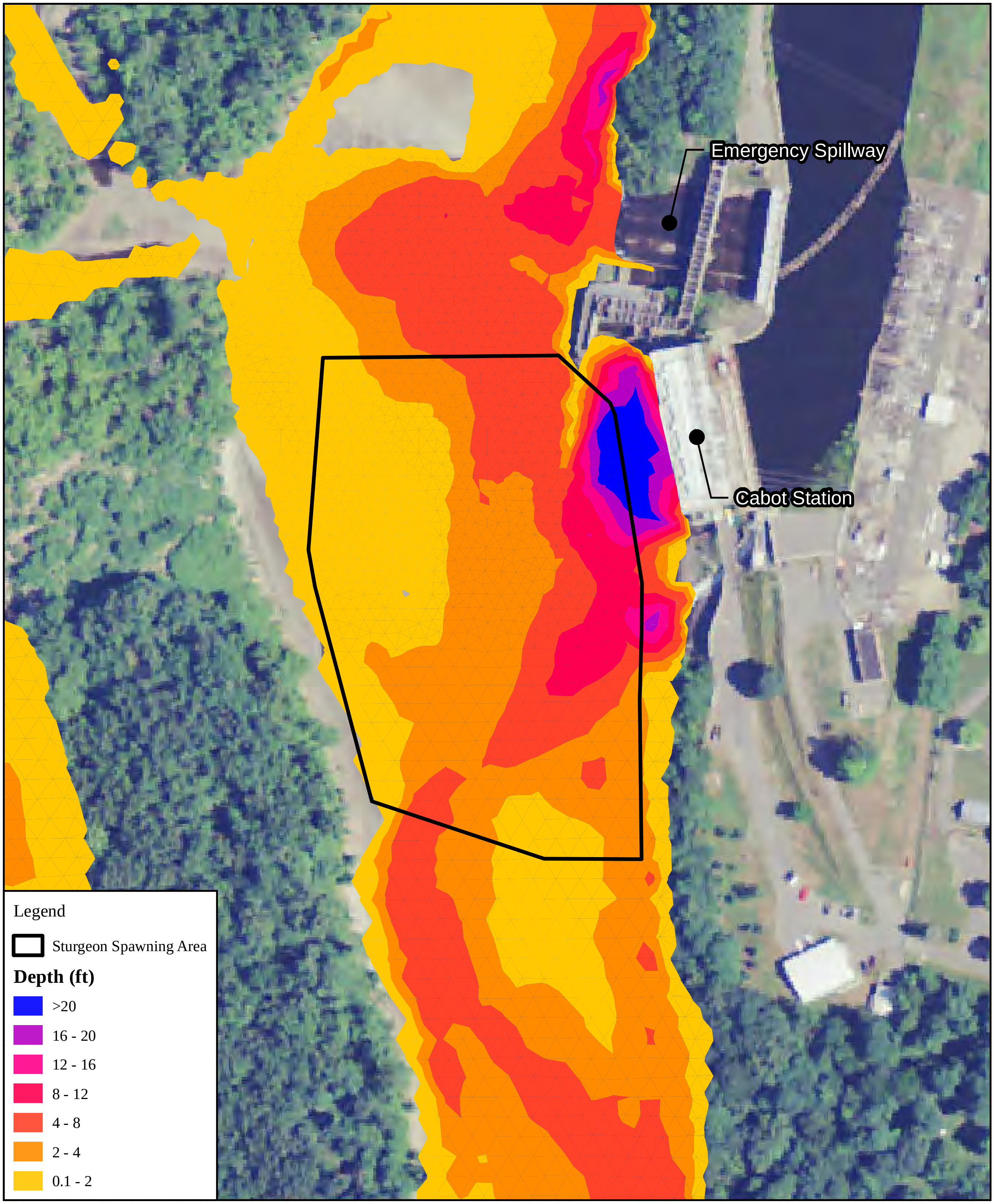
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix C
Depth Scenario E1a S1500:
Bypass Reach 500 cfs
Cabot Station 0 cfs
Deerfield River 200 cfs
Emergency Spillway 1500 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E1a_S1500.mxd



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Turners Falls Hydroelectric Project No. 1889

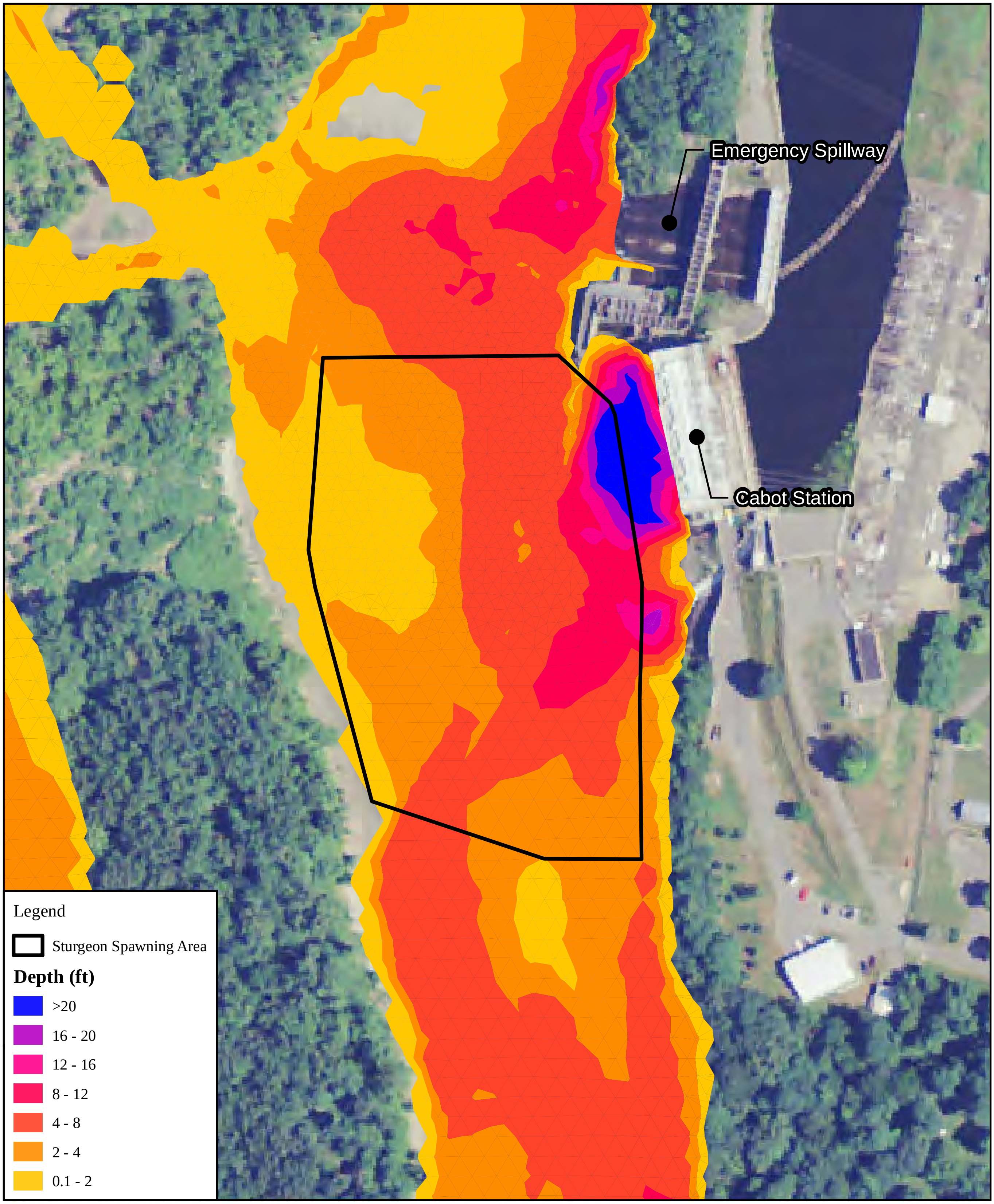
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario E2a S1500:
Bypass Reach 2,500 cfs
Cabot Station 0 cfs
Deerfield River 200 cfs
Emergency Spillway 1,500 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E2a_S1500.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

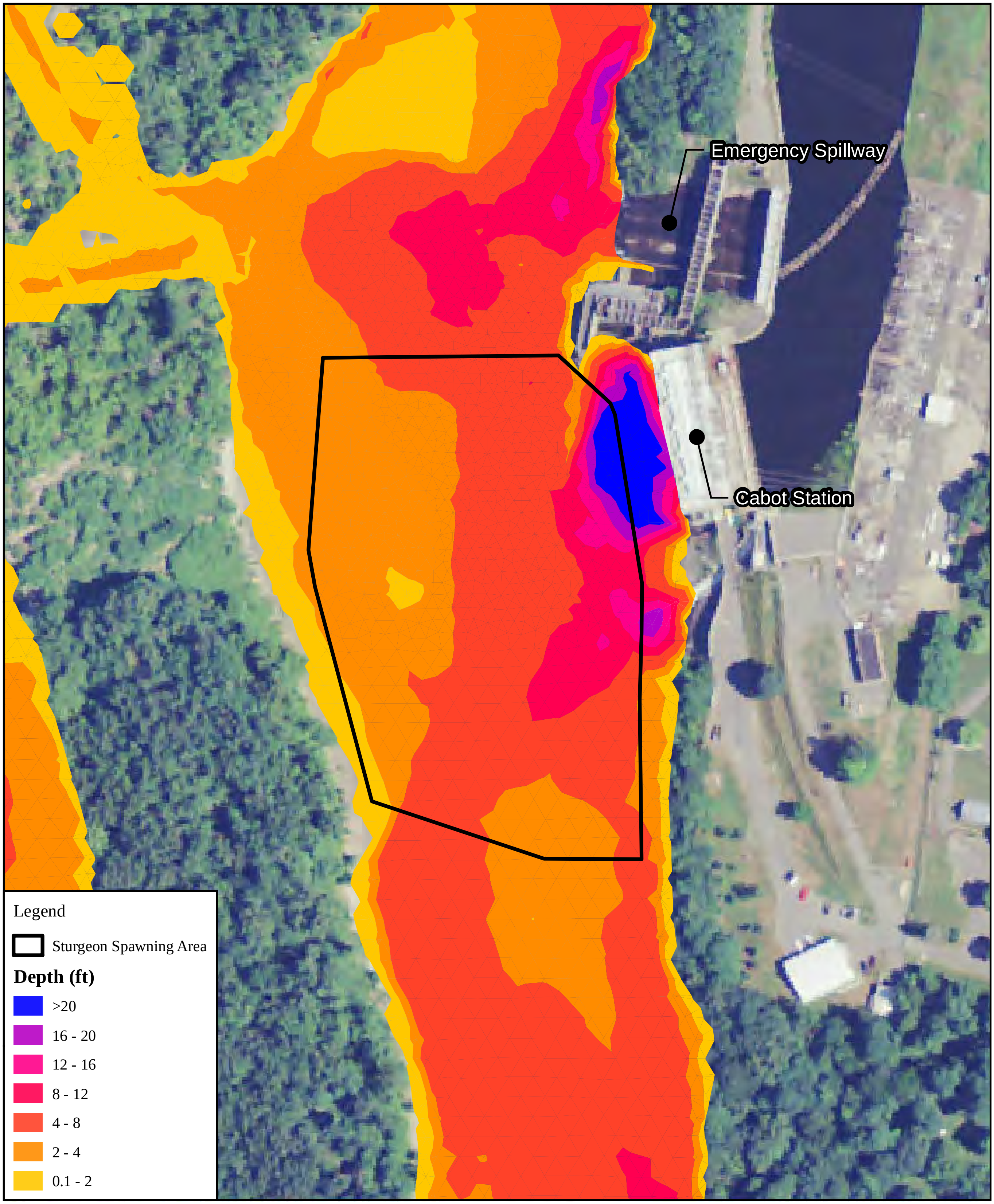
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario E3 S3000:
Bypass Reach 2,500 cfs
Cabot Station 0 cfs
Deerfield River 1,445 cfs
Emergency Spillway 3,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E3_S3000.mxd



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Turners Falls Hydroelectric Project No. 1889

