

HYDROLOGIC AND HYDRAULIC ASSESSMENT

SHADOW LAKE DAM

VT DEC ID NO. 81.02

Town of Glover, Vermont
Orleans County

Prepared for:
Vermont Department of Environmental Conservation
Dam Safety Program



Prepared by:

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D&K #127862

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SHADOW LAKE DAM GLOVER, VERMONT

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1.0 INTRODUCTION / BACKGROUND

DuBois & King, Inc. (D&K) has completed a hydrologic and hydraulic (H&H) analysis, dam breach assessment, flood inundation maps, and evaluation of dam hazard classification of Shadow Lake Dam in Glover, VT. The dam is owned and operated by the Town of Glover and is identified by the Vermont Department of Environmental Conservation, Dam Safety Program (DSP) as No. 81.02.

D&K conducted an H&H analysis of the dam in 2020 for the Town, which included an updated assessment of the hydraulic capacity using modern hydrologic and hydraulic modeling techniques and current climatology data. This analysis provided suitable technical information for use in this subsequent dam breach analysis and inundation mapping project. D&K found the hydraulic capacity of the dam and its spillway, based on the dam's current SIGNIFICANT hazard classification, and did not meet the intended performance of the Vermont Dam Safety Regulations and USACE guidelines. In 2021 the DSP performed a simplified DSS-WISE Lite dam failure analysis to verify/determine if the SIGNIFICANT hazard potential classification was still appropriate due to changes in the hazard classification definitions which were implemented as part of the Administrative Dam Safety Rules put into effect August 1st, 2020. The simplified DSS-WISE Lite dam failure analysis determined that the dam was borderline SIGNIFICANT/HIGH hazard potential and that a more detailed study without the limitations of DSS-WISE Lite was warranted. The DSP secured FEMA funding to perform a more detailed study.

As part of the current Hydrologic and Hydraulic Assessment D&K has completed a dam failure evaluation of downstream impacts, hazard potential classification determination, and selection of the dam's inflow design flood (IDF). The hazard potential classification and inflow design flood selection are necessary to determine appropriate dam rehabilitation alternatives to bring the dam into compliance with dam safety design criteria.

2.0 DATA COLLECTION

D&K conducted a site visit on June 29, 2022 at Shadow Lake Dam to re-measure and affirm major hydraulic features that were obtained during prior investigations. D&K also measured the principal spillway structure and evaluated partially obstructed flow due to the presence of

the wooden debris rack and partially closed / inoperable outlet gate. D&K provided a spreadsheet of the updated principal spillway rating curve calculations based on the field evaluation and measurements (see **Appendix A**).

D&K completed documentation of the downstream floodway using field notes and captioned photographs (**Appendix C**). D&K documented culvert opening geometries and deck elevations downstream of the dam using survey grade GPS equipment in the NAVD88 vertical datum to accurately model the structures and confirm the accuracy of the LiDAR DEM. D&K initially measured span, rise, and channel inverts at nineteen stream crossing structures. Based on model stability issues related to rapidly changing dam failure flood wave velocities and depths at structures 8, 11, 13, 14, 16, 17, and 18, D&K elected to model these structures without a bridge deck (flow between abutment width). The DSP agreed with this compromise. A summary of the various structure geometries and elevations is included in **Appendix B**.

D&K’s Hydraulic Engineer and In-House Survey Crew inspected culvert structures within the study limits to assess the likely impact on flows. The table below references measurements obtained from the June 29, 2022 site visit.

Table 1: Shadow Lake Dam Description.

Physical Properties – Shadow Lake Dam	
Type	Earth fill with masonry walls
Length	130 feet
Structural Height	11.5 feet (1,399.8’ – 1,388.3’)
Impoundment Height	13.6 feet (1,399.8’ – 1,386.2’)
Top Width	Varies 7 to 8 feet
Side Slopes	Upstream face approx. 3H:1V, Downstream face approx. 3H:1V
Description	15 foot wide broad crested weir with concrete chute
Top of Dam	1,399.8 (NAVD88 ft)
Auxiliary Spillway	1,396.2 (NAVD88 ft)
Toe of Embankment	1,388.3 (NAVD88 ft)
Streambed at Toe of Embankment	1,386.2 (NAVD88 ft)

Table 2: Shadow Lake Principal Spillway Description.

Physical Properties – Shadow Lake Dam	
Principal Spillway Inlet / Normal Pool	1,394.6 (NAVD88 ft)
Principal Spillway Outlet (Orifice)	1392.5 (NAVD88 ft)
Debris Rack Length	5.2 feet
Debris Rack Height	5.2 feet
Effective Debris Rack Inlet Opening Length	2.6 feet
Effective Debris Rack Inlet Obstruction Length	2.6 feet (8 wood bars x 3.9 in/bar)
Principal Spillway Outlet Dimension	3.5 ft W x 1.8 ft L Semi-Circular
Principal Spillway Outlet (Orifice) Height - Obstructed	1.2 feet

3.0 HYDROLOGIC ANALYSIS

A hydrologic analysis of Shadow Lake Dam and downstream areas was performed using US Army Corps of Engineers HEC-HMS version 4.9 hydrologic & hydraulic modeling software. D&K completed a HEC-HMS model in 2021 for the Shadow Lake Association which evaluated spring runoff conditions and estimated lake levels from snow melt. As part of the current evaluation D&K updated the 2021 hydrologic basin model and the previously completed 2020 H&H model to consider the following:

- 1) D&K updated the principal spillway rating curve calculations to include the flow restrictions created by the debris rack, and the outlet gate which cannot be fully opened. The debris rack results in a 50% area reduction at the inlet, and the gate results in a 40% area reduction at the outlet, and
- 2) D&K utilized the 2021 HEC-HMS hydrology model which included the Daniels Pond Basin, Daniels Pond, a reach representing travel time for flow to go from Daniels Pond to Shadow Lake, the Shadow Lake Basin, and Shadow Lake Dam. The previous 2020 hydraulic analysis was performed using a HEC-HMS model which only calculated inflow to the Daniels Pond, and Shadow Lake Dam because

HEC-RAS was used to compute the time it took for flow to travel from Daniels Pond to Shadow Lake. However for this study which incorporates downstream flood routings it was determined an inefficient use of computation resources to include to calculate the travel time within HEC-RAS.

Table 3 below summarizes hydrologic inputs used to characterize and evaluate the current Shadow Lake Dam watershed model. Applicable inputs defined below were estimated based on methodology contained in the NRCS National Engineering Handbook (NEH), Part 630 Hydrology. Key inputs for the hydrologic model were sourced from the previous H&H analysis and are summarized in the following table.

Table 3: Hydrologic Input Data Sources (D&K 2021, 2020 H&H Analysis).

Rainfall Data	NOAA ATLAS-14 PFDS, NOAA HMR-51 & HMR-52
Time of Concentration	NRCS Watershed Lag Method
Number of Watershed Subcatchments	2
Number of Ponds	2
Number of Reaches	1
Hydrograph Method	NRCS Unit Hydrograph
Rainfall Distribution (Probable Maximum Precipitation)	24-hr NOAA HMR-51, 52 NRCS 5-pt Distribution
Rainfall Distribution (Recurrence Interval Storms, i.e. 100-yr)	24-Hour Center Weighted Frequency Distribution Generated from NOAA ATLAS-14 Data
Elevation Datum	NAVD88 Feet

The drainage area was divided into two subcatchments including Daniels Pond (1.43 sq. mi.) and Shadow Lake (3.86 sq. mi.). The time of concentration for each subcatchment was determined using the NRCS Watershed Lag Method, as defined in the above referenced NEH Part 630 Hydrology, Chapter 15, Time of Concentration. This method requires data defining

the longest flow path within the subcatchment such starting elevation, ending elevation, and flow length.

The SCS curve numbers used to calculate watershed runoff were determined using standard NRCS reference values based on land cover and hydrologic soil group classification. Using GIS software the land cover data and soils data were paired together and tabulated to allow for SCS curve number determination. Approximately 76% of the watershed is forested, 8% of the watershed is residential development, 7% of the watershed is field/open land, and 9% of the watershed is either a waterbody or soils most often completely saturated with water.

The depth-duration rainfall values used to define the recurrence interval storms (2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, 200-yr, 500-yr, and 1000-yr) were obtained from the US National Oceanic and Atmospheric Administration’s (NOAA) ALTAS-14 Precipitation Frequency Data Server (PFDS). The depth-duration rainfall value used to define the probable maximum precipitation (PMP) was obtained from the NOAA’s Hydro-meteorological Reports No. 51 and No. 52. Precipitation data is presented in **Appendix D**.

D&K conducted an updated hydrologic watershed analysis for Shadow Lake Dam for inflow hydrographs for the following events: 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, 500-year, 1,000-year, and Full PMF. Table 4 below provides a comparison of the updated hydrologic results with D&K’s previous studies and a copy of the HEC HMS model results are included in **Appendix E**.

Table 4: The Comparison of 2023 & 2020 Recurrence Interval Storm Results.

Event	Annual Chance Exceedance	Precipitation Depth (in)	2023 Peak Inflow to Shadow Lake Dam (cfs)	2020 Peak Inflow to Shadow Lake Dam (cfs)
24-hr PMF	-	26.00	11631	11382
24-hr 1000-yr	0.1%	7.92	4728	5248
24-hr 500-yr	0.2%	7.08	4284	4604
24-hr 200-yr	0.5%	6.88	3796	4053

24-hr 100-yr	1%	5.40	3272	3214
24-hr 50-yr	2%	4.82	2875	2697
24-hr 25-yr	4%	4.28	2496	-
24-hr 10-yr	10%	3.55	1983	-
24-hr 5-yr	20%	3.02	1617	-
24-hr 2-yr	50%	2.38	1171	-

4.0 SUMMARY OF DAM FAILURE ANALYSIS INPUT AND OUTPUT

4.1 Summary of Dam Failure Analysis Input and Output

The Dam Failure analysis was performed using US Army Corps of Engineers HEC-RAS (2D) flood modeling software version 6.1.0. Using detailed terrain data (LIDAR DEM and/or survey) HEC-RAS 2D enables the user to create a computational mesh, which divides the model area into a series of cells that capture the elevation data of the terrain surface and roughness values of the land cover. Surface roughness was estimated using the 2019 National Land Cover Database (NLCD) raster data set that is publicly available from the Multi-Resolution Land Characteristics Consortium (MRLC). The land cover classifications part of the dataset correspond to a manning's 'n' value which represents degree of surface roughness and is used to calculate energy losses within the hydraulic model. The terrain surface of the 2D HEC-RAS model was based off of a 2014 Hydroflattened LIDAR DEM with a corresponding 0.7 meter x 0.7 meter resolution. HEC-RAS employs an implicit finite difference method to determine flow characteristics such as flow direction, velocity and depth at each cell within the computational mesh. The 2D model will route flow through the computation mesh using a physically derived equation selected by the user (diffusion wave or full momentum). The full momentum equation was selected in order to represent the momentum component of the dam failure flood wave.

Shadow Lake Dam was modeled with a combination of storage area, 2D flow area and hydraulic structures. The hydraulic structures were used to represent the auxiliary spillway, principal spillway, and portion of the dam with a relatively consistent dam crest (elevation 1399.8' NAVD88 FT). HEC-RAS has the ability to calculate discharge over dam structures (such as the Shadow Lake Dam auxiliary spillway and dam crest) based on headwater and

tailwater elevations and can vary the discharge coefficient accordingly. The discharge coefficient is initially defined by the user based on the type of spillway. Both the auxiliary spillway and dam crest overtopping flow were represented with discharge coefficients corresponding to broad crested weir flow. The dam crest was represented with a weir coefficient of 2.63.

The breach model includes a study area from the dam and extending downstream to just past the VT Route 5 Bridge located near the intersection of Kinsey Rd and VT Route 5 in the Town of Barton. The breach model relied on the updated HEC-HMS Shadow Lake Dam watershed model for estimating unsteady hydrograph inflows at the dam and relied on USGS Stream Stats data for estimating steady state peak discharge inflows from tributaries downstream of the dam. Based upon the size of the Barton River watershed upstream of the Shadow Lake Brook confluence (2.8 sq. mi.) in relation to the Shadow Lake Dam watershed (5.3 sq. mi.) it was determined reasonable to assume that if Shadow Lake was experiencing flooding, that the Barton River would also be in a flood stage.

Table 5 below provides a summary of the corresponding recurrence intervals that were used in the model for tributaries downstream of Shadow Lake Dam. Additionally, for the sunny day dam breach, tributary inflows are represented by an approximate average annual baseflow. HEC RAS model geometry/layout is provided in **Appendix F**.

Table 5: The Shadow Lake Storm Day Flood Recurrence Intervals.

Inflow at Shadow Lake Dam (cfs)	Downstream Tributary Flows (cfs)
PMF	500-yr
¾ PMF	500-yr * 0.75
½ PMF	500-yr * 0.5
1000-yr	100-yr
500-yr	50-yr
200-yr	25-yr
100-yr	10-yr
50-yr	10-yr
25-yr	5-yr
10-yr	2-yr
2-yr	Baseflow

Baseflow (cfs) = Drainage Area * 2 cfs/sq.mile

4.2 Sunny Day Piping Failure

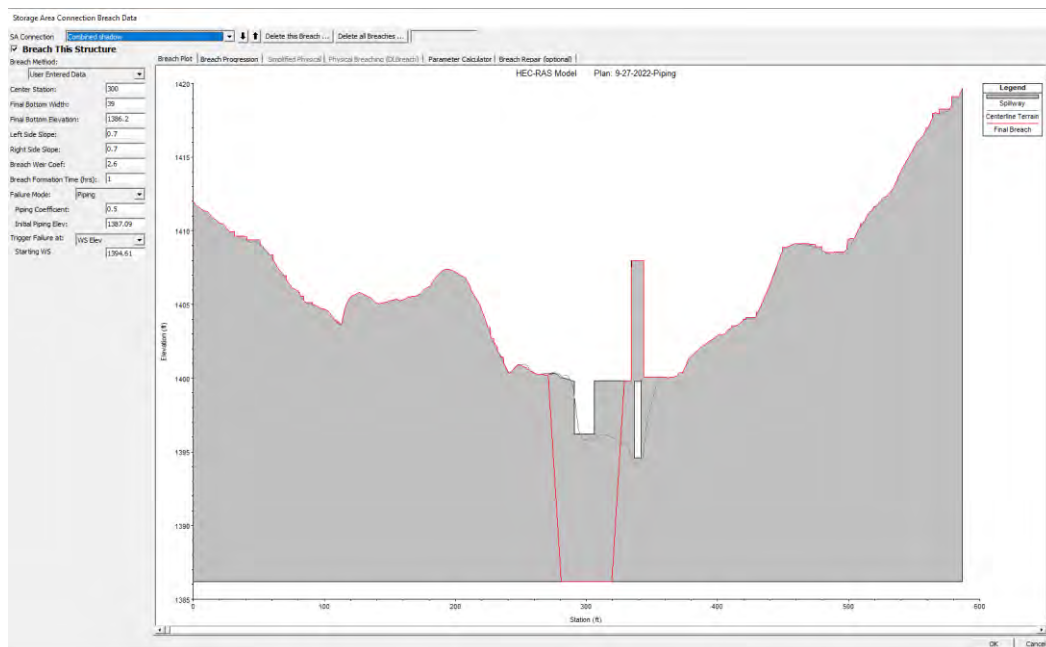
For conservancy and hazard classification purposes, the initial piping elevation should be set at or near the interface of the dam foundation with natural grade (1387.09). Additionally, the failure time for this piping failure to occur was calculated to be 2.4 hrs. FERC guidance which is typically followed for VT DSP dam failure analyses recommends a failure time between 0.1 and 1 hrs. D&K utilized the upper limit of the recommended FERC range (1 hour).

The Froehlich 2008 breach equations compute an average breach width of 124 ft for the sunny day failure with water level at the auxiliary spillway crest invert (1396.2).

The Sunny Day Piping Failure calculated a breach bottom width of 15 feet with 0.7H: 1V side slopes, which results in a 31.2 ft wide top width.

FERC recommends an average breach width of $\text{Height of Dam} < \text{Avg. B Breach Width} < 5 \times \text{Height of Dam}$ for Earthen Structures that would correspond to $13 \text{ ft} < X < 65 \text{ ft}$. For masonry gravity structures FERC recommends an Avg. Breach Width of $< 0.5 \times \text{Dam Crest Length}$ which would correspond to $X < 65 \text{ ft}$. Based on these recommended ranges it appears the upper limit of the breach average width is 65 ft while the lower limit is 13 ft. An average of these two values yields 39 ft which is larger than the 31.2 ft top width currently being modeled.

The Sunny Day Piping Failure dimensions are shown on the figure below.

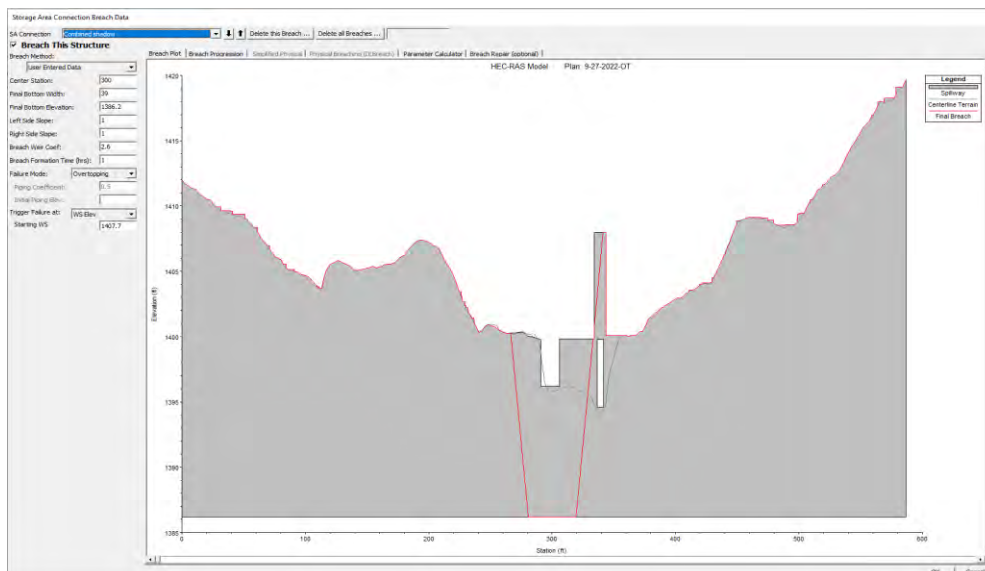


4.3 Storm Day Overtopping Failure

The Storm Day PMF Overtopping Failure was set to occur with water surface trigger elevation set to 1399.8 that corresponds to the dam crest. Based on the hydrologic analysis the dam overtops by approximately 8 ft during the PMF and would correspond to a water surface elevation of 1407.8. The PMF overtopping failure takes into account the worst case scenario of the dam failing with the peak PMF water surface elevation and the maximum amount of water being rapidly released from the dam. Similarly to the Sunny Day Piping Failure the breach formation time should fall within the FERC recommended range of 0.1 to 1 hr. D&K utilized the upper limit of the recommended FERC range (1 hour).

The Froehlich 2008 breach equations compute an average breach width of 205 ft for the Storm Day PMF dam failure with the reservoir elevation at the peak of 1407.8. The Storm Day Overtopping Failure calculated a breach bottom width of 15 feet with 1H: 1V side slopes that results in a 41 ft wide top width.

FERC recommends an average breach width of $\text{Height of Dam} < \text{Avg. B Breach Width} < 5 \times \text{Height of Dam}$ for Earthen Structures which would correspond to $13 \text{ ft} < X < 65 \text{ ft}$. For masonry gravity structures FERC recommends an Avg. Breach Width of $< 0.5 \times \text{Dam Crest Length}$ that would correspond to $X < 65 \text{ ft}$. Based on these recommended ranges it appears the upper limit of the breach average width is 65 ft while the lower limit is 13 ft. An average of these two values yields 39 ft, which is similar to the 41 ft top width utilized in the model. The Storm Day Overtopping Failure dimensions are shown on the figure below.



D&K completed storm-day and sunny-day dam breach modeling of Shadow Lake Dam using HEC RAS and a variety of breach parameters which are summarized in Tables 6A and 6B below.

Table 6A: Shadow Lake Storm-day & Sunny-day Dam Breach Modeling Results.

	PMF OT Failure	PMF No Failure	0.75 PMF OT Failure	0.75 PMF No Failure	0.5 PMF OT Failure	0.5 PMF No Failure
Peak Inflow (cfs)	11,623	11,623	8,723	8,723	5,812	5,812
Peak Discharge (cfs)	18,926	11,163	10,283	7,233	7,118	3,955
Volume Release (acre-ft)	14,973	6,169	7,239	4,300	5,557	2,611
Peak Reservoir WSEL	1,407.73	1407.78	1,406.34	1,406	1,404.32	1,404.38
Dam Crest Overtopping (ft) *	7.93	7.98	6.54	6.60	4.52	4.58

*Available Freeboard (-) or Overtopping Depth (+)

Table 6B: Shadow Lake Storm-day & Sunny-day Dam Breach Modeling Results.

