Dam Failure Analysis

Laitsch Dam

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9/9/22

Dam Failure Analysis

Laitsch Dam

Town of Mukwonago
Waukesha County, Wisconsin

Prepared for:

Spring Brook Watershed Lake Management District
c/o Jim McNelly

September 9, 2022

Prepared by:

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1. EXECUTIVE SUMMARY

Stormwater Solutions Engineering, LLC performed a Dam Failure Analysis for Laitsch Dam utilizing HEC-RAS and the resultant hydraulic shadow to determine the impacts to Spring Brook resulting from a breach of Laitsch Dam.

The impacts to potential loss of life, economic losses, lifeline disruption, and environmental damage were evaluated. The hydraulic shadow developed from the HEC-RAS model resulted in expansion of the 100-year Spring Brook flows onto private property, but affecting no accessory building and no habitable structures. The limited impacts from the modeled hydraulic shadow are largely within the WDNR 2014 identified "Zone AE" floodplain and WDNR identified wetlands.

The analysis resulted in finding of a "low" risk hazard rating.

CONTENTS

2. INTRODUCTION

Stormwater Solutions Engineering, LLC was contracted by the Spring Brook Watershed Lake Management District (District) to conduct a Dam Failure Analysis (DFA) on Laitsch Dam. The objective of the analysis is to determine the extent of the dam failure floodplain (hydraulic shadow) if it were to fail and identify the dam's hazard rating based on the affected development downstream. The District will ultimately use the DFA to develop and implement a detailed emergency action plan for the dam.

3. BACKGROUND

Laitsch Dam is currently classified by the Wisconsin Department of Natural Resources (WDNR) Dam Safety program as a large earthen dam. The dam is located at the downstream outlet of Willow Springs Lake in the Town of Mukwonago, Waukesha County. The drainage basin contributing to Willow Springs Lake is approximately 3.10 square miles. Laitsch Dam contains approximately 220-acre-ft of water, with a maximum storage of 590 acre feet. The dam structure consists of a 1,940-linear foot, 20-foot high earthen embankment with a clay core. The primary outlet is a 42-inch corrugated metal drop pipe structure with the invert at 913.50' (NAVD88). The auxiliary outlet is a 30-ft wide spillway with an invert elevation of 916.70'. The dam discharges to Spring Brook within Dunlop Marsh approximately 0.75 miles upstream of the Road X culvert crossing (Figure 3.1). Spring Brook then meanders another 1.2 miles through mapped wetlands (Genesee Marsh) to the STH 83 bridge. Spring Brook joins Genesee Creek 1.3 miles downstream of STH 83 and shortly thereafter discharges to Saylesville Millpond in the Town of Genesee. Laitsch Dam is managed by the Spring Brook Watershed Lake Management District.

In 2014 WDNR completed a floodplain analysis for the Spring Brook watershed, including hydrologic HEC-HMS analysis and a hydraulic HEC-RAS analysis. The updated models were used as the effective hydrologic and hydraulic conditions for this dam failure analysis. In 2021, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) performed an informal dam break analysis for Laitsch Dam. Results found that the downstream wetland areas, including Dunlop and Genesee Marsh, had capacity to contain the volume of water associated with the dam breach (Attachment 1). The SEWRPC analysis, however, made the assumption that the dam would only breach to an elevation of 909 ft because the existing ground elevation on the northeast side of the dam would stay in place. The DFA herein assumes that the dam will breach down to the bottom of the lake (900') to determine the impact in the worst-case scenario.

Figure 3.1 Location map for Laitsch Dam, Spring Brook and associated crossings, and Saylesville Millpond.

4. METHODS OF ANALYSIS

The resulting models from the WDNR 2014 Spring Brook steady state floodplain analysis served as the starting point, as well as calibration for the unsteady dam failure analysis. Detailed descriptions of the application of the 2014 study for this DFA are provided below.

4.1. Hydrology

WDNR created a HEC-HMS model in May 2014 to determine the hydrograph along Spring Brook and flow inputs into various points along the stream. The 100-year hydrographs used from the 2014 study area presented in Table 4.1. Inflow hydrographs are available in Attachment 2.

Table 4.1 HEC-HMS 100-year hydrographs used for Laitsch DFA.

HEC-HMS Node ID	HEC-HMS Hydrograph Type	HEC-RAS DFA Hydrograph Input Type	River Station(s) Location
Willow Springs Lake	Instream	Input Hydrograph	19513
W480	Input	Uniform Lateral Inflow	17488 to 14090
W470	Input	Uniform Lateral Inflow	13821 to 11566
Reservoir-7	Input	Lateral Inflow	11011
W220	Input	Uniform Lateral Inflow	9939 to 7779
W210	Input	Uniform Lateral Inflow	7248 to 5674

As the dam is currently estimated as having a low hazard rating, the effective low hazard rating peak flows from the 2014 WDNR floodplain analysis were used to evaluate the dam performance for the design event (Table 4.2).

Table 4.2 Steady state design storm flows.

River Station	Flow (cfs)	
	10-yr ARI	100-yr ARI
19513	27	74
17808	50	61
14090	56	81
11011	105	226
7779	124	267
5674	131	282

4.2. Hydraulic Model

Hydraulic modeling was done using HEC-RAS v. 6.2. The WDNR 2014 Spring Brook model served as a starting point for the steady state model development. The model was truncated at River Station (RS) 19513, the cross section just upstream of Willow Springs Lake, as upstream hydraulics are not critical to the scope of the Laitsch DFA. The 2014 model uses an inline structure-combined with a dummy culvert to represent the drop pipe structure at Laitsch Dam (Attachment 3). Since the model configuration does not allow for a dam breach analysis (modeled culverts do not allow for breaching), the drop pipe inlet on the inline structure, culvert, and upstream cross section (RS 17626) were removed. In place of the removed items, a routing curve was developed from the drop pipe-culvert outlet structure using HydroCAD v. 10.00-26 (Figure 4.1) and included in the HEC-RAS inline structure representing Laitsch Dam per WDNR 2014 survey (Attachment 4). Model stability was finalized using selected interpolated cross sections calculated every 50 feet based on P.G. Samuels (Samuels, 1989) equation:

$$\Delta x \leq 0.15D \div S$$

where:

- D = average main channel bankful depth (feet); 2.71 feet
- S = the bed slope (feet/feet); 0.00885
- Δx = cross section spacing distance (feet); calculated as 45.9 feet

The input hydrographs defined the model boundary conditions. Normal depth (slope = 0.00152) was used as the boundary condition for the downstream end of the model. The resulting model is shown in Figure 4.2. Initial model run time was set to May 19, 2022 at 21:30 with an initial lake elevation of 514.75, as calculated through iterations.

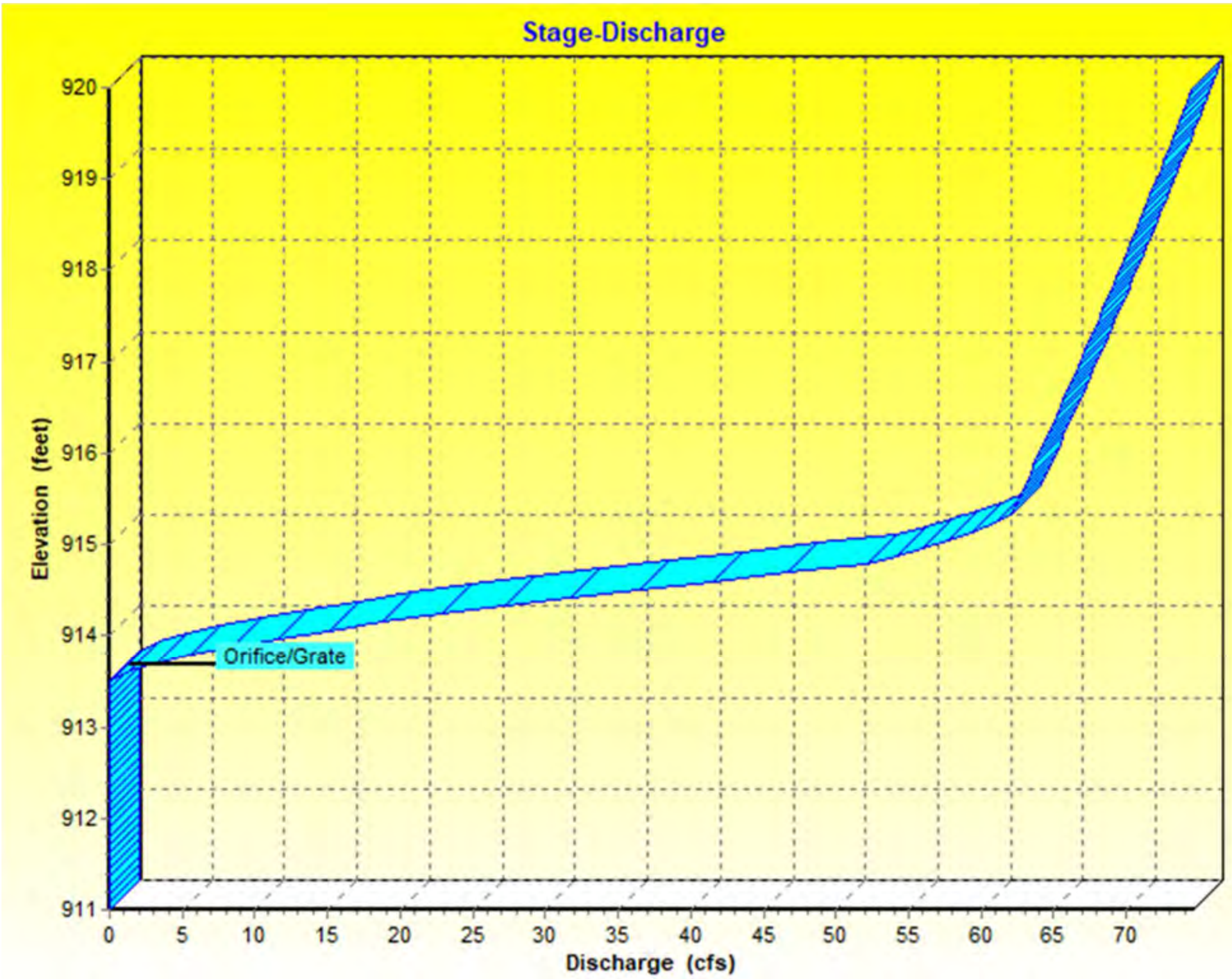


Figure 4.1 Routing curve for the drop-pipe culvert structure (principal spillway) at Laitsch Dam

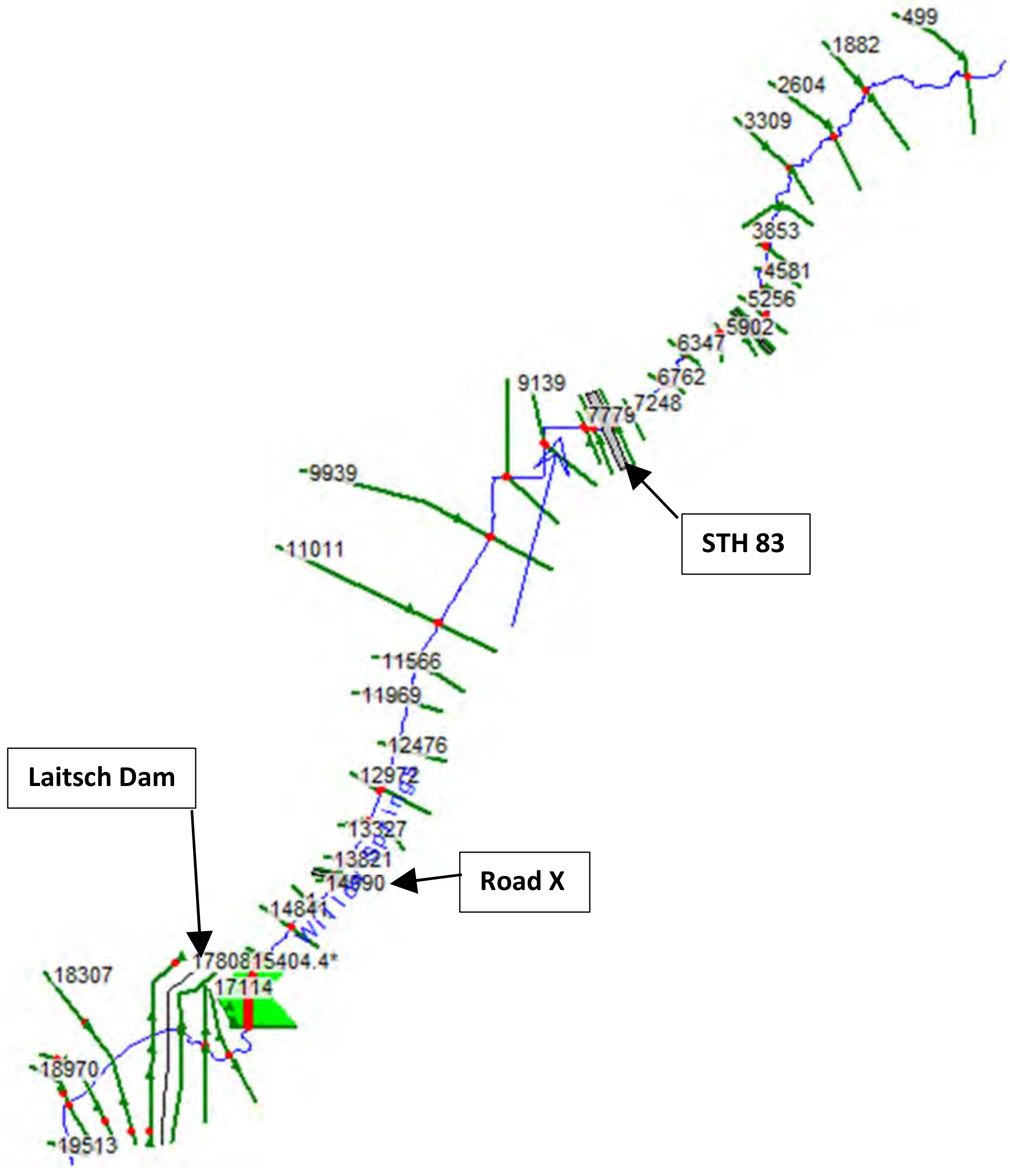


Figure 4.2 Updated HEC-RAS model for Laitsch DFA.

4.3. Breach

Breach parameters were estimated using a variety of regression equations appropriate for Laitsch Dam height and volume. Dam failure was assumed to occur where the downstream elevation is lowest (station 900 selected). Failure mode was assumed as piping (worst-case scenario) since the downstream embankment toe is at a higher elevation than the culvert outlet location. It was assumed that piping could be possible near or around the existing outlet culvert. Reservoir volume was calculated to be 590 ac-ft (727,470 cubic meters). Breach height is assumed to be the full dam height, or 20 feet (6.10 meters). The piping coefficient was set to 0.5. A summary of the equations and resulting parameters are provided in Table 4.3. Dam breach was triggered by a water surface elevation of 916.20', or just prior to peak elevation of Willow Springs Lake during the 100-year event.

Table 4.3 Regression equations used to determine dam breach characteristics and sensitivity analysis.