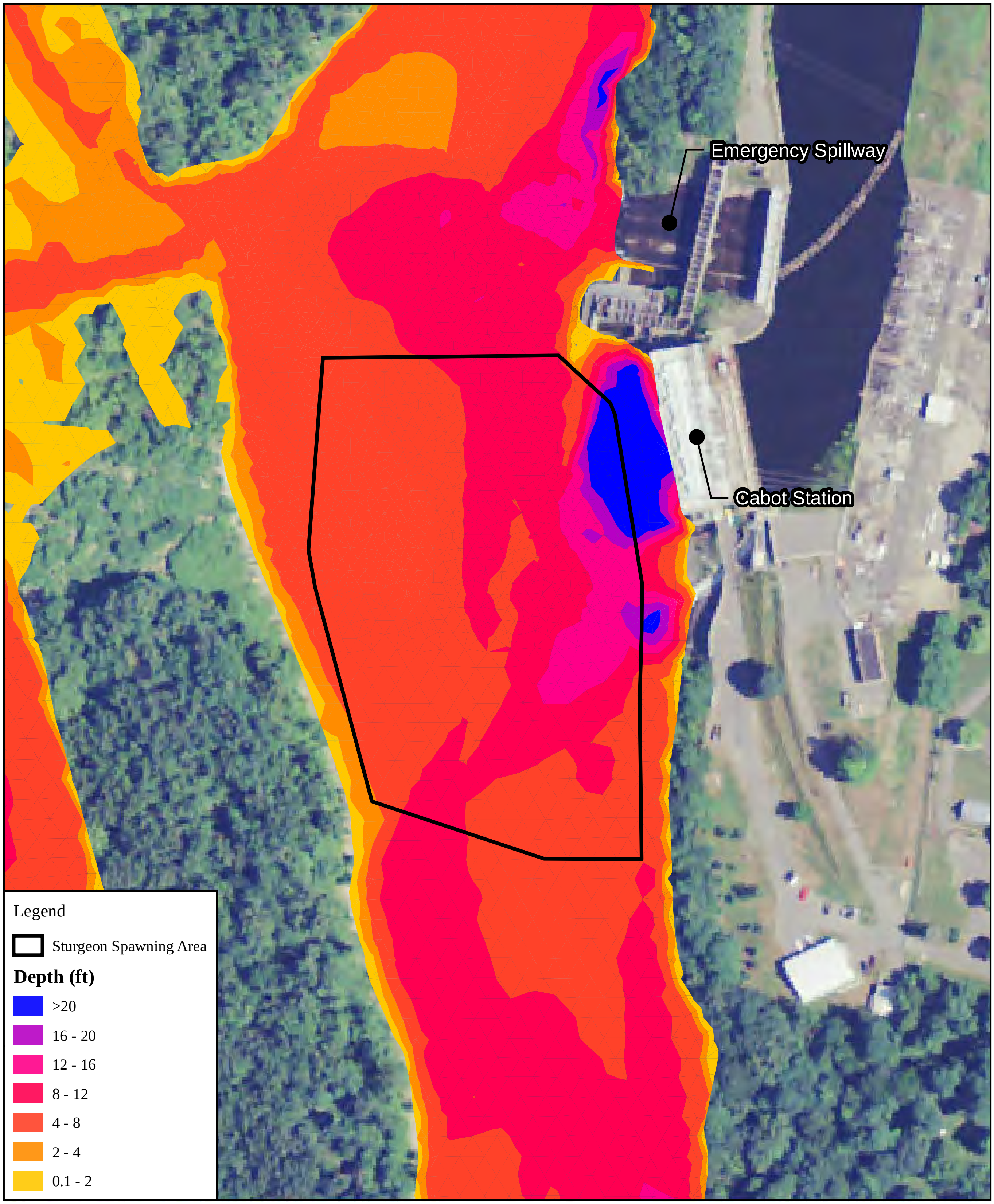
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario E4 S5000:
Bypass Reach 2,500 cfs
Cabot Station 0 cfs
Deerfield River 1,445 cfs
Emergency Spillway 5,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E4_S5000.mxd



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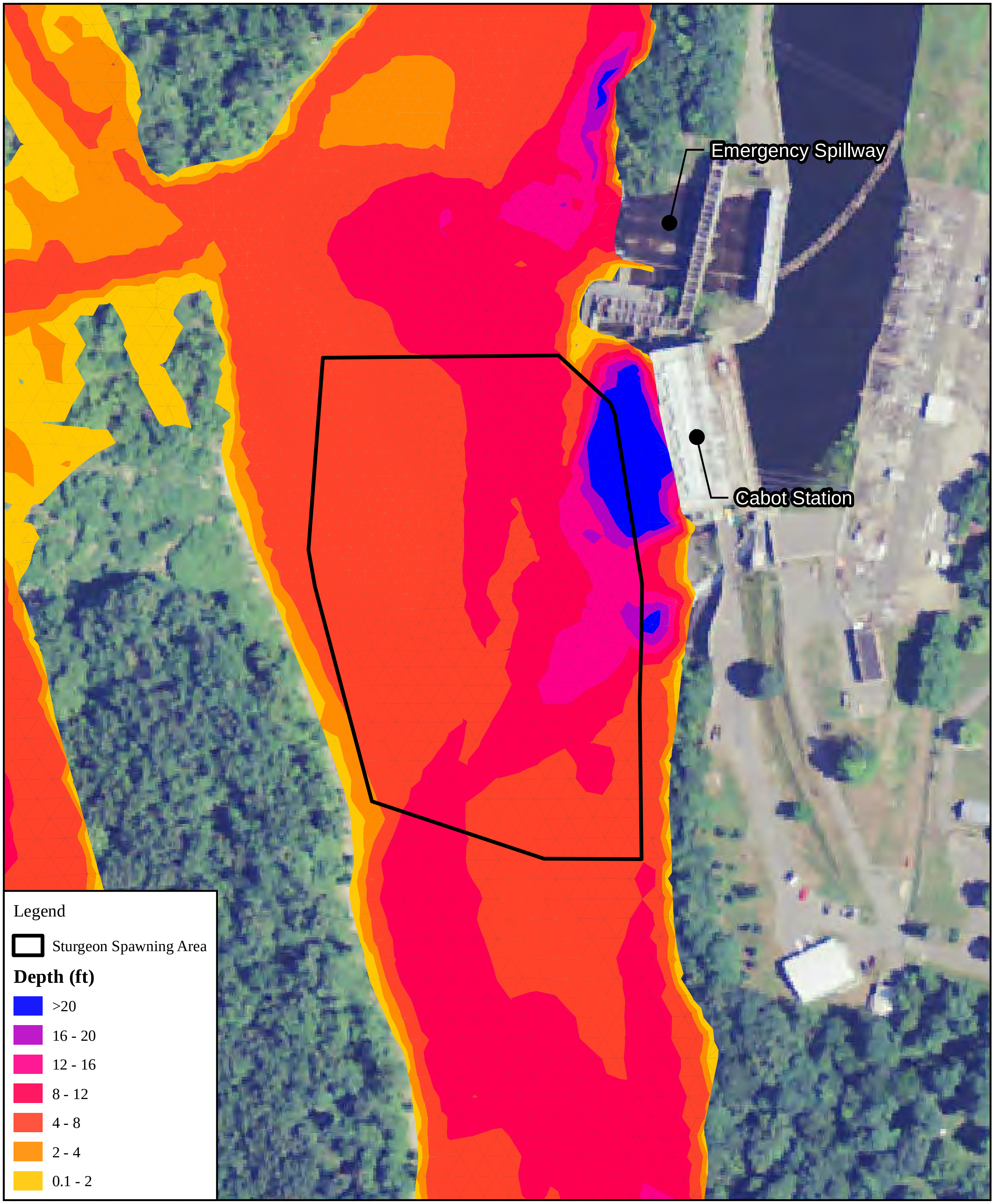
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix C
Depth Scenario E5b S3000:
Bypass Reach 2,500 cfs
Cabot Station 11,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 3,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E5b_S3000.mxd



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Turners Falls Hydroelectric Project No. 1889

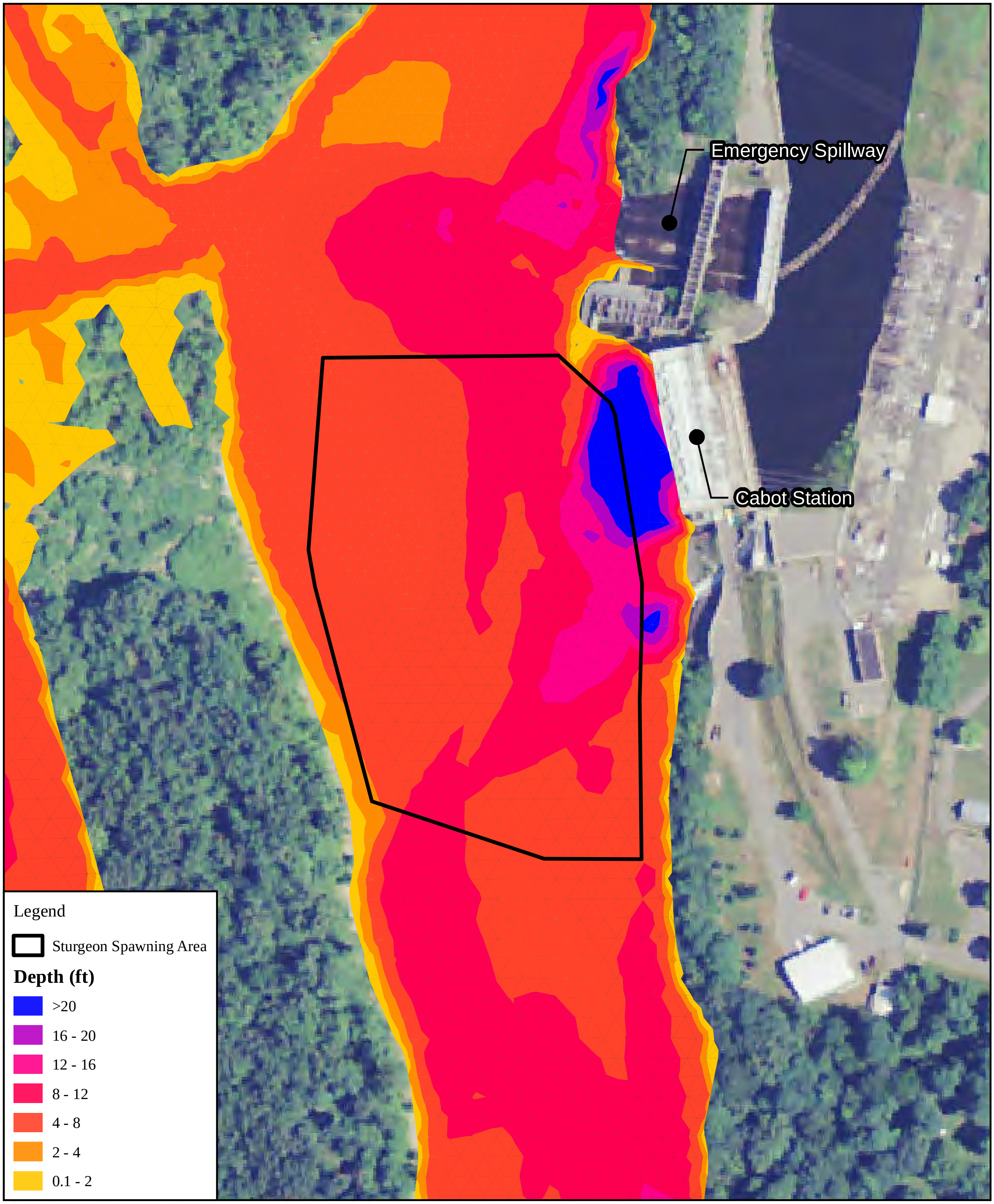
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario E5b S5000:
Bypass Reach 2,500 cfs
Cabot Station 9,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 5,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E5b_S5000.mxd



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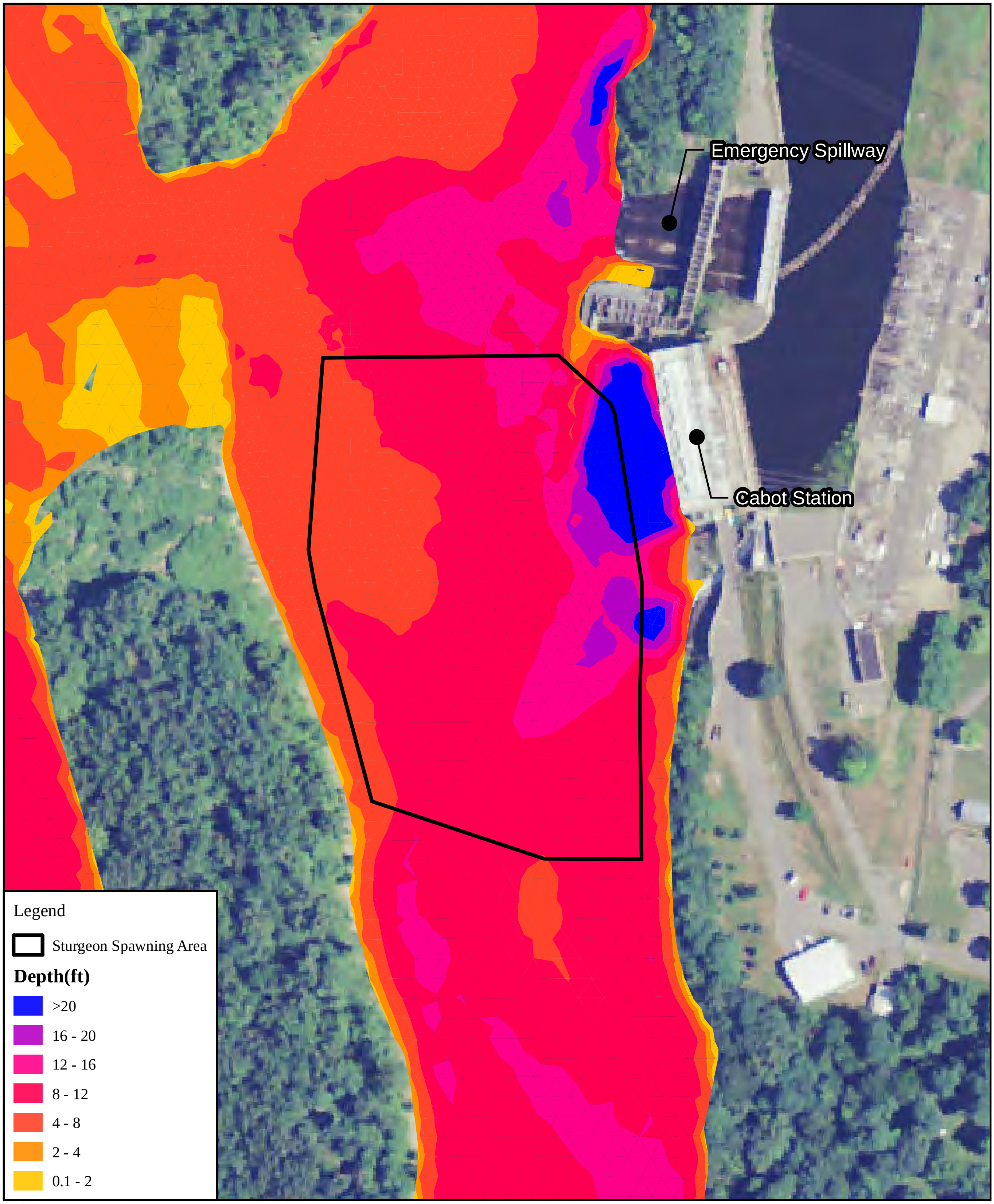
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix C
Depth Scenario E5b S8000:
Bypass Reach 2,500 cfs
Cabot Station 6,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 8,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E5b_S8000.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