	1000-yr OT Failure	1000-yr No Failure	500-yr Piping Failure	500-yr No Failure	Sunny Failure
Peak Inflow (cfs)	4,722	4,722	4,284	4,284	11
Peak Discharge (cfs)	3,701	343	2,387	274	986.9
Volume Release (acre-ft)	3,714	777	1,481	636	1490
Peak Reservoir WSEL	1399.91	1400.01	1399.39	1399.49	1394.61
Dam Crest Overtopping (ft) *	0.11	0.21	-0.41	-0.31	-5.19

*Available Freeboard (-) or Overtopping Depth (+)

4.4 Hazard Potential Classification Determination

D&K performed a hazard potential classification assessment following the methodology described in US Bureau of Reclamation (USBR) ACER Technical Memorandum No. 11 “Downstream Hazard Classification Guidelines” (1988).

D&K evaluated potential loss of life, property damage, and environmental impacts to determine the hazard potential classification for Shadow Lake Dam for several storm events. Dam failure events were analyzed using storm events including the Probable Maximum Flood (PMF), 0.75 PMF, and 0.5 PMF, 0.25 PMF, 1000-yr, and 500-yr. The hazard potential classification is selected based on the storm event that results in the largest observed differential between dam failure flooding impacts, and natural (without dam failure occurring flood affects) following the methodology described in USBR ACER-11. In accordance with the DSP hazard potential classification definitions, in order for Shadow Lake Dam to be considered HIGH hazard potential the analysis would need to determine that loss of life is considered probable as a result of the dam failure flooding impacts.

Upon reviewing the results of the dam failure analysis, it was determined that during the Sunny Day dam failure event that loss of life was not considered probable, and that the controlling

Storm Day failure event (the event which had the greatest incremental difference between the dam failing and the dam not failing) was during the 1000-yr storm event. When comparing the results of the 1000-yr Storm Day failure event to the 1000-yr Storm Day non-failure event it was concluded that loss of life because of the incremental flooding difference caused by the dam failing was not probable. A summarized reasoning for this determination is provided below. However, it is first important to note that the following interpretations consistent with current DSP application of the USBR ACER-11 guidance were applied when evaluating the results.

- Loss of life is primarily evaluated at structures such as commercial business and residential homes with the thought that in all likelihood that persons standing outside will seek shelter or evacuate to higher ground. Exceptions may be applied in areas with unique circumstances such as campgrounds next to streams, or heavily populated city areas, but for the Shadow Lake Dam failure analysis no such unique circumstances were identified.
- It is assumed by default that structures with foundations have a first-floor elevation of at least 1 foot higher than the adjacent native grade (represented by LIDAR DEM elevation data). In unique circumstances first floor elevations higher than 1-foot can be applied if it is possible to verify the data in the field. Depths used in the loss of life evaluation take first floor elevation into account.
- If the depth velocity relationship measured at an impacted structure (commercial building or home) plot with the LOW danger zone, then loss of life is assumed to be not probable.
- If the depth velocity relationship measured at an impacted structure plots within the lower half of the JUDGEMENT zone, loss of life is considered not probable, unless the application of engineering judgment indicates otherwise.
- If the depth velocity relationship measured at an impacted structure plots within the upper half of the JUDGEMENT zone, loss of life is considered probable, unless the application of engineering judgment advocates for otherwise.
- If the depth velocity relationship measured at an impacted structure plots within the HIGH danger zone, loss of life is considered probable.

In addition, when evaluating storm day dam failure vs storm day non-failure results, in order for loss of life to be considered probable as a result of the dam failing, the incremental rise in flooding depth needs to be 2 feet or greater for structures with foundations, and 1 foot or greater for structures without foundations. This interpretation is applied to address fringe cases where insignificant increases in flooding such as a 0.1 ft rise result in loss of life being considered probable because the without dam failure depth-velocity relationship was sitting

just below the dividing line between loss of life being considered probable and loss of life being considered not probable. The significance of 1 – 2 feet of incremental rise is consistent with federal guidance such as the guidance provided in the Federal Energy Regulatory Commission (FERC) Engineering Guidelines for the Evaluation of Hydropower Projects - Chapter 2 “Selecting and accommodating Inflow Design Floods for Dams” (2015).

4.5 Summarized loss of life evaluation results

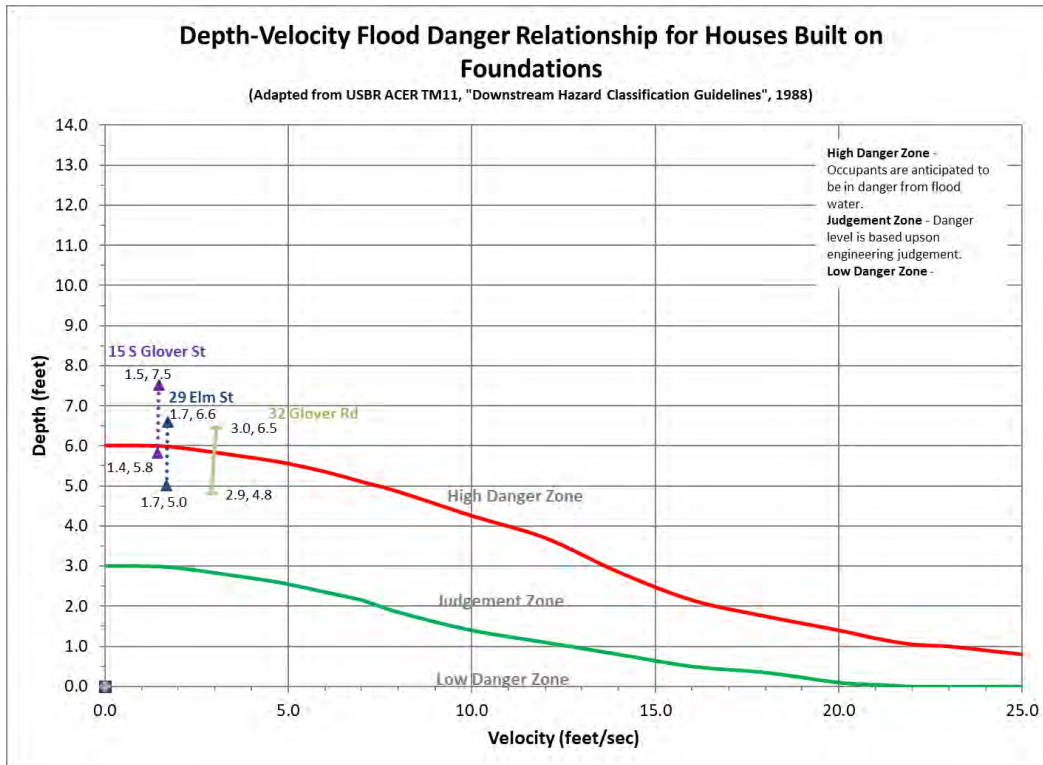
The following depth-velocity model results were obtained following the USBR ACER-11 guidance as it pertains to evaluating potential loss of life:

1. During the 1000-yr dam failure vs 1000-yr no dam failure comparison, three (3) structures were identified that transition from being in the JUDGEMENT zone (Yellow) to the HIGH danger zone (Red) on the USBR ACER- 11 chart. These structures, summarized in table 7 below were already located within the upper half of the JUDGEMENT zone which generally indicates that the loss of life is likely. In addition, the increase in flooding depth at these structures’ ranges from 1.58 to 1.68 ft which is less than the applied 2-foot threshold for structures with foundations. Furthermore, the incremental increase in flood velocity was only 10% to 20%.

Table 7: The 1000-yr dam failure vs 1000-yr no dam failure comparison.

Address	Structure type	1000-yr Failure			1000-yr No Failure			Rise (ft)
		Hazard	Depth (ft)	Velocity (ft/s)	Hazard	Depth (ft)	Velocity (ft/s)	
29 Elm St, Barton, VT 05822	House	Red	7.59	1.71	Yellow	6.01	1.68	1.58
32 Glover Rd, Barton, VT 05822	House	Red	7.46	3.03	Yellow	5.80	2.90	1.66
15 S Glover St, Glover, VT 05839	Church	Red	8.51	1.47	Yellow	6.83	1.44	1.68

*Listed depth values not adjusted to account for first floor elevation.



*Listed depth values shown on the chart are taking into account first floor elevation.

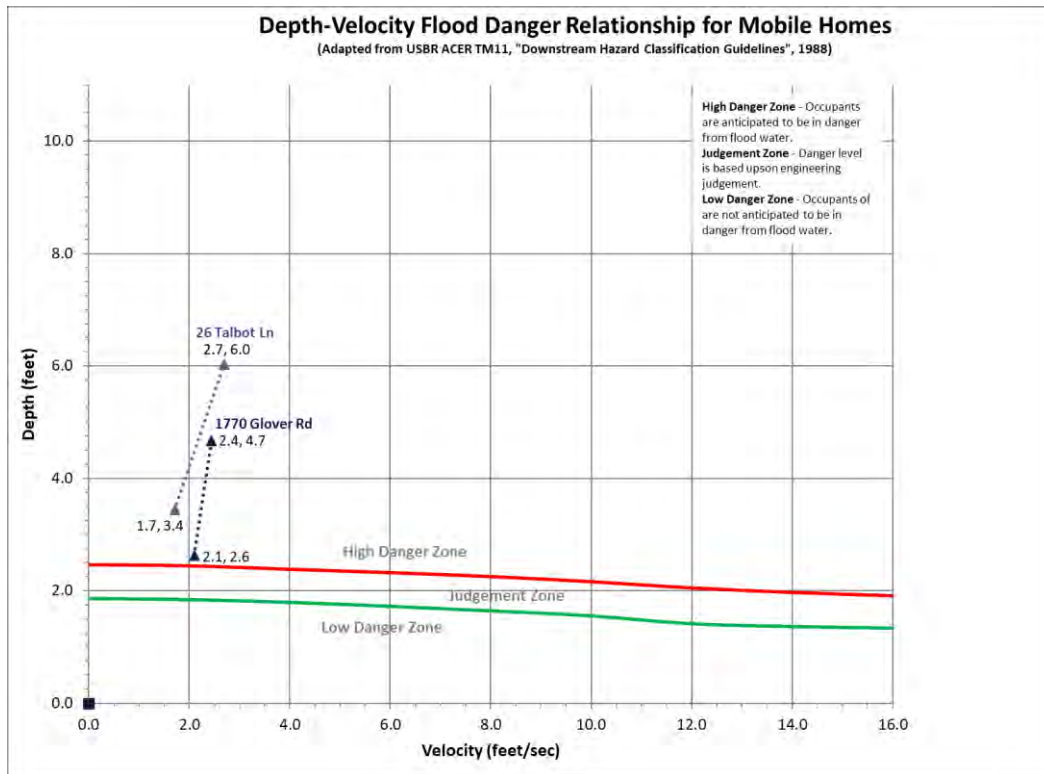
2. During the 1000-yr dam failure vs 1000-yr no dam failure comparison, four (4) structures were identified that experience incremental flooding rises greater than 2 feet (maximum of 2.98 feet). Of these four structures, two (2) structures plotted in the HIGH danger zone (Red) with and without dam failure. The remaining two (2) structures transition from the LOW danger zone (Green) to the Judgment Zone (Yellow), but both structures end up plotting in the middle to lower half of the JUDGMENT zone, and therefore loss of life was not considered probable. See table 8.

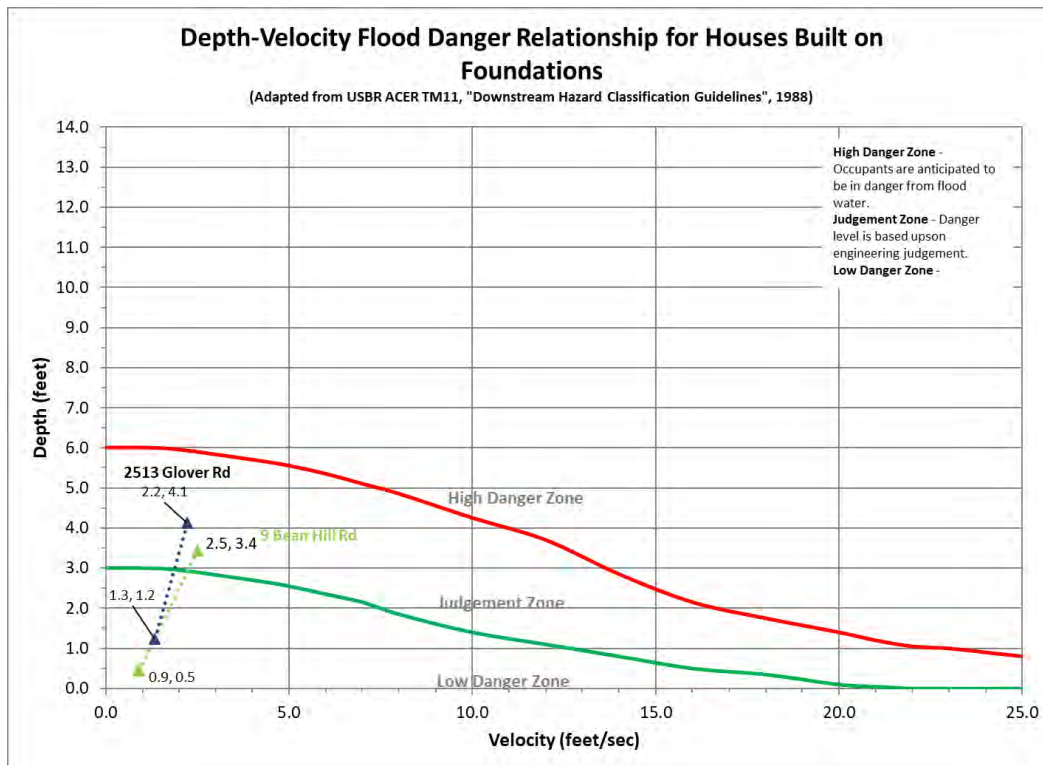
Table 8: The 1000-yr dam failure vs 1000-yr no dam failure comparison

Address	Structure type	1000-yr Failure			1000-yr No Failure			Rise (ft)
		Hazard	Depth (ft)	Velocity (ft/s)	Hazard	Depth (ft)	Velocity (ft/s)	
1770 Glover Rd, Barton, VT 05822	Mobile Home	Red	4.67	2.44	Red	2.63	2.10	2.04

2513 Glover Rd, Glover, VT 05839	House	Yellow	5.13	2.22	Green	2.24	1.34	2.89
26 Talbot Ln, Glover, VT 05839	Mobile Home	Red	6.02	2.69	Red	3.44	1.71	2.58
9 Bean Hill Rd, Glover, VT 05839	House	Yellow	6.43	2.52	Green	3.45	0.89	2.98

*Listed depth values not adjusted to account for first floor elevation.





*Listed depth values show on the chart are taking into account first floor elevation.

** The two connected green dots are 9 Bean Hill road. This is the structure which has a first floor elevation 3 ft plus higher than native grade (by counting steps when looking at google street view). By accounting for a 3 ft above native grade the dam failure point will no longer plot in the upper half of the judgement zone.

4.6 Inflow Design Flood (IDF) Selection

The IDF is the flood flow above which the incremental increase in water surface elevation due to failure of the dam or other water impounding structure is no longer considered to present an unacceptable threat to downstream life and property (FERC, 2015). Currently in the State of Vermont the IDF is the flood at which the dam can safely convey flow while maintaining a minimum of 1.5 feet of freeboard, unless measures to address overtopping are implemented. Currently the State of Vermont applies federal guidance found in FEMA P-94 “Selecting and Accommodating Inflow Design Floods for Dams” (2013) for determining the IDF for dams. FEMA P-94 outlines prescriptive IDFs based on a dam’s hazard potential classification as summarized in Table 9 below.

Table 9: The prescriptive IDFs based on a dam’s hazard potential classification.

Hazard Potential Classification	Prescriptive IDF
HIGH	Probable Maximum Flood (PMF)
SIGNIFICANT	1000-yr Flood (0.1% Annual Chance Exceedance)
LOW	100-yr Flood (1% Annual Chance Exceedance)

The starting point for a dam’s IDF is the prescriptive IDF outlined in the table above (1000-yr for Shadow Lake Dam). FEMA-94 then goes on out describe how the IDF can be reduced from the prescriptive IDF based on performing one of three analyses. These analyses include the following:

1. A site specific probable maximum precipitation study,
2. Incremental Consequence Analysis,
3. Risk-Informed Hydrologic Hazard Analyses.

FEMA P-94 states that the lower allowable threshold for a SIGNIFICANT hazard potential dam is the 100-yr flood. For this study, an incremental consequence analysis was performed to determine if the IDF could be reduced. This involved comparing dam failure vs no dam failure impacts for the following commonly used design flood events 1000-yr, 500-yr, 200-yr, and 100-yr. The results of the incremental consequence analysis indicated that the IDF could not be reduced to a flood frequency lower than the 1000-yr flood. This determination was made based on the incremental flooding difference between the dam failing and not failing being greater than the generally applied 2-foot allowable threshold by various federal agencies.

5.0 SUMMARY OF HYDRAULIC PERFORMANCE OF EXISTING DAM AND PROPOSED ALTERNATIVE CONFIGURATIONS

5.1 Existing Conditions Dam Performance

D&K re-evaluated the performance of the existing dam in reference to the IDF and additional storm events to determine the hydraulic adequacy of the existing structure. The existing conditions hydraulic performance evaluation utilized the HEC-HMS model developed as part of the prior 2020 and 2021 analysis work. The HEC-HMS model was updated to account for

the flow restriction of the wooden debris rack in front of the principal spillway structure, and also the contraction of the slide gate which partially blocks the outlet of the principal spillway. The results of this analysis are summarized in the table below. The key takeaway being that the dam is unable to maintain 1.5 feet of freeboard during the IDF, and therefore by State of Vermont standards is considered hydraulically inadequate.

Table 10: Performance of Shadow Lake Dam in reference to the IDF, and additional storm events.

Event	Annual Chance Exceedance	Precipitation Depth (in)	Peak Inflow to Dam (cfs)	Peak Outflow from Dam (cfs)	Starting WSEL (NAVD88 ft)	Peak WSEL (NAVD88 ft)	Rise in Water Surface Elevation from Normal Pool (ft)	Freeboard (+) or Overtopping (-) (ft)
24-hr PMF	-	26.00	11631	11163	1394.6	1407.8	13.2	-8.0
24-hr 1000-yr	0.1%	7.92	4728	343	1394.6	1400.0	5.4	-0.2
24-hr 500-yr	0.2%	7.08	4284	274	1394.6	1399.5	4.9	0.3
24-hr 200-yr	0.5%	6.88	3796	264	1394.6	1399.4	4.8	0.4
24-hr 100-yr	1%	5.40	3272	155	1394.6	1398.3	3.7	1.5
24-hr 50-yr	2%	4.82	2875	117	1394.6	1397.9	3.3	1.9
24-hr 25-yr	4%	4.28	2496	84	1394.6	1397.5	2.9	2.3
24-hr 10-yr	10%	3.55	1983	44	1394.6	1397.0	2.4	2.8
24-hr 5-yr	20%	3.02	1617	21	1394.6	1396.6	2.0	3.2
24-hr 2-yr	50%	2.38	1171	9	1394.6	1396.1	1.5	3.7

5.2 Conceptual Alternatives

Once the dam hazard potential classification, inflow design flood, and hydraulic performance were established D&K developed conceptual alternatives to address design deficiencies such as the inability of the dam to safely convey the IDF. Additional concerns have been voiced about the dam's ability to pass smaller, more frequent flood events such as springtime snow/ice melt/rain events, which result in lake level rises and damage to lakefront properties. In 2021, D&K performed a study for the Shadow Lake Association which evaluated the ability of the dam to handle springtime snow/ice melt/rain events. The study found that principal spillway had a limited discharge capacity/ability to drawdown the lake level back to the normal pool elevation, making the dam and surrounding lake front properties susceptible to extended duration or back-to-back flood events. The conceptual alternatives were developed to address hydraulic performance concerns while attempting to balance the downstream consequences of releasing water, and the upstream impacts of storing water. Some preliminary ideas regarding the alternatives are listed below:

1) **Alternative 1: Lowering the auxiliary spillway crest to the principal spillway crest to make the dam “run of river”**

Alternative 1 includes:

- Increasing the width of the auxiliary spillway from 15-ft wide to 40-ft wide, and converting the spillway to an Ogee weir with a discharge coefficient of 3.8.
- Lowering the auxiliary spillway crest elevation to 1394.6 to match the principal spillway crest.
- Eliminating the hydraulic constrictions created by the principal spillway debris rack, and gate which partially block the principal spillway outlet opening.
- The model indicated that Alternative 1 would achieve 1.5 ft of freeboard during the IDF with a peak water surface elevation of 1398.3 ft and a peak discharge of 1191 cfs.

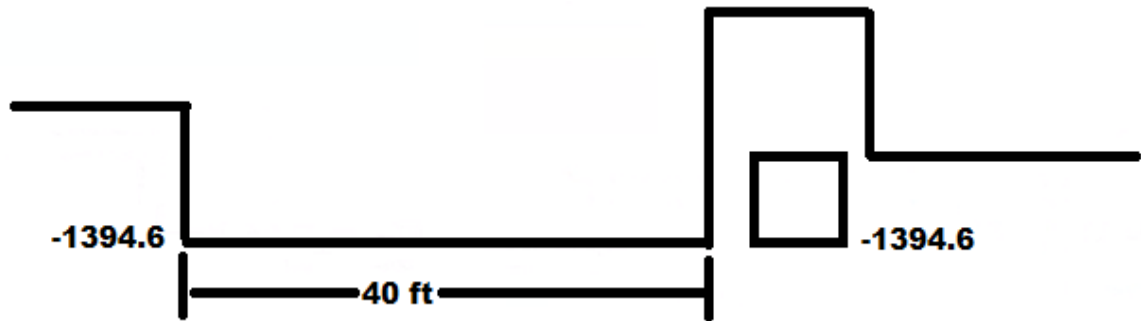


Fig.1. Alternative 1

The hydraulic performance of Alternative 1 is presented in the table below:

Table 11: Alternative 1 Hydraulic Performance.

