SWM Consulting

Updated Hydrologic and Hydraulic Analysis Report

New Jersey Transit - Estling Lake Dam
NJDEP Dam File No. 25-169
Denville Township, Morris County, New Jersey

January 4, 2019

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Joseph J. Skupien, PE, PP
NJPE License No. 25913

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Updated Hydrologic and Hydraulic Analysis

January 4, 2019

1. Introduction

This Report has been prepared to document the basis, methods, and results of an updated hydrologic and hydraulic analysis of Estling Lake Dam jointly owned by New Jersey Transit (NJT) and the Estling Lake Corporation (ELC). The Dam is part of the NJT's Morristown Line and is located on Den Brook in Denville Township, Morris County, New Jersey. A general location of the Dam is shown in Figure 1.

The updated hydrologic and hydraulic analysis documented herein was performed in response to the recommended Hydrologic and Hydraulic Evaluation contained in the 2017 Estling Lake *Formal Inspection Report* prepared for NJT by HDR and submitted to the New Jersey Department of Environmental Protection in August 2018. A copy of the section of the Report making this recommendation is contained in **Appendix A – Previous Analyses and Reports.** As described in the Inspection Report, the updated hydrologic and hydraulic analysis was performed to re-evaluate the suitability of the Dam's Spillway Design Storm (SDS).

This SDS was previously approved as the One-Half Probable Maximum Precipitation (0.5 PMP) by the Bureau of Dam Safety (BDS) of the New Jersey Department of Environmental Protection (NJDEP) following a hydrologic, hydraulic, dam failure, and downstream impact analysis conducted for NJT by Clough Harbor Associates, LLP (CHA), Woidt Engineering & Consulting, PC, (WEC) and Stormwater Management Consulting, LLC (SWM). The results of this analysis were presented to the BDS in the report titled *Lake Estling Dam – Dam Break Analysis/Inundation Mapping Report* prepared by WEC on May 12, 2014. A copy of this report is also contained in **Appendix A – Previous Analyses and Reports**.

2. Scope of Analysis

To perform the recommended re-evaluation of Estling Lake Dam's 0.5 PMP SDS, the updated hydrologic and hydraulic analysis documented herein included the following steps:

1. Reanalyze the Estling Lake Dam's watershed using updated land cover, soil, and rainfall data and compute updated runoff hydrographs.

2. Update the routing data for Estling Lake Dam and the one upstream and two downstream lakes in the Dam's watershed using data on file with the BDS. The names and locations of these lakes are shown in Figure 2.

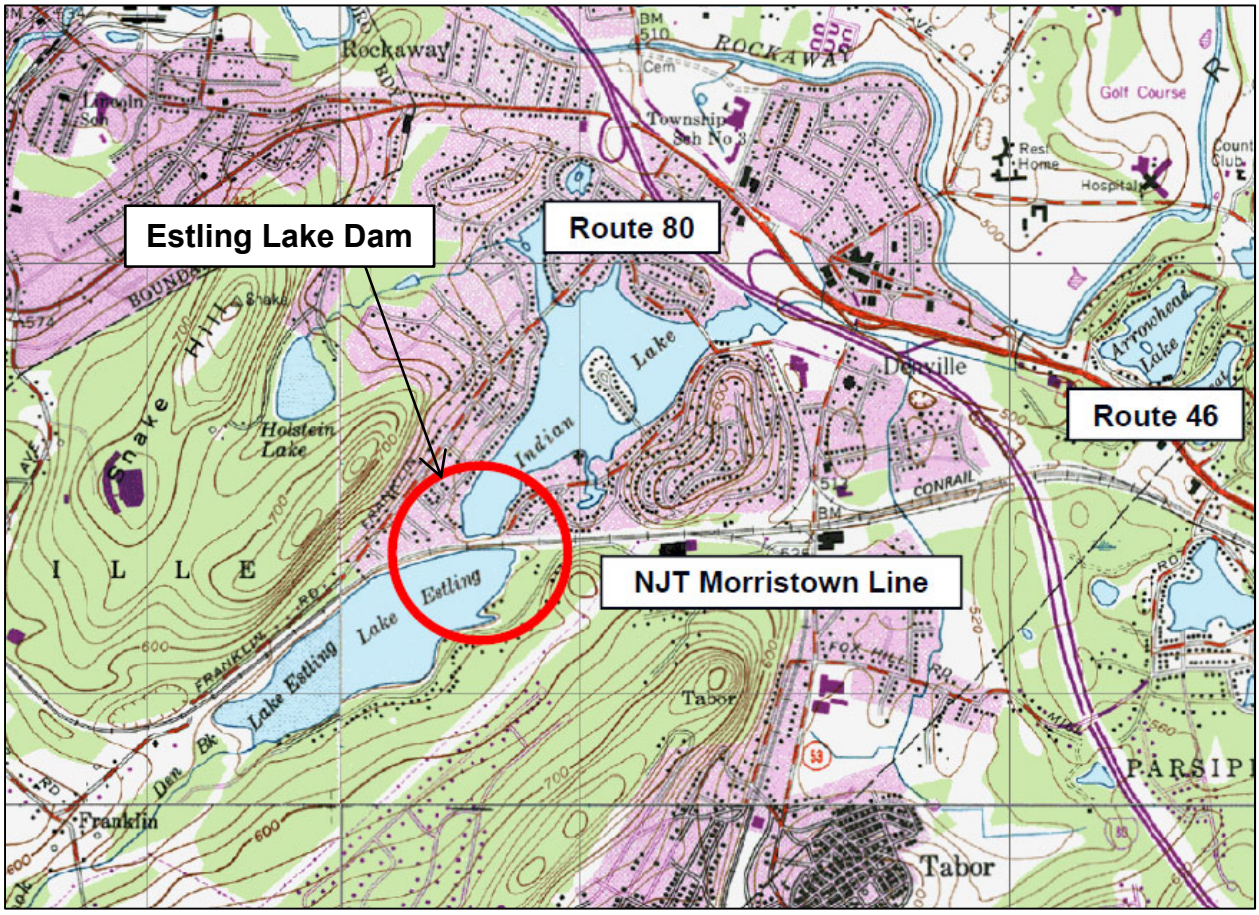
3. Compute updated peak inflows, outflows, and water surface elevations at Estling Lake Dam.

4. Perform updated dam breach analysis of Estling Lake Dam for the 0.5 PMP storm event.

5. Compare the results of updated watershed, runoff, routing, and breach analyses with those used in the development of the NJDEP-approved 0.5 PMP SDS for Estling Lake Dam.

6. Re-affirm the suitability of Estling Lake Dam's 0.5 PMP SDS and provide updated flows, water surface elevations (WSELs), and updated inundation mapping as necessary.

Figure 1
Estling Lake Dam Location
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam



3. Basis of Analysis

As noted above, the updated hydrologic and hydraulic analysis was performed to determine the continued suitability of Estling Lake Dam's 0.5 PMP SDS in light of updated hydrologic and hydraulic data regarding the Estling Lake Dam's watershed. As such, the analysis was based upon the data used to originally develop the Dam's BDS-approved SDS. This data is described in the May 2014 *Lake Estling Dam – Dam Break Analysis/Inundation Mapping Report* prepared for NJT by CHA and WEC noted above and the PowerPoint presentation prepared by SWM Consulting for the Estling Lake Progress Meeting held between the BDS, NJT, CHA, WEC, and SWM Consulting on March 5, 2012. In addition to the 2014 CHA and WEC Report, a copy of the 2012 meeting presentation is contained in **Appendix A – Previous Analyses and Reports.**

Descriptions of additional data used as the basis for the hydrologic and hydraulic analysis of Estling Lake Dam is described in the appropriate Report sections below.

4. Updated Watershed Characteristics

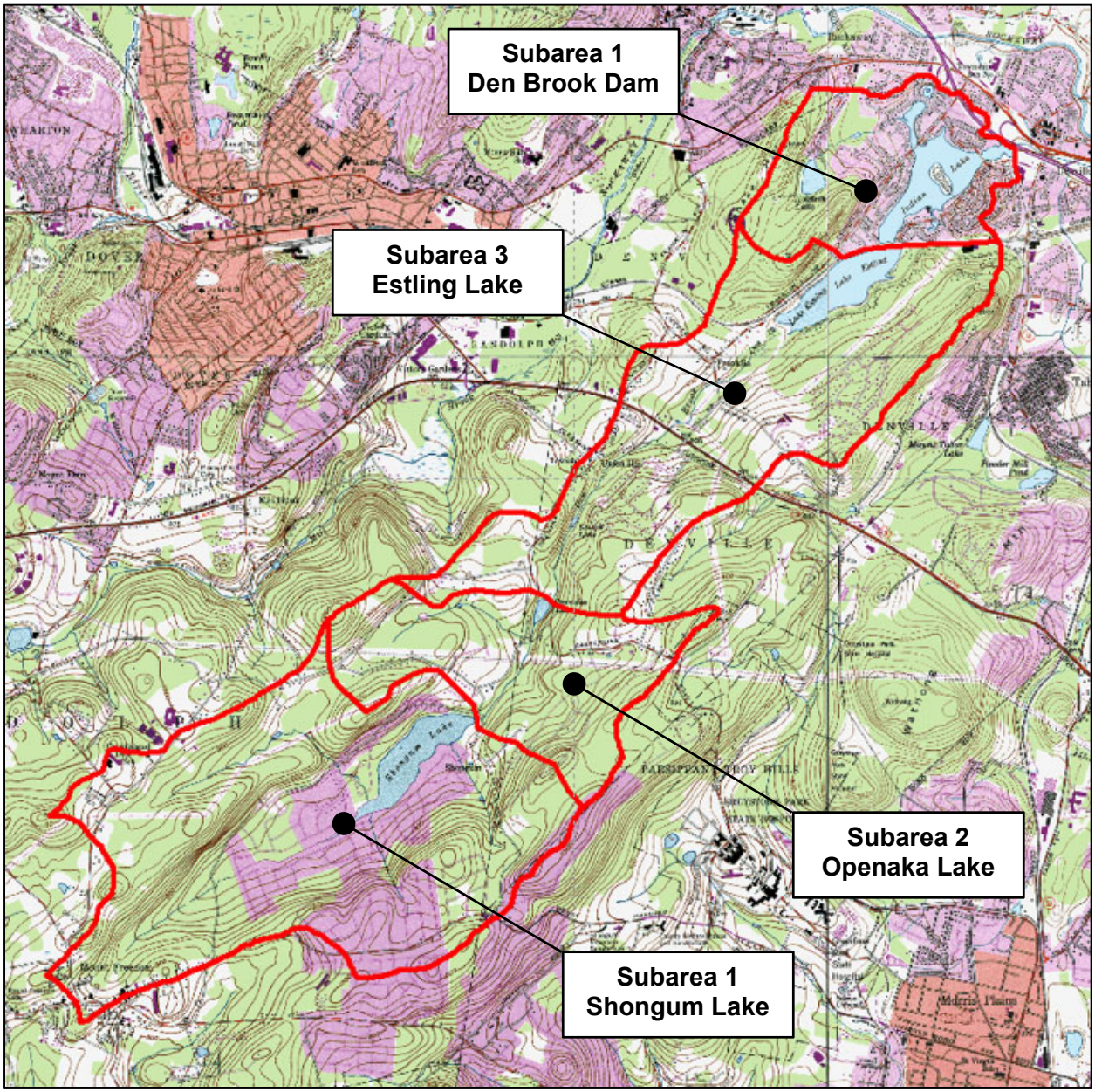
Updating of the Estling Lake watershed characteristics begin the development of new watershed limits and the delineation of new subarea boundaries to Estling Lake Dam and the one downstream and two upstream dams. As shown in Figure 2, these dams are Den Brook Dam downstream and Shongum Lake and Openaka Lake Dams upstream. The updated watershed and subarea limits were based upon the topographic mapping shown on U.S. Geological Survey (USGS) Dover and Boonton 7.5 Minute Series Quadrangles and checked using the USGS StreamStats drainage area delineation software. A comparison of these updated watershed and subarea sizes with those from the original 2014 analysis is presented in Table 1.

Table 1
Comparison of Previous and Updated Subarea Sizes
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Subarea No.	Subarea Name	Drainage Area (Acres)	
		Previous 2014	Updated 2018
1	Shongum Lake	1,984	1,977
2	Openaka Lake	685	722
3	Estling Lake	1,504	1,499
4	Den Brook Dam	640	612
	Total Watershed	4,813	4,810

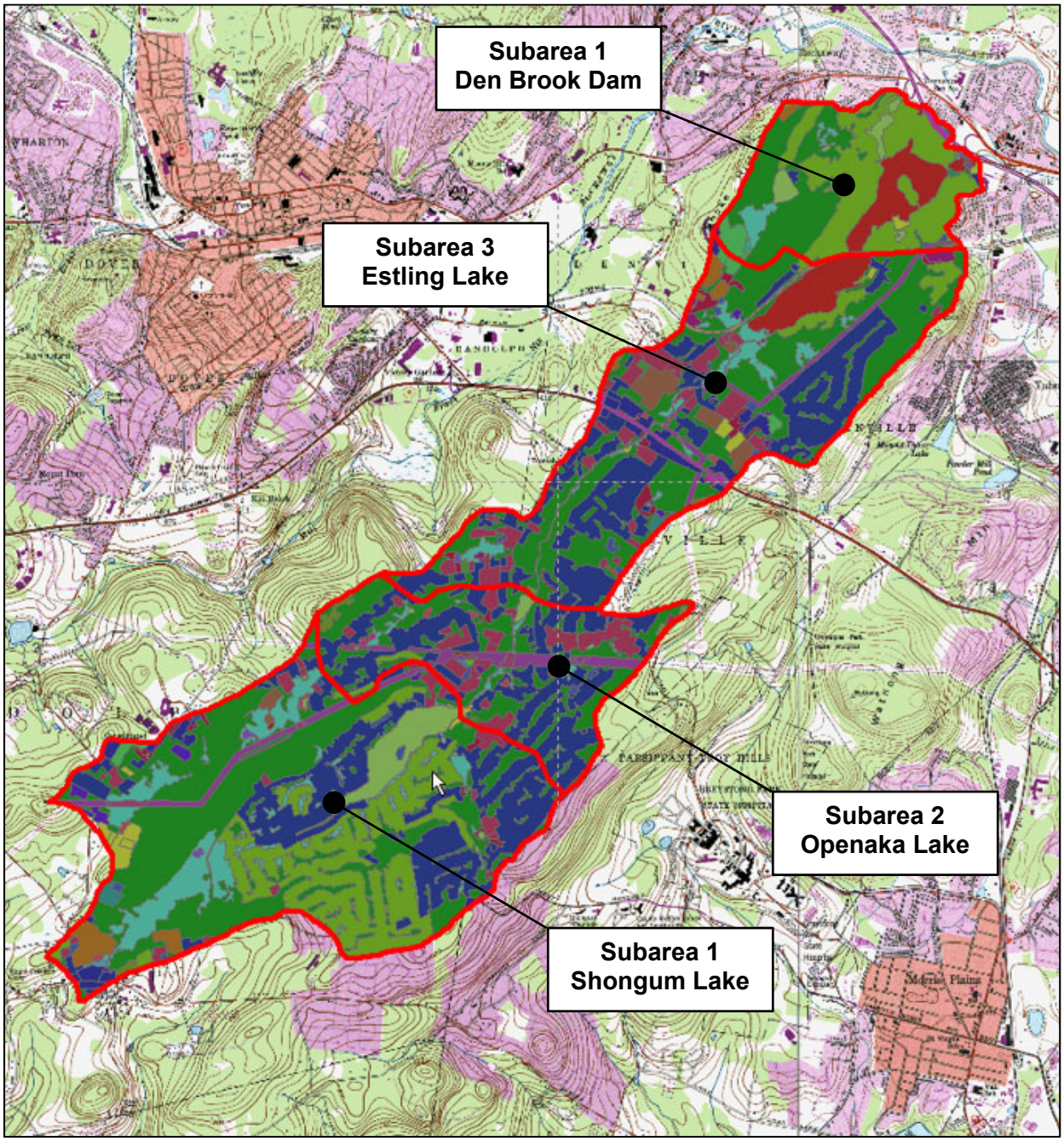
Updated subarea land cover data was based upon existing development as depicted by the NJDEP 2012 Land Use/Land Cover data available from the New Jersey Office of GIS. The limits of the various land cover zones within each drainage subarea are shown in Figure 3.

Figure 2
Updated Watershed and Subarea Limits
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

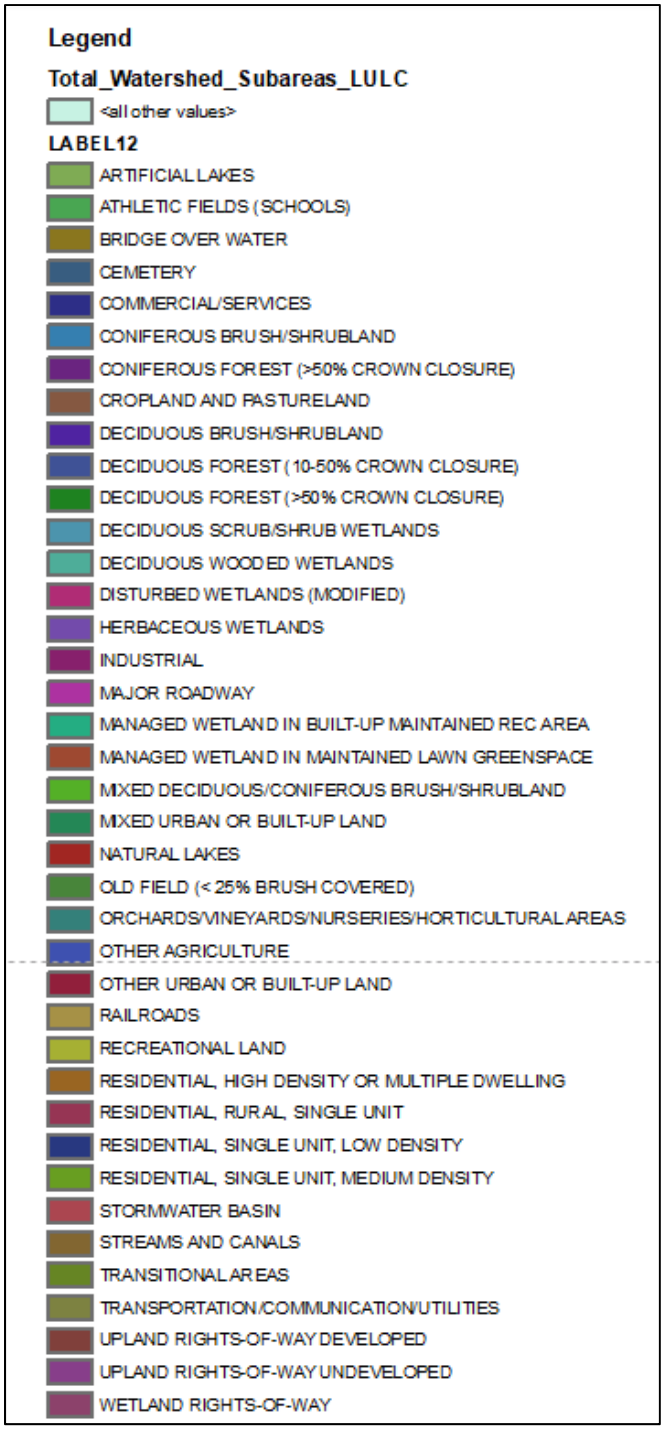


Note: Topographic Mapping based upon USGS Dover and Boonton Quadrangles

Figure 3
Updated Watershed and Subarea Land Cover Data
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

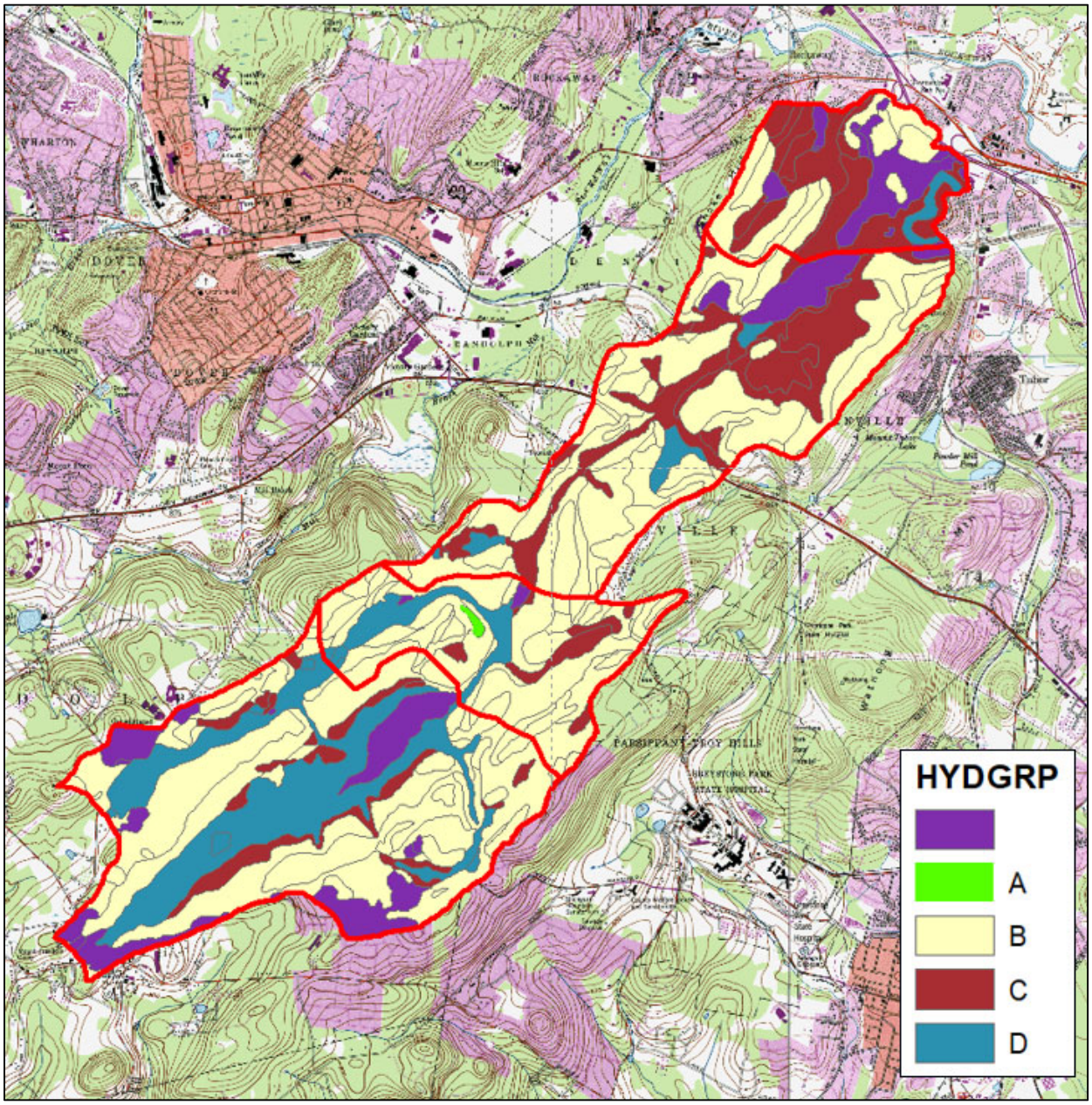


Note: Land Covers based upon 2012 NJGIS Land Use/Land Cover Data



Soil data for the drainage subareas was obtained from the SSURGO Soil Layer Data for Morris County compiled by the NRCS and available from the New Jersey Office of GIS. A plan view of the NRCS Hydrologic Soil Groups (HSGs) within each drainage subarea is shown in Figure 4. As can be seen in the Figure, the drainage area is primarily comprised of a combination of HSG B soils with HSG C and D soils in the lower waterway and floodplain areas.

Figure 4
Updated Watershed and Subarea Hydrologic Soil Group Data
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam



Note: Hydrologic Soil Groups based upon Morris County SSURGO Data

Computation of NRCS Runoff Curve Numbers (CNs) for each drainage subarea was performed using ESRI ArcGIS 10.6 and Microsoft Excel. In accordance with NJDEP recommendations, runoff volumes from pervious and directly connected impervious area were computed separately. A comparison of the updated subarea CNs with those from the previous 2014 analysis is presented in Table 2. It should be noted that, to enable the comparison, the updated CN values in the Table are based upon weighted average values for each subarea's pervious and impervious areas.

Table 2
Comparison of Previous and Updated Subarea Runoff Curve Numbers
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Subarea No.	Subarea Name	Weighted Average Runoff Curve Number	
		Previous 2014	Updated 2018
1	Shongum Lake	69	69
2	Openaka Lake	69	65
3	Estling Lake	71	69
4	Den Brook Dam	77	76

Based upon a review of the Times of Concentration (TCs) previously computed for each drainage subarea for the original 2014 analysis, which were developed in accordance with Chapter 3 of the NRCS' *Technical Release 55 – Urban Hydrology for Small Watersheds*, it was decided to retain these TC values for the updated analysis. Due to the evenly distributed nature of the impervious surfaces throughout each drainage subarea, a single TC was used for both impervious and pervious areas in each subarea. A summary of these TCs are presented in Table 3.

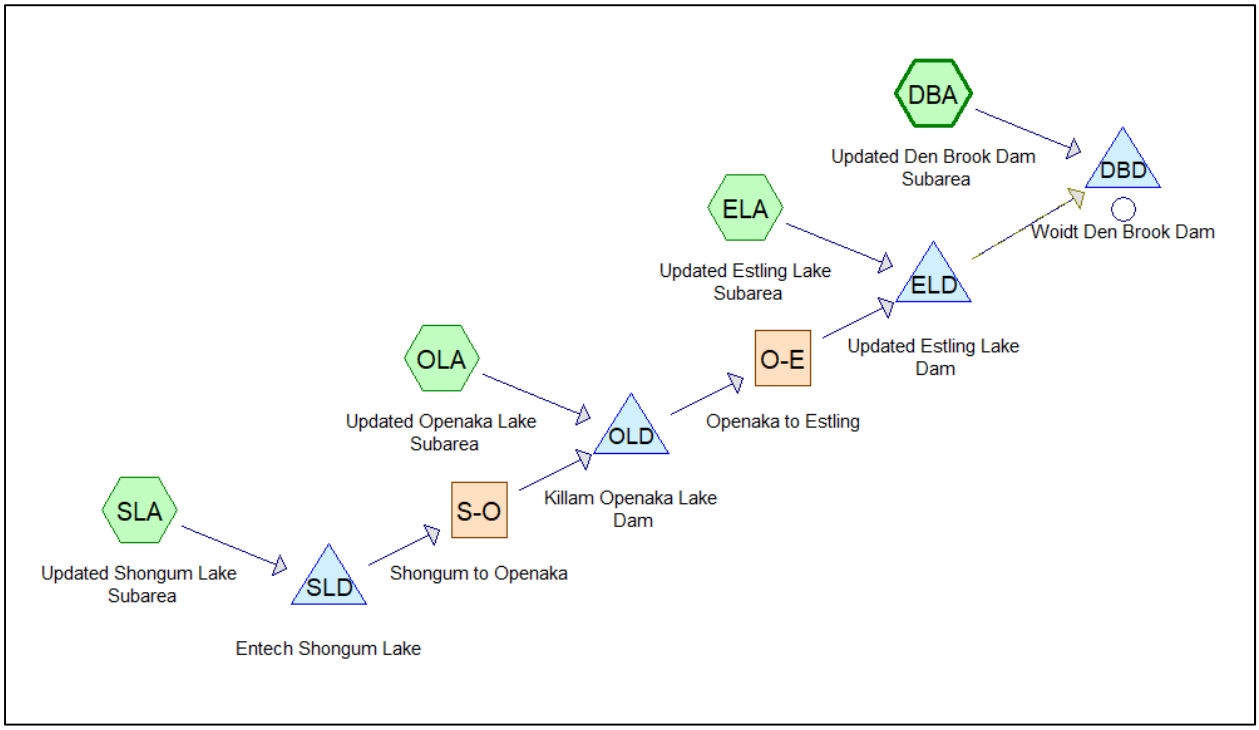
Table 3
Summary of Subarea Times of Concentration
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Subarea No.	Subarea Name	Time of Concentration (Minutes)
1	Shongum Lake	67
2	Openaka Lake	46
3	Estling Lake	52
4	Den Brook Dam	38

Note: Times of Concentration in Updated Analysis are Same as Previous Analysis

Similar to the previous 2014 analysis, the updated hydrologic and hydraulic analysis for Estling Lake Dam was based upon Version 10 of the HydroCAD software developed by HydroCAD Software Solutions, LLC. A schematic view of the updated HydroCAD model of the overall watershed is presented in Figure 5.

Figure 5
HydroCAD Model Schematic of Updated Watershed
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam



Similar to the previous 2014 analysis, the updated analysis of Estling Lake Dam was based upon 72-hour rainfalls temporally distributed in accordance with the NRCS Type III Design Storm distribution. A review of the 72-Hour rainfalls used in the previous analysis determined that they remain applicable to the updated analysis. Similar to the previous analysis, rainfall depths for the 100-Year to Probable Maximum Precipitation (PMP) was used in the updated analysis. A summary of these 72-Hour rainfall depths is presented in Table 4.

Table 4
Summary of 72-Hour Rainfalls
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Storm Event	Total 72-Hour Rainfall Depth (Inches)
100-Year	9.97
0.3 PMP	11.35
0.4 PMP	15.13
0.5 PMP	18.92
PMP	37.83

Final rainfall-runoff parameters for each drainage subarea are shown in Table 5 below. Copies of pertinent hydrologic data and computations, including HydroCAD input and output data are contained in **Appendix B – Updated Analysis Data, Models, and Results** and on the project data compact disk in **Appendix C**.

Table 5
Summary of Updated Subarea Runoff Parameters
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Subarea Parameter	Drainage Subarea			
	1 - Shongum	2 - Openaka	3 - Estling	4 - Den
Area (Acres)	1,977	722	1,499	612
Pervious Area (Acres)	1,784	670	1,333	545
Impervious Area (Acres)	193	52	166	67
Pervious CN	66	62	65	73
% Impervious	10%	7%	11%	11%
TC (Minutes)	67	46	52	38

5. Updated Routing Data

As noted above, the updated hydrologic and hydraulic analysis of Estling Lake Dam included a review of the stage-storage-discharge relationships for all four Dams in the study watershed that were used in the previous 2014 analysis. This included the relationships for Estling Lake, Shongum Lake, Openaka Lake, and Den Brook Dams. Based upon this review, the following updates were made to these Dams:

Shongum Lake Dam – The previous stage-storage-discharge relationship was updated using the most current data on file with the NJDEP BDS. This included updated storage and discharge data from the September 2002 *Dam Breach Analysis and Hazard Classification Determination with Design Storm Evaluation* prepared by The Entech Group. Copies of this data are on file with the NJDEP BDS. It should be noted that this data was used in place of the previous 2014 stage-storage-discharge relationship due primarily to its more detailed discharge analysis and more extensive stage-area data for the Dam.

Openaka Lake Dam - The previous stage-storage-discharge relationship was also updated using the most current data on file with the NJDEP BDS. This included updated storage and discharge data from the May 2010 *Review of Prior Hydrologic and Hydraulic Analyses* prepared by Hatch Mott MacDonald. Copies of this data are on file with the NJDEP BDS. It should be noted that, similar to Shongum Lake Dam, this data was used in place of the previous 2014 stage-storage-discharge relationship due primarily to its more detailed discharge analysis and more extensive stage-area data for the Dam.

Estling Lake Dam – A review of the previous 2014 stage-discharge relationship for the Dam was considered adequate for the updated analysis, particularly because it was based upon a detailed hydraulic analysis of flow of the NJT railroad embankment that serves as the Dam. The stage-storage relationship was updated to more accurately reflect storage volumes below the Dam's permanent pool elevation. This updated information was obtained from 2010 bathymetric data of Estling Lake developed by Princeton Hydro and provided by the Estling Lake Corporation.

Den Brook Dam – A review of the most current data on file with the NJDEP BDS determined that the previous 2014 stage-storage-discharge relationship for Den Brook Dam provided a more detailed and comprehensive relationship for the Dam. As such, this previous 2014 data was retained in the updated analysis.

Reach Routings – In addition to the four Dams described above, the previous 2014 analysis of Estling Lake Dam included normal depth routings for the reaches of Den Brook between Shongum Lake and Openaka Lake Dams and between Openaka Lake and Estling Lake Dams. A review of these routings determined that they were also suitable and were retained in the updated analysis. However, in order to be compatible with the updated stage-storage-discharge relationships described above for Shongum Lake and Openaka Lake Dams and provide accurate tailwater elevations downstream of both Dams, it was necessary to adjust the stage elevations in the reach routings to the same vertical datums as those used for the Dams.

The final stage-storage-discharge data for all four Dams used in the updated analysis are presented in **Appendix B – Updated Analysis Data, Models, and Results.**

6. Updated Peak Flows and Elevations

The peak inflows, outflows, and water depths for the Estling Lake Dam's 0.5 PMP SDS at all four Dams computed with the updated HydroCAD model of the study watershed shown in Figure 5 are summarized in Table 6. Also included in the Table are the flows and depths computed in the previous 2014 analysis. It should be noted that, due to the difference in vertical datums at Shongum and Openaka Lake Dams, it was necessary to report maximum flow depths in Table 6 instead of water surface elevations.

Table 6
Comparison of Previous and Updated Subarea 0.5 PMP SDS Runoff Results
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Dam Name	Previous 2014 Analysis Peaks			Updated 2018 Analysis Peaks		
	In (CFS)	Out (CFS)	Depth (FT)	In (CFS)	Out (CFS)	Depth (Feet)
Shongum	10,818	4,727	5.8	10,645	7,049	6.45
Openaka	6,459	6,419	6.6	8,581	8,568	6.6
Estling	13,840	10,212	12.4	13,769	11,219	12.6
Den	11,575	8,581	10.5	12,246	9,221	10.9

A more detailed summary of the updated results for Estling Lake Dam are presented in Table 7, including the maximum water surface elevation (WSEL) at the Dam in the NGVD 1929 vertical datum.

Table7
Summary of Updated Estling Lake Dam Analysis 0.5 PMP SDS Results
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Description	Updated Result
Peak Inflow Rate	13,769 CFS
Peak Outflow Rate	11,219 CFS
Peak Principal Spillway Outflow Rate	6,540 CFS
Peak Overtopping Outflow Rate	4,679 CFS
Maximum Water Surface Elevation	527.3 Feet NGVD29*
Permanent Pool Elevation	514.70 Feet NGVD29*
Minimum Top of Dam Elevation	525.6 Feet NGVD29*
Maximum Overtopping Depth	1.7 Feet
Overtopping Duration	2.8 Hours

***Note:** Conversion to NAVD 1988 Vertical Datum = -0.82 Feet

7. Updated Dam Breach and Downstream Impact Analysis

Based upon the updated peak 0.5 PMP SDS inflow and Estling Lake Dam stage-storage-discharge relationship discussed above, an updated dam breach analysis was performed. This analysis was based upon the same dam breach parameters used in the previous 2016 analysis. These parameters are summarized in Table 8 below.

Table 8
Summary of Dam Breach Parameters for 0.5 PMP SDS
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Parameter Description	Parameter Value
Top of Embankment	525.6 Feet NGVD29
Breach Start	Maximum Water Surface Elevation
Maximum Water Surface Elevation	527.3 Feet NGVD29*
Bottom of Breach Elevation	508.0 Feet NGVD29*
Maximum Breach Height	17.6 Feet
Breach Bottom Width	43 Feet
Breach Side Angle	53.2 Degrees
Breach Discharge Coefficient	2.54
Breach Time	15 Minutes
Breach Location	At Lowest Toe of Embankment

***Note:** Conversion to NAVD 1988 Vertical Datum = -0.82 Feet

A summary of the dam breach results from the updated analysis is presented in Table 9 below. This Table also includes the results of the previous 2014 analysis.

Table 9
Summary of Previous and Updated 0.5 PMP SDS Dam Breach Analysis Results
Updated Hydrologic and Hydraulic Analysis of Estling Lake Dam

Description	Result		Difference	Percent Difference
	Previous 2014	Updated 2018		
Peak Inflow (CFS)	13,840	13,769	-71	-0.5%
Peak Breach Outflow (CFS)	19,191	19,862	671	3.5%
Peak Non-Breach Outflow (CFS)	10,212	11,219	1,007	9.9%
Peak Den Brook Dam Inflow (CFS)	20,296	20,714	418	2.1%
Peak Den Brook Dam Outflow (CFS)	11,613	12,078	465	4.0%
Peak Den Brook Dam Depth (Feet)	12.1	12.3	0.2	1.7%
Peak Den Brook Dam Non-Breach Depth (Feet)	10.5	10.9	0.4	3.8%
Den Brook Depth Increase Due to Breach (Feet)	1.6	1.4	-0.2	-12.5%

As can be seen in Table 9, the updated dam breach analysis of Estling Lake Dam for the Dam's 0.5 PMP SDS indicates that the peak outflow from the Dam during an assumed dam breach will be 671 CFS (3.5 percent). This will result in a 418 CFS (2.1%) increase in the peak inflow to Den Brook Dam downstream. However, due to the updated analysis 1,007 CFS (9.9%) increase in the peak non-breach outflow from Estling Lake Dam to Den Brook Dam, the updated analysis indicates that the increase in downstream water surface elevation (WSEL) in Den Brook due to the assumed Estling Lake Dam breach will be reduced by 0.2 feet from 1.6 feet computed by the previous 2016 analysis to 1.4 feet by the updated 2018 analysis.

In light of a) the updated 1.4-foot increase in downstream WSEL due to a breach of Estling Lake Dam and b) that this increase will be 0.2-feet less than the previously computed increase of 1.6 feet, it can be concluded that the Dam's 0.5 PMP SDS that was approved by the NJDEP BDS based upon the previous 2014 analysis is still appropriate for design of rehabilitation and dam safety measures for Estling Lake Dam.

8. Summary and Conclusions

An updated hydrologic and hydraulic analysis of New Jersey Transit's Estling Lake Dam has been performed in accordance with the recommendations contained in the Dam's 2017 *Formal Dam Inspection Report*. This analysis included updated watershed rainfall-runoff characteristics, dam stage-storage-discharge relationships at Estling Lake Dam and the three other dams in the overall watershed, and peak Dam inflows, outflows, and water surface elevations.

Using the results from the above analysis, an updated dam breach and downstream impact analysis of Estling Lake Dam was also performed. This updated breach analysis confirmed that a Spillway Design Storm (SDS) based upon the rainfall from the One-Half Probable Maximum Precipitation (0.5 PMP) storm is appropriate for the design of rehabilitation and dam safety measures at Estling Lake Dam.

Descriptions of the various tasks and summaries of the results of the updated hydrologic and hydraulic analysis of Estling Lake Dam are presented in the text above. Details of the data and results are contained in **Appendix B – Updated Analysis Data, Models, and Results** and on the Project Data Disk in **Appendix C**.

Appendix A
Previous Analyses and Reports

- **Excerpts from 2017 Estling Lake Dam Formal Inspection Report**

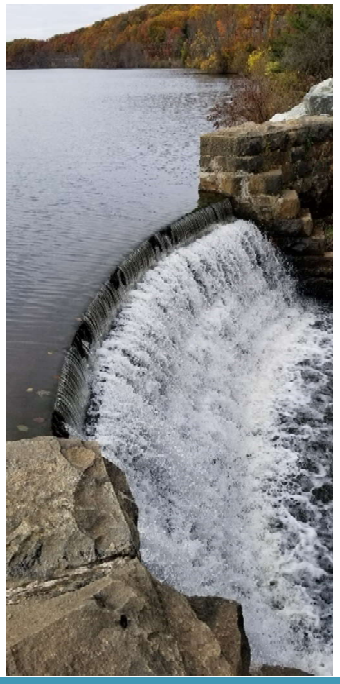
- **2014 CHA and WEC Lake Estling Dam Break Analysis/Inundation Mapping Report**

- **Estling Lake Progress Meeting PowerPoint NJDEP Bureau of Dam Safety March 5, 2012**

- **Updated 2018 Analysis HydroCAD Model Without Dam Failure**

- **Updated 2018 Analysis HydroCAD Model With Dam Failure**

Excerpts from 2017 Estling Lake Dam Formal Inspection Report



Estling Lake Formal Inspection Report

New Jersey Transit

August 21, 2018

CONCLUSION (continued)

Recommended repairs be to be made immediately (30-90 days):

1. Develop and implement a Vegetation Management Plan. (New Jersey Transit). The following elements should be considered as part of that plan.

   For upstream and downstream embankments, extending 10 feet from downstream toe:

   a) Cut shrubs and trees with trunk diameters of 8 inches or less to the ground. Do not remove root balls.

   b) Clear all brush throughout the noted extents.

   c) Have an arborist assess the health of trees and shrubs with trunk diameters greater than 8 inches and recommend removal of unhealthy plants with advice and oversight buy a professional engineer.

Recommended improvements to be made long term (2-3 year):

1. Restore spalling concrete on culvert wingwalls (Estling Lake Corporation) and culvert (New Jersey Transit).

2. Restore and regrout spillway joints (Estling Lake Corporation).

3. Replace missing low level outlet intake trash rack. It is the middle trash rack on the east low level outlet. (Estling Lake Corporation).

4. Complete baseline spillway crack mapping and high precision survey (Estling Lake Corporation)

The following studies are recommended (New Jersey Transit):

- [X] Hydrologic and Hydraulic Engineering Evaluation to update the 0.5 PMP SDS
- [X] Potential Failure Mode Analysis for dam and spillway
- [X] Comprehensive Embankment and Spillway Stability Evaluation for all modes of potential failure due to seismic loads, ice loads and those caused by the updated 0.5 PMP SDS flood, including through-seepage, under-seepage, overtopping, and spillway failure
- [X] Design of remedial measures to address spillway inadequacy and dam overtopping and additional deficiencies identified in the studies above

- [ ] Failure/Inundation analysis

- [ ] None

2014 CHA and WEC Lake Estling
Dam Break Analysis/Inundation Mapping Report

LAKE ESTLING DAM
DAM BREAK ANALYSIS/
INUNDATION MAPPING REPORT

Denville Township
Morris County, New Jersey

Prepared for:

Clough Harbor Associates, LLP
6 Campus Drive
Parsippany, New Jersey

Prepared by:

Woidt Engineering & Consulting, P.C.
41 Chenango Street, Suite 200
Binghamton, NY 13901

May 12th, 2014

LAKE ESTLING DAM
DAM BREAK ANALYSIS/
INUNDATION MAPPING REPORT

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1.0 Project Location & Description

This investigation was conducted to assess and develop downstream inundation mapping for a sudden failure of Lake Estling Dam. The dam break analysis and preparation of inundation mapping will benefit the dam owner and Denville Township as it will provide a clearer definition of the downstream hazard area and impacts that will be included in an Emergency Action Plan (EAP). A secondary purpose of the investigation was to confirm the spillway capacity of the dam. It is noted that the current NJDEP hazard classification for Lake Estling Dam is High (Class 1). The investigation was conducted by Woidt Engineering & Consulting, PC (WEC) in conjunction with Storm Water Management Consulting, LLC (SWMC).

Lake Estling Dam is a 19' +/- high railroad embankment dam located in Denville Township, Morris County, NJ and is owned and maintained by the New Jersey Transit Authority. The dam crest supports twin tracks with catenaries for a Transit Authority commuter rail line. The primary spillway consists of a masonry stepped spillway that connects to a 26' wide by 13' high rectangular concrete box culvert that passes through the railroad embankment. The box culvert discharges directly into a downstream lake (Indian Lake), which is the primary hazard area (see Inundation Mapping - Appendix A).

2.0 Inundation Mapping Development History

The development of the dam break analysis and inundation mapping for Lake Estling Dam has a long history dating back to an original analysis and submission prepared by Jenny Engineering in September 2003. As noted in the NJDEP letter dated April 2007, (see Appendix C), NJDEP Dam Safety identified a number of deficiencies in the original analysis. At that point WEC and eventually SWMC became involved in updating and refining the dam break analysis. A series of meetings with NJDEP Dam Safety, NJ Transit Authority, WEC, and eventually SWMC, were held relative to the refinements of the dam break analysis and the choice of an appropriate spillway design flood (SDF). Meeting minutes from these meetings summarizing the development of the final dam break analysis and SDF are included in Appendix C.

In short, through multiple updates of the hydrologic and hydraulic modeling and incremental dam break analysis, it was determined that a 0.50PMP inflow flood would be utilized for the SDF and developing the "rainy day" inundation mapping. The final dam break model and methodology is discussed in greater detail in section 3.0.

3.0 Final Hydrologic & Hydraulic/Dam Break Analysis

3.1 Spillway Capacity

As described in the meeting minutes in Appendix C, the final hydrologic model was developed cooperatively by WEC and SWMC using the proprietary software package HydroCAD, version 10.0. The final HydroCAD model included refined overtopping analysis utilizing detailed railroad survey data, as well as adjusting the stage-storage characteristics of Lake Estling and Indian Lake, located immediately downstream of the dam. The revised stage-storage data utilized four (4') contour interval mapping obtained from Morris County GIS services. This information was not available when the original Jenny Engineering Study was completed. The updated HydroCAD model results confirmed previous conclusions that

the Lake Estling Dam has inadequate spillway capacity to pass a full PMP storm event. Table 1 depicts the overtopping depth and duration of overtopping for various precipitation events.

TABLE 1 – LAKE ESTLING DAM DISCHARGES/STAGES/DURATIONS OF OVERTOPPING FOR VARIOUS STORM EVENTS

Storm Event	Peak Inflow (cfs)	Peak Outflow (cfs)	Maximum Stage	Depth of Overtopping* (feet)	Duration of overtopping (hours)
PMP	31,164	30,512	528.95	3.35	6.2
0.50 PMP	13,847	8,897	526.87	1.27	3.0
0.40 PMP	10,362	5,397	525.29	0	0

***** Top of Dam = Low Point in railroad grade approximately 700'+/- west of spillway = 525.6

As can be observed from Table 1, Lake Estling Dam has adequate spillway capacity to pass approximately the 0.40PMP storm event without overtopping. All storms exceeding this storm event will begin to overtop the top of railroad (dam crest) beginning at the low point located west of the primary spillway.

