BRIDGE HYDRAULICS REPORT

24 ROAD BIKE PATH
LEACH CREEK PEDESTRIAN BRIDGE
GRAND JUNCTION, COLORADO

PROJECT NO. MTF M555-035

March 2021
Revised February 2022

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CITY OF GRAND JUNCTION
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PREPARED BY

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SGM Project # 2020-385.001

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1.0 Introduction

1.1 Purpose and Scope

This report presents the results of the hydraulic study performed by SGM of the existing and proposed conditions of Leach Creek at the site of a proposed pedestrian bridge in Grand Junction, Colorado.

The purpose of this report is to document the pedestrian bridge hydraulic design process in accordance with the 2019 CDOT Drainage Design Manual (DDM) for the CDOT Final Office Review (FOR) submittal. This report provides hydraulic design parameters and results, including a scour analysis of the proposed bridge and recommended riprap sizing for scour protection.

1.2 Site Location

The proposed pedestrian bridge is located on Leach Creek, approximately 70 ft upstream from the confluence with North Leach Creek, in the City of Grand Junction, Colorado (Figure 1).

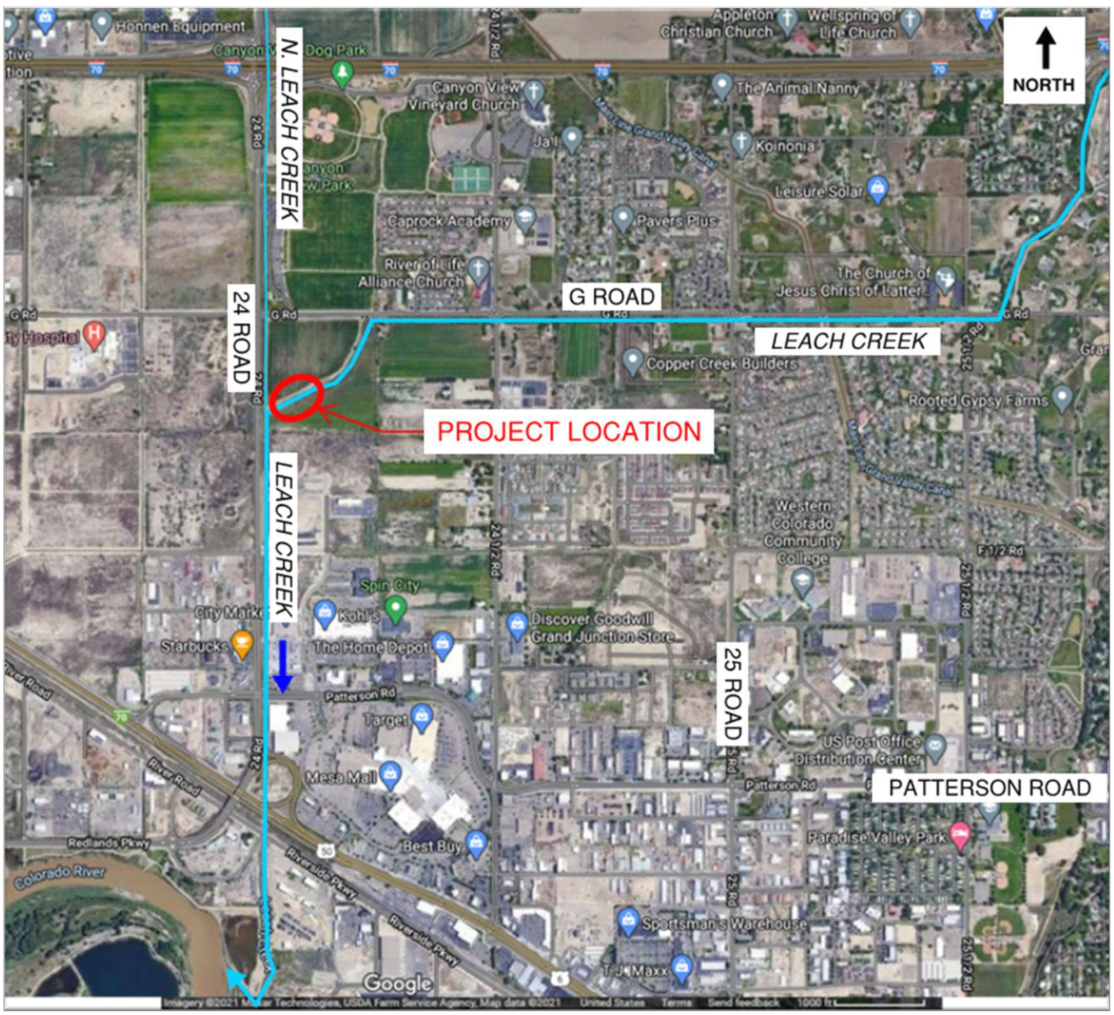

Figure 1. Site Map (Google Earth)