Event	Annual Chance Exceedance	Precipitation Depth (in)	Peak Inflow to Dam (cfs)	Peak Outflow from Dam (cfs)	Starting WSEL (NAVD88 ft)	Peak WSEL (NAVD88 ft)	Rise in Water Surface Elevation from Normal Pool (ft)	Freeboard (+) or Overtopping (-) (ft)
24-hr 1000-yr	0.1%	7.92	4728	1191	1394.6	1398.3	3.7	1.5
24-hr 100-yr	1%	5.40	3272	651	1394.6	1397.1	2.5	2.7
24-hr 2-yr	50%	2.38	1171	144	1394.6	1395.5	0.9	4.3

2) Alternative 2: Modify the auxiliary spillway to include a stepwise shape

Alternative 2 includes:

- Increasing the width of the auxiliary spillway from 15-ft wide to 69-ft wide, and converting the spillway to a broad crested weir with a discharge coefficient of 2.7.
- The auxiliary spillway consists of three parts (Figure 2). These sections are middle (Width: 15-ft, Elevation: 1394.6 ft), right, and left sides (Width: 27-ft, Elevation: 1395.0 ft).
- Eliminating the hydraulic constrictions created by the principal spillway

debris rack, and gate which partially block the principal spillway outlet opening.

- The model indicated that Alternative 2 would achieve 1.5 ft of freeboard during the IDF with a peak water surface elevation of 1398.3 ft and a peak discharge of 1264 cfs.

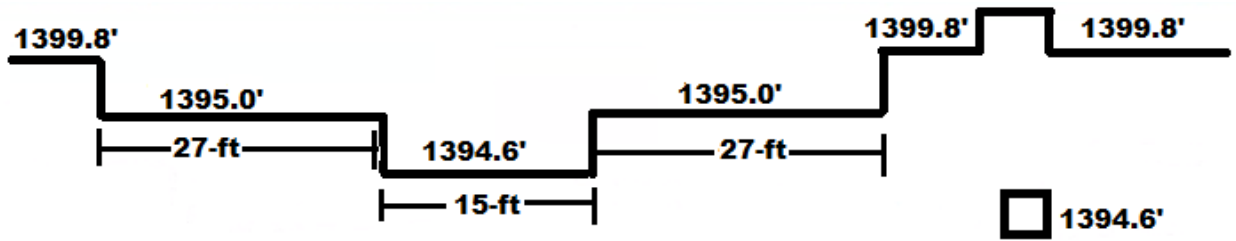


Fig.2. Alternative 2

The hydraulic performance of Alternative 2 is presented in the table below:

Table 12: Alternative 2 Hydraulic Performance.

Event	Annual Chance Exceedance	Precipitation Depth (in)	Peak Inflow to Dam (cfs)	Peak Outflow from Dam (cfs)	Starting WSEL (NAVD88 ft)	Peak WSEL (NAVD88 ft)	Rise in Water Surface Elevation from Normal Pool (ft)	Freeboard (+) or Overtopping (-) (ft)
24-hr 1000-yr	0.1%	7.92	4728	1264	1394.6	1398.3	3.7	1.5
24-hr 100-yr	1%	5.40	3272	666	1394.6	1397.1	2.5	2.7
24-hr 2-yr	50%	2.38	1171	117	1394.6	1395.6	1.0	4.2

3) Alternative 3: Lowering the Principal Spillway and Increasing Discharge Capacity

Alternative 3 includes:

- Maintaining the auxiliary spillway crest elevation and width (Width: 15-ft, Elevation: 1396.2 ft) as existing, and converting the spillway to a broad crested weir with a discharge coefficient of 2.7.
- Eliminating the hydraulic constrictions created by the principal spillway debris rack, and gate which partially block the principal spillway outlet opening.
- Increasing discharge capacity of widened principal spillway inlet and outlet controls from its current size to 6.7-ft and lowering the invert elevation to 1392.5 ft (Figure 3).
- The model indicated that Alternative 3 would achieve 0.6 ft of freeboard during the IDF with a peak water surface elevation of 1399.2 ft and a peak discharge of 522 cfs.

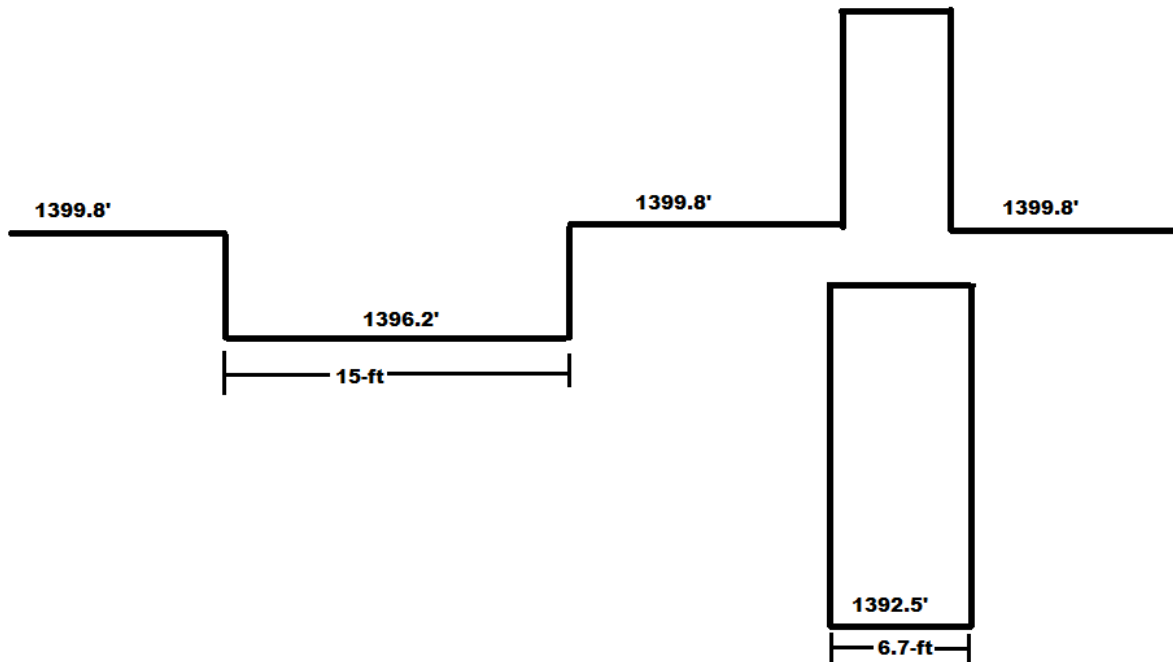


Fig.3. Alternative 3

The hydraulic performance of Alternative 3 is presented in the table below:

Table 13: Alternative 3 Hydraulic Performance.

Event	Annual Chance Exceedance	Precipitation Depth (in)	Peak Inflow to Dam (cfs)	Peak Outflow from Dam (cfs)	Starting WSEL (NAVD88 ft)	Peak WSEL (NAVD88 ft)	Rise in Water Surface Elevation from Normal Pool (ft)	Freeboard (+) or Overtopping (-) (ft)
24-hr 1000-yr	0.1%	7.92	4728	522	1392.5	1399.2	6.7	0.6
24-hr 100-yr	1%	5.40	3272	269	1392.5	1397.6	5.1	2.2
24-hr 2-yr	50%	2.38	1171	88	1392.5	1395.4	2.9	4.4

* Top of Dam Elevation: 1399.8' (NAVD 88).

5.3 Drawdown Analysis

D&K estimated how long it would take to drawdown Shadow Lake from the existing auxiliary spillway elevation (1396.2 ft) to within 10% of the normal pool for each alternative. Since Alternative 3 proposes a modified normal pool elevation of 1392.5 two separate calculations were made; one with the starting elevation at the auxiliary spillway elevation and a second also starting at the auxiliary spillway elevation but only drawing down to the current normal pool elevation of 1394.6 ft. These results are summarized in the table below.

Table 14: Alternatives Drawdown Time.

Alternative	Normal Pool Elevation (NAVD88 ft)	Drawdown Time (Day, hr, min)
EXISTING	1394.6	40 days, 14 hr, 48 min
ALT 1	1394.6	1 day, 14 hr, 54 min

ALT 2	1394.6	3 days, 16 hr, 48 min
ALT 3	1392.5	4 days, 21 hr, 30 min
ALT 3	1394.6	12 hr, 06 min

5.4 Summary of downstream flood routings conceptual alternatives vs. existing dam

D&K performed a downstream flood routing analysis to determine if any new or additional impacts occur as a result of increasing spillway discharge capacity to pass the IDF. D&K also compared the conceptual alternative dam configuration inundation depths and velocities at key property/infrastructure locations in relation to the flood conditions of the existing dam configuration in a tabulated format for each alternative. The extent of the downstream comparison extended to Culvert 15 in the Town of Barton after which there is no notable difference between the existing and proposed condition(s). The analysis included the 2-year, 10-year, 50-year, 100-year, and 500-year flood events. In general, flow depths increased by up to two or more feet at downstream structures based on the various alternative configurations. Likewise, flow velocities are expected to increase by up to 1.0 to 1.5 ft/s at downstream structures, depending on the storm event, location and alternative selected. D&K noted that of the three options evaluated that Alternative 3 resulted in the least impact to downstream flow depths and velocities.

Table 15: Comparison of Alternative 1 flow depths and velocities in relation to existing.

Name	500YR Diff. Depth (ft)	500YR Diff. Vel. (ft/s)	100YR Diff. Depth (ft)	100YR Diff. Vel. (ft/s)	50YR Diff. Depth (ft)	50YR Diff. Vel. (ft/s)	10YR Diff. Depth (ft)	10YR Diff. Vel. (ft/s)	2YR Diff. Depth (ft)	2YR Diff. Vel. (ft/s)
Culvert 3 – Perron Hill Rd	2.0	1.4	1.7	1.2	1.5	1.1	1.3	1.1	1.5	1.2
Culvert 4 – Aldrich Ln	2.7	1.2	2.2	1.1	1.9	1.0	1.5	0.9	1.3	1.9
Culvert 5 – Still Hill Rd	1.1	0.8	1.0	0.6	0.9	0.5	1.1	0.7	1.3	1.1
29 Elm St, Barton	0.5	0.0	0.4	0.1	0.3	0.07	0.3	0.0	0.0	0.0
1770 Glover Rd, Barton	0.7	0.1	0.6	0.2	0.5	0.2	0.5	0.0	0.0	0.0
2513 Glover Rd, Glover	1.2	0.6	0.8	0.3	0.7	0.1	0.2	0.1	0.0	0.0
26 Talbot Ln, Glover	1.1	0.4	1.3	0.3	1.2	0.2	0.3	0.1	0.0	0.0

9 Bean Hill Rd, Glover	2.2	1.0	1.4	0.1	1.1	0.0	0.1	0.0	0.0	0.0
Culvert 7 – Bean Hill Rd	2.1	0.4	1.8	0.1	1.6	0.03	1.2	1.1	1.0	1.8
Culvert 9 – Talbot Ln	1.1	0.1	1.2	0.3	1.1	0.3	1.3	0.6	1.4	1.2
Culvert 10 – Sargent Ln	1.7	0.2	1.7	0.6	1.5	0.6	1.2	0.7	1.4	1.1
Culvert 12 – Fulton Ln	0.5	0.1	0.6	0.7	0.5	0.1	1.0	0.5	1.5	0.9
Culvert 15 – Interstate 91	2.7	0.2	1.4	0.7	1.2	0.6	0.8	0.6	1.7	0.8
Culvert 19 – Railway Rd	1.2	0.3	0.9	0.3	0.8	0.2	0.7	0.2	0.8	0.9

Table 16: Comparison of Alternative 2 flow depths and velocities in relation to existing.

Name	500Y R Diff. Depth (ft)	500Y R Diff. Vel. (ft/s)	100Y R Diff. Depth (ft)	100Y R Diff. Vel. (ft/s)	50YR Diff. Depth (ft)	50YR Diff. Vel. (ft/s)	10YR Diff. Depth (ft)	10YR Diff. Vel. (ft/s)	2YR Diff. Depth (ft)	2YR Diff. Vel. (ft/s)
Culvert 3 – Perron Hill Rd	2.1	1.0	1.8	1.1	1.5	1.0	1.2	1.0	1.2	1.3
Culvert 4 – Aldrich Ln	2.9	1.2	2.2	0.8	1.9	0.7	1.5	0.6	1.1	1.5
Culvert 5 – Still Hill Rd	1.2	0.8	1.1	0.6	1.0	0.5	1.0	0.5	1.1	0.9
29 Elm St, Barton	0.6	0.1	0.4	0.1	0.3	0.1	0.2	0.1	0.0	0.0
1770 Glover Rd, Barton	0.8	0.2	0.6	0.2	0.5	0.1	0.4	0.1	0.0	0.0
2513 Glover Rd, Glover	1.3	0.5	1.0	0.4	0.8	0.2	0.6	0.1	0.0	0.0
26 Talbot Ln, Glover	1.3	0.3	1.2	0.3	1.2	0.3	0.1	0.0	0.0	0.0
9 Bean Hill Rd, Glover	2.0	0.6	1.3	0.1	1.1	0.1	0.2	0.0	0.0	0.0
Culvert 7 – Bean Hill Rd	2.2	0.4	1.8	0.1	1.6	0.1	1.2	1.1	0.8	1.0
Culvert 9 – Talbot Ln	1.2	0.2	1.2	0.2	1.2	0.1	1.2	0.5	1.2	1.2
Culvert 10 – Sargent Ln	1.8	0.2	1.8	0.5	1.5	0.5	1.2	0.5	1.1	1.0
Culvert 12 – Fulton Ln	0.6	0.1	0.6	0.1	0.5	0.1	1.0	0.5	1.3	0.8
Culvert 15 – Interstate 91	2.8	0.3	1.5	0.2	1.2	0.1	0.8	0.1	1.4	0.6
Culvert 19 – Railway Rd	1.2	0.3	0.9	0.3	0.8	0.2	0.7	0.2	0.6	0.7

Table 17: Comparison of Alternative 3 flow depths and velocities in relation to existing.

Name	500Y R Diff. Depth (ft)	500Y R Diff. Vel. (ft/s)	100Y R Diff. Depth (ft)	100Y R Diff. Vel. (ft/s)	50YR Diff. Depth (ft)	50YR Diff. Vel. (ft/s)	10YR Diff. Depth (ft)	10YR Diff. Vel. (ft/s)	2YR Diff. Depth (ft)	2YR Diff. Vel. (ft/s)
Culvert 3 – Perron Hill Rd	0.5	0.3	0.4	0.3	0.4	0.3	0.4	0.3	1.0	1.0
Culvert 4 – Aldrich Ln	0.6	0.3	0.5	0.2	0.5	0.2	0.5	0.1	0.8	1.0
Culvert 5 – Still Hill Rd	0.3	0.2	0.3	0.1	0.3	0.1	0.4	0.3	0.9	0.8
29 Elm St, Barton	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1770 Glover Rd, Barton	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
2513 Glover Rd, Glover	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
26 Talbot Ln, Glover	0.4	0.1	0.4	0.1	0.4	0.1	0.0	0.0	0.0	0.0
9 Bean Hill Rd, Glover	0.5	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.0
Culvert 7 – Bean Hill Rd	0.5	0.1	0.4	0.4	0.1	0.4	0.4	0.5	0.6	0.9
Culvert 9 – Talbot Ln	0.3	0.1	0.4	0.1	0.4	0.1	0.5	0.2	0.9	0.9
Culvert 10 – Sargent Ln	0.5	0.1	0.4	0.1	0.4	0.2	0.4	0.2	0.9	0.7
Culvert 12 – Fulton Ln	0.1	0.9	0.2	0.0	0.2	0.0	0.4	0.2	1.0	0.7
Culvert 15 – Interstate 91	0.6	0.1	0.3	0.2	0.3	0.2	0.3	0.2	1.1	0.6
Culvert 19 – Railway Rd	0.3	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.5	0.6

D&K evaluated downstream structures and bridges/roads for potential impacts as a result of increasing spillway discharge capacity to pass the 2-year, 10-year, 50-year, 100-year, and 500-year flood events for the various alternatives. The analysis included an inventory of buildings being flooded that otherwise would not be, and bridges/roads being overtopped that would otherwise not be.

D&K noted that of the three alternatives evaluated, Alternative 3 resulted in the least impact to downstream structures and bridges/roads. Also, there was no observed difference in impacted structures and bridges/roads for the 2-year flood event. Further evaluation will be required to

optimize hydraulic performance at the dam while balancing downstream impacts to property and infrastructure.

Table 18: The results of increasing spillway discharge on structures & bridges/roads (500-year).

Name	EXISTING	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
Culvert 3 – Perron Hill Rd	NO	YES	YES	NO
Culvert 4 – Aldrich Ln	NO	NO	NO	NO
Culvert 5 – Still Hill Rd	NO	YES	YES	NO
Culvert 7 – Bean Hill Rd	NO	YES	YES	NO
Culvert 9 – Talbot Ln	NO	NO	NO	NO
Culvert 10 – Sargent Ln	NO	YES	YES	NO
Culvert 12 – Fulton Ln	YES	YES	YES	YES
Culvert 15 – Interstate 91	NO	NO	NO	NO
Culvert 19 – Railway Rd	NO	NO	NO	NO
123 Peron Hill Rd.	NO	YES	YES	YES
3103 Glover St.	NO	YES	YES	NO
2864 Glover St.	NO	YES	YES	NO
2861 Glover St.	NO	YES	YES	NO
2421 Glover St.	NO	YES	YES	NO
1938 Glover St.	NO	YES	YES	NO
1318 Glover St.	NO	YES	YES	NO

Table 19: The results of increasing spillway discharge on structures & bridges/roads (100-year).

Name	EXISTING	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
Culvert 3 – Perron Hill Rd	NO	NO	NO	NO
Culvert 4 – Aldrich Ln	NO	NO	NO	NO
Culvert 5 – Still Hill Rd	NO	NO	NO	NO
Culvert 7 – Bean Hill Rd	NO	NO	NO	NO
Culvert 9 – Talbot Ln	NO	NO	NO	NO
Culvert 10 – Sargent Ln	NO	NO	NO	NO
Culvert 12 – Fulton Ln	YES	YES	YES	YES
Culvert 15 – Interstate 91	NO	NO	NO	NO
Culvert 19 – Railway Rd	NO	NO	NO	NO
123 Peron Hill Rd.	NO	YES	YES	NO
2984 Glover St.	NO	YES	YES	NO
2972 Glover St.	NO	YES	YES	NO
2956 Glover St.	NO	YES	YES	NO
2944 Glover St.	NO	YES	YES	NO

Table 20: The results of increasing spillway discharge on structures & bridges/roads (50-year).

Name	EXISTING	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
Culvert 3 – Perron Hill Rd	NO	NO	NO	NO
Culvert 4 – Aldrich Ln	NO	NO	NO	NO
Culvert 5 – Still Hill Rd	NO	NO	NO	NO
Culvert 7 – Bean Hill Rd	NO	NO	NO	NO
Culvert 9 – Talbot Ln	NO	NO	NO	NO
Culvert 10 – Sargent Ln	NO	NO	NO	NO
Culvert 12 – Fulton Ln	YES	YES	YES	YES
Culvert 15 – Interstate 91	NO	NO	NO	NO
Culvert 19 – Railway Rd	NO	NO	NO	NO
2972 Glover St.	NO	YES	YES	NO
3074 Glover St.	NO	YES	YES	NO
2894 Glover St.	NO	YES	YES	YES
2880 Glover St.	NO	YES	YES	YES

Table 21: The results of increasing spillway discharge on structures & bridges/roads (10-year).

Name	EXISTING	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
Culvert 3 – Perron Hill Rd	NO	NO	NO	NO
Culvert 4 – Aldrich Ln	NO	NO	NO	NO
Culvert 5 – Still Hill Rd	NO	NO	NO	NO
Culvert 7 – Bean Hill Rd	NO	NO	NO	NO
Culvert 9 – Talbot Ln	NO	NO	NO	NO
Culvert 10 – Sargent Ln	NO	NO	NO	NO
Culvert 12 – Fulton Ln	NO	NO	NO	NO
Culvert 15 – Interstate 91	NO	NO	NO	NO
Culvert 19 – Railway Rd	NO	NO	NO	NO
3132 Glover St.	NO	YES	YES	NO
26 Talbot Ln.	NO	YES	YES	NO

* **Structure:** YES: Being flooded; NO: Not be flooded; **Bridge/road:** YES: Be overtopped; NO: Not be overtopped.

6.0 CONCLUSIONS

Based upon the results of this Hydrologic and Hydraulic Assessment, the following summary and conclusions are provided:

1. D&K conducted an updated hydrologic watershed analysis for Shadow Lake Dam for inflow hydrographs including the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, 500-year, 1,000-year, and Full PMF storm events. The updated model included principal spillway rating curves that accounted for partially obstructed flows at the wooden trash rack and inoperable principal spillway gate. The updated hydrologic analysis also included multiple basin components to refine inflow values.