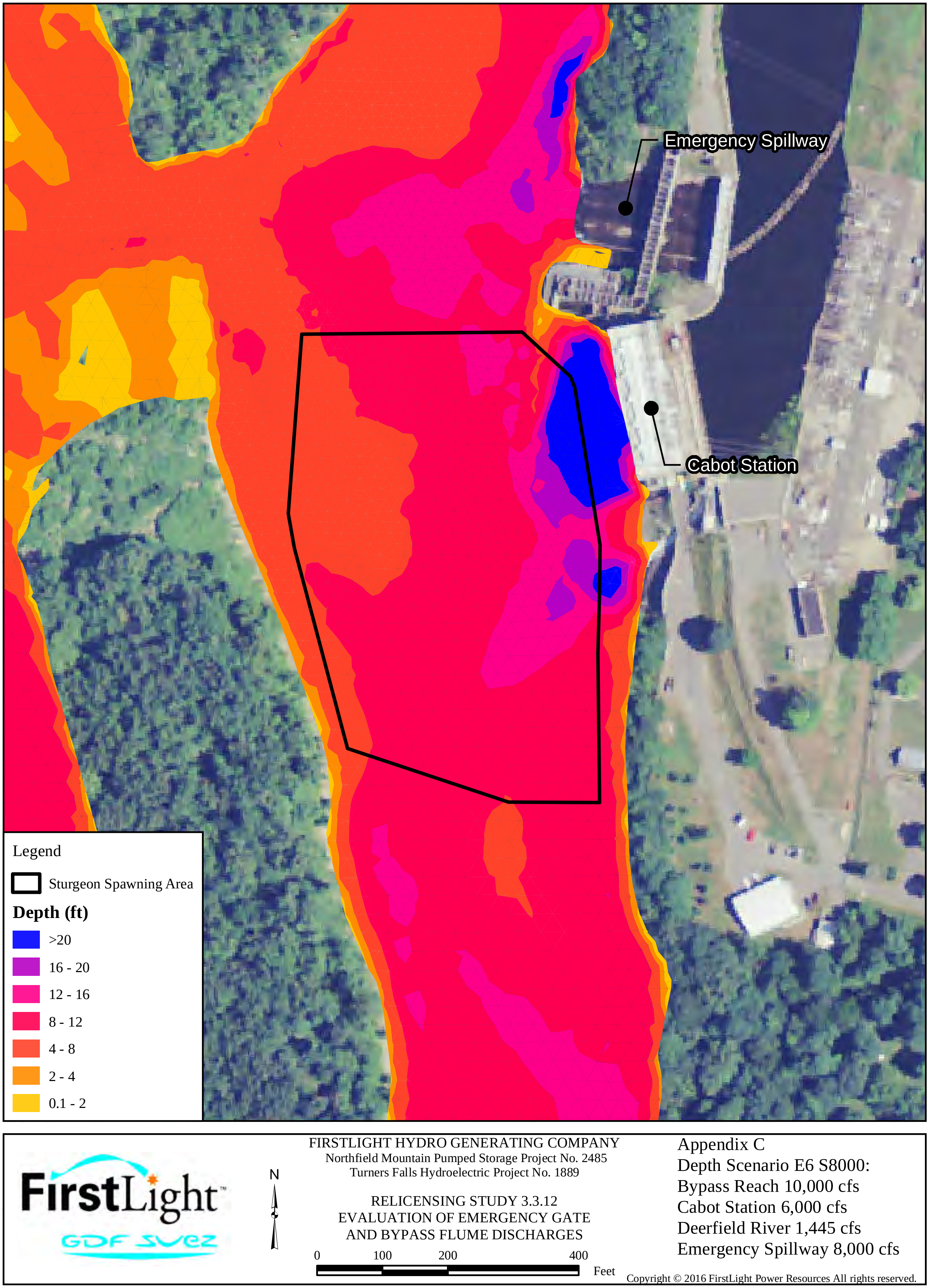
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix C
Depth Scenario E6 S5000:
Bypass Reach 10,000 cfs
Cabot Station 9,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 5,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E6_S5000.mxd



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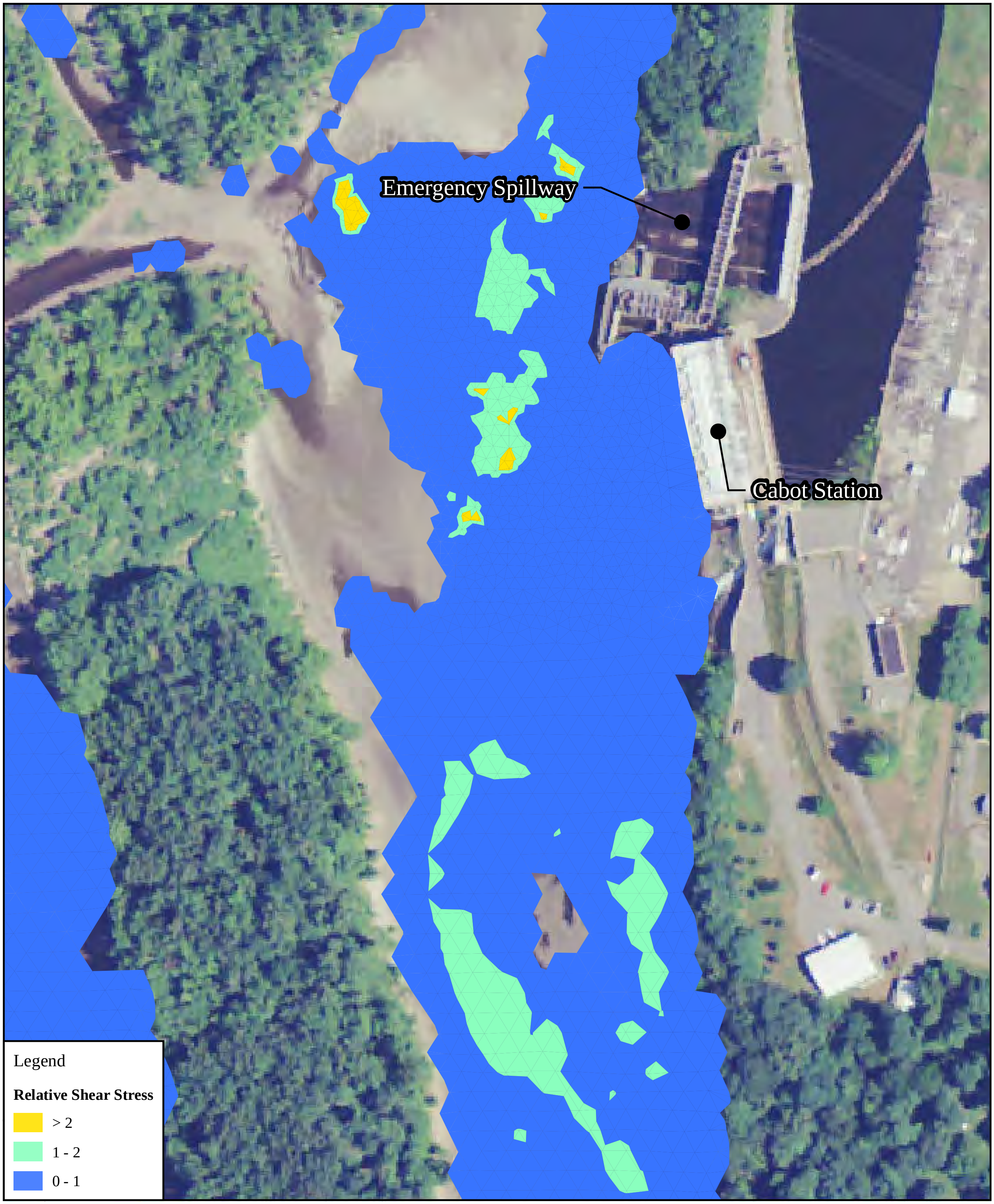
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

Appendix C
Depth Scenario E6 S8000:
Bypass Reach 10,000 cfs
Cabot Station 6,000 cfs
Deerfield River 1,445 cfs
Emergency Spillway 8,000 cfs

Path: W:\gis\studies\3_3_12\maps\depth_scenario_E6_S8000.mxd

APPENDIX D – MODELED RELATIVE SHEAR STRESS MAPS



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Turners Falls Hydroelectric Project No. 1889

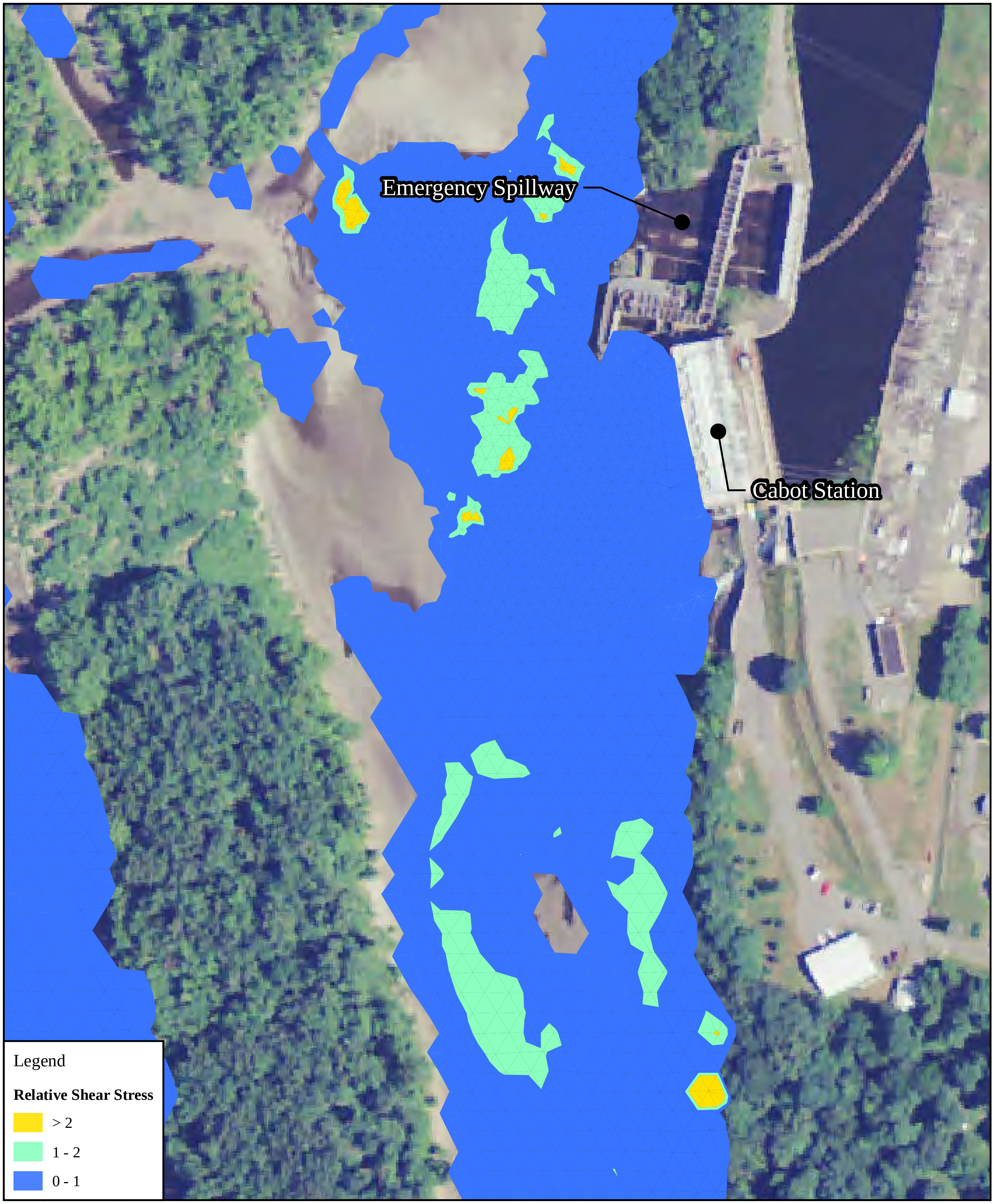
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B1a

Path: W:\gis\studies\3_3_12\maps\RSS_B1a.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY
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Turners Falls Hydroelectric Project No. 1889