3.2 Dam Break Analysis

Initially, a sunny day failure analysis was conducted assuming a sudden dam failure would occur at the normal summer pool elevation with low base flow conditions downstream of the dam. The breach parameters used in the dam break analysis were developed in accordance with NJDEP Dam Safety recommended guidelines. Breach parameters used for the sunny day failure were:

Elevation bottom of breach:	508.0 (invert of primary spillway)
Bottom width of breach:	55 feet (approximately 3 times dam height)
Side slopes of breach:	0.5H:1V
Development time:	0.25 hour
Elevation of failure:	514.65 (normal summer pool elevation)

Note that the dam failure was assumed to occur at the primary spillway location even though the railroad embankment will initially overtop at the low point west of the spillway. This assumption was made and confirmed by NJDEP Dam Safety as it represents a higher embankment height and more conservative dam breach hydrograph.

Rainy Day Event (0.50PMP)

The "rainy-day event" compares the 0.50 PMP (the spillway design flood) with a dam break to the 0.50PMP without a dam break to assess the incremental effects of the dam break. Similar dam break parameters were used for this analysis with the exception that the failure was triggered at elevation 526.85, which represents a reservoir stage just below the peak reservoir elevation during the storm. Since the dam actively overtops during the 0.50PMP event, the failure mode was modeled as an overtopping failure.

Downstream Flood Routing

The sunny day dam failure hydrograph, 0.50PMP hydrograph without dambreak and the 0.50PMF hydrograph with dambreak were then routed downstream of the dam using the HydroCAD program. The downstream routings were terminated at Interstate I-80 which effectively acts as a dam embankment for Den Brook Dam, which is located approximately 1.0 miles downstream of Lake Estling Dam. Outflows through the I-80 dam embankment are regulated by Den Brook Dam, which consists of a concrete spillway that discharges to a concrete box culvert that conveys outflows under the I-80 embankment. In addition, two underpasses, (Franklin Road and East Main Street) also convey flow underneath I-80 during extreme storm events.

Indian Lake Dam is located approximately 900' upstream of Den Brook Dam/I-80 Embankment. The normal pool elevation (508.0) of Indian Lake Dam is approximately 5.5' higher than that of the Den Brook Dam (502.5).

The sunny day dam failure and 0.50PMP with and without dam failure results are shown in Tables 2 and 3.

Table 2 - Sunny Day Dam Failure Results

Location	Peak Inflow (cfs)	Peak Outflow (cfs)	Maximum Stage
Lake Estling Dam	0	3,132	514.70
Indian Lake Dam	3,132	336	509.84
Den Brook Dam/I-80	336	330	504.35

Table 3 - 0.50 PMP Without and With Dam Failure

Location	0.50 PMP without dam failure			0.50 PMP with dam failure			Difference (feet)
	Peak Inflow (cfs)	Peak Outflow (cfs)	Max. Stage	Peak Inflow (cfs)	Peak Outflow (cfs)	Max. Stage	
Lake Estling Dam	13,847	8,898	526.86	13847	21410	526.86	0.00
Indian Lake Dam*	n/a	n/a	512.43	n/a	n/a	514.41	1.98
Den Brook Dam	9,928	7647	512.43	23,305	11,348	514.41	1.98

* Stage and flows at Indian Lake controlled by backwater from Den Brook Dam

As can be observed from the results in Table 2, the Sunny Day dam failure outflows and downstream flood stages are controlled by the large downstream storage area of Indian Lake. The sunny day dam break elevations will increase 1.84' over the normal pool level of Indian Lake resulting in minor shoreline flooding around the perimeter of the lake. The large storage volume of Indian Lake results in significant attenuation of peak outflow to the smaller storage area above Den Brook Dam and I-80. The sunny day dam break results in a 1.85' increase in water surface elevations at Den Brook Dam that does not result in any flooding of developed areas.

For the rainy day dam failure scenario, the large magnitude of the inflow hydrograph results in overtopping of the NJ Transit Tracks over a several thousand foot length of track beginning at a low point located approximately 700' west of the primary spillway of Lake Estling Dam. The large outflows from both the 0.50PMP with and without dam break result in stages at Den Brook Dam that significantly submerge the crest elevation of Indian Lake Dam. As such, the downstream water surface elevations are controlled by the Den Brook/I-80 Dam resulting in a backwater condition that extends back to Lake Estling Dam.

Key information regarding flooding depths, arrival times of flood wave and peak stages for the sunny day, 0.50PMP and 0.50PMP events are identified on the Inundation Map in Appendix A. HydroCAD summary results are included in Appendix B.

4.0 Conclusions & Recommendations

The hydrologic and hydraulic analysis identified that Lake Estling Dam has insufficient spillway capacity to safely pass storm events exceeding approximately the 0.40PMP without dam overtopping. With regard to the spillway capacity issue, NJ Transit is currently investigating options to either increase spillway capacity or investigate armoring options such that the railroad embankment could withstand the overtopping depths and durations associated with the 0.50PMP storm.

With regard to downstream flooding, a dam break analysis and subsequent downstream hydrologic/hydraulic routings were conducted to assess downstream hazards. For the Sunny Day dam break scenario, downstream flooding will be limited to minor shoreline flooding around the perimeter of Indian Lake. For the 0.50PMP dam break scenario, the flooding extents are much greater and numerous homes and commercial development will be located within the expected flood extents. However, due to the large magnitude of the 0.50PMP storm, the flooding extents between the 0.50PMP storm with and without the dam failure is not significantly different. The differences in inundation areas can be observed on the Inundation Map.

Due to the presence of Indian Lake, the expected flood wave velocities are expected to be low except for the area immediately downstream of the Lake Estling Dam embankment. The main difference between the 0.50PMP with and without dam break is the water depth which converges to less than 2' at the Den Brook Dam/I-80. The limits of Inundation Mapping were terminated at this point due to the convergence of the water surface elevations, as well as the likelihood that areas downstream of I-80 would already be flooded by the Rockaway River.

Estling Lake Progress Meeting PowerPoint
NJDEP Bureau of Dam Safety
March 5, 2012

New Jersey Transit

Estling Lake Dam Progress Meeting

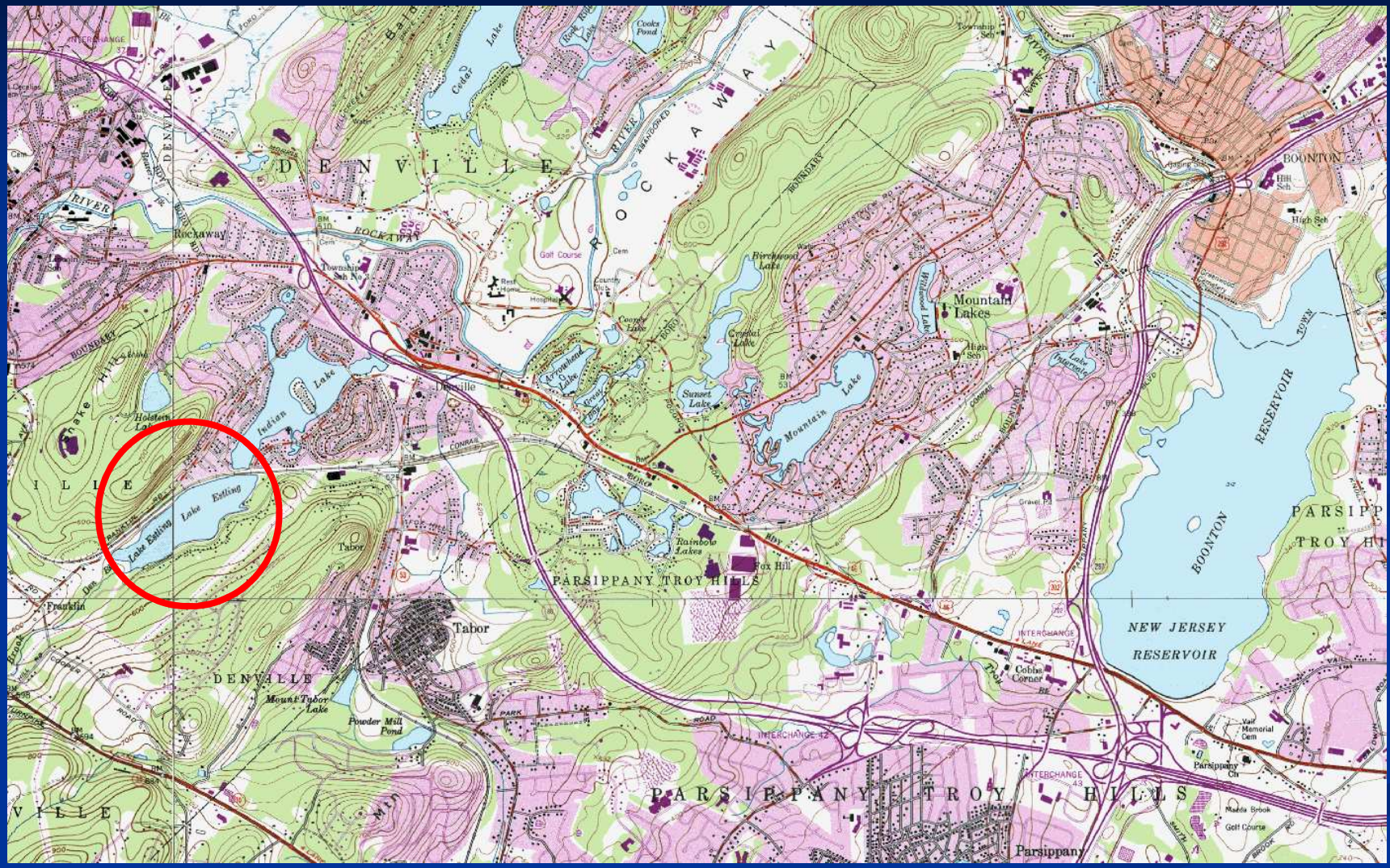
Spillway Design Storm Determination and Inundation Mapping

NJDEP Bureau of Dam Safety and Flood Control

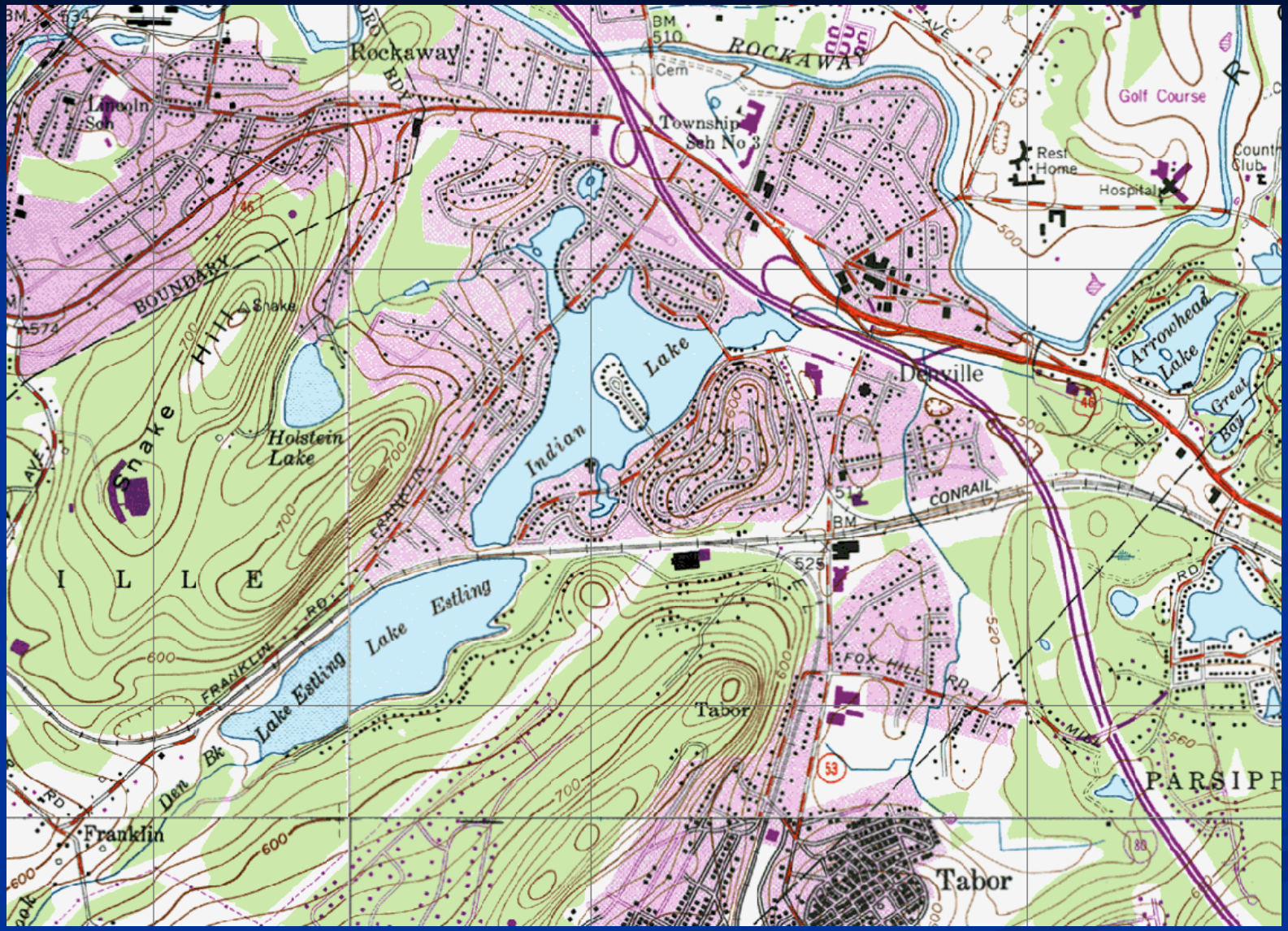
March 5, 2012

Meeting Agenda

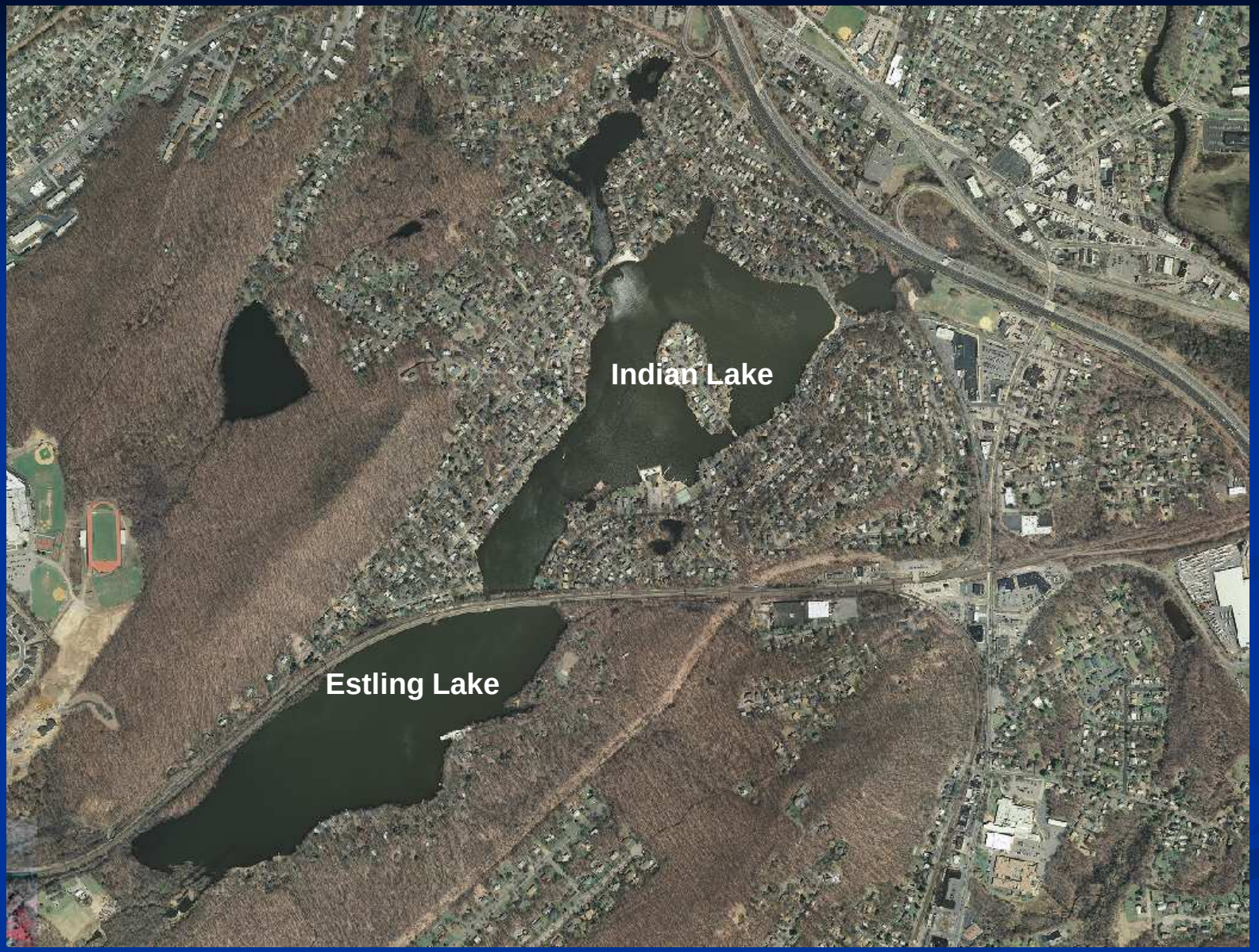
- Overall Goal: Identify Appropriate SDS and Complete EAP Inundation Mapping
- Review Past Results and Meetings
- Provide Update on New Analyses:
  - HydroCAD Watershed Model
  - Unsteady HEC-RAS Model
- Identify Next Steps



Storm Water Management Consulting, LLC



Storm Water Management Consulting, LLC


Indian Lake
Estling Lake


Indian Lake
Estling Lake

Dam Looking West

Dam Looking East

Upstream Dam Face

Spillways

Spillways and Upstream Face of Bridges

Downstream Face of Bridges

Indian Lake Downstream of Spillway and Bridges

Previous Woidt Study Results

HEC-1 Lake Estling Dam Results with Detailed RR Survey					
Storm Event	Stage	Duration of Overtopping (hours)	Peak Outflow PMF (cfs)	Maximum depth of overtopping (ft)	Length of overtopping (ft)
PMF	528.82	6.25	30,039	3.12	>3700′
0.50PMF	527.26	3.00	10,834	1.56	2225′ +/-
0.40PMF	526.03	1.50	6,291	0.33	700′ +/-

HEC-1 Dam Break Results @ Den Brook Dam with detailed RR Survey					
Storm Event	Max. Elevation no Dam Break	Max. Elevation with Dam Break	Incremental Increase in Elevation (feet)	Peak Outflow no Dam Break (cfs)	Peak Outflow with Dam Break (cfs)
PMF	519.97	520.36	0.39	22,129	22,979
0.50 PMF	513.27	514.81	1.54	9,075	12,075
0.40 PMF	511.45	513.52	2.07	6,174	9,463

Results Based Upon Dam Failure at Spillway Where Dam Height = 18 Feet

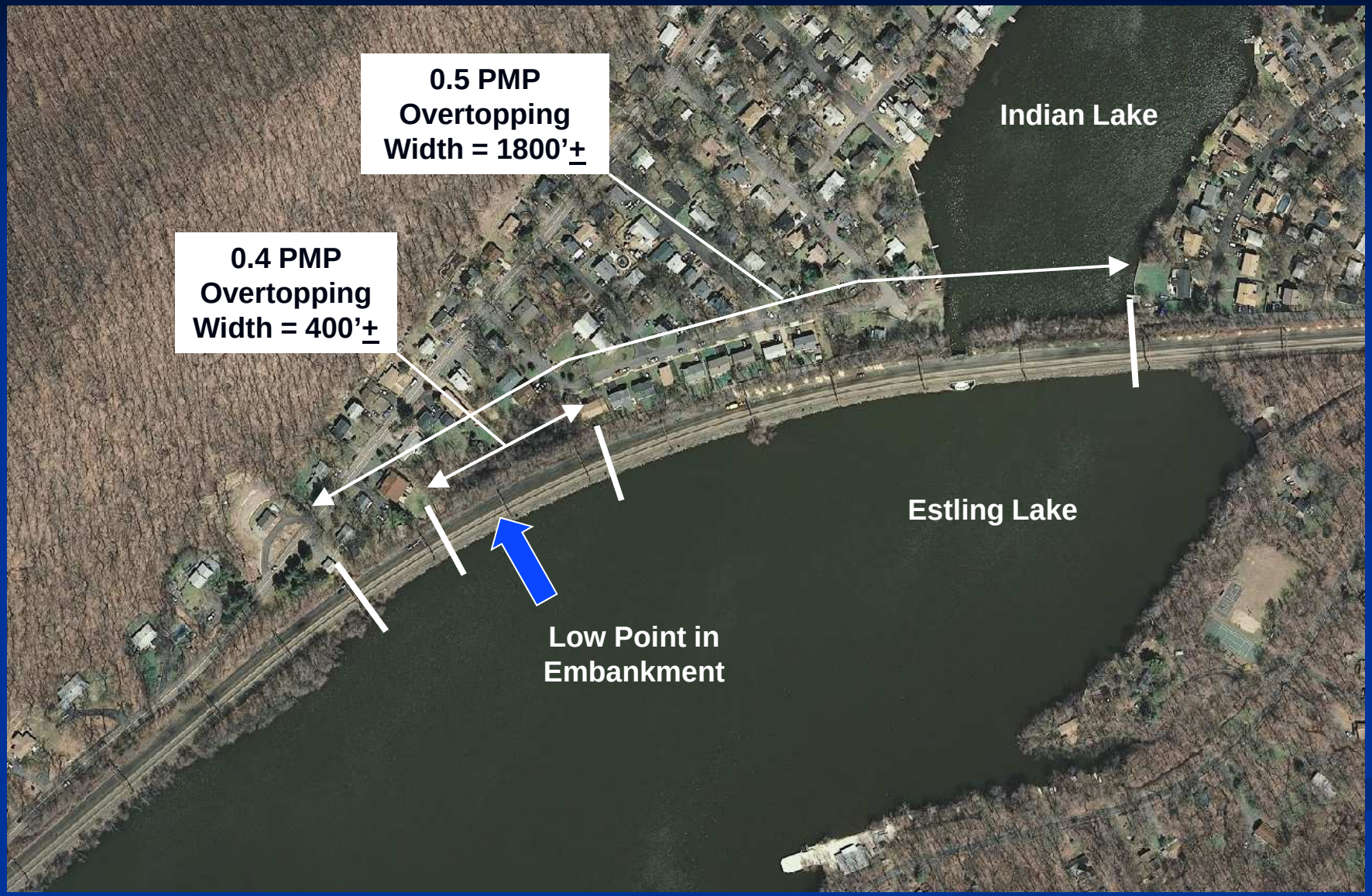
Previous Woidt Study Results

HEC-1 Dam Break Results @ Den Brook Dam with Dam Break near low point of tracks					
Storm Event	Max. Elevation no Dam Break	Max. Elevation with Dam Break	Incremental Increase in Elevation (feet)	Peak Outflow no Dam Break (cfs)	Peak Outflow with Dam Break (cfs)
0.50 PMF	513.27	513.64	0.37	9,036	9,720
0.40 PMF	511.45	512.11	0.66	6,174	7,154

As can be observed from the HEC-1 results, the incremental effect of a dam break is significantly less when the dam failure is located near the low point of the tracks away from the spillway location. This is due to the higher hydraulic head associated with a dam break at the spillway area adjacent to Indian Lake.

In summary, it is my opinion that a Spillway Design Flood (SDF) for Lake Estling Dam in the range of 0.40 to 0.50 of the PMF is appropriate. Furthermore a range of dam failure scenarios for the 0.50PMF event have been identified with the smallest incremental impact being associated with a failure near the low point (and greatest overtopping depth and duration) to the highest incremental failure being associated with a failure at the spillway location (with the greatest failure height). For the 0.40PMF storm event the peak stage does not reach the spillway area so the failure would be near the low point that has a consistent embankment height of about 6-7 feet throughout the overtopping area (Station 41+50 to 48+50).

Results Based Upon Dam Failure at Low Point Where Dam Height = 6 to 7 Feet


0.5 PMP
Overtopping
Width = 1800'±
0.4 PMP
Overtopping
Width = 400'±
Indian Lake
Estling Lake
Low Point in
Embankment

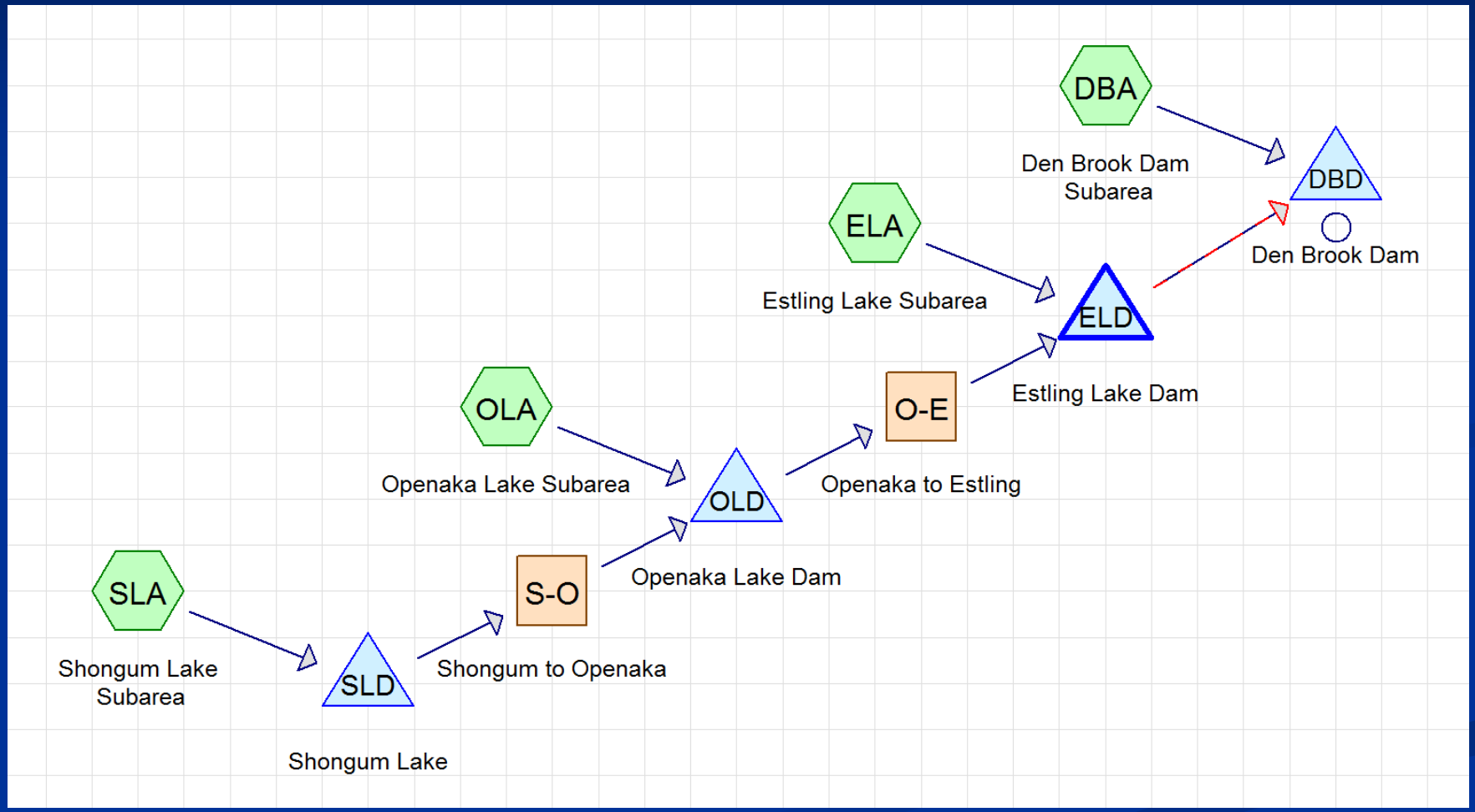
New HydroCAD and HEC-RAS Models

- Convert Woidt HEC-1 Models to HydroCAD to Recompute Immediate Downstream Dam Failure Effects. Use Same Watershed, Spillway, and Dam Failure Data.
- Develop New Stage-Discharge Relationship for Dam Overtopping to Determine Hydrographs from Dam through Downstream Area for Unsteady HEC-RAS.
- Develop Unsteady HEC-RAS Model of Downstream Area Using NJ Transit Field Surveys of Downstream Face of Dam and Morris County Topographic Mapping to Estimate Depths and Velocities Without and With Dam Failure at Low Point.
- Limited Field Surveys Performed to Obtain Preliminary Results. Additional Field Surveys to be Performed as Necessary.

New HydroCAD and HEC-RAS Models

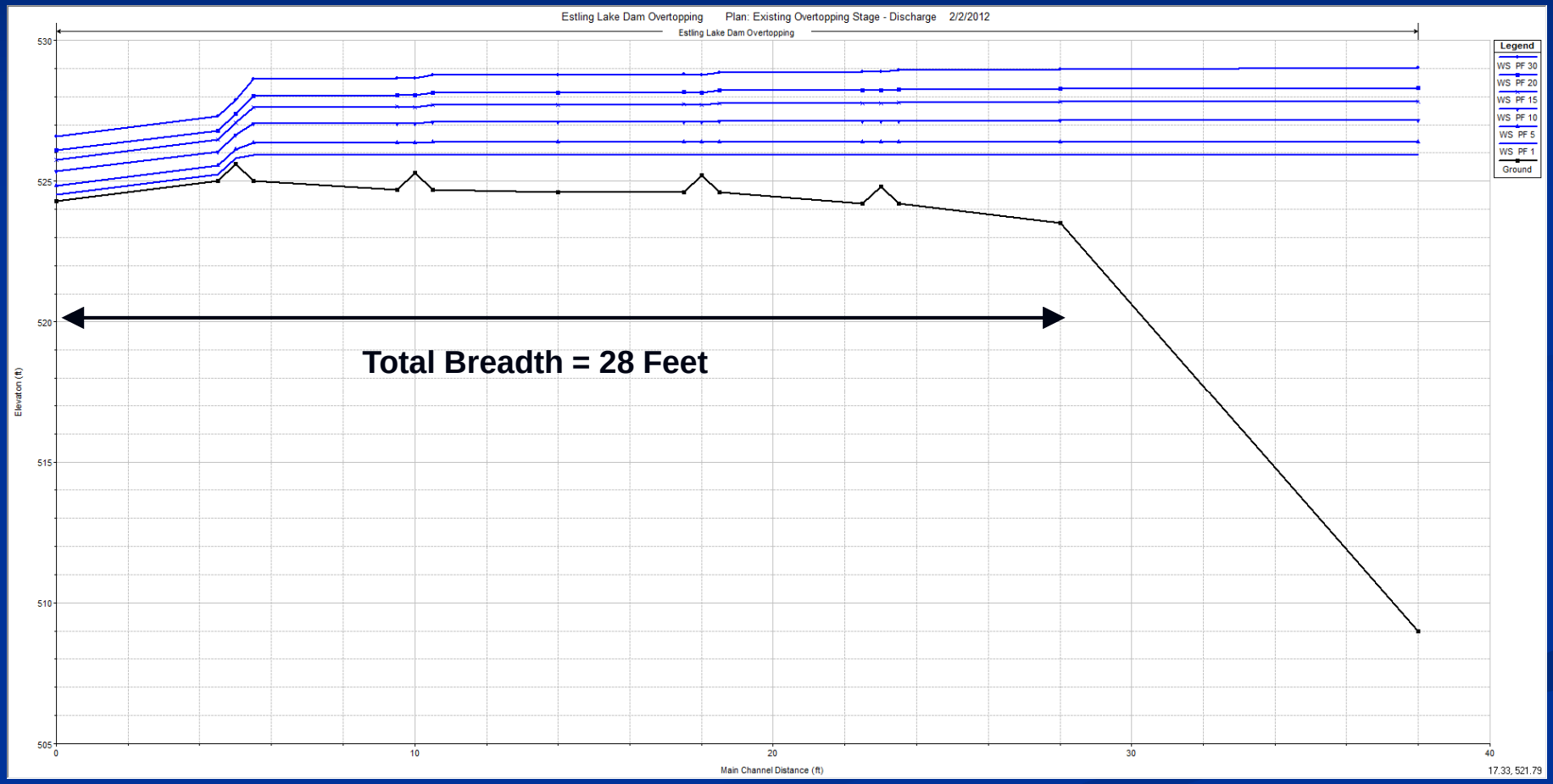
- **Important: In light of limited field survey data, geometric and hydraulic complexity, and need for BDS&FC approval, results of analysis summarized below are preliminary only.**

New HydroCAD Model

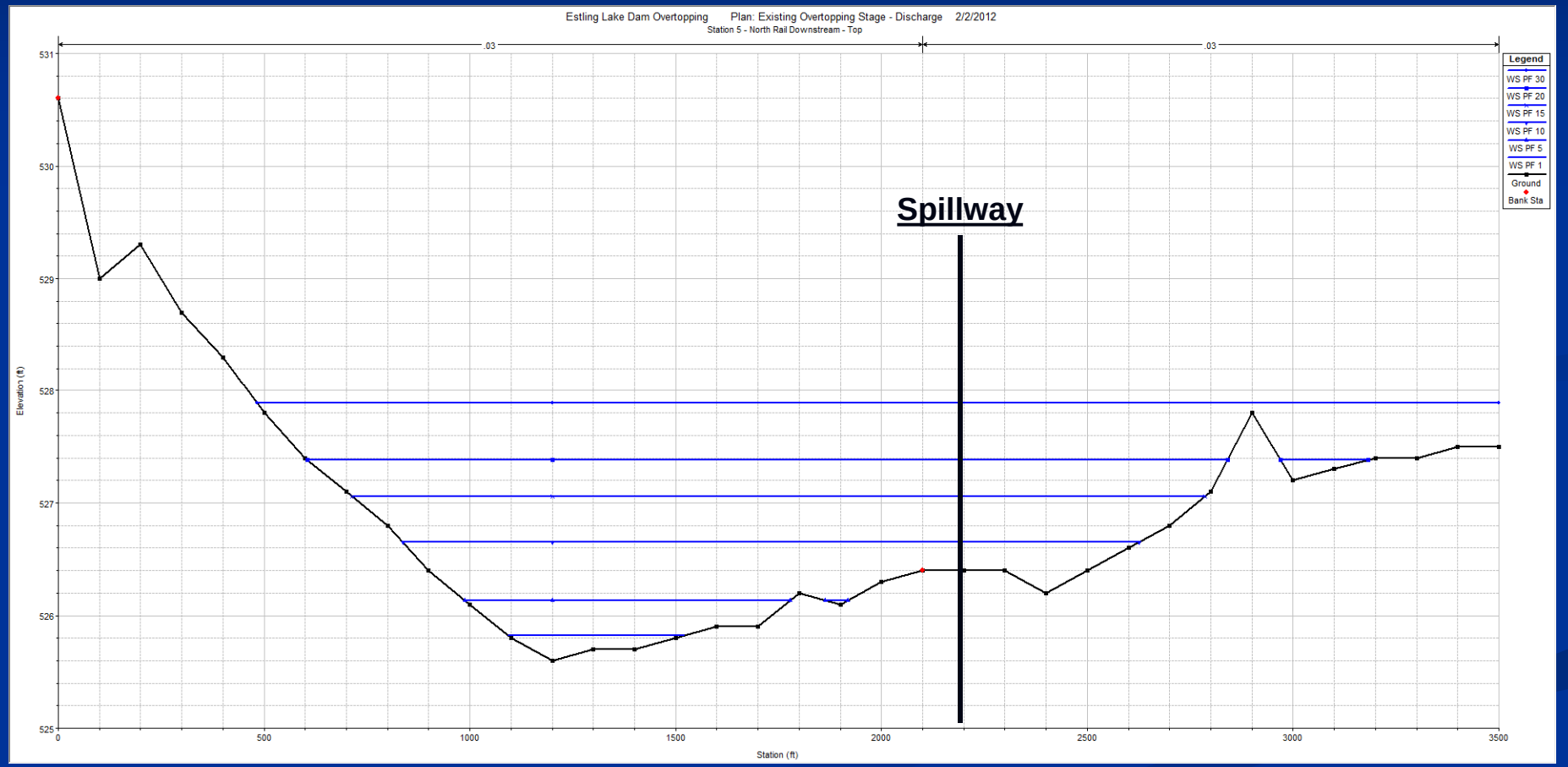


New Overtopping Stage-Discharge

Overtopping Profile



Overtopping Section at Station 5



New HydroCAD Model

Storm = 0.4 PMP						
	Peak Flow (CFS)		Peak Time (Hours)		Peak WS	
Location	HEC-1	HydroCAD	HEC-1	HydroCAD	HEC-1	HydroCAD
Shongum Area	8045	8233	39.75	39.71	-	-
Shongum In	8045	8233	39.75	39.71	-	-
Shongum Out	3634	3523	40.75	40.69	720.02	719.94
Shongum to Openaka	3626	3510	41.00	40.83	-	-
Openaka Area	3153	3334	39.50	39.46	-	-
Openaka In	4806	4656	40.00	39.64	-	-
Openaka Out	4826	4615	40.00	39.74	683.71	683.58
Openaka to Estling	4810	4365	40.50	40.70	-	-
Estling Area	6828	7139	39.75	39.53	-	-
Estling In	10060	10357	39.75	39.63	-	-
Estling Out	6291	5929	41.25		526.03	525.76
Den Brook In	6968	6550	41.00		-	-
Den Brook Out	6174	5920	42.00		511.45	511.26

New HydroCAD Model

Storm = 0.5 PMP						
	Peak Flow (CFS)		Peak Time (Hours)		Peak WS	
Location	HEC-1	HydroCAD	HEC-1	HydroCAD	HEC-1	HydroCAD
Shongum Area	10580	10818	39.75	39.70	-	-
Shongum In	10580	10818	39.75	39.70	-	-
Shongum Out	4780	4727	40.75	40.65	720.83	720.79
Shongum to Openaka	4767	4712	41.00	40.79	-	-
Openaka Area	4150	4375	39.50	39.45	-	-
Openaka In	6628	6459	39.75	39.66	-	-
Openaka Out	6626	6419	40.00	39.75	684.70	684.59
Openaka to Estling	6573	5960	40.25	40.41	-	-
Estling Area	8892	9317	39.75	39.52	-	-
Estling In	13506	13840	39.75	39.63	-	-
Estling Out	10834	10212	40.50		527.26	527.11
Den Brook In	12152	11575	40.50		-	-
Den Brook Out	9036	8581	41.25		513.27	513.00

New HydroCAD Model

New Jersey Transit - Estling Lake Dam Analysis

Comparison of Original HEC-1 and New HydroCAD Maximum Water Surface Increases at Den Brook Dam Due to Estling Lake Dam Failure

December 29, 2011

	WS Increase Due to Estling Lake Dam Failure	
Storm Event	Original HEC-1 Model	New HydroCAD Model
0.4 PMP	0.66	0.89
0.5 PMP	0.37	0.61
0.6 PMP	-	0.32
0.7 PMP	-	0.23
0.8 PMP	-	0.19
0.9 PMP	-	0.15
PMP	-	0.13

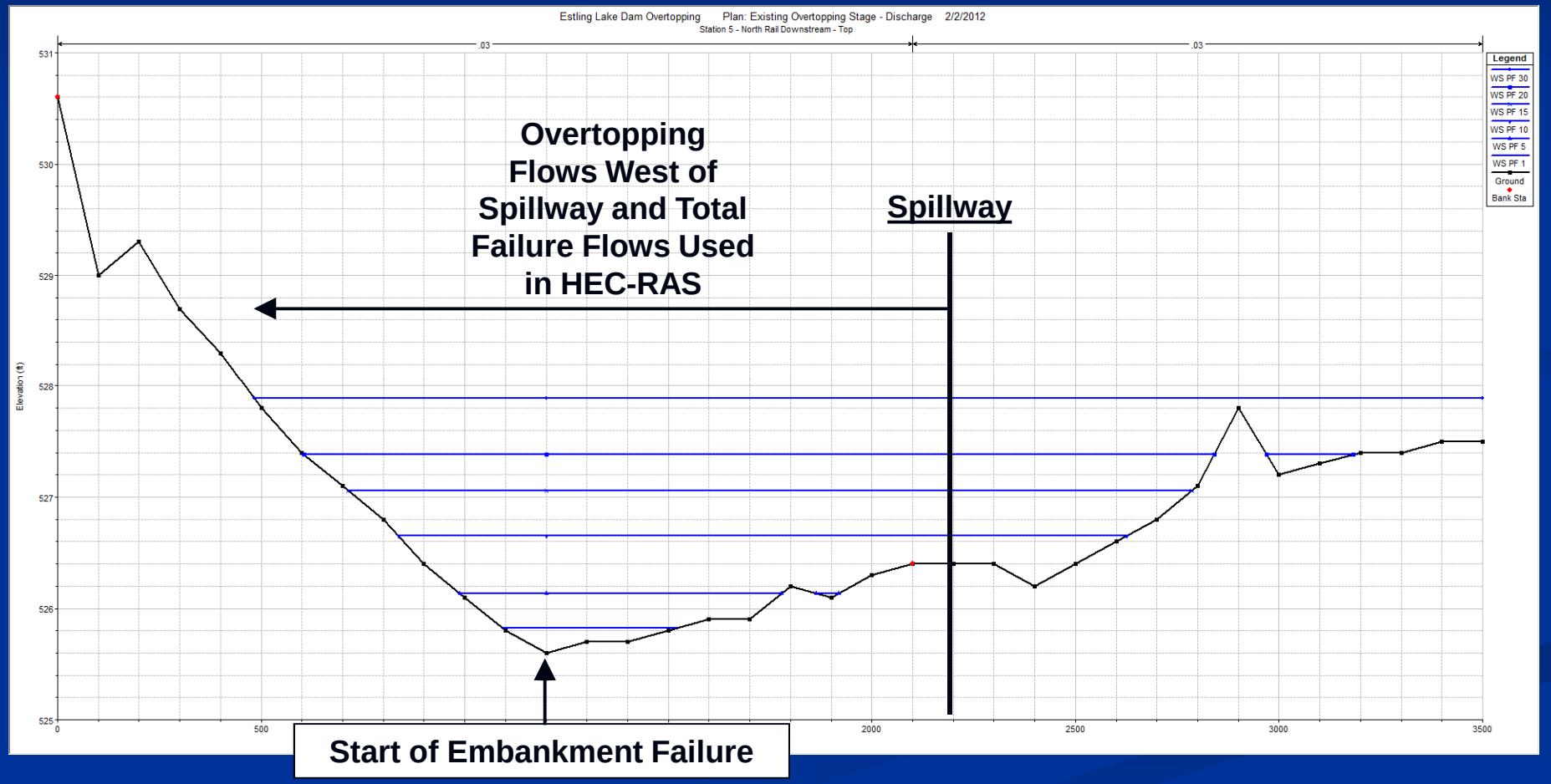
Results Based Upon Dam Failure at Low Point Where Dam Height = 6 to 7 Feet

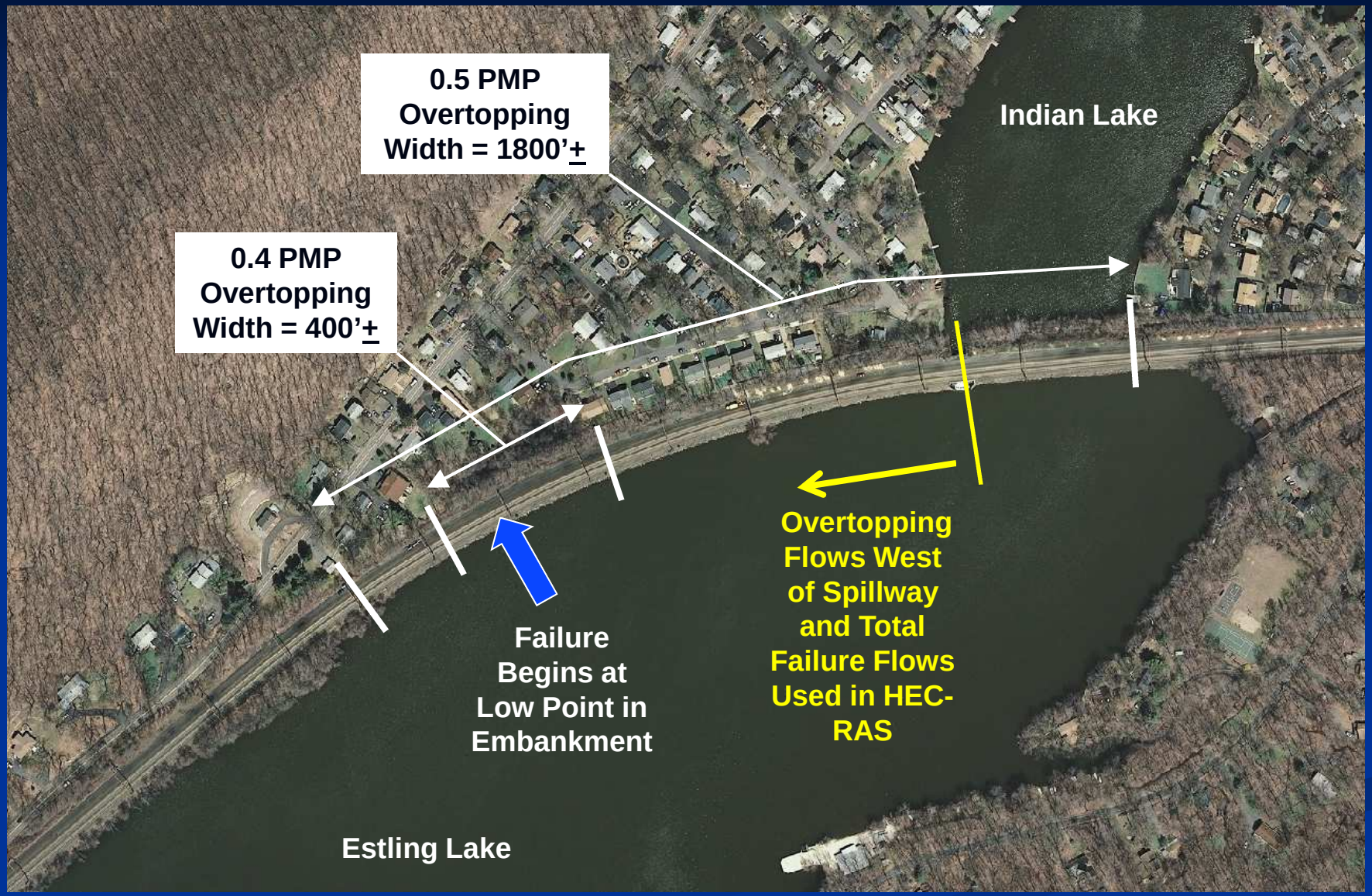

Estling Lake Dam Failure Analysis
Preliminary HEC-RAS Section Locations
Scale: 1" = 100'
October 11, 2011