1.3 Previous Studies

FEMA Flood Insurance Study (FIS)
FEMA FIS 08077CV000B is the most current Flood Insurance Study for Leach Creek, revised in October of 2012. Several revisions and amendments have been made since. The most pertinent amendment effecting the project site is the 2016 Letter of Map Revision (LOMR) described below.

2016 LOMR
The most recent study of Leach Creek and North Leach Creek was a Letter of Map Revision (LOMR) done for FEMA by ICON Engineering, Inc in 2016 (2016 LOMR). This was done to revise the model and consequent National Flood Insurance Program (NFIP) mapping due to the construction of a detention basin upstream. The 2016 LOMR study covered the full reach from the detention basin to the confluence of Leach Creek with the Colorado River, including the North Leach Creek tributary. This study was first done in the NAVD27 vertical datum and then converted to NAVD88 vertical datum at FEMA's request. The full analysis report and model results are provided in the Leach Creek Detention Basin LOMR Report by Icon, March 25, 2016.

1.4 Regulatory Floodplain

The proposed crossing is located on FEMA Flood Insurance Rate Map (FIRM) panel 08077C0801G, effective 10/16/2012. The proposed bridge crossing is skewed 20 degrees from perpendicular to the direction of flow in the river. The regulatory floodplain is designated as Zone AE, indicating that base flood elevations (BFE) have been defined for this reach of the river. No regulatory floodway has been designated in this reach. The proposed abutments shall be located within the FEMA regulatory floodplain, or flood fringe, as defined by Mesa County.

The crossing is located between FEMA Flood Insurance Study (FIS) cross sections H and I. There are only two cross sections in the LOMR model spanning the 1,000 feet between these two BFE cross sections. Due to this lack of topographic and model detail, a new model was developed to assess the impact of the proposed trail bridge on the immediate surroundings.

1.5 Topographic Data

The new model developed for this study utilized new topography data collected by the City of Grand Junction with ground surveying methods in August and November 2019 (2019 GJ survey). This survey is in the Mesa County Local Coordinate System-13 (MCLCS-13), NAVD88-92 (Vertical), and WGS-84 (Horizontal). This survey extends 170 ft up Leach Creek from the confluence with North Leach Creek, and 300 ft downstream from it. This survey also covers the intersection of G Road and 24 Road.

1.6 Bridge and Scour Design Flood Frequency

This bridge design follows regulations in the 2019 CDOT Drainage Design Manual (CDOT DDM) and the City of Grand Junction Municipal Code Stormwater Management Manual (SWMM). This report includes the comparison of the 10-, 50-, 100-, and 500-year flood events in existing conditions without a bridge and in proposed conditions with the bridge.

The CDOT DDM provides guidance on which frequency storm is to be used for the design storm. Section 7.3.6 specifies that the design storm shall be the 100-year peak flow because the proposed bridge is in the FEMA regulatory floodplain Zone AE. Design guidance from CDOT DDM Table 7.2 recommends design storms of 2-yr to 5-yr for pedestrian walkways and bikeways.

CDOT DDM Section 10.2.2 specifies that the low chord of the bridge be designed with a minimum freeboard of 2 feet above the water surface elevation (WSEL) of the design storm at cross-sections 50 – 100 feet upstream of the bridge.

The City of Grand Junction (the City) is requesting to proceed with the bridge design that provides 1-foot of freeboard above the 100-year WSEL, which equates to greater than 2 feet of freeboard above the 10-year WSEL. The model results supporting this request are presented in this report.

The bridge foundation was designed to withstand scour of the 500-year flood frequency, per CDOT DDM Section 10.6 and Table 10.1. The 500-year scour impacts were modeled in HEC-RAS and the results are presented in this report.