Breach ID	Method	Breach Bottom Width (ft)	Breach Side Slopes (H:1V)	Breach Failure Time (hrs)	Breach Type	Qpeak @ Dam	WSE @ US Dam	WSE @ DS Dam	WSE @ US Rd X		Δ Qpeak Mean
Breach1	Reclamation (1988)	60	1	0.20	piping	946.80	916.20	911.76	893.40		0.02
Breach2	McDonald	60	0.5	0.32	piping	928.11	916.20	911.82	893.40		18.67
Breach3	Forehlich 1995	45	0.9	0.64	piping	1045.31	916.20	911.74	893.40		98.53
Breach4	Froehlich 2008	58	0.7	0.78	piping	810.17	916.20	911.74	893.40		136.61
Breach5	Von Thun & Gillete	51	0.5	0.35	piping	1102.38	916.20	911.80	893.40		155.6
Breach6	Xu & Zhang	38	0.74	1.26	piping	847.91	916.20	911.62	893.39		98.87

	Qpeak @ Dam	WSE @ US Dam	WSE @ DS Dam	WSE @ US Rd X
Mean	946.78	916.20	911.75	893.40
Median	937.46	916.20	911.75	893.40
Max	1102.38	916.20	911.82	893.40
Min	810.17	916.20	911.62	893.39
% Varience	-14.43%	0.00%	-0.01%	0.00%

The breach parameters were input into HEC-RAS via "User Entered Data Method" and evaluated to determine the worst-case scenario.

4.4. Model Analysis

4.4.1. Model Calibration

Using the hydrologic and hydraulic data provided above, the unsteady "Dam-in-Place" (DIP) model was calibrated to both the effective steady state WDNR 2014 and the steady state SSE updated model (Figure 4.3). The maximum deviation in water surface elevation (WSE) of the updated SSE model from the WDNR 2014 model was 4.5 feet (higher) approximately between Willow Spring Lake and Road X (Table 4.4). The model also deviated by 1.5 feet (higher) just upstream of the STH 83 crossing. Average and median absolute difference between WSE for each of the models was 1.27 and 1.17 feet, respectively, with the SSE updated model tending to result in a higher WSE than the WDNR 2014 model. Differences leveled out at Saylesville Mill Pond. Given that the SSE model is conservative and primarily differs at the dam affected location, it was determined that this SSE updated model was representative of the effective flood mapping to proceed with the DFA.

Figure 4.3 Water surface elevation calibration between WDNR 2014, updated SSE steady state, and the SSE unsteady state models.

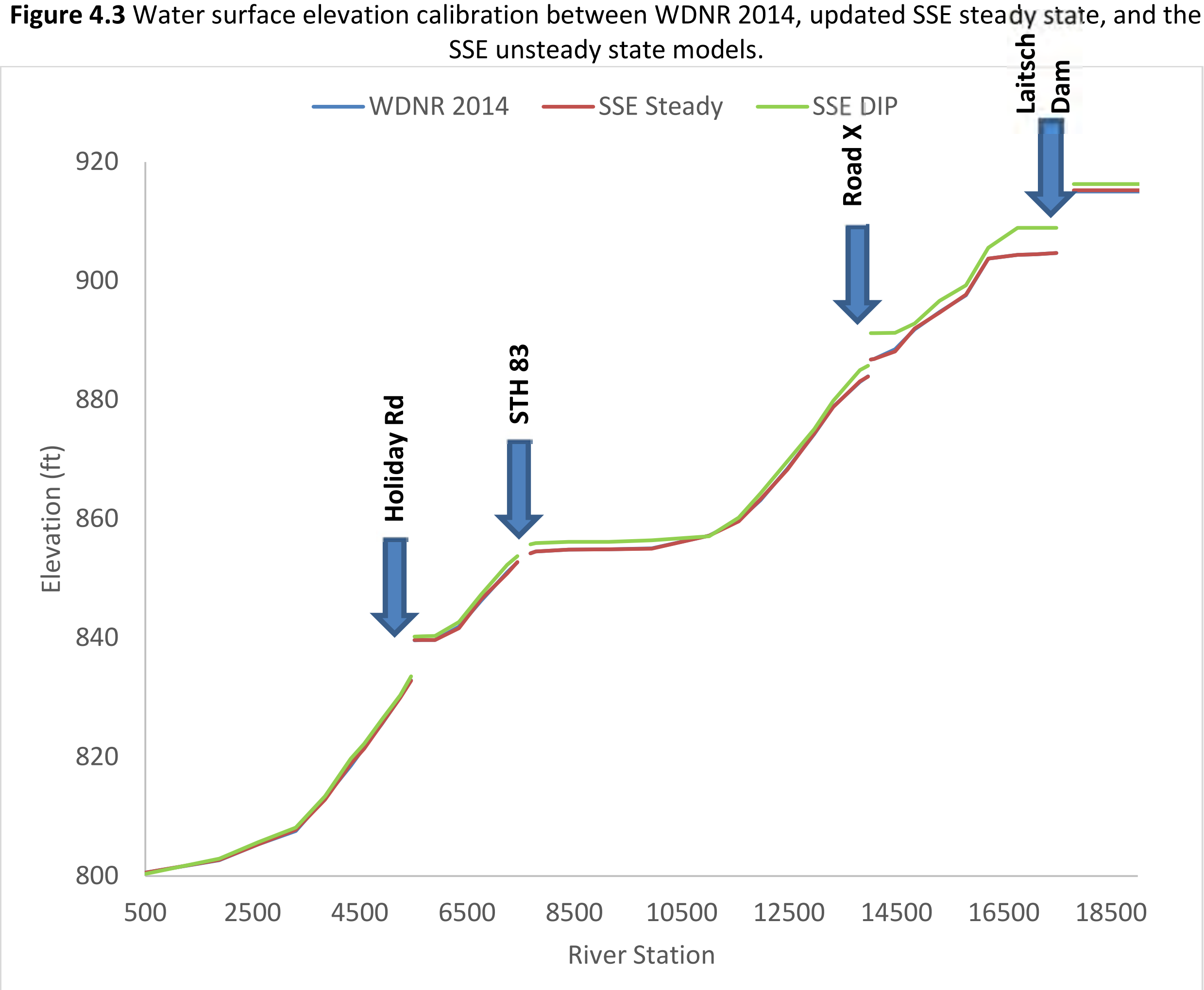


Table 4.4 Statistical analysis of the difference in water surface elevation (WSE) between the effective (WDNR 2014), SSE updated steady state, and the SSE dam in place (DIP) models

	SSE Steady v. WDNR	DIP v. WDNR	DIP v. SSE Steady
Abs[1] Max	0.36	4.52	4.52
Abs Mean	0.10	1.27	1.26
Abs Median	0.06	1.17	1.01
True Mean[2]	0.01	1.26	1.25

[1] Absolute value of the difference
[2] Indicates if the WSE in the SSE model on average is higher or lower than the WDNR 2014 model; (+) value indicates higher

4.4.2. Breach Analysis

Different breach scenarios were evaluated considering the different regression equations and potential breach times. A summary of the results for each analysis are presented in Table 4.3. A sensitivity analysis showed that the difference in breach parameters had very minor impact on downstream water surface elevations and the greatest impact on breach flow. Ultimately, Breach 1 was the scenario to determine the hydraulic shadow and risk related to dam failure because it most represented them mean flow between the regression equations.

4.4.3. Spillway Evaluation

The 10- and 100-year ARI steady state flows were evaluated for the SSE updated steady state model to determine the primary and auxiliary spillway performance. The 100-year event never reached the invert elevation of the secondary spillway, therefore the primary spillway is able to convey up to the 100-year event. This meets the design standard for all dam hazard ratings.

5. RESULTS OF HYDRAULIC SHADOW ANALYSIS

The hydraulic shadow was determined using the RAS Mapper tool in HEC-RAS v. 6.2. A terrain file was created from the 2015 Waukesha County 1-ft contours available from the County. The terrain data showed a relative match to the model's cross-sectional shape when compared.

Convergence between the hydraulic shadow and the dam in place flood elevation occurred on the upstream side of STH 83. The hydraulic shadow from the dam breach is limited primarily to the river channel and surrounding wetlands (Attachment 9). Both private and public properties are impacted by the shadow. However, no structures are impacted.

6. RISK BASED ASSESSMENT OF DAM FAILURE

6.1. Risk of Economic Loss

The dam breach hydraulic shadow impacts both public and private land primarily between Laitsch dam and STH 83. The majority of the shadow is contained within WDNR designated wetlands (see Attachment 10 for flood maps), including Dunlop Marsh and Genesee Marsh. Areas where the inundation zone is outside of the wetlands includes adjacent to Road X, where it infringes, in part, on a 3 acre privately owned parcel used for agricultural purposes. It is notable that this parcel is also partially inundated during the 100-year flood. Minor economic loss may be associated with loss of crops, if the agricultural land is planted here. However, aerial and streetside imagery do not show recent agricultural activity, but rather brush and early succession woody vegetation. Therefore, the economic loss of the dam breach is considered low.

6.2. Risk of Loss of Life

Fatality risk estimates can be derived from empirical equations based on dam failure elapsed warning time, or based on severity of damage to structures from the dam failure. Because of the rural downstream area, and the size and scope of dam, it is assumed no warning is issued for the dam failure as modeled. Therefore, severity of damage to structures can be an appropriate risk analysis tool.

Utilizing appropriate equations from "A Procedure for Estimating Loss of Life Caused by Dam Failure," Department of the Interior, Bureau of Reclamation, DSO-99-06 September 1999, by Wayne J. Graham, P.E., as originally developed by DeKay and McClelland (20) (See Attachment 7), results in a Risk of Loss of Life of 0.07 persons.

Since 0.07 persons is less than 0.50 persons, the threshold where a life could be probabilistically lost, there is no probable loss of life from dam failure as modeled.

6.3. Risk of Environmental Loss

Because the existing downstream floodplain and area of the expanded hydraulic shadow consist of established vegetation of various types, including trees, shrubs, and grasses, it is assumed that there is relatively low probability of significant erosion caused by the dam failure.

An earthen dam breach would result in a downstream wash of sediment, likely to be deposited in the surrounding Dunlop Marsh. The accumulated sediment would negatively impact the storage of the wetland. However, the wetland is not currently a high-functioning wetland and is in need of invasive species control (e.g. buckthorn). Therefore, the added sediment is not likely to negatively impact beneficial species within the wetland.

6.4. Risk of Lifeline Facilities

The hydraulic shadow of the dam breach does overtop Road X by a depth of 26 inches. This makes Road X impassable at this location. However, properties within this neighborhood can be accessed from STH 59 to the west as well. Therefore, lifeline facilities are still accessible to these property owners. The next downstream crossing, STH 83, has remaining freeboard and will remain functional during a dam breach.

6.5. Overall Dam Hazard Rating

NR 333.06(1) identifies Dam hazard ratings as follows:

(a) Low hazard. A low hazard rating shall be assigned to those dams that have no development unrelated to allowable open space use in the hydraulic shadow where the failure or mis−operation of the dam would result in no probable loss of human life, low economic losses (losses are principally limited to the Dam Owners property), low environmental damage, no significant disruption of lifeline facilities, and have land use controls in place to restrict future development in the hydraulic shadow.

(b) Significant hazard. A significant hazard rating shall be assigned to those dams that have no existing development in the hydraulic shadow that would be inundated to a depth greater than 2 feet and have land use controls in place to restrict future development in the hydraulic shadow. Potential for loss of human life during failure must be unlikely. Failure or mis−operation of the dam would result in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities.

(c) High hazard. A high hazard rating shall be assigned to those dams that have existing development in the hydraulic shadow that will be inundated to a depth greater than 2 feet or do not have land use controls in place to restrict future development in the hydraulic shadow. This rating must be assigned if loss of human life during failure or mis−operation of the dam is probable.

Given the risk analysis above, including low economic and environmental loss, no risk to loss of life, and no disruption of lifeline facilities, Laitsch Dam should be assigned a hazard rating of **low**.

7. SUMMARY OF RESULTS

From the Hydraulic Shadow analysis, there are no residential or commercial structures that are impacted, there is little to no potential for loss of human life, and the potential for economic loss, environmental loss and disruption of lifeline facilities are all low.

Future area impacted by the hydraulic shadow appear to be limited as the modeled dam break hydraulic shadow is predominantly within the FEMA identified Zone AE floodplain and within WDNR designated wetlands.

Overall, the Dam Failure Analysis identifies Laitsch Dam has a “low” hazard risk.

8. LIST OF EXHIBITS AND ATTACHMENTS

ATTACHMENT 1: SEWRPC INFORMAL DFA

Laitsch Dam Break Analysis

7/21/2021, JCO

Willow Spring Lake Volume:

To help estimate the volume of Willow Spring Lake during a 100-year storm event, Commission staff obtained preliminary modeling of Spring Book by the Wisconsin Department of Natural Resources as part of a RiskMAP effort for the Upper Fox River Watershed. Willow Spring Lake has a water surface elevation of about 915.07 ft NAVD88 during a 100-year event, according to the preliminary modeling. An average-end-area calculation was done using the 100-year water surface and five cross sections along Willow Spring Lake from the modeling to estimate the volume of the lake during a 100-year storm event. This calculation gave that **Willow Spring Lake would contain about 370 acre-feet of water during a 100-year storm event**.

However, due to a downstream high ground up to 909 ft on the northeast side of the downstream wetland area, it is possible that a dam break would not cause the lake to drain entirely (down to the lake bottom of 899.9 ft) but would instead lower to an elevation of 909 ft, depending on whether the high ground would wash out during a Laitsch Dam break. **If the high ground were to stay in place, then Willow Springs Lake would lower to 909 ft water surface elevation and would spill approximately 230 acre-feet of water downstream**. This estimate was based on an average-end-area calculation using the preliminary model cross sections along the lake and the predicted 100-year water surface elevation.

Storage Capacity Downstream of Laitsch Dam:

There are three floodplain storage areas identified in this analysis, labeled A, B, and C on the map. Each of these areas is defined by an elevation at which the storage area will begin to spill. It was assumed that these three areas would be dry and would not already contain any floodwaters during the time of dam failure.