Low Point in Dam

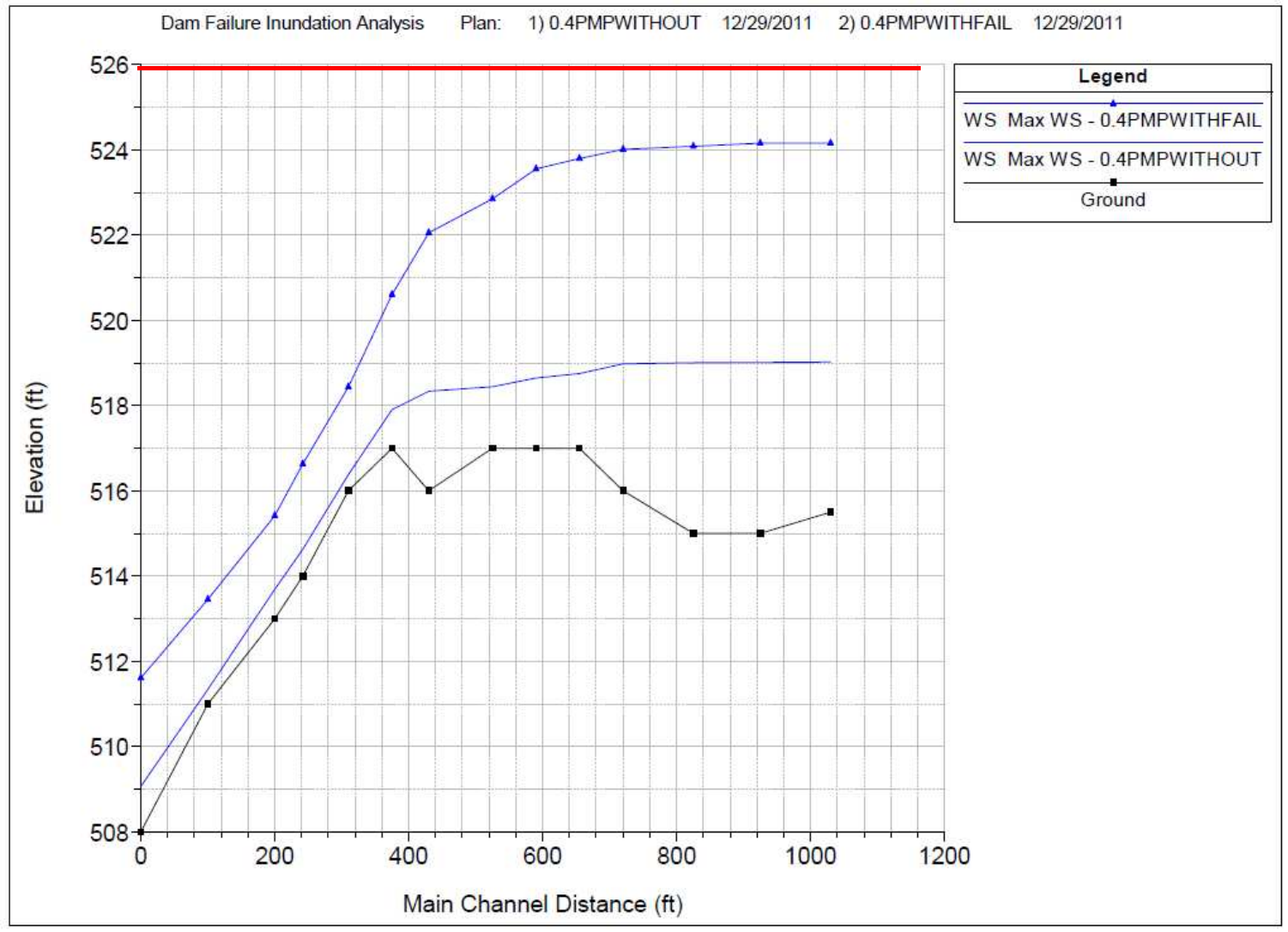
Downstream of Low Point in Dam

Overtopping Section at Station 5

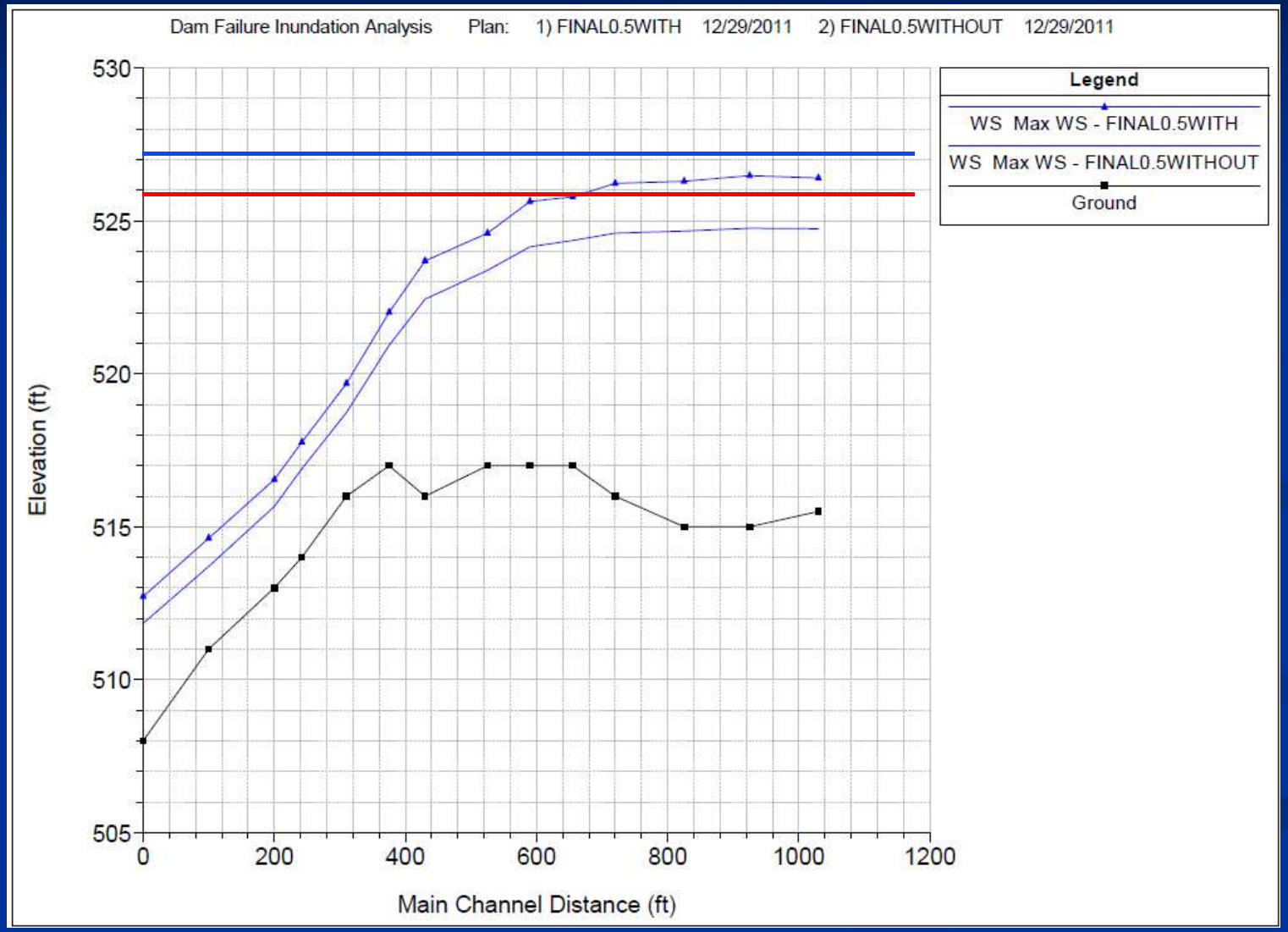



0.5 PMP
Overtopping
Width = 1800'±
0.4 PMP
Overtopping
Width = 400'±
Indian Lake
Overtopping
Flows West
of Spillway
and Total
Failure Flows
Used in HEC-
RAS
Failure
Begins at
Low Point in
Embankment
Estling Lake

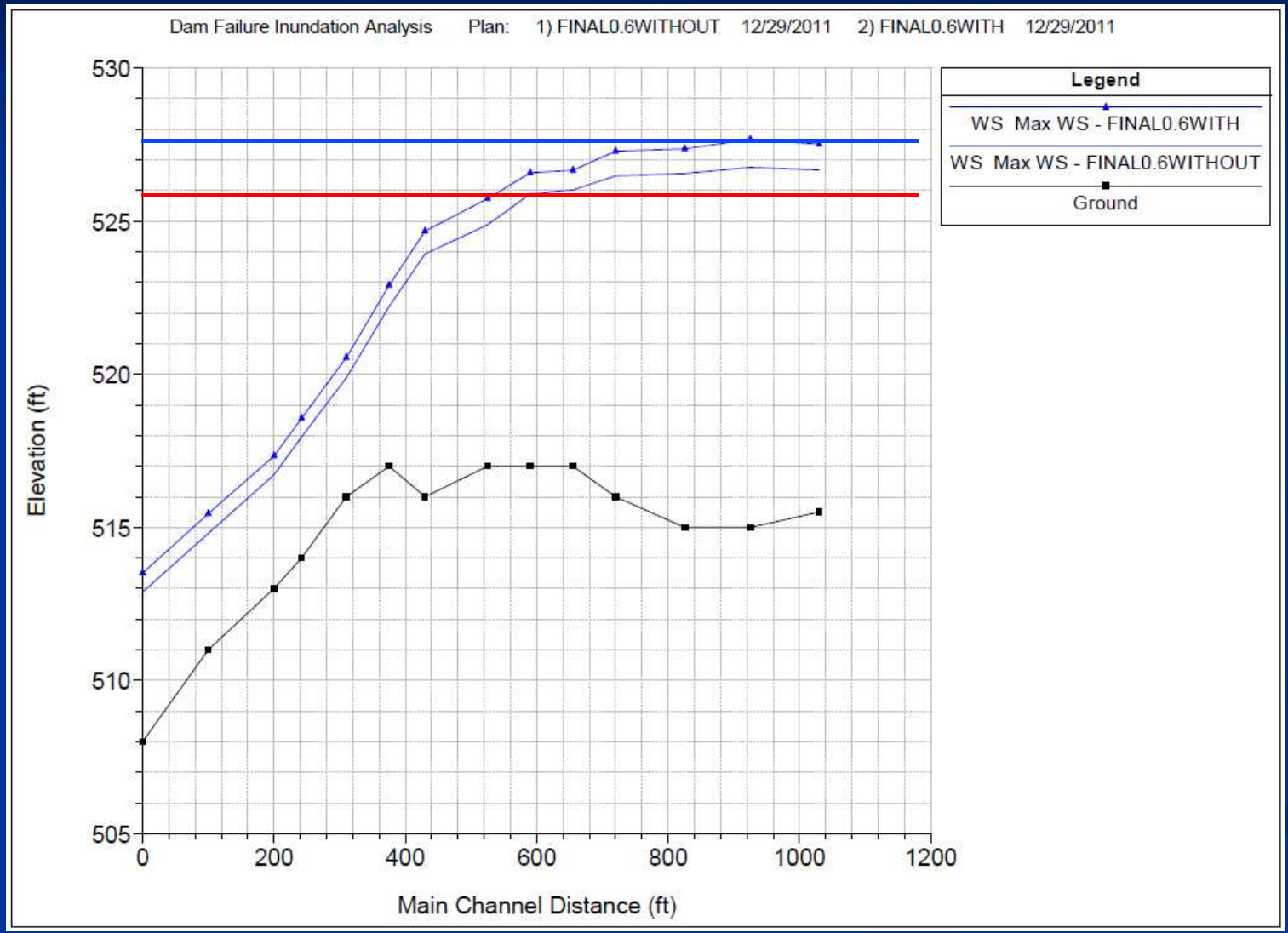
0.4 PMP HEC-RAS



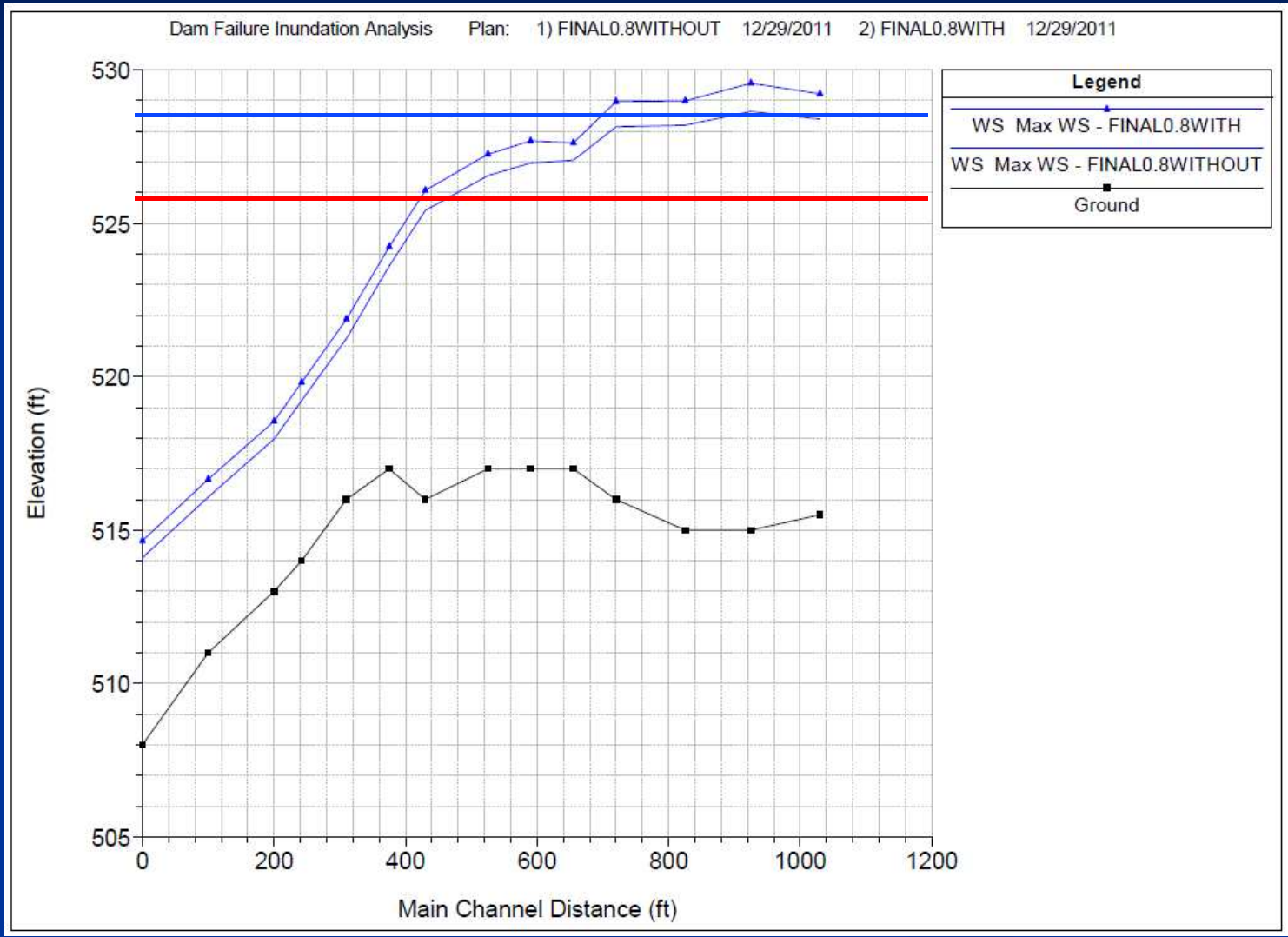
0.5 PMP HEC-RAS



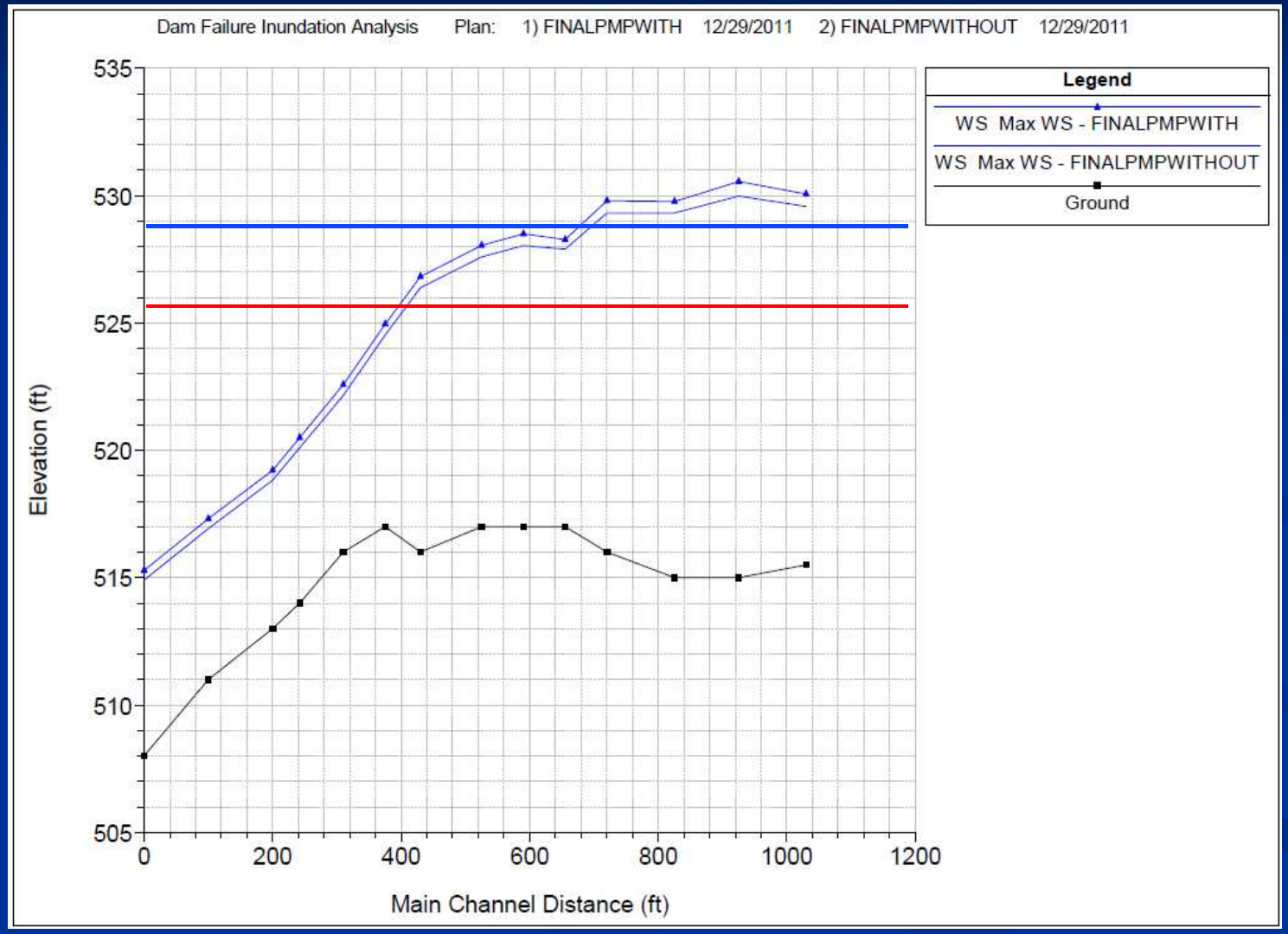
0.6 PMP HEC-RAS



0.8 PMP HEC-RAS



PMP HEC-RAS


Dam Failure Inundation Analysis Plan: 1) FINALPMPWITH 12/29/2011 2) FINALPMPWITHOUT 12/29/2011
Legend
WS Max WS - FINALPMPWITH
WS Max WS - FINALPMPWITHOUT
Ground
Elevation (ft)
535
530
525
520
515
510
505
0
200
400
600
800
1000
1200
Main Channel Distance (ft)

Maximum Water Surface Increases

Event	Dam Condition	WS	Difference (Feet)
0.4 PMP	Without Failure	518.3	
	With Failure	525.2	6.9
0.5 PMP	Without Failure	524.8	
	With Failure	526.5	1.7
0.6 PMP	Without Failure	526.8	
	With Failure	527.7	0.9
0.7 PMP	Without Failure	527.9	
	With Failure	528.8	0.9
0.8 PMP	Without Failure	528.7	
	With Failure	529.6	0.9
0.9 PMP	Without Failure	529.3	
	With Failure	530.6	1.2
PMP	Without Failure	530.0	
	With Failure	530.6	0.6

Summary

- Past Analyses and Meetings Indicated 0.4 - 0.5 PMP as Appropriate SDS at Downstream Lakes and Route 80
- New Hydro Watershed Model:
  - Developed to Allow More Detailed Analysis of Failures and Discharges
  - Used Same Watershed and Failure Data
  - Used New Overtopping Stage-Discharge
  - Results Reasonably Match Results from Previous HEC-1 Model

Summary

- **Preliminary Downstream Unsteady HEC-RAS Model:**
  - **Based upon Limited NJT Field Survey Data and Morris County Topo Mapping of Immediate Downstream Area**
  - **More Detailed Surveys and Modeling can be Performed**
  - **Results Indicate 0.4 - 0.5 PMP may be Appropriate SDS for Immediate Downstream Area**

Summary

- **Next Steps:**
  - **Determine if Additional Analysis Required**
  - **Obtain Additional Field Surveys as Necessary**
  - **Perform Additional Analyses as Necessary**
  - **Complete EAP Mapping for Selected SDS**
  - **Discuss Embankment Protection Options**
  - **Investigate Potential for Embankment Failure via Overtopping Erosion?**

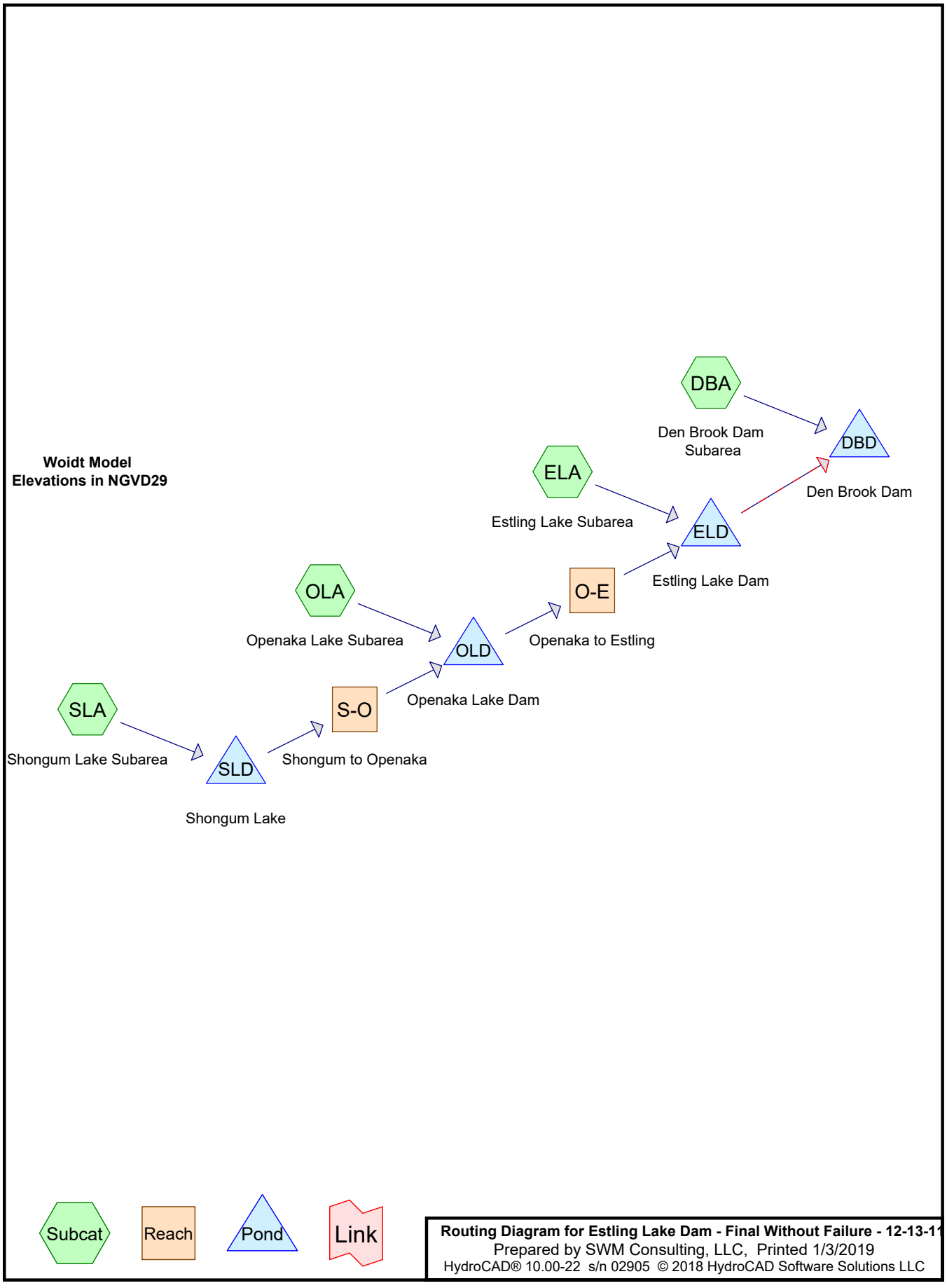
Estimated Overtoppings

Storm Event	Maximum Depth at Section 5 (Feet)	Duration (Hours)	Maximum Top Width (Feet)
0.4 PMP	0.2	1.2	300
0.5 PMP	1.1	3.2	1800
0.6 PMP	1.5	4.0	2100
0.8 PMP	2.0	5.3	2800+
PMP	2.3	6.4	3100+

Joseph J. Skupien, PE, PP
President
Storm Water Management Consulting, LLC
1108 Old York Road
P.O. Box 727
Ringoes, New Jersey 08551

Phone: 908-806-7700
Fax: 908-806-7721
joeskupien@swmconsulting.com

Previous 2014 Analysis HydroCAD Model Without Dam Failure



Routing Diagram for Estling Lake Dam - Final Without Failure - 12-13-11
Prepared by SWM Consulting, LLC, Printed 1/3/2019

Summary for Subcatchment DBA: Den Brook Dam Subarea

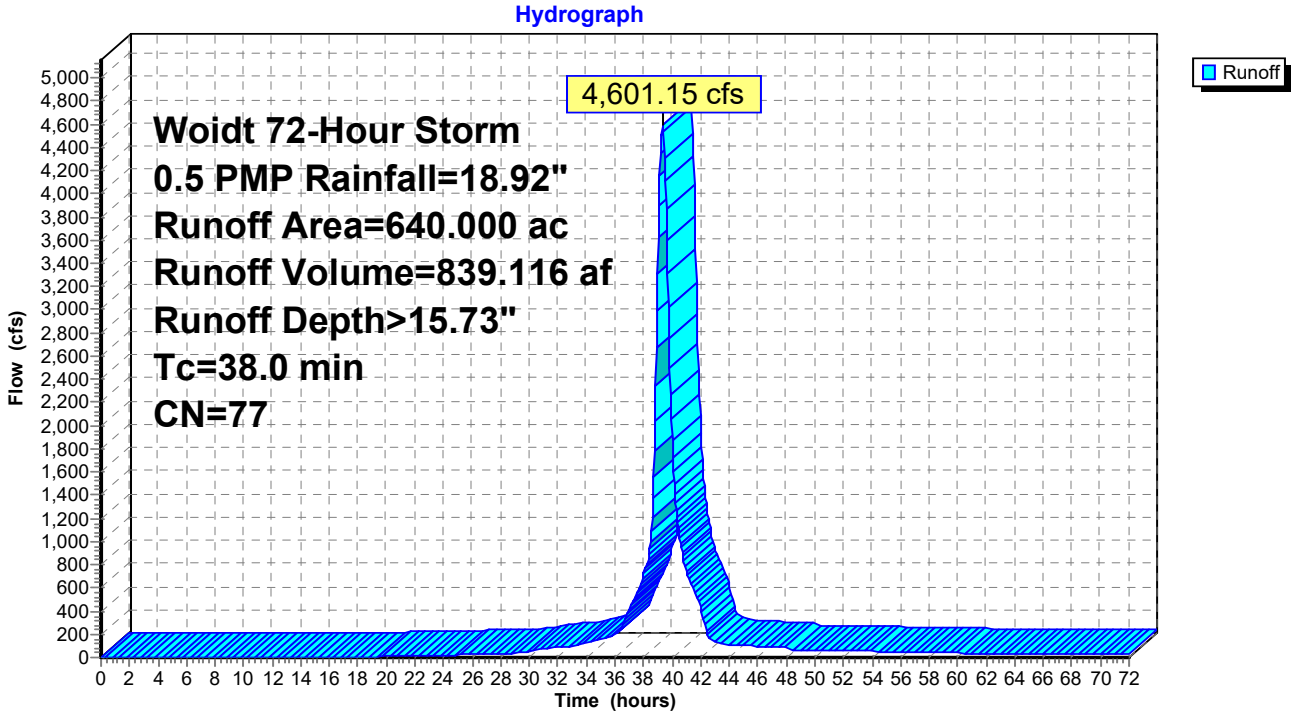
Runoff = 4,601.15 cfs @ 39.34 hrs, Volume= 839.116 af, Depth>15.73"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	640.000	77	See Woidt HEC-1
	640.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.0					**Direct Entry, See Woidt HEC-1**

Subcatchment DBA: Den Brook Dam Subarea



Summary for Subcatchment ELA: Estling Lake Subarea

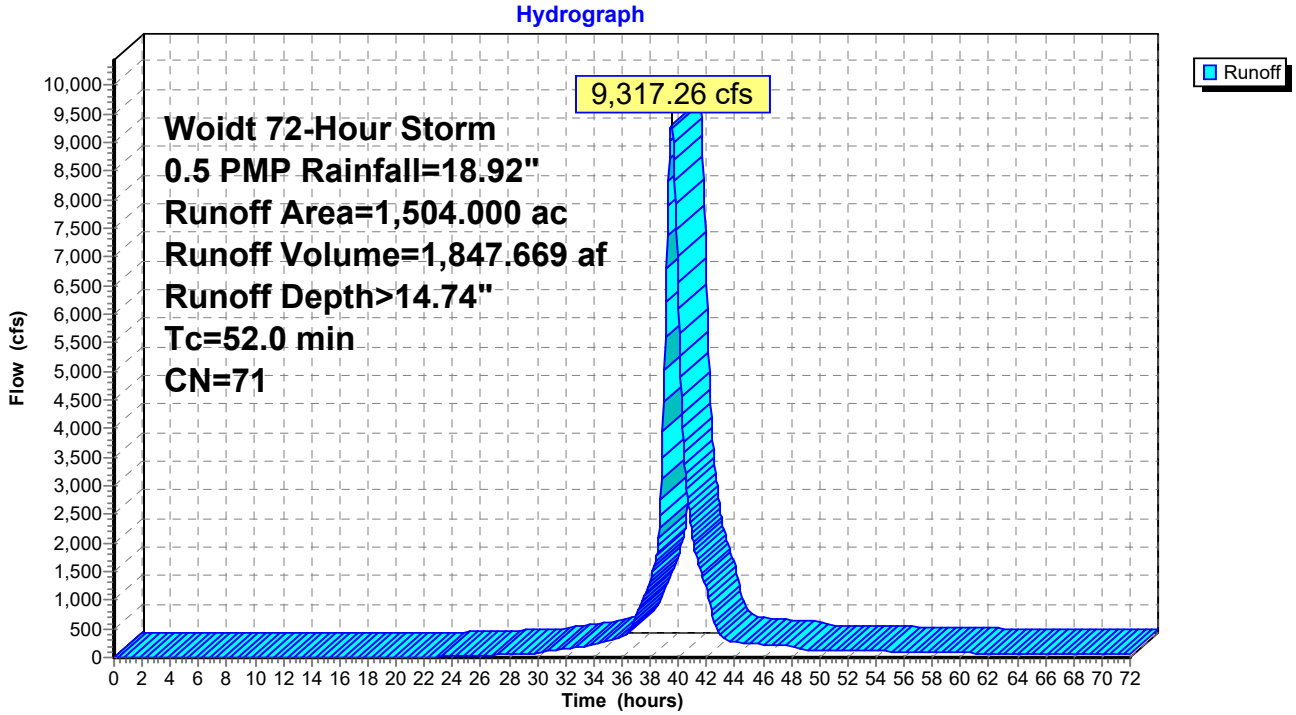
Runoff = 9,317.26 cfs @ 39.52 hrs, Volume= 1,847.669 af, Depth>14.74"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,504.000	71	See Woidt HEC-1
	1,504.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
52.0					**Direct Entry, See Woidt HEC-1**

Subcatchment ELA: Estling Lake Subarea



Summary for Subcatchment OLA: Openaka Lake Subarea

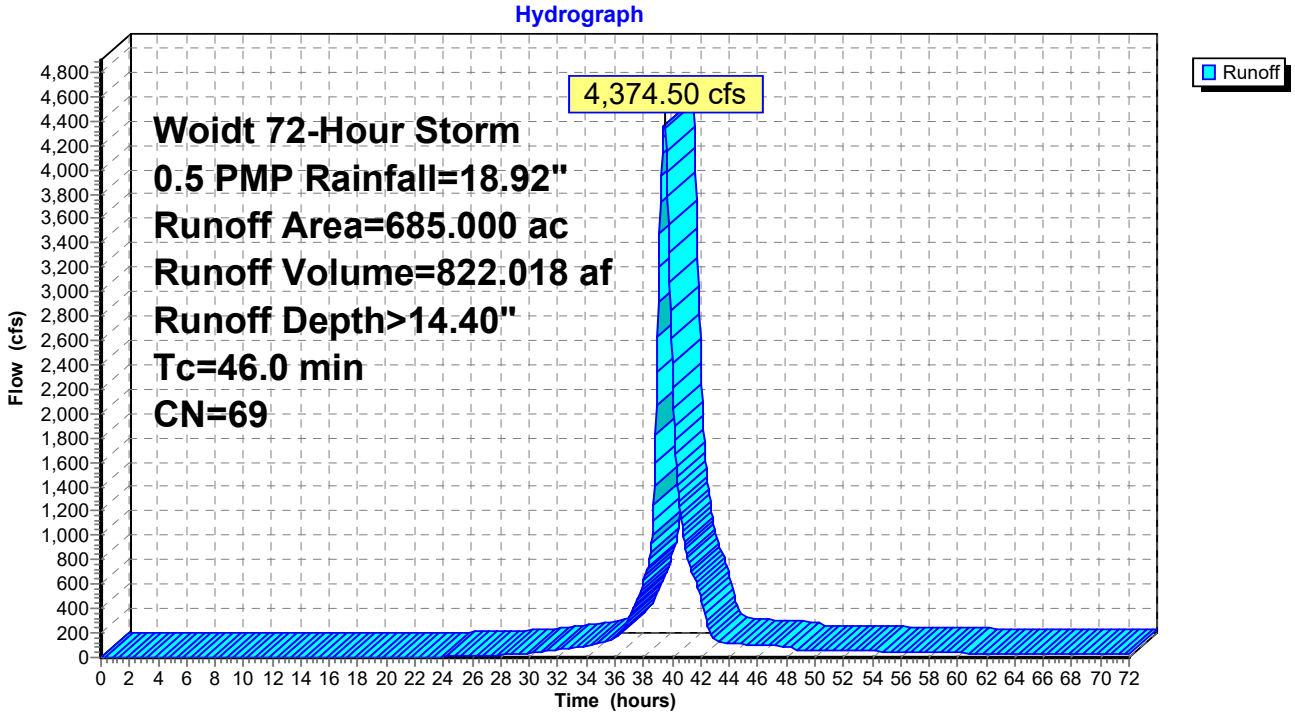
Runoff = 4,374.50 cfs @ 39.45 hrs, Volume= 822.018 af, Depth>14.40"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	685.000	69	See Woidt HEC-1
	685.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
46.0					**Direct Entry, See Woidt HEC-1**

Subcatchment OLA: Openaka Lake Subarea



Summary for Subcatchment SLA: Shongum Lake Subarea

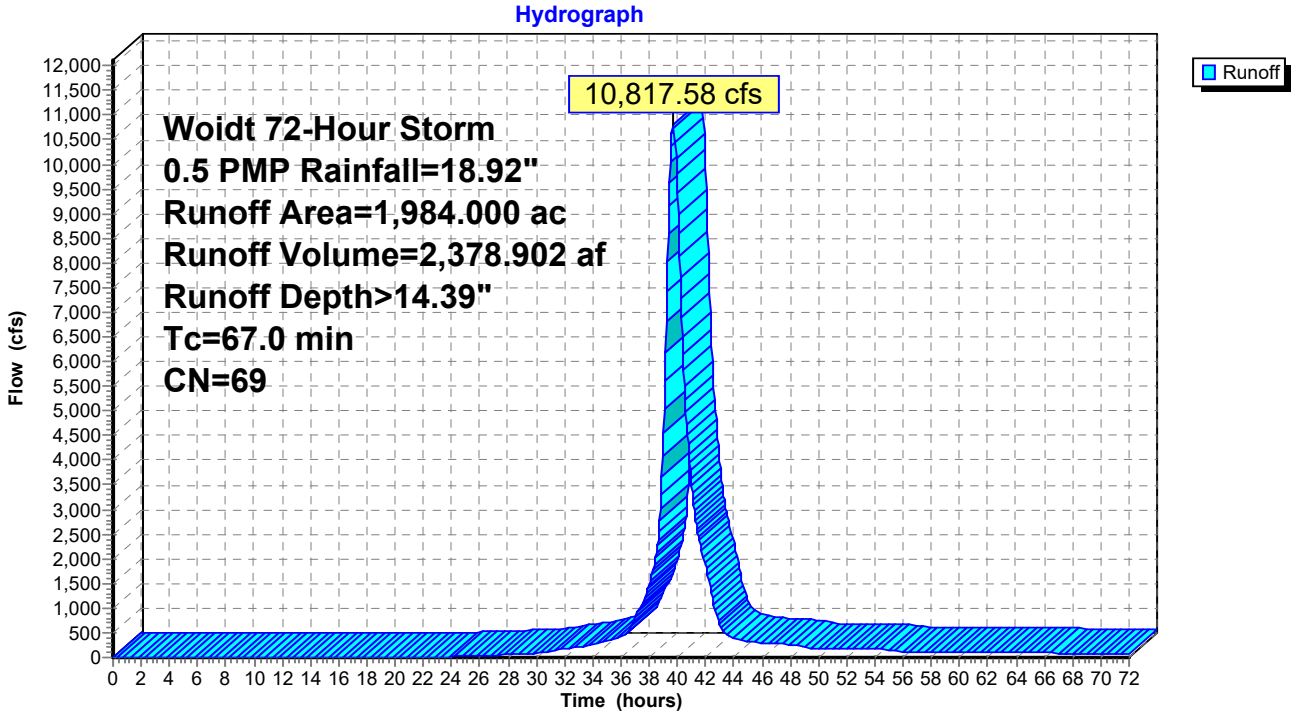
Runoff = 10,817.58 cfs @ 39.70 hrs, Volume= 2,378.902 af, Depth>14.39"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,984.000	69	See Woidt HEC-1
	1,984.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
67.0					**Direct Entry, See Woidt HEC-1**

Subcatchment SLA: Shongum Lake Subarea



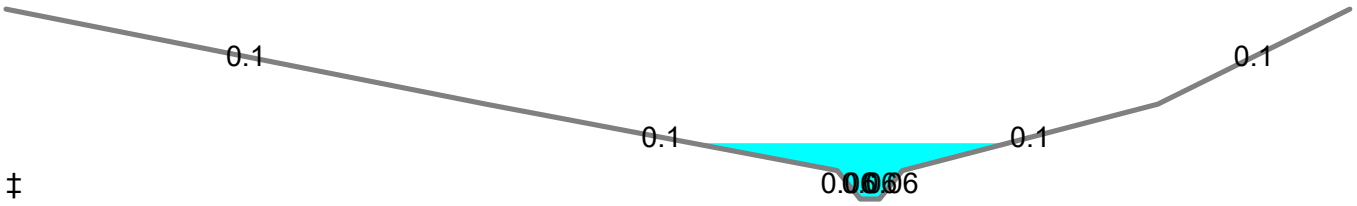
Summary for Reach O-E: Openaka to Estling

Inflow Area = 2,669.000 ac, 0.00% Impervious, Inflow Depth > 14.07" for 0.5 PMP event
Inflow = 6,418.79 cfs @ 39.75 hrs, Volume= 3,129.201 af
Outflow = 5,959.50 cfs @ 40.41 hrs, Volume= 3,122.024 af, Atten= 7%, Lag= 39.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.67 fps, Min. Travel Time= 21.0 min
Avg. Velocity = 5.24 fps, Avg. Travel Time= 34.7 min

Peak Storage= 7,651,510 cf @ 40.41 hrs
Average Depth at Peak Storage= 11.76'
Bank-Full Depth= 40.00' Flow Area= 13,320.0 sf, Capacity= 219,014.09 cfs

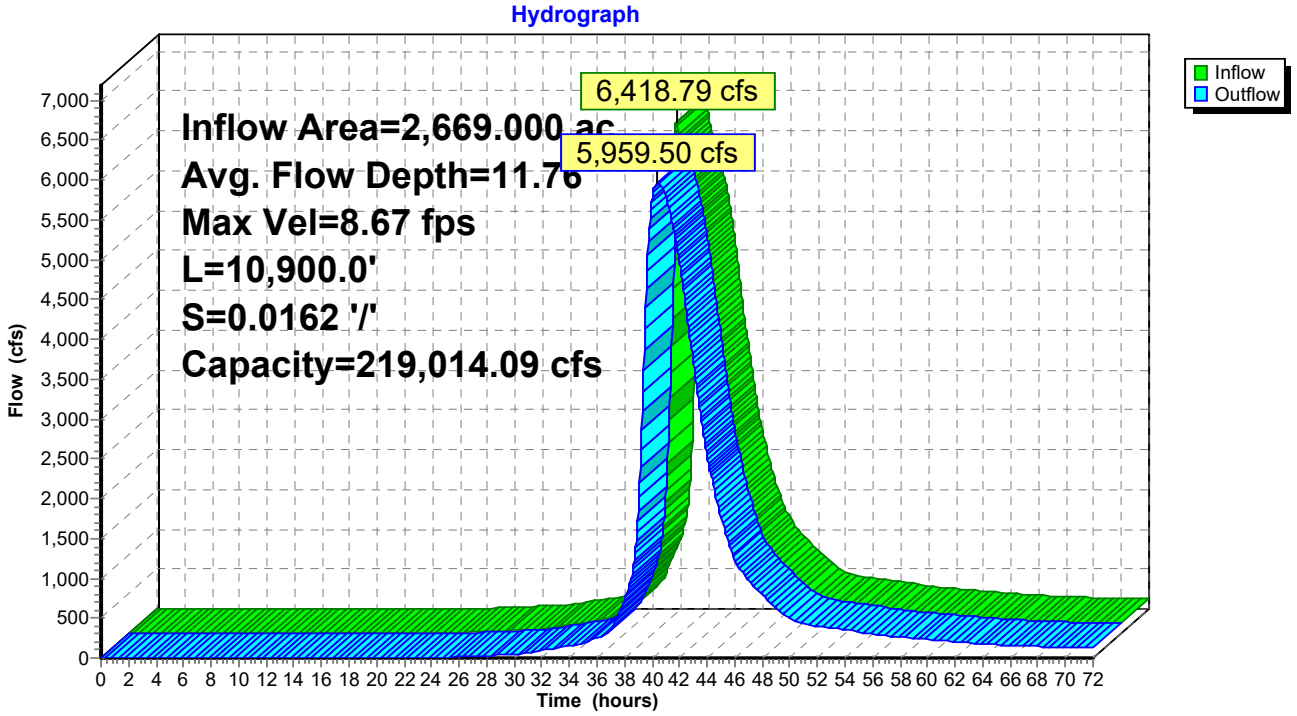
Custom cross-section, Length= 10,900.0' Slope= 0.0162 '/'
Flow calculated by Segment Subdivision method
Inlet Invert= 640.00', Outlet Invert= 463.42'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
550.00	680.00	0.00		
800.00	660.00	20.00	0.100	
983.00	646.00	34.00	0.100	
995.00	640.00	40.00	0.060	
1,005.00	640.00	40.00	0.060	
1,017.00	646.00	34.00	0.060	
1,150.00	660.00	20.00	0.100	
1,250.00	680.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
6.00	132.0	36.8	1,438,800	1,062.78
20.00	2,820.0	354.1	30,738,000	27,807.57
40.00	13,320.0	706.9	145,188,000	219,014.09

Reach O-E: Openaka to Estling



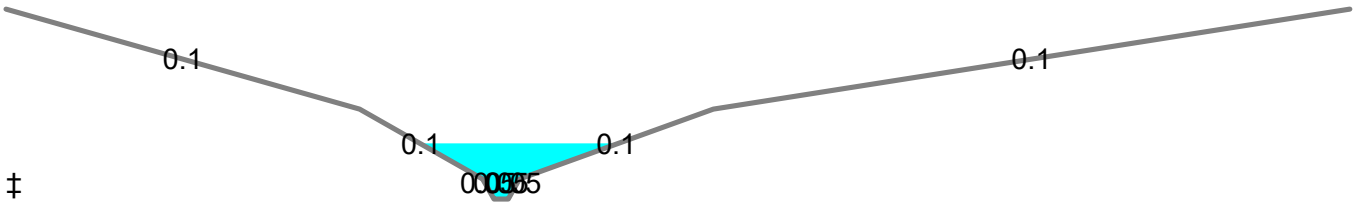
Summary for Reach S-O: Shongum to Openaka