2.0 Hydrology

2.1 Hydrologic Data

The project site is in a mixed urbanized area that contains commercial, recreation, agriculture, and residential land uses. The Leach Creek Detention Basin is located within hydrologic sub-basin L11, 10,000 feet upstream of the Government Highline Canal (2016 LOMR). Hydrologic data for this modeling analysis was taken from the 2016 LOMR report. Flood frequency data from the 2016 LOMR Report Table 4.1 and 4.2 are shown below in Table 1. The upper Leach Creek reach, “Reach 1” in the model, has a 100-year peak flow of 721 cfs. Leach Creek downstream of the confluence is “Reach 2” in the model and the 100-year peak flow is 1,230 cfs. North Leach Creek is named “North Reach” in the model, with the 100-year peak flow of 548 cfs.

Table 1: Flood frequency peak flows (cfs) from the 2016 LOMR report Table 4.1 and 4.2.

Model Reach	Location Name (from LOMR Table 4.1 and 4.2)	10-year Peak flow (cfs)	50-year Peak flow (cfs)	100-year Peak flow (cfs)	500-year Peak flow (cfs)
Reach 1	Approx. 1,3000 ft. Downstream of 24 ½ Road	312	617	721	730
Reach 2	24 Road / Confluence with North Leach Creek	420	954	1,230	1,379
North Reach	G Road	127	370	548	1,050

3.0 Hydraulic Design

3.1 Existing Conditions

There is no crossing structure at the proposed location. The channel at the project site is natural and unimpacted by improvements or modifications. The channel bed slope is flat, 0.4% from station 0+22 to station 1+45. The channel bottom in this section is 10-13 ft wide with bank slopes steeper than 2:1, with the lower 4 feet of bank having slopes steeper than 1:1. The channel depth in this section is uniformly 8 ft from top of bank. The banks are well vegetated with dense grasses, mature shrubs, and some trees. The property on either side of the channel is currently agricultural land use.

3.2 Model Input

The following input information was required for the preparation of the HEC-RAS model. (The final model version is called "LC-NLC-FULL-finetune" and is located in the SGM project folder under "B-Calcs\SGM RAS Model\LC and NLC FULL Model\220128-update".)

3.2.1 Geometry

The HEC-RAS model developed for the G-Road Bridge improvement project on North Leach Creek was added into the model of Leach Creek at the confluence just downstream of the proposed pedestrian bridge. There is a junction at the confluence of the three reaches: North Leach Creek and Leach Creek Reach 1 coming into the junction, and Leach Creek Reach 2 leaving the junction.

The cross-sections at the proposed pedestrian bridge crossing were located as prescribed in RD-42 (Hydrologic Engineering Center, 1995). Topographic data from the 2019 GJ Survey was imported into the HEC-RAS model to represent the channel geometry under existing conditions.

The bridge was designed to completely span the 500-year floodplain that was first modeled in an existing conditions model of Leach Creek Reach 1 by itself with no other reaches or junctions. Once the bridge was added into the full model including the confluence, the abutments are within the 100-year and 500-year floodplain due to backwater. Scour was modeled in this full confluence model and riprap protection was designed based on the results.

The bridge deck and connecting trail were modeled in the proposed condition (Figure 2). Expansion and contraction coefficients were set to 0.5 and 0.3, respectively, at the cross sections upstream (STA 0+76) and downstream (STA 0+51) of the bridge. The proposed bridge skew of 20 degrees from normal to the direction of the flow was not entered into the model because HEC-RAS design guidance indicates the projected length can be used to model skew angles up to 30 degrees for small flow contractions which this is, and the minor skew angle (20 degrees or less) does not have a hydraulic impact on the channel flow.

Due to the design span and abutment placement, riprap protection around the abutments is proposed, but no major channel modifications are recommended. This is to limit channel disturbance that might initiate bank erosion and widening, which might accelerate channel erosion, migration, and headcutting. The proposed riprap protection is to be added only around the abutments on the upper banks where finished grading is necessary to tie-in the new trail to existing ground. The channel is recommended to not be disturbed to minimize erosive forces.