2. The existing Shadow Lake dam spillway provides freeboard up to the 500-yr storm event. The dam is overtopped at the 1,000-yr and greater storm events. The minimum desired freeboard of 1.5-ft is achieved at the 100-year and less storm events.
3. D&K performed a hazard potential classification assessment following the methodology described in US Bureau of Reclamation (USBR) ACER Technical Memorandum No. 11. The hazard potential classification was selected based on the storm event that results in the largest observed differential between dam failure flooding impacts and natural (without dam failure occurring flood affects).
4. It was determined that during the Sunny Day dam failure event that loss of life was not considered probable, and that the controlling Storm Day failure event (the event which had the greatest incremental difference between the dam failing and the dam not failing) was under the 1000-yr storm. Based on the incremental analysis the hazard potential classification for Shadow Lake Dam is considered SIGNIFICANT.
5. Based on the hazard potential classification of SIGNIFICANT the prescriptive Inflow Design Flood (IDF) is considered to be the 1,000-yr storm event. An incremental consequence analysis was performed to determine if the IDF could be reduced. This involved comparing dam failure vs no dam failure impacts for the 1000-yr, 500-yr, 200-yr, and 100-yr storm events. The results of the analysis indicated that the IDF could not be reduced to a flood frequency lower than the 1000-yr flood.
6. Conceptual dam configuration alternatives were developed to convey the IDF while attempting to balance the downstream consequences of releasing water. Although the hydraulic performance of the dam may be improved by the potential alternatives, further evaluation will be required to optimize dam performance while balancing downstream impacts to property and infrastructure.



APPENDIX A

STAGE STORAGE CURVE / PRINCIPAL SPILLWAY RATING CURVE

Shadow Lake Stage Storage Curve					
Elevation NAVD88 ft	Surface Area sq.	Surface Area	Volume cu. ft.	Volume	Description
1386.2	8513403	195.4	0	0.0	Streambed elevation at toe of slope.
1386.6	8534391	195.9	340924	78.3	
1387	8556434	196.4	682762	156.	
1388	8612090	197.7	154119	353.	
1389	8667533	199.0	240517	552.	
1390	8723055	200.3	327469	751.	
1390.6	8768314	201.3	379916	872.	
1391	8832597	202.8	415118	953.	
1392	9004009	206.7	504298	1157.	
1393	9179238	210.7	595211	1366.	
1394	9358282	214.8	687896	1579.	
1394.6	9467527	217.3	7443728	1708.	Approx. Normal Pool (Primary Spillway LIDAR Contours begin
1395	9585279	220.0	782387	1796.	
1396	9638450	221.3	878508	2016.	
1396.2	9648118	221.5	897794	2061.	Auxiliary Spillway Invert
1397	9688011	222.4	975124	2238.	
1398	9740273	223.6	1072256	2461.	
1399	9799508	225.0	1169940	2685.	
1399.8	9842054	225.9	1248510	2866.	Top of Dam (Height = 13.6 feet)
1400	9855405	226.3	1268205	2911.	
1401	9916496	227.7	1367043	3138.	
1402	9992223	229.4	1466540	3366.	
1403	1009053	231.6	1566868	3597.	
1404	1024624	235.2	1668326	3830.	
1405	1047500	240.5	1771613	4067.	
1406	1071544	246.0	1877348	4309.	
1407	1094181	251.2	1985420	4557.	
1408	1114573	255.9	2095682	4811.	
1409	1133433	260.2	2207904	5068.	
1410	1149983	264.0	2321992	5330.	

*Values computed using ArcGIS volume tool on merged bathymetry & LIDAR surface. Bathymetry based upon digitized contours from VT DEC mapping.

Shadow Lake Dam Principal Spillway Rating Curve





Normal Pool (NAVD88 ft)	1394.6		Each Rack Length, Wood (in)	3.9	
Aux Spillway Crest (NAVD88 ft)	1396.2				
Top of Dam (NAVD88 ft)	1399.8				
Orifice Coefficient	0.62				
Orifice Diameter (ft)	3.5				
Acceleration due to gravity (ft/s ²)	32.2				
Rack Opening Weir Length (ft)	2.6				
Weir Coefficient	2.6				
Orifice Opening Height (ft)	1.8				
Debris Rack Length (ft)	5.2				
Water surface Elevation (NAVD88 ft)	Weir Head (ft)	Weir Flow (cfs)	Orifice Head (ft)	Orifice Flow (cfs)	Selected Rating Curve Flow (cfs)
1394.6	0	0.0	0	0.0	0.0
1394.7	0.1	0.2	0	0.0	0.2
1394.8	0.2	0.6	0	0.0	0.6
1394.9	0.3	1.1	0	0.0	1.1
1395	0.4	1.7	0	0.0	1.7
1395.1	0.5	2.4	0	0.0	2.4
1395.2	0.6	3.1	0	0.0	3.1
1395.3	0.7	4.0	0	0.0	4.0
1395.4	0.8	4.8	0	0.0	4.8
1395.5	0.9	5.8	0	0.0	5.8
1395.6	1	6.8	0	0.0	6.8
1395.8	1.2	8.9	0	0.0	8.9
1396	1.4	11.2	0	0.0	9.0
1396.2	1.6	13.7	0	0.0	9.4
1396.4	1.8	16.3	0	0.0	10.1
1396.6	2	19.1	0.2	10.7	10.7
1396.8	2.2	22.1	0.4	15.1	15.1
1397	2.4	25.1	0.6	18.5	18.5
1397.2	2.6	28.3	0.8	21.4	21.4
1397.4	2.8	31.7	1	23.9	23.9
1397.6	3	35.1	1.2	26.2	26.2
1397.8	3.2	38.7	1.4	28.3	28.3
1398.1	3.5	44.3	1.7	31.2	31.2
1398.6	4	54.1	2.2	35.5	35.5
1399.1	4.5	64.5	2.7	39.3	39.3
1399.6	5	75.6	3.2	42.8	42.8
1399.8	5.2	80.2	3.4	44.1	44.1
1400.1	5.5	87.2	3.7	46.0	46.0
1400.6	6	99.4	4.2	49.0	49.0
1401.1	6.5	112.0	4.7	51.9	51.9
1401.6	7	125.2	5.2	54.6	54.6
1402.1	7.5	138.8	5.7	57.1	57.1
1402.6	8	153.0	6.2	59.6	59.6
1403.1	8.5	167.5	6.7	61.9	61.9
1403.6	9	182.5	7.2	64.2	64.2
1404.1	9.5	197.9	7.7	66.4	66.4
1404.6	10	213.8	8.2	68.5	68.5
1405.1	10.5	230.0	8.7	70.6	70.6
1405.6	11	246.6	9.2	72.6	72.6
1406.1	11.5	263.6	9.7	74.5	74.5
1406.6	12	281.0	10.2	76.4	76.4




APPENDIX B
CULVERT OPENING GEOMETRIES

Culvert Opening Geometries Description.




No	Span (ft)	Rise (ft)	INLET (ft)	OUTLET (ft)		Culvert Length (ft)
<u>1 (Stone Shore Rd)</u>	14	7.1	1383.5	1383.4		19
<u>2 (Dwinell Dr.)</u>	10	6.5	1190.15	1190.10		16
<u>3 (Perron Hill Rd)</u>	35	6.5	1129.35	1129.0		23
<u>4 (Aldrich Ln)</u>	27.5	9	1083.0	1082.3		17

No	Span (ft)	Rise (ft)	INLET (ft)	OUTLET (ft)		Culvert Length (ft)
<u>5 (Still Hill Rd)</u>	44	6	956.4	956.3		24
<u>6 (School St)</u>	21.5	7	945.2	945.1		21.5
<u>7 (Bean Hill Rd)</u>	37	7	939.6	939.3		32
<u>8 (Glover Rd)</u>	51	7	938.3	937.5		37

No	Span (ft)	Rise (ft)	INLET (ft)	OUTLET (ft)		Culvert Length (ft)
<u>9 (Talbot Ln)</u>	31	11.5	902.3	902.2	 A photograph showing a concrete bridge with a metal railing crossing a stream. The stream is surrounded by lush green vegetation and trees. The sky is blue with some clouds. A timestamp '08/29/2012 14:35' is visible in the bottom right corner of the photo.	18
<u>10 (Sargent Ln)</u>	34	9	897.8	897.6	 A photograph of a concrete bridge with a metal railing crossing a stream. The stream is surrounded by green vegetation and trees. The sky is blue with some clouds. A timestamp '08/29/2012 14:36' is visible in the bottom right corner of the photo.	26
<u>11 (Glover Rd)</u>	61	8.5	892.68	892.11	 A photograph of a concrete bridge with a metal railing crossing a stream. The stream is surrounded by green vegetation and trees. The sky is blue with some clouds. A timestamp '08/29/2012 14:37' is visible in the bottom right corner of the photo.	37
<u>12 (Fulton Ln)</u>	32	8	877.0	876.95	 A photograph of a concrete bridge with a metal railing crossing a stream. The stream is surrounded by green vegetation and trees. The sky is blue with some clouds. A timestamp '08/29/2012 14:38' is visible in the bottom left corner of the photo.	17

No	Span (ft)	Rise (ft)	INLET (ft)	OUTLET (ft)	Culvert Length (ft)
<u>13 (1532 Glover Rd)</u>	35	9	866	865.8	16
<u>14 (Ingersol Ln)</u>	30	8	863.17	863.0	15
<u>15 (Interstate 91)</u>	15 (2)	10 (2)	853.2	852.9	142.5
<u>16 (Roaring Brook Rd)</u>	57.5	7	849.77	849.45	25



No	Span (ft)	Rise (ft)	INLET (ft)	OUTLET (ft)		Culvert Length (ft)
<u>17 (Elm St)</u>	12 (4)	8 (4)	847.89	847.0		30
<u>18 (Barton Orleans Rd)</u>	34	13	841.23	840.8		32
<u>19 (Barton Railroad)</u>	35	21	833.1	832.05		30



APPENDIX C
PHOTOGRAPHIC LOG



PHOTO LOG


Project Name: Shadow Lake Dam Breach Analysis	Site Location: Glover, Vermont	Project No.: 127862
---	--	-------------------------------

Photo No.: 1	Date: 6-29-2022	
Photo Orientation: West		
Description: Shadow Lake		



PHOTO LOG

Project Name: Shadow Lake Dam Breach Analysis	Site Location: Glover, Vermont	Project No.: 127862
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Photo No.: 2	Date: 6-29-2022	
Photo Orientation: East		
Description: Shadow Lake Dam auxiliary spillway (chute)		


Project Name: Shadow Lake Dam Breach Analysis	Site Location: Glover, Vermont	Project No.: 127862
---	--	-------------------------------

Photo No.: 3	Date: 6-29-2022	
Photo Orientation: South		
Description: Shadow Lake Dam center section and primary spillway gatehouse.		

Photo No.: 4	Date: 6-29-2022	
Photo Orientation: South		
Description: Shadow Lake Dam primary spillway gatehouse structure inlet and southern end of dam.		

06/29/2022 06:36

Project Name: Shadow Lake Dam Breach Analysis	Site Location: Glover, Vermont	Project No.: 127862
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Photo No.: 5	Date: 6-29-2022	
Photo Orientation: North West		
Description: Shadow Lake Dam primary spillway gatehouse outlet.		



APPENDIX D
PRECIPITATION DATA



NOAA Atlas 14, Volume 10, Version 3
 Location name: Glover, Vermont, USA*
 Latitude: 44.6666°, Longitude: -72.2165°
 Elevation: 1394.36 ft**
 * source: ESRI Maps
 ** source: USGS



POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

[PF tabular](#) | [PF graphical](#) | [Maps & aeriels](#)

PF tabular

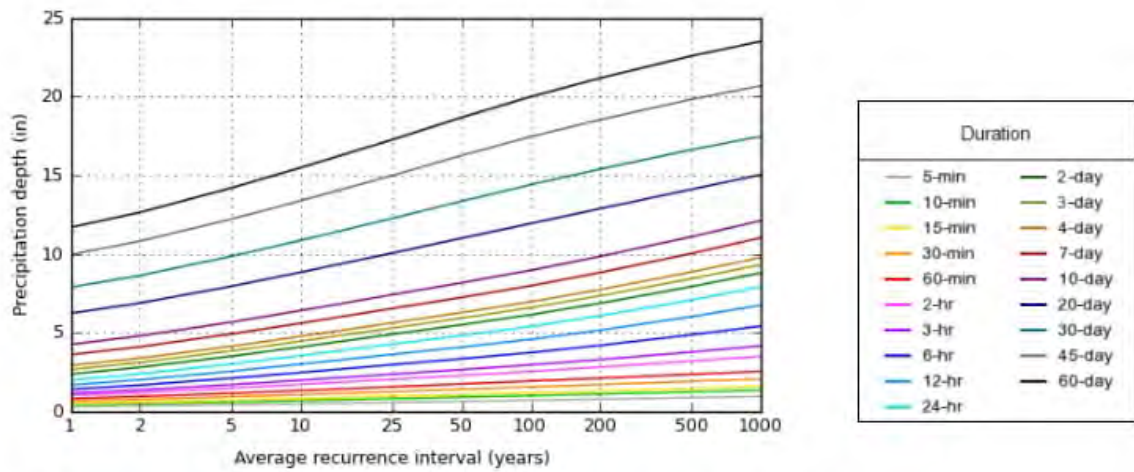
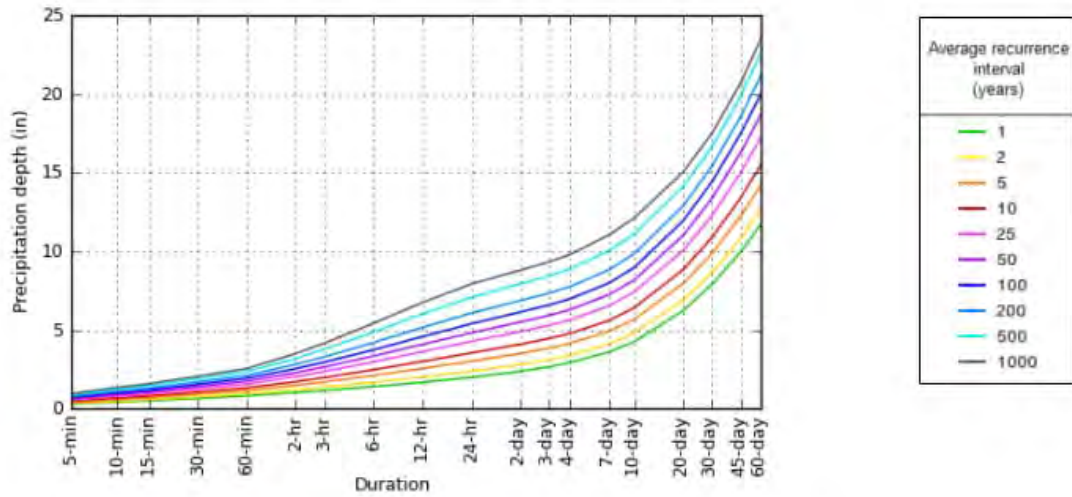
PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches) ¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.304 (0.238-0.386)	0.351 (0.274-0.446)	0.428 (0.332-0.545)	0.491 (0.380-0.630)	0.578 (0.432-0.768)	0.645 (0.471-0.873)	0.712 (0.503-0.996)	0.783 (0.529-1.13)	0.879 (0.571-1.31)	0.954 (0.604-1.45)
10-min	0.431 (0.337-0.547)	0.497 (0.368-0.631)	0.605 (0.471-0.771)	0.695 (0.537-0.889)	0.818 (0.611-1.09)	0.913 (0.668-1.24)	1.01 (0.713-1.41)	1.11 (0.749-1.60)	1.25 (0.808-1.86)	1.35 (0.866-2.06)
15-min	0.507 (0.396-0.643)	0.584 (0.456-0.743)	0.711 (0.553-0.906)	0.817 (0.632-1.05)	0.963 (0.719-1.28)	1.07 (0.784-1.46)	1.19 (0.839-1.66)	1.31 (0.881-1.88)	1.47 (0.952-2.16)	1.59 (1.01-2.42)
30-min	0.666 (0.521-0.845)	0.768 (0.600-0.976)	0.935 (0.728-1.19)	1.08 (0.831-1.38)	1.27 (0.945-1.68)	1.41 (1.03-1.91)	1.56 (1.10-2.18)	1.71 (1.16-2.47)	1.92 (1.24-2.85)	2.07 (1.31-3.15)
60-min	0.826 (0.645-1.05)	0.952 (0.744-1.21)	1.16 (0.901-1.48)	1.33 (1.03-1.71)	1.57 (1.17-2.08)	1.75 (1.28-2.37)	1.93 (1.38-2.70)	2.12 (1.43-3.05)	2.37 (1.54-3.52)	2.55 (1.61-3.86)
2-hr	1.03 (0.811-1.30)	1.20 (0.948-1.52)	1.49 (1.17-1.88)	1.72 (1.34-2.19)	2.05 (1.54-2.71)	2.29 (1.69-3.10)	2.55 (1.81-3.56)	2.82 (1.91-4.04)	3.20 (2.08-4.75)	3.51 (2.23-5.30)
3-hr	1.16 (0.918-1.46)	1.37 (1.08-1.72)	1.71 (1.34-2.15)	1.99 (1.55-2.52)	2.37 (1.79-3.13)	2.66 (1.97-3.59)	2.96 (2.12-4.14)	3.30 (2.24-4.72)	3.78 (2.46-5.59)	4.17 (2.65-6.29)
6-hr	1.41 (1.12-1.78)	1.68 (1.33-2.10)	2.11 (1.67-2.65)	2.48 (1.95-3.12)	2.98 (2.26-3.92)	3.35 (2.49-4.50)	3.74 (2.71-5.23)	4.20 (2.86-5.97)	4.87 (3.18-7.18)	5.43 (3.46-8.14)
12-hr	1.68 (1.35-2.09)	2.02 (1.61-2.50)	2.56 (2.04-3.19)	3.01 (2.38-3.77)	3.63 (2.78-4.75)	4.09 (3.07-5.48)	4.58 (3.34-6.38)	5.16 (3.63-7.30)	6.03 (3.95-8.82)	6.75 (4.32-10.1)
24-hr	1.99 (1.61-2.46)	2.38 (1.92-2.94)	3.02 (2.42-3.74)	3.55 (2.83-4.42)	4.28 (3.29-5.57)	4.82 (3.63-6.42)	5.40 (3.95-7.47)	6.08 (4.17-8.55)	7.08 (4.66-10.3)	7.92 (5.08-11.8)
2-day	2.37 (1.92-2.90)	2.81 (2.27-3.44)	3.51 (2.83-4.31)	4.10 (3.28-5.06)	4.91 (3.79-6.33)	5.51 (4.17-7.26)	6.15 (4.50-8.41)	6.88 (4.74-9.61)	7.93 (5.24-11.5)	8.81 (5.67-13.0)
3-day	2.67 (2.17-3.25)	3.12 (2.53-3.80)	3.85 (3.12-4.71)	4.46 (3.59-5.49)	5.30 (4.11-6.81)	5.93 (4.50-7.78)	6.60 (4.84-8.98)	7.35 (5.08-10.2)	8.43 (5.59-12.2)	9.33 (6.02-13.7)
4-day	2.93 (2.39-3.55)	3.39 (2.78-4.12)	4.14 (3.38-5.06)	4.77 (3.85-5.85)	5.64 (4.38-7.21)	6.28 (4.78-8.22)	6.97 (5.12-9.46)	7.74 (5.36-10.7)	8.86 (5.88-12.7)	9.78 (6.32-14.4)
7-day	3.61 (2.96-4.36)	4.11 (3.37-4.97)	4.93 (4.02-5.98)	5.61 (4.55-6.84)	6.54 (5.12-8.32)	7.25 (5.53-9.42)	7.99 (5.89-10.8)	8.82 (6.14-12.2)	10.0 (6.68-14.4)	11.0 (7.15-16.1)
10-day	4.26 (3.51-5.13)	4.80 (3.94-5.78)	5.68 (4.66-6.87)	6.41 (5.21-7.79)	7.42 (5.82-9.39)	8.18 (6.26-10.6)	8.97 (6.62-12.0)	9.85 (6.87-13.6)	11.1 (7.41-15.8)	12.1 (7.88-17.7)
20-day	6.24 (5.17-7.45)	6.89 (5.70-8.24)	7.96 (6.56-9.55)	8.84 (7.24-10.7)	10.1 (7.92-12.6)	11.0 (8.43-14.0)	11.9 (8.78-15.7)	12.9 (9.03-17.6)	14.1 (9.46-20.0)	15.0 (9.78-21.8)
30-day	7.89 (6.57-9.39)	8.64 (7.18-10.3)	9.86 (8.16-11.8)	10.9 (8.93-13.1)	12.3 (9.68-15.3)	13.4 (10.3-16.9)	14.4 (10.6-18.8)	15.4 (10.8-20.9)	16.6 (11.2-23.5)	17.5 (11.4-25.2)
45-day	9.96 (8.32-11.8)	10.8 (9.02-12.8)	12.2 (10.2-14.6)	13.4 (11.0-16.0)	15.0 (11.8-18.5)	16.3 (12.5-20.5)	17.5 (12.8-22.6)	18.5 (13.1-25.1)	19.8 (13.4-27.9)	20.7 (13.5-28.8)
60-day	11.7 (9.80-13.8)	12.7 (10.6-15.0)	14.2 (11.8-16.9)	15.5 (12.8-18.5)	17.3 (13.7-21.3)	18.7 (14.4-23.5)	20.0 (14.7-25.8)	21.2 (15.0-28.6)	22.6 (15.3-31.7)	23.5 (15.4-33.7)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