Inflow Area = 1,984.000 ac, 0.00% Impervious, Inflow Depth > 13.99" for 0.5 PMP event
Inflow = 4,727.02 cfs @ 40.65 hrs, Volume= 2,312.327 af
Outflow = 4,711.89 cfs @ 40.79 hrs, Volume= 2,310.443 af, Atten= 0%, Lag= 7.9 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 7.10 fps, Min. Travel Time= 7.5 min
Avg. Velocity = 4.44 fps, Avg. Travel Time= 12.0 min

Peak Storage= 2,123,522 cf @ 40.79 hrs
Average Depth at Peak Storage= 11.12'
Bank-Full Depth= 38.00' Flow Area= 14,004.0 sf, Capacity= 155,556.64 cfs

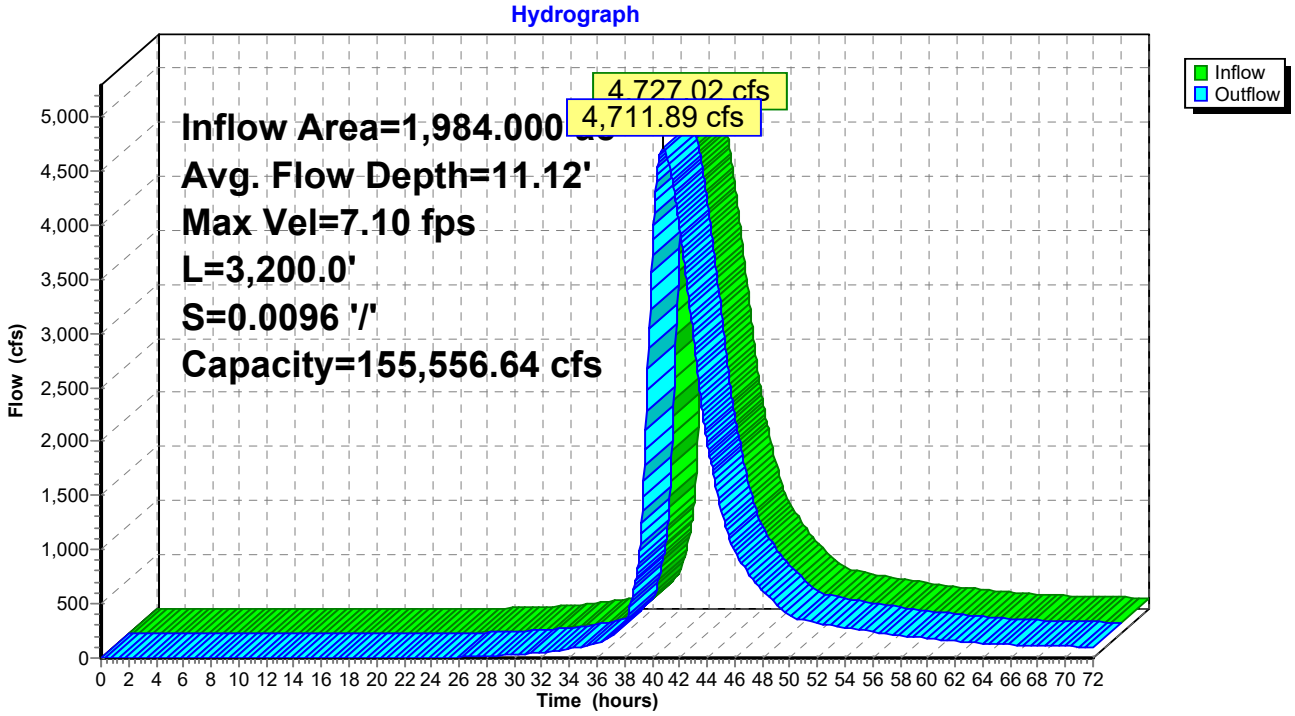
Custom cross-section, Length= 3,200.0' Slope= 0.0096 '/' (102 Elevation Intervals)
Flow calculated by Segment Subdivision method
Inlet Invert= 702.00', Outlet Invert= 671.28'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
650.00	740.00	0.00		
900.00	720.00	20.00	0.100	
987.00	706.00	34.00	0.100	
995.00	702.00	38.00	0.050	
1,005.00	702.00	38.00	0.050	
1,013.00	706.00	34.00	0.050	
1,150.00	720.00	20.00	0.100	
1,600.00	740.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
4.00	72.0	27.9	230,400	430.82
18.00	2,004.0	253.7	6,412,800	16,303.00
38.00	14,004.0	955.0	44,812,800	155,556.64

Reach S-O: Shongum to Openaka



Summary for Pond DBD: Den Brook Dam

Inflow Area = 4,813.000 ac, 0.00% Impervious, Inflow Depth > 14.20" for 0.5 PMP event
Inflow = 11,574.69 cfs @ 40.20 hrs, Volume= 5,695.597 af
Outflow = 8,581.06 cfs @ 41.27 hrs, Volume= 5,687.643 af, Atten= 26%, Lag= 64.1 min
Primary = 8,581.06 cfs @ 41.27 hrs, Volume= 5,687.643 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 502.50' Surf.Area= 4.640 ac Storage= 8.120 af
Peak Elev= 513.00' @ 41.27 hrs Surf.Area= 168.271 ac Storage= 673.956 af (665.836 af above start)

Plug-Flow detention time= 44.5 min calculated for 5,675.582 af (100% of inflow)
Center-of-Mass det. time= 37.5 min (2,704.3 - 2,666.8)

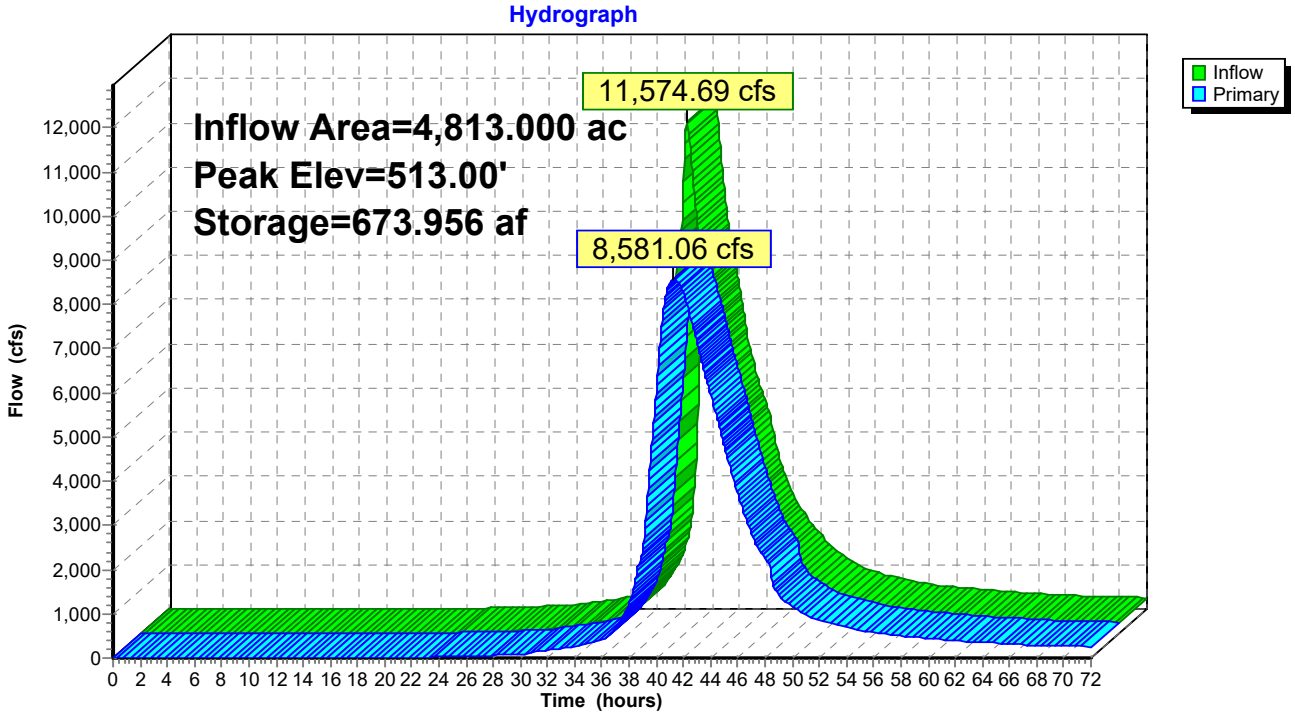
Volume	Invert	Avail.Storage	Storage Description
#1	499.00'	2,888.123 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
499.00	0.000	0.000	0.000
502.50	4.640	8.120	8.120
507.90	8.500	35.478	43.598
508.00	82.000	4.525	48.123
520.00	289.000	2,226.000	2,274.123
522.00	325.000	614.000	2,888.123

Device	Routing	Invert	Outlet Devices
#1	Primary	502.50'	**See Woidt HEC-1 - Half Flows - Extrapolated X 2.00** Elev. (feet) 502.50 503.50 504.50 505.50 506.50 507.50 508.50 509.50 510.50 511.50 512.50 513.50 514.50 515.50 516.50 517.50 518.50 Disch. (cfs) 0.000 64.000 182.500 371.000 592.000 855.500 1,254.000 1,828.500 2,440.500 3,124.500 3,872.500 4,706.500 5,766.500 6,649.000 7,575.000 8,513.000 9,506.500

Primary OutFlow Max=8,580.50 cfs @ 41.27 hrs HW=513.00' (Free Discharge)
↑**1=See Woidt HEC-1 - Half Flows - Extrapolated** (Custom Controls 8,580.50 cfs)

Pond DBD: Den Brook Dam



Summary for Pond ELD: Estling Lake Dam

[62] Hint: Exceeded Reach O-E OUTLET depth by 52.11' @ 43.45 hrs

Inflow Area = 4,173.000 ac, 0.00% Impervious, Inflow Depth > 14.29" for 0.5 PMP event
Inflow = 13,839.60 cfs @ 39.63 hrs, Volume= 4,969.693 af
Outflow = 10,211.73 cfs @ 40.25 hrs, Volume= 4,856.481 af, Atten= 26%, Lag= 37.3 min
Primary = 6,444.10 cfs @ 40.25 hrs, Volume= 4,450.221 af
Secondary = 3,767.63 cfs @ 40.25 hrs, Volume= 406.260 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 514.70' Surf.Area= 58.683 ac Storage= 196.587 af
Peak Elev= 527.11' @ 40.25 hrs Surf.Area= 104.664 ac Storage= 1,273.625 af (1,077.038 af above start)

Plug-Flow detention time= 223.6 min calculated for 4,659.894 af (94% of inflow)
Center-of-Mass det. time= 117.5 min (2,705.6 - 2,588.1)

Volume	Invert	Avail.Storage	Storage Description
#1	508.00'	2,848.110 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
508.00	0.000	0.000	0.000
516.70	76.200	331.470	331.470
520.00	85.400	266.640	598.110
540.00	139.600	2,250.000	2,848.110

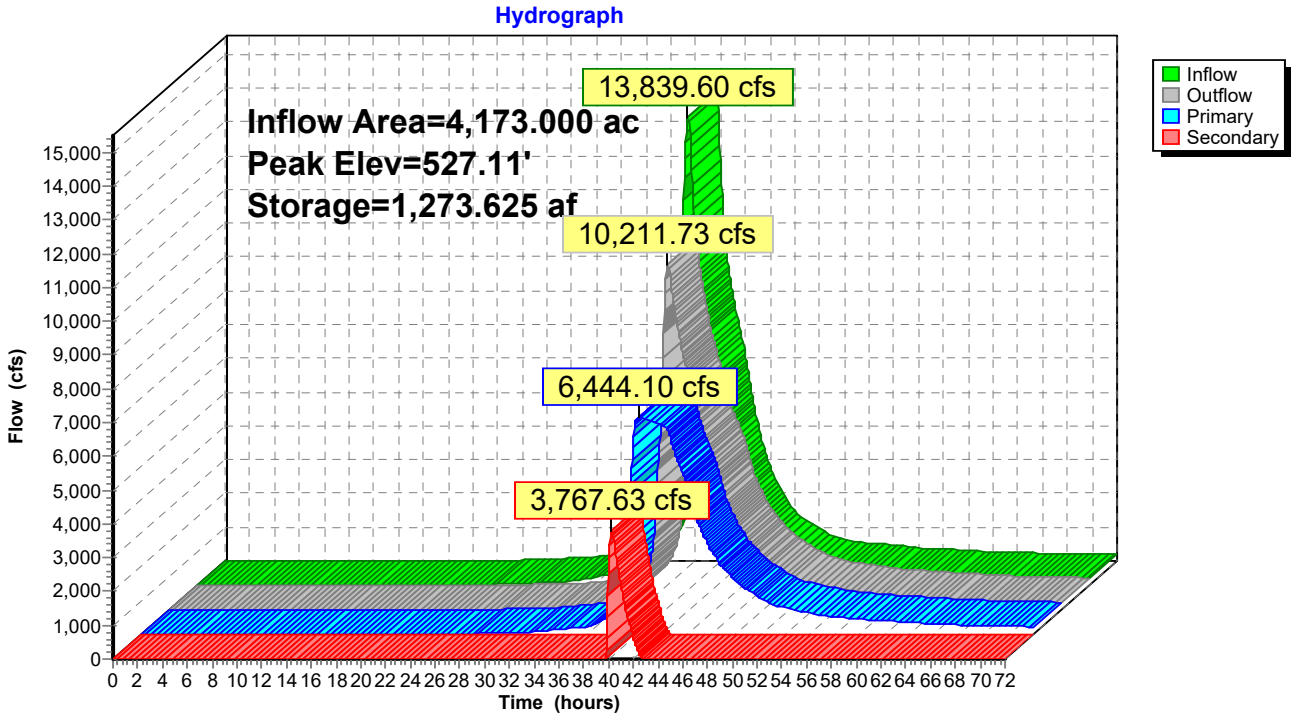
Device	Routing	Invert	Outlet Devices
#1	Primary	514.70'	**Woidt Culvert Flows** Elev. (feet) 514.70 516.70 517.70 518.70 519.70 520.70 521.70 522.70 523.70 525.00 526.00 526.50 527.00 527.50 528.00 528.50 529.00 Disch. (cfs) 0.000 267.000 511.000 883.000 1,350.000 1,886.000 2,530.000 3,240.000 4,299.000 5,100.000 6,118.000 6,247.000 6,375.000 6,694.000 7,013.000 7,268.000 7,523.000
#2	Secondary	525.60'	**Western Overtopping from HEC-RAS - Half Flows X 2.00** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 50.000 100.000 200.000 300.000 400.000 500.000 747.000 986.000 1,423.000 1,840.000 2,245.000 2,637.000 3,021.000 3,401.000 3,773.000 4,142.000 4,503.000 4,858.000 5,212.000 5,553.000 5,892.000 6,227.000 6,562.000 6,856.000 7,185.000 7,525.000 7,857.000 8,347.000 8,655.000 8,962.000
#3	Secondary	525.60'	**Eastern Embankment Overtopping from HEC-RAS** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02

Disch. (cfs) 0.000 0.000 0.000 0.000 0.000 0.000 0.000 6.000
28.000 154.000 319.000 511.000 726.000 958.000 1,197.000
1,453.000 1,717.000 1,993.000 2,284.000 2,577.000 2,894.000
3,216.000 3,545.000 3,876.000 4,289.000 4,631.000 4,950.000
5,286.000 5,307.000 5,690.000 6,076.000

Primary OutFlow Max=6,443.86 cfs @ 40.25 hrs HW=527.11' TW=512.01' (Dynamic Tailwater)
└─**1=Woidt Culvert Flows** (Custom Controls 6,443.86 cfs)

Secondary OutFlow Max=3,765.48 cfs @ 40.25 hrs HW=527.11' TW=512.01' (Dynamic Tailwater)
└─**2=Western Overtopping from HEC-RAS - Half Flows**(Custom Controls 3,485.05 cfs)
└─**3=Eastern Embankment Overtopping from HEC-RAS**(Custom Controls 280.43 cfs)

Pond ELD: Estling Lake Dam



Summary for Pond OLD: Openaka Lake Dam

[62] Hint: Exceeded Reach S-O OUTLET depth by 6.73' @ 20.95 hrs

Inflow Area = 2,669.000 ac, 0.00% Impervious, Inflow Depth > 14.08" for 0.5 PMP event
Inflow = 6,459.24 cfs @ 39.66 hrs, Volume= 3,132.461 af
Outflow = 6,418.79 cfs @ 39.75 hrs, Volume= 3,129.201 af, Atten= 1%, Lag= 5.4 min
Primary = 6,418.79 cfs @ 39.75 hrs, Volume= 3,129.201 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 678.00' Surf.Area= 2.300 ac Storage= 15.640 af
Peak Elev= 684.59' @ 39.75 hrs Surf.Area= 12.397 ac Storage= 75.084 af (59.444 af above start)

Plug-Flow detention time= 24.1 min calculated for 3,113.561 af (99% of inflow)
Center-of-Mass det. time= 8.7 min (2,635.5 - 2,626.8)

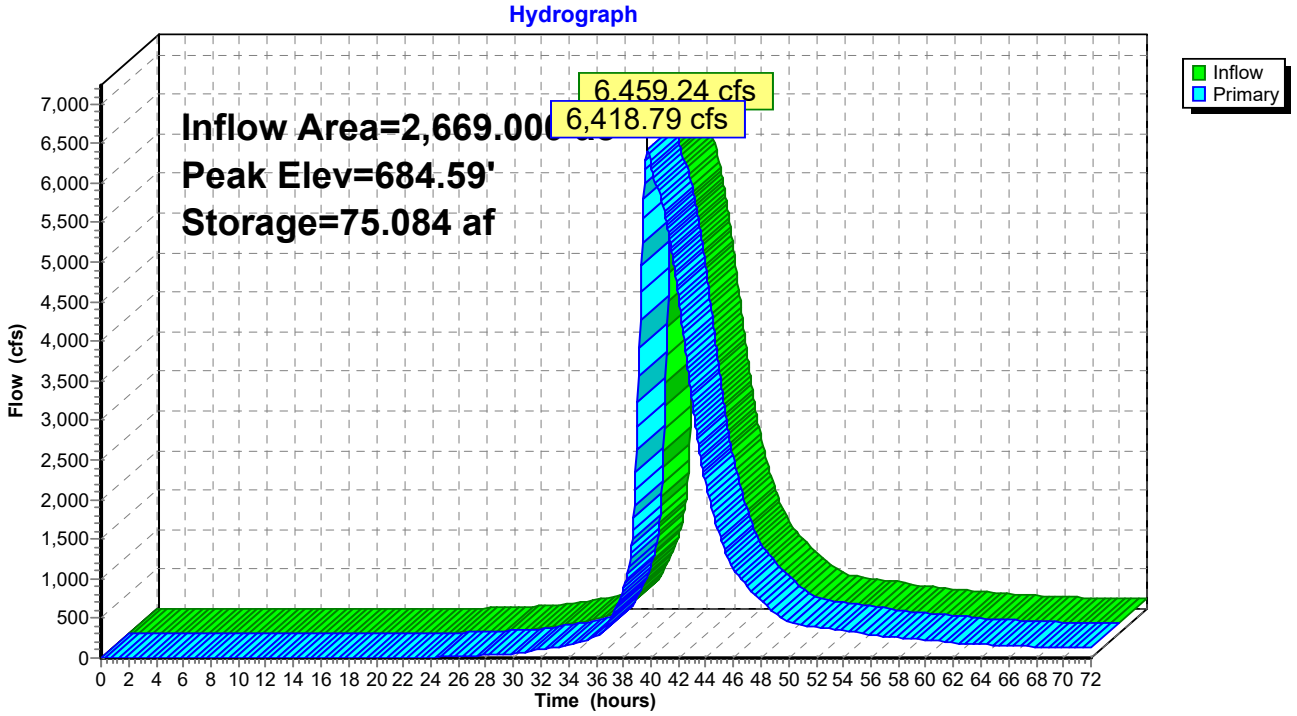
Volume	Invert	Avail.Storage	Storage Description
#1	664.40'	1,018.640 af	**See Woidt HEC-1 - Extrapolated (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
664.40	0.000	0.000	0.000
678.00	2.300	15.640	15.640
680.00	8.700	11.000	26.640
700.00	24.800	335.000	361.640
720.00	40.900	657.000	1,018.640

Device	Routing	Invert	Outlet Devices
#1	Primary	678.00'	**See Woidt HEC-1 - Half Flows - Extrapolated X 2.00** Elev. (feet) 678.00 678.50 679.00 679.50 679.90 680.00 681.00 682.00 683.00 684.00 685.00 690.00 Disch. (cfs) 0.000 26.500 75.000 136.500 194.500 213.500 576.500 1,141.000 1,835.500 2,648.000 3,595.500 8,333.000

Primary OutFlow Max=6,418.34 cfs @ 39.75 hrs HW=684.59' TW=651.22' (Dynamic Tailwater)
↑—**1=See Woidt HEC-1 - Half Flows - Extrapolated** (Custom Controls 6,418.34 cfs)

Pond OLD: Openaka Lake Dam



Summary for Pond SLD: Shongum Lake

Inflow Area = 1,984.000 ac, 0.00% Impervious, Inflow Depth > 14.39" for 0.5 PMP event
Inflow = 10,817.58 cfs @ 39.70 hrs, Volume= 2,378.902 af
Outflow = 4,727.02 cfs @ 40.65 hrs, Volume= 2,312.327 af, Atten= 56%, Lag= 57.2 min
Primary = 4,727.02 cfs @ 40.65 hrs, Volume= 2,312.327 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 715.00' Surf.Area= 65.200 ac Storage= 326.000 af
Peak Elev= 720.79' @ 40.65 hrs Surf.Area= 279.002 ac Storage= 1,322.627 af (996.627 af above start)

Plug-Flow detention time= 375.8 min calculated for 1,984.949 af (83% of inflow)
Center-of-Mass det. time= 180.7 min (2,673.7 - 2,492.9)

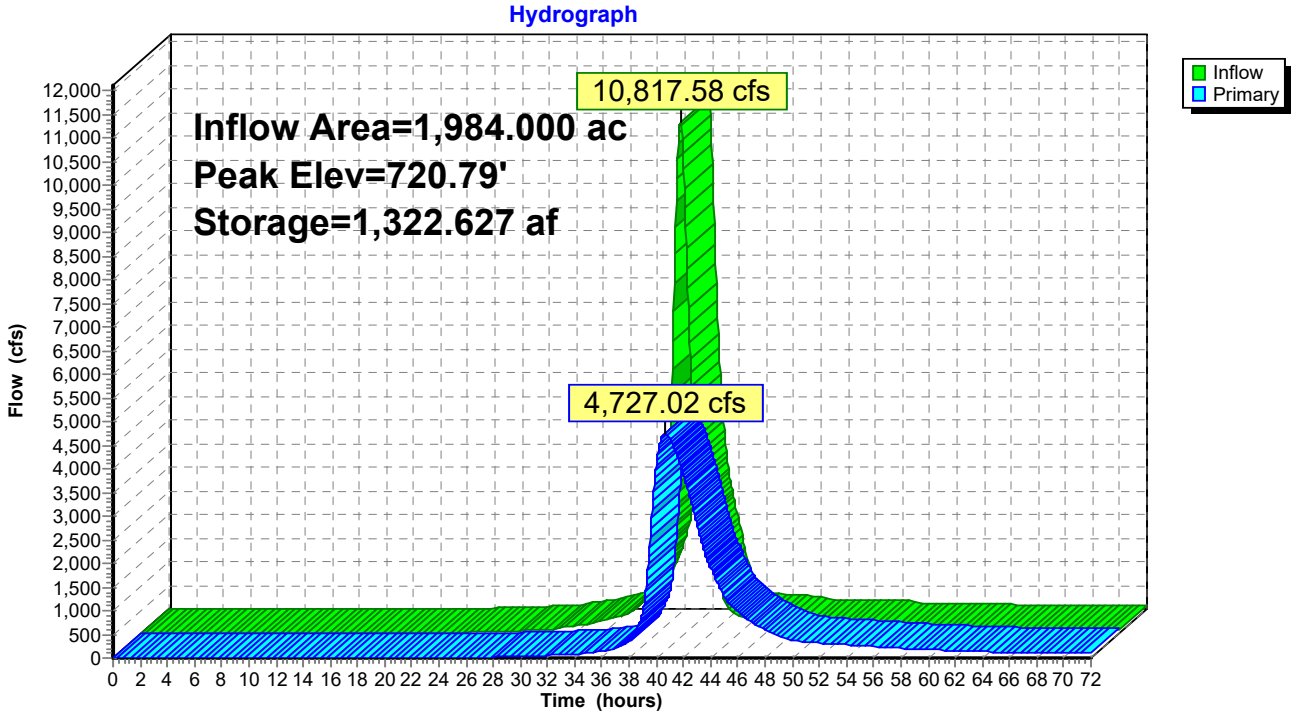
Volume	Invert	Avail.Storage	Storage Description
#1	705.00'	6,094.960 af	**See Woidt HEC-1 - Extrapolated (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
705.00	0.000	0.000	0.000
715.00	65.200	326.000	326.000
720.00	249.800	787.500	1,113.500
731.00	655.920	4,981.460	6,094.960

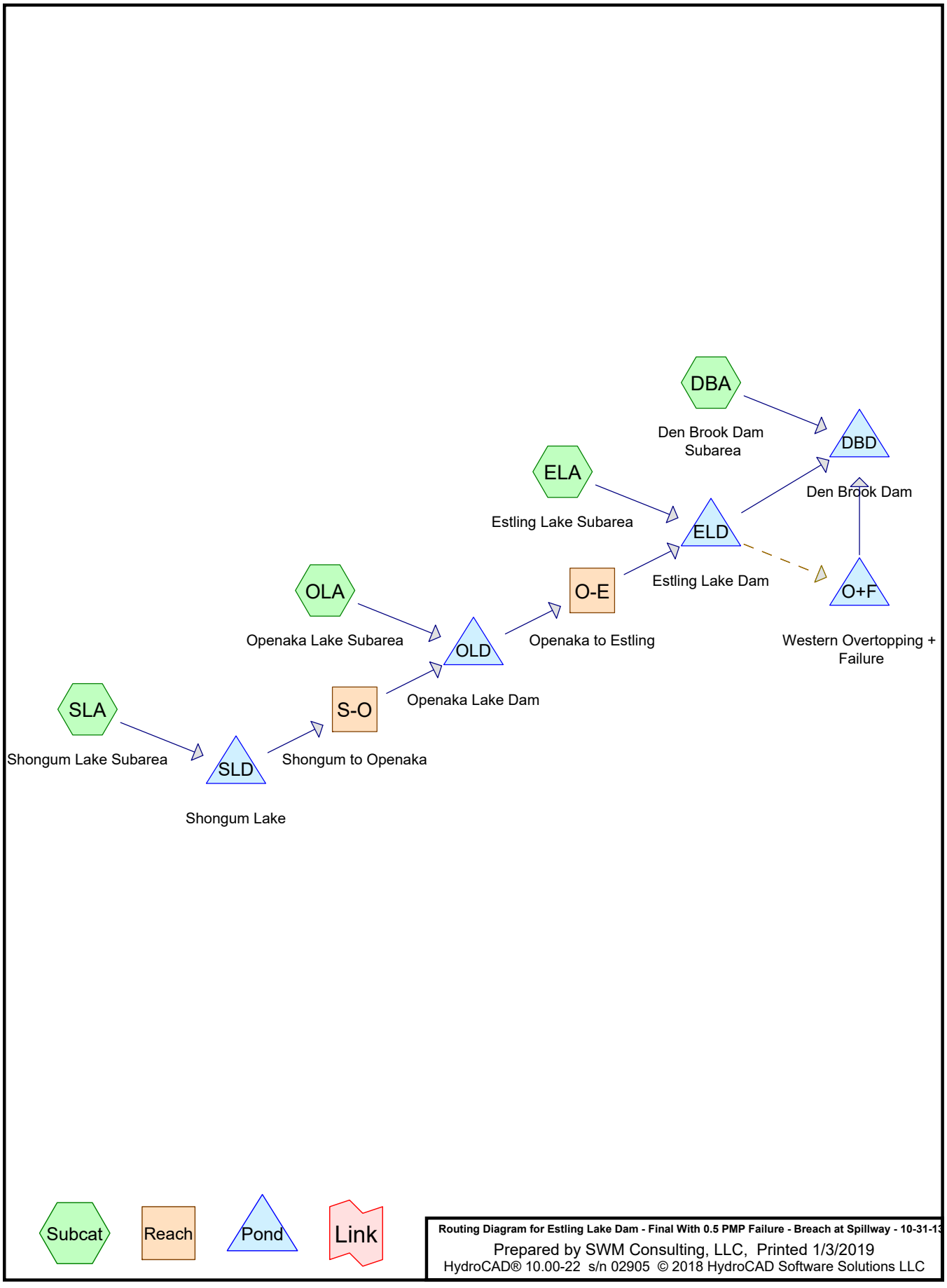
Device	Routing	Invert	Outlet Devices
#1	Primary	715.00'	**See Woidt HEC-1 - Half Flows - Extrapoloated X 2.00** Elev. (feet) 715.00 716.00 717.00 718.00 719.00 720.00 731.00 Disch. (cfs) 0.000 60.500 184.500 543.500 1,100.000 1,805.500 9,566.000

Primary OutFlow Max=4,726.86 cfs @ 40.65 hrs HW=720.79' TW=713.11' (Dynamic Tailwater)
↑—**1=See Woidt HEC-1 - Half Flows - Extrapoloated** (Custom Controls 4,726.86 cfs)

Pond SLD: Shongum Lake



Previous 2014 Analysis HydroCAD Model With Dam Failure


DBA
Den Brook Dam Subarea
DBD
Den Brook Dam
ELA
Estling Lake Subarea
ELD
Estling Lake Dam
O+F
Western Overtopping + Failure
OLA
Openaka Lake Subarea
O-E
Openaka to Estling
OLD
Openaka Lake Dam
S-O
SLA
Shongum Lake Subarea
SLD
Shongum Lake
Shongum to Openaka
Subcat
Reach
Pond
Link

Summary for Subcatchment DBA: Den Brook Dam Subarea

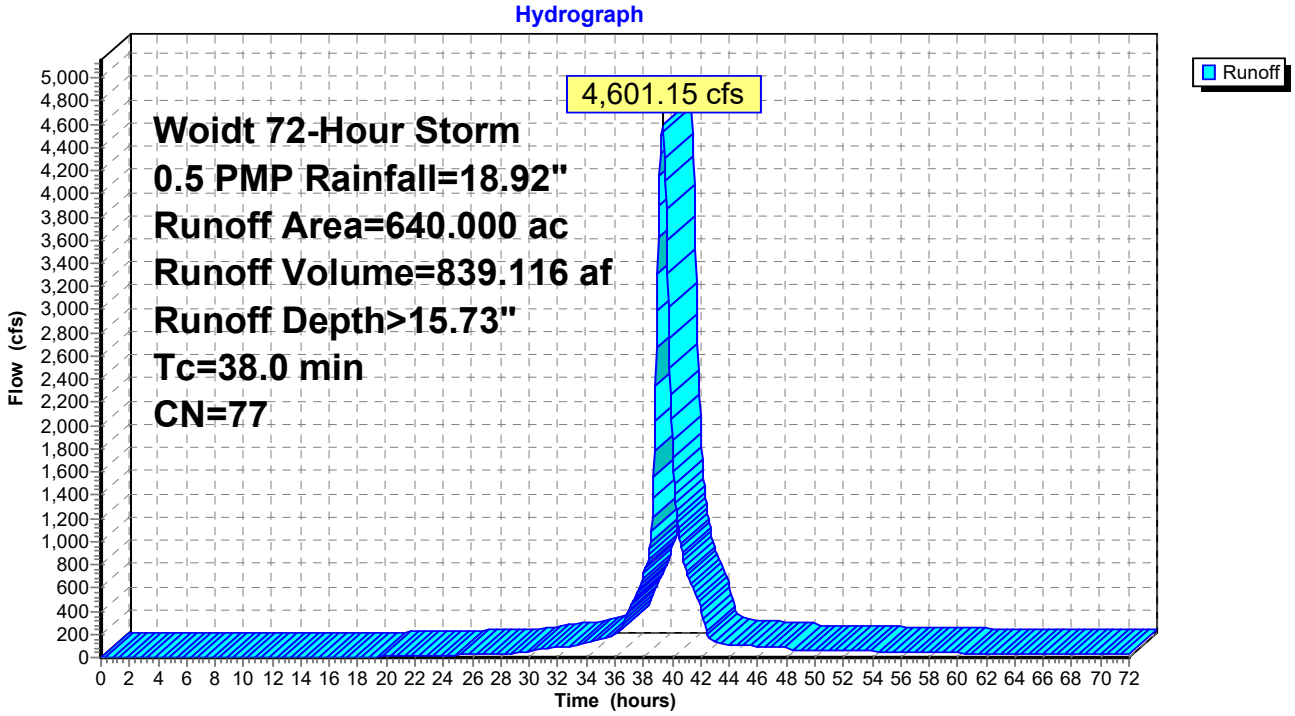
Runoff = 4,601.15 cfs @ 39.34 hrs, Volume= 839.116 af, Depth>15.73"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	640.000	77	See Woidt HEC-1
	640.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.0					**Direct Entry, See Woidt HEC-1**

Subcatchment DBA: Den Brook Dam Subarea



Summary for Subcatchment ELA: Estling Lake Subarea

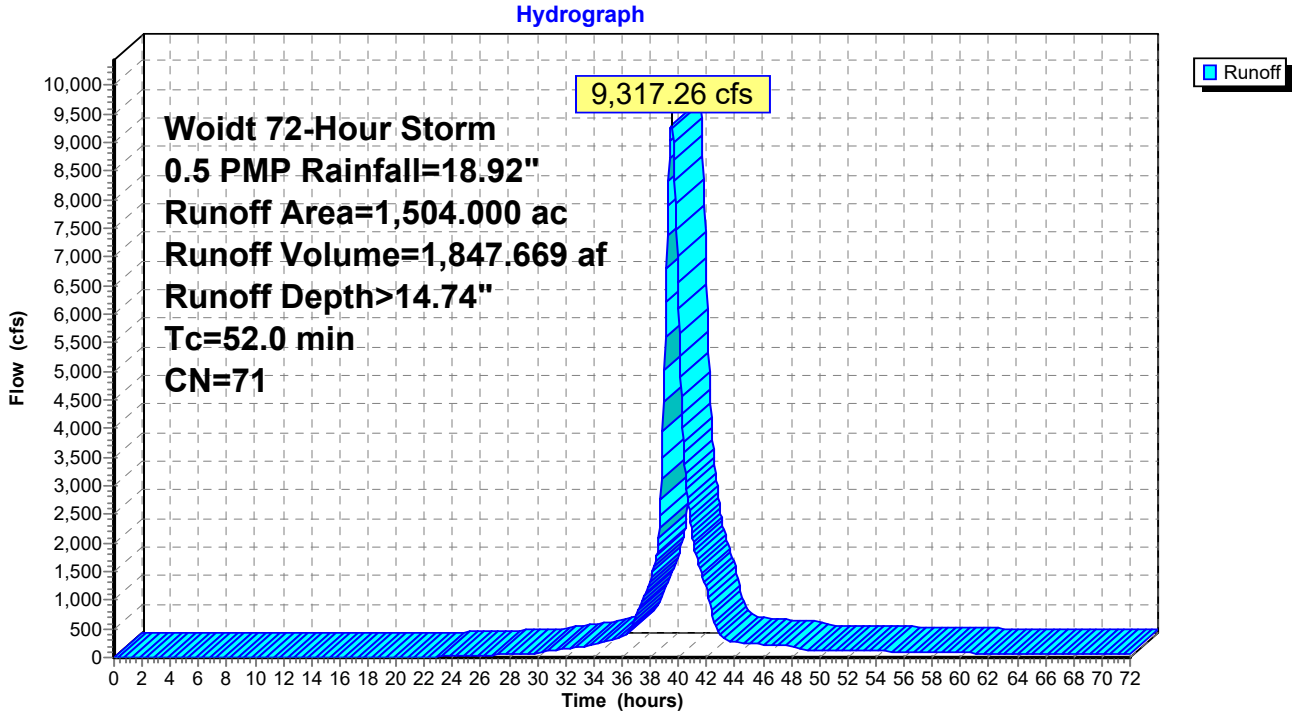
Runoff = 9,317.26 cfs @ 39.52 hrs, Volume= 1,847.669 af, Depth>14.74"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,504.000	71	See Woidt HEC-1
	1,504.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
52.0					**Direct Entry, See Woidt HEC-1**

Subcatchment ELA: Estling Lake Subarea



Summary for Subcatchment OLA: Openaka Lake Subarea

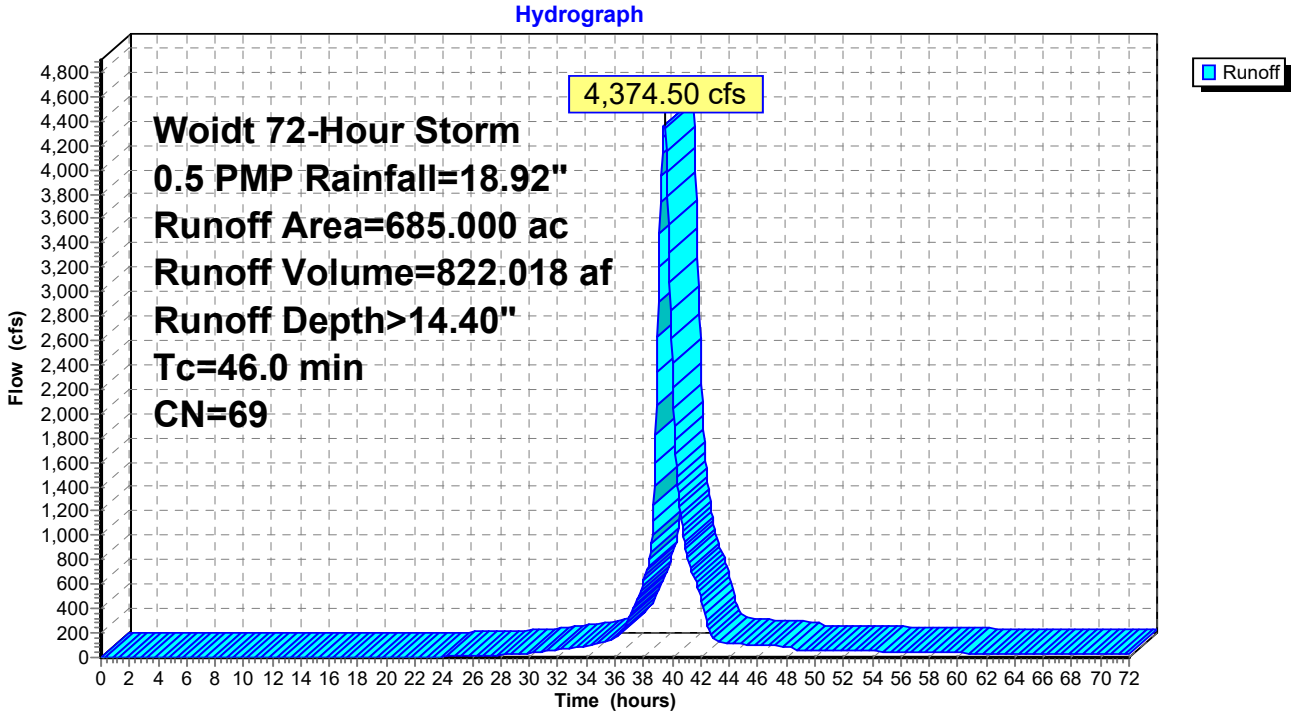
Runoff = 4,374.50 cfs @ 39.45 hrs, Volume= 822.018 af, Depth>14.40"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	685.000	69	See Woidt HEC-1
	685.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
46.0					**Direct Entry, See Woidt HEC-1**

Subcatchment OLA: Openaka Lake Subarea



Summary for Subcatchment SLA: Shongum Lake Subarea

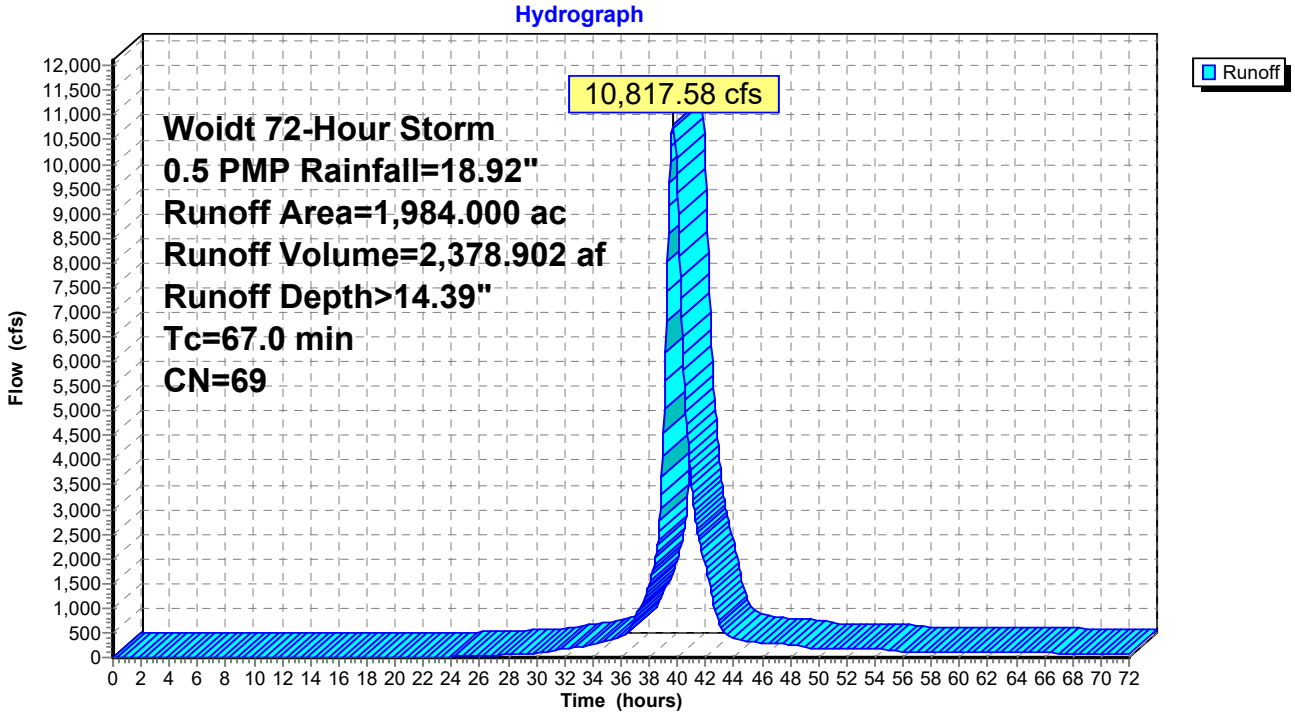
Runoff = 10,817.58 cfs @ 39.70 hrs, Volume= 2,378.902 af, Depth>14.39"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,984.000	69	See Woidt HEC-1
	1,984.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
67.0					**Direct Entry, See Woidt HEC-1**

Subcatchment SLA: Shongum Lake Subarea



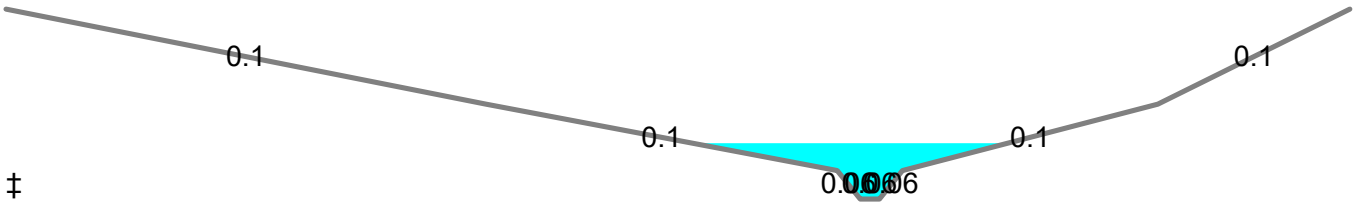
Summary for Reach O-E: Openaka to Estling

Inflow Area = 2,669.000 ac, 0.00% Impervious, Inflow Depth > 14.07" for 0.5 PMP event
Inflow = 6,418.79 cfs @ 39.75 hrs, Volume= 3,129.201 af
Outflow = 5,959.50 cfs @ 40.41 hrs, Volume= 3,122.024 af, Atten= 7%, Lag= 39.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.67 fps, Min. Travel Time= 21.0 min
Avg. Velocity = 5.24 fps, Avg. Travel Time= 34.7 min

Peak Storage= 7,651,510 cf @ 40.41 hrs
Average Depth at Peak Storage= 11.76'
Bank-Full Depth= 40.00' Flow Area= 13,320.0 sf, Capacity= 219,014.09 cfs