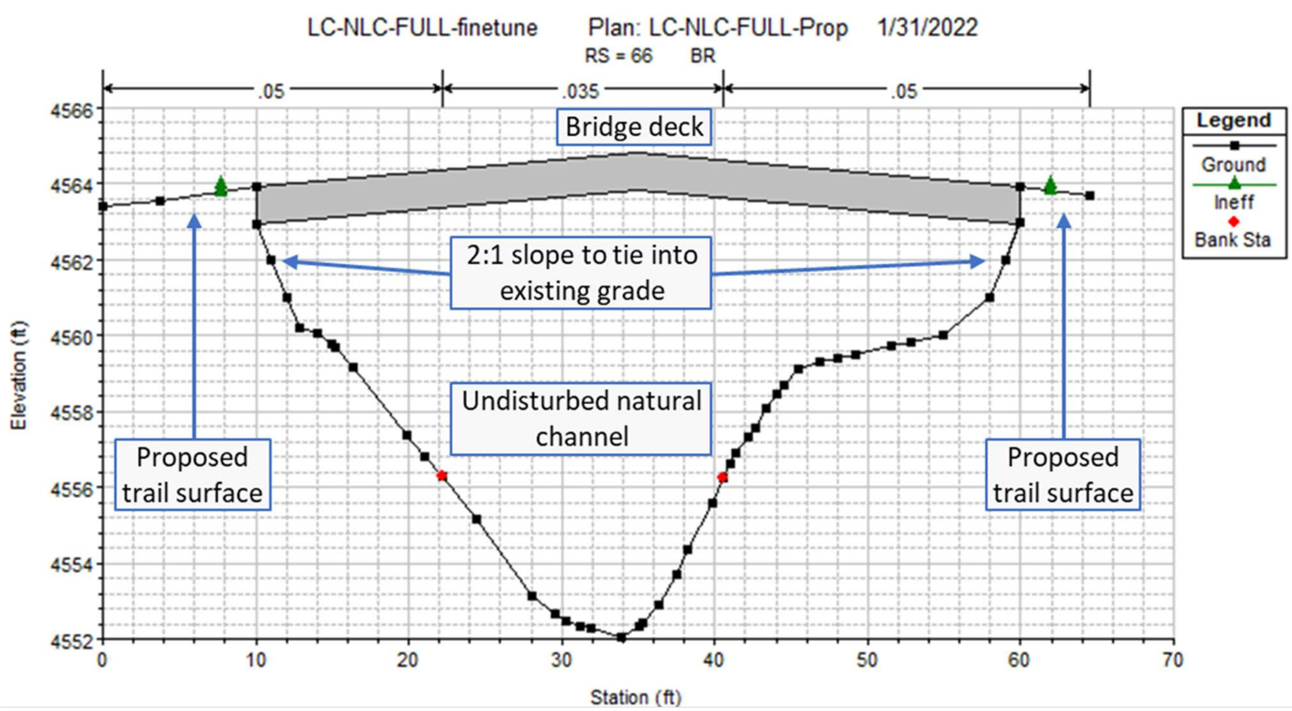

Figure 2. Proposed pedestrian bridge as modeled in HEC-RAS

3.2.2 Roughness

The FEMA FIS provides roughness coefficients that were used in the delineation of the regulatory floodplain. The FIS channel roughness values for Leach Creek are still valid within this reach and are applied in this model unchanged (Table 2). The channel bottom is cobble lined with densely vegetated banks. Separate roughness coefficients (Manning's N) were used for the channel and banks.

Table 2. FIS Roughness Coefficients (Manning's N values) for Leach Creek at the Project Site

Reach	Channel	Bank
Leach Creek	0.035	0.05

3.2.3 Ineffective Flow Areas and Obstructions

Bridge crossings that do not clear span the entire floodplain are often characterized during flood events by a contraction reach upstream of the bridge, a constricted reach between the bridge abutments, and an expansion reach downstream of the bridge. Prescriptive guidelines for identifying the locations of these transition reaches are provided in RD-42 (Hydrologic Engineering Center, 1995). Ineffective flow areas due to the bridge crossing were defined accordingly to represent these contraction and expansion zones at the upstream and downstream cross sections in the proposed HEC-RAS model.

3.2.4 Steady Flow Analysis and Boundary Conditions

The 2016 LOMR updated the peak flood discharges from the 2012 FIS based on the detention facility upstream on Leach Creek. The 10-, 50-, 100-, and 500-year flood events were modeled in this study. The peak discharges from the 2016 LOMR are shown in Table 1 in this report Section 2.1, Hydrologic Data.