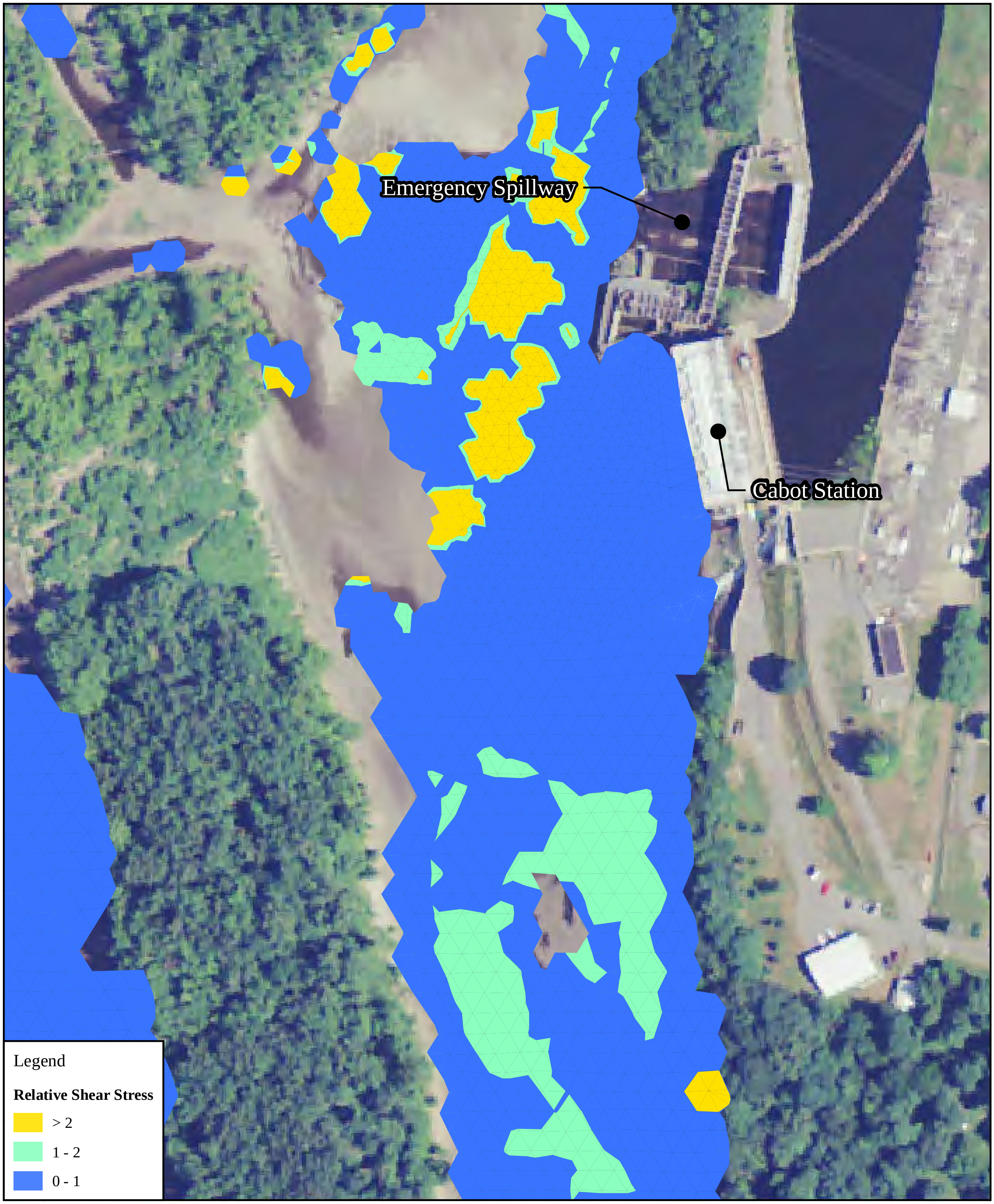
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B1b

Path: W:\gis\studies\3_3_12\maps\RSS_B1b.mxd



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Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B2a

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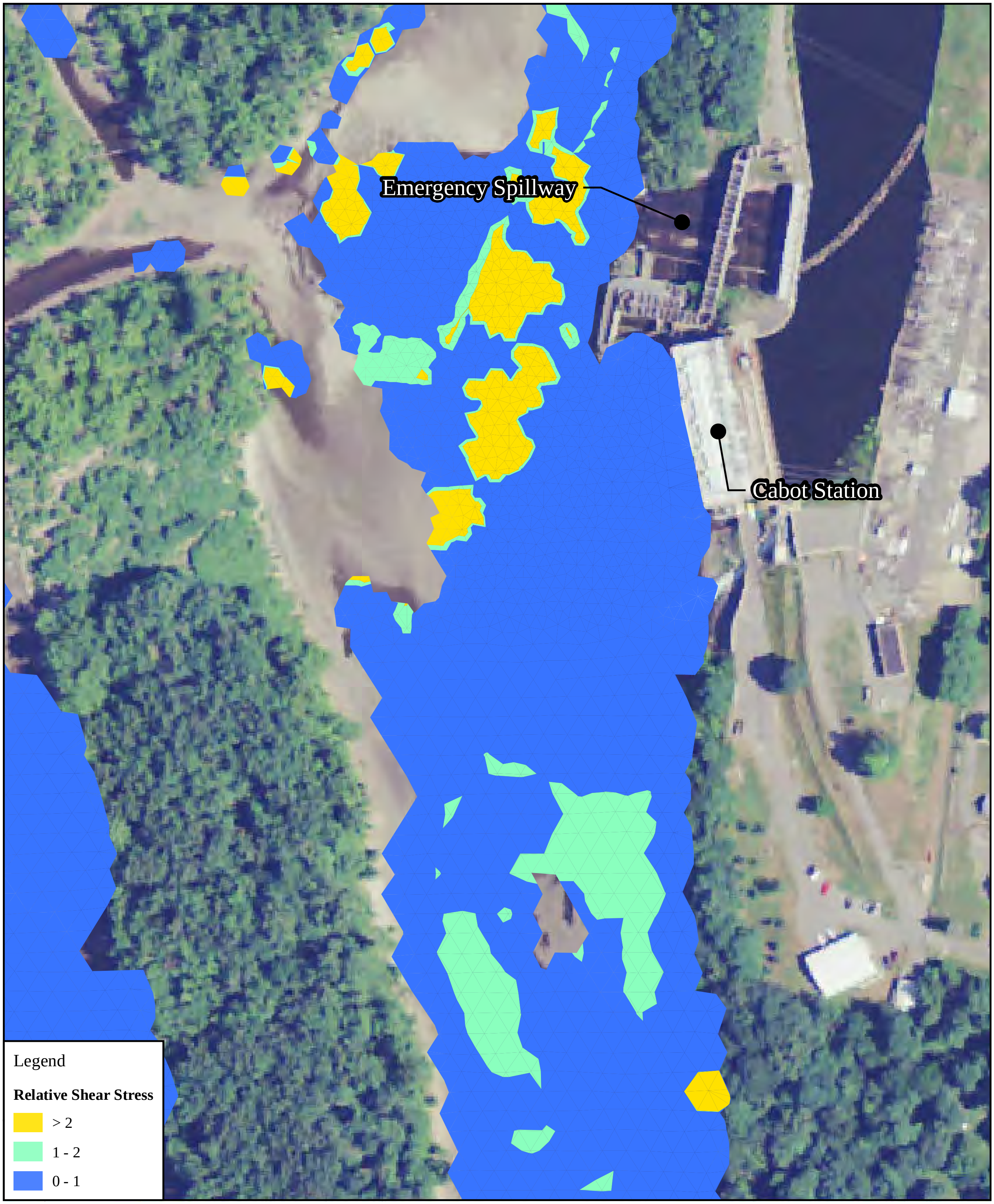

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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

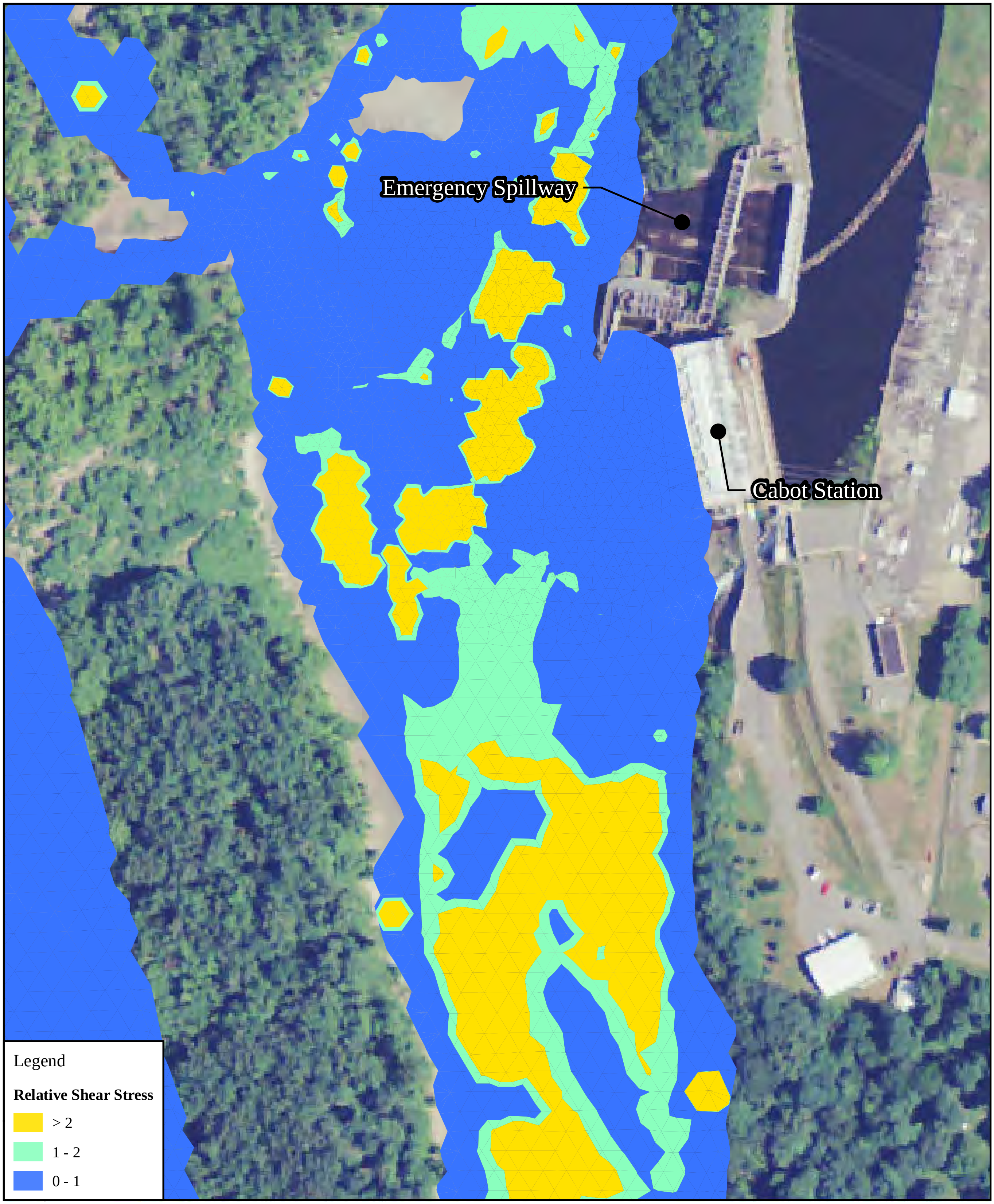
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B2b

Path: W:\gis\studies\3_3_12\maps\RSS_B2b.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