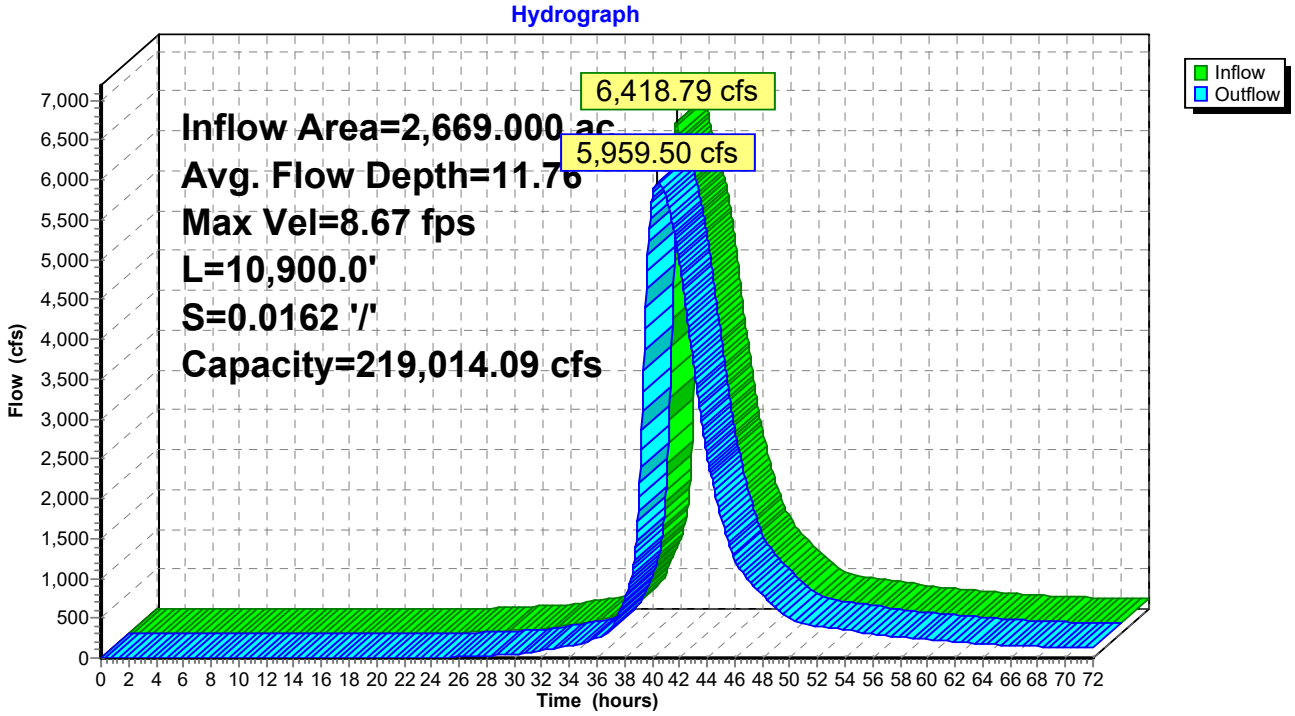
Custom cross-section, Length= 10,900.0' Slope= 0.0162 '/'
Flow calculated by Segment Subdivision method
Inlet Invert= 640.00', Outlet Invert= 463.42'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
550.00	680.00	0.00		
800.00	660.00	20.00	0.100	
983.00	646.00	34.00	0.100	
995.00	640.00	40.00	0.060	
1,005.00	640.00	40.00	0.060	
1,017.00	646.00	34.00	0.060	
1,150.00	660.00	20.00	0.100	
1,250.00	680.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
6.00	132.0	36.8	1,438,800	1,062.78
20.00	2,820.0	354.1	30,738,000	27,807.57
40.00	13,320.0	706.9	145,188,000	219,014.09

Reach O-E: Openaka to Estling



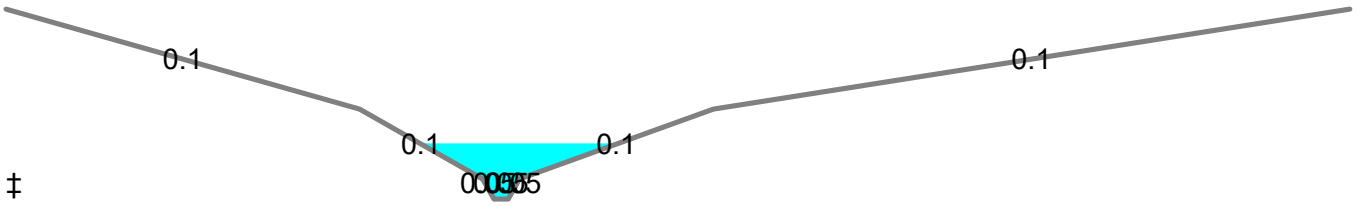
Summary for Reach S-O: Shongum to Openaka

Inflow Area = 1,984.000 ac, 0.00% Impervious, Inflow Depth > 13.99" for 0.5 PMP event
Inflow = 4,727.02 cfs @ 40.65 hrs, Volume= 2,312.327 af
Outflow = 4,711.89 cfs @ 40.79 hrs, Volume= 2,310.443 af, Atten= 0%, Lag= 7.9 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 7.10 fps, Min. Travel Time= 7.5 min
Avg. Velocity = 4.44 fps, Avg. Travel Time= 12.0 min

Peak Storage= 2,123,522 cf @ 40.79 hrs
Average Depth at Peak Storage= 11.12'
Bank-Full Depth= 38.00' Flow Area= 14,004.0 sf, Capacity= 155,556.64 cfs

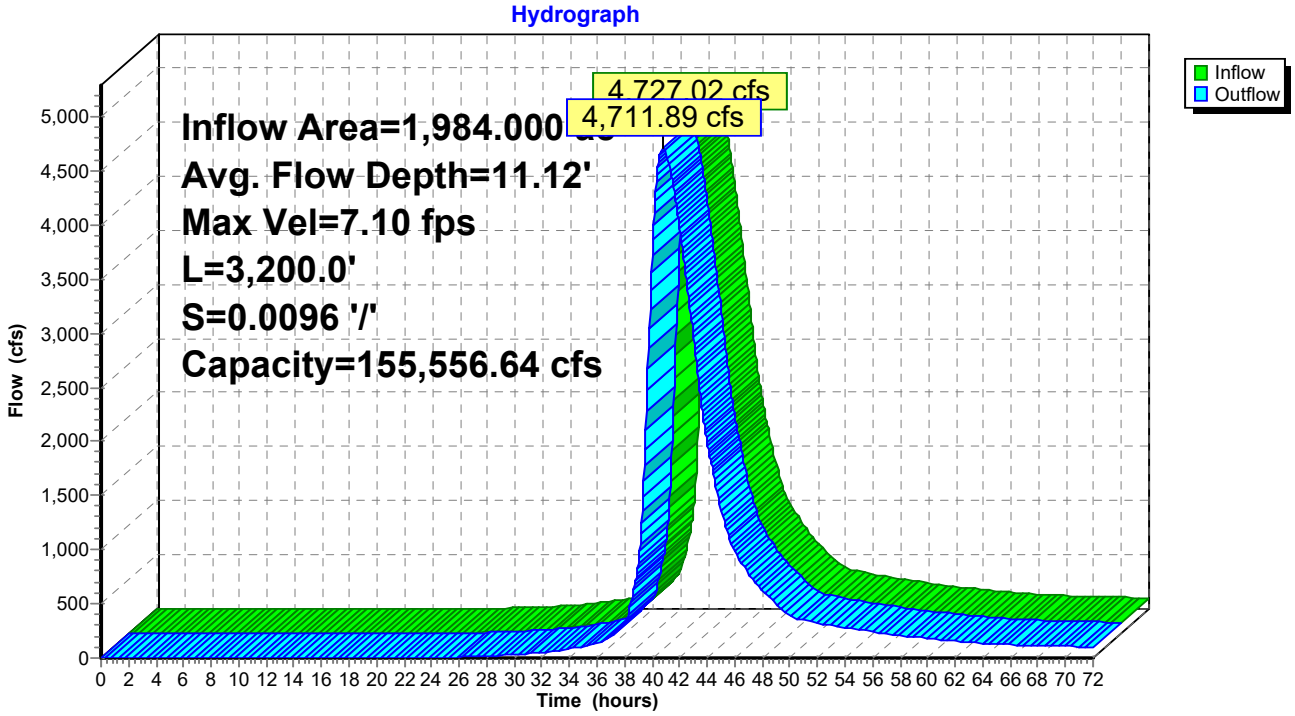
Custom cross-section, Length= 3,200.0' Slope= 0.0096 '/' (102 Elevation Intervals)
Flow calculated by Segment Subdivision method
Inlet Invert= 702.00', Outlet Invert= 671.28'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
650.00	740.00	0.00		
900.00	720.00	20.00	0.100	
987.00	706.00	34.00	0.100	
995.00	702.00	38.00	0.050	
1,005.00	702.00	38.00	0.050	
1,013.00	706.00	34.00	0.050	
1,150.00	720.00	20.00	0.100	
1,600.00	740.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
4.00	72.0	27.9	230,400	430.82
18.00	2,004.0	253.7	6,412,800	16,303.00
38.00	14,004.0	955.0	44,812,800	155,556.64

Reach S-O: Shongum to Openaka



Summary for Pond DBD: Den Brook Dam

Inflow Area = 4,813.000 ac, 0.00% Impervious, Inflow Depth > 14.96" for 0.5 PMP event
Inflow = 20,295.90 cfs @ 40.46 hrs, Volume= 5,998.912 af
Outflow = 11,612.74 cfs @ 41.27 hrs, Volume= 5,983.893 af, Atten= 43%, Lag= 48.4 min
Primary = 11,612.74 cfs @ 41.27 hrs, Volume= 5,983.893 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 514.55' @ 41.27 hrs Surf.Area= 194.904 ac Storage= 954.317 af

Plug-Flow detention time= 47.6 min calculated for 5,983.893 af (100% of inflow)
Center-of-Mass det. time= 43.5 min (2,661.7 - 2,618.2)

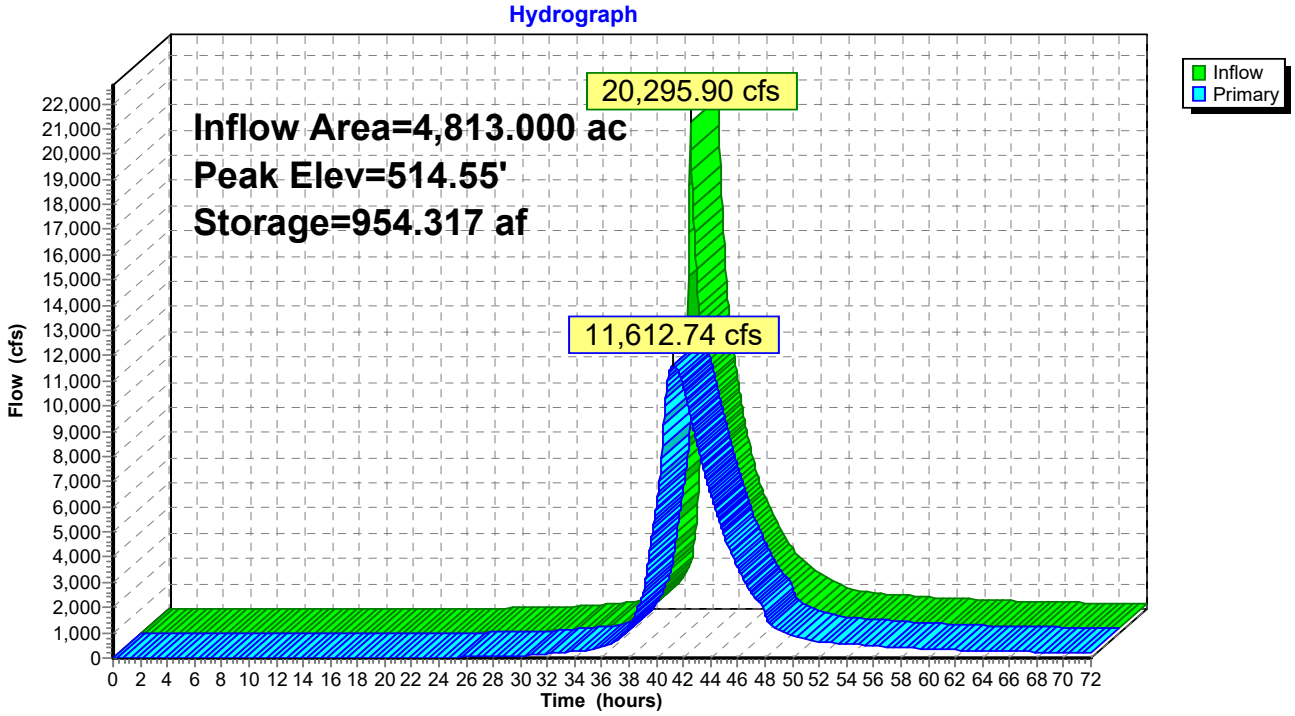
Volume	Invert	Avail.Storage	Storage Description
#1	499.00'	2,888.123 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
499.00	0.000	0.000	0.000
502.50	4.640	8.120	8.120
507.90	8.500	35.478	43.598
508.00	82.000	4.525	48.123
520.00	289.000	2,226.000	2,274.123
522.00	325.000	614.000	2,888.123

Device	Routing	Invert	Outlet Devices
#1	Primary	502.50'	**See Woidt HEC-1 - Half Flows - Extrapolated X 2.00** Elev. (feet) 502.50 503.50 504.50 505.50 506.50 507.50 508.50 509.50 510.50 511.50 512.50 513.50 514.50 515.50 516.50 517.50 518.50 Disch. (cfs) 0.000 64.000 182.500 371.000 592.000 855.500 1,254.000 1,828.500 2,440.500 3,124.500 3,872.500 4,706.500 5,766.500 6,649.000 7,575.000 8,513.000 9,506.500

Primary OutFlow Max=11,611.51 cfs @ 41.27 hrs HW=514.54' (Free Discharge)
1=See Woidt HEC-1 - Half Flows - Extrapolated (Custom Controls 11,611.51 cfs)

Pond DBD: Den Brook Dam



Summary for Pond ELD: Estling Lake Dam

Inflow Area = 4,173.000 ac, 0.00% Impervious, Inflow Depth > 14.29" for 0.5 PMP event
Inflow = 13,839.60 cfs @ 39.63 hrs, Volume= 4,969.693 af
Outflow = 19,191.32 cfs @ 40.46 hrs, Volume= 5,159.796 af, Atten= 0%, Lag= 49.7 min
Primary = 6,715.20 cfs @ 40.20 hrs, Volume= 1,404.485 af
Secondary = 3,457.96 cfs @ 40.20 hrs, Volume= 124.243 af
Tertiary = 12,680.81 cfs @ 40.47 hrs, Volume= 3,631.068 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 514.70' Surf.Area= 58.683 ac Storage= 196.587 af
Peak Elev= 527.10' @ 40.20 hrs Surf.Area= 104.647 ac Storage= 1,272.973 af (1,076.386 af above start)

Plug-Flow detention time= 81.5 min calculated for 4,959.765 af (100% of inflow)
Center-of-Mass det. time= 58.7 min (2,646.8 - 2,588.1)

Volume	Invert	Avail.Storage	Storage Description
#1	508.00'	2,848.110 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
508.00	0.000	0.000	0.000
516.70	76.200	331.470	331.470
520.00	85.400	266.640	598.110
540.00	139.600	2,250.000	2,848.110

Device	Routing	Invert	Outlet Devices
#1	Primary	514.70'	**Woidt Culvert Flows** Elev. (feet) 514.70 516.70 517.70 518.70 519.70 520.70 521.70 522.70 523.70 525.00 526.00 526.50 527.00 527.50 528.00 528.50 529.00 Disch. (cfs) 0.000 267.000 511.000 883.000 1,350.000 1,886.000 2,530.000 3,240.000 4,299.000 5,100.000 6,118.000 6,247.000 6,375.000 6,694.000 7,013.000 7,268.000 7,523.000
#2	Secondary	525.60'	**Western Overtopping from HEC-RAS - Half Flows X 2.00** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 50.000 100.000 200.000 300.000 400.000 500.000 747.000 986.000 1,423.000 1,840.000 2,245.000 2,637.000 3,021.000 3,401.000 3,773.000 4,142.000 4,503.000 4,858.000 5,212.000 5,553.000 5,892.000 6,227.000 6,562.000 6,856.000 7,185.000 7,525.000 7,857.000 8,347.000 8,655.000 8,962.000
#3	Primary	525.60'	**Eastern Embankment Overtopping from HEC-RAS** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 0.000 0.000 0.000 0.000 0.000 0.000 6.000

28.000 154.000 319.000 511.000 726.000 958.000 1,197.000
1,453.000 1,717.000 1,993.000 2,284.000 2,577.000 2,894.000
3,216.000 3,545.000 3,876.000 4,289.000 4,631.000 4,950.000
5,286.000 5,307.000 5,690.000 6,076.000

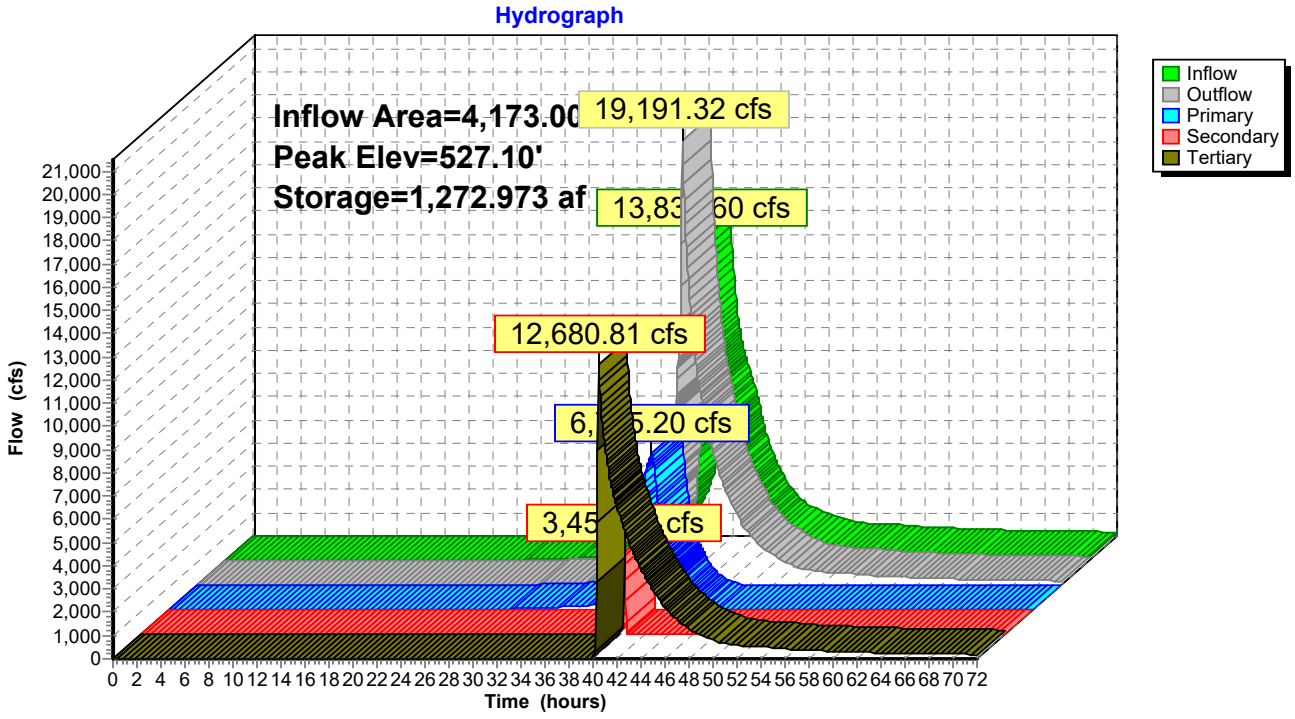
#4	Tertiary	508.00'	**53.2 deg x 43.0' wide x 17.60' high Dam Breach** C= 2.54 Top of breach = 525.60' Bottom of breach = 508.00' Breach starts at 527.10' WSE and develops over 0.25 hrs

Primary OutFlow Max=6,713.56 cfs @ 40.20 hrs HW=527.10' TW=511.89' (Dynamic Tailwater)
└─**1=Woidt Culvert Flows** (Custom Controls 6,439.45 cfs)
└─**3=Eastern Embankment Overtopping from HEC-RAS**(Custom Controls 274.10 cfs)

Secondary OutFlow Max=3,453.08 cfs @ 40.20 hrs HW=527.10' TW=0.00' (Dynamic Tailwater)
└─**2=Western Overtopping from HEC-RAS - Half Flows**(Custom Controls 3,453.08 cfs)

Tertiary OutFlow Max=12,227.86 cfs @ 40.47 hrs HW=526.11' TW=0.00' (Dynamic Tailwater)
└─**4=Dam Breach** (Orifice Controls 12,227.86 cfs @ 13.41 fps)

Pond ELD: Estling Lake Dam

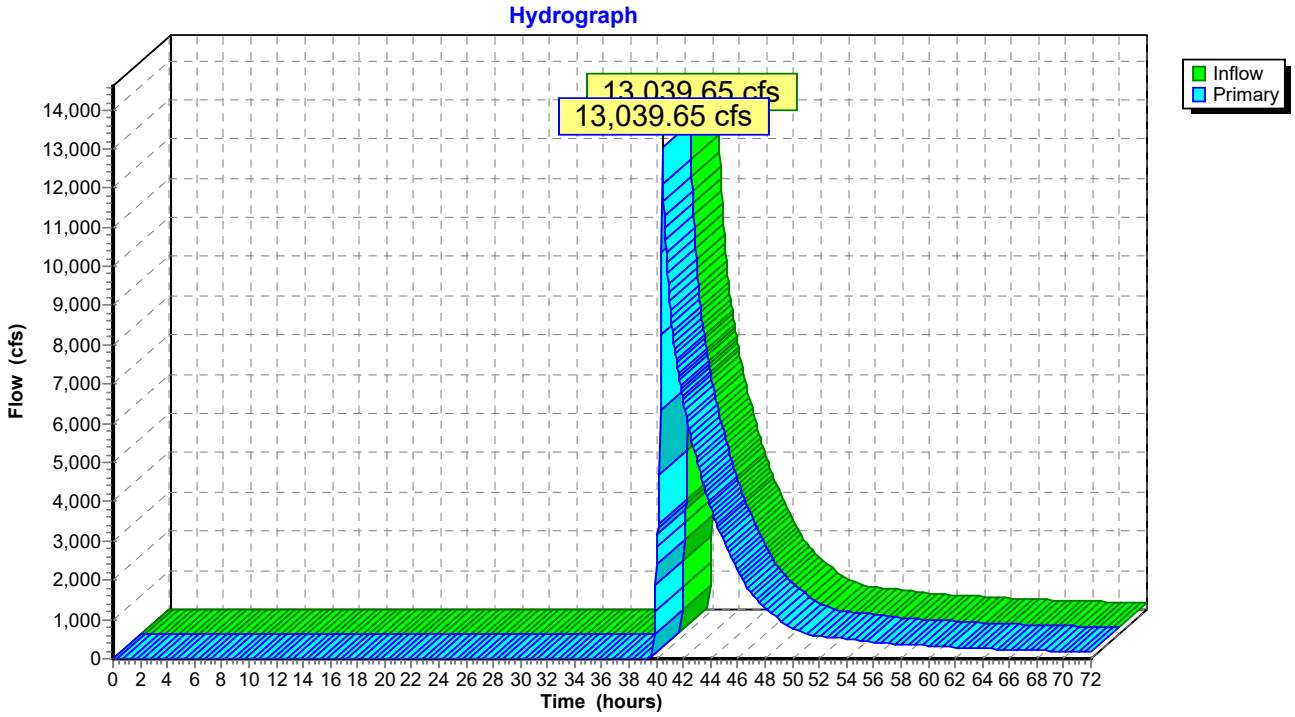


Summary for Pond O+F: Western Overtopping + Failure

Inflow = 13,039.65 cfs @ 40.46 hrs, Volume= 3,755.311 af
Primary = 13,039.65 cfs @ 40.46 hrs, Volume= 3,755.311 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Pond O+F: Western Overtopping + Failure



Summary for Pond OLD: Openaka Lake Dam

Inflow Area = 2,669.000 ac, 0.00% Impervious, Inflow Depth > 14.08" for 0.5 PMP event
Inflow = 6,459.24 cfs @ 39.66 hrs, Volume= 3,132.461 af
Outflow = 6,418.79 cfs @ 39.75 hrs, Volume= 3,129.201 af, Atten= 1%, Lag= 5.4 min
Primary = 6,418.79 cfs @ 39.75 hrs, Volume= 3,129.201 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 678.00' Surf.Area= 2.300 ac Storage= 15.640 af
Peak Elev= 684.59' @ 39.75 hrs Surf.Area= 12.397 ac Storage= 75.084 af (59.444 af above start)

Plug-Flow detention time= 24.1 min calculated for 3,113.561 af (99% of inflow)
Center-of-Mass det. time= 8.7 min (2,635.5 - 2,626.8)

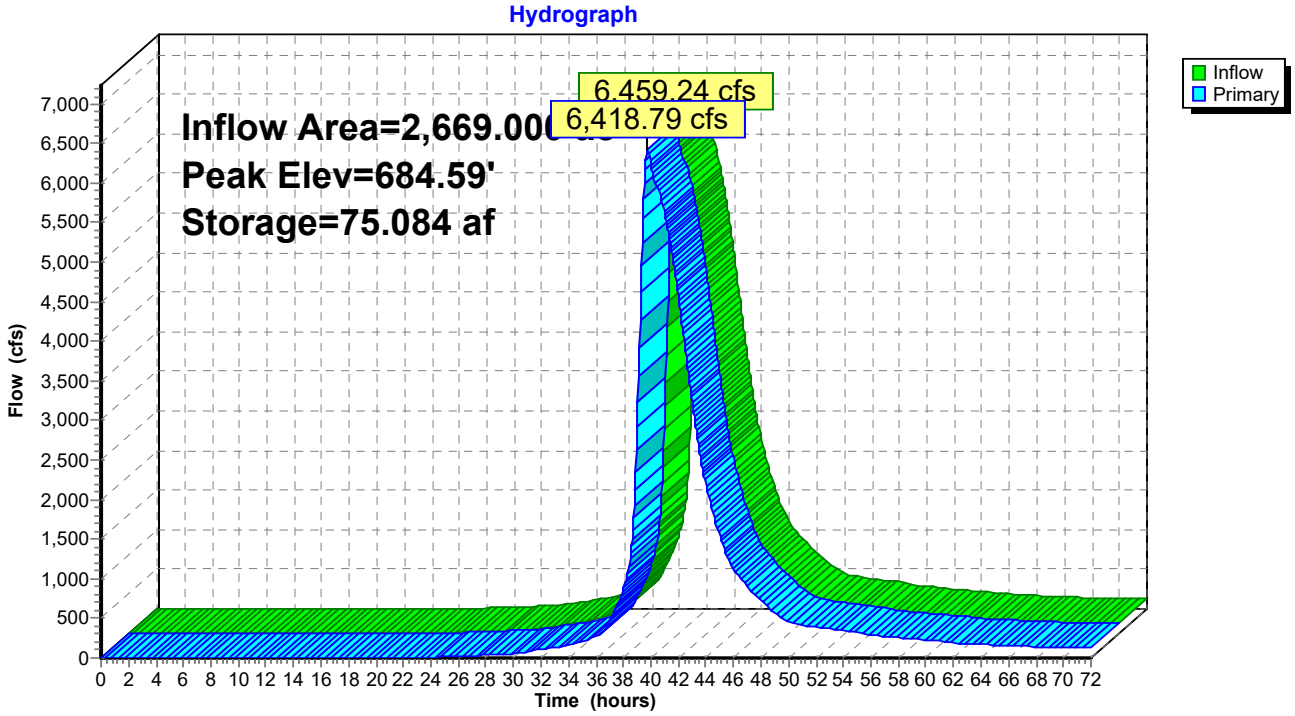
Volume	Invert	Avail.Storage	Storage Description
#1	664.40'	1,018.640 af	**See Woidt HEC-1 - Extrapolated (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
664.40	0.000	0.000	0.000
678.00	2.300	15.640	15.640
680.00	8.700	11.000	26.640
700.00	24.800	335.000	361.640
720.00	40.900	657.000	1,018.640

Device	Routing	Invert	Outlet Devices
#1	Primary	678.00'	**See Woidt HEC-1 - Half Flows - Extrapolated X 2.00** Elev. (feet) 678.00 678.50 679.00 679.50 679.90 680.00 681.00 682.00 683.00 684.00 685.00 690.00 Disch. (cfs) 0.000 26.500 75.000 136.500 194.500 213.500 576.500 1,141.000 1,835.500 2,648.000 3,595.500 8,333.000

Primary OutFlow Max=6,418.34 cfs @ 39.75 hrs HW=684.59' TW=651.22' (Dynamic Tailwater)
↑—**1=See Woidt HEC-1 - Half Flows - Extrapolated** (Custom Controls 6,418.34 cfs)

Pond OLD: Openaka Lake Dam



Summary for Pond SLD: Shongum Lake

Inflow Area = 1,984.000 ac, 0.00% Impervious, Inflow Depth > 14.39" for 0.5 PMP event
Inflow = 10,817.58 cfs @ 39.70 hrs, Volume= 2,378.902 af
Outflow = 4,727.02 cfs @ 40.65 hrs, Volume= 2,312.327 af, Atten= 56%, Lag= 57.2 min
Primary = 4,727.02 cfs @ 40.65 hrs, Volume= 2,312.327 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 715.00' Surf.Area= 65.200 ac Storage= 326.000 af
Peak Elev= 720.79' @ 40.65 hrs Surf.Area= 279.002 ac Storage= 1,322.627 af (996.627 af above start)

Plug-Flow detention time= 375.8 min calculated for 1,984.949 af (83% of inflow)
Center-of-Mass det. time= 180.7 min (2,673.7 - 2,492.9)

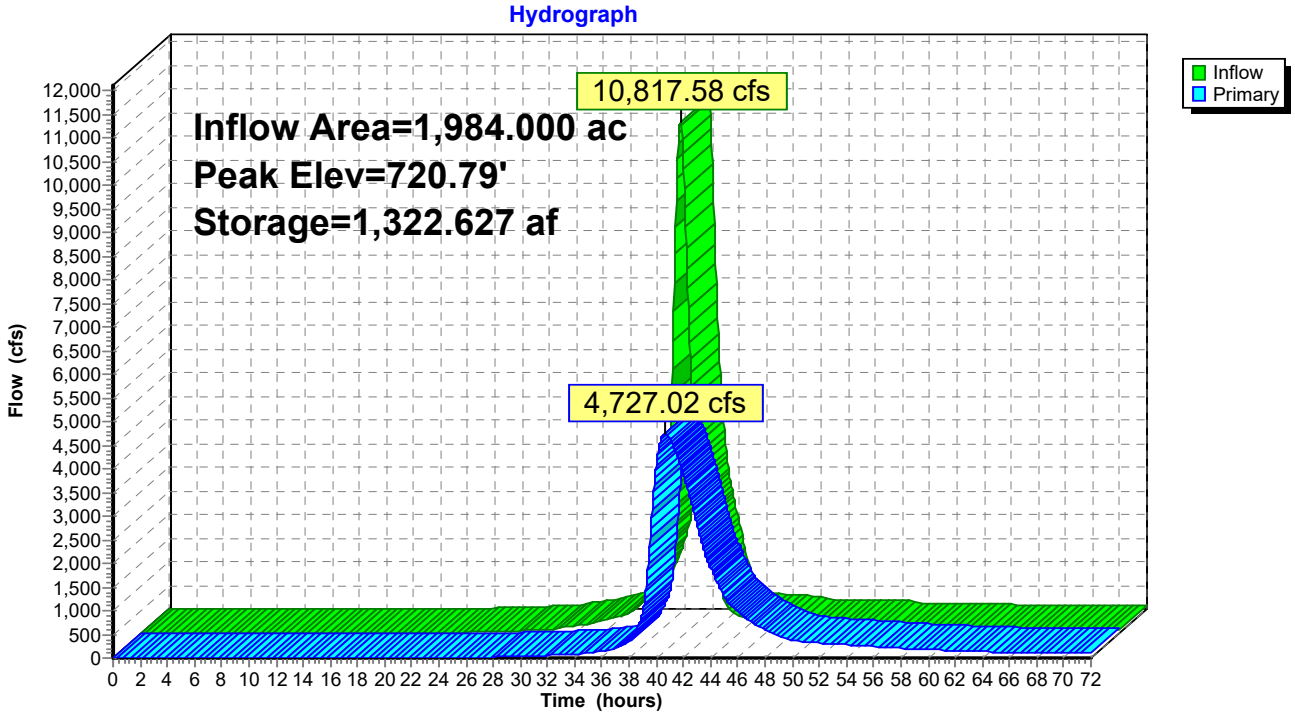
Volume	Invert	Avail.Storage	Storage Description
#1	705.00'	6,094.960 af	**See Woidt HEC-1 - Extrapolated (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
705.00	0.000	0.000	0.000
715.00	65.200	326.000	326.000
720.00	249.800	787.500	1,113.500
731.00	655.920	4,981.460	6,094.960

Device	Routing	Invert	Outlet Devices
#1	Primary	715.00'	**See Woidt HEC-1 - Half Flows - Extrapoloated X 2.00** Elev. (feet) 715.00 716.00 717.00 718.00 719.00 720.00 731.00 Disch. (cfs) 0.000 60.500 184.500 543.500 1,100.000 1,805.500 9,566.000

Primary OutFlow Max=4,726.86 cfs @ 40.65 hrs HW=720.79' TW=713.11' (Dynamic Tailwater)
↑—**1=See Woidt HEC-1 - Half Flows - Extrapoloated** (Custom Controls 4,726.86 cfs)

Pond SLD: Shongum Lake



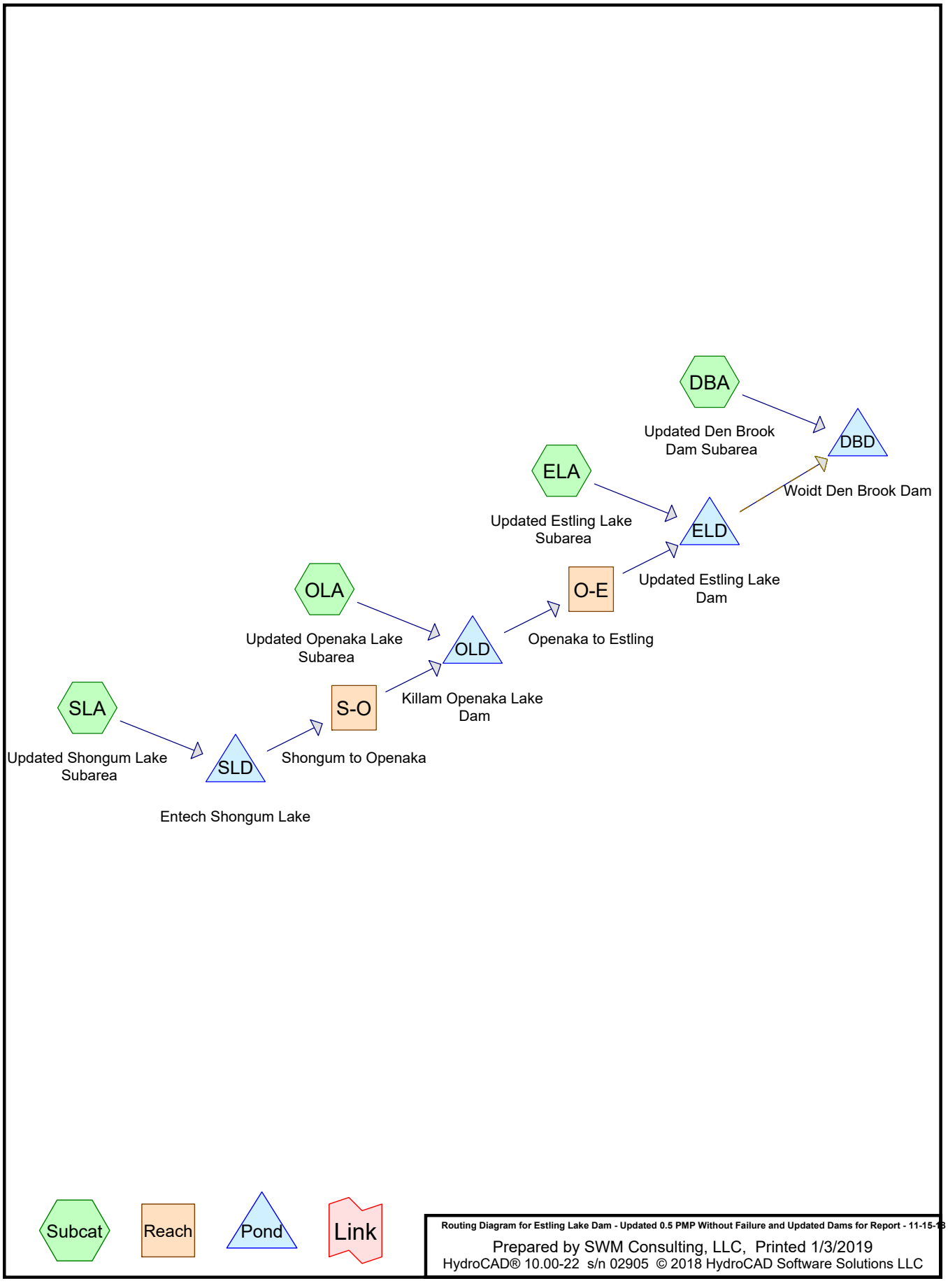
Appendix B
Updated Analysis Data, Models, and Results

- **Updated 2018 Analysis HydroCAD Model Without Dam Failure**

- **Updated 2018 Analysis HydroCAD Model With Dam Failure**

- **Estling Lake Progress Meeting PowerPoint NJDEP Bureau of Dam Safety November 27, 2018**

Updated 2018 Analysis HydroCAD Model Without Dam Failure



Routing Diagram for Estling Lake Dam - Updated 0.5 PMP Without Failure and Updated Dams for Report - 11-15-18

Prepared by SWM Consulting, LLC, Printed 1/3/2019

Summary for Subcatchment DBA: Updated Den Brook Dam Subarea

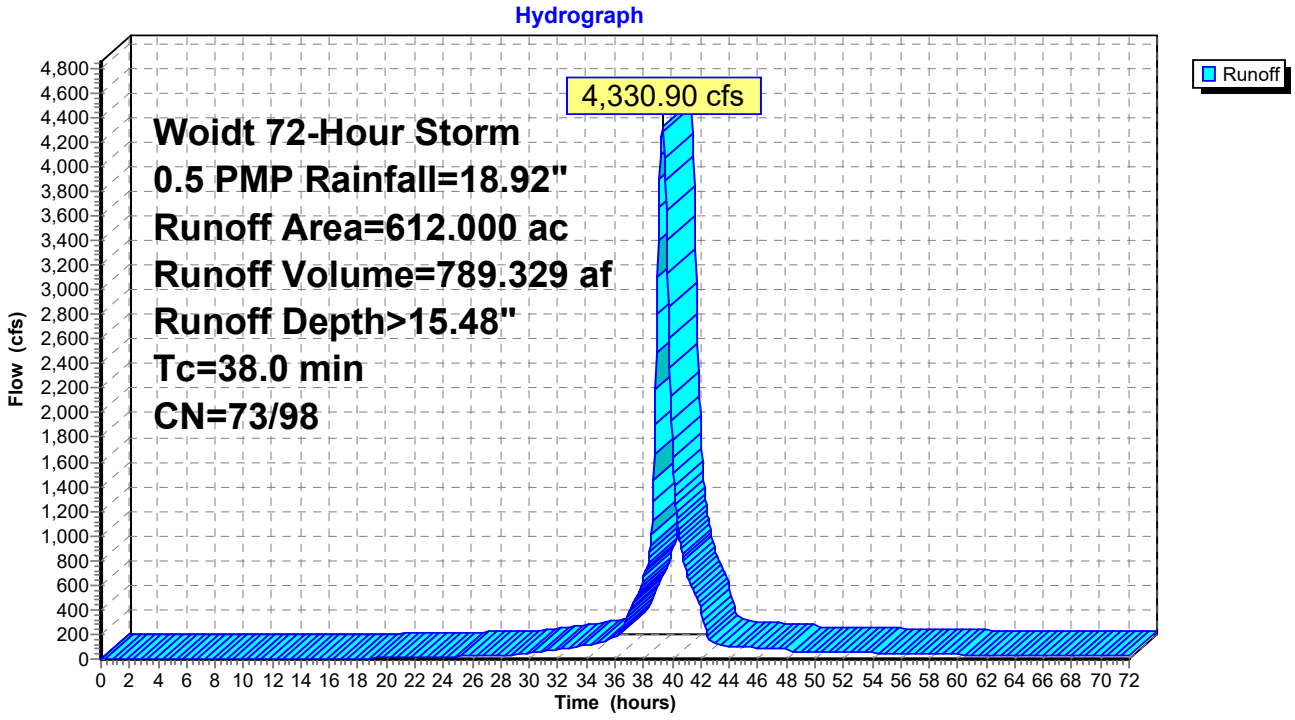
Runoff = 4,330.90 cfs @ 39.34 hrs, Volume= 789.329 af, Depth>15.48"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	545.000	73	Pervious - See Excel
*	67.000	98	Impervious - See Excel
	612.000	76	Weighted Average
	545.000	73	89.05% Pervious Area
	67.000	98	10.95% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.0					**Direct Entry, See Woidt HEC-1**

Subcatchment DBA: Updated Den Brook Dam Subarea



Summary for Subcatchment ELA: Updated Estling Lake Subarea

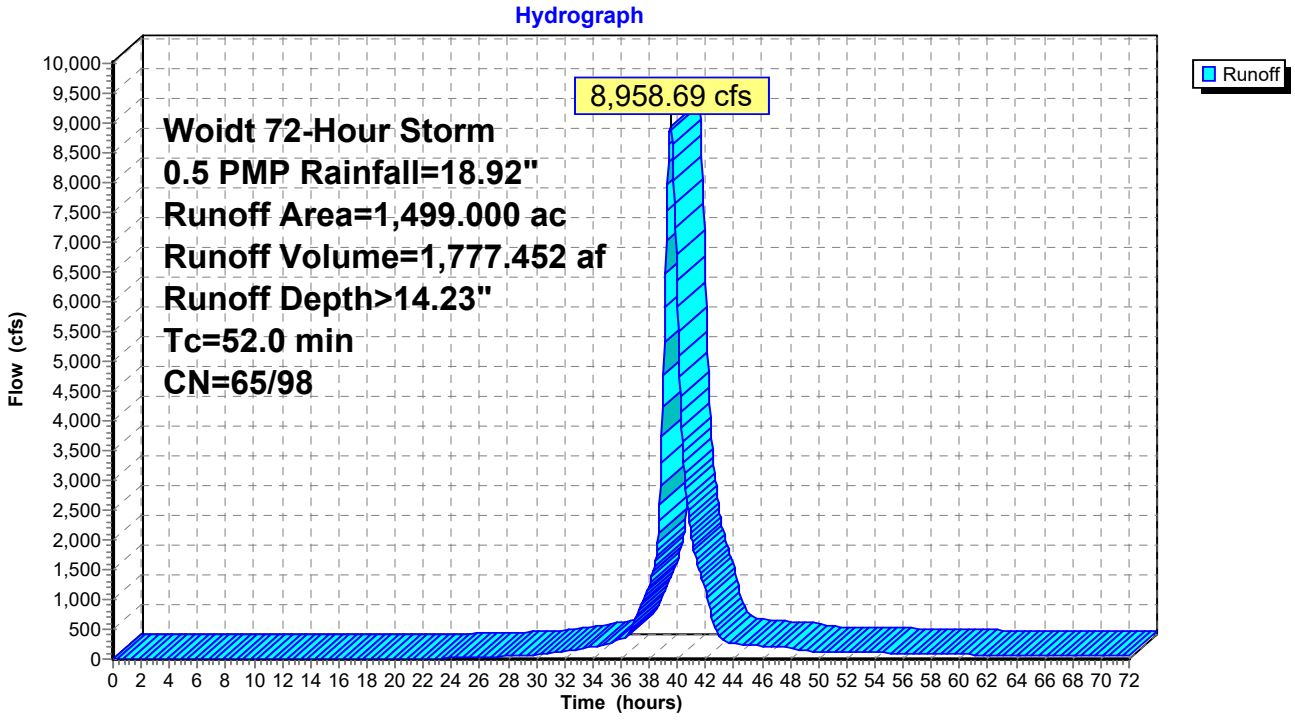
Runoff = 8,958.69 cfs @ 39.52 hrs, Volume= 1,777.452 af, Depth>14.23"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,333.000	65	Pervious - See Excel
*	166.000	98	Impervious - See Excel
	1,499.000	69	Weighted Average
	1,333.000	65	88.93% Pervious Area
	166.000	98	11.07% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
52.0					**Direct Entry, See Woidt HEC-1**

Subcatchment ELA: Updated Estling Lake Subarea



Summary for Subcatchment OLA: Updated Openaka Lake Subarea

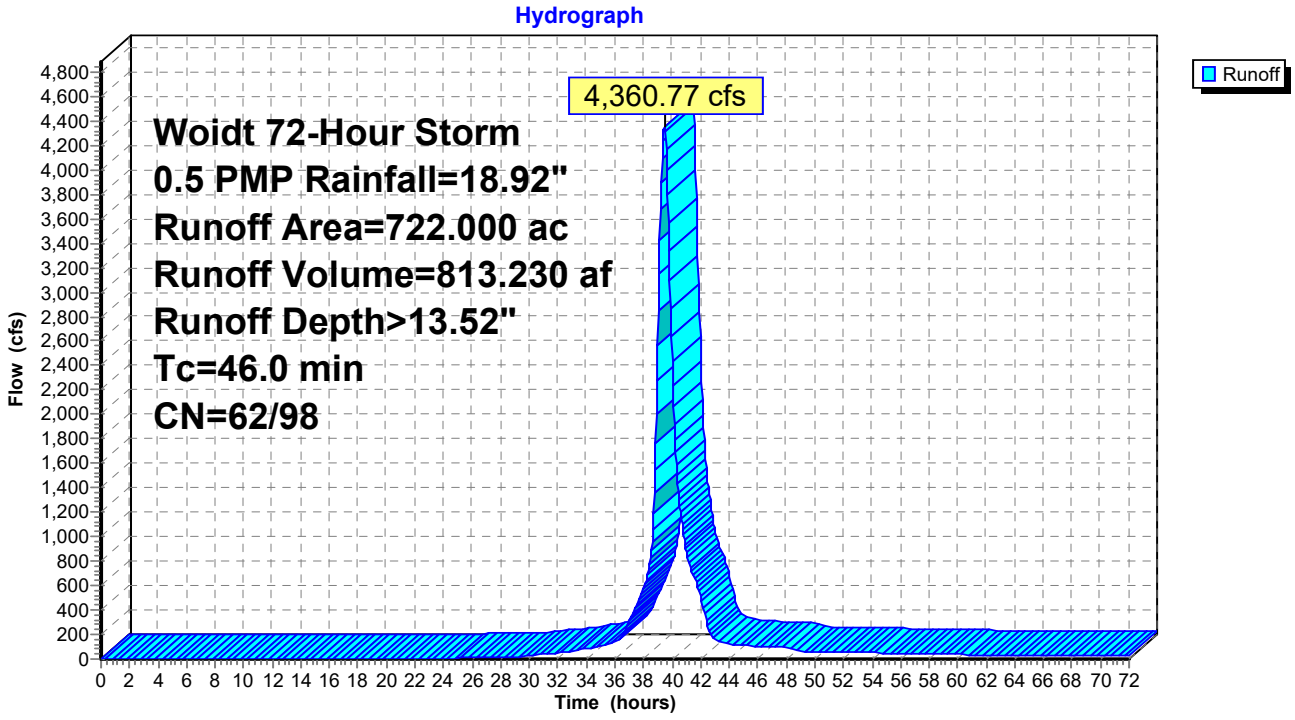
Runoff = 4,360.77 cfs @ 39.46 hrs, Volume= 813.230 af, Depth>13.52"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	670.000	62	Pervious - See Excel
*	52.000	98	Impervioius - See Excel
	722.000	65	Weighted Average
	670.000	62	92.80% Pervious Area
	52.000	98	7.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
46.0					**Direct Entry, See Woidt HEC-1**