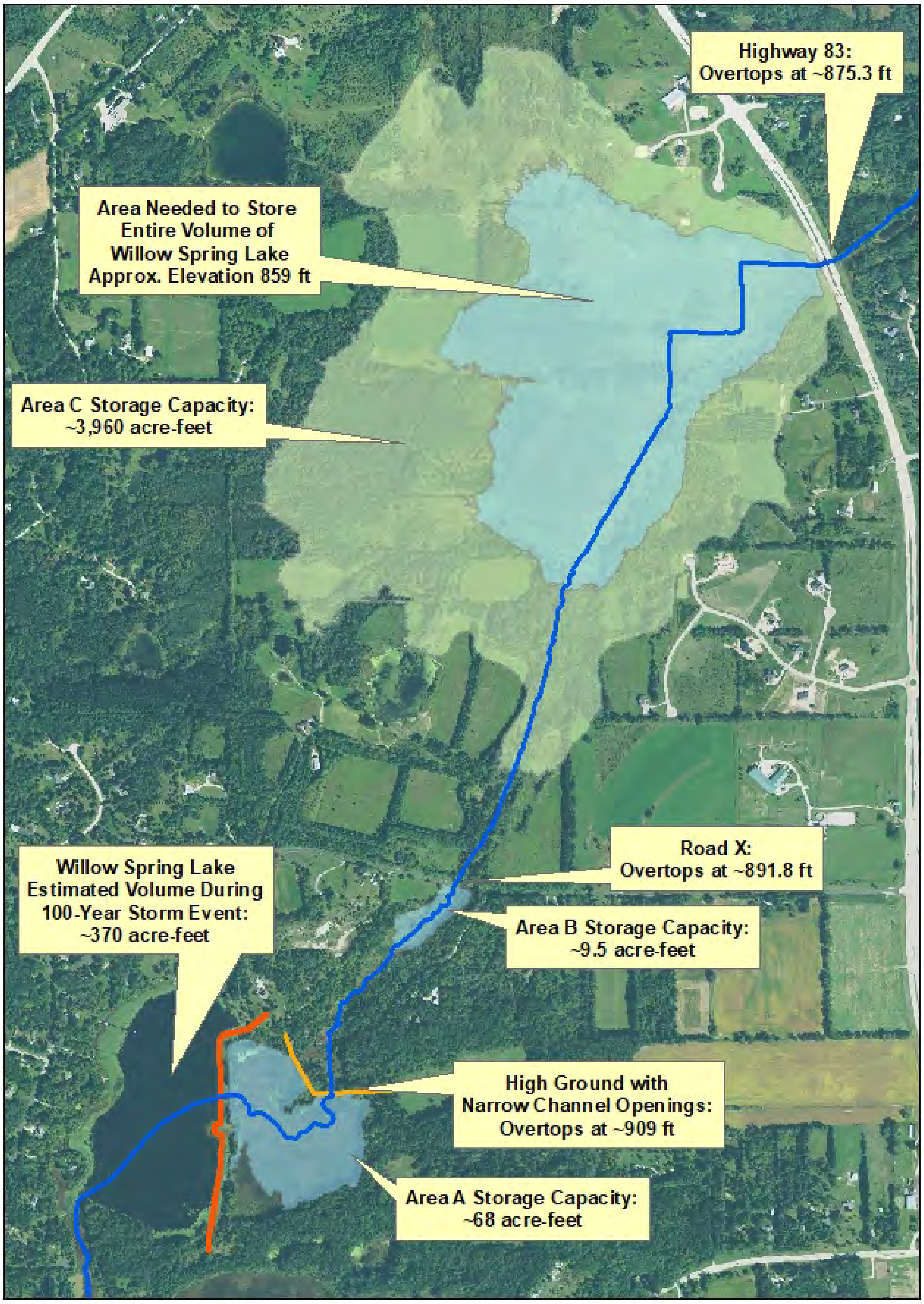
Area A is a wetland area just downstream of Laitsch Dam. This area has a high ground up to approximately 909 ft NAVD88 (based on the 2015 contours) along its northeastern (downstream) side. The berm contains two openings about 30 feet wide that appear to allow for free flow of normal flows and slower release of flood flows. It was assumed that floodwaters would spill downstream when water surface elevations exceeded 909 ft. Based on an average-end-area calculation using the 2015 Waukesha County contours, **it is estimated that Area A could hold about 68 acre-feet of floodwater before spilling over the high ground** (909 ft elevation) into the next downstream area, if the high ground on the northeast side were to stay intact. If the high ground were to break and allow free flow of floodwater downstream, the capacity of Area A would be less.

Area B is downstream of Area A, just upstream of Road X. It is expected that Road X would overtop when water surface elevations exceed 891.8 ft, based on the Road X structure geometry in the preliminary modeling. Based on an average-end-area calculation using the 2015 Waukesha County contours**, it is estimated that Area B could hold about 9.5 acre-feet of floodwater before overtopping Road X**.

Area C is further downstream and is by far the largest floodplain storage area. This area is just upstream of Highway 83, which would overtop when floodwaters exceed about 875.3 ft (according to the preliminary model). Based on an average-end-area calculation using the 2015 Waukesha County contours, **it is estimated that Area C would hold about 3,960 acre-feet of floodwater before overtopping Highway 83.** This is far more storage capacity than would be necessary to contain the volume of Willow Spring Lake; it is estimated that Area C could contain the entire volume of Willow Spring Lake at a water surface elevation of ~859 ft, which is far below the elevation of Highway 83.

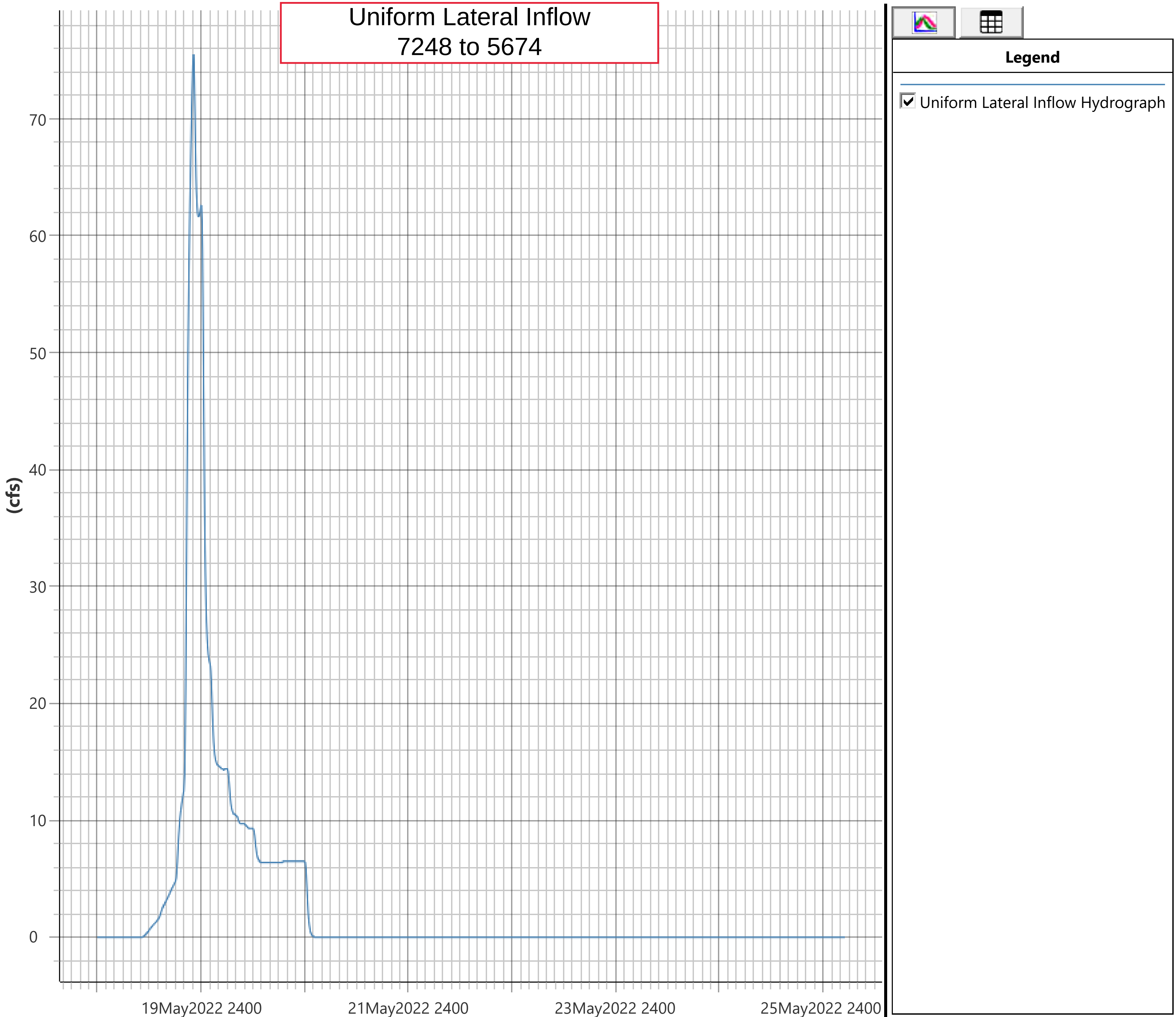
Comparison of Willow Spring Lake Volume and Downstream Storage Capacity:

Based on the above analysis, it appears that if Laitsch Dam were to fail when Willow Spring Lake is at 100-year storm water levels, the downstream Road X would be overtopped, however there would be adequate storage capacity downstream to prevent Highway 83 from being overtopped. It appears that these storage areas would not flood any nearby structures.

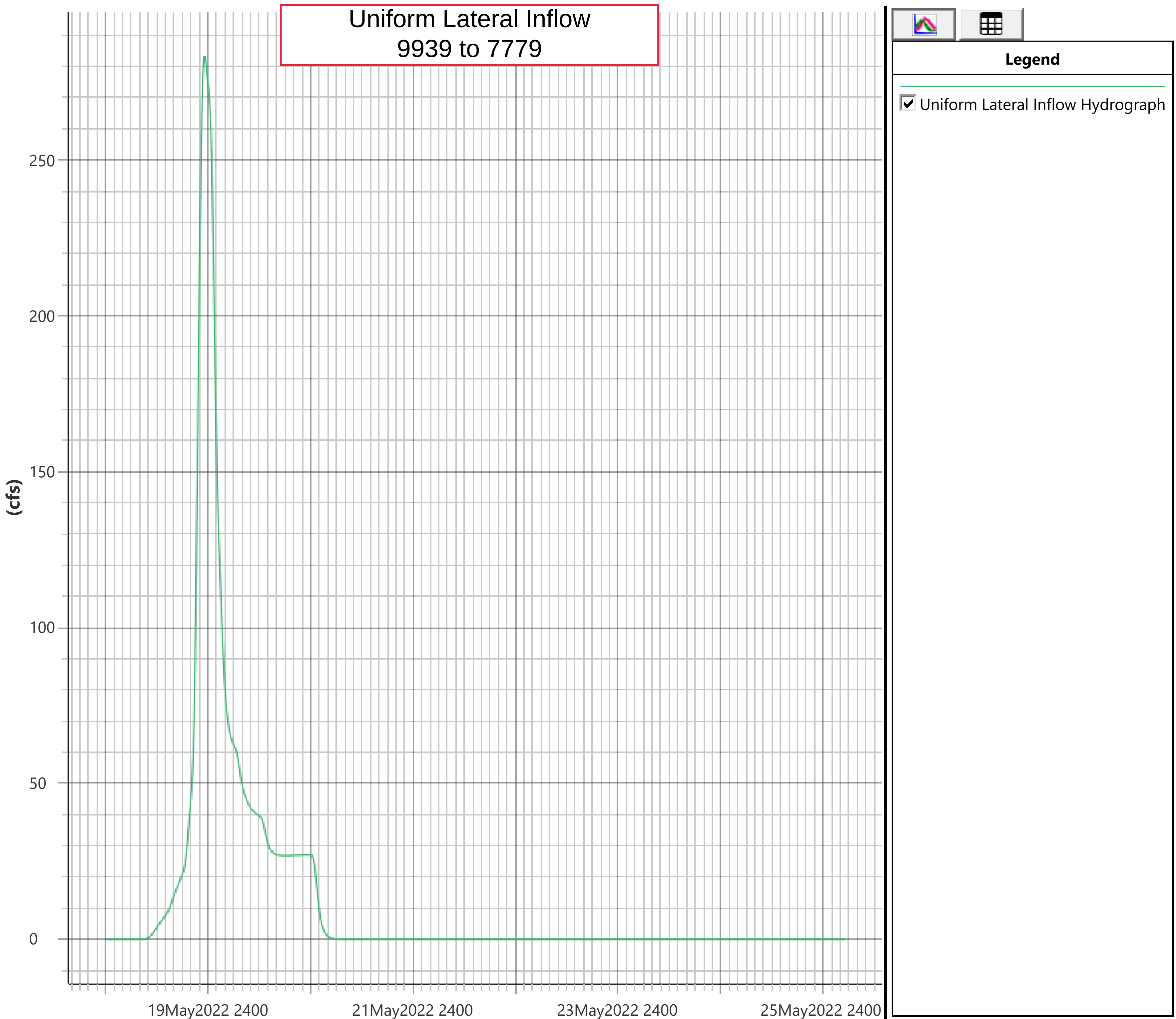


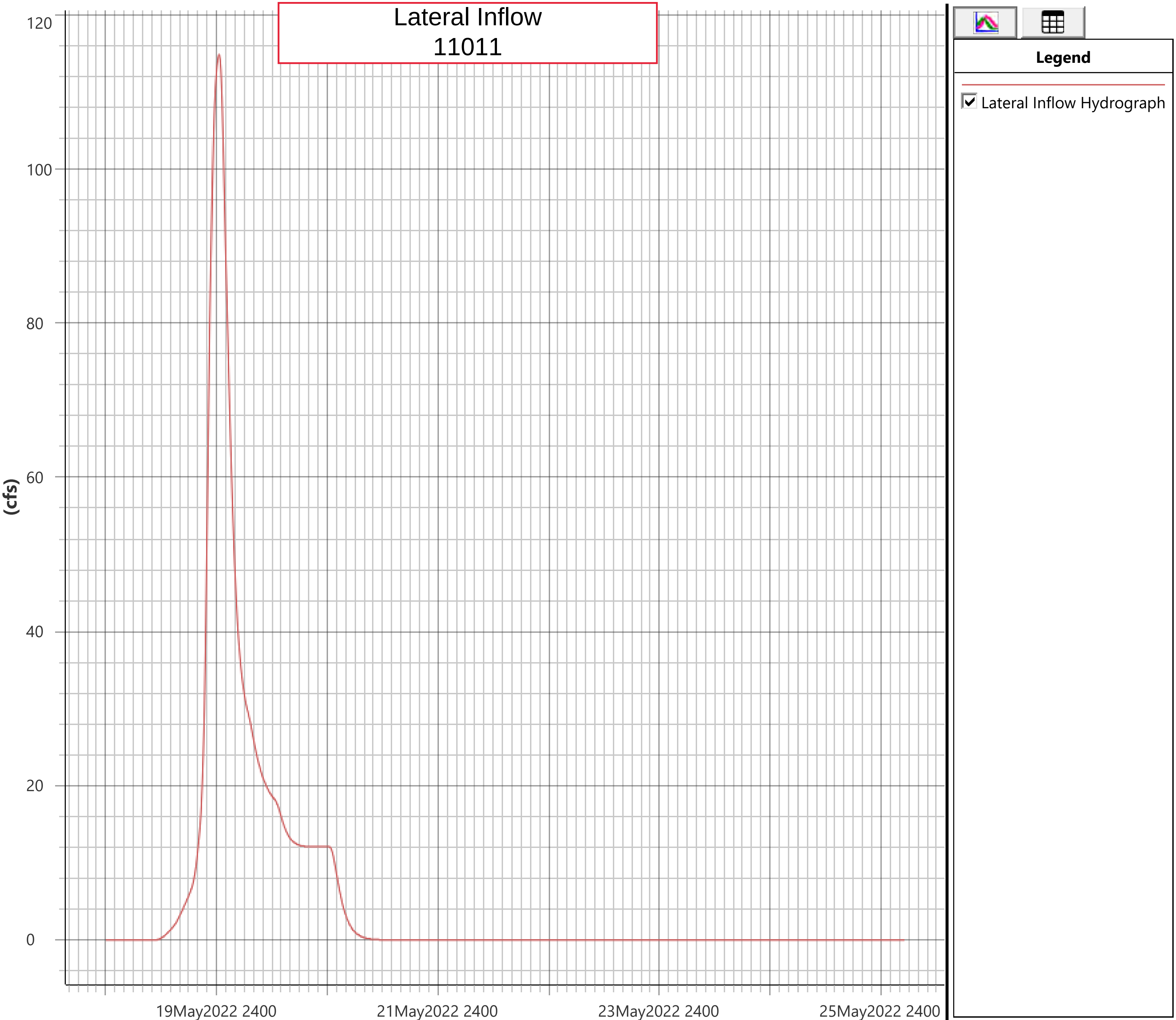
North ↑, Map is Not to Scale (NTS)