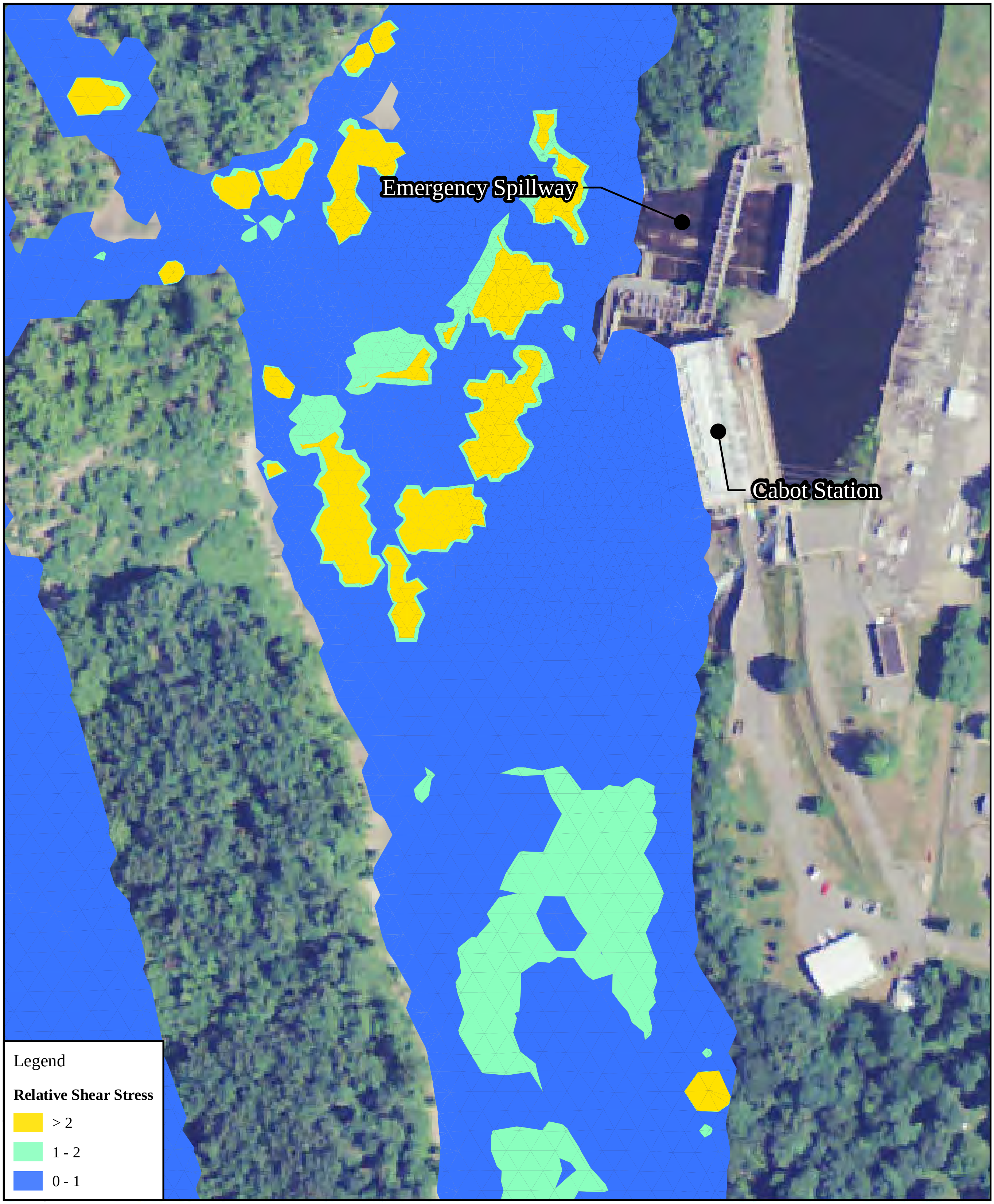
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B3

Path: W:\gis\studies\3_3_12\maps\RSS_B3.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

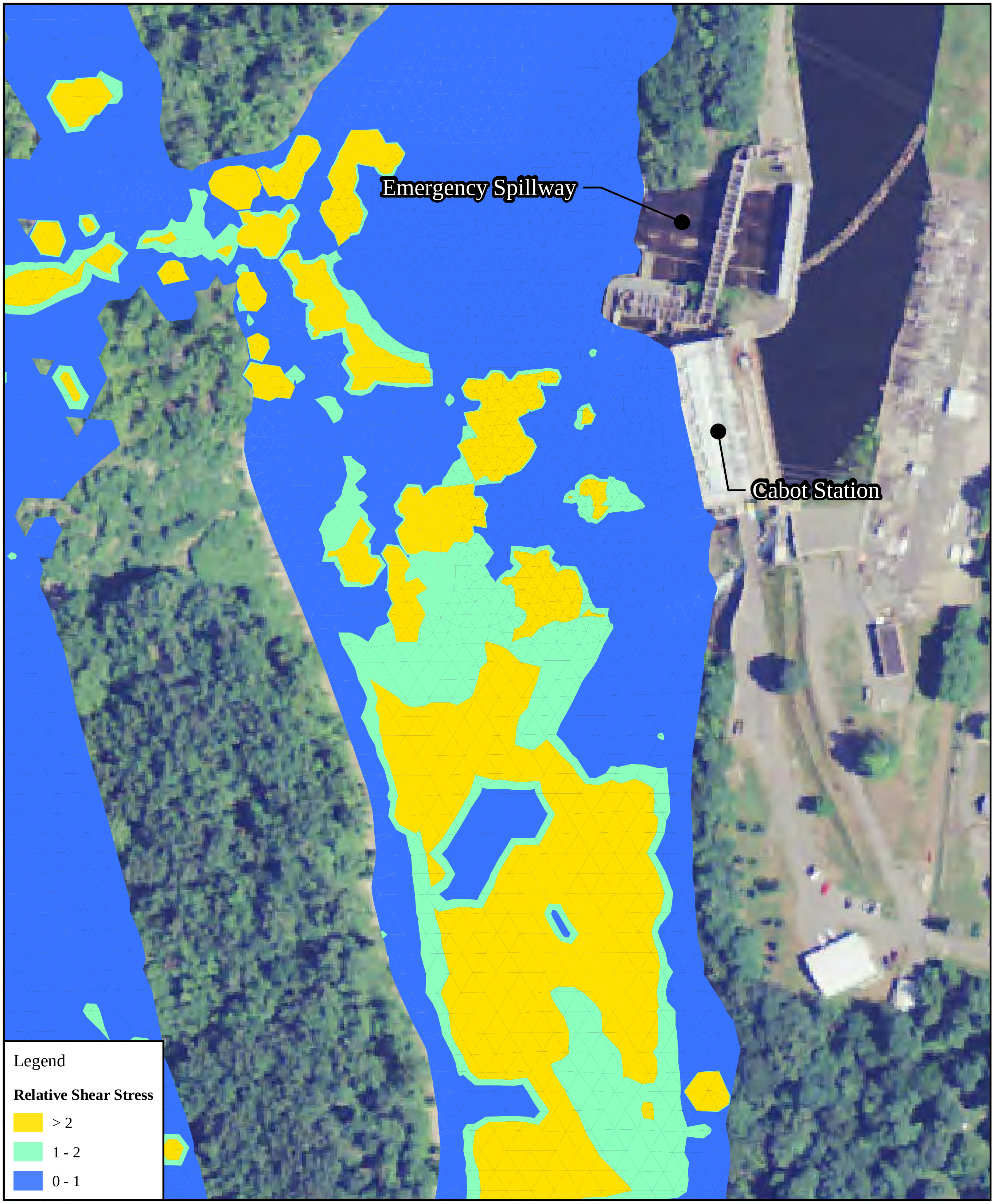
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B4

Path: W:\gis\studies\3_3_12\maps\RSS_B4.mxd



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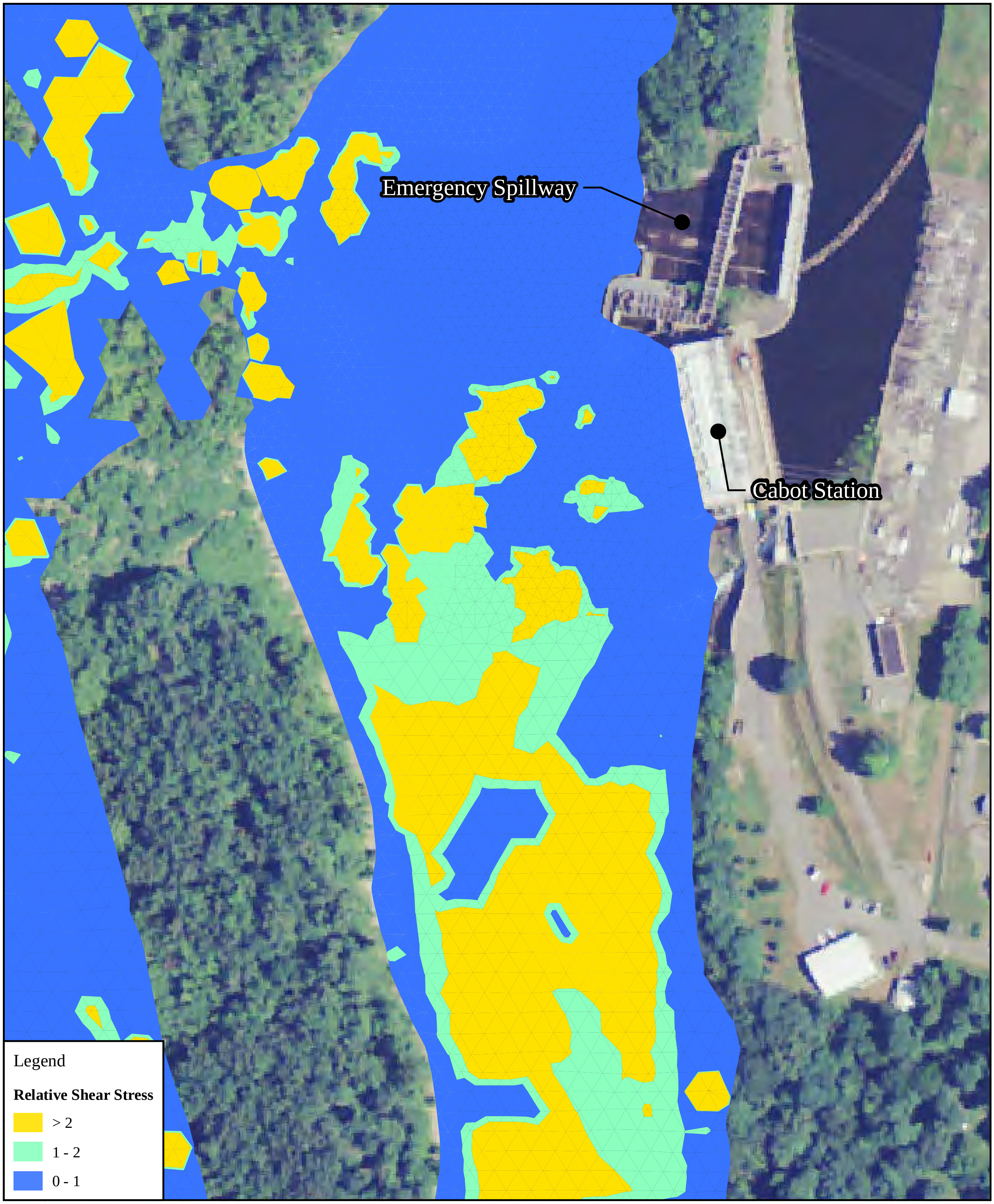
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario B5a

Path: W:\gis\studies\3_3_12\maps\RSS_B5a.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
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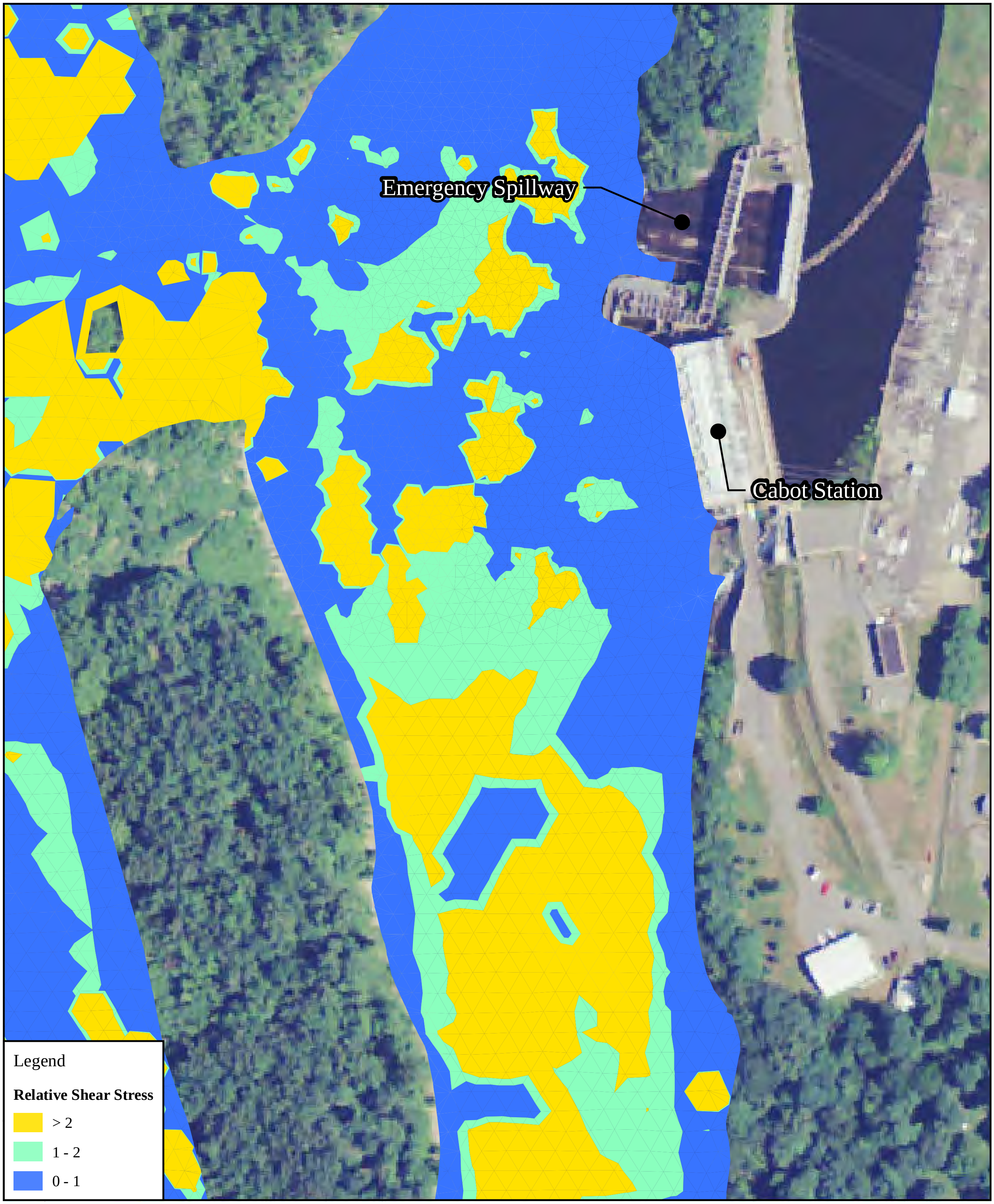
N