Subcatchment OLA: Updated Openaka Lake Subarea



Summary for Subcatchment SLA: Updated Shongum Lake Subarea

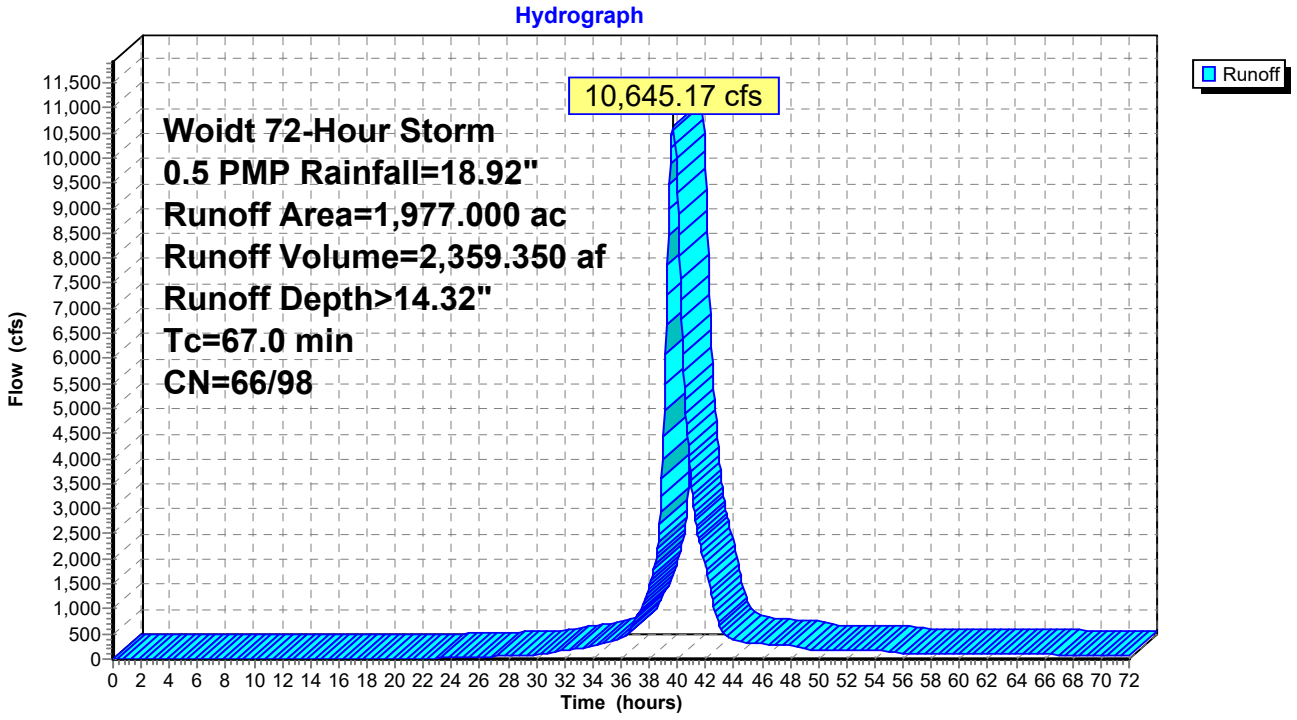
Runoff = 10,645.17 cfs @ 39.70 hrs, Volume= 2,359.350 af, Depth>14.32"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,784.000	66	Pervious - See Excel
*	193.000	98	Impervious - See Excel
	1,977.000	69	Weighted Average
	1,784.000	66	90.24% Pervious Area
	193.000	98	9.76% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
67.0					**Direct Entry, See Woidt HEC-1**

Subcatchment SLA: Updated Shongum Lake Subarea



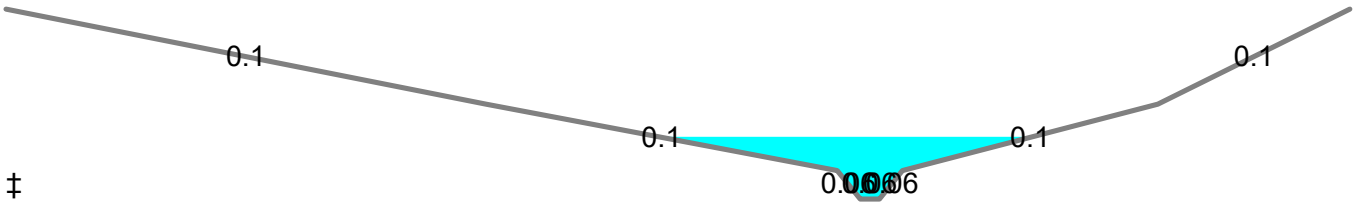
Summary for Reach O-E: Openaka to Estling

Inflow Area = 2,699.000 ac, 9.08% Impervious, Inflow Depth > 12.59" for 0.5 PMP event
Inflow = 8,567.90 cfs @ 40.25 hrs, Volume= 2,831.953 af
Outflow = 8,145.94 cfs @ 40.58 hrs, Volume= 2,825.435 af, Atten= 5%, Lag= 20.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.67 fps, Min. Travel Time= 21.0 min
Avg. Velocity = 3.98 fps, Avg. Travel Time= 45.7 min

Peak Storage= 10,317,196 cf @ 40.58 hrs
Average Depth at Peak Storage= 13.12'
Bank-Full Depth= 40.00' Flow Area= 13,320.0 sf, Capacity= 219,014.09 cfs

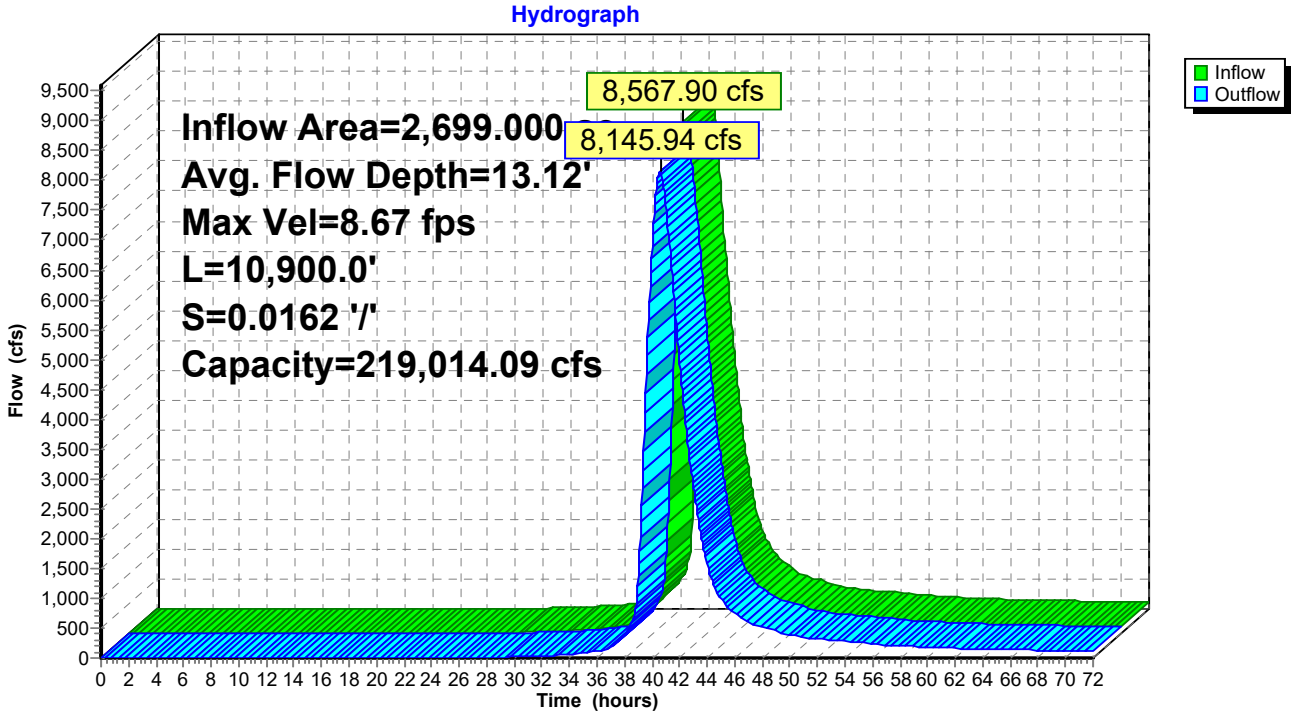
Custom cross-section, Length= 10,900.0' Slope= 0.0162 '/'
Flow calculated by Segment Subdivision method
Inlet Invert= 602.00', Outlet Invert= 425.42'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
550.00	642.00	0.00		
800.00	622.00	20.00	0.100	
983.00	608.00	34.00	0.100	
995.00	602.00	40.00	0.060	
1,005.00	602.00	40.00	0.060	
1,017.00	608.00	34.00	0.060	
1,150.00	622.00	20.00	0.100	
1,250.00	642.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
6.00	132.0	36.8	1,438,800	1,062.78
20.00	2,820.0	354.1	30,738,000	27,807.57
40.00	13,320.0	706.9	145,188,000	219,014.09

Reach O-E: Openaka to Estling



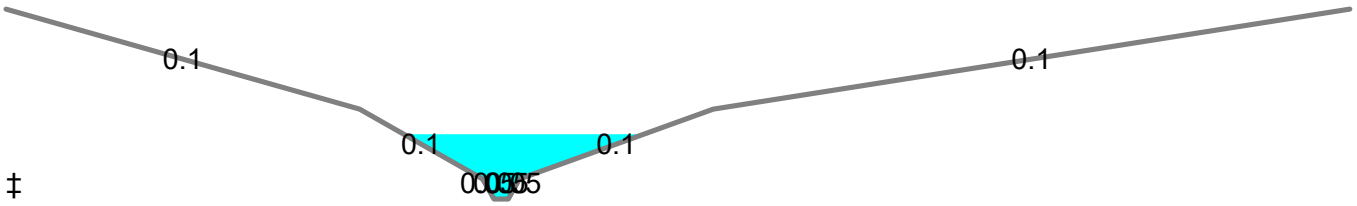
Summary for Reach S-O: Shongum to Openaka

Inflow Area = 1,977.000 ac, 9.76% Impervious, Inflow Depth > 12.30" for 0.5 PMP event
Inflow = 7,049.39 cfs @ 40.25 hrs, Volume= 2,025.807 af
Outflow = 6,973.98 cfs @ 40.38 hrs, Volume= 2,024.155 af, Atten= 1%, Lag= 7.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 7.34 fps, Min. Travel Time= 7.3 min
Avg. Velocity = 5.02 fps, Avg. Travel Time= 10.6 min

Peak Storage= 3,040,890 cf @ 40.38 hrs
Average Depth at Peak Storage= 12.98'
Bank-Full Depth= 38.00' Flow Area= 14,004.0 sf, Capacity= 155,556.64 cfs

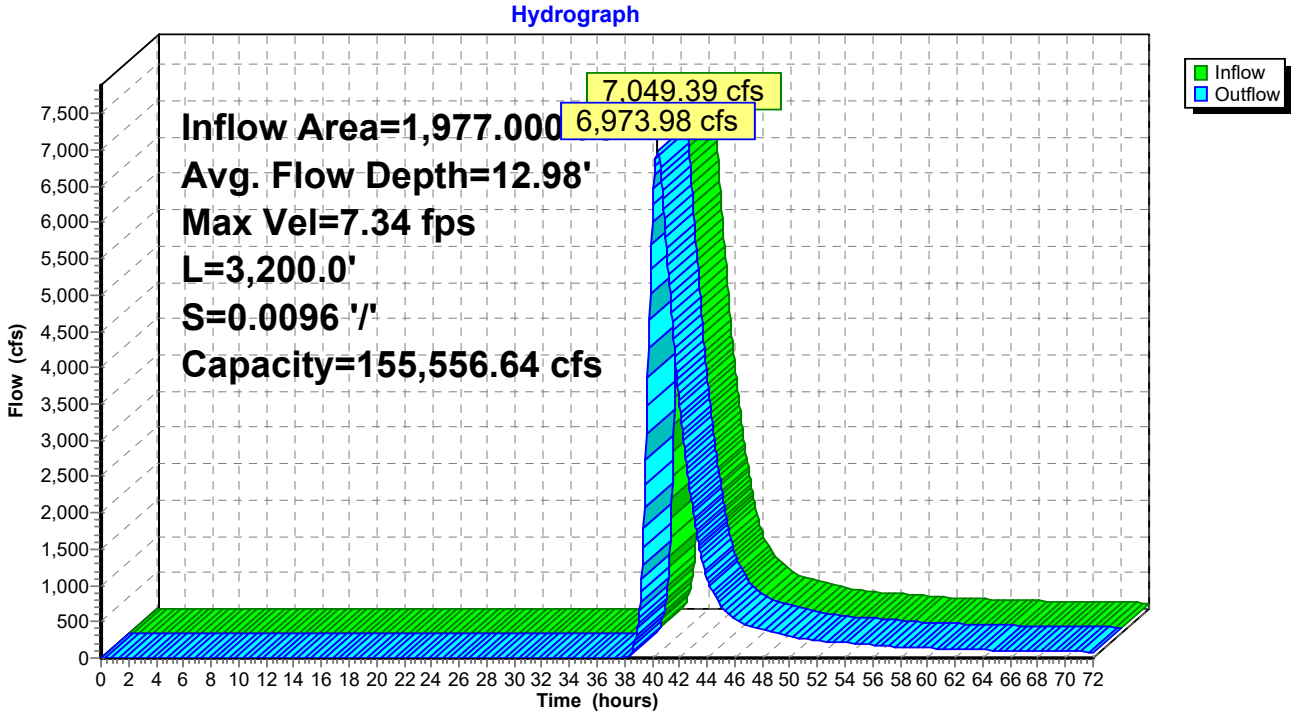
Custom cross-section, Length= 3,200.0' Slope= 0.0096 '/' (102 Elevation Intervals)
Flow calculated by Segment Subdivision method
Inlet Invert= 689.00', Outlet Invert= 658.28'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
650.00	727.00	0.00		
900.00	707.00	20.00	0.100	
987.00	693.00	34.00	0.100	
995.00	689.00	38.00	0.050	
1,005.00	689.00	38.00	0.050	
1,013.00	693.00	34.00	0.050	
1,150.00	707.00	20.00	0.100	
1,600.00	727.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
4.00	72.0	27.9	230,400	430.82
18.00	2,004.0	253.7	6,412,800	16,303.00
38.00	14,004.0	955.0	44,812,800	155,556.64

Reach S-O: Shongum to Openaka



Summary for Pond DBD: Woidt Den Brook Dam

Inflow Area = 4,810.000 ac, 9.94% Impervious, Inflow Depth > 13.16" for 0.5 PMP event
Inflow = 12,245.83 cfs @ 40.46 hrs, Volume= 5,275.338 af
Outflow = 9,221.11 cfs @ 41.50 hrs, Volume= 5,267.856 af, Atten= 25%, Lag= 62.2 min
Primary = 9,221.11 cfs @ 41.50 hrs, Volume= 5,267.856 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 502.50' Surf.Area= 4.640 ac Storage= 8.120 af
Peak Elev= 513.38' @ 41.50 hrs Surf.Area= 174.891 ac Storage= 739.796 af (731.676 af above start)

Plug-Flow detention time= 46.4 min calculated for 5,256.086 af (100% of inflow)
Center-of-Mass det. time= 38.4 min (2,686.5 - 2,648.1)

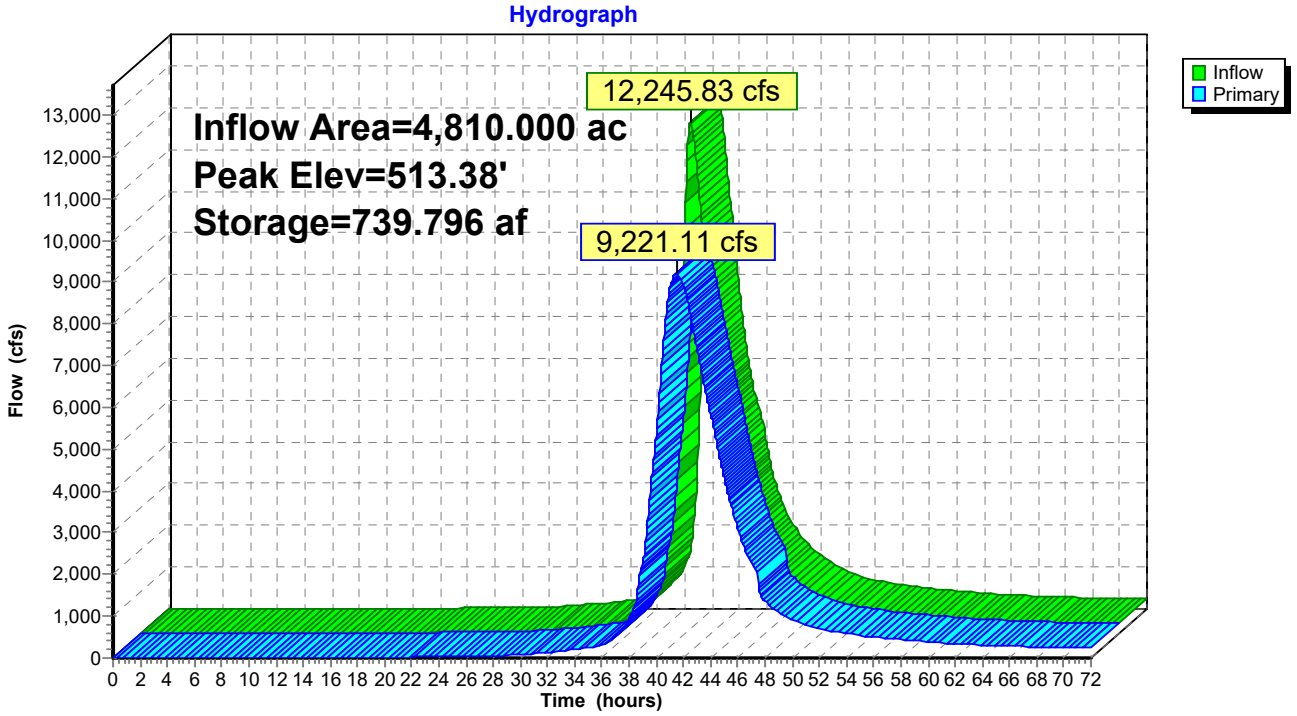
Volume	Invert	Avail.Storage	Storage Description
#1	499.00'	2,888.123 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
499.00	0.000	0.000	0.000
502.50	4.640	8.120	8.120
507.90	8.500	35.478	43.598
508.00	82.000	4.525	48.123
520.00	289.000	2,226.000	2,274.123
522.00	325.000	614.000	2,888.123

Device	Routing	Invert	Outlet Devices
#1	Primary	502.50'	**See Woidt HEC-1 - Half Flows - Extrapolated X 2.00** Elev. (feet) 502.50 503.50 504.50 505.50 506.50 507.50 508.50 509.50 510.50 511.50 512.50 513.50 514.50 515.50 516.50 517.50 518.50 Disch. (cfs) 0.000 64.000 182.500 371.000 592.000 855.500 1,254.000 1,828.500 2,440.500 3,124.500 3,872.500 4,706.500 5,766.500 6,649.000 7,575.000 8,513.000 9,506.500

Primary OutFlow Max=9,220.96 cfs @ 41.50 hrs HW=513.38' (Free Discharge)
↑**1=See Woidt HEC-1 - Half Flows - Extrapolated** (Custom Controls 9,220.96 cfs)

Pond DBD: Woidt Den Brook Dam



Summary for Pond ELD: Updated Estling Lake Dam

Inflow Area = 4,198.000 ac, 9.79% Impervious, Inflow Depth > 13.16" for 0.5 PMP event
Inflow = 13,769.47 cfs @ 39.69 hrs, Volume= 4,602.887 af
Outflow = 11,219.43 cfs @ 40.51 hrs, Volume= 4,486.009 af, Atten= 19%, Lag= 49.2 min
Primary = 6,540.02 cfs @ 40.51 hrs, Volume= 3,940.737 af
Secondary = 4,230.03 cfs @ 40.51 hrs, Volume= 510.318 af
Tertiary = 449.38 cfs @ 40.51 hrs, Volume= 34.954 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 514.70' Surf.Area= 72.176 ac Storage= 418.057 af
Peak Elev= 527.26' @ 40.51 hrs Surf.Area= 105.071 ac Storage= 1,525.198 af (1,107.141 af above start)

Plug-Flow detention time= 282.8 min calculated for 4,065.130 af (88% of inflow)
Center-of-Mass det. time= 117.0 min (2,684.8 - 2,567.8)

Volume	Invert	Avail.Storage	Storage Description
#1	504.00'	3,083.917 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
504.00	0.181	0.000	0.000
505.00	6.019	3.100	3.100
506.00	13.430	9.725	12.824
507.00	22.330	17.880	30.704
508.00	30.571	26.450	57.155
509.00	38.814	34.692	91.847
510.00	45.995	42.404	134.252
511.00	53.600	49.798	184.049
512.00	59.120	56.360	240.409
513.00	64.348	61.734	302.143
514.00	68.797	66.572	368.716
515.00	73.624	71.210	439.926
516.70	76.200	127.350	567.277
520.00	85.400	266.640	833.917
540.00	139.600	2,250.000	3,083.917

Device	Routing	Invert	Outlet Devices
#1	Primary	514.70'	**Woidt Culvert Flows** Elev. (feet) 514.70 516.70 517.70 518.70 519.70 520.70 521.70 522.70 523.70 525.00 526.00 526.50 527.00 527.50 528.00 528.50 529.00 Disch. (cfs) 0.000 267.000 511.000 883.000 1,350.000 1,886.000 2,530.000 3,240.000 4,299.000 5,100.000 6,118.000 6,247.000 6,375.000 6,694.000 7,013.000 7,268.000 7,523.000
#2	Secondary	525.60'	**Western Overtopping from HEC-RAS - Half Flows X 2.00** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 50.000 100.000 200.000 300.000 400.000

500.000 747.000 986.000 1,423.000 1,840.000 2,245.000
2,637.000 3,021.000 3,401.000 3,773.000 4,142.000 4,503.000
4,858.000 5,212.000 5,553.000 5,892.000 6,227.000 6,562.000
6,856.000 7,185.000 7,525.000 7,857.000 8,347.000 8,655.000
8,962.000

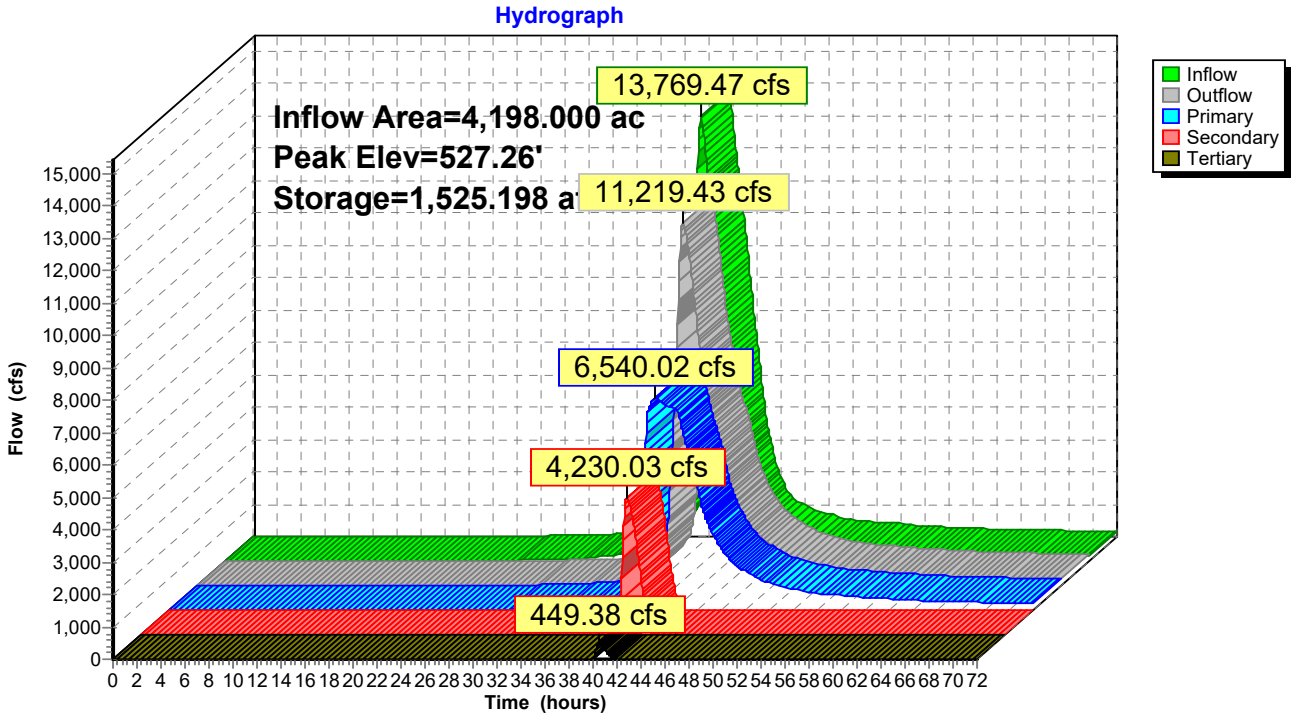
#3	Tertiary	525.60'	**Eastern Embankment Overtopping from HEC-RAS** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 0.000 0.000 0.000 0.000 0.000 0.000 6.000 28.000 154.000 319.000 511.000 726.000 958.000 1,197.000 1,453.000 1,717.000 1,993.000 2,284.000 2,577.000 2,894.000 3,216.000 3,545.000 3,876.000 4,289.000 4,631.000 4,950.000 5,286.000 5,307.000 5,690.000 6,076.000

Primary OutFlow Max=6,539.68 cfs @ 40.51 hrs HW=527.26' TW=512.30' (Dynamic Tailwater)
└─**1=Woidt Culvert Flows** (Custom Controls 6,539.68 cfs)

Secondary OutFlow Max=4,227.39 cfs @ 40.51 hrs HW=527.26' TW=512.30' (Dynamic Tailwater)
└─**2=Western Overtopping from HEC-RAS - Half Flows**(Custom Controls 4,227.39 cfs)

Tertiary OutFlow Max=448.75 cfs @ 40.51 hrs HW=527.26' TW=512.30' (Dynamic Tailwater)
└─**3=Eastern Embankment Overtopping from HEC-RAS**(Custom Controls 448.75 cfs)

Pond ELD: Updated Estling Lake Dam



Summary for Pond OLD: Killam Openaka Lake Dam

Inflow Area = 2,699.000 ac, 9.08% Impervious, Inflow Depth > 12.62" for 0.5 PMP event
Inflow = 8,581.03 cfs @ 40.19 hrs, Volume= 2,837.385 af
Outflow = 8,567.90 cfs @ 40.25 hrs, Volume= 2,831.953 af, Atten= 0%, Lag= 3.3 min
Primary = 8,567.90 cfs @ 40.25 hrs, Volume= 2,831.953 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 670.00' Surf.Area= 0.000 ac Storage= 49.400 af
Peak Elev= 676.58' @ 40.25 hrs Surf.Area= 0.000 ac Storage= 109.753 af (60.353 af above start)

Plug-Flow detention time= 51.5 min calculated for 2,782.553 af (98% of inflow)
Center-of-Mass det. time= 8.9 min (2,608.6 - 2,599.7)

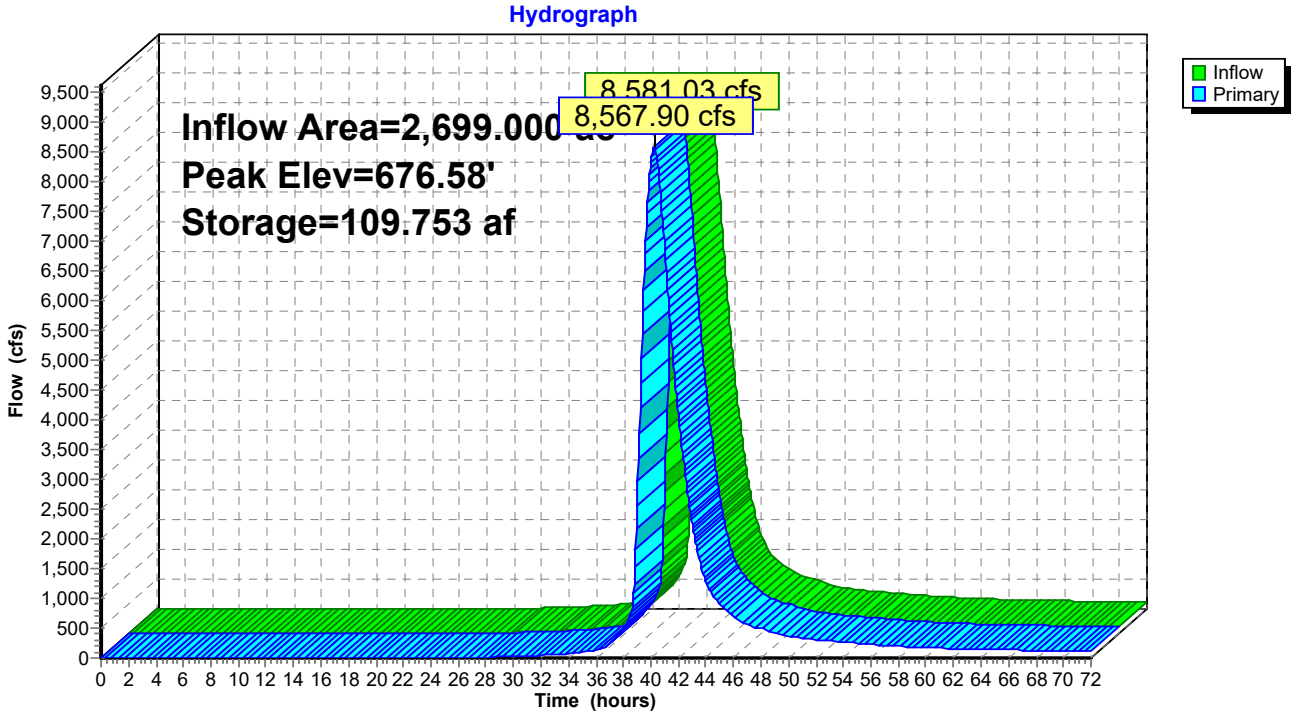
Volume	Invert	Avail.Storage	Storage Description
#1	657.43'	156.800 af	**See Killam Report** Listed below

Elevation (feet)	Cum.Store (acre-feet)
657.43	0.000
658.00	0.600
670.00	49.400
672.00	63.300
676.00	101.700
680.00	156.800

Device	Routing	Invert	Outlet Devices
#1	Primary	670.00'	**See Killam Report** Elev. (feet) 670.00 670.50 671.00 671.50 672.00 673.37 673.66 673.88 674.06 674.22 674.37 674.50 674.63 674.75 674.87 674.98 675.08 675.19 675.29 675.39 675.48 675.57 675.66 675.74 675.82 675.90 675.98 676.06 676.14 676.21 676.29 676.36 676.43 Disch. (cfs) 0.000 54.000 154.000 282.000 434.000 1,150.000 1,476.000 1,774.000 2,057.000 2,332.000 2,603.000 2,866.000 3,130.000 3,390.000 3,651.000 3,907.000 4,159.000 4,416.000 4,669.000 4,922.000 5,170.000 5,419.000 5,668.000 5,912.000 6,157.000 6,401.000 6,646.000 6,891.000 7,137.000 7,377.000 7,623.000 7,894.000 8,104.000

Primary OutFlow Max=8,566.99 cfs @ 40.25 hrs HW=676.58' TW=614.88' (Dynamic Tailwater)
↑—**1=See Killam Report** (Custom Controls 8,566.99 cfs)

Pond OLD: Killam Openaka Lake Dam



Summary for Pond SLD: Entech Shongum Lake

Inflow Area = 1,977.000 ac, 9.76% Impervious, Inflow Depth > 14.32" for 0.5 PMP event
Inflow = 10,645.17 cfs @ 39.70 hrs, Volume= 2,359.350 af
Outflow = 7,049.39 cfs @ 40.25 hrs, Volume= 2,025.807 af, Atten= 34%, Lag= 33.0 min
Primary = 7,049.39 cfs @ 40.25 hrs, Volume= 2,025.807 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 704.55' @ 40.27 hrs Surf.Area= 140.413 ac Storage= 931.549 af

Plug-Flow detention time= 283.2 min calculated for 2,024.401 af (86% of inflow)
Center-of-Mass det. time= 157.2 min (2,640.8 - 2,483.7)

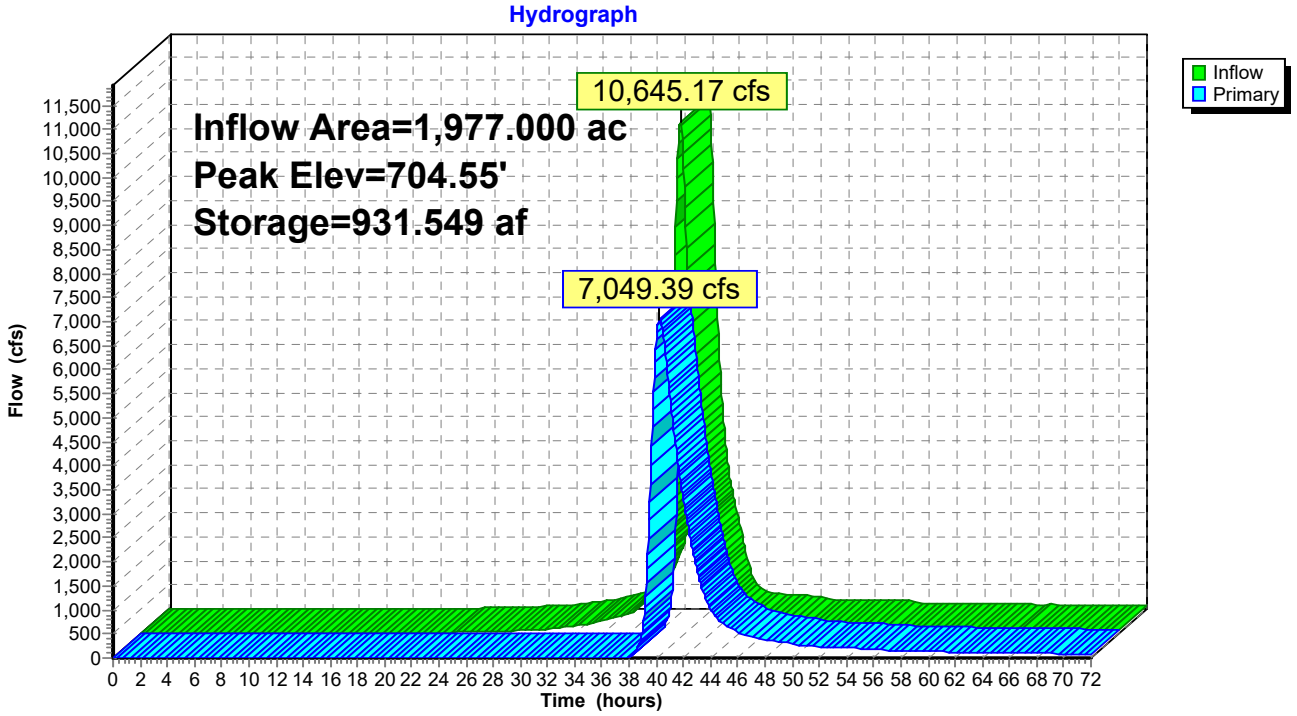
Volume	Invert	Avail.Storage	Storage Description
#1	689.20'	1,160.790 af	**Entech 2002 Report Stage-Area (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
689.20	0.000	0.000	0.000
691.50	15.800	18.170	18.170
693.20	24.300	34.085	52.255
694.80	43.000	53.840	106.095
698.10	65.600	179.190	285.285
699.00	74.300	62.955	348.240
700.00	89.000	81.650	429.890
701.00	100.700	94.850	524.740
702.00	105.400	103.050	627.790
703.00	114.100	109.750	737.540
704.00	127.200	120.650	858.190
705.00	151.300	139.250	997.440
706.00	175.400	163.350	1,160.790

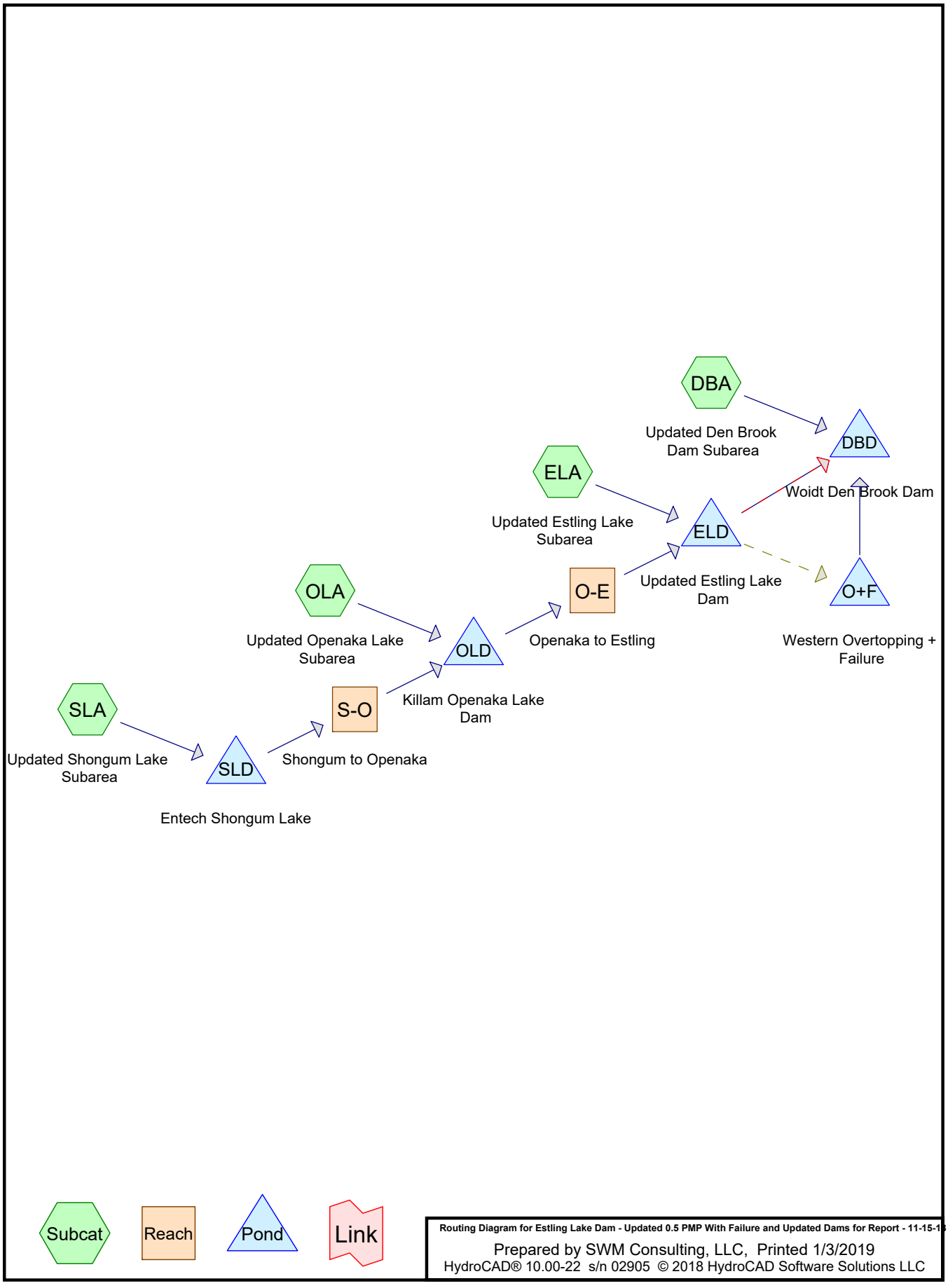
Device	Routing	Invert	Outlet Devices
#1	Primary	689.20'	**Entech 2002 Report SQSE Data** Elev. (feet) 689.20 698.10 698.50 699.00 699.60 700.00 700.50 701.00 702.00 703.00 704.00 705.00 706.00 Disch. (cfs) 0.000 0.000 30.500 118.200 291.100 435.300 736.900 1,092.300 2,099.200 3,284.900 4,829.600 6,862.900 9,326.600
#2	Primary	700.50'	**55.0' long x 10.0' breadth Entech 2002 Report ST Data** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 2.00 3.00 4.00 5.00 Coef. (English) 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68

Primary OutFlow Max=7,040.87 cfs @ 40.25 hrs HW=704.55' TW=701.91' (Dynamic Tailwater)
1=Entech 2002 Report SQSE Data (Custom Controls 5,942.65 cfs)
2=Entech 2002 Report ST Data (Weir Controls 1,098.22 cfs @ 4.93 fps)

Pond SLD: Entech Shongum Lake



Updated 2018 Analysis HydroCAD Model With Dam Failure


DBA
Updated Den Brook Dam Subarea
DBD
ELA
Updated Estling Lake Subarea
ELD
Woidt Den Brook Dam
OLA
Updated Openaka Lake Subarea
O-E
Updated Estling Lake Dam
O+F
OLD
Openaka to Estling
Western Overtopping + Failure
SLA
Updated Shongum Lake Subarea
S-O
Killam Openaka Lake Dam
SLD
Shongum to Openaka
Entech Shongum Lake
Subcat
Reach
Pond
Link
Routing Diagram for Estling Lake Dam - Updated 0.5 PMP With Failure and Updated Dams for Report - 11-15-1
Prepared by SWM Consulting, LLC, Printed 1/3/2019
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Summary for Subcatchment DBA: Updated Den Brook Dam Subarea

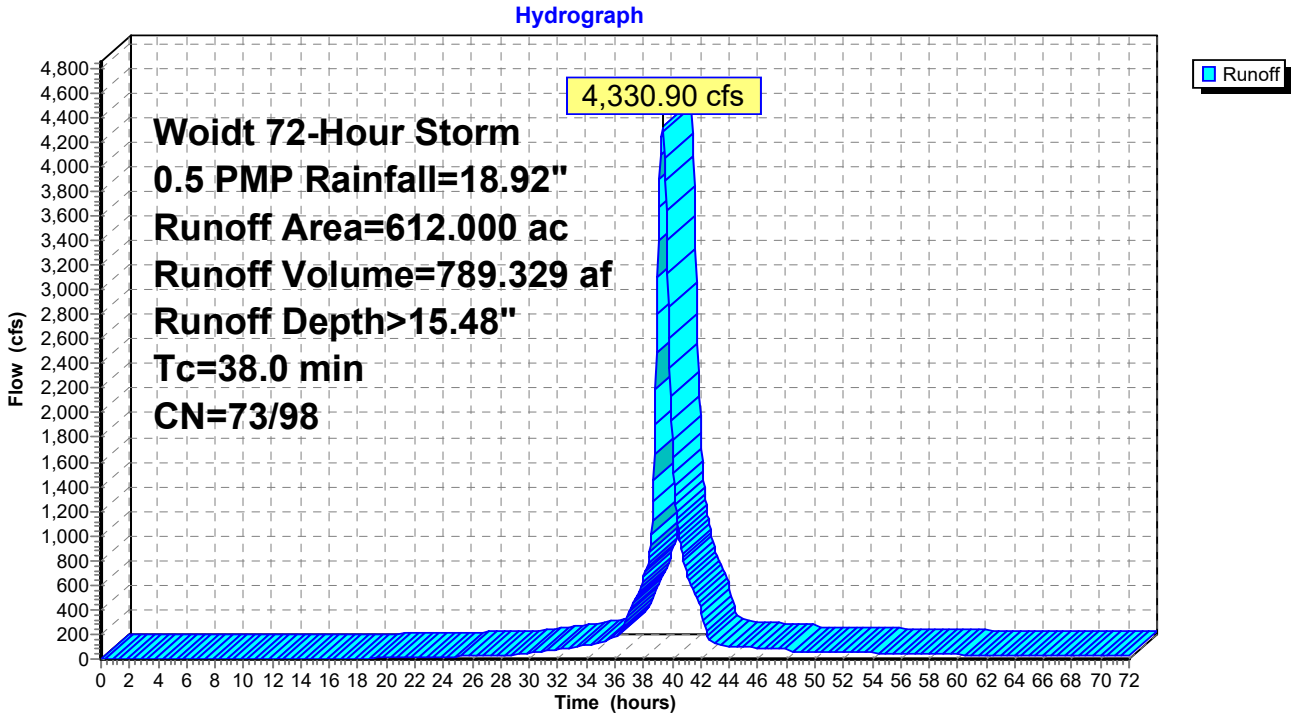
Runoff = 4,330.90 cfs @ 39.34 hrs, Volume= 789.329 af, Depth>15.48"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	545.000	73	Pervious - See Excel
*	67.000	98	Impervious - See Excel
	612.000	76	Weighted Average
	545.000	73	89.05% Pervious Area
	67.000	98	10.95% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.0					**Direct Entry, See Woidt HEC-1**