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PF graphical

PDS-based depth-duration-frequency (DDF) curves
 Latitude: 44.6666°, Longitude: -72.2165°



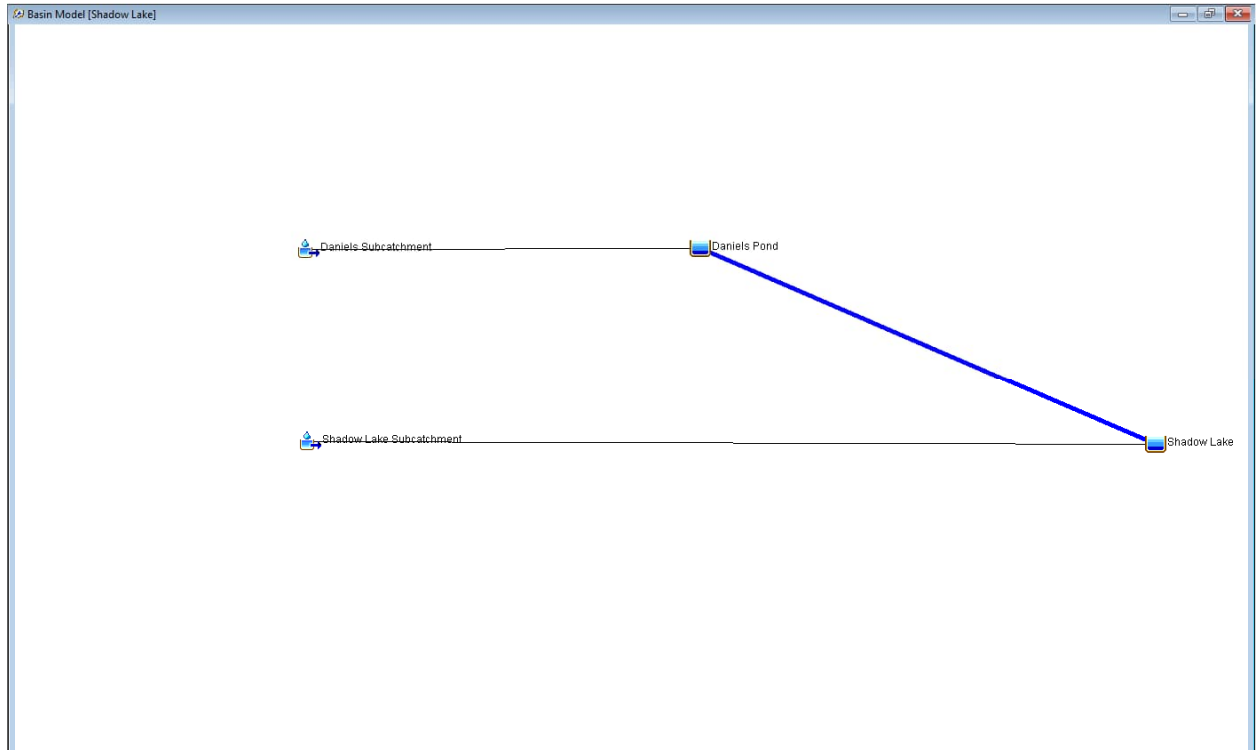
Maps & aerials

Small scale terrain



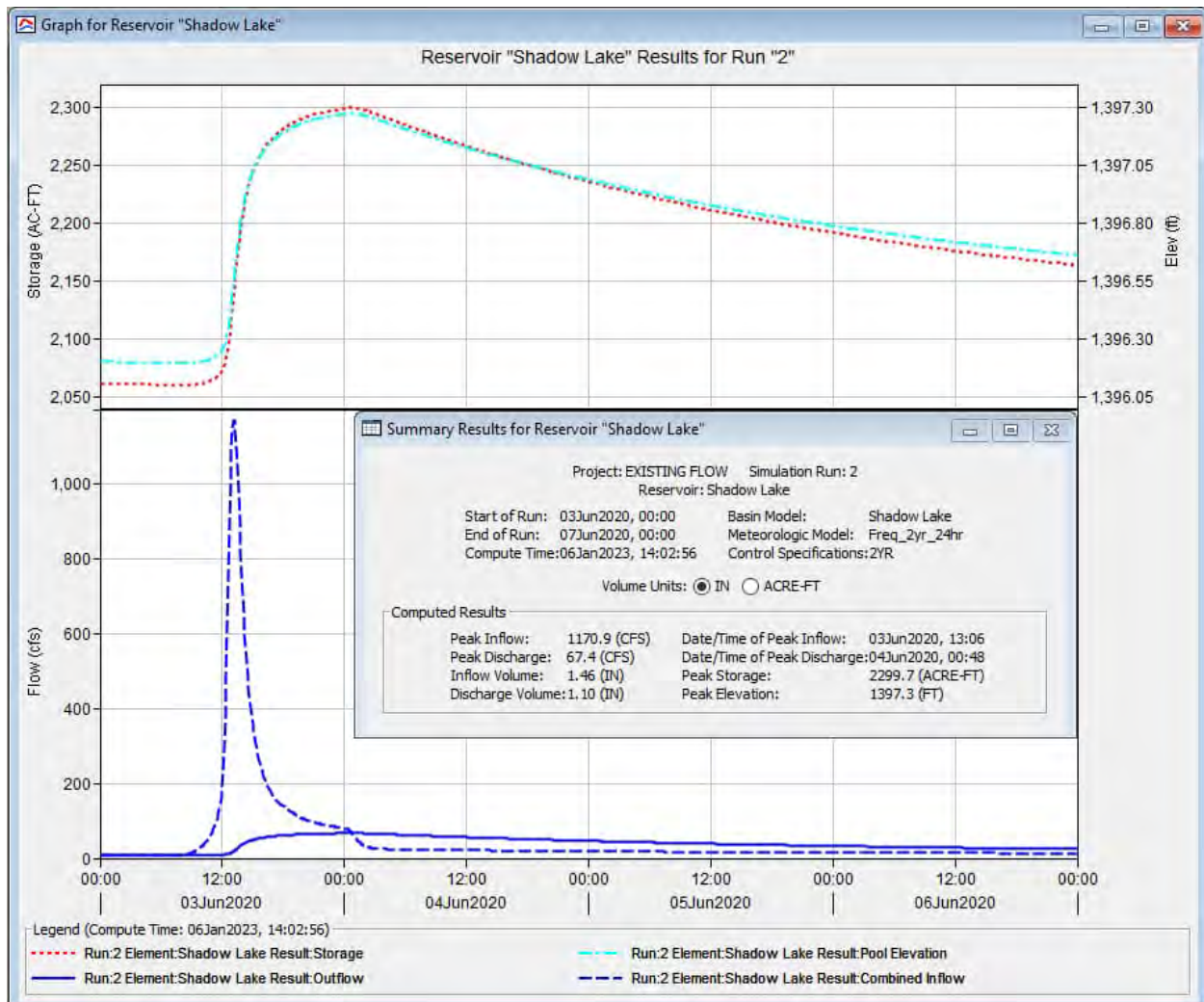
APPENDIX E
HEC-HMS MODEL

HEC-HMS Model Input



- The Shadow Lake Dam existing conditions results provided in the report were based on HEC-RAS and not HEC-HMS. HEC-HMS was only used to calculate inflow hydrographs.

2-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "2"

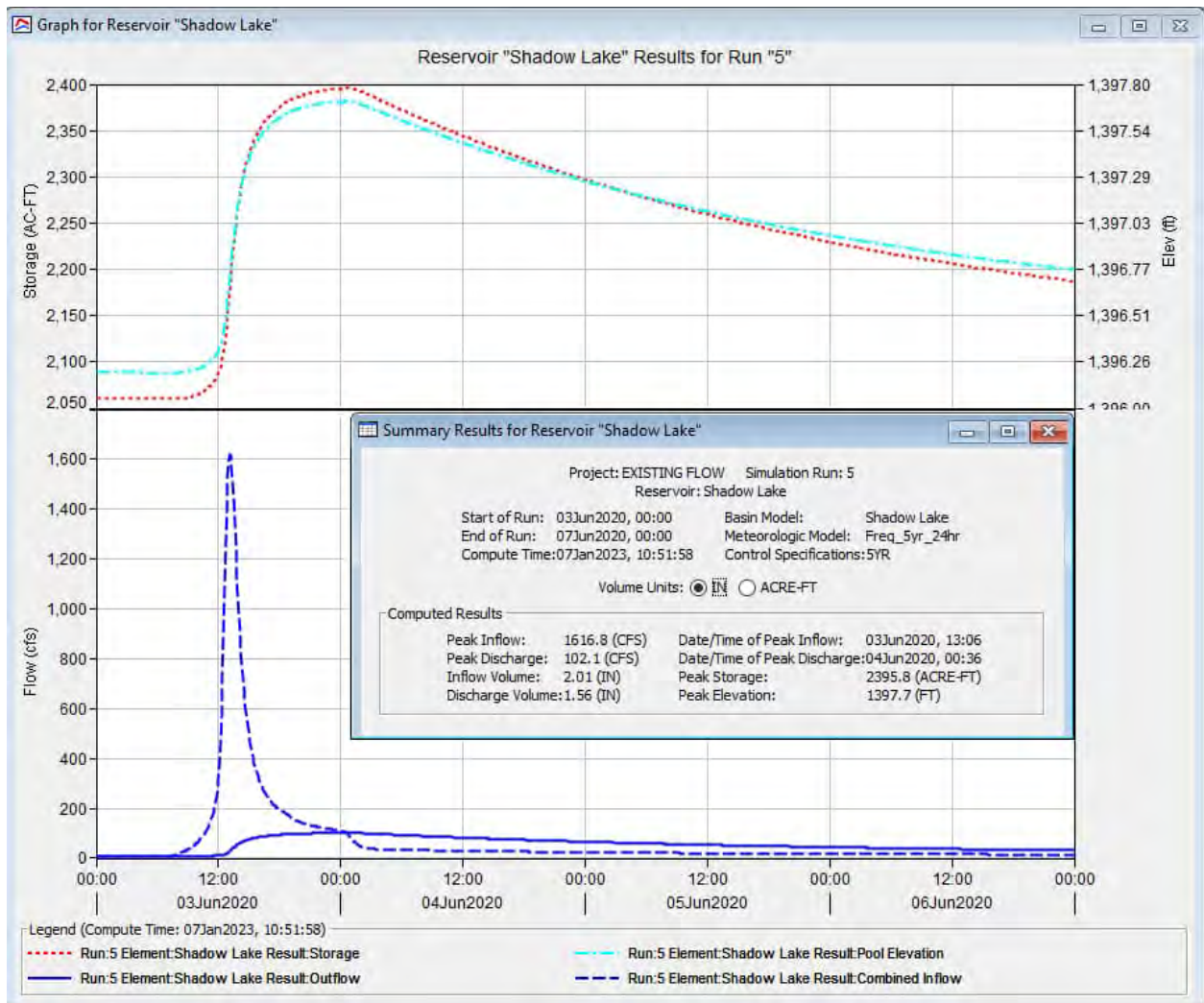
Project: EXISTING FLOW Simulation Run: 2

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_2yr_24hr
Compute Time: 06Jan2023, 14:02:56 Control Specifications: 2YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	426.5	03Jun2020, 13:06	1.58
Daniels Pond	1.4312	17.6	04Jun2020, 00:48	0.94
Shadow Lake Subcat...	3.8628	1169.7	03Jun2020, 13:06	1.65
Daniels to Shadow	1.4312	17.6	04Jun2020, 00:54	0.94
Shadow Lake	5.2940	67.4	04Jun2020, 00:48	1.10

5-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "5"

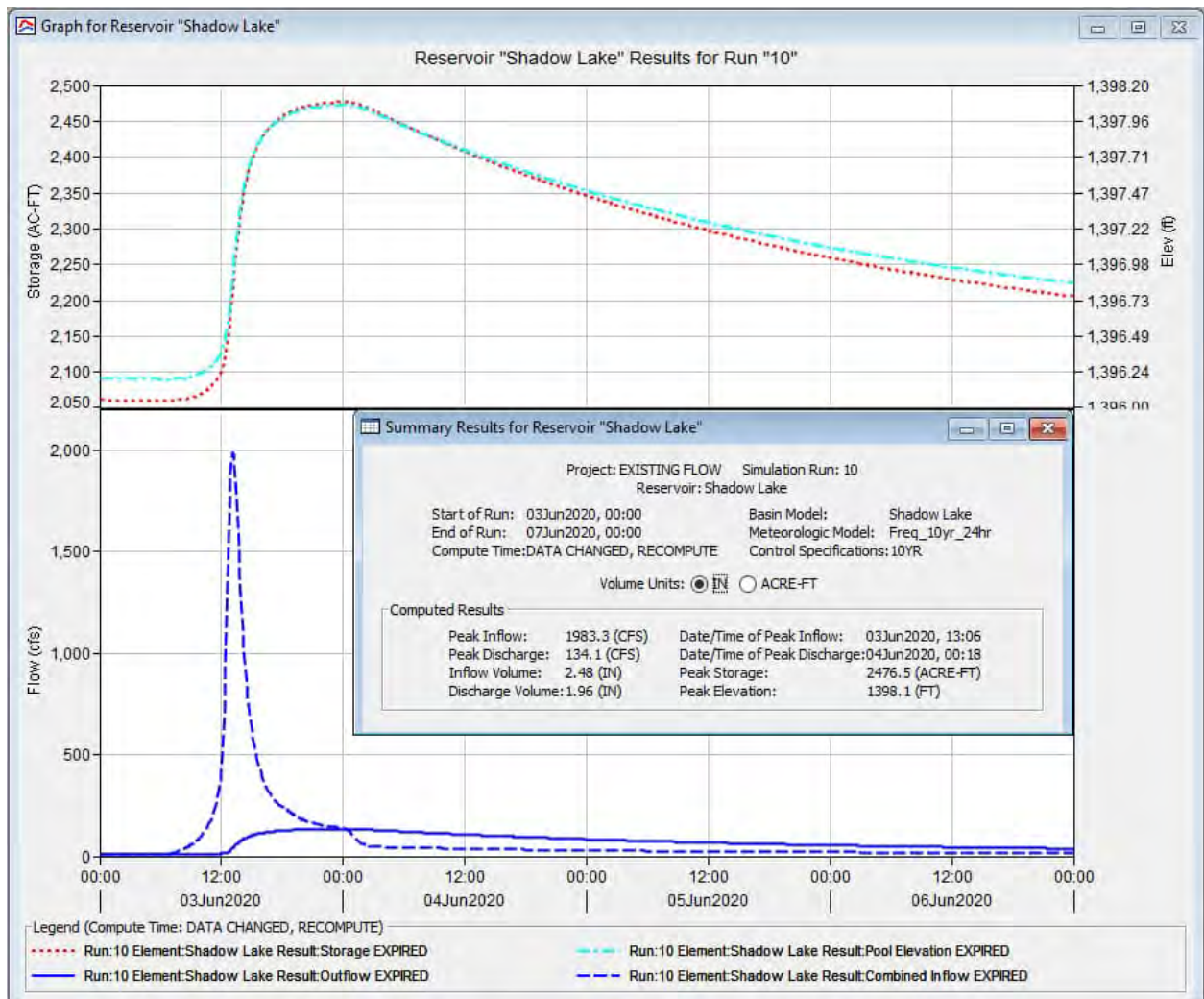
Project: EXISTING FLOW Simulation Run: 5

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_5yr_24hr
Compute Time: 07Jan2023, 10:51:58 Control Specifications: 5YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	594.5	03Jun2020, 13:06	2.14
Daniels Pond	1.4312	29.5	04Jun2020, 00:06	1.43
Shadow Lake Subcat...	3.8628	1613.5	03Jun2020, 13:06	2.22
Daniels to Shadow	1.4312	29.5	04Jun2020, 00:18	1.43
Shadow Lake	5.2940	102.1	04Jun2020, 00:36	1.56

10-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "10"

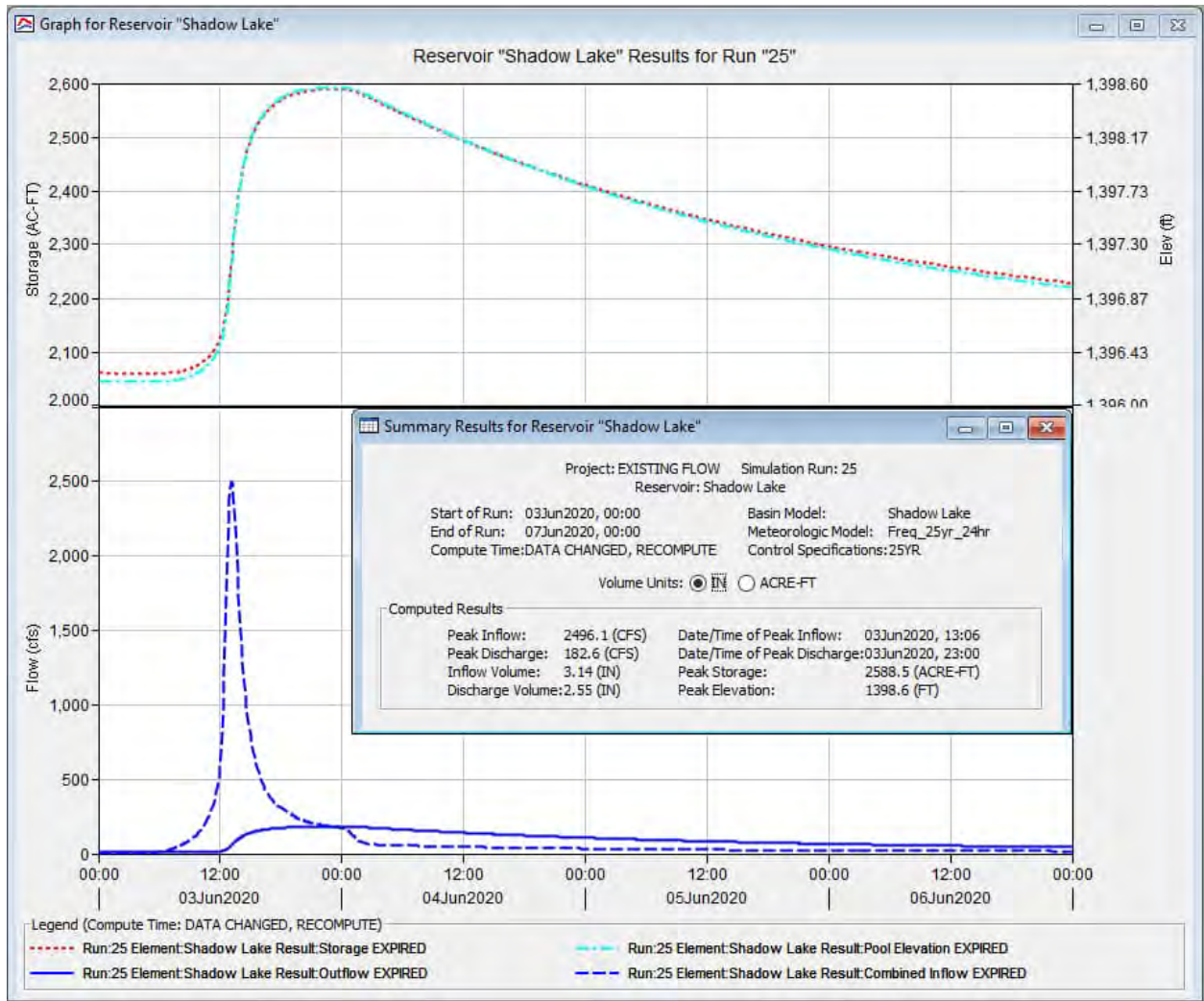
Project: EXISTING FLOW Simulation Run: 10

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
 End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_10yr_24hr
 Compute Time: DATA CHANGED, RECOMPUTE Control Specifications: 10YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	732.7	03Jun2020, 13:06	2.62
Daniels Pond	1.4312	40.4	03Jun2020, 22:06	1.86
Shadow Lake Subcat...	3.8628	1977.3	03Jun2020, 13:06	2.71
Daniels to Shadow	1.4312	40.4	03Jun2020, 22:18	1.86
Shadow Lake	5.2940	134.1	04Jun2020, 00:18	1.96

25-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "25"