0 100 200 400 Feet

Appendix D
RSS Scenario B5b

Path: W:\gis\studies\3_3_12\maps\RSS_B5b.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
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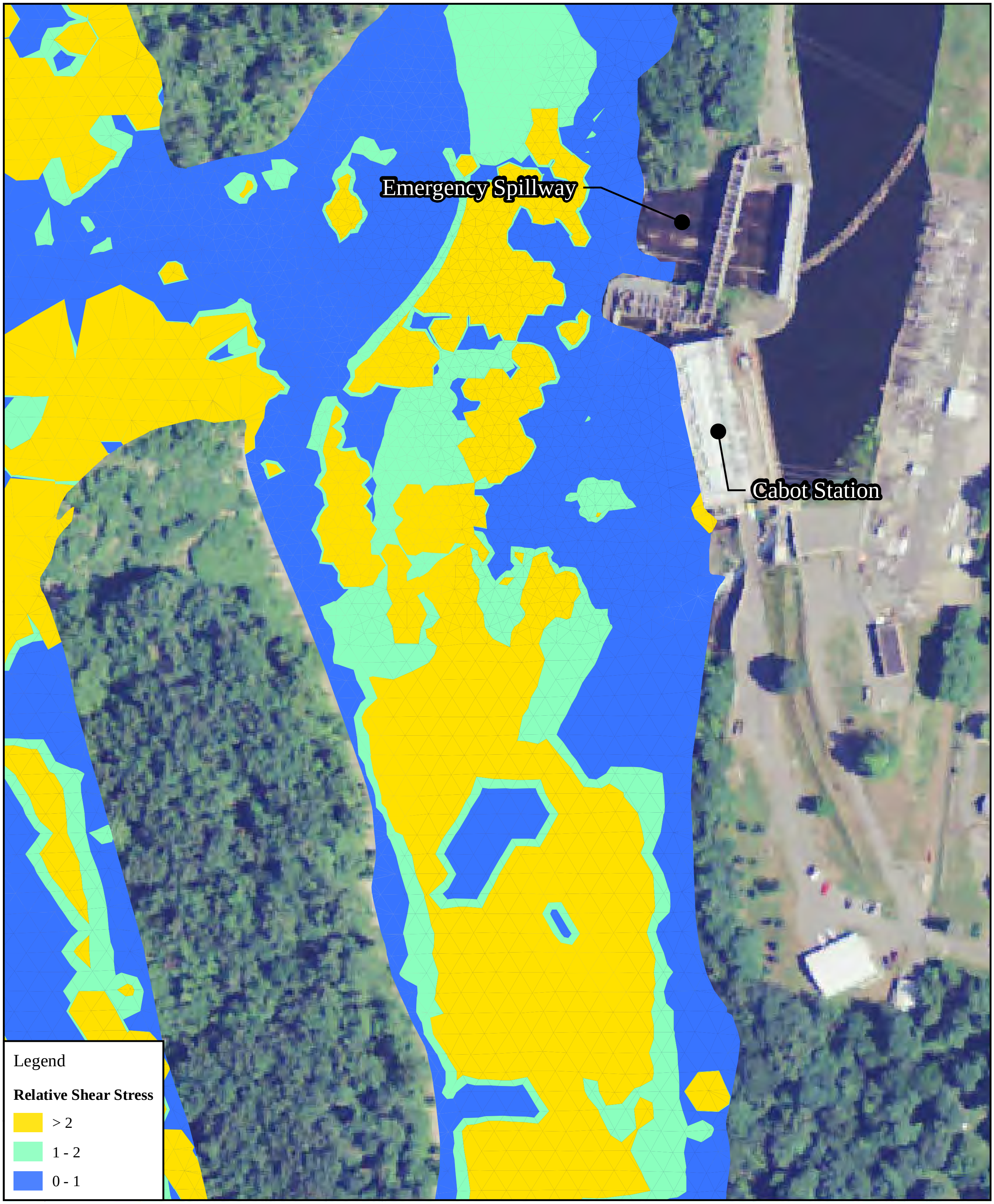
0 100 200 400
Feet

Appendix D
RSS Scenario B6

Path: W:\gis\studies\3_3_12\maps\RSS_B6.mxd



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N

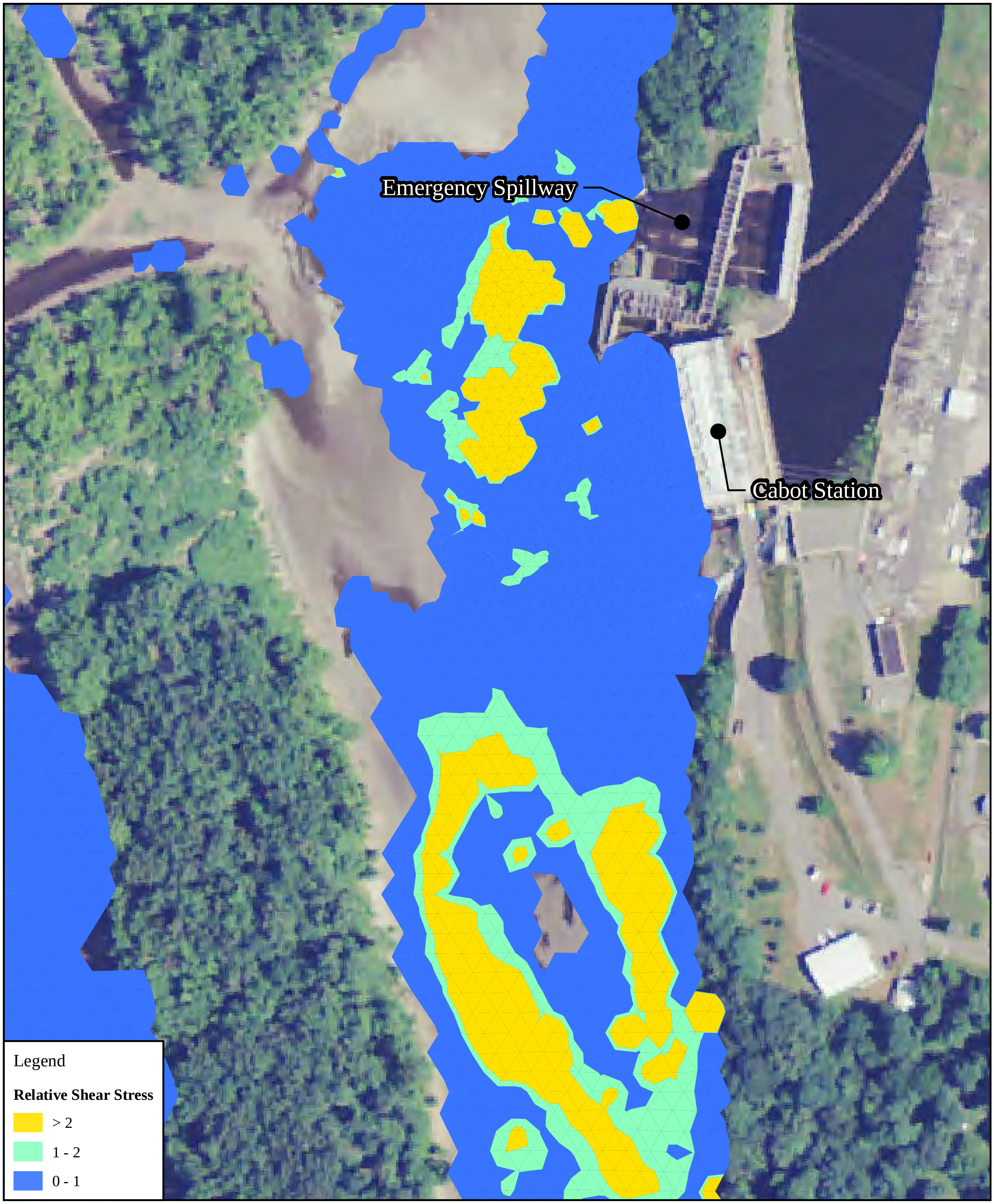
FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix D
RSS Scenario B7

Path: W:\gis\studies\3_3_12\maps\RSS_B7.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

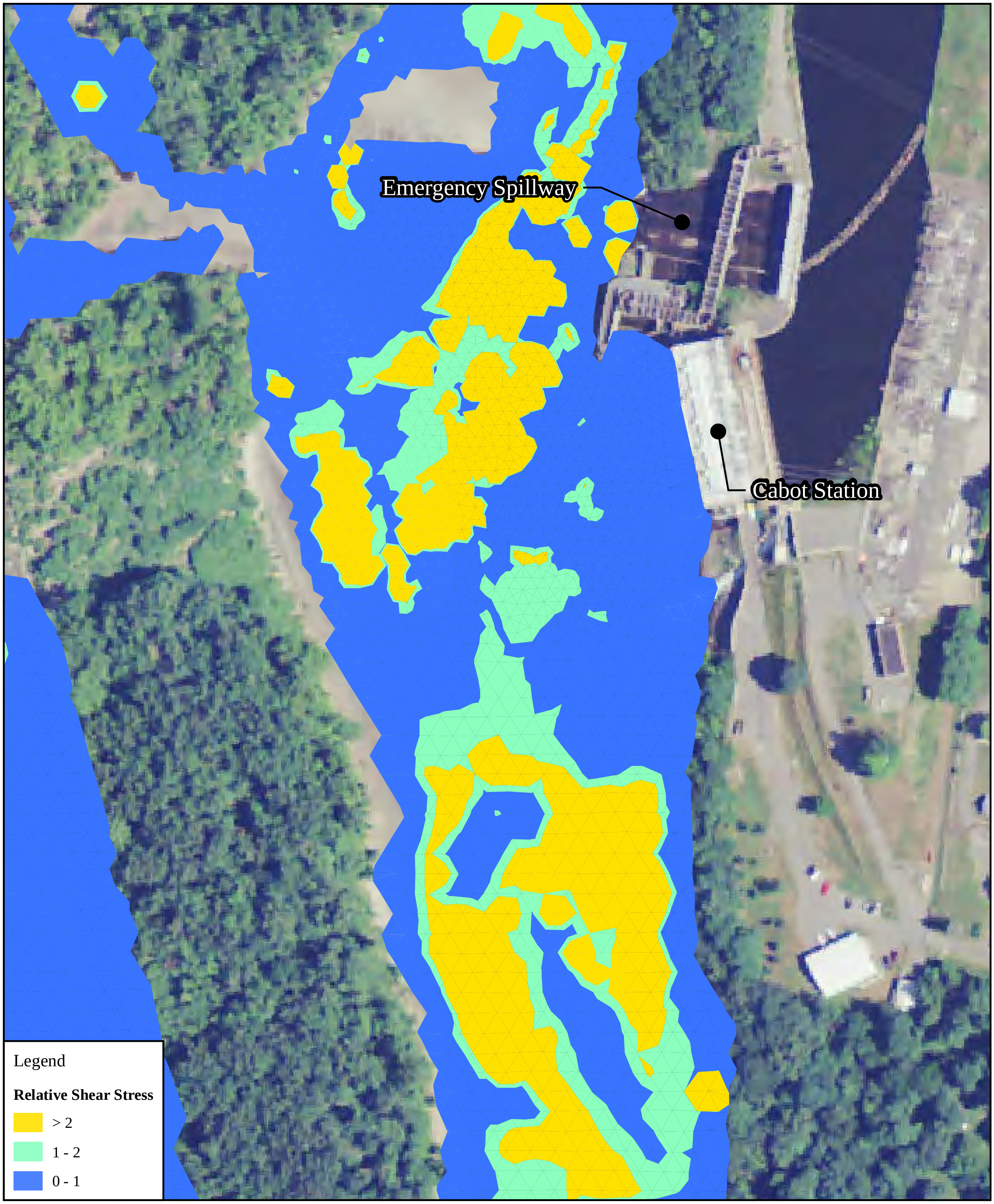
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario E1a