Subcatchment DBA: Updated Den Brook Dam Subarea



Summary for Subcatchment ELA: Updated Estling Lake Subarea

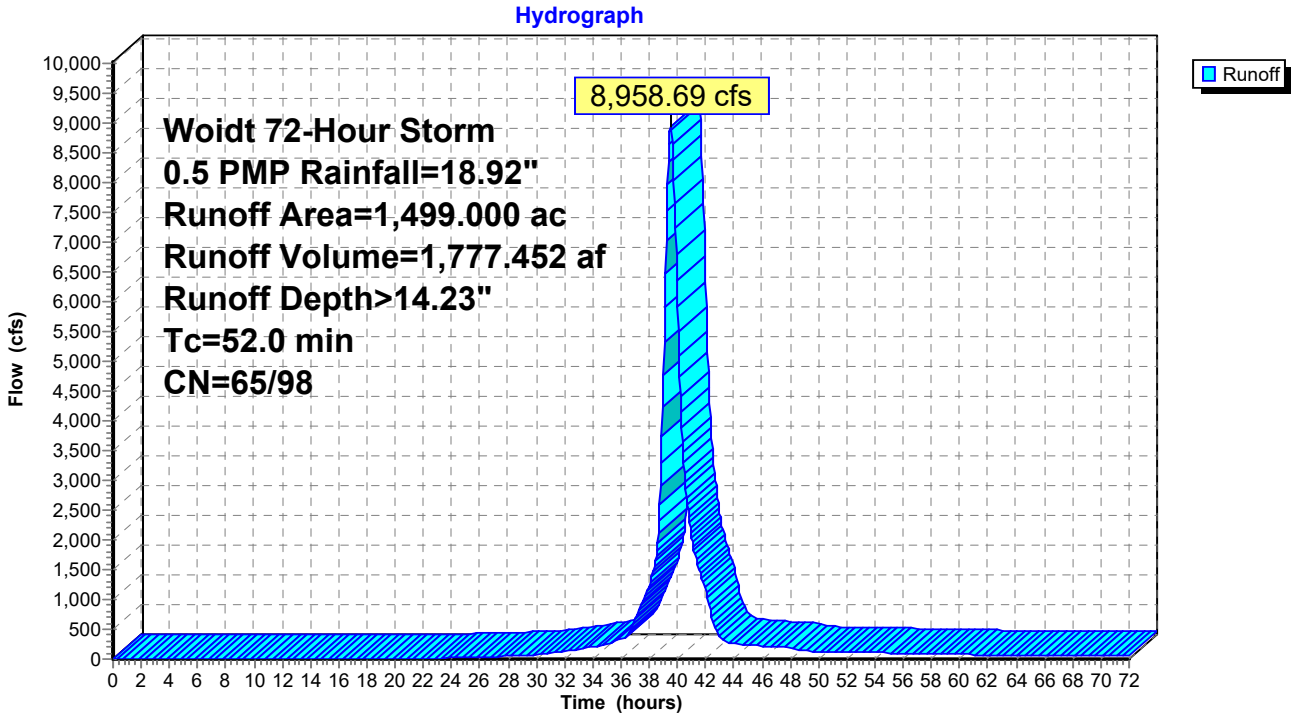
Runoff = 8,958.69 cfs @ 39.52 hrs, Volume= 1,777.452 af, Depth>14.23"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,333.000	65	Pervious - See Excel
*	166.000	98	Impervious - See Excel
	1,499.000	69	Weighted Average
	1,333.000	65	88.93% Pervious Area
	166.000	98	11.07% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
52.0					**Direct Entry, See Woidt HEC-1**

Subcatchment ELA: Updated Estling Lake Subarea



Summary for Subcatchment OLA: Updated Openaka Lake Subarea

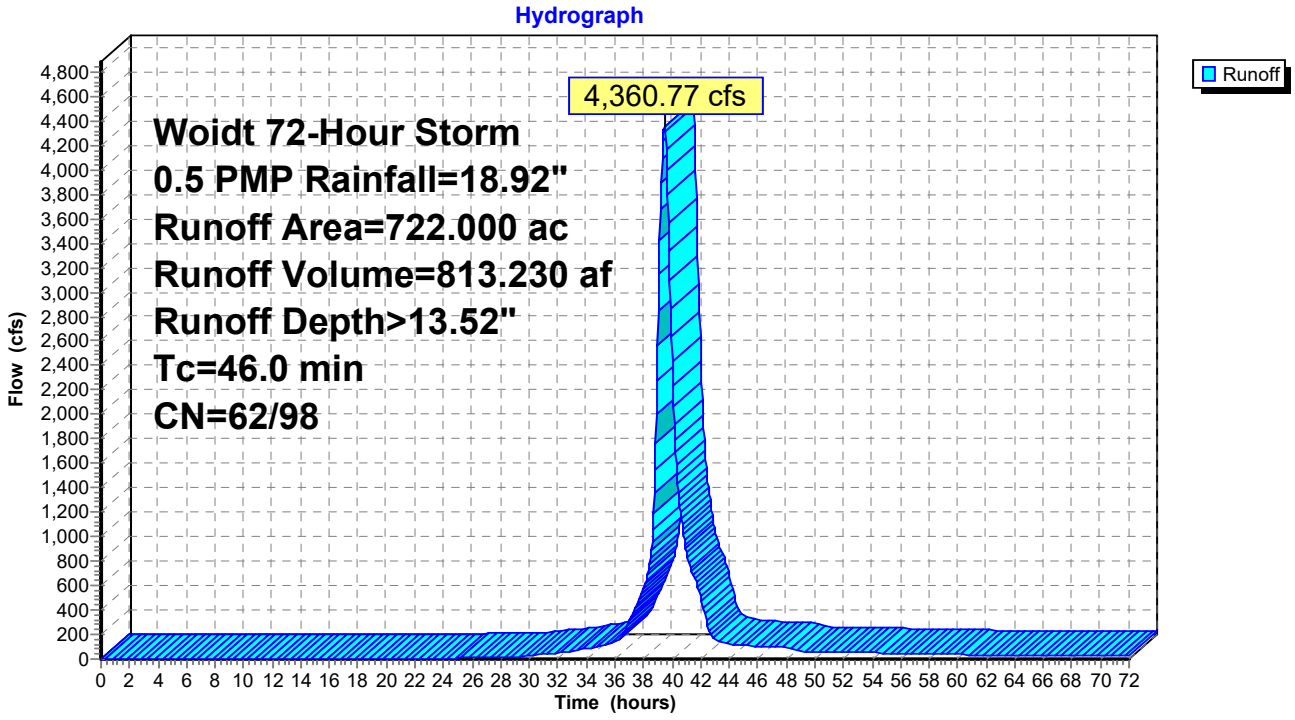
Runoff = 4,360.77 cfs @ 39.46 hrs, Volume= 813.230 af, Depth>13.52"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	670.000	62	Pervious - See Excel
*	52.000	98	Impervioius - See Excel
	722.000	65	Weighted Average
	670.000	62	92.80% Pervious Area
	52.000	98	7.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
46.0					**Direct Entry, See Woidt HEC-1**

Subcatchment OLA: Updated Openaka Lake Subarea



Summary for Subcatchment SLA: Updated Shongum Lake Subarea

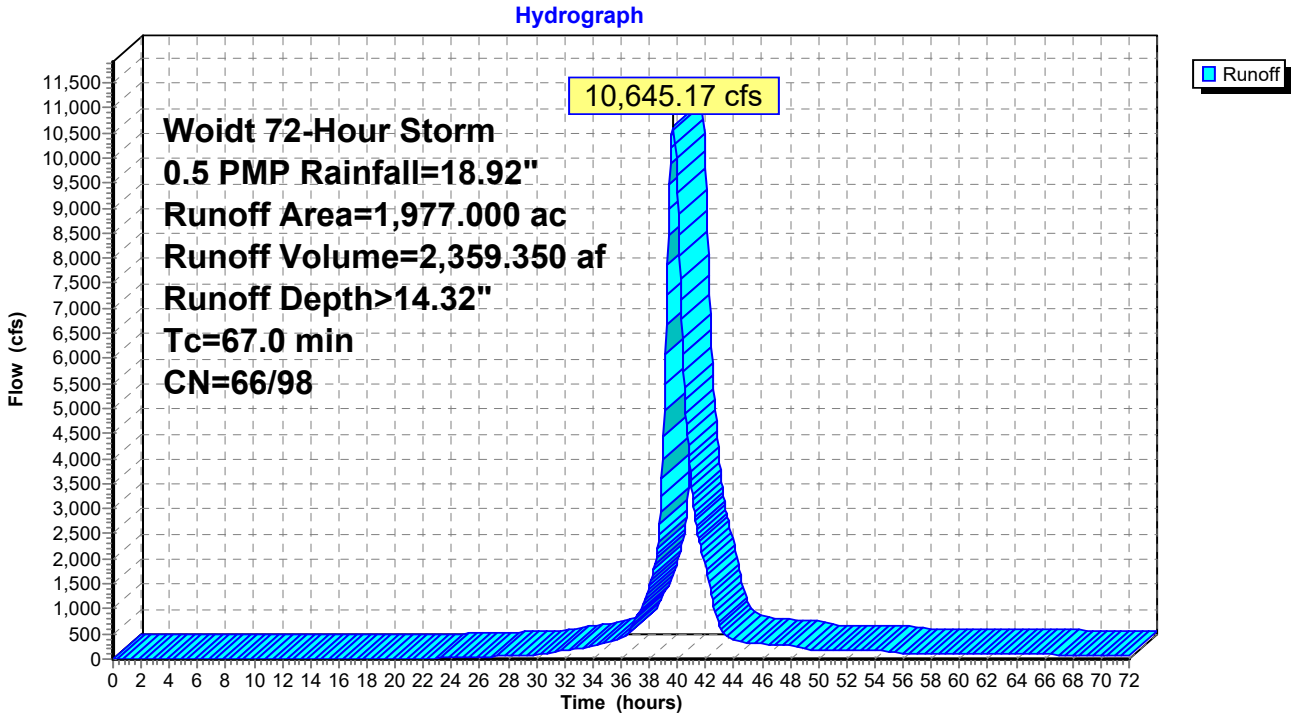
Runoff = 10,645.17 cfs @ 39.70 hrs, Volume= 2,359.350 af, Depth>14.32"

Runoff by SCS TR-20 method, UH=SCS, Split Pervious/Imperv. UI as Pervious, Time Span= 0.00-72.00 hrs, dt= 0.05
Woidt 72-Hour Storm 0.5 PMP Rainfall=18.92"

	Area (ac)	CN	Description
*	1,784.000	66	Pervious - See Excel
*	193.000	98	Impervious - See Excel
	1,977.000	69	Weighted Average
	1,784.000	66	90.24% Pervious Area
	193.000	98	9.76% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
67.0					**Direct Entry, See Woidt HEC-1**

Subcatchment SLA: Updated Shongum Lake Subarea



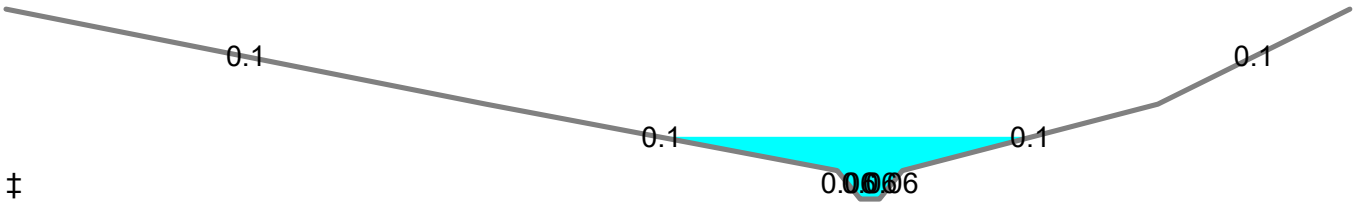
Summary for Reach O-E: Openaka to Estling

Inflow Area = 2,699.000 ac, 9.08% Impervious, Inflow Depth > 12.59" for 0.5 PMP event
Inflow = 8,567.90 cfs @ 40.25 hrs, Volume= 2,831.953 af
Outflow = 8,145.94 cfs @ 40.58 hrs, Volume= 2,825.435 af, Atten= 5%, Lag= 20.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.67 fps, Min. Travel Time= 21.0 min
Avg. Velocity = 3.98 fps, Avg. Travel Time= 45.7 min

Peak Storage= 10,317,196 cf @ 40.58 hrs
Average Depth at Peak Storage= 13.12'
Bank-Full Depth= 40.00' Flow Area= 13,320.0 sf, Capacity= 219,014.09 cfs

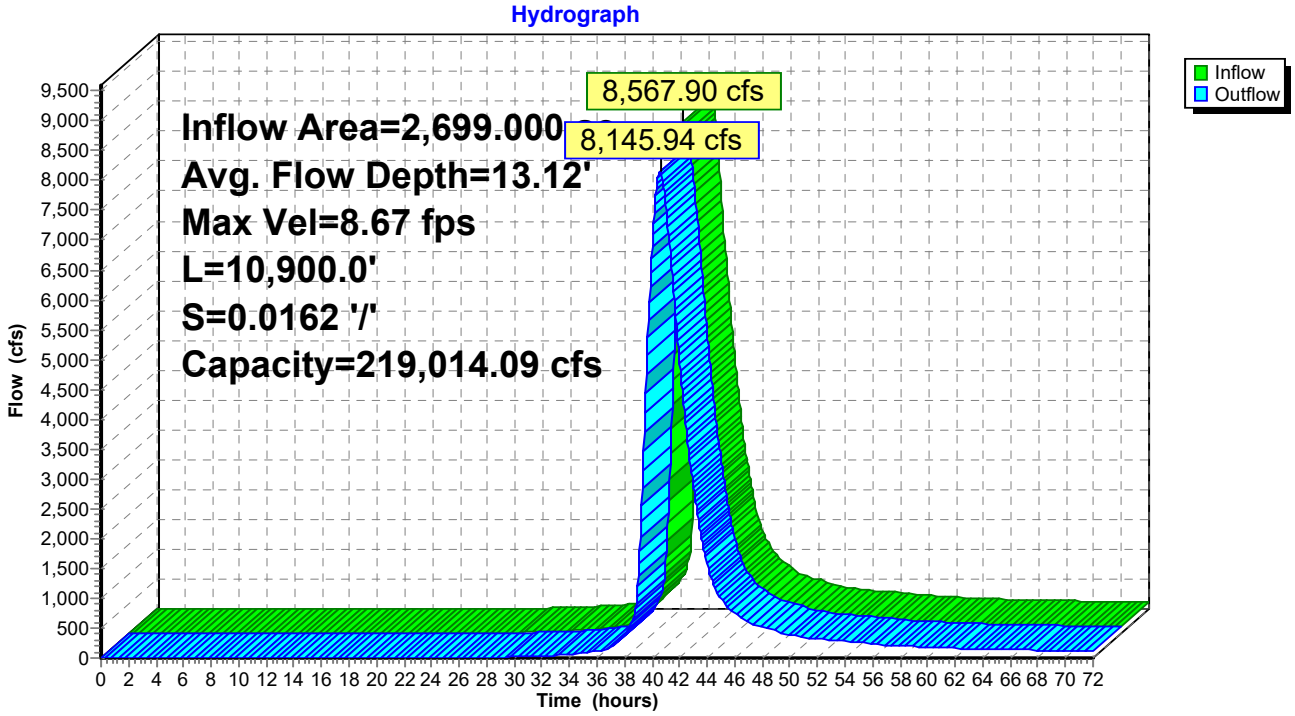
Custom cross-section, Length= 10,900.0' Slope= 0.0162 '/'
Flow calculated by Segment Subdivision method
Inlet Invert= 602.00', Outlet Invert= 425.42'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
550.00	642.00	0.00		
800.00	622.00	20.00	0.100	
983.00	608.00	34.00	0.100	
995.00	602.00	40.00	0.060	
1,005.00	602.00	40.00	0.060	
1,017.00	608.00	34.00	0.060	
1,150.00	622.00	20.00	0.100	
1,250.00	642.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
6.00	132.0	36.8	1,438,800	1,062.78
20.00	2,820.0	354.1	30,738,000	27,807.57
40.00	13,320.0	706.9	145,188,000	219,014.09

Reach O-E: Openaka to Estling



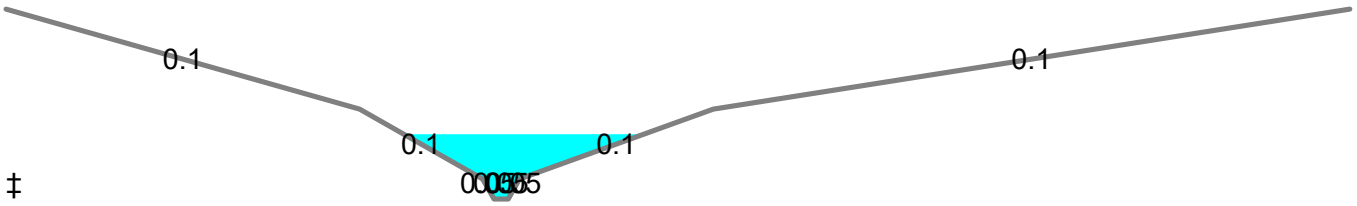
Summary for Reach S-O: Shongum to Openaka

Inflow Area = 1,977.000 ac, 9.76% Impervious, Inflow Depth > 12.30" for 0.5 PMP event
Inflow = 7,049.39 cfs @ 40.25 hrs, Volume= 2,025.807 af
Outflow = 6,973.98 cfs @ 40.38 hrs, Volume= 2,024.155 af, Atten= 1%, Lag= 7.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Max. Velocity= 7.34 fps, Min. Travel Time= 7.3 min
Avg. Velocity = 5.02 fps, Avg. Travel Time= 10.6 min

Peak Storage= 3,040,890 cf @ 40.38 hrs
Average Depth at Peak Storage= 12.98'
Bank-Full Depth= 38.00' Flow Area= 14,004.0 sf, Capacity= 155,556.64 cfs

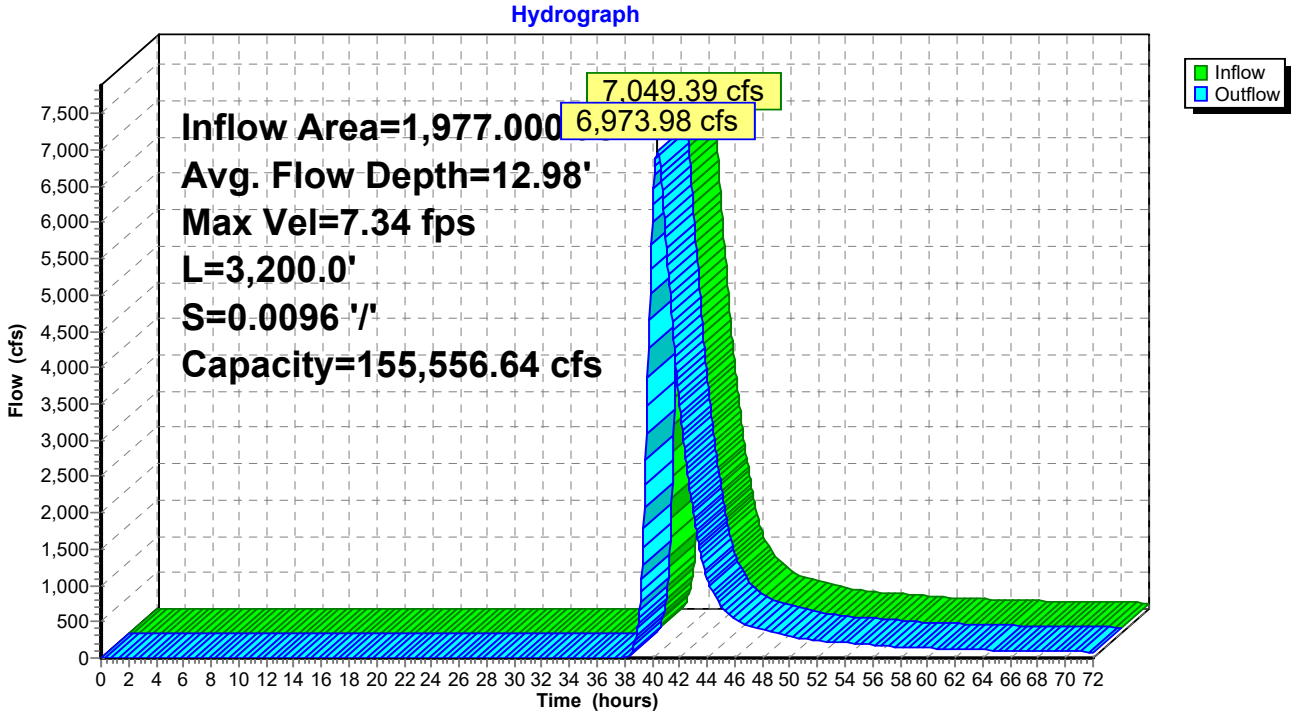
Custom cross-section, Length= 3,200.0' Slope= 0.0096 '/' (102 Elevation Intervals)
Flow calculated by Segment Subdivision method
Inlet Invert= 689.00', Outlet Invert= 658.28'



Offset (feet)	Elevation (feet)	Chan.Depth (feet)	n	Description
650.00	727.00	0.00		
900.00	707.00	20.00	0.100	
987.00	693.00	34.00	0.100	
995.00	689.00	38.00	0.050	
1,005.00	689.00	38.00	0.050	
1,013.00	693.00	34.00	0.050	
1,150.00	707.00	20.00	0.100	
1,600.00	727.00	0.00	0.100	

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	10.0	0	0.00
4.00	72.0	27.9	230,400	430.82
18.00	2,004.0	253.7	6,412,800	16,303.00
38.00	14,004.0	955.0	44,812,800	155,556.64

Reach S-O: Shongum to Openaka



Summary for Pond DBD: Woidt Den Brook Dam

Inflow Area = 4,810.000 ac, 9.94% Impervious, Inflow Depth > 14.25" for 0.5 PMP event
Inflow = 20,714.28 cfs @ 40.71 hrs, Volume= 5,711.494 af
Outflow = 12,077.83 cfs @ 41.54 hrs, Volume= 5,704.835 af, Atten= 42%, Lag= 49.7 min
Primary = 12,077.83 cfs @ 41.54 hrs, Volume= 5,704.835 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 502.50' Surf.Area= 4.640 ac Storage= 8.120 af
Peak Elev= 514.81' @ 41.54 hrs Surf.Area= 199.450 ac Storage= 1,006.275 af (998.155 af above start)

Plug-Flow detention time= 49.4 min calculated for 5,692.761 af (100% of inflow)
Center-of-Mass det. time= 42.2 min (2,655.3 - 2,613.1)

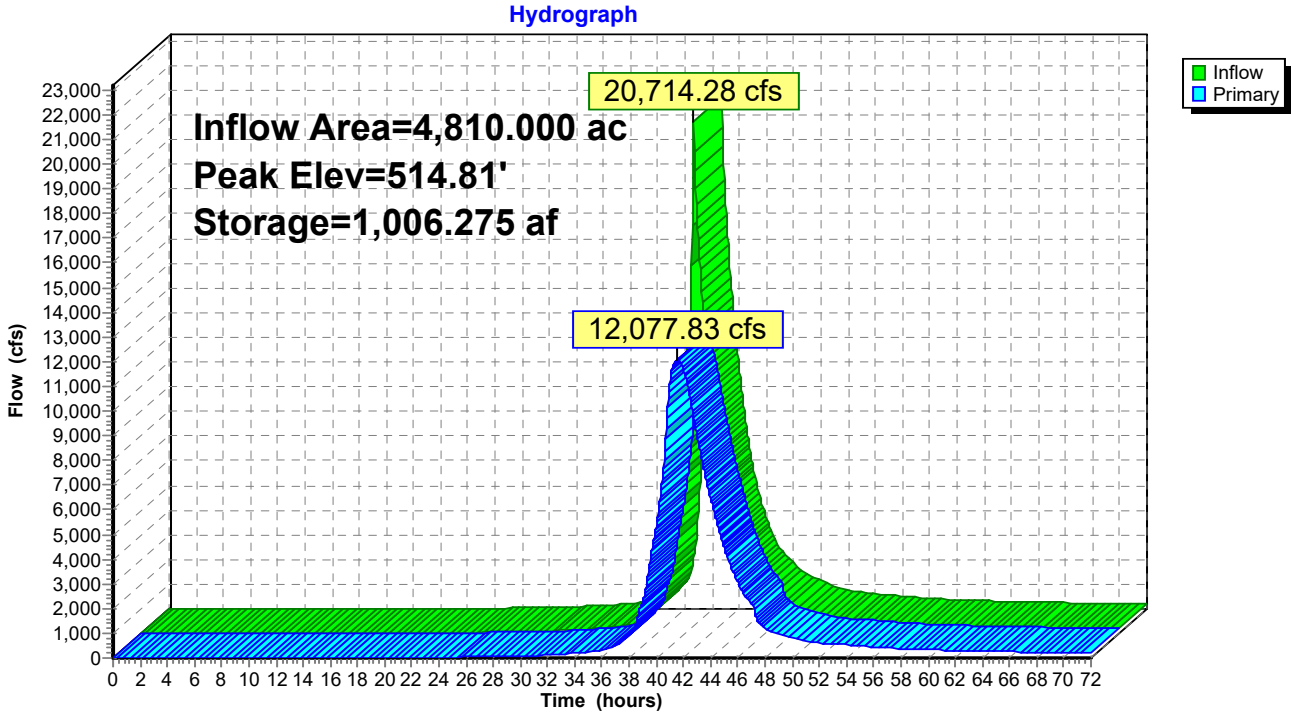
Volume	Invert	Avail.Storage	Storage Description
#1	499.00'	2,888.123 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
499.00	0.000	0.000	0.000
502.50	4.640	8.120	8.120
507.90	8.500	35.478	43.598
508.00	82.000	4.525	48.123
520.00	289.000	2,226.000	2,274.123
522.00	325.000	614.000	2,888.123

Device	Routing	Invert	Outlet Devices
#1	Primary	502.50'	**See Woidt HEC-1 - Half Flows - Extrapolated X 2.00** Elev. (feet) 502.50 503.50 504.50 505.50 506.50 507.50 508.50 509.50 510.50 511.50 512.50 513.50 514.50 515.50 516.50 517.50 518.50 Disch. (cfs) 0.000 64.000 182.500 371.000 592.000 855.500 1,254.000 1,828.500 2,440.500 3,124.500 3,872.500 4,706.500 5,766.500 6,649.000 7,575.000 8,513.000 9,506.500

Primary OutFlow Max=12,076.75 cfs @ 41.54 hrs HW=514.81' (Free Discharge)
1=See Woidt HEC-1 - Half Flows - Extrapolated (Custom Controls 12,076.75 cfs)

Pond DBD: Woidt Den Brook Dam



Summary for Pond ELD: Updated Estling Lake Dam

Inflow Area = 4,198.000 ac, 9.79% Impervious, Inflow Depth > 13.16" for 0.5 PMP event
Inflow = 13,769.47 cfs @ 39.69 hrs, Volume= 4,602.887 af
Outflow = 19,862.45 cfs @ 40.71 hrs, Volume= 4,922.165 af, Atten= 0%, Lag= 60.9 min
Primary = 6,537.49 cfs @ 40.44 hrs, Volume= 1,397.057 af
Secondary = 4,209.97 cfs @ 40.44 hrs, Volume= 192.336 af
Tertiary = 12,870.62 cfs @ 40.72 hrs, Volume= 3,332.772 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 514.70' Surf.Area= 72.176 ac Storage= 418.057 af
Peak Elev= 527.25' @ 40.44 hrs Surf.Area= 105.060 ac Storage= 1,524.781 af (1,106.725 af above start)

Plug-Flow detention time= 142.1 min calculated for 4,504.108 af (98% of inflow)
Center-of-Mass det. time= 73.1 min (2,640.9 - 2,567.8)

Volume	Invert	Avail.Storage	Storage Description
#1	504.00'	3,083.917 af	**See Woidt HEC-1 (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
504.00	0.181	0.000	0.000
505.00	6.019	3.100	3.100
506.00	13.430	9.725	12.824
507.00	22.330	17.880	30.704
508.00	30.571	26.450	57.155
509.00	38.814	34.692	91.847
510.00	45.995	42.404	134.252
511.00	53.600	49.798	184.049
512.00	59.120	56.360	240.409
513.00	64.348	61.734	302.143
514.00	68.797	66.572	368.716
515.00	73.624	71.210	439.926
516.70	76.200	127.350	567.277
520.00	85.400	266.640	833.917
540.00	139.600	2,250.000	3,083.917

Device	Routing	Invert	Outlet Devices
#1	Primary	514.70'	**Woidt Culvert Flows** Elev. (feet) 514.70 516.70 517.70 518.70 519.70 520.70 521.70 522.70 523.70 525.00 526.00 526.50 527.00 527.50 528.00 528.50 529.00 Disch. (cfs) 0.000 267.000 511.000 883.000 1,350.000 1,886.000 2,530.000 3,240.000 4,299.000 5,100.000 6,118.000 6,247.000 6,375.000 6,694.000 7,013.000 7,268.000 7,523.000
#2	Secondary	525.60'	**Western Overtopping from HEC-RAS - Half Flows X 2.00** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 50.000 100.000 200.000 300.000 400.000

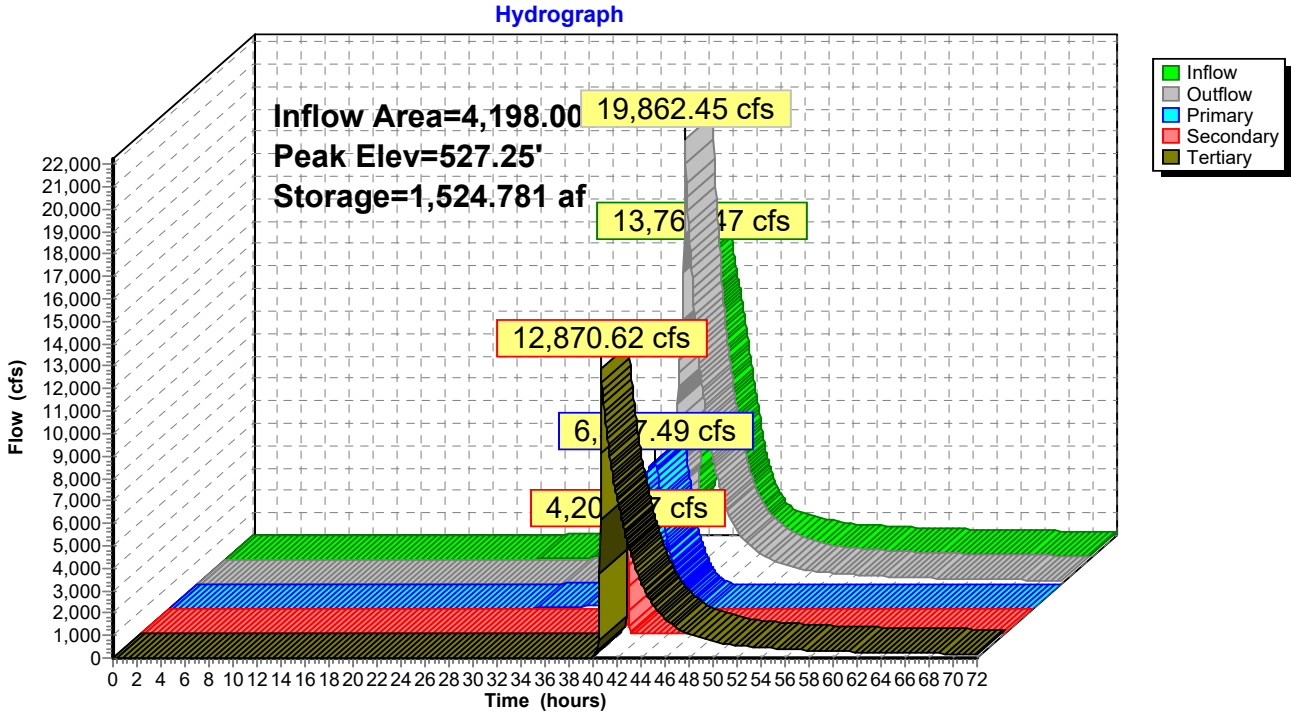
			500.000 747.000 986.000 1,423.000 1,840.000 2,245.000 2,637.000 3,021.000 3,401.000 3,773.000 4,142.000 4,503.000 4,858.000 5,212.000 5,553.000 5,892.000 6,227.000 6,562.000 6,856.000 7,185.000 7,525.000 7,857.000 8,347.000 8,655.000 8,962.000
#3	Tertiary	525.60'	**Eastern Embankment Overtopping from HEC-RAS** Elev. (feet) 525.60 525.92 526.02 526.17 526.29 526.38 526.46 526.63 526.75 526.97 527.15 527.31 527.46 527.60 527.72 527.83 527.93 528.03 528.13 528.22 528.30 528.38 528.46 528.53 528.59 528.67 528.74 528.81 528.89 528.95 529.02 Disch. (cfs) 0.000 0.000 0.000 0.000 0.000 0.000 0.000 6.000 28.000 154.000 319.000 511.000 726.000 958.000 1,197.000 1,453.000 1,717.000 1,993.000 2,284.000 2,577.000 2,894.000 3,216.000 3,545.000 3,876.000 4,289.000 4,631.000 4,950.000 5,286.000 5,307.000 5,690.000 6,076.000
#4	Tertiary	508.00'	**53.2 deg x 43.0' wide x 17.60' high Dam Breach at Spillway** C= 2.54 Top of breach = 525.60' Bottom of breach = 508.00' Breach starts at 527.25' WSE and develops over 0.25 hrs

Primary OutFlow Max=6,536.31 cfs @ 40.44 hrs HW=527.25' TW=512.12' (Dynamic Tailwater)
└**1=Woidt Culvert Flows** (Custom Controls 6,536.31 cfs)

Secondary OutFlow Max=4,200.61 cfs @ 40.44 hrs HW=527.25' TW=512.12' (Dynamic Tailwater)
└**2=Western Overtopping from HEC-RAS - Half Flows**(Custom Controls 4,200.61 cfs)

Tertiary OutFlow Max=12,417.66 cfs @ 40.72 hrs HW=526.32' TW=0.00' (Dynamic Tailwater)
├**3=Eastern Embankment Overtopping from HEC-RAS**(Custom Controls 0.00 cfs)
└**4=Dam Breach at Spillway** (Orifice Controls 12,417.66 cfs @ 13.62 fps)

Pond ELD: Updated Estling Lake Dam

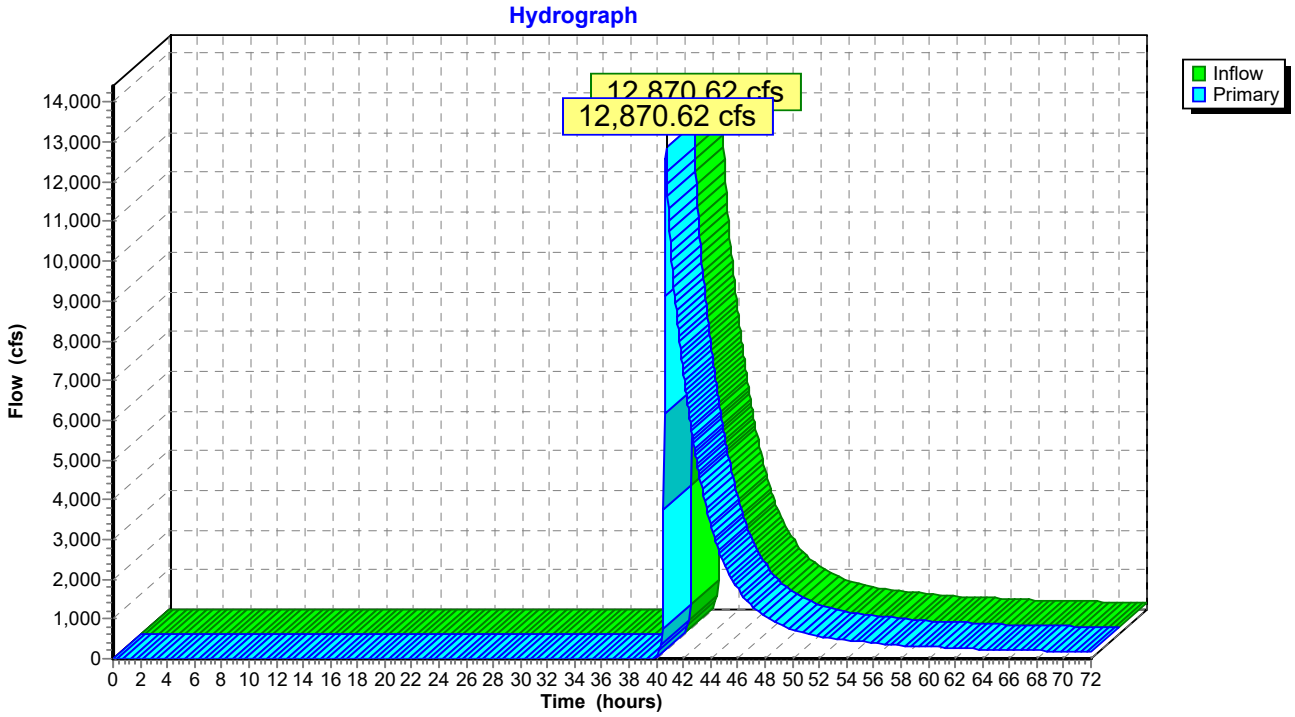


Summary for Pond O+F: Western Overtopping + Failure

Inflow = 12,870.62 cfs @ 40.72 hrs, Volume= 3,332.772 af
Primary = 12,870.62 cfs @ 40.72 hrs, Volume= 3,332.772 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Pond O+F: Western Overtopping + Failure



Summary for Pond OLD: Killam Openaka Lake Dam

Inflow Area = 2,699.000 ac, 9.08% Impervious, Inflow Depth > 12.62" for 0.5 PMP event
Inflow = 8,581.03 cfs @ 40.19 hrs, Volume= 2,837.385 af
Outflow = 8,567.90 cfs @ 40.25 hrs, Volume= 2,831.953 af, Atten= 0%, Lag= 3.3 min
Primary = 8,567.90 cfs @ 40.25 hrs, Volume= 2,831.953 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Starting Elev= 670.00' Surf.Area= 0.000 ac Storage= 49.400 af
Peak Elev= 676.58' @ 40.25 hrs Surf.Area= 0.000 ac Storage= 109.753 af (60.353 af above start)

Plug-Flow detention time= 51.5 min calculated for 2,782.553 af (98% of inflow)
Center-of-Mass det. time= 8.9 min (2,608.6 - 2,599.7)

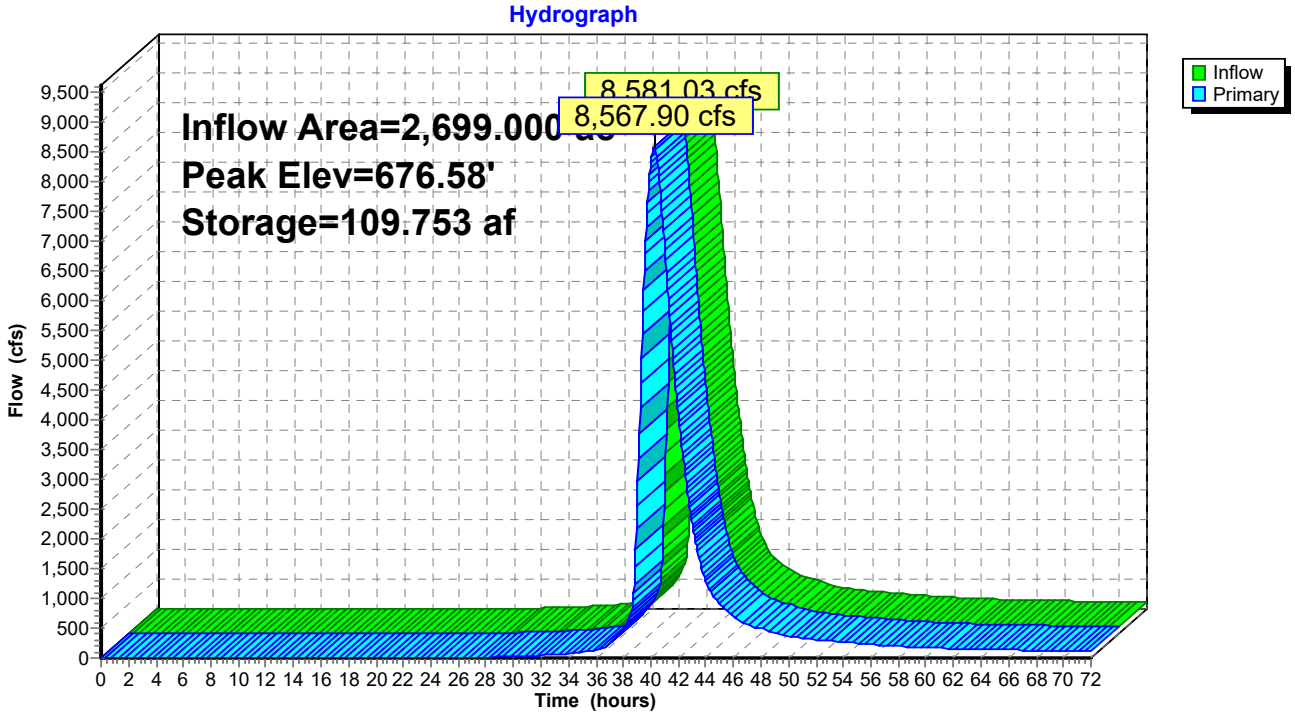
Volume	Invert	Avail.Storage	Storage Description
#1	657.43'	156.800 af	**See Killam Report** Listed below

Elevation (feet)	Cum.Store (acre-feet)
657.43	0.000
658.00	0.600
670.00	49.400
672.00	63.300
676.00	101.700
680.00	156.800

Device	Routing	Invert	Outlet Devices
#1	Primary	670.00'	**See Killam Report** Elev. (feet) 670.00 670.50 671.00 671.50 672.00 673.37 673.66 673.88 674.06 674.22 674.37 674.50 674.63 674.75 674.87 674.98 675.08 675.19 675.29 675.39 675.48 675.57 675.66 675.74 675.82 675.90 675.98 676.06 676.14 676.21 676.29 676.36 676.43 Disch. (cfs) 0.000 54.000 154.000 282.000 434.000 1,150.000 1,476.000 1,774.000 2,057.000 2,332.000 2,603.000 2,866.000 3,130.000 3,390.000 3,651.000 3,907.000 4,159.000 4,416.000 4,669.000 4,922.000 5,170.000 5,419.000 5,668.000 5,912.000 6,157.000 6,401.000 6,646.000 6,891.000 7,137.000 7,377.000 7,623.000 7,894.000 8,104.000

Primary OutFlow Max=8,566.99 cfs @ 40.25 hrs HW=676.58' TW=614.88' (Dynamic Tailwater)
↑—**1=See Killam Report** (Custom Controls 8,566.99 cfs)

Pond OLD: Killam Openaka Lake Dam



Summary for Pond SLD: Entech Shongum Lake

Inflow Area = 1,977.000 ac, 9.76% Impervious, Inflow Depth > 14.32" for 0.5 PMP event
Inflow = 10,645.17 cfs @ 39.70 hrs, Volume= 2,359.350 af
Outflow = 7,049.39 cfs @ 40.25 hrs, Volume= 2,025.807 af, Atten= 34%, Lag= 33.0 min
Primary = 7,049.39 cfs @ 40.25 hrs, Volume= 2,025.807 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 704.55' @ 40.27 hrs Surf.Area= 140.413 ac Storage= 931.549 af

Plug-Flow detention time= 283.2 min calculated for 2,024.401 af (86% of inflow)
Center-of-Mass det. time= 157.2 min (2,640.8 - 2,483.7)

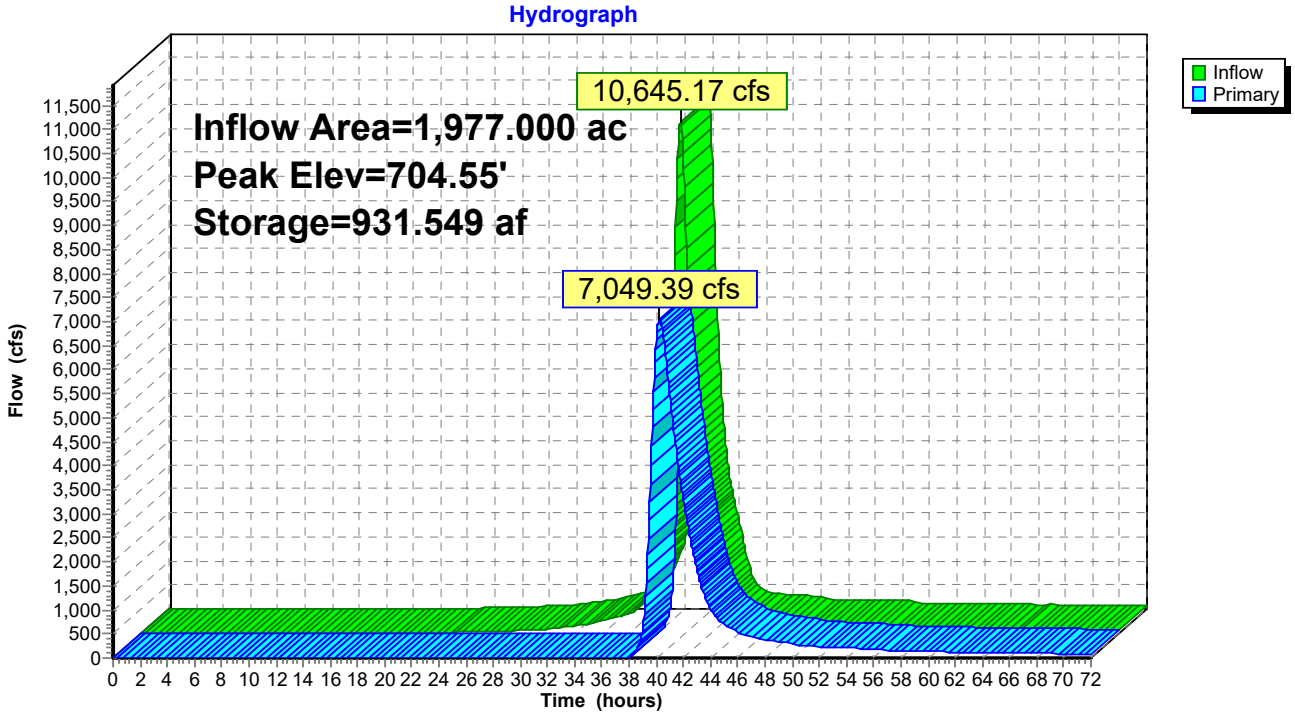
Volume	Invert	Avail.Storage	Storage Description
#1	689.20'	1,160.790 af	**Entech 2002 Report Stage-Area (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
689.20	0.000	0.000	0.000
691.50	15.800	18.170	18.170
693.20	24.300	34.085	52.255
694.80	43.000	53.840	106.095
698.10	65.600	179.190	285.285
699.00	74.300	62.955	348.240
700.00	89.000	81.650	429.890
701.00	100.700	94.850	524.740
702.00	105.400	103.050	627.790
703.00	114.100	109.750	737.540
704.00	127.200	120.650	858.190
705.00	151.300	139.250	997.440
706.00	175.400	163.350	1,160.790