ATTACHMENT 2: INFLOW HYDROGRAPHS FROM WDNR HYDROLOGIC ANALYSIS

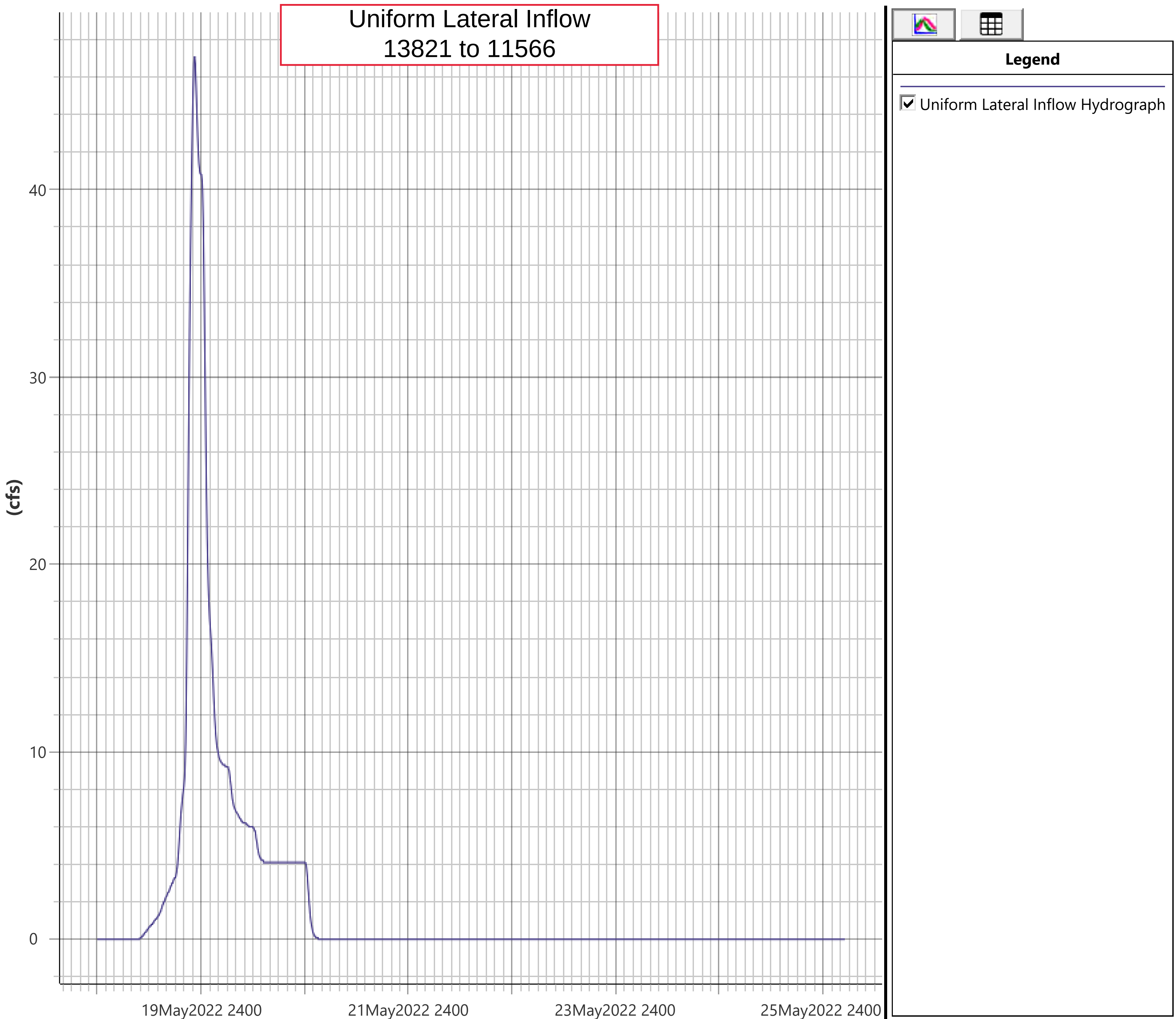


Uniform Lateral Inflow
7248 to 5674
Legend
Uniform Lateral Inflow Hydrograph
(cfs)
70
60
50
40
30
20
10
0
19May2022 2400
21May2022 2400
23May2022 2400
25May2022 2400

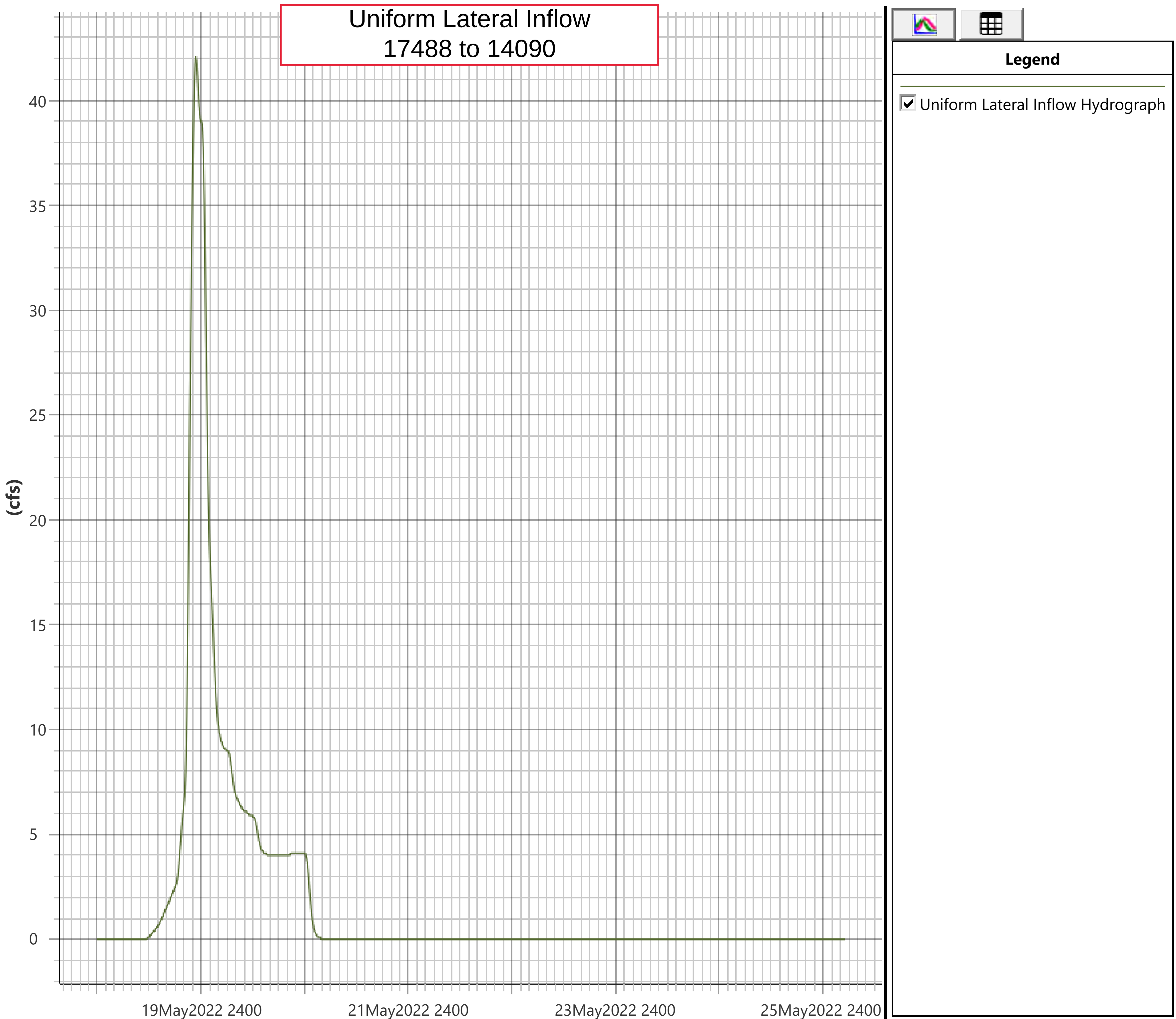

Uniform Lateral Inflow
9939 to 7779
(cfs)
250
200
150
100
50
0
19May2022 2400
21May2022 2400
23May2022 2400
25May2022 2400
Legend
Uniform Lateral Inflow Hydrograph



Lateral Inflow
11011
(cfs)
120
100
80
60
40
20
0
19May2022 2400
21May2022 2400
23May2022 2400
25May2022 2400
Legend
Lateral Inflow Hydrograph



Uniform Lateral Inflow
13821 to 11566
(cfs)
40
30
20
10
0
19May2022 2400
21May2022 2400
23May2022 2400
25May2022 2400
Legend
Uniform Lateral Inflow Hydrograph



Uniform Lateral Inflow
17488 to 14090
(cfs)
40
35
30
25
20
15
10
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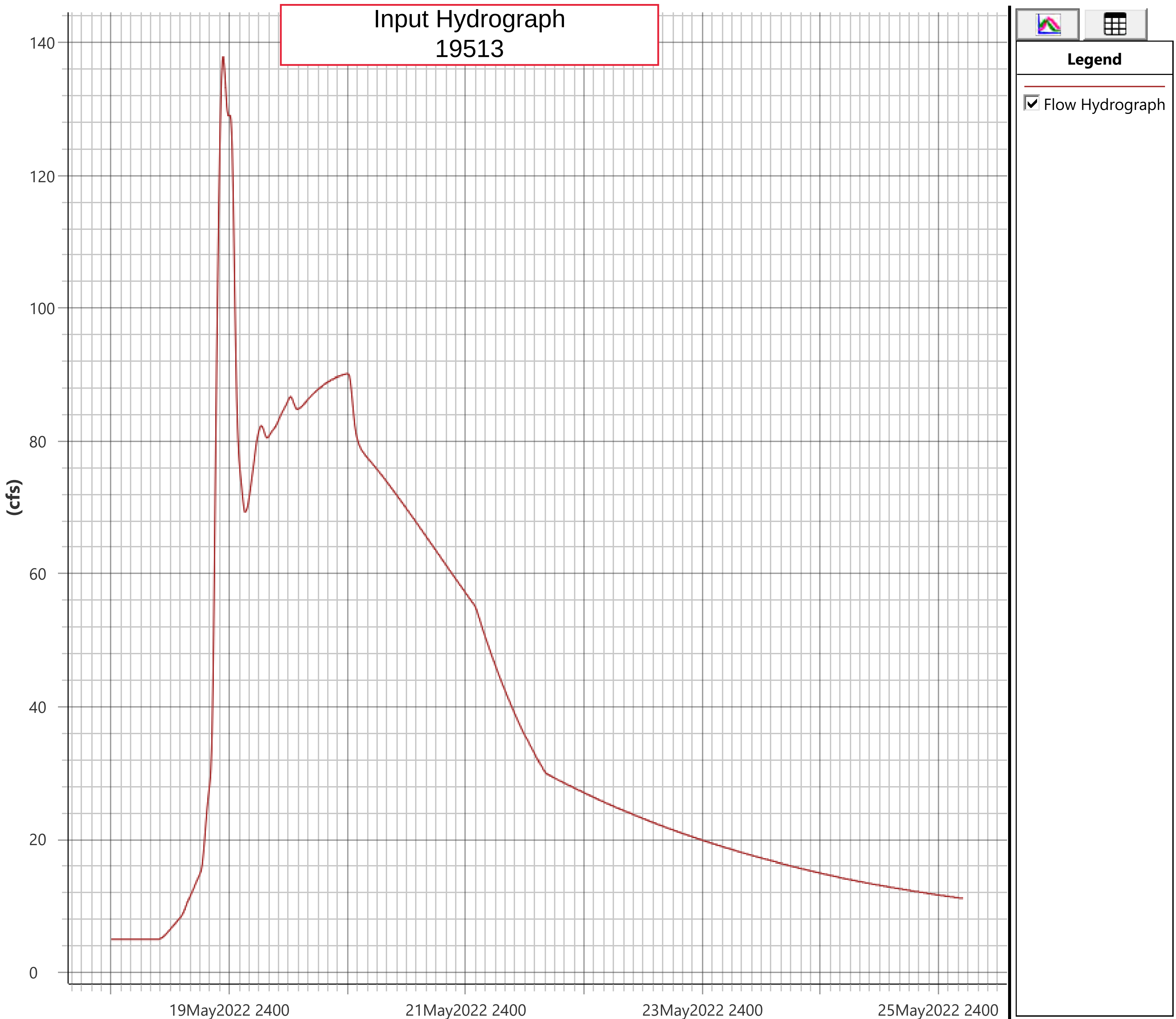
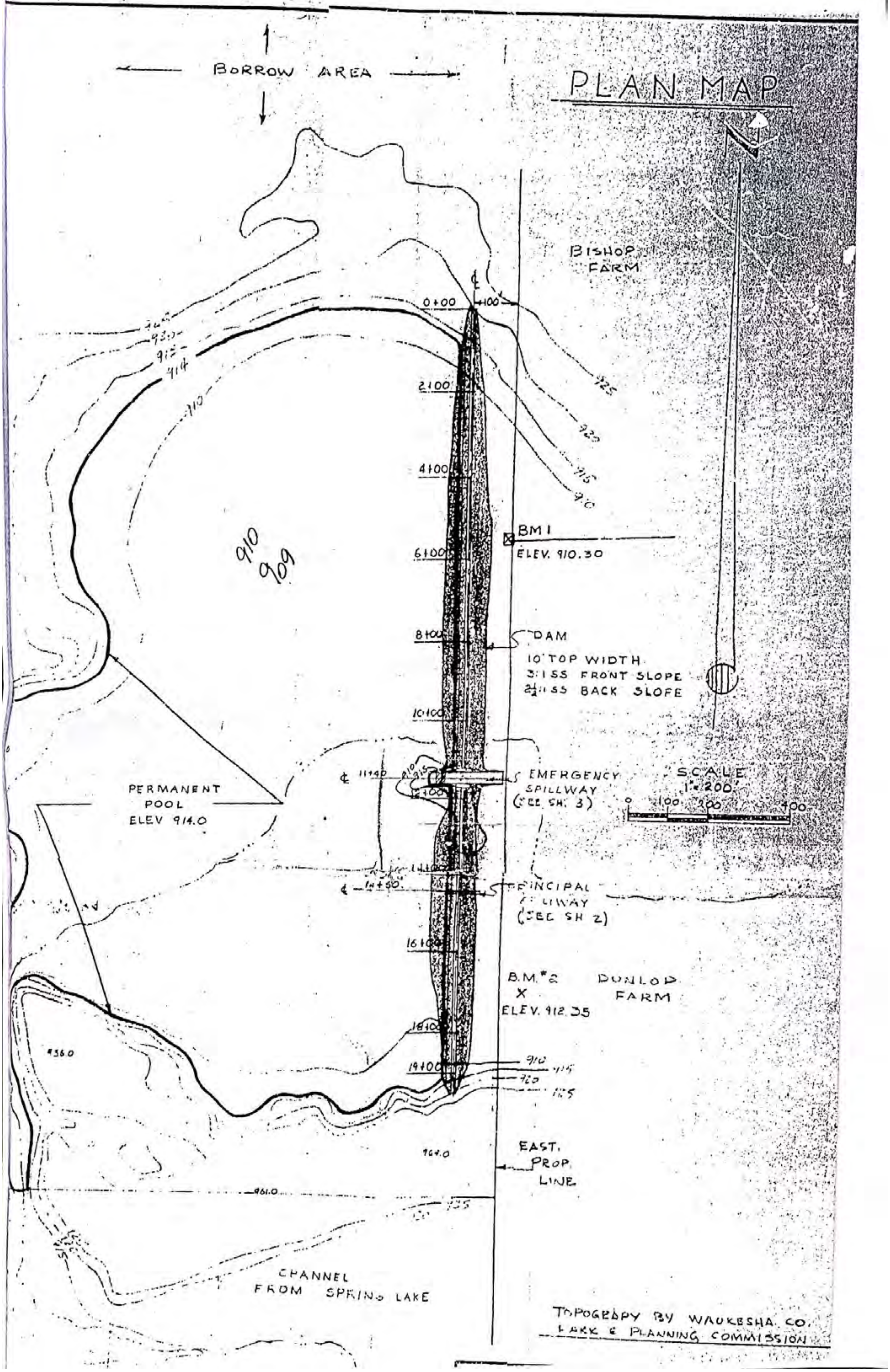
0
19May2022 2400
21May2022 2400
23May2022 2400
25May2022 2400
Legend
Uniform Lateral Inflow Hydrograph