Path: W:\gis\studies\3_3_12\maps\RSS_E1a.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
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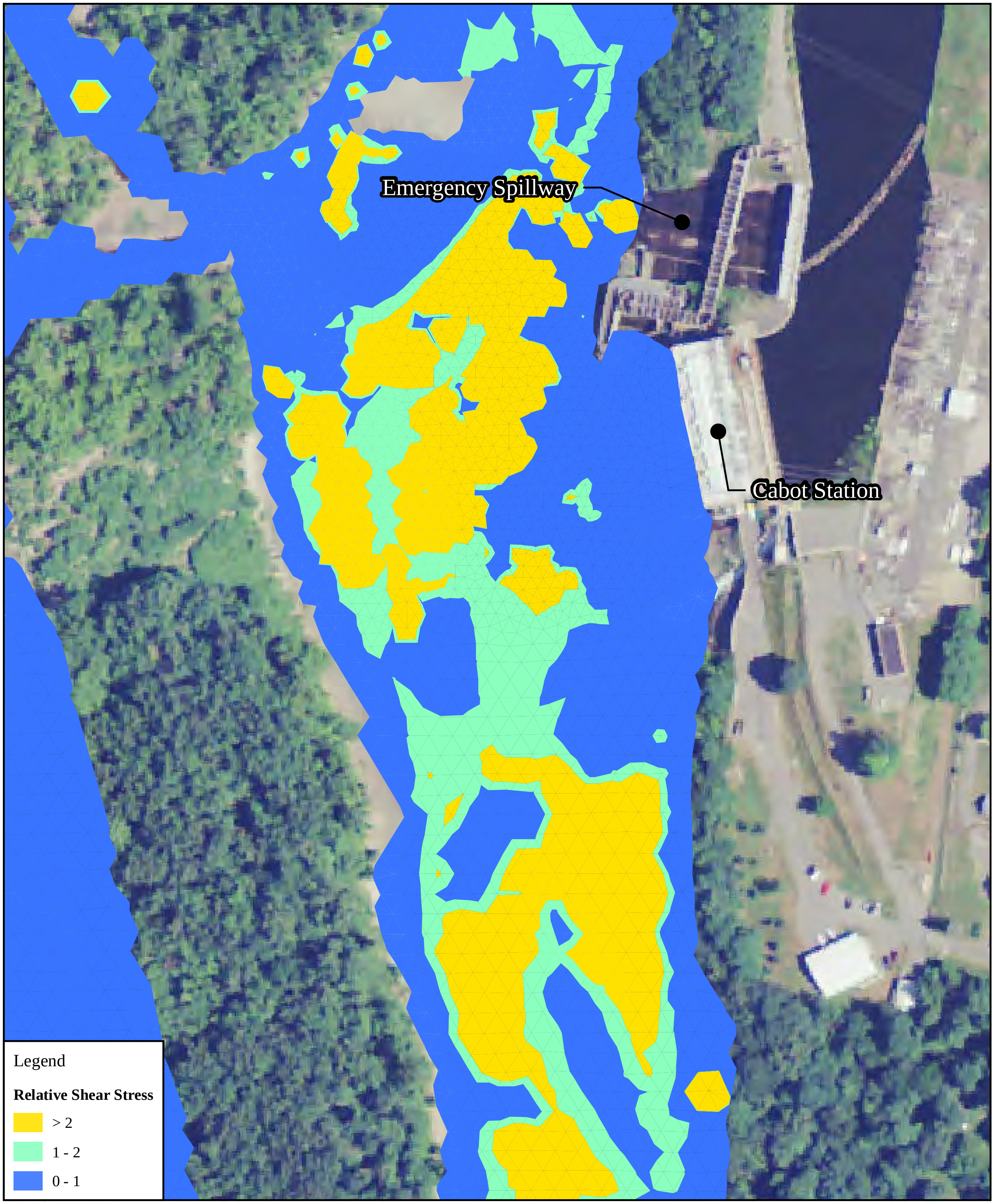
N

0 100 200 400 Feet

Appendix D
RSS Scenario E2a

Path: W:\gis\studies\3_3_12\maps\RSS_E2a.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
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RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
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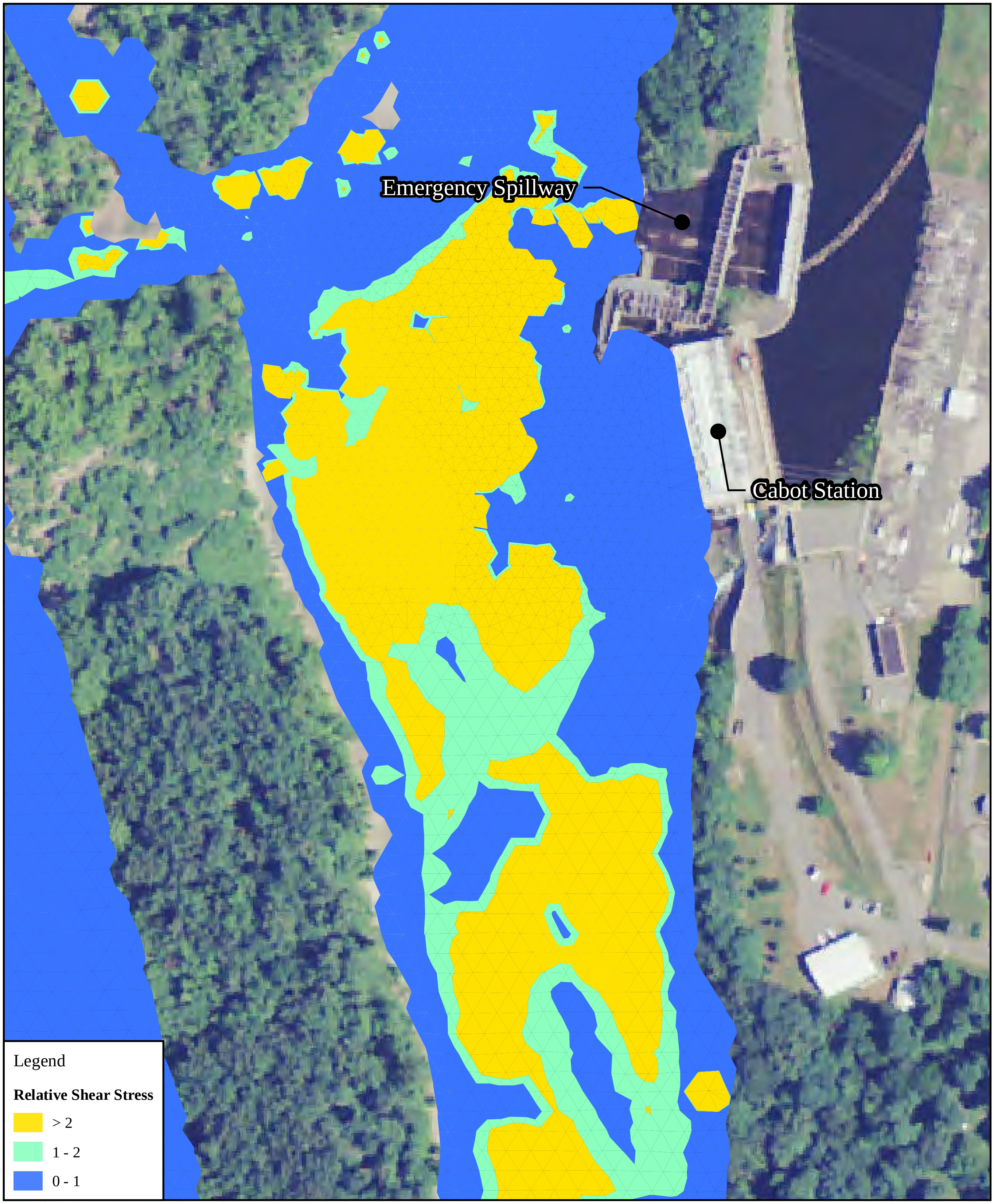
N

0 100 200 400 Feet

Appendix D
RSS Scenario E3

Path: W:\gis\studies\3_3_12\maps\RSS_E3.mxd



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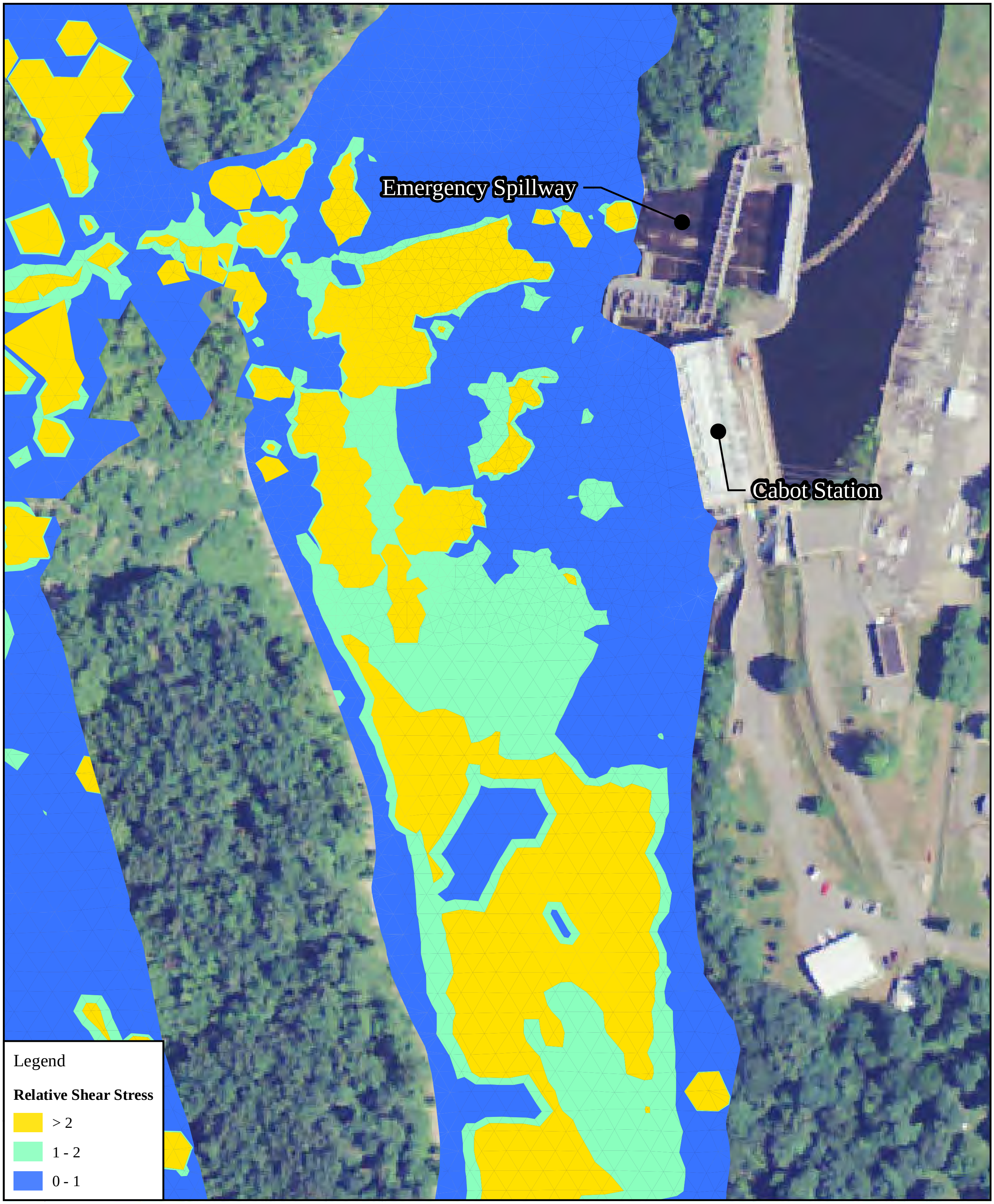
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

0 100 200 400 Feet

Appendix E
RSS Scenario E4

Path: W:\gis\studies\3_3_12\maps\RSS_E4.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
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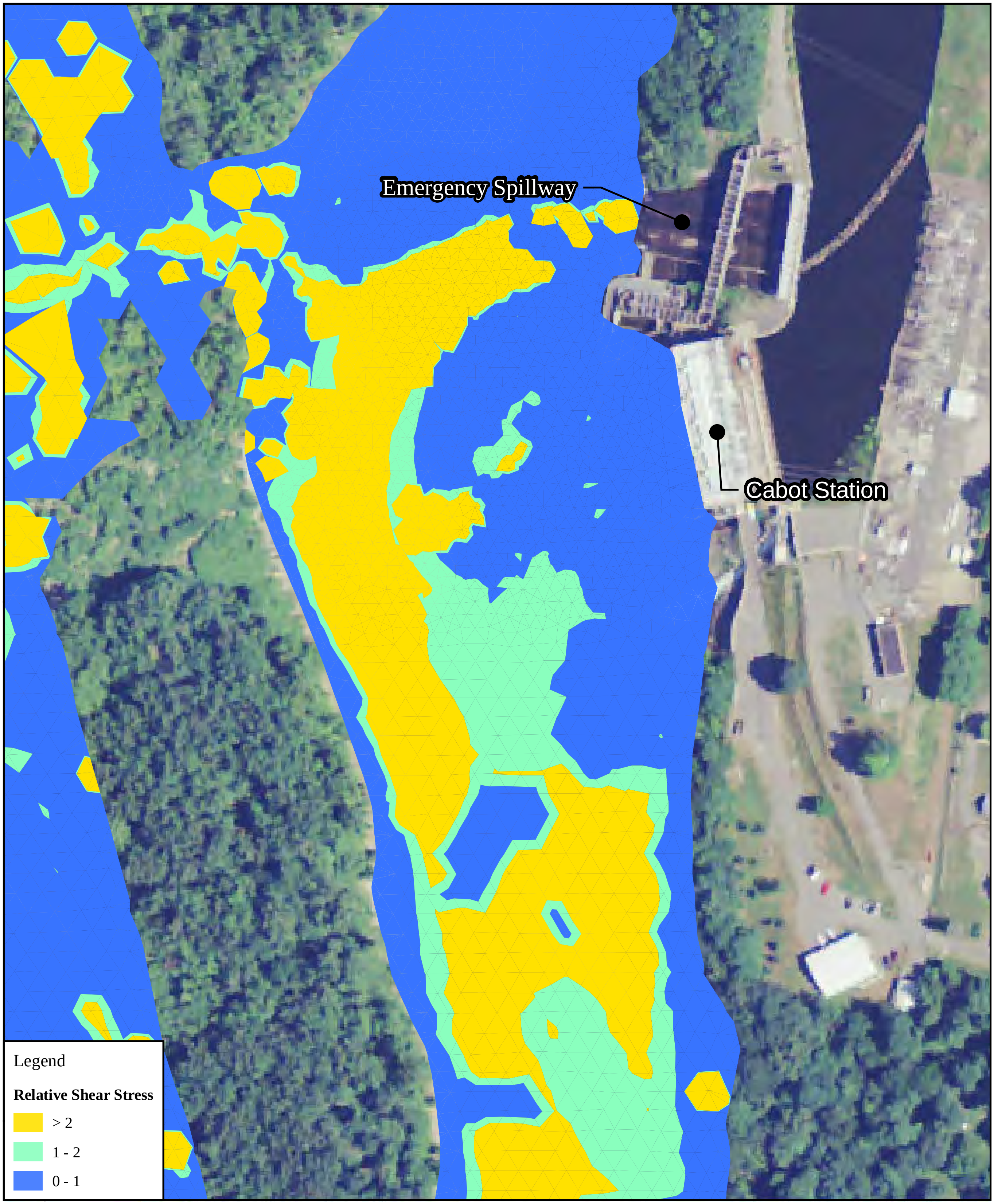
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario E5b S3000