Due to the relatively flat bed slope of this reach, 0.4%, the subcritical flow regime was applied in HEC-RAS. Boundary conditions were set based on the 2016 LOMR model. Normal depth was used, with slope of 0.005 foot/foot at the upstream limit of Leach Creek Reach 1, a slope of 0.00484 foot/foot at the upstream limit of North Leach Creek, and slope of 0.003 foot/foot at the downstream limit of Leach Creek Reach 2. HEC-RAS sets the boundary conditions within the modeled junction of North Leach Creek and Leach Creek.

3.2.5 Bridge Scour

The computational procedures within HEC-RAS for bridge scour are based on HEC-18 (Federal Highway Administration, 2012). HEC-RAS can analyze two components of total scour as outlined in HEC-18, contraction scour and local scour at piers and abutments.

Bridge contraction scour was computed in HEC-RAS, utilizing the default parameters except for user-input median particle size of 0.01 mm based on the RockSol Geotechnical Report completed November 12, 2020, and water temperature of 60 degrees Fahrenheit. The model was set to automatically determine to apply the live-bed, or the clear-water scour equations based on the discharge velocity.

Contraction scour was assessed for the 500-year flood event at three cross-sections within 100 feet upstream of the bridge. Local scour was assessed at the abutments for the 500-year peak flow.

3.3 Model Output

The following sections provide a discussion of the HEC-RAS model output, as run with the input variables described in the previous sections of this report. All model outputs are included in Appendix A.

3.3.1 Proposed Model Results

Table 3 shows the existing and proposed 100-year water surface elevations for the modeled cross sections, with station 0+00 at the confluence with North Leach Creek. Figure 3 shows the cross-sections in the vicinity of the proposed bridge and the extent of the 500-year inundation. The proposed model showed slight water surface elevation decreases near the bridge and increases downstream of the bridge (-0.03 to +0.04 ft).

Table 3. Existing and Proposed Water Surface Elevations in the HEC-RAS Model

Cross Section Station Bridge CL @ 0+66	100-Year Water Surface Elevations (ft)		
	Existing	Proposed	Change (ft)
0+36	4561.47	4561.44	-0.03
0+51	4561.43	4561.41	-0.02
Bridge 0+66			0
0+76	4561.48	4561.47	-0.01
0+99	4561.54	4561.58	0.04
1+19	4561.59	4561.63	0.04
1+45	4561.57	4561.61	0.04

3.3.2 Velocity Distribution

The backwater effects of the confluence cause overbank flooding along the full Reach 1 in which the 50-, 100-, and 500-year events overtop the banks and exceed the modeled cross-section widths. The breakout flood waters spill into open fields on either side of the channel, however, collecting full topographic data to model the extents of the breakout was outside the scope of this study. Therefore, the modeled cross-sections are cut off at reasonable left and right extents since the overbank areas do not convey the bulk channel flow. The velocities in all overbank areas, even in the 500-year event, are less than 1.0 fps.

Because the flooding is beyond the extents of the cross-sections, the 100-year and 500-year floodplain extents look the same in the plan view because they are cut off at the end of the cross-sections (Figure 3).

The proposed bridge abutments are within the 100-year and 500-year floodplain extents, however, the velocities at the abutment locations are below 2.0 feet per second (fps) so this area does not convey the main channel flow and has less erosive energy (see Figure 4). 2.0 fps was used as a conservative design value to size riprap (see section 3.3.5). The velocity in the center of the channel is less than 5.0 fps, so this velocity was also tested as a conservative upper bound for riprap sizing.

The existing condition velocities are similarly below 2.0 fps upstream of the bridge near the proposed abutment locations. The proposed bridge does not significantly increase the velocities in the channel or on the banks.