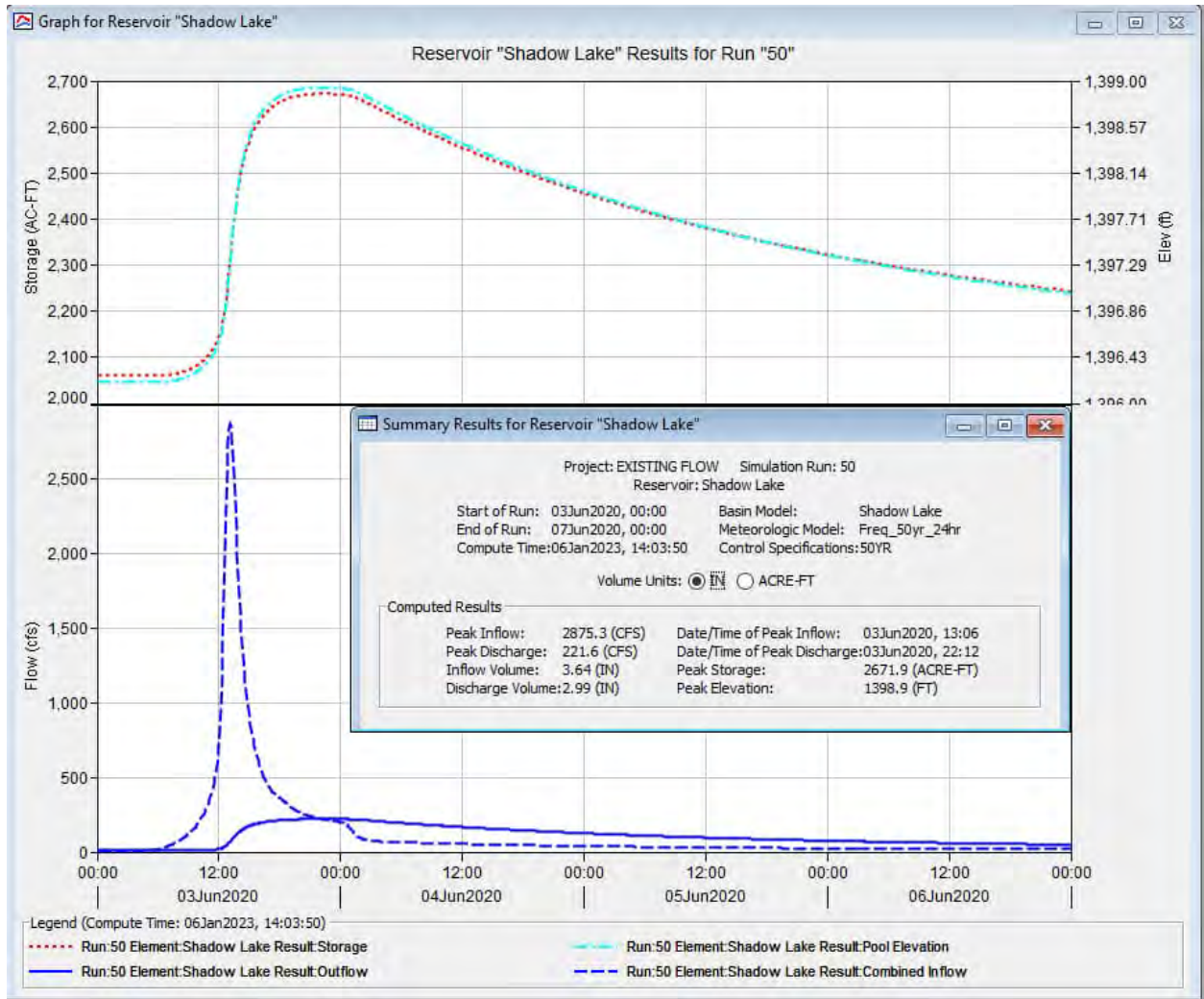
Project: EXISTING FLOW Simulation Run: 25

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_25yr_24hr
Compute Time: DATA CHANGED, RECOMPUTE Control Specifications: 25YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	926.1	03Jun2020, 13:06	3.29
Daniels Pond	1.4312	57.3	03Jun2020, 20:30	2.47
Shadow Lake Subcat...	3.8628	2485.2	03Jun2020, 13:06	3.39
Daniels to Shadow	1.4312	57.3	03Jun2020, 20:42	2.47
Shadow Lake	5.2940	182.6	03Jun2020, 23:00	2.55

50-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "50"

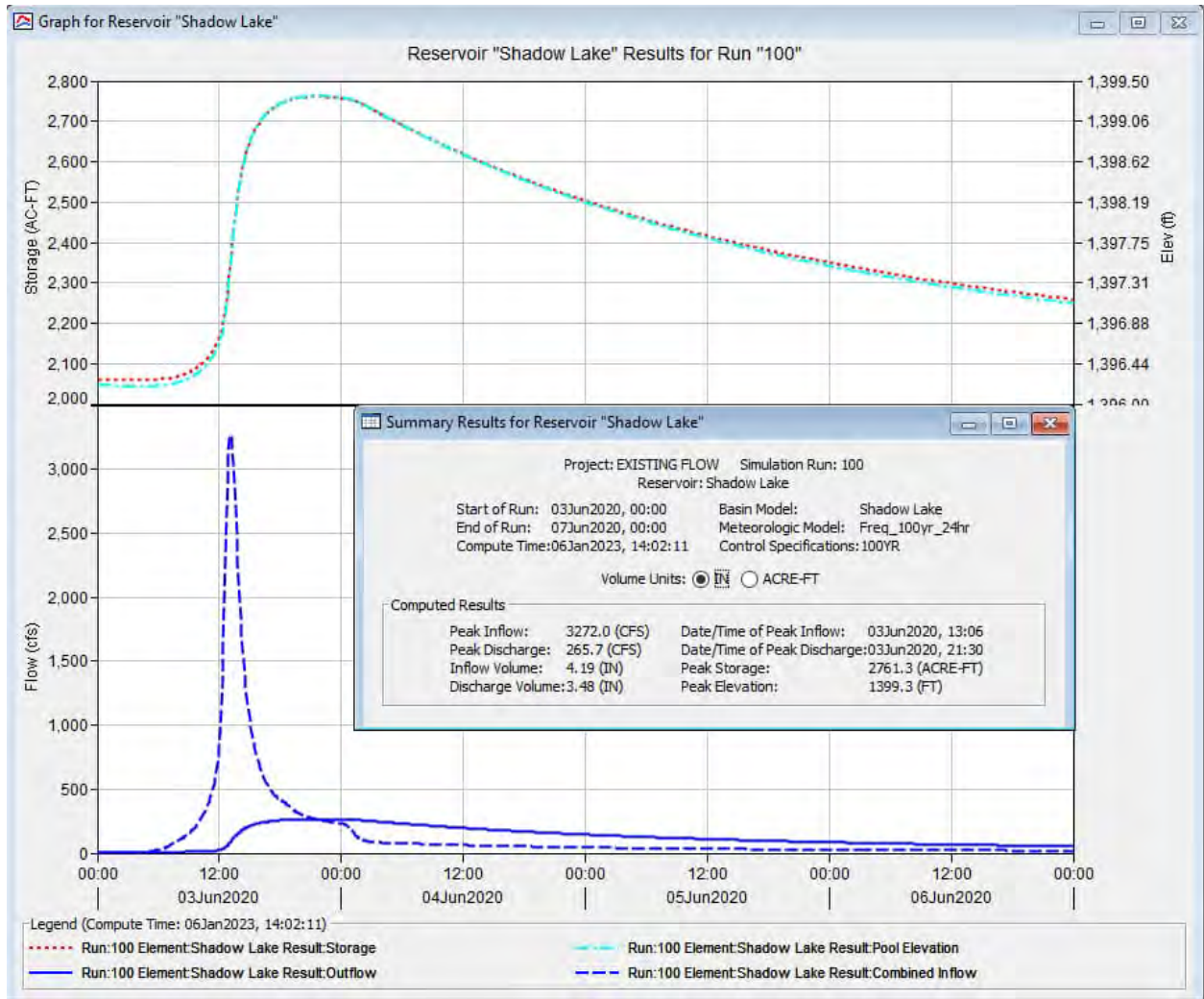
Project: EXISTING FLOW Simulation Run: 50

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_50yr_24hr
Compute Time:06Jan2023, 14:03:50 Control Specifications:50YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	1069.2	03Jun2020, 13:06	3.80
Daniels Pond	1.4312	70.7	03Jun2020, 19:54	2.94
Shadow Lake Subcat...	3.8628	2860.3	03Jun2020, 13:06	3.90
Daniels to Shadow	1.4312	70.7	03Jun2020, 20:06	2.94
Shadow Lake	5.2940	221.6	03Jun2020, 22:12	2.99

100-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "100"

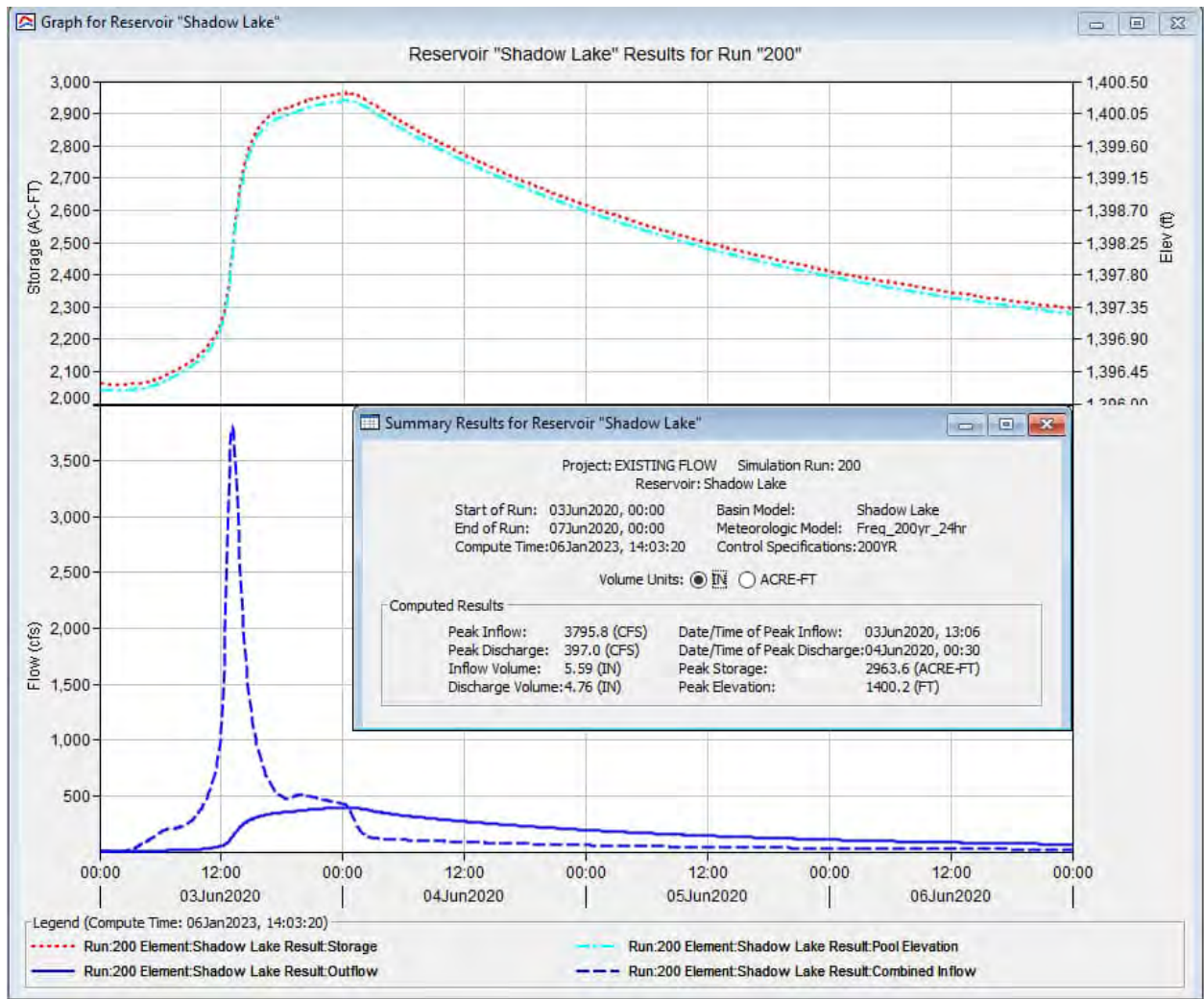
Project: EXISTING FLOW Simulation Run: 100

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
 End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_100yr_24hr
 Compute Time: 06Jan2023, 14:02:11 Control Specifications: 100YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	1218.6	03Jun2020, 13:06	4.35
Daniels Pond	1.4312	85.1	03Jun2020, 19:36	3.45
Shadow Lake Subcat...	3.8628	3251.6	03Jun2020, 13:06	4.46
Daniels to Shadow	1.4312	85.1	03Jun2020, 19:42	3.45
Shadow Lake	5.2940	265.7	03Jun2020, 21:30	3.48

200-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "200"

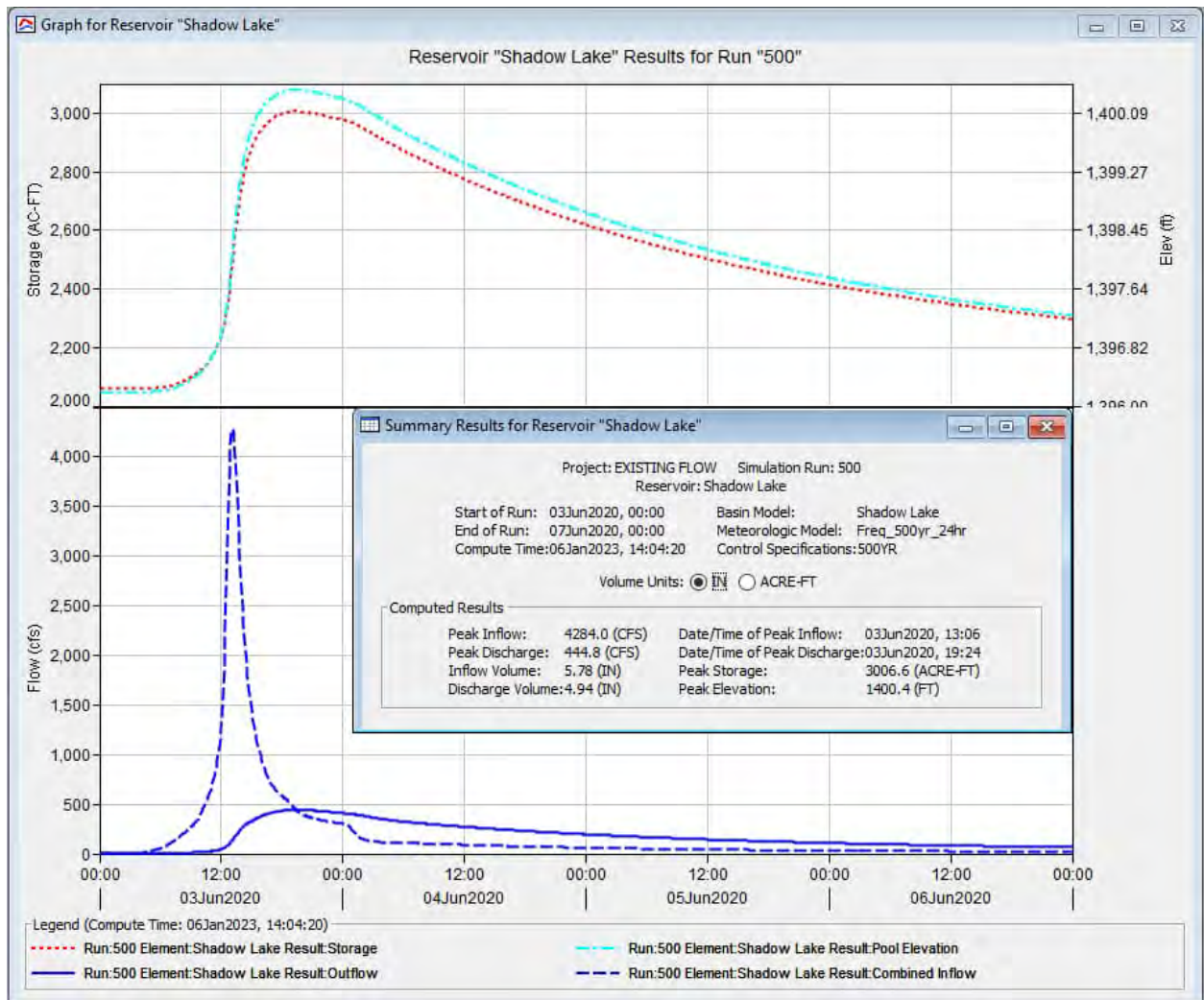
Project: EXISTING FLOW Simulation Run: 200

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_200yr_24hr
Compute Time: 06Jan2023, 14:03:20 Control Specifications: 200YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	1416.1	03Jun2020, 13:00	5.78
Daniels Pond	1.4312	111.8	04Jun2020, 00:18	4.77
Shadow Lake Subcat...	3.8628	3758.6	03Jun2020, 13:06	5.89
Daniels to Shadow	1.4312	111.8	04Jun2020, 00:30	4.77
Shadow Lake	5.2940	397.0	04Jun2020, 00:30	4.76

500-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "500"

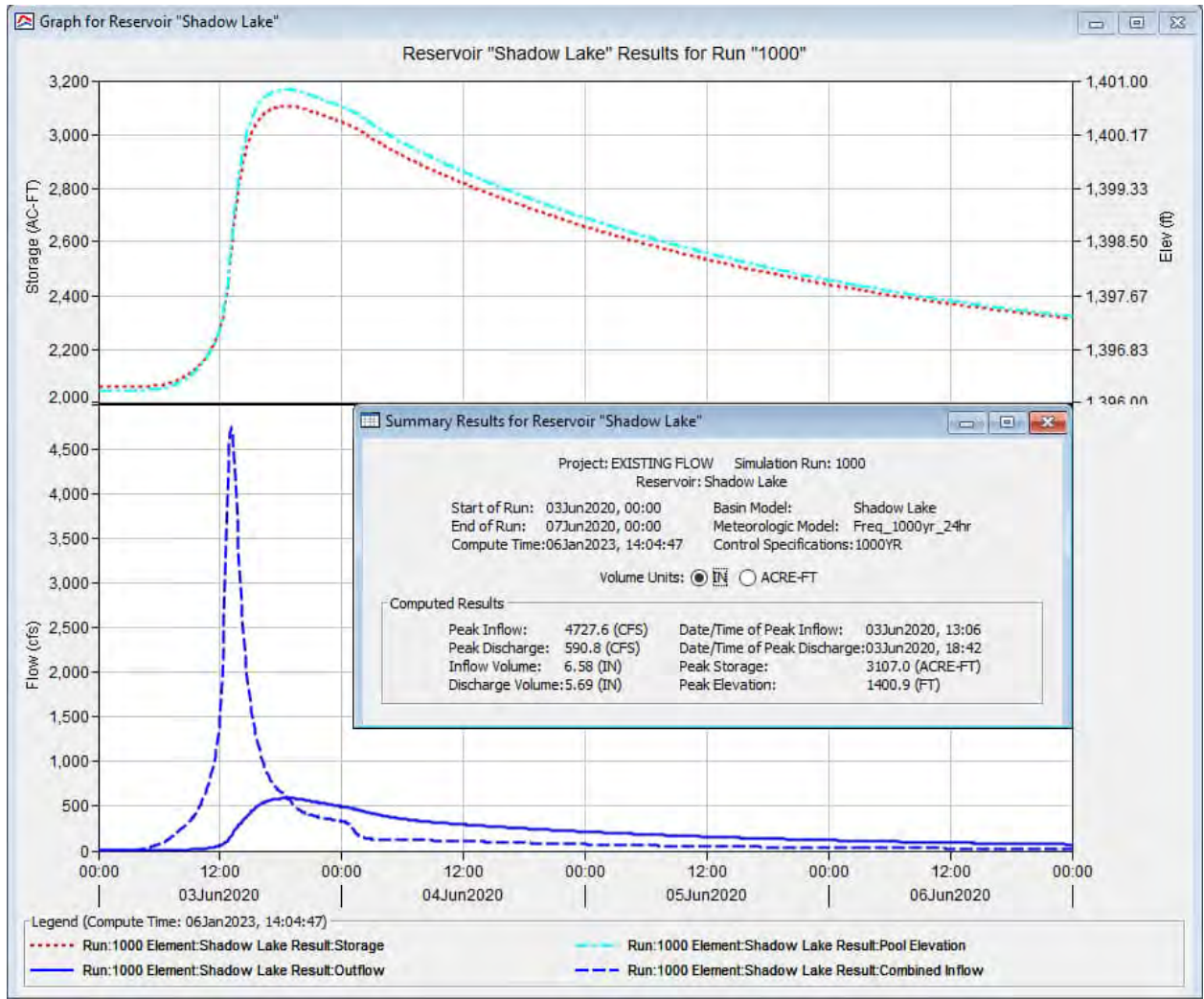
Project: EXISTING FLOW Simulation Run: 500

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_500yr_24hr
Compute Time: 06Jan2023, 14:04:20 Control Specifications: 500YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	1598.5	03Jun2020, 13:00	5.97
Daniels Pond	1.4312	115.1	03Jun2020, 19:30	4.95
Shadow Lake Subcat...	3.8628	4245.2	03Jun2020, 13:06	6.09
Daniels to Shadow	1.4312	115.1	03Jun2020, 19:42	4.95
Shadow Lake	5.2940	444.8	03Jun2020, 19:24	4.94

1000-YR Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "1000"