Path: W:\gis\studies\3_3_12\maps\RSS_E5b_S3000.mxd



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FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
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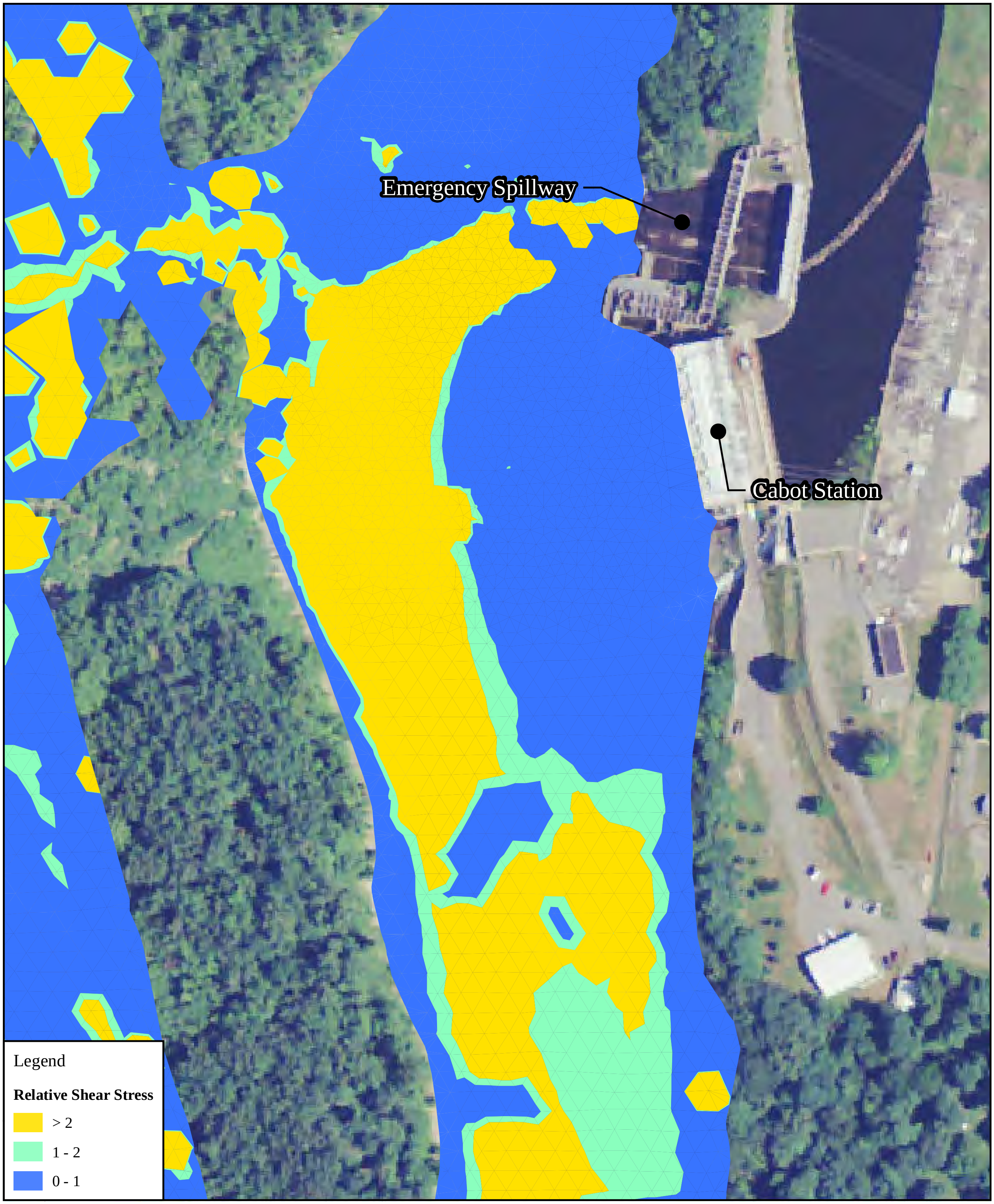
0 100 200 400 Feet

Appendix D
RSS Scenario E5b S5000

Path: W:\gis\studies\3_3_12\maps\RSS_E5b_S5000.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

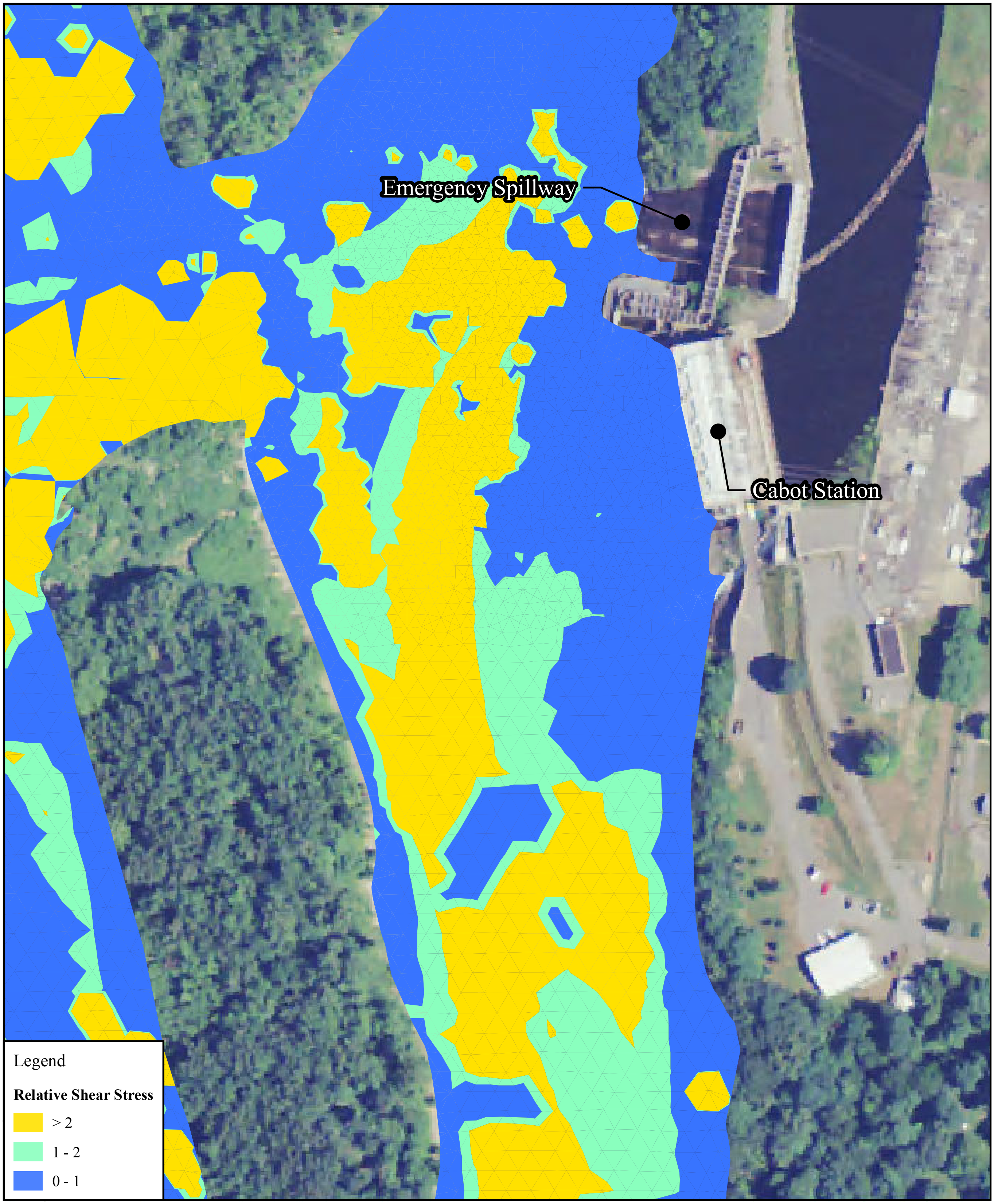
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario E5b S8000

Path: W:\gis\studies\3_3_12\maps\RSS_E5b_S8000.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

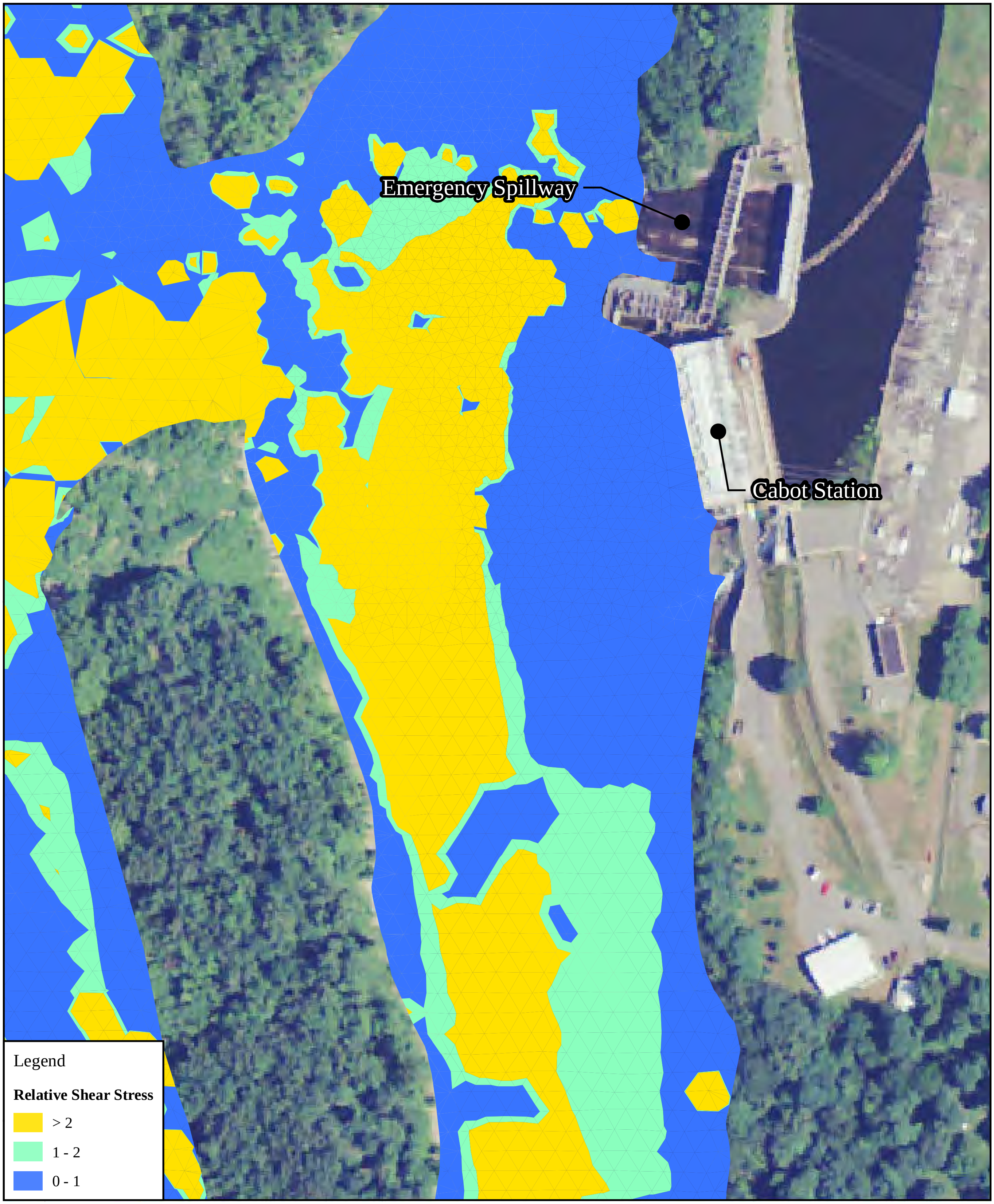
RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario E6 S5000

Path: W:\gis\studies\3_3_12\maps\RSS_E6_S5000.mxd



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Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889

RELICENSING STUDY 3.3.12
EVALUATION OF EMERGENCY GATE
AND BYPASS FLUME DISCHARGES

N

0 100 200 400 Feet

Appendix D
RSS Scenario E6 S8000

Path: W:\gis\studies\3_3_12\maps\RSS_E6_S8000.mxd