Input Hydrograph
19513
(cfs)
140
120
100
80
60
40
20
0
19May2022 2400
21May2022 2400
23May2022 2400
25May2022 2400
Legend
Flow Hydrograph

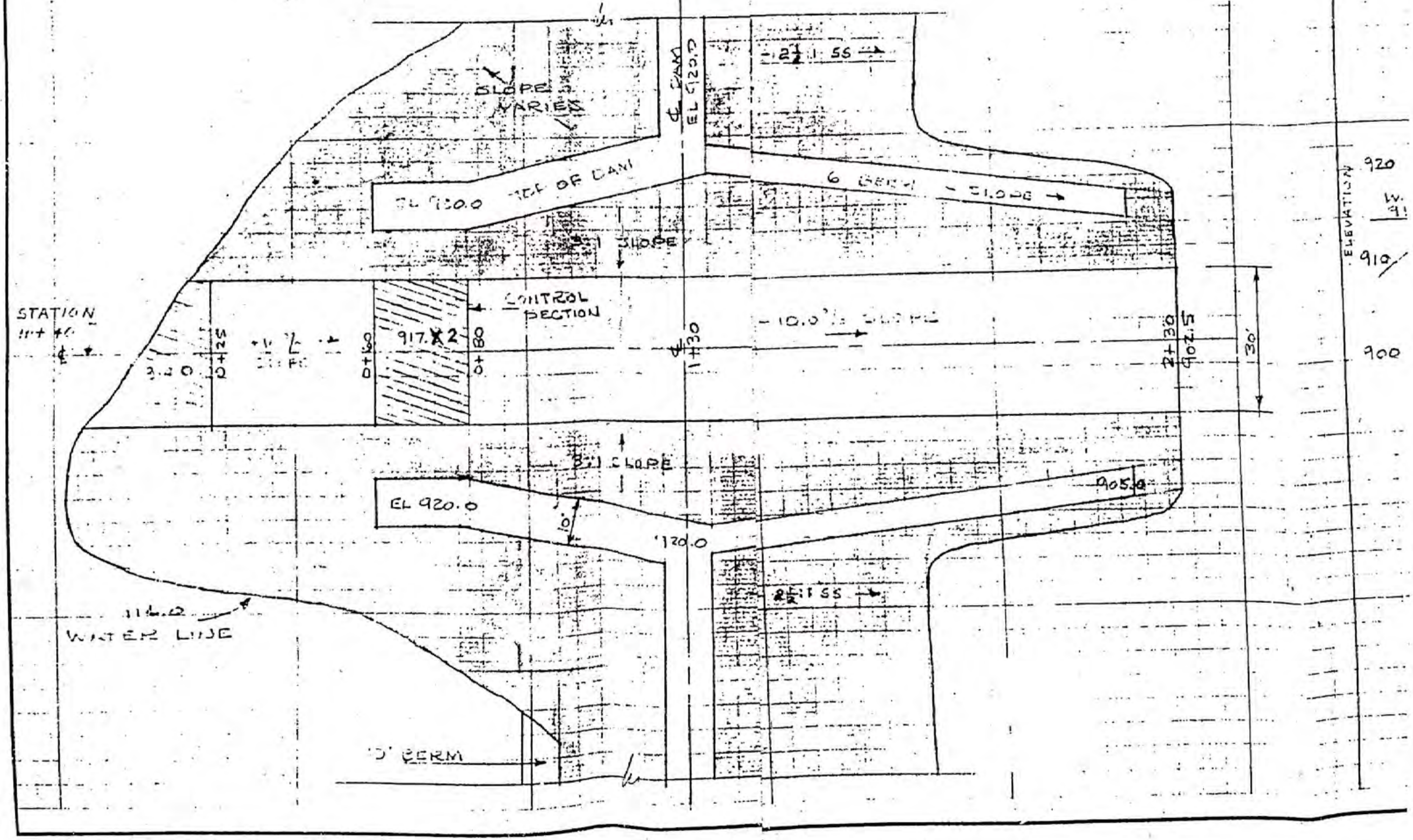
ATTACHMENT 3: LAITSCH DAM AS-BUILTS

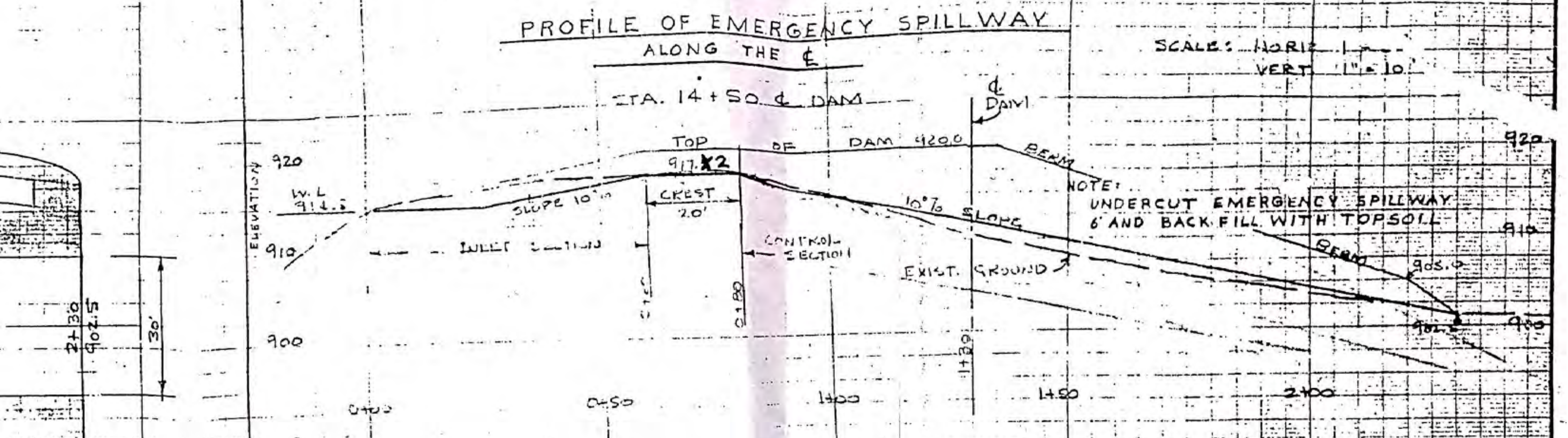


BORROW AREA
PLAN MAP
BISHOP FARM
0+00
2+00
4+00
6+00
8+00
10+00
12+00
14+00
16+00
18+00
19+00
BM 1
ELEV. 910.30
DAM
10' TOP WIDTH
3:1 SS FRONT SLOPE
2½:1 SS BACK SLOPE
EMERGENCY SPILLWAY (SEE SH. 3)
SCALE 1" = 200'
0 100 200 400
PRINCIPAL SPILLWAY (SEE SH 2)
PERMANENT POOL ELEV 914.0
B.M.#2
ELEV. 912.35
DUNLOP FARM
EAST. PROP. LINE
CHANNEL FROM SPRING LAKE
TOPOGRAPHY BY WAUKESHA CO. PARK & PLANNING COMMISSION

PLAN OF EMERGENCY SPILLWAY

SCALE 1" = 20'





R. LAITSCH
LAKE DEVELOPMENT
WAUKESHA CO.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	Date	Approved by
Paul A. Johnson	2/66	Title State Conservation Engineer
Drawn R. H. Wackkuhn	4/66	Title
Traced		Sheet No. 3 of 5 — Drawing No. WI 7-288
Checked Paul A. Johnson	4/66	

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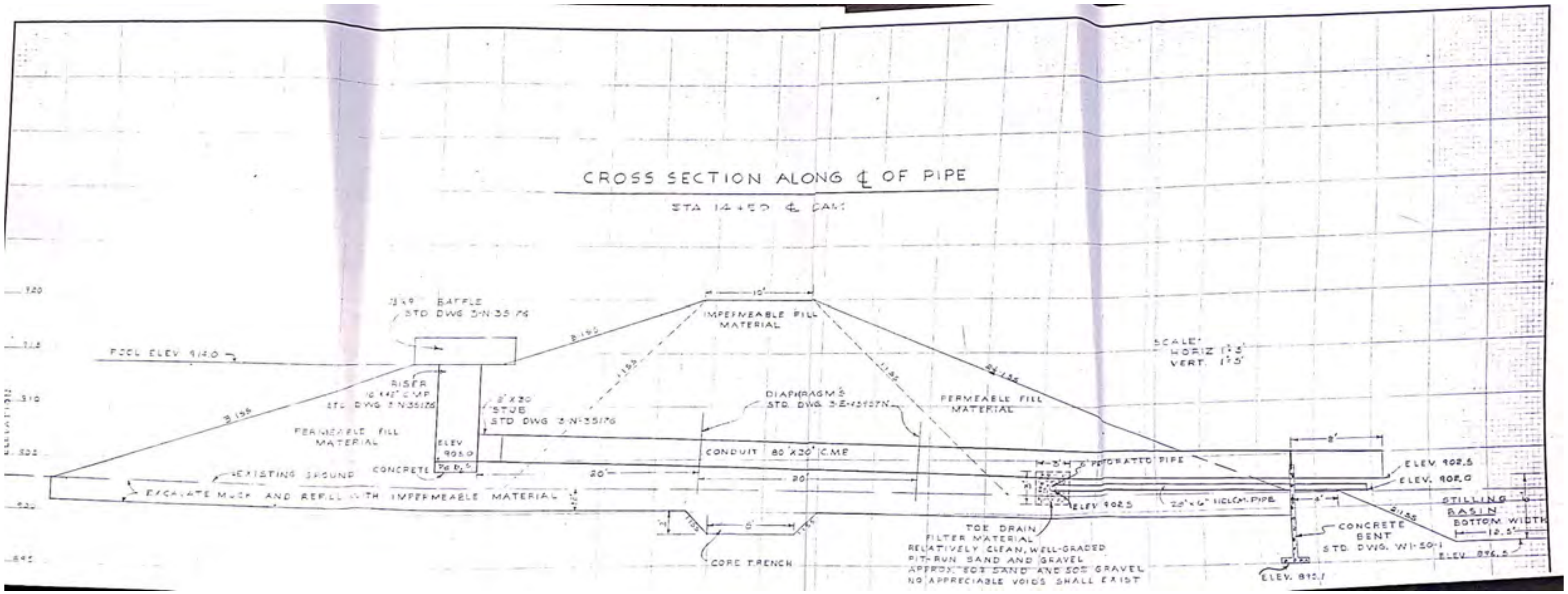


Scanned with CamScanner

ATTACHMENT 4: WDNR SURVEY AND BM FORM

Benchmark Guidelines

1. It is desirable for each dam to have at least 3 benchmarks: one (1) located on the dam structure and two (2) located away from the structure.
2. New benchmarks should be tied to dam's historical datum, if present, as well as NAVD 88.
3. Check if control points or benchmarks exist near dam location on National Geodetic Survey (NGS) Data Explorer website: https://geodesy.noaa.gov/NGSDataExplorer/. Zoom to location, expand "Map Layers" tab, click "Find Marks" button to display points, click on point to display identification information, click on "Datasheet" to view more detailed information about the point (elevation, datum, location, history, etc.).
4. If a Flood Insurance Study (FIS) has been completed for the municipality or county where the dam is located, benchmark elevations need to be tied to the datum used in the study. Is there a FIS associated with the dam?

☐ **No** ☒ **Yes**

Study Name	WDNR 2014 Flood Study
Date	2014
Datum	NAVD 88
Date	
Datum	

Dam Information

Formal Name	Willow Springs Lake
Field File	67.45
DKSN	429
County	Waukesha
Location	SE 1/4 of the NE 1/4 of Section 04, Township 05N, Range 18E

Contact Information

	Person who Performed Survey		Person who Completed Form
Name	WDNR 2014	Name	Adrienne Cizek
Address		Address	247 Freshwater Way, Suite 410
Email		Email	adrienne@stormwater-solutions-engineering.com
Phone		Phone	262-490-1434

Surveyor Signature ____________________ Date ____________________

Surveyor Seal

Benchmark

Elevation	100
Datum	LD
Date Established	6/17/1980
Longitude	
Latitude	
Description of Location	BM2241-A is a cut in the top of the downstream end of the outlet culvert underdike
Description of Benchmark	Mark Seq No 15653

Benchmark

Elevation	113.79
Datum	LD
Date Established	6/17/1980
Longitude	
Latitude	
Description of Location	BM2241-B the top of an old well head about 5-in in dia located about 150 ft W of the end of the dike, 75 feet SE of an 8-in wood corner fence post, and about 4-ft N of the water, Mark Seq No 15654
Description of Benchmark	

Benchmark

Elevation	893.34 ft
Datum	NAVD 88
Date Established	March 2017
Longitude	088 20 46.98 (W)
Latitude	42 55 20.78 (N)
Description of Location	7 Mi NW of Big Bend, 7 Mi NE of Eagle, and 3 Mi E of North Prairie W of Roundabout Jct STH 83 and CTH I, Center of raised median on CTH I
Description of Benchmark	Bronze WI DOT Geodetic Survey Control Station Disk

Sketch or Diagram

(Does not need to be to scale, but include measurement)