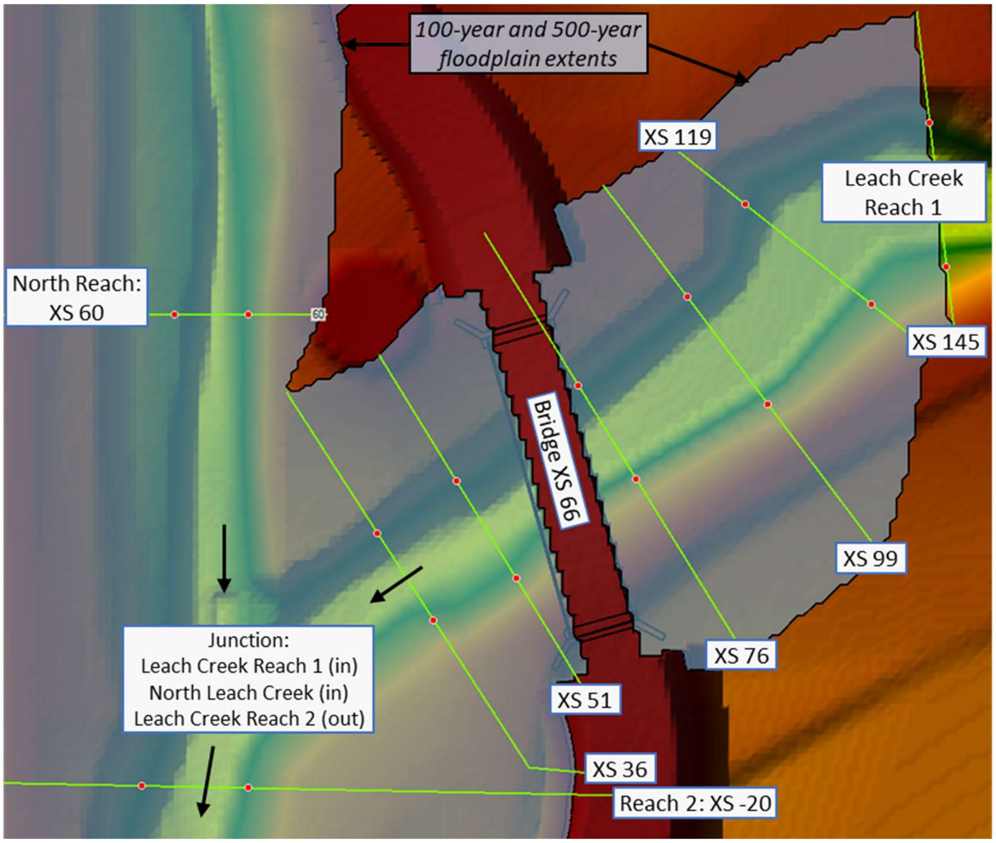

Figure 3. HEC-RAS model terrain, cross-sections, proposed bridge, and modeled water surface elevations