Device	Routing	Invert	Outlet Devices
#1	Primary	689.20'	**Entech 2002 Report SQSE Data** Elev. (feet) 689.20 698.10 698.50 699.00 699.60 700.00 700.50 701.00 702.00 703.00 704.00 705.00 706.00 Disch. (cfs) 0.000 0.000 30.500 118.200 291.100 435.300 736.900 1,092.300 2,099.200 3,284.900 4,829.600 6,862.900 9,326.600
#2	Primary	700.50'	**55.0' long x 10.0' breadth Entech 2002 Report ST Data** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 2.00 3.00 4.00 5.00 Coef. (English) 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68 2.68

Primary OutFlow Max=7,040.87 cfs @ 40.25 hrs HW=704.55' TW=701.91' (Dynamic Tailwater)
1=Entech 2002 Report SQSE Data (Custom Controls 5,942.65 cfs)
2=Entech 2002 Report ST Data (Weir Controls 1,098.22 cfs @ 4.93 fps)

Pond SLD: Entech Shongum Lake



Estling Lake Progress Meeting PowerPoint
NJDEP Bureau of Dam Safety
November 27, 2018

New Jersey Transit

Estling Lake Dam Progress Meeting

Hydrologic & Hydraulic Evaluation

NJDEP Bureau of Dam Safety and Flood Control

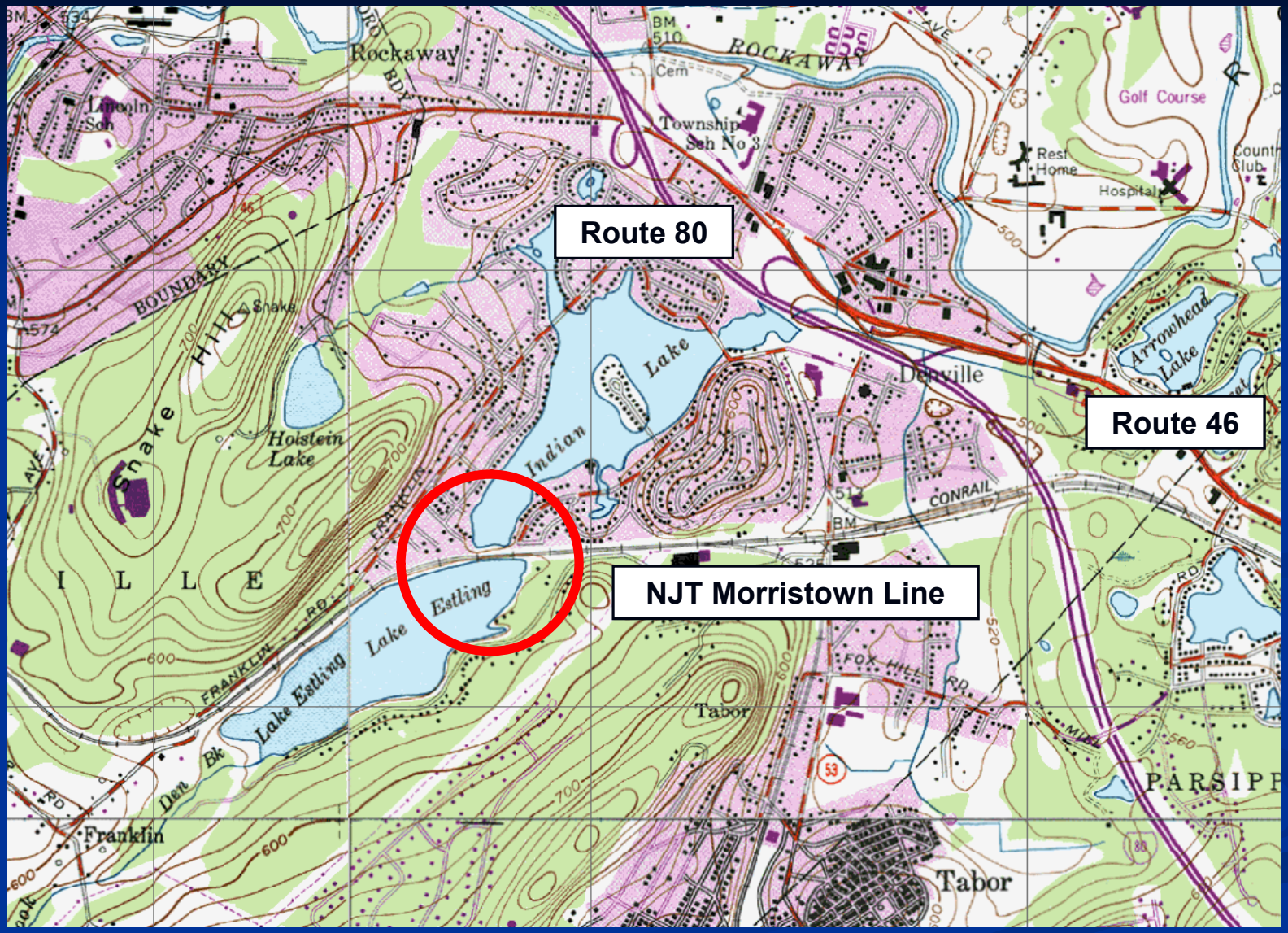
November 27, 2018

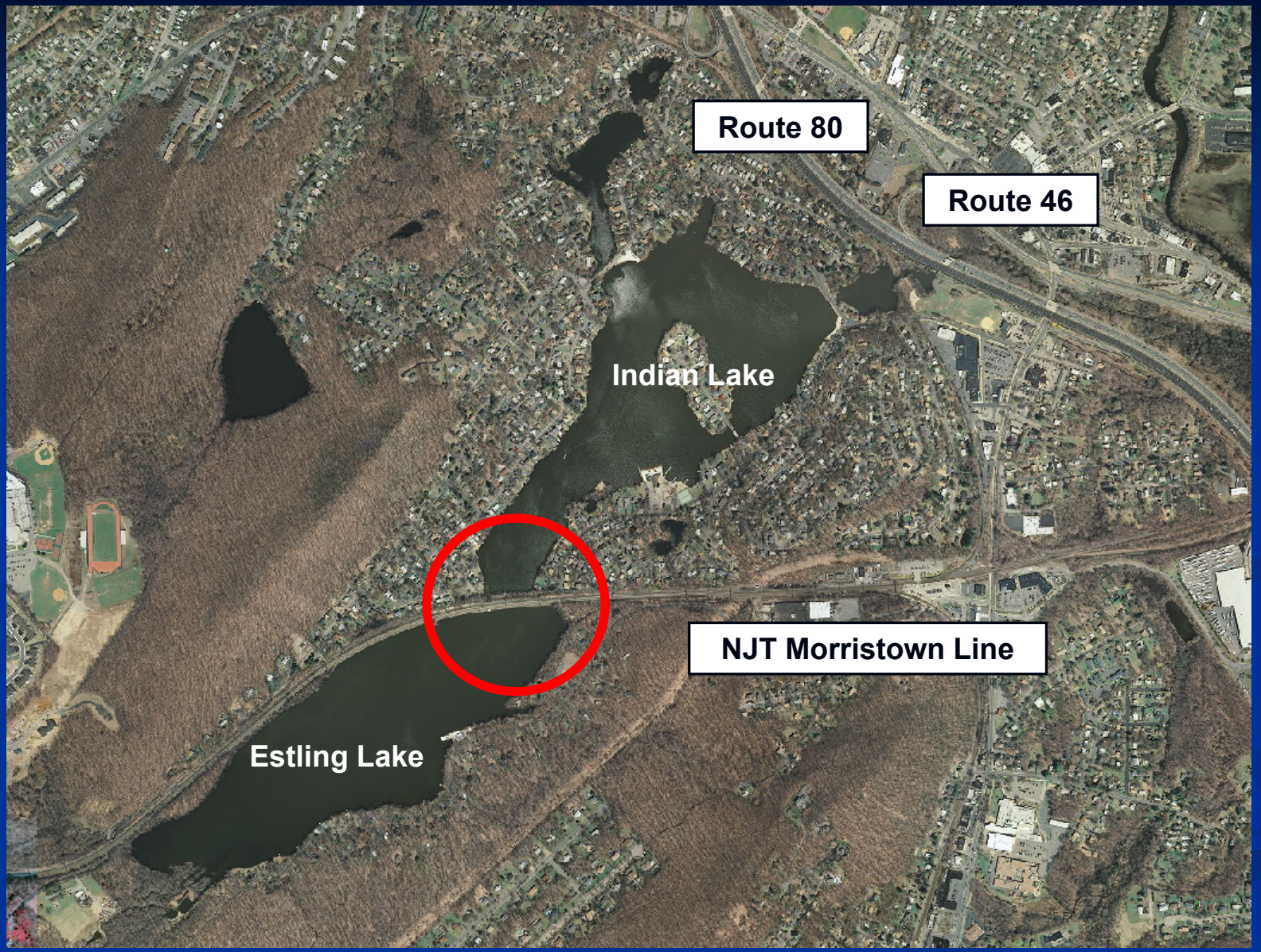
Purpose of Meeting

- Update BDS&FC on Basis and Results of New Hydrologic & Hydraulic Evaluation of Estling Lake Dam as Specified in 2017 Formal Inspection Report

Purpose of Analysis

- Update Watershed Limits, Soils, Land Cover, and Runoff
- Update Upstream Lakes and Dams with NJDEP Data as Appropriate
- Update Estling Lake Peak Dam Inflows, Outflows, and Water Surfaces
- Update Dam Breach Flows and Impacts
- Evaluate 0.5 PMP Spillway Design Storm


Route 80
Route 46
NJT Morristown Line
Rockaway
ROCKAWAY
Golf Course
Township Sch No 3
Rest Home
Hospital
Lake
Denville
Arrowhead Lake
Shake
Holstein Lake
Indian
Estling
Lake Estling
CONRAIL
FOX HILL RD
Tabor
Franklin
Den Bk
FRANKLIN RD
BOUNDARY
I L L E
P A R S I P P


Route 80
Route 46
Indian Lake
NJT Morristown Line
Estling Lake


Indian Lake
Spillways
and Bridges
Estling Lake

NJT Embankment Looking West

NJT Embankment Looking East

Upstream Embankment Face

Downstream Embankment Face

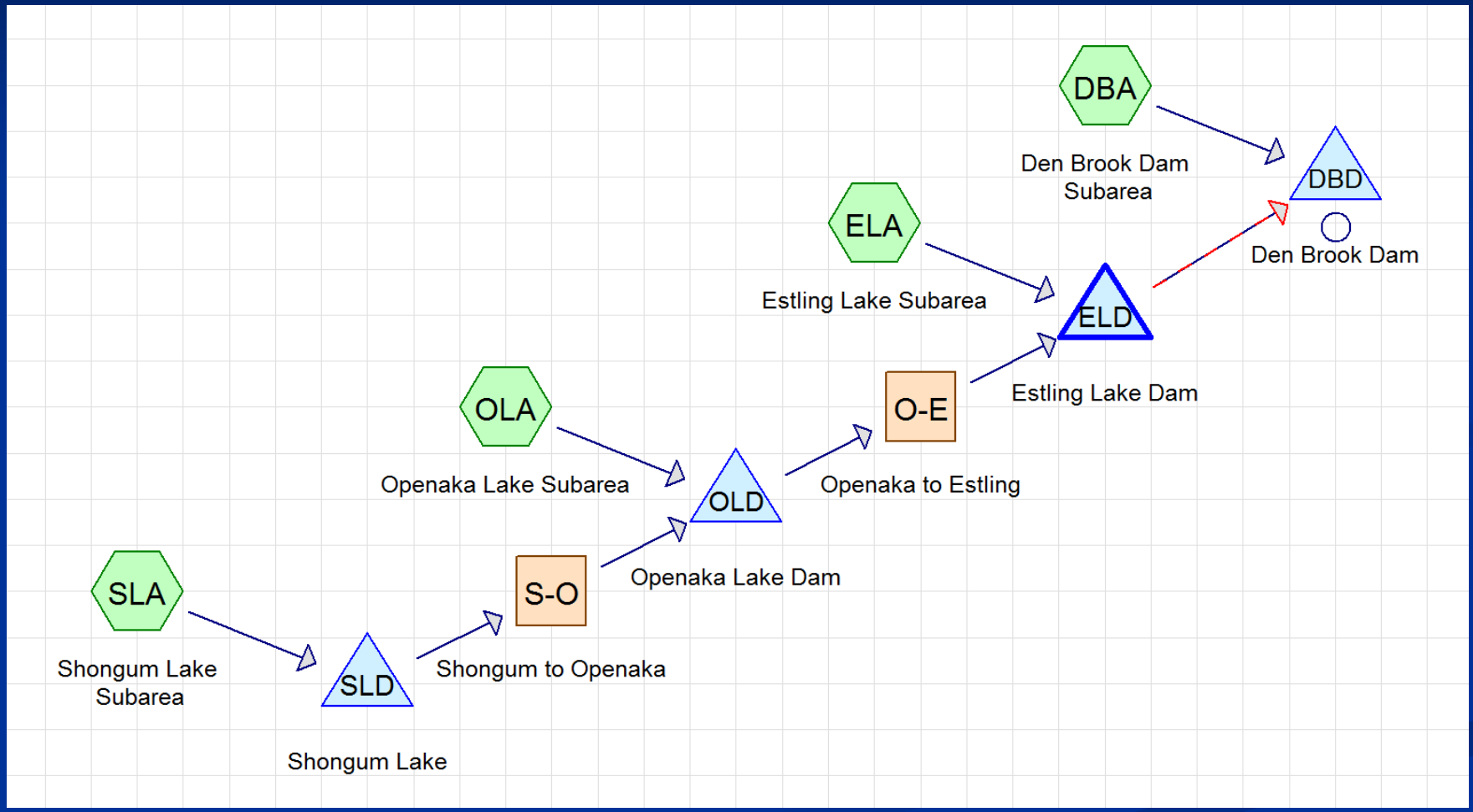
Spillways

Spillways and Upstream Face of Bridges

Downstream Face of Bridges

Indian Lake Downstream of Spillway and Bridges

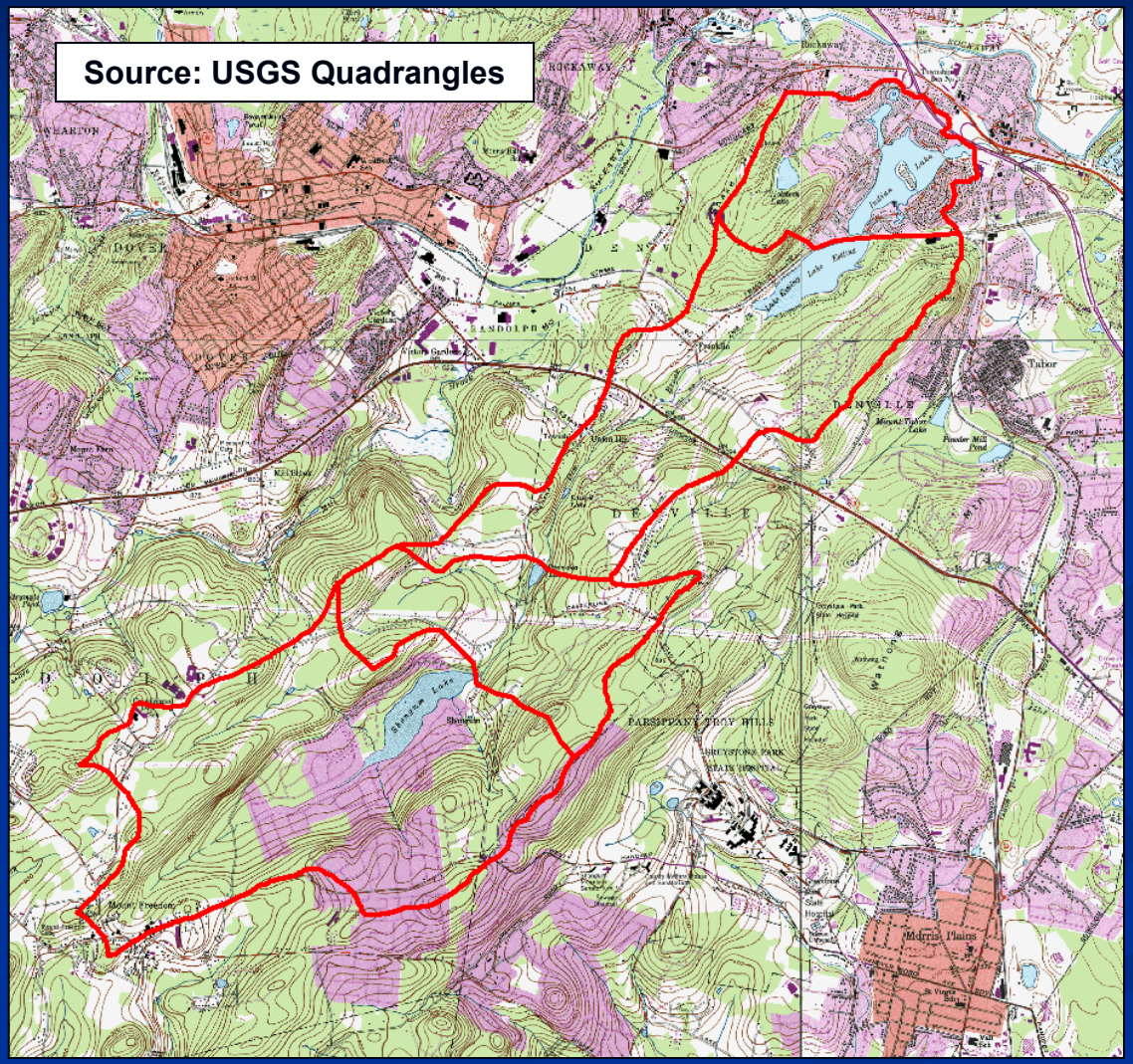
2013 HydroCAD Model



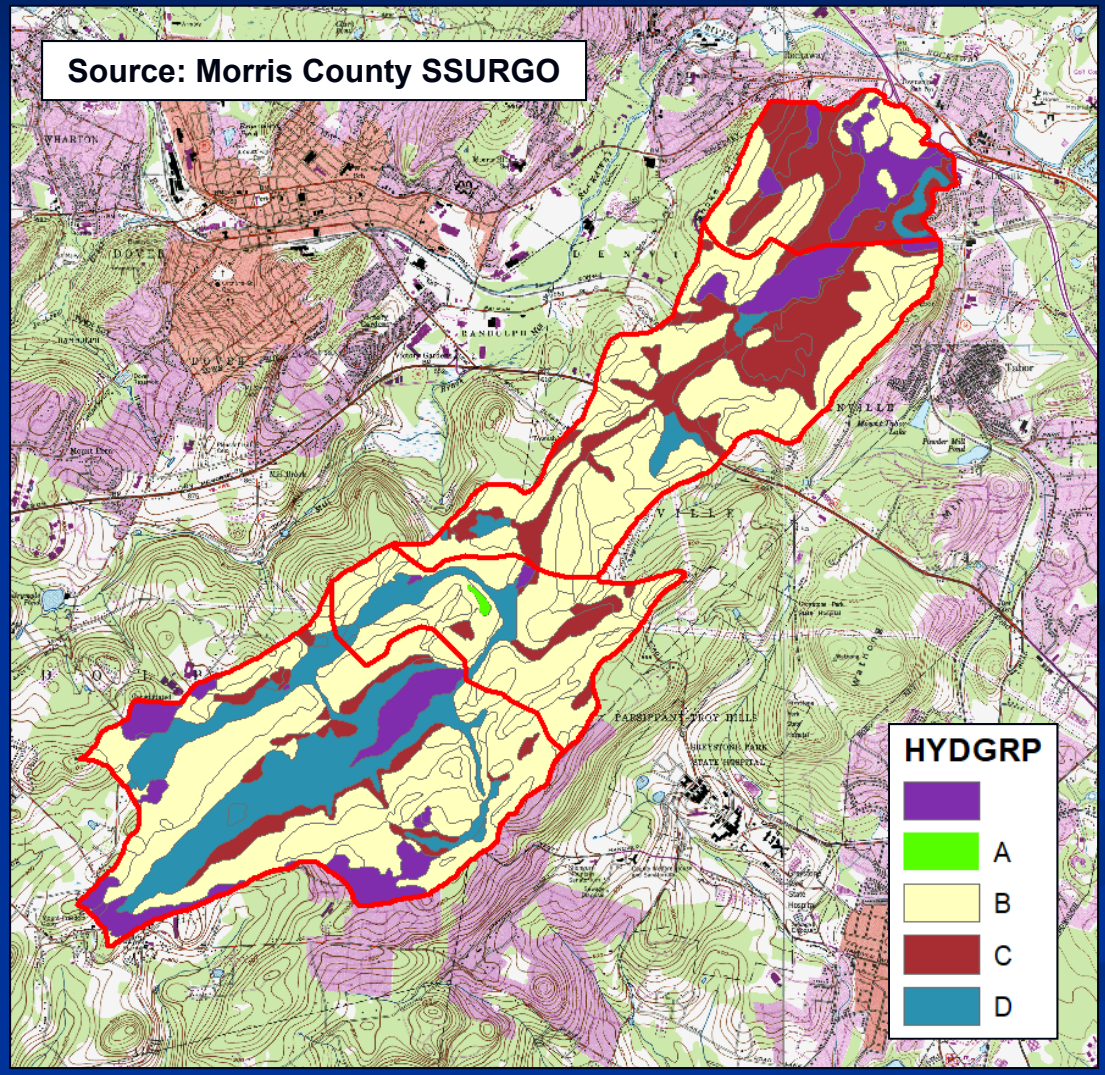
HydroCAD Model Updates

- Computed New Subareas Sizes, Soils, Land Cover, and NRCS CNs
- Retained Previous Subarea TCs
- Used Shongum and Openaka Lake Dam Stage-Storage-Discharge from BDS&FC File Reports
  - Shongum: 2002 Entech Report
  - Openaka: 2010 HMM Report

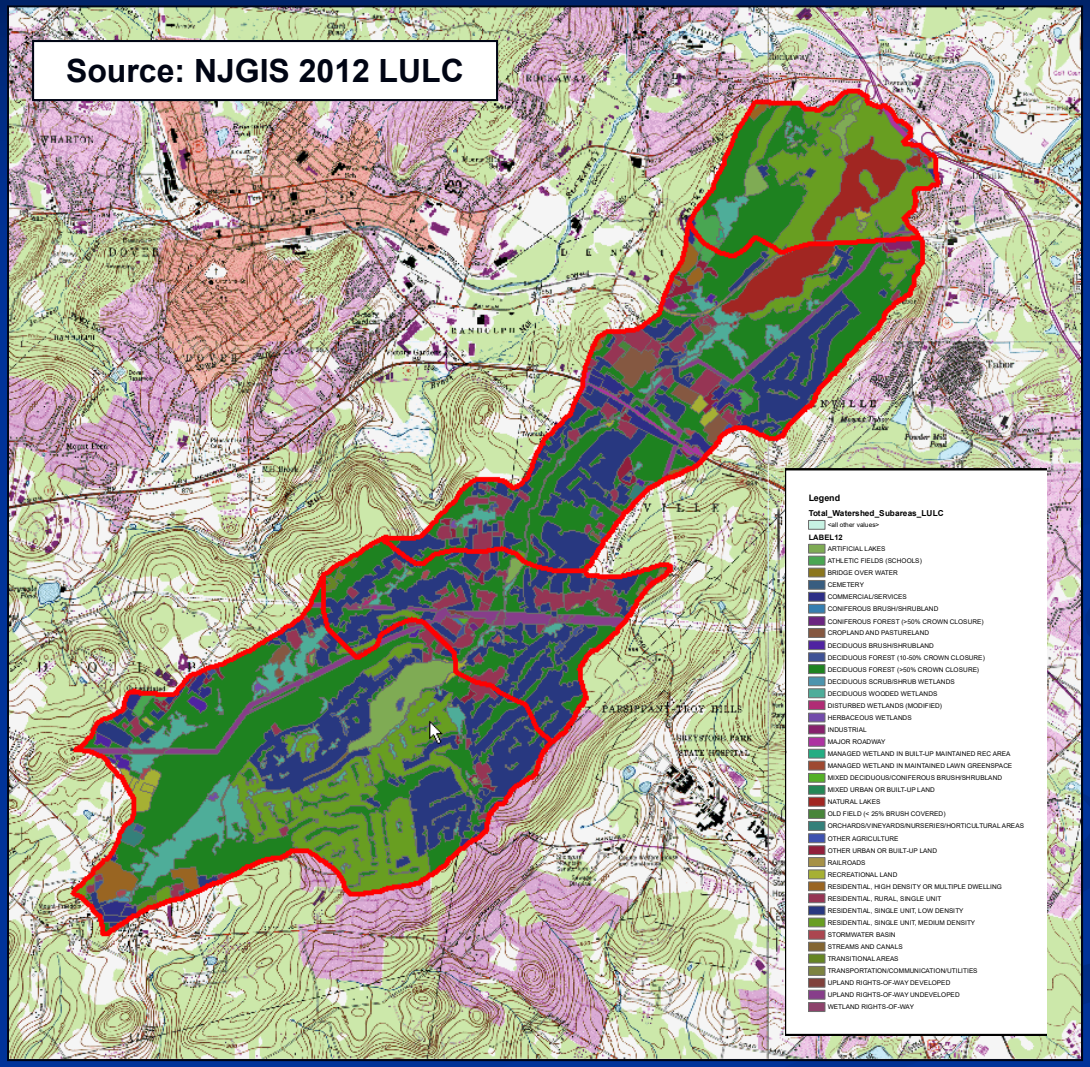
Updated Subarea Sizes



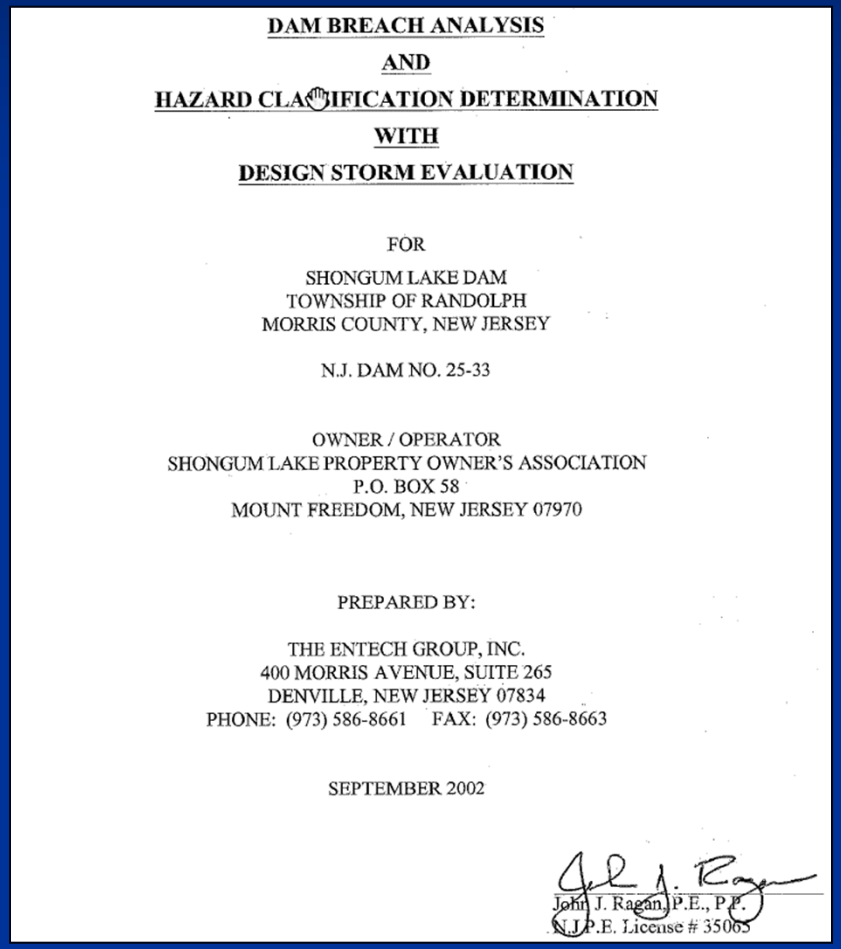
Updated Subarea Soils



Updated Subarea Land Cover



Shongum and Openaka Reports



DAM BREACH ANALYSIS

AND

HAZARD CLASSIFICATION DETERMINATION

WITH

DESIGN STORM EVALUATION

FOR

SHONGUM LAKE DAM
TOWNSHIP OF RANDOLPH
MORRIS COUNTY, NEW JERSEY

N.J. DAM NO. 25-33

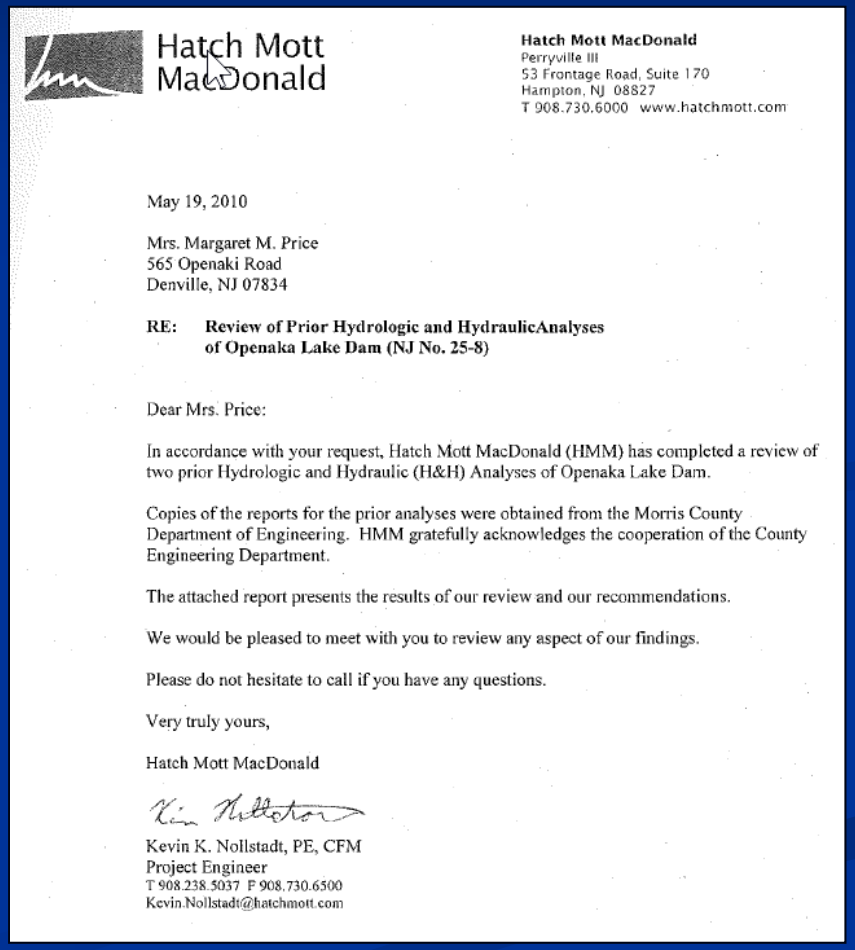
OWNER / OPERATOR
SHONGUM LAKE PROPERTY OWNER'S ASSOCIATION
P.O. BOX 58
MOUNT FREEDOM, NEW JERSEY 07970

PREPARED BY:

THE ENTECH GROUP, INC.
400 MORRIS AVENUE, SUITE 265
DENVILLE, NEW JERSEY 07834
PHONE: (973) 586-8661 FAX: (973) 586-8663

SEPTEMBER 2002

John J. Ragan, P.E., P.P.
N.J.P.E. License # 35065



Hatch Mott MacDonald

Hatch Mott MacDonald
Perryville III
53 Frontage Road, Suite 170
Hampton, NJ 08827
T 908.730.6000 www.hatchmott.com

May 19, 2010

Mrs. Margaret M. Price
565 Openaki Road
Denville, NJ 07834

RE: Review of Prior Hydrologic and HydraulicAnalyses of Openaka Lake Dam (NJ No. 25-8)

Dear Mrs. Price:

In accordance with your request, Hatch Mott MacDonald (HMM) has completed a review of two prior Hydrologic and Hydraulic (H&H) Analyses of Openaka Lake Dam.

Copies of the reports for the prior analyses were obtained from the Morris County Department of Engineering. HMM gratefully acknowledges the cooperation of the County Engineering Department.

The attached report presents the results of our review and our recommendations.

We would be pleased to meet with you to review any aspect of our findings.

Please do not hesitate to call if you have any questions.

Very truly yours,

Hatch Mott MacDonald

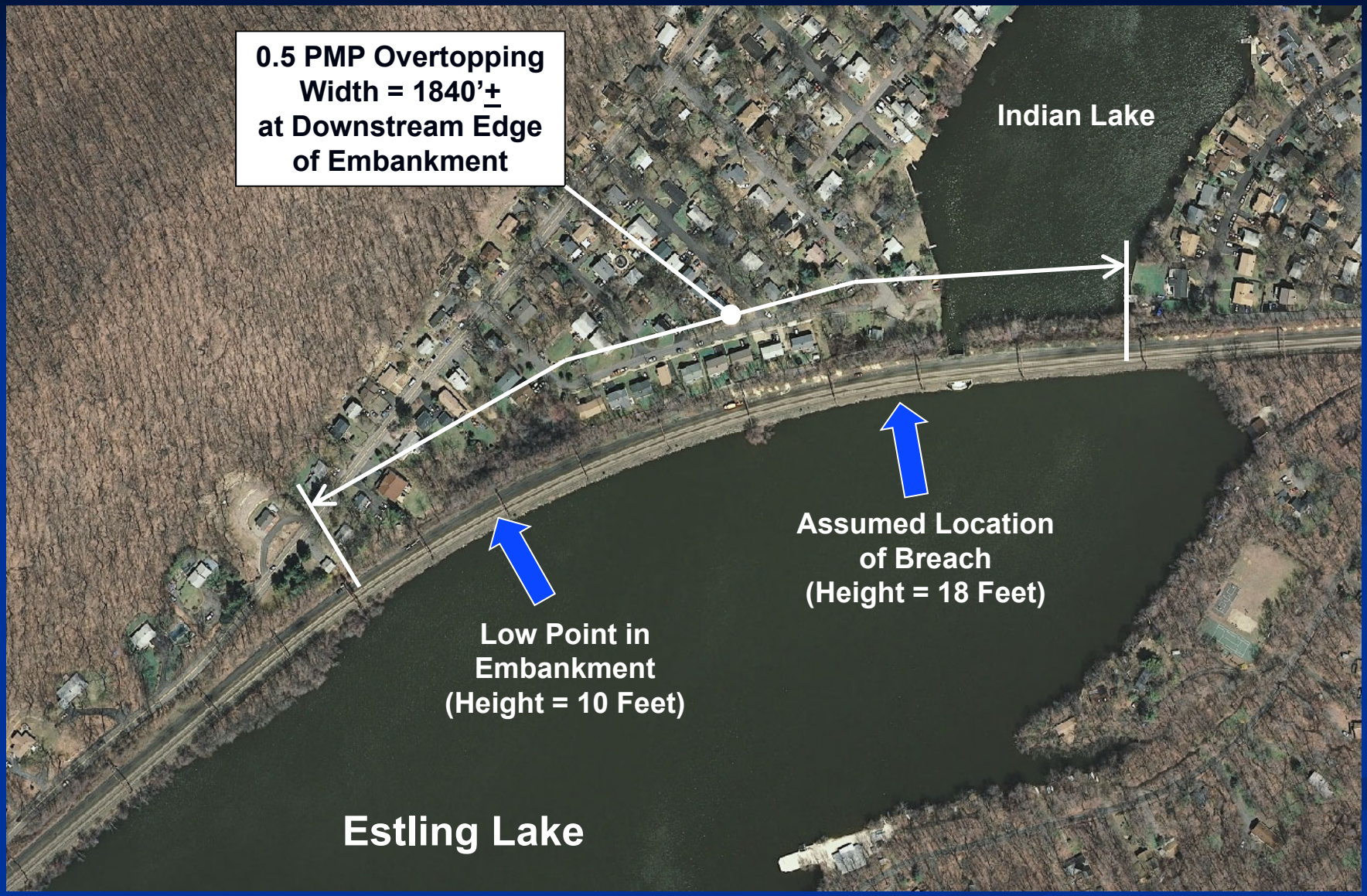
Kevin K. Nollstadt, PE, CFM
Project Engineer
T 908.238.5037 F 908.730.6500
Kevin.Nollstadt@hatchmott.com

HydroCAD Model Updates

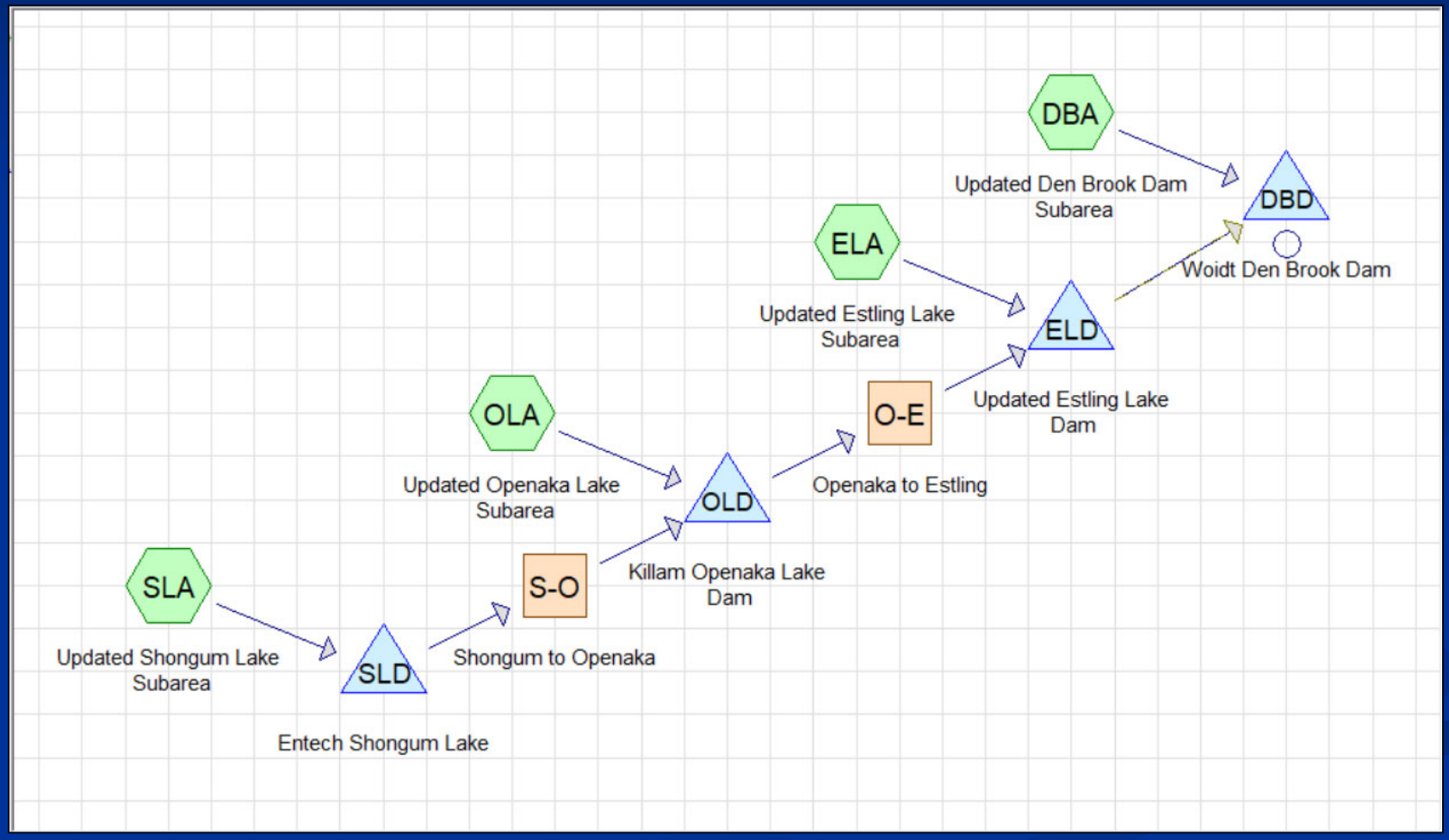
- Retained Woidt Den Brook Stage-Storage-Discharge
- Retained Woidt Reach Routings
- Retained Dynamic Dam and Reach Routings Instead of Storage Indication
  - Required for Dam Breach
  - Higher Estling Overtopping
- Retained Estling Breach Parameters

Estling Dam Breach Parameters

- Breach Located at Spillway and Bridge
- Top Elevation = Top of Embankment
- Bottom Elevation = Lowest Downstream Contour
- Breach Height = 525.6 – 508 = 17.6 Feet
- Bottom Width = 43 Feet (2.4 X Height)
- Start Breach at Maximum WSEL
- Breach Time = 15 Minutes


0.5 PMP Overtopping
Width = 1840'±
at Downstream Edge
of Embankment
Indian Lake
Assumed Location
of Breach
(Height = 18 Feet)
Low Point in
Embankment
(Height = 10 Feet)
Estling Lake

Updated HydroCAD Model



Comparison of 0.5 PMP Results

Parameter	Original Model	Updated Model	Difference	% Difference
Total Drainage Area (SM)	7.52	7.52	0.00	0.0%
Shongum Subarea (SM)	3.10	3.09	-0.01	-0.2%
Openaka Subarea (SM)	1.07	1.13	0.06	5.4%
Estling Subarea (SM)	2.35	2.34	-0.01	-0.3%
Den Subarea (SM)	1.00	0.96	-0.04	-4.4%
Shongum Subarea CN	69	69	0	0.0%
Openaka Subarea CN	69	65	-4	-5.8%
Estling Subarea CN	71	69	-2	-2.8%
Den Subarea CN	77	75	-2	-2.6%
Shongum Subarea TC	67	67	0	0.0%
Openaka Subarea TC	46	46	0	0.0%
Estling Subarea TC	52	52	0	0.0%
Den Subarea TC	38	38	0	0.0%
Shongum Subarea 0.5 PMP Peak	10,818	10,645	-173	-1.6%
Openaka Subarea 0.5 PMP Peak	4,375	4,361	-14	-0.3%
Estling Subarea 0.5 PMP Peak	9,317	8,959	-358	-3.8%
Den Subarea 0.5 PMP Peak	4,601	4,331	-270	-5.9%

Parameter	Original Model	Updated Model	Difference	% Difference
Shongum Lake 0.5 PMP In	10,818	10,645	-173	-1.6%
Shongum Lake 0.5 PMP Out	4,727	7,049	2,322	49.1%
Shongum Lake 0.5 PMP Dmax	5.8	6.45	0.66	11.4%
Openaka Lake 0.5 PMP In	6,459	8,581	2,122	32.9%
Openaka Lake 0.5 PMP Out	6,419	8,568	2,149	33.5%
Openaka Lake 0.5 PMP Dmax	6.6	6.6	0	0.0%
Estling Lake 0.5 PMP In	13,840	13,769	-71	-0.5%
Estling Lake 0.5 PMP Out	10,212	11,219	1,007	9.9%
Estling Lake 0.5 PMP WSEL	527.11	527.26	0.15	N/A
Estling Lake Overtopping Flow	3,768	4,679	911	24.2%
Den 0.5 PMP In	11,575	12,246	671	5.8%
Den 0.5 PMP Out	8,581	9,221	640	7.5%
Den 0.5 PMP Dmax	10.5	10.9	0.4	3.8%
Estling 0.5 PMP Fail Out	19,191	19,862	671	3.5%
Estling 0.5 PMP Fail WSEL	527.11	527.26	0.15	N/A
Estling 0.5 PMP Fail Dmax	1.51	1.66	0.15	10.0%
Den 0.5 PMP Fail In	20,296	20,714	418	2.1%
Den 0.5 PMP Fail Out	11,613	12,078	465	4.0%
Den 0.5 PMP Fail Dmax	12.1	12.3	0.2	1.7%
Den Brook WSEL Increase	1.6	1.4	-0.2	-12.5%

Increased Overtopping Flow

Flow Parameter	Original Analysis	Updated Analysis	Difference
Peak Flow (CFS)	3,768	4,679	911
DS Edge Topwidth (Feet)	1,750	1,840	90
Average Unit Flow (CFS/FT)	2.2	2.5	0.3
Maximum Unit Flow (CFS/FT)	4.2	5.0	0.8
Mannings Roughness	0.030	0.030	N/A
Maximum Velocity (FPS)	14.7	15.7	1.0

Task 1 Results Summary

- 0.5 PMP SDS Remains Appropriate (Den Brook Dam WS Rise Decreases 0.2 Feet)
- 0.5 PMP Overtopping Depth Increases 0.2 Feet (10 Percent ±)
- 0.5 PMP Overtopping Flow Increases 900 CFS (24 Percent ±)
- 0.5 PMP Unit Overtopping Flow Increases from 4.2 CFS to 5.0 CFS (20 Percent)
- 0.5 PMP Maximum Overtopping Velocity Increases from 14.7 to 15.7 FPS for n = 0.030

Joseph J. Skupien, PE, PP
President
Storm Water Management Consulting, LLC
141 Mountain Road
P.O. Box 727
Ringoes, New Jersey 08551

Phone: 908-806-7700
Fax: 908-806-7721
joeskupien@swmconsulting.com

Appendix C
Project Data Disk