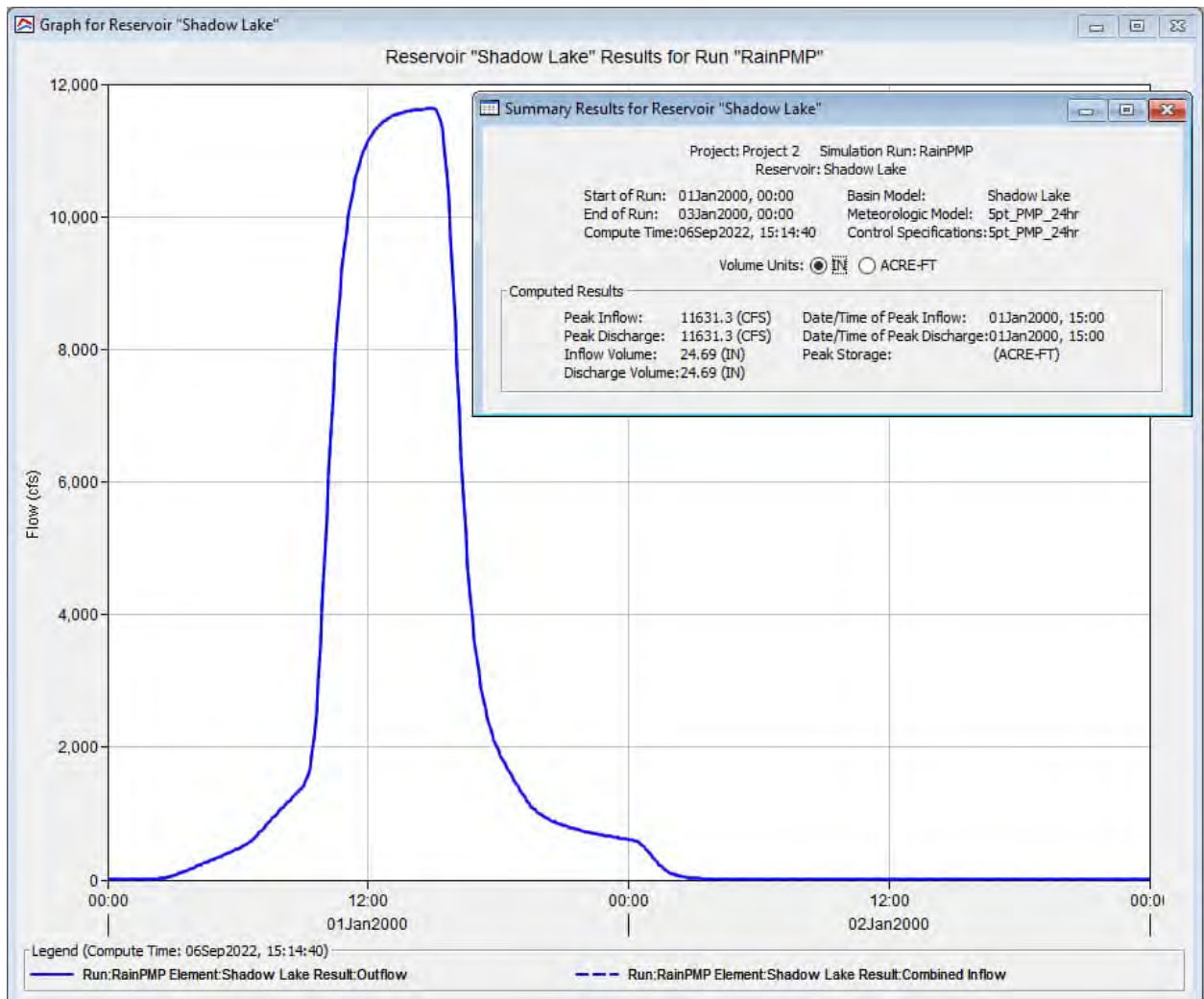
Project: EXISTING FLOW Simulation Run: 1000

Start of Run: 03Jun2020, 00:00 Basin Model: Shadow Lake
 End of Run: 07Jun2020, 00:00 Meteorologic Model: Freq_1000yr_24hr
 Compute Time: 06Jan2023, 14:04:47 Control Specifications: 1000YR

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	1765.2	03Jun2020, 13:00	6.79
Daniels Pond	1.4312	124.5	03Jun2020, 19:42	5.70
Shadow Lake Subcat...	3.8628	4678.1	03Jun2020, 13:06	6.91
Daniels to Shadow	1.4312	124.5	03Jun2020, 19:48	5.70
Shadow Lake	5.2940	590.8	03Jun2020, 18:42	5.69

PMP Peak Inflow to Shadow Lake Dam (Existing Conditions)



Global Summary Results for Run "RainPMP"

Project: Project 2 Simulation Run: RainPMP

Start of Run: 01Jan2000, 00:00 Basin Model: Shadow Lake
End of Run: 03Jan2000, 00:00 Meteorologic Model: Spt_PMP_24hr
Compute Time: 06Sep2022, 15:14:40 Control Specifications: Spt_PMP_24hr

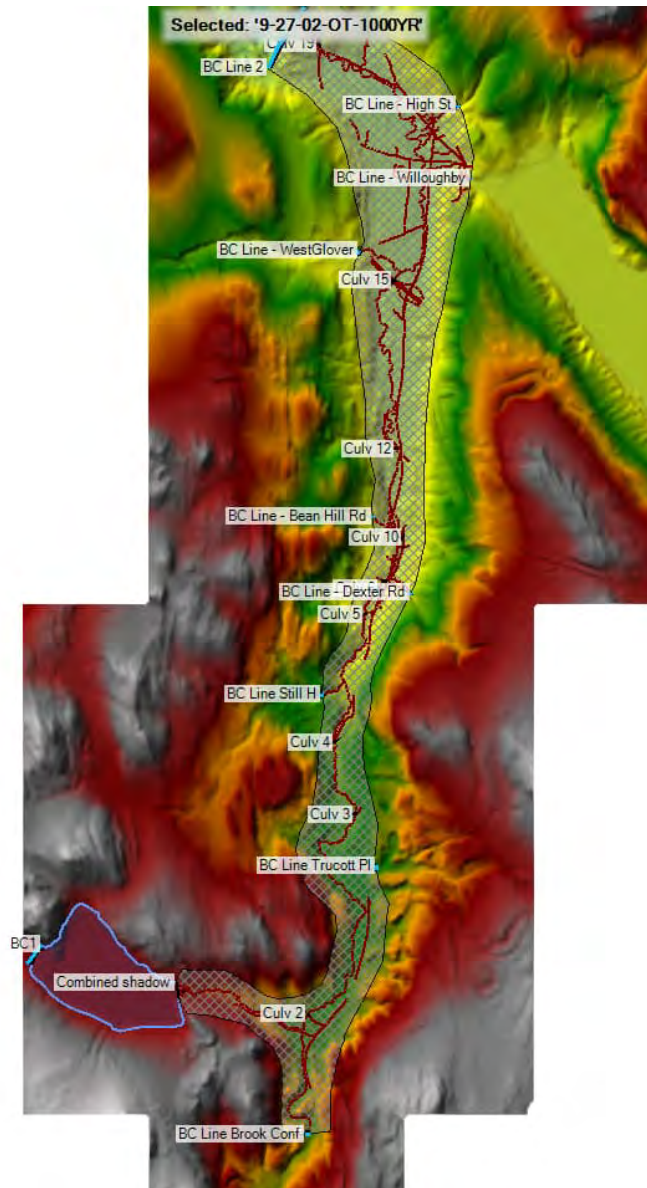
Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI ²)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Daniels Subcatchment	1.4312	3143.1	01Jan2000, 15:00	24.58
Daniels Pond	1.4312	3143.1	01Jan2000, 15:00	24.58
Shadow Lake Subcat...	3.8628	8489.1	01Jan2000, 15:00	24.72
Daniels to Shadow	1.4312	3142.8	01Jan2000, 15:06	24.58
Shadow Lake	5.2940	11631.3	01Jan2000, 15:00	24.69



APPENDIX F
HEC-RAS MODEL GEOMETRY/LAYOUT

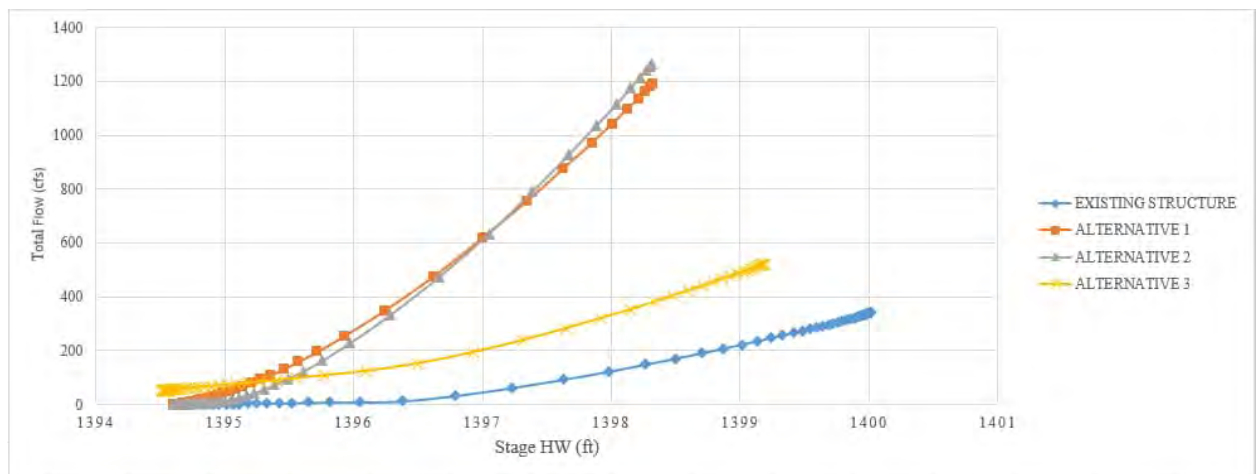
HEC-RAS Model Geometry/Layout



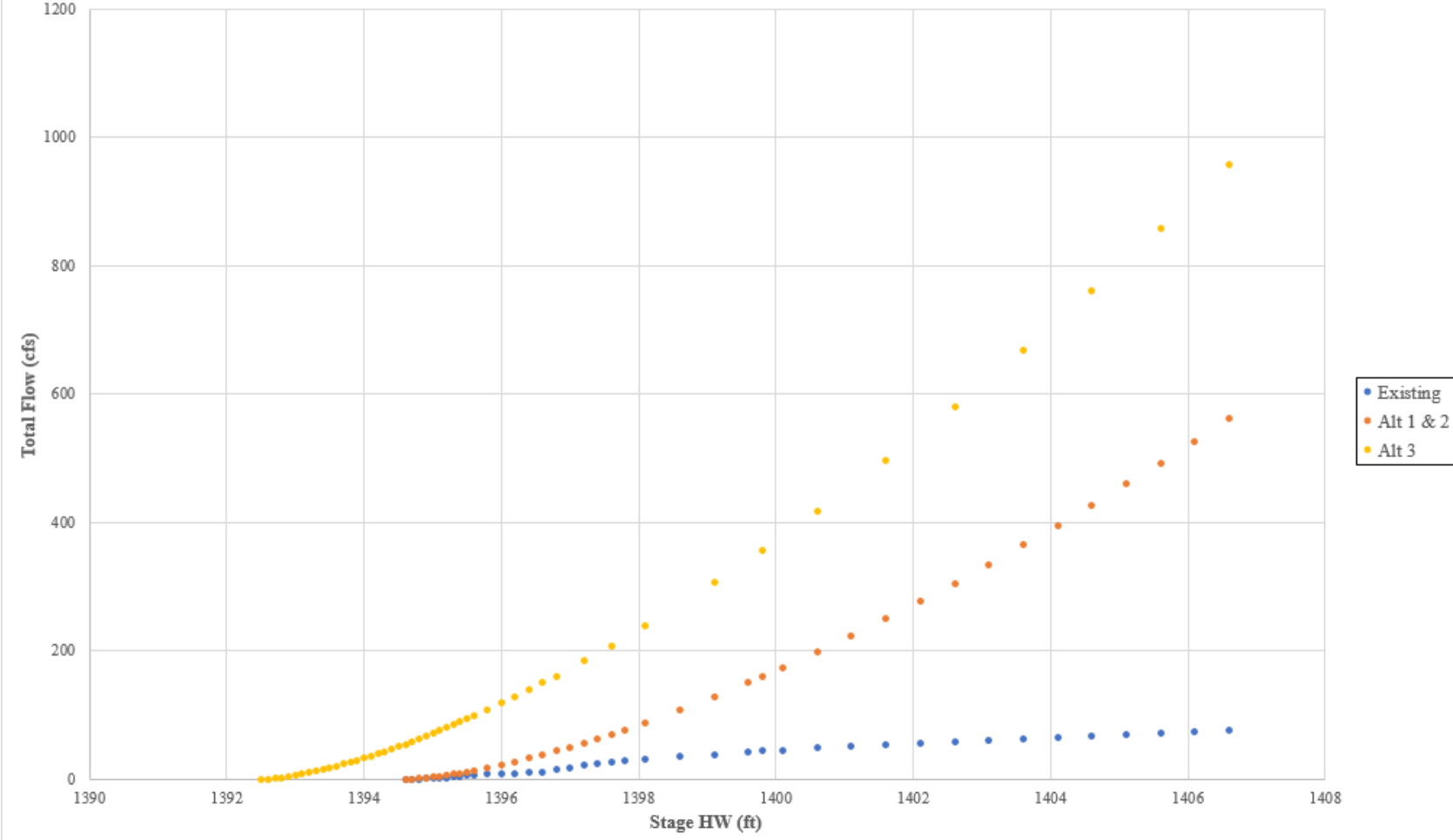


APPENDIX G
THE COMPOSITE RATING CURVE

THE COMPOSITE RATING CURVE FOR THE EXISTING STRUCTURE, ALT 1, ALT 2, & ALT3 (IDF STORM EVENT)

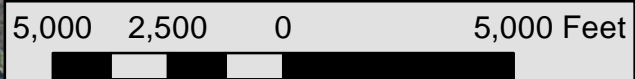
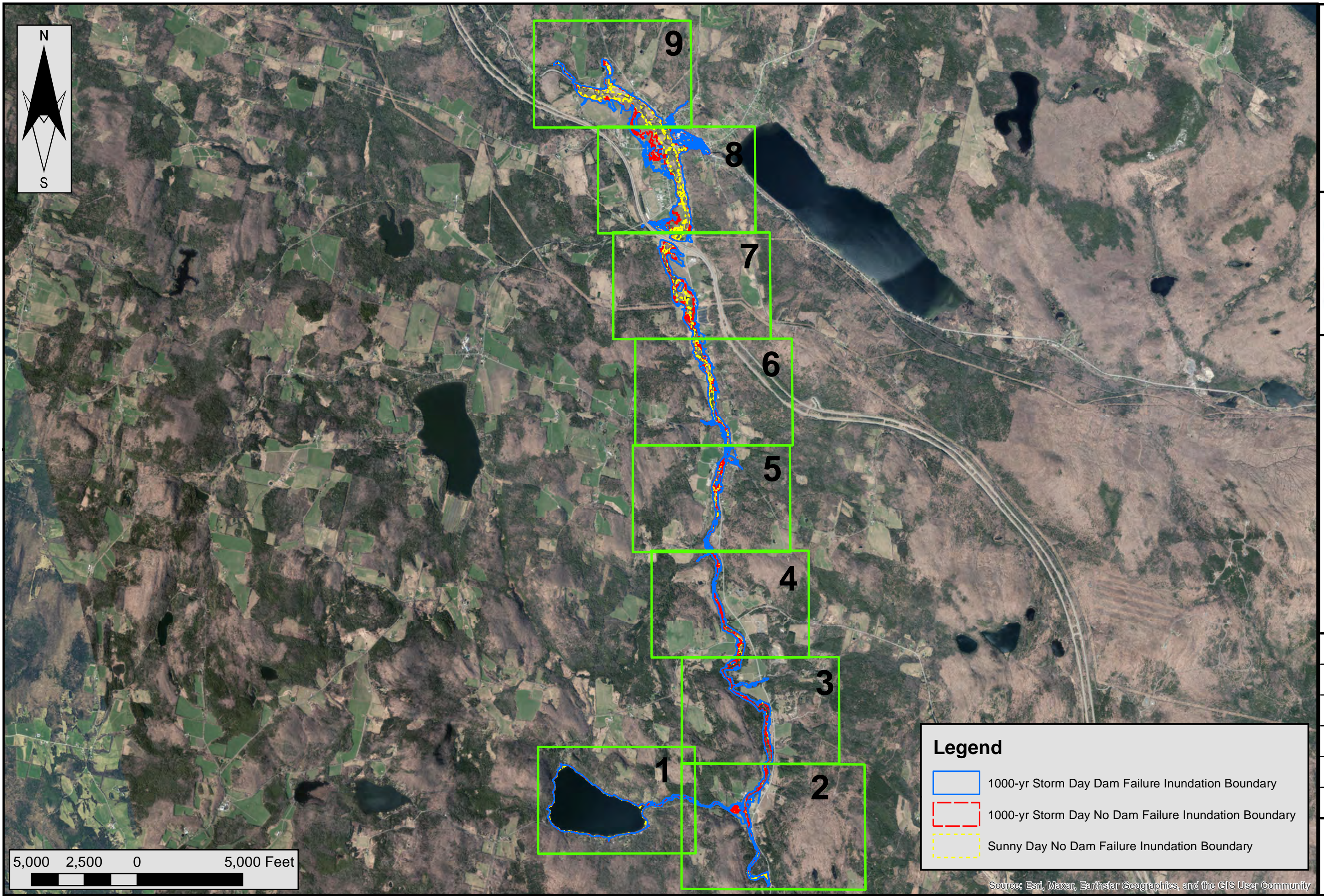


Principal Spillway Discharge Rating Curves








APPENDIX H
INUNDATION MAPS



Legend

-  1000-yr Storm Day Dam Failure Inundation Boundary
-  1000-yr Storm Day No Dam Failure Inundation Boundary
-  Sunny Day No Dam Failure Inundation Boundary

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

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MONTPELIER, VT 05620



INUNDATION MAP
SHADOW LAKE DAM
Index Map

DESIGNED BY:
AF

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DRAWN BY:
AF

CHECKED BY:

PROJECT NO:
127862L1

DATE:
01/30/2023

FIGURE NO:

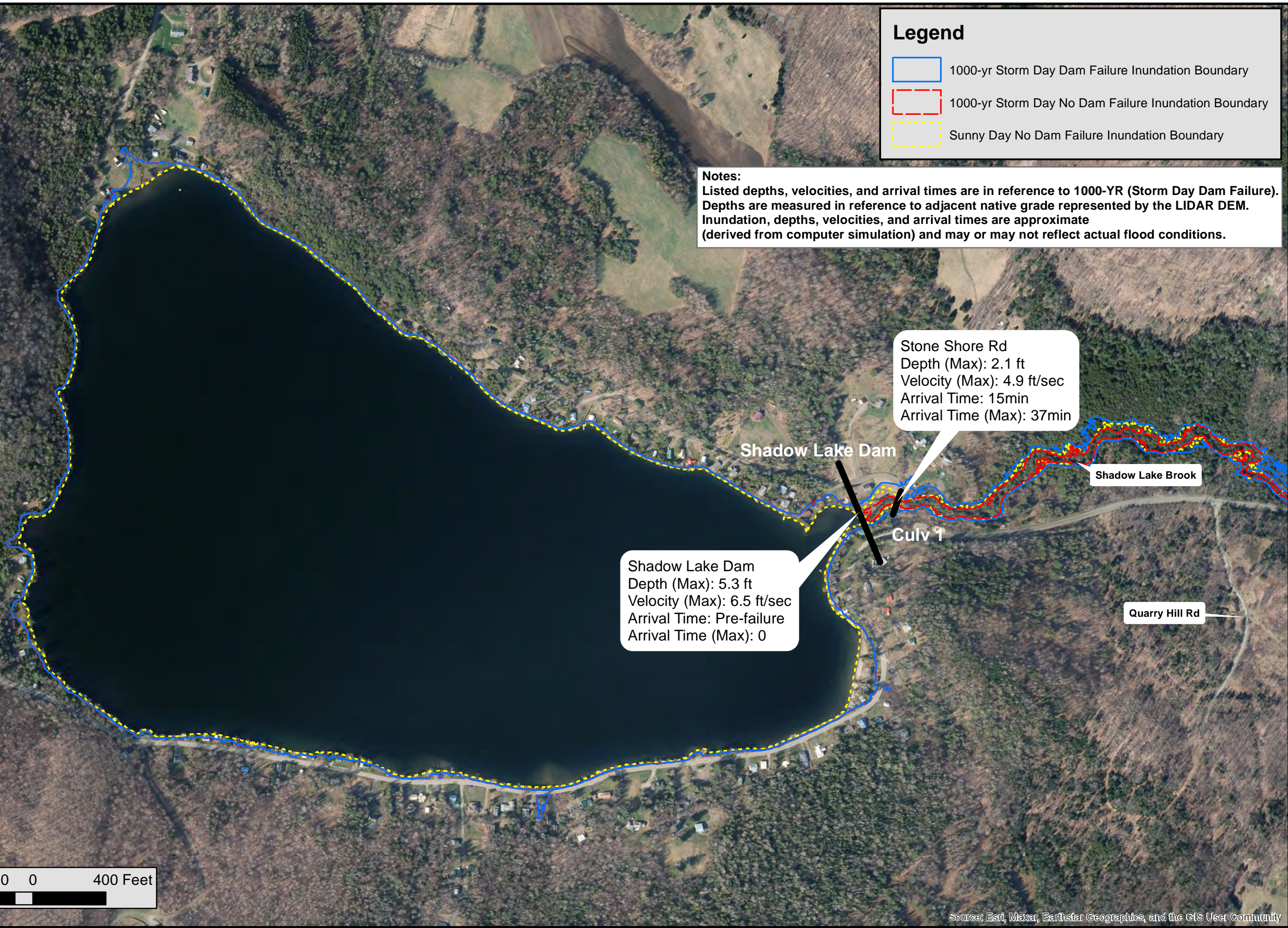
INDEX



Legend

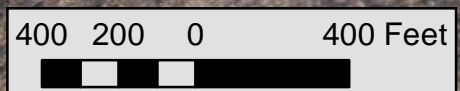
- 1000-yr Storm Day Dam Failure Inundation Boundary
- 1000-yr Storm Day No Dam Failure Inundation Boundary
- Sunny Day No Dam Failure Inundation Boundary

Notes:
 Listed depths, velocities, and arrival times are in reference to 1000-YR (Storm Day Dam Failure). Depths are measured in reference to adjacent native grade represented by the LIDAR DEM. Inundation, depths, velocities, and arrival times are approximate (derived from computer simulation) and may or may not reflect actual flood conditions.