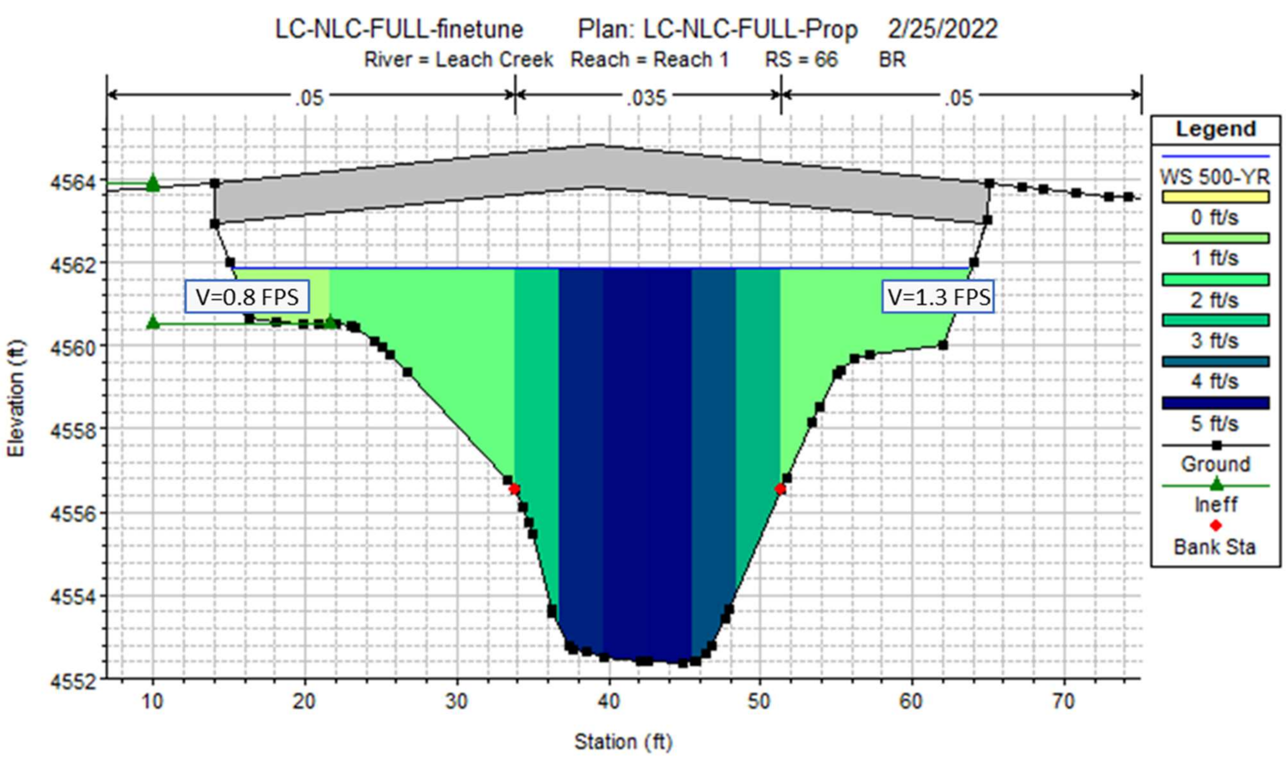

Figure 4. HEC-RAS model velocity distribution at upstream bridge cross-section

3.3.3 **Freeboard and Capacity**

The proposed bridge will span the channel as a crest vertical curve. The modeled 100-year water surface elevation (WSEL) at cross sections 50-100 ft upstream of the bridge is used to set the low chord for the bridge. The 100-year WSEL at cross section 145 (73 ft upstream of the bridge opening) is 4561.6. As discussed in this report section 1.6, the City is requesting to proceed with 1 foot of freeboard above the 100-year WSEL. In the bridge plans, the low chord of the proposed bridge at each end is specified to be 4562.6, which provides 1-foot of freeboard. The proposed low chord elevation provides 4.6 feet of freeboard above the 10-year event.

Table 4. Flood event data table upstream of bridge. Low chord of bridge is 4562.6 ft.

Location	River Station	Distance to upstream bridge entrance (ft)	Proposed 10-year water surface elevation (ft)	Proposed 100-year water surface elevation (ft)	500-year scour depth mid-channel (ft)
Bridge-US	0+72				
XS 76	0+76	4	4557.84	4561.47	
XS 99	0+99	27	4557.97	4561.58	1.80
XS 119	1+19	47	4558.04	4561.63	2.62
XS 145	1+45	73	4558.03	4561.61	1.59

3.3.4 **Bridge Scour**

The appropriate mode of bed material transport within the channel for the 500-year peak discharge was determined to be live bed. The maximum 500-year contraction scour depth was found to be 2.62 feet at cross-section 119, 47 feet upstream of the bridge entrance (Figure 5). The left and right banks also showed the greatest scour at this cross-section location during the 500-year event with 0.91 and 0.84 feet of scour. The designed bridge foundations extend well below these depths (for foundation design information, see the Structure Selection Report). Riprap protection around the abutments will help minimize the scour at those locations.

3.3.5 **Abutment Riprap Protection**

The maximum velocity around the abutments was modeled to be 1.6 fps. 2.0 fps was applied in several riprap sizing calculations from the United States Department of Agriculture's National Engineering Handbook Technical Supplement 14C "Stone sizing criteria" to determine a recommended riprap size. The results were uniformly 0.6-inch D50 of riprap. Even for the maximum mid-channel velocity of 5.0 fps, the maximum riprap size calculated was 6 inches.

Therefore, 6-inch D50 riprap or larger, at least 1-foot thick, can be used around the abutments, depending on material availability and best cost at the time of construction. Refer to the bridge design plans for riprap specs and placement. Riprap calculations are included in Appendix B.

As discussed previously, to minimize disturbance and erosion in the natural channel, modifications or riprap within the channel are not recommended, only around the abutments.