See Attached Survey Sheet

Datum to Staff Gauge Conversion

Elevation ______________________________

Datum ______________________________

Location of Staff Gauge ______________________________

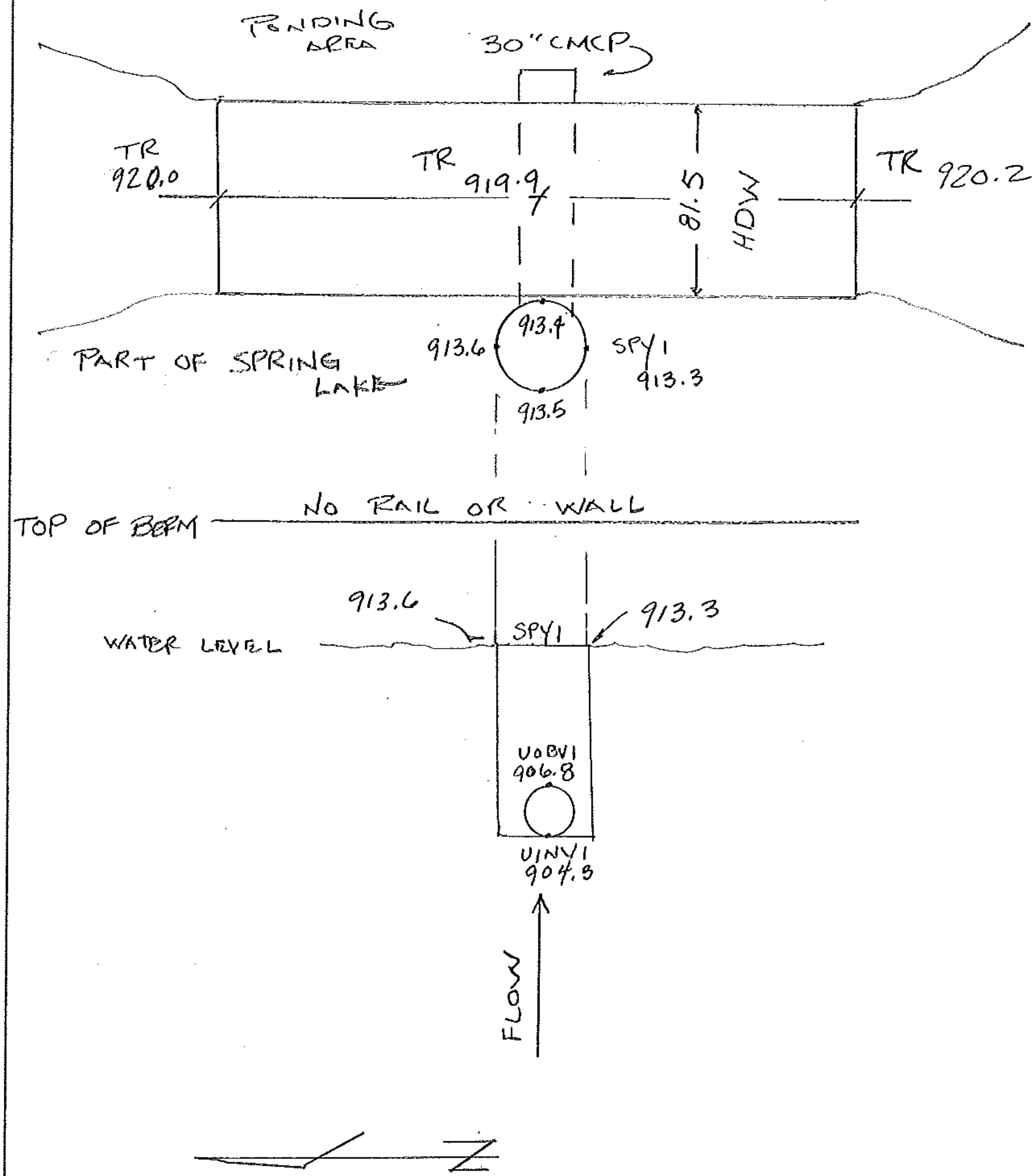
Reading on Staff Gauge ______________________________

Conversion ______________________________

Existing Benchmarks

Mark SeqNo	Old Mark ID	Elevation	Datum	Description
	2241-A	100	LD	BM 2241-A IS AN X CUT IN THE TOP OF THE DOWNSTREAM END OF THE OUTLET CULVERT UNDER DIKE.
	2241-B	113.79	LD	BM 2241-B THE TOP OF AN OLD WELL HEAD ABOUT 5 IN. IN DIAMETER, LOCATED ABOUT 150 FT. W OF THE N END OF THE DIKE, 75 FT. SE OF AN 8 IN. WOOD CORNER FENCE POST, AND ABOUT 4 FT. N OF THE WATER.

PLAN VIEW TOP OF BERM DAM



PROFILE VIEW LOOKING DOWNSTREAM

State of Wisconsin
DEPARTMENT OF NATURAL RESOURCES
Waukesha Service Center
141 NW Barstow St. Room 180
Waukesha WI 53188

Tony Evers, Governor
Preston D. Cole, Secretary
Telephone 608-266-2621
Toll Free 1-888-936-7463
TTY Access via relay - 711

April 5, 2022

Spring Brook Watershed Lake Management District
c/o Jim McNelly
via email

SUBJECT: Dam Safety Inspection – Willow Springs Dam, Field File # 67.45, Waukesha County

Dear Mr. McNelly:

We have reviewed the inspection report prepared by Adrienne Cizek, P.E. from Stormwater Solutions Engineering, LLC, which was submitted to the Department of Natural Resources on March 9, 2022.

Based on information from your inspection and the Department's file, I completed a Sufficiency Rating for the Willow Springs Dam. The Sufficiency Rating is a snapshot of the dam's physical condition and compliance with NR 333 requirements. The dam is classified as **Fair** because a dam failure analysis is required, which is currently being developed, and zoning updated accordingly. The Sufficiency Rating helps the Dam Safety Program track progress of the dam and whether the Program is meeting its goal of promoting safe dams. The rating has no direct consequence of enforcement.

The inspection report identified items to complete with time frames to complete them. The report noted no benchmarks were found. The DNR has the following record for benchmarks.

Geomarks

Mark SeqNo	Old Mark ID	Elevation	Datum	Status	Status Date	Description
15653	2241-A	100	LD	Verified (Surveyed)	06/17/1980	BM 2241-A IS AN X CUT IN THE TOP OF THE DOWNSTREAM END OF THE OUTLET CULVERT UNDER DIKE.
15654	2241-B	113.79	LD	Verified (Surveyed)	06/17/1980	BM 2241-B THE TOP OF AN OLD WELL HEAD ABOUT 5 IN. IN DIAMETER, LOCATED ABOUT 150 FT. W OF THE N END OF THE DIKE, 75 FT. SE OF AN 8 IN. WOOD CORNER FENCE POST, AND ABOUT 4 FT. N OF THE WATER.

Summary of Requirements	**Due Date**
Submit a Dam Failure Analysis	Previously extended to June 1, 2022
Install or verify benchmarks	October 1, 2023
Embankment maintenance (tree removal, muskrat burrows, etc)	October 1, 2023
Install new trash rack	October 1, 2023

Your next required inspection is scheduled for 2031. You will need to hire an engineer to conduct the inspection and submit to the Department.

Any plans for modifications to dam, excluding routine maintenance, must be submitted to the Department for review and approval.

Thank you for continuing to maintain your dam.

If you have any questions, please contact me at michelle.hase@wi.gov or 262-208-0447.

Sincerely,

Michelle Hase, P.E.
Water Management Engineer

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.5.14
Starting Datasheet Retrieval...
1        National Geodetic Survey,   Retrieval Date = JULY 27, 2022
 DQ4497 ***********************************************************************
 DQ4497  DESIGNATION -  1X57
 DQ4497  PID         -  DQ4497
 DQ4497  STATE/COUNTY-  WI/WAUKESHA
 DQ4497  COUNTRY     -  US
 DQ4497  USGS QUAD   -  GENESEE (2018)
 DQ4497
 DQ4497                         *CURRENT SURVEY CONTROL
 DQ4497  ______________________________________________________________________
 DQ4497* NAD 83(1986) POSITION- 42 55 20.78   (N) 088 20 46.98   (W)   HD_HELD1
 DQ4497* NAVD 88 ORTHO HEIGHT -   272.290 (meters)      893.34  (feet) ADJUSTED
 DQ4497  ______________________________________________________________________
 DQ4497  GEOID HEIGHT    -        -34.521 (meters)                     GEOID18
 DQ4497  DYNAMIC HEIGHT  -        272.215 (meters)      893.09  (feet) COMP
 DQ4497  MODELED GRAVITY -    980,339.8   (mgal)                       NAVD 88
 DQ4497
 DQ4497  VERT ORDER      -  SECOND    CLASS I
 DQ4497
 DQ4497.The horizontal coordinates were determined by differentially corrected
 DQ4497.hand held GPS observations or other comparable positioning techniques
 DQ4497.and have an estimated accuracy of +/- 3 meters.
 DQ4497.
 DQ4497.The orthometric height was determined by differential leveling and
 DQ4497.adjusted by the NATIONAL GEODETIC SURVEY
 DQ4497.in March 2017.
 DQ4497
 DQ4497.Significant digits in the geoid height do not necessarily reflect accuracy.
 DQ4497.GEOID18 height accuracy estimate available here.
 DQ4497
 DQ4497.Click photographs - Photos may exist for this station.
 DQ4497
 DQ4497.The dynamic height is computed by dividing the NAVD 88
 DQ4497.geopotential number by the normal gravity value computed on the
 DQ4497.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 DQ4497.degrees latitude (g = 980.6199 gals.).
 DQ4497
 DQ4497.The modeled gravity was interpolated from observed gravity values.
 DQ4497
 DQ4497;                   North         East    Units  Estimated Accuracy
 DQ4497;SPC WI S     -   103,813.0     734,993.7     MT  (+/- 3 meters HH1 GPS)
 DQ4497
 DQ4497_U.S. NATIONAL GRID SPATIAL ADDRESS: 16TCN9011953081(NAD 83)
 DQ4497
 DQ4497                          SUPERSEDED SURVEY CONTROL
 DQ4497
 DQ4497.No superseded survey control is available for this station.
 DQ4497
 DQ4497_MARKER: DD = SURVEY DISK
 DQ4497_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
 DQ4497_STAMPING: 1X57 2012
 DQ4497_MARK LOGO: WIDT
 DQ4497_PROJECTION: FLUSH
 DQ4497_MAGNETIC: R = STEEL ROD IMBEDDED IN MONUMENT
 DQ4497_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 DQ4497_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
```

```
DQ4497+SATELLITE: SATELLITE OBSERVATIONS - July 07, 2016
DQ4497
DQ4497  HISTORY     - Date     Condition        Report By
DQ4497  HISTORY     - 2012     MONUMENTED       WIDT
DQ4497  HISTORY     - 20160707 GOOD             WIDT
DQ4497
DQ4497                          STATION DESCRIPTION
DQ4497
DQ4497'DESCRIBED BY WI DEPT OF TRANSP 2016 (EPS)
DQ4497'THE STATION IS 7 MI (11.3 KM) NORTHWEST OF BIG BEND, 7 MI (11.3 KM)
DQ4497'NORTHEAST OF EAGLE AND 3 MI (4.8 KM) EAST OF NORTH PRAIRIE.
DQ4497'
DQ4497'THE STATION IS LOCATED WEST OF THE ROUND-A-BOUT JUNCTION OF STATE
DQ4497'HIGHWAY 83 WITH COUNTY HIGHWAY I, ABOUT 4 MI (6.4 KM) NORTH OF THE
DQ4497'VILLAGE OF MUKWONAGO.
DQ4497'
DQ4497'THE STATION IS 8.5 M (27.9 FT) SOUTH OF THE CENTER OF THE RAISED
DQ4497'MEDIAN OF COUNTY HIGHWAY I, 32.8 M (107.6 FT) EAST-NORTHEAST OF THE
DQ4497'SOUTH END OF A CONCRETE CULVERT, 10.2 M (33.5 FT) NORTHWEST OF A
DQ4497'STREET LIGHT POLE -BMU6- AND 0.6 M (2.0 FT) SOUTH OF A WHITE PLASTIC
DQ4497'WITNESS POST.
DQ4497'
DQ4497'NOTE-THIS STATION IS OBSTRUCTED BY OVERHEAD UTILITY WIRES TO THE EAST
DQ4497'AND TO THE SOUTH AND THE REFERENCED STREET LIGHT POLE TO THE SOUTHEAST
DQ4497'OF THE STATION.
DQ4497'
DQ4497'NOTE-THE STATION IS A BRONZE WISCONSIN DEPARTMENT OF TRANSPORTATION
DQ4497'GEODETIC SURVEY CONTROL STATION DISK SET IN THE TOP OF A 40 CM (16
DQ4497'INCHES) DIAMETER CONCRETE POST, ABOUT LEVEL WITH THE PAVEMENT GRADE.



*** retrieval complete.
Elapsed Time = 00:00:04
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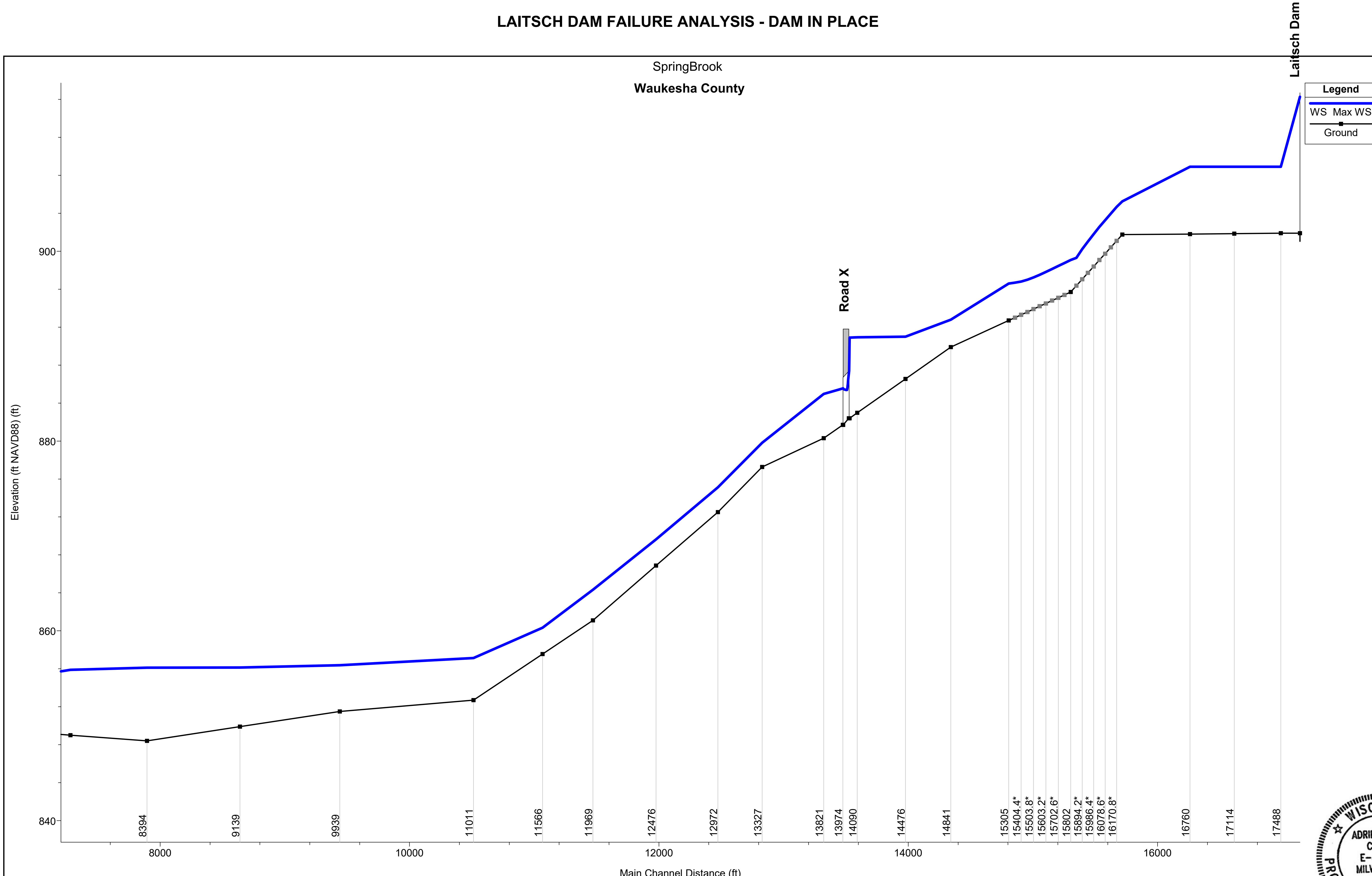
ATTACHMENT 5: 100-YR MODEL PROFILE