Stone Shore Rd
 Depth (Max): 2.1 ft
 Velocity (Max): 4.9 ft/sec
 Arrival Time: 15min
 Arrival Time (Max): 37min

Shadow Lake Dam
 Depth (Max): 5.3 ft
 Velocity (Max): 6.5 ft/sec
 Arrival Time: Pre-failure
 Arrival Time (Max): 0



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INUNDATION MAP
 SHADOW LAKE DAM PROJECT

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


FIGURE NO:
 1

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

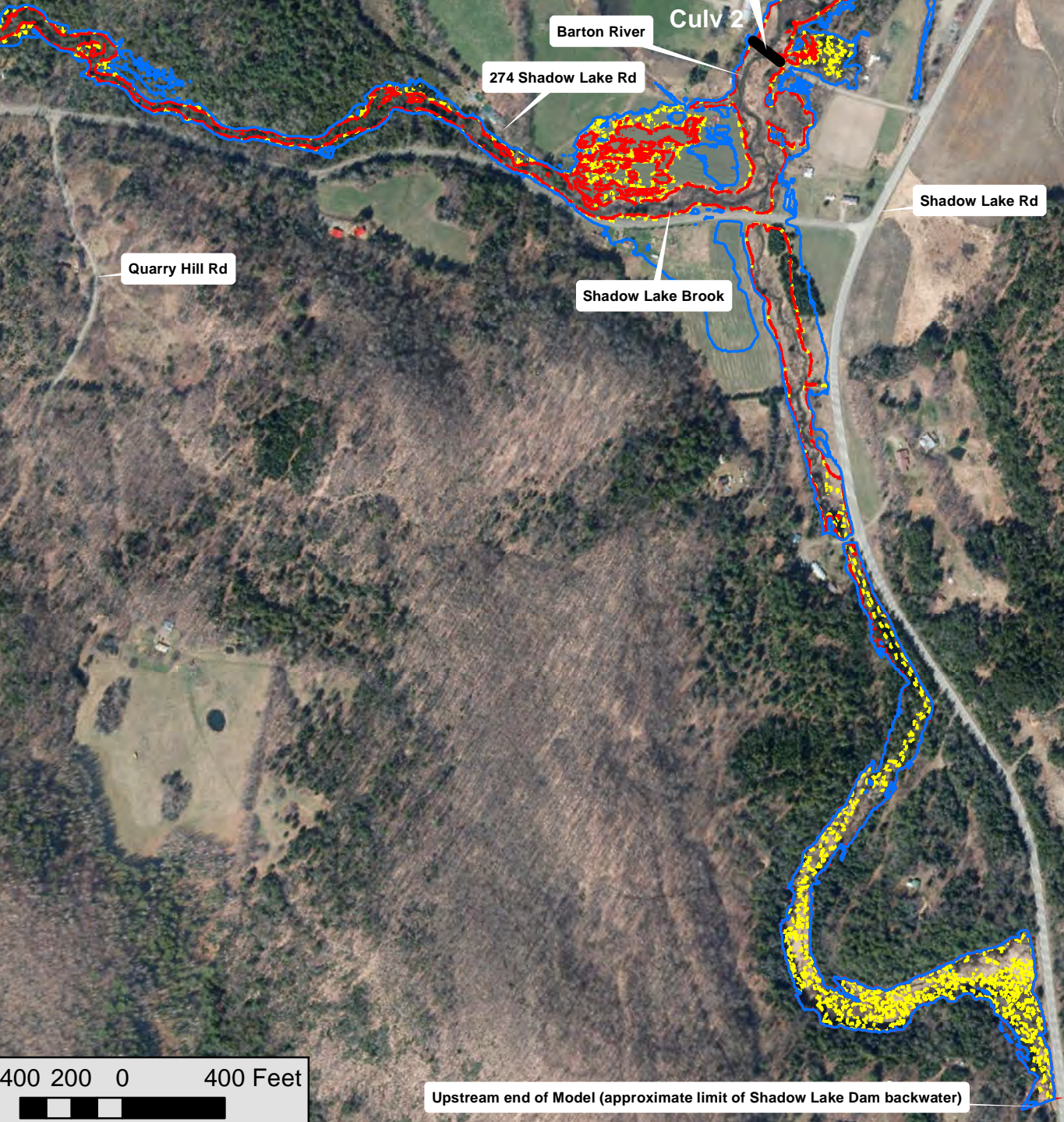


Dwinell Drive
 Depth (Max): 1.6 ft
 Velocity (Max): 4.6 ft/sec
 Arrival Time: 30min
 Arrival Time (Max): 58min

Legend

-  1000-yr Storm Day Dam Failure Inundation Boundary
-  1000-yr Storm Day No Dam Failure Inundation Boundary
-  Sunny Day No Dam Failure Inundation Boundary

Notes:
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


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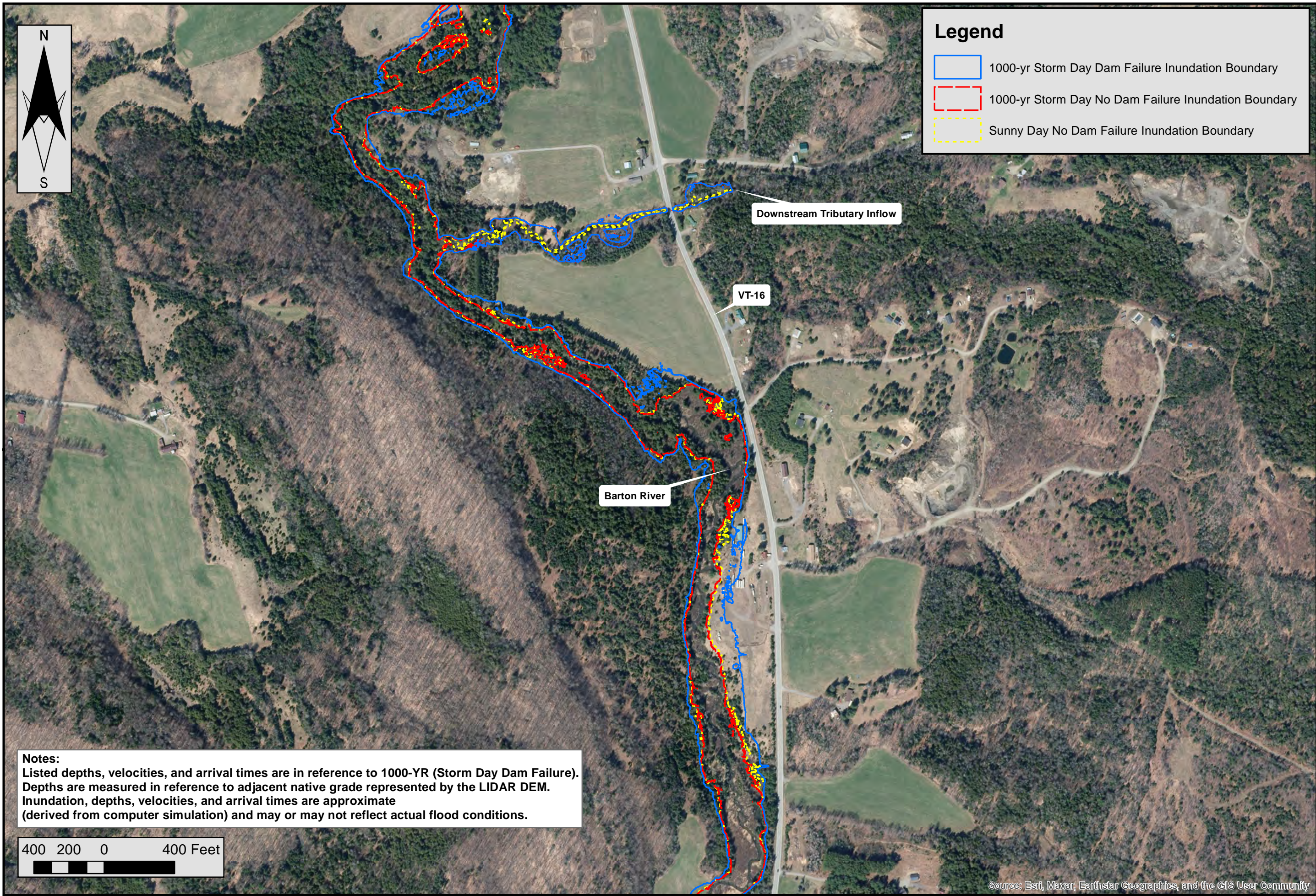
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

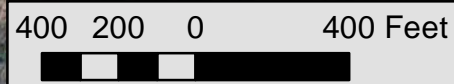


Legend

-  1000-yr Storm Day Dam Failure Inundation Boundary
-  1000-yr Storm Day No Dam Failure Inundation Boundary
-  Sunny Day No Dam Failure Inundation Boundary



Notes:
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


FIGURE NO:

3



Downstream Tributary Inflow

Legend

-  1000-yr Storm Day Dam Failure Inundation Boundary
-  1000-yr Storm Day No Dam Failure Inundation Boundary
-  Sunny Day No Dam Failure Inundation Boundary

Aldrich Ln
 Depth (Max): 2.9 ft
 Velocity (Max): 3.2 ft/sec
 Arrival Time: 1hr, 30min
 Arrival Time (Max): 1hr, 52min

Culv 4

Barton River

VT-16

Heights Rd

Perron Hill Rd
 Depth (Max): 1.1 ft
 Velocity (Max): 5.4 ft/sec
 Arrival Time: 1hr, 15min
 Arrival Time (Max): 1hr, 42min

Culv 3

Notes:
 Listed depths, velocities, and arrival times are in reference to 1000-YR (Storm Day Dam Failure).
 Depths are measured in reference to adjacent native grade represented by the LIDAR DEM.
 Inundation, depths, velocities, and arrival times are approximate
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INUNDATION MAP
 SHADOW LAKE DAM PROJECT

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FIGURE NO:

4



Legend

- 1000-yr Storm Day Dam Failure Inundation Boundary
- 1000-yr Storm Day No Dam Failure Inundation Boundary
- Sunny Day No Dam Failure Inundation Boundary

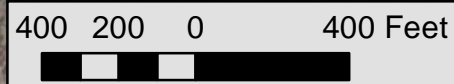
9 Bean Hill Rd, Glover
 Depth (Max): 6.4 ft
 Velocity (Max): 2.5 ft/sec
 Arrival Time: 2hr, 4min
 Arrival Time (Max): 2hr, 7min

School St.
 Depth (Max): 2.3 ft
 Velocity (Max): 5.2 ft/sec
 Arrival Time: 2hr
 Arrival Time (Max): 2hr, 7min

Still Hill Rd
 Depth (Max): 2.2 ft
 Velocity (Max): 4.7 ft/sec
 Arrival Time: 1hr, 45min
 Arrival Time (Max): 2hr, 3min

Bean Hill Rd
 Depth (Max): 2.3 ft
 Velocity (Max): 4.2 ft/sec
 Arrival Time: 2hr, 3min
 Arrival Time (Max): 2hr, 8min

Notes:
 Listed depths, velocities, and arrival times are in reference to 1000-YR (Storm Day Dam Failure). Depths are measured in reference to adjacent native grade represented by the LIDAR DEM. Inundation, depths, velocities, and arrival times are approximate (derived from computer simulation) and may or may not reflect actual flood conditions.



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

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INUNDATION MAP
 SHADOW LAKE DAM PROJECT




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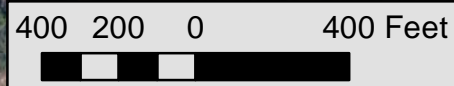
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 FIGURE NO:
5



Legend

-  1000-yr Storm Day Dam Failure Inundation Boundary
-  1000-yr Storm Day No Dam Failure Inundation Boundary
-  Sunny Day No Dam Failure Inundation Boundary

Notes:
 Listed depths, velocities, and arrival times are in reference to 1000-YR (Storm Day Dam Failure).
 Depths are measured in reference to adjacent native grade represented by the LIDAR DEM.
 Inundation, depths, velocities, and arrival times are approximate
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1770 Glover Rd, Barton
 Depth (Max): 4.7 ft
 Velocity (Max): 2.4 ft/sec
 Arrival Time: 2hr, 15min
 Arrival Time (Max): 2hr, 31min

Fulton Ln
 Depth (Max): 3.3 ft
 Velocity (Max): 4.8 ft/sec
 Arrival Time: 2hr, 15min
 Arrival Time (Max): 2hr, 22min

2513 Glover Rd, Glover
 Depth (Max): 5.1 ft
 Velocity (Max): 2.2 ft/sec
 Arrival Time: 2hr, 12min
 Arrival Time (Max): 2hr, 14min

Sargent Ln
 Depth (Max): 2.8 ft
 Velocity (Max): 4.2 ft/sec
 Arrival Time: 2hr, 10min
 Arrival Time (Max): 2hr, 14min

Talbot Ln
 Depth (Max): 1.8 ft
 Velocity (Max): 4.1 ft/sec
 Arrival Time: 2hr, 7min
 Arrival Time (Max): 2hr, 12min

26 Talbot Ln, Glover
 Depth (Max): 6 ft
 Velocity (Max): 2.7 ft/sec
 Arrival Time: 2hr, 6min
 Arrival Time (Max): 2hr, 11min

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 SHADOW LAKE DAM PROJECT

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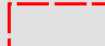

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FIGURE NO:

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Legend

-  1000-yr Storm Day Dam Failure Inundation Boundary
-  1000-yr Storm Day No Dam Failure Inundation Boundary
-  Sunny Day No Dam Failure Inundation Boundary

July 15
 Interstate 91
 Depth (Max): 1.1 ft
 Velocity (Max): 0.2 ft/sec
 Arrival Time: 3hr, 15min
 Arrival Time (Max): 5hr, 6min

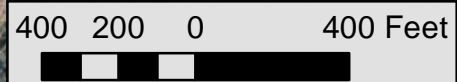
Barton River

Glover Rd

I-91S

I-91N

Notes:
 Listed depths, velocities, and arrival times are in reference to 1000-YR (Storm Day Dam Failure). Depths are measured in reference to adjacent native grade represented by the LIDAR DEM. Inundation, depths, velocities, and arrival times are approximate (derived from computer simulation) and may or may not reflect actual flood conditions.



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DATE:
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FIGURE NO:

7



Elm St
 Depth (Max): 0.5 ft
 Velocity (Max): 0.7 ft/sec
 Arrival Time: 4hr, 30min
 Arrival Time (Max): 9hr, 34min

Legend

- 1000-yr Storm Day Dam Failure Inundation Boundary
- 1000-yr Storm Day No Dam Failure Inundation Boundary
- Sunny Day No Dam Failure Inundation Boundary

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 SHADOW LAKE DAM PROJECT

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 FIGURE NO:

Downstream Tributary Inflow

32 Glover Rd, Barton
 Depth (Max): 7.5 ft
 Velocity (Max): 3 ft/sec
 Arrival Time: 4hr, 22min
 Arrival Time (Max): 9hr, 30min

29 Elm St, Barton
 Depth (Max): 7.6 ft
 Velocity (Max): 1.7 ft/sec
 Arrival Time: 4hr, 25min
 Arrival Time (Max): 9hr, 32min

Glover Rd

Roaring Brook Rd
 Depth (Max): 0.7 ft
 Velocity (Max): 0.1 ft/sec
 Arrival Time: 4hr
 Arrival Time (Max): 9hr, 4min

Duck Pond Rd

Lake St

Barton River

Park St

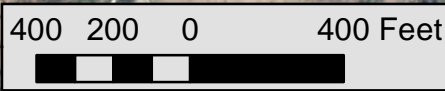
I-91S

I-91N

Roaring Brook Rd

Downstream Tributary Inflow

Notes:
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 Depths are measured in reference to adjacent native grade represented by the LIDAR DEM.
 Inundation, depths, velocities, and arrival times are approximate
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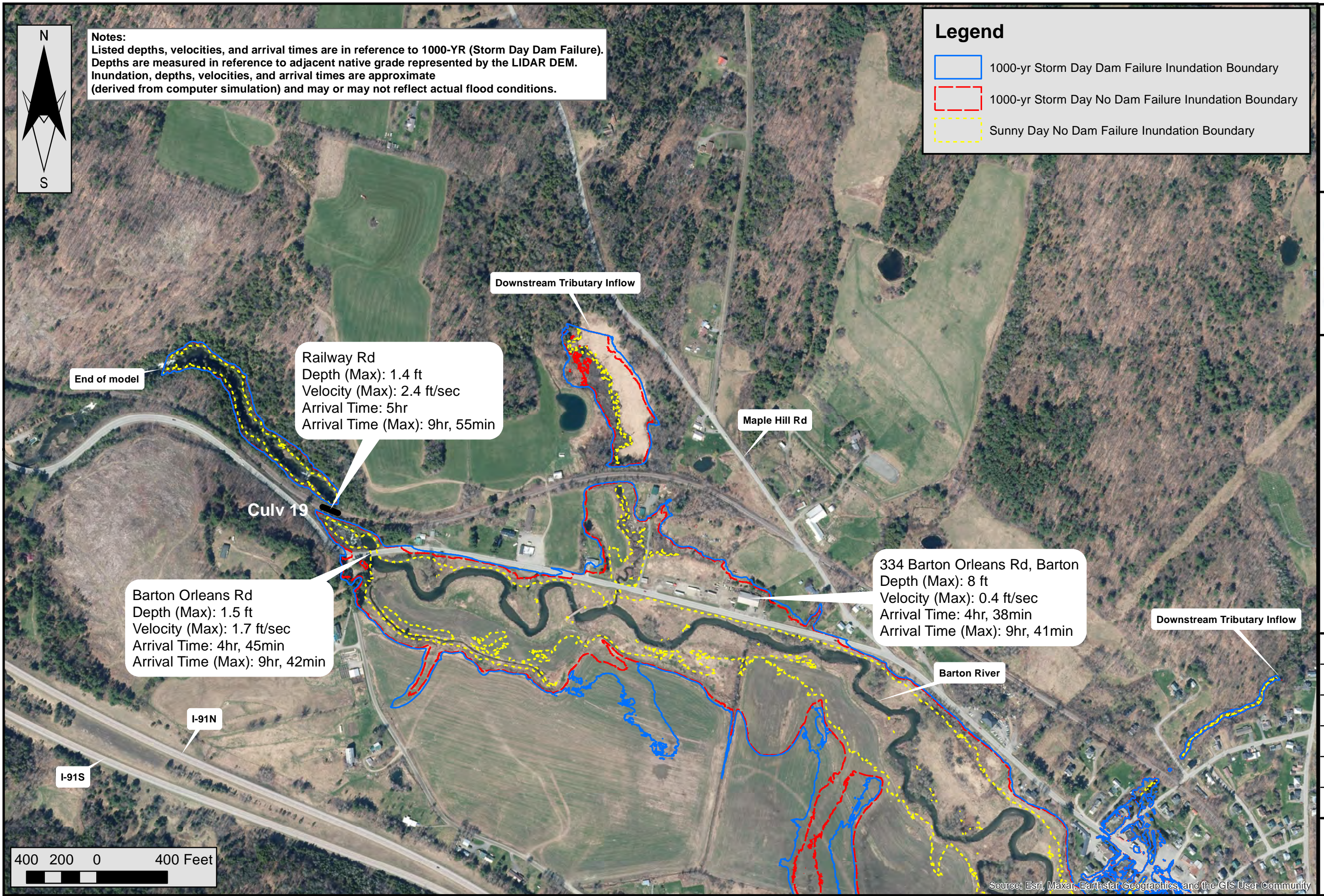
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Notes:
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Legend

- 1000-yr Storm Day Dam Failure Inundation Boundary
- 1000-yr Storm Day No Dam Failure Inundation Boundary
- Sunny Day No Dam Failure Inundation Boundary



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 SHADOW LAKE DAM PROJECT

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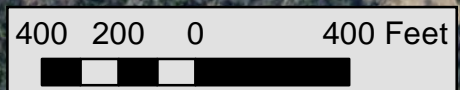
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PROJECT NO:
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DATE:
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FIGURE NO:

9



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community