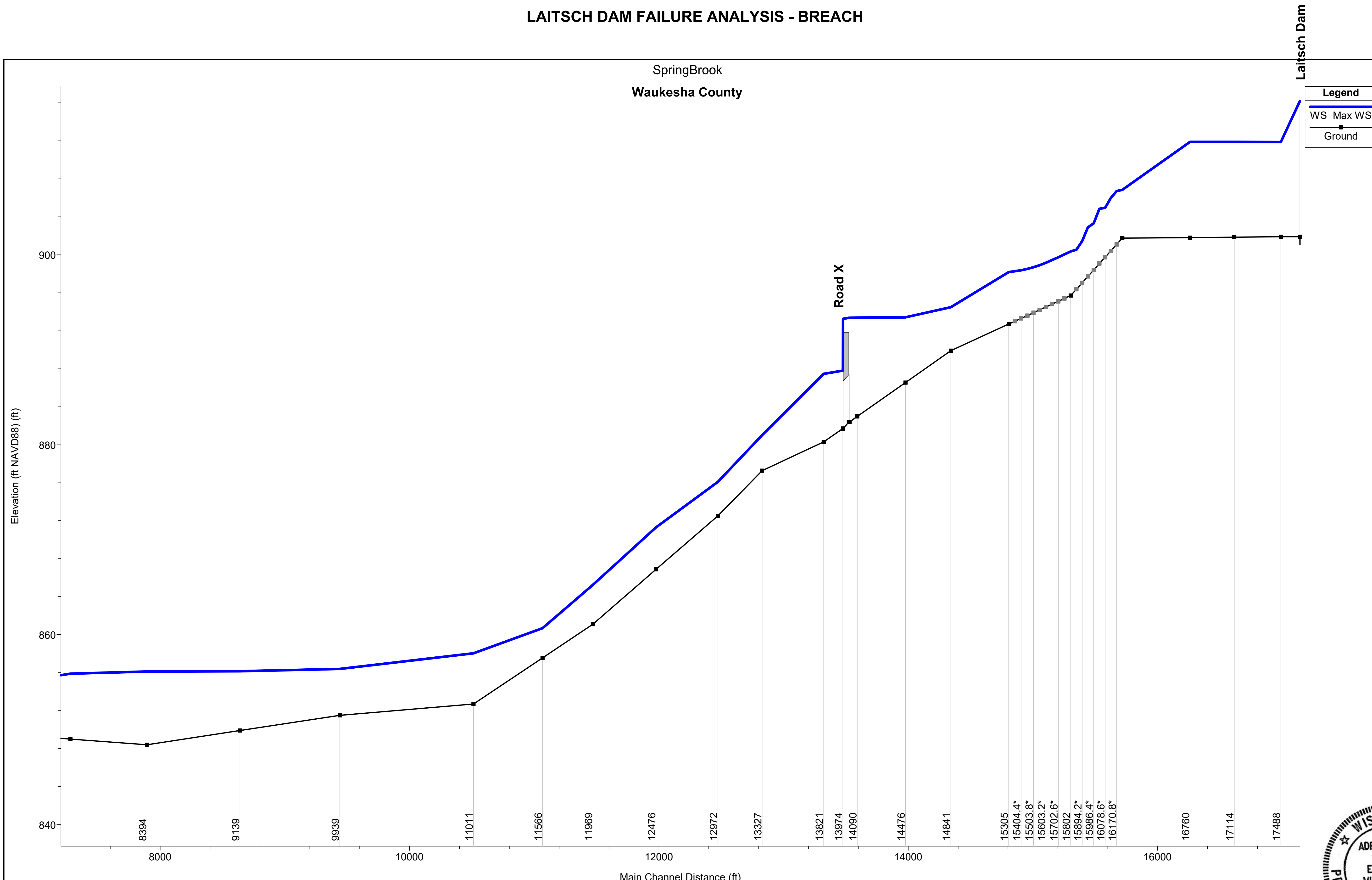
LAITSCH DAM FAILURE ANALYSIS - DAM IN PLACE



WISCONSIN
ADRIENNE R. CIZEK
E-46560
MILWAUKEE
WIS
PROFESSIONAL ENGINEER

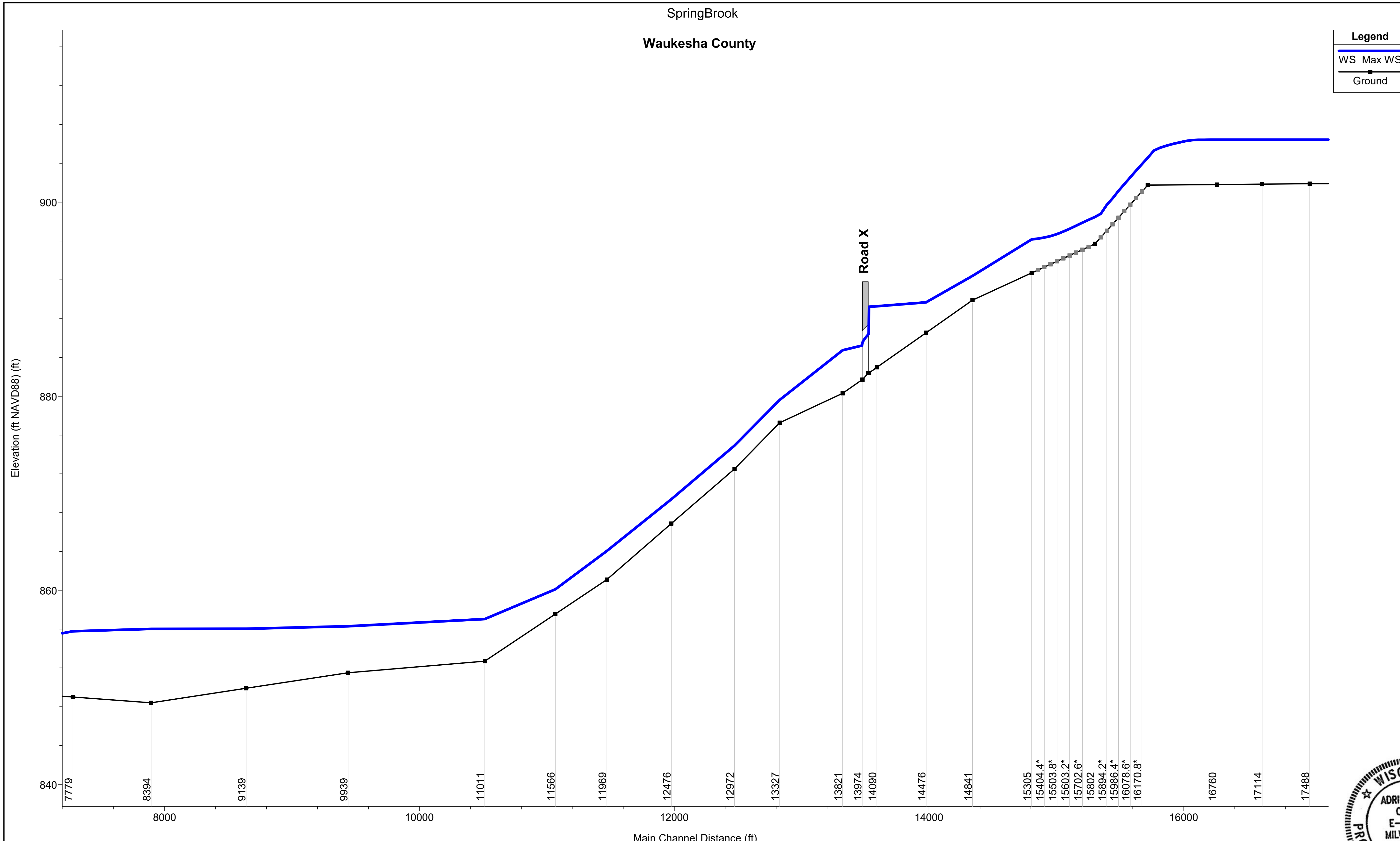
9/9/22

LAITSCH DAM FAILURE ANALYSIS - BREACH



WISCONSIN
ADRIENNE R.
CIZEK
E-46560
MILWAUKEE
WIS
PROFESSIONAL ENGINEER
9/9/22

LAITSCH DAM FAILURE ANALYSIS - DAM REMOVED



WISCONSIN
ADRIENNE R. CIZEK
E-46560
MILWAUKEE
WIS
PROFESSIONAL ENGINEER
9/9/22

ATTACHMENT 6: FLOODWAY TABLES

FLOODING SOURCE		FLOODWAY**			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION STATIONING[3]	DISTANCE*	WIDTH (FEET)	SECTION AREA (SQ.FEET)	MEAN VELOCITY (FEET/SEC.)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
SPRING BROOK								
17488	374	148	4,227	0.2	908.9	908.9	908.9	0.0
17114	355	896	4,341	0.0	908.9	908.9	908.9	0.0
16760	543	698	4,367	0.1	908.9	908.9	908.9	0.0
16217	46	17	52	6.5	905.3	905.3	905.3	0.0
15802	50	72	81	3.1	899.1	899.1	899.1	0.0
15305	464	130	171	1.4	896.6	896.6	896.6	0.0
14841	364	58	60	4.1	892.8	892.8	892.8	0.0
14476	386	231	406	0.5	891.0	891.0	891.0	0.0
14090	61	137	955	0.3	890.9	890.9	890.9	0.0
14028	6	14	425	2.0	890.9	890.9	890.9	0.0
14005	49	5	20	10.3	887.4	887.4	887.4	0.0
13974	153	11	68	5.9	885.5	885.5	885.5	0.0
13821	494	79	128	1.6	885.0	885.0	885.0	0.0
13327	356	21	34	6.2	879.8	879.8	879.8	0.0
12972	495	28	55	4.7	875.1	875.1	875.1	0.0
12476	507	22	40	5.8	869.6	869.6	869.6	0.0
11969	404	27	62	5.2	864.3	864.3	864.3	0.0
11566	554	320	203	1.2	860.3	860.3	860.3	0.0
11011	1,072	434	704	0.6	857.1	857.1	857.1	0.0
9939	800	479	693	0.5	856.4	856.4	856.4	0.0
9139	746	1,074	2,561	0.2	856.1	856.1	856.1	0.0
8394	615	755	1,712	0.3	856.1	856.1	856.1	0.0
7779	98	245	438	1.2	855.9	855.9	855.9	0.0
7681	75	176	244	2.1	855.7	855.7	855.7	0.0

* Feet to next cross section

** Values reported are based on averages calculated across evaluation lines. Refer to model grids for modeled variability in elevation and surcharge across the floodway.

*** Floodway computed by 2D or hybrid 1D, 2D model at this location

TABLE 1

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

WAUKESHA COUNTY, WI

AND INCORPORATED AREAS

FLOODWAY DATA LAITSCH DAM IN PLACE

SPRING BROOK

FLOODING SOURCE		FLOODWAY**			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION STATIONING[3]	DISTANCE*	WIDTH (FEET)	SECTION AREA (SQ.FEET)	MEAN VELOCITY (FEET/SEC.)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE**** (FEET)
SPRING BROOK								
17488	374	999	8,164	0.1	911.9	911.9	911.9	0.0
17114	355	1,299	8,129	0.1	911.9	911.9	911.9	0.0
16760	543	1,188	7,874	0.1	911.9	911.9	911.9	0.0
16217	46	22	112	9.9	906.8	906.8	906.8	0.0
15802	50	153	251	2.6	900.4	900.4	900.4	0.0
15305	464	185	431	1.5	898.2	898.2	898.2	0.0
14841	364	98	336	3.0	894.5	894.5	894.5	0.0
14476	386	281	1,029	0.6	893.4	893.4	893.4	0.0
14090	61	290	1,585	0.4	893.4	893.4	893.4	0.0
14028	6	158	952	0.7	893.4	893.4	893.4	0.0
14005	49	158	162	12.0	893.4	893.4	893.4	0.0
13974	153	126	271	2.1	887.8	887.8	887.8	0.0
13821	494	153	422	1.4	887.5	887.5	887.5	0.0
13327	356	195	135	4.5	881.0	881.0	881.0	0.0
12972	495	344	265	2.1	876.1	876.1	876.1	0.0
12476	507	30	88	6.8	871.3	871.3	871.3	0.0
11969	404	73	119	4.7	865.3	865.3	865.3	0.0
11566	554	366	321	1.7	860.7	860.7	860.7	0.0
11011	1,072	481	1,643	0.6	858.0	858.0	858.0	0.0
9939	800	479	696	0.5	856.4	856.4	856.4	0.0
9139	746	1,076	2,568	0.2	856.2	856.2	856.2	0.0
8394	615	756	1,717	0.3	856.1	856.1	856.1	0.0
7779	98	260	439	1.2	855.9	855.9	855.9	0.0
7681		176	246	2.0	855.7	855.7	855.7	0.0

* Feet to next cross section

** Values reported are based on averages calculated across evaluation lines. Refer to model grids for modeled variability in elevation and surcharge across the floodway.

*** Floodway computed by 2D or hybrid 1D, 2D model at this location

****Only noted if >0, all negative numbers are 0.0

TABLE 1

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

WAUKESHA COUNTY, WI

AND INCORPORATED AREAS

FLOODWAY DATA LAITSCH DAM BREACH HYRDAULIC SHADOW

SPRING BROOK

FLOODING SOURCE		FLOODWAY**			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION STATIONING[3]	DISTANCE*	WIDTH (FEET)	SECTION AREA (SQ.FEET)	MEAN VELOCITY (FEET/SEC.)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE**** (FEET)
SPRING BROOK								
17488	374	664	1,967	0.1	906.4	906.4	906.4	0.0
17114	355	527	1,646	0.2	906.4	906.4	906.4	0.0
16760	543	531	1,713	0.1	906.4	906.4	906.4	0.0
16217	46	15	32	5.7	904.6	904.6	904.6	0.0
15802	50	43	43	3.4	898.5	898.5	898.5	0.0
15305	464	100	119	1.3	896.2	896.2	896.2	0.0
14841	364	41	40	4.0	892.4	892.4	892.4	0.0
14476	386	103	142	1.4	889.7	889.7	889.7	0.0
14090	61	138	597	0.3	889.3	889.3	889.3	0.0
14028	6	14	203	2.1	889.2	889.2	889.2	0.0
14005	49	20	17	9.9	886.4	886.4	886.4	0.0
13974	153	11	54	5.4	885.2	885.2	885.2	0.0
13821	494	74	111	1.2	884.7	884.7	884.7	0.0
13327	356	20	30	5.8	879.6	879.6	879.6	0.0
12972	495	27	43	4.5	874.9	874.9	874.9	0.0
12476	507	21	35	5.5	869.4	869.4	869.4	0.0
11969	404	25	48	5.2	864.0	864.0	864.0	0.0
11566	554	113	131	3.6	860.1	860.1	860.1	0.0
11011	1,072	433	611	0.6	857.0	857.0	857.0	0.0
9939	800	474	630	0.5	856.3	856.3	856.3	0.0
9139	746	1,053	2,458	0.2	856.0	856.0	856.0	0.0
8394	615	747	1,637	0.3	856.0	856.0	856.0	0.0
7779	98	254	408	1.2	855.8	855.8	855.8	0.0
7681	75	166	219	2.2	855.5	855.5	855.5	0.0

* Feet to next cross section

** Values reported are based on averages calculated across evaluation lines. Refer to model grids for modeled variability in elevation and surcharge across the floodway.

*** Floodway computed by 2D or hybrid 1D, 2D model at this location

****Only noted if >0, all negative numbers are 0.0

TABLE 1

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

WAUKESHA COUNTY, WI

AND INCORPORATED AREAS

FLOODWAY DATA LAITSCH DAM NONEXISTANT

SPRING BROOK

ATTACHMENT 7: RISK OF LOSS OF LIFE

From “A Procedure for Estimating Loss of Life Caused by Dam Failure,” Department of the Interior, Bureau of Reclamation, DSO-99-06 September 1999, by Wayne J. Graham, P.E., presents this method as originally developed by DeKay and McClelland (20):

High Force Conditions: Where 20% or more of flooded residences are either destroyed or heavily damaged:

(eq 7-1)

$$Deaths = \frac{PAR}{1 + 13.277(PAR^{0.440})(e^{2.982(wt)-3.790})}$$

Low Lethality Conditions: Where less than 20% or more of flooded residences are either destroyed or heavily damaged:

(eq 7-2)

$$Deaths = \frac{PAR}{1 + 13.277(PAR^{0.440})(e^{0.759(WT)})}$$

Where, PAR is the number of people at risk and WT is the is the time in hours from the initiation of dam failure warning until the dam failure floodwater reaches a community or other group of people. Warning time must therefore consider the time it takes for flood water to reach the community or group of people. When dam failure warnings do not precede the arrival of dam failure flooding in an area, WT would be zero.

As the economic loss hazard is low (less than 20% of affected residences destroyed or heavily damaged), equation 7-2 should be utilized.

Graham’s guideline to PAR assessment is: "Take a snapshot and count the people." As downstream riparian land is privately held and does not host recreational or other activities, PAR is assumed to be 1. As identified herein, the WT is 0 hr.

Therefore, as applied in eq 7-3, the Risk of Loss of Life is 0.07 persons.

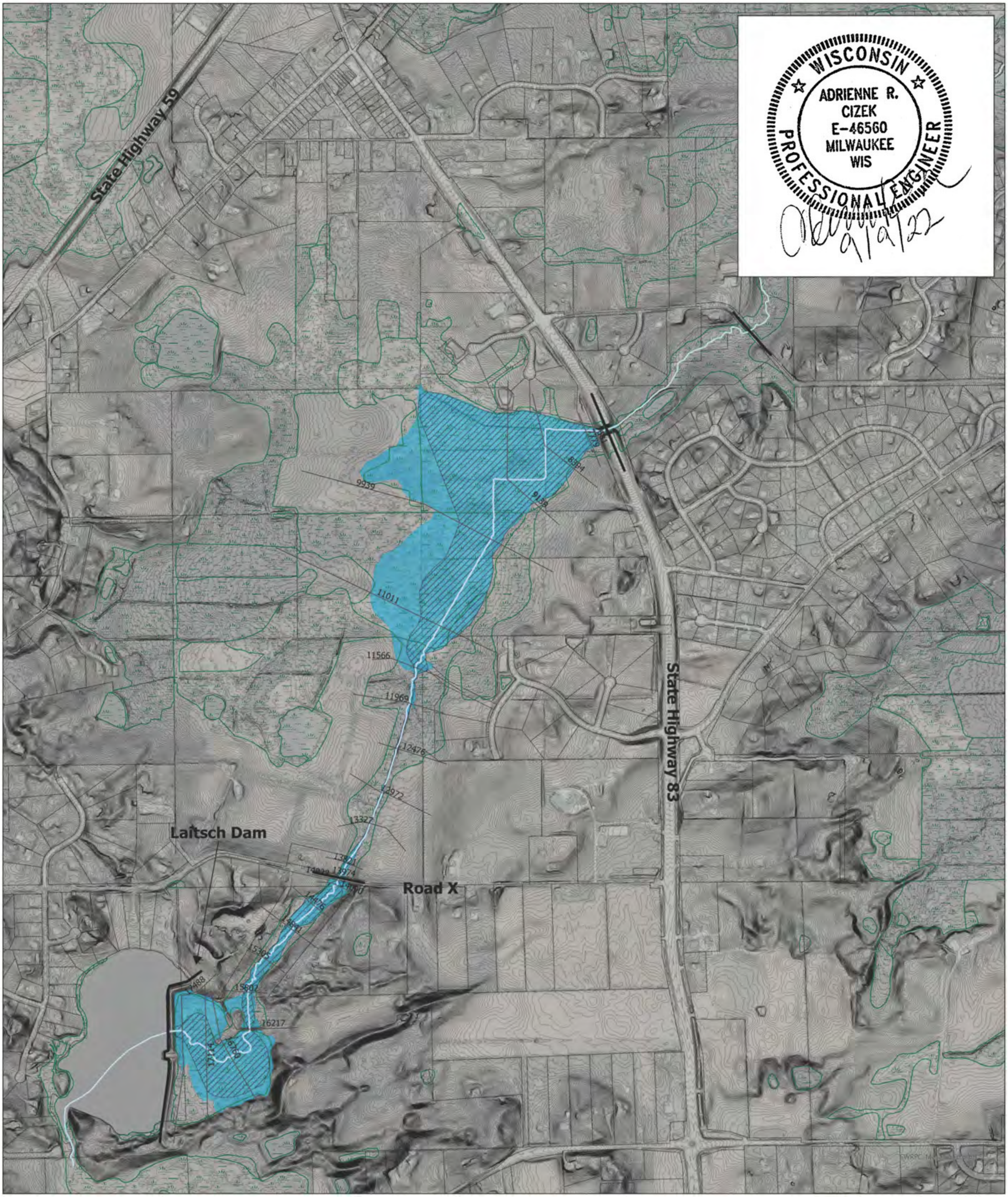
(eq 7-3)

$$Deaths = \frac{1}{1 + 13.277(1\text{^}0.440)(e^{0.759(0)})} = 0.07$$

Since 0.07 persons is less than 0.50 persons, the threshold where a life could be probabilistically lost, there is no probable loss of life from dam failure as modeled.

ATTACHMENT 8: HEC-RAS HYDRAULIC MODEL (ELECTRONIC)

ATTACHMENT 9: DFA FLOOD MAPS AND ASSOCIATED GIS FILES



Legend

Cross Sections
Iterpolated
N
Y
Dam
Bridges
Streamline
Floodway
Flood Hazard Zone
WDNR Wetlands
TaxParcel
Contours

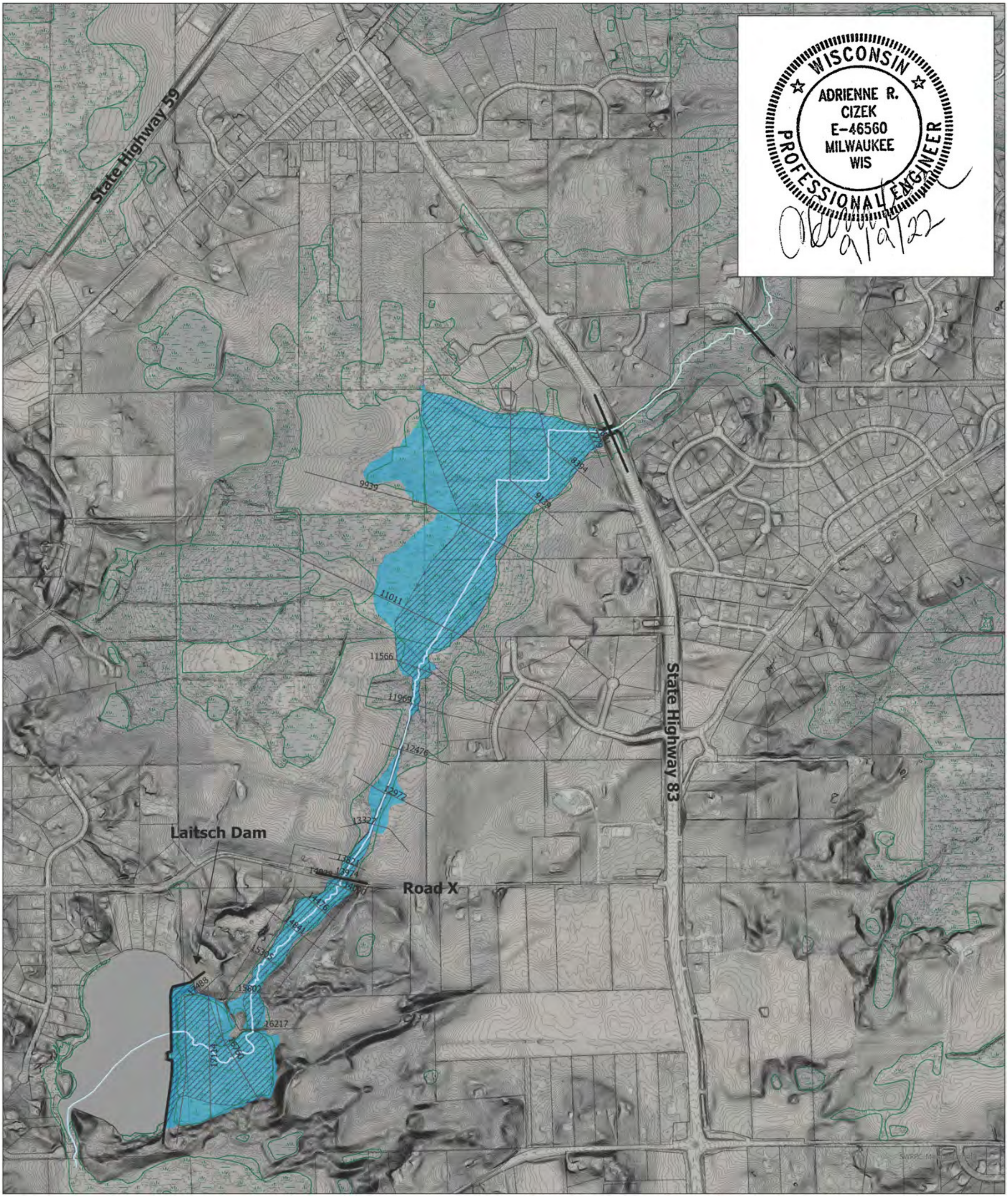
0 0.07 0.15 0.3 0.45 0.6 Miles

N

STORMWATER SOLUTIONS ENGINEERING LLC

LAITSCH DAM FAILURE ANALYSIS
Dam in Place

Map created by Stormwater Solutions Engineering, LLC on July 27, 2022
Coordinate System: NAD83 (2011) State Plane
Vertical Datum: NAVD88



Legend

Cross Sections
Iterpolated
N
Y
Dam
Bridges

Streamline
Floodway
Flood Hazard Zone
WDNR Wetlands
TaxParcel
Contours

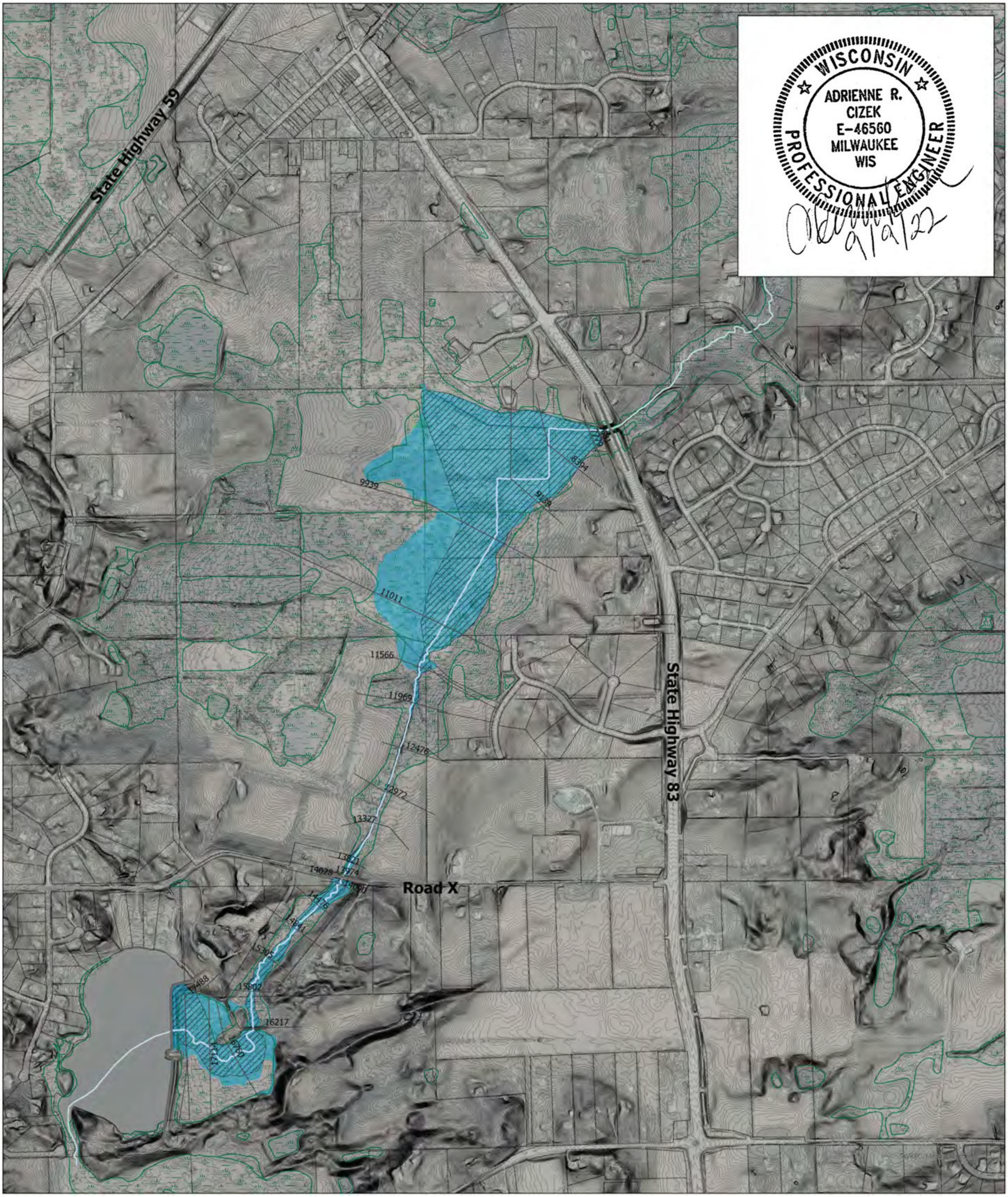
0 0.07 0.15 0.3 0.45 0.6 Miles

N

LAITSCH DAM FAILURE ANALYSIS
Dam Breach

Map created by Stormwater Solutions Engineering, LLC on July 27, 2022
Coordinate System: NAD83 (2011) State Plane
Vertical Datum: NAVD88

STORMWATER SOLUTIONS ENGINEERING LLC



Legend

Cross Sections
Iterpolated
N
Y
Bridges
Streamline
Floodway
Flood Hazard Zone
WDNR Wetlands
TaxParcel
Contours

0 0.07 0.15 0.3 0.45 0.6 Miles

N

LAITSCH DAM FAILURE ANALYSIS
Dam Non-Existent

Map created by Stormwater Solutions Engineering, LLC on July 27, 2022
Coordinate System: NAD83 (2011) State Plane
Vertical Datum: NAVD88

STORMWATER SOLUTIONS ENGINEERING LLC