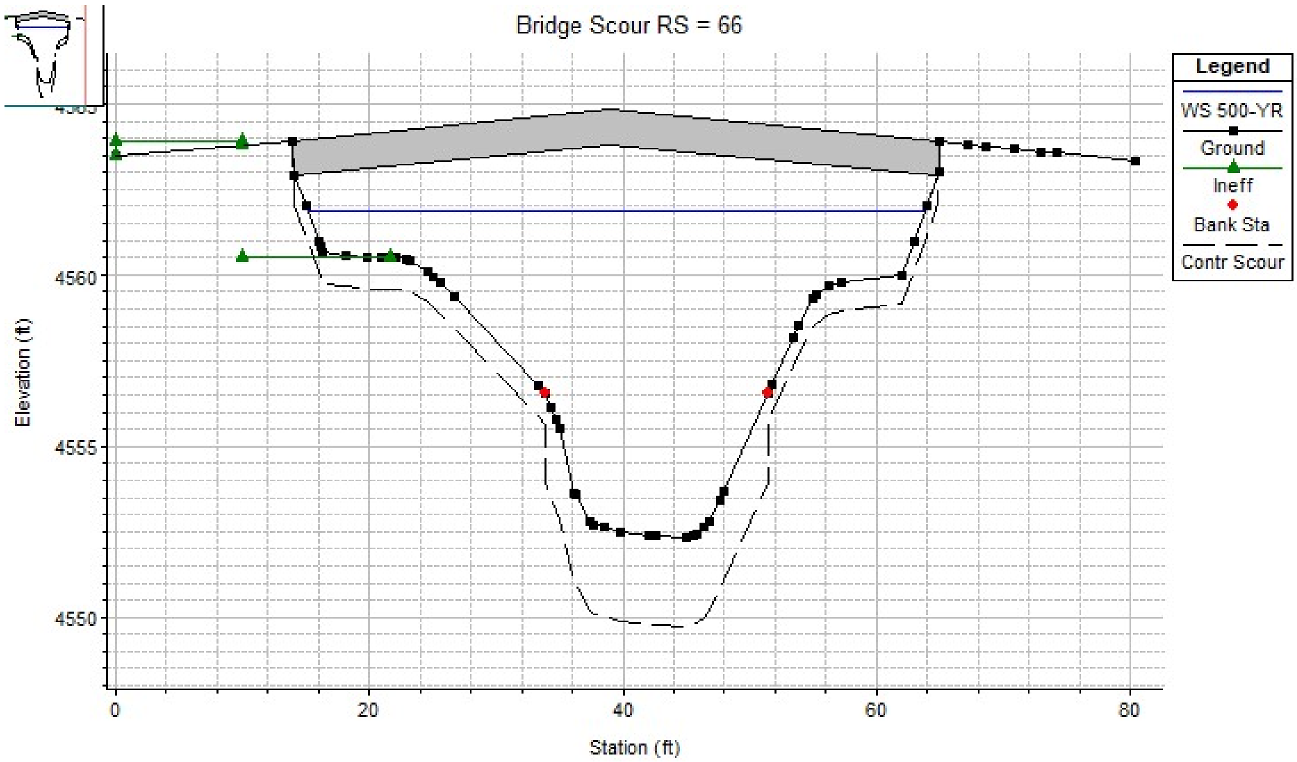

Figure 5: 500-year scour with cross-section 119 showing maximum scour.

4.0 Conclusions

The proposed pedestrian bridge crossing has been analyzed hydraulically for compliance with local hydraulic design requirements and CDOT drainage design criteria. The proposed water surface elevations do not increase significantly from the existing conditions.

The City is requesting to proceed with the bridge design that provides 1-foot of freeboard above the 100-year water surface elevation. The model results in this report indicate that the low chord of the bridge be specified at an elevation of 4562.6 feet to meet this criterion. This equates to 4.6 feet of freeboard during the 10-year event.

The proposed condition velocities at the bridge location do not substantially increase compared to the existing condition. Maximum scour in the 500-year event is 2.6 ft in the center of the channel. The proposed bridge foundation design adequately accounts for these findings. These results indicate that the stability of the channel will be maintained relative to existing conditions. SGM does not recommend disturbing the existing channel by re-grading or placing riprap within the channel, however, 6-inch riprap (or larger depending on availability and cost) is recommended around the abutments due to the reduced freeboard from 2 feet to 1 foot.

Periodic inspections of the completed bridge should be carried out and post-project bank conditions monitored for evidence of excessive scour. If post-project field conditions vary from those expected and discussed in this report, SGM should be contacted to evaluate the conditions, and to recommend scour countermeasures if necessary.

5.0 Certification

I, Katherine A. Radavich, a duly registered professional engineer in the State of Colorado (registration #58365), have prepared this report and supervised the production of related documents, and exhibits. The information included is, to the best of my knowledge, accurate and consistent with professional practices in the State of Colorado.

COLORADO LICENSED
KATHERINE A. RADAVICH
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PROFESSIONAL ENGINEER

February 25, 2022

6.0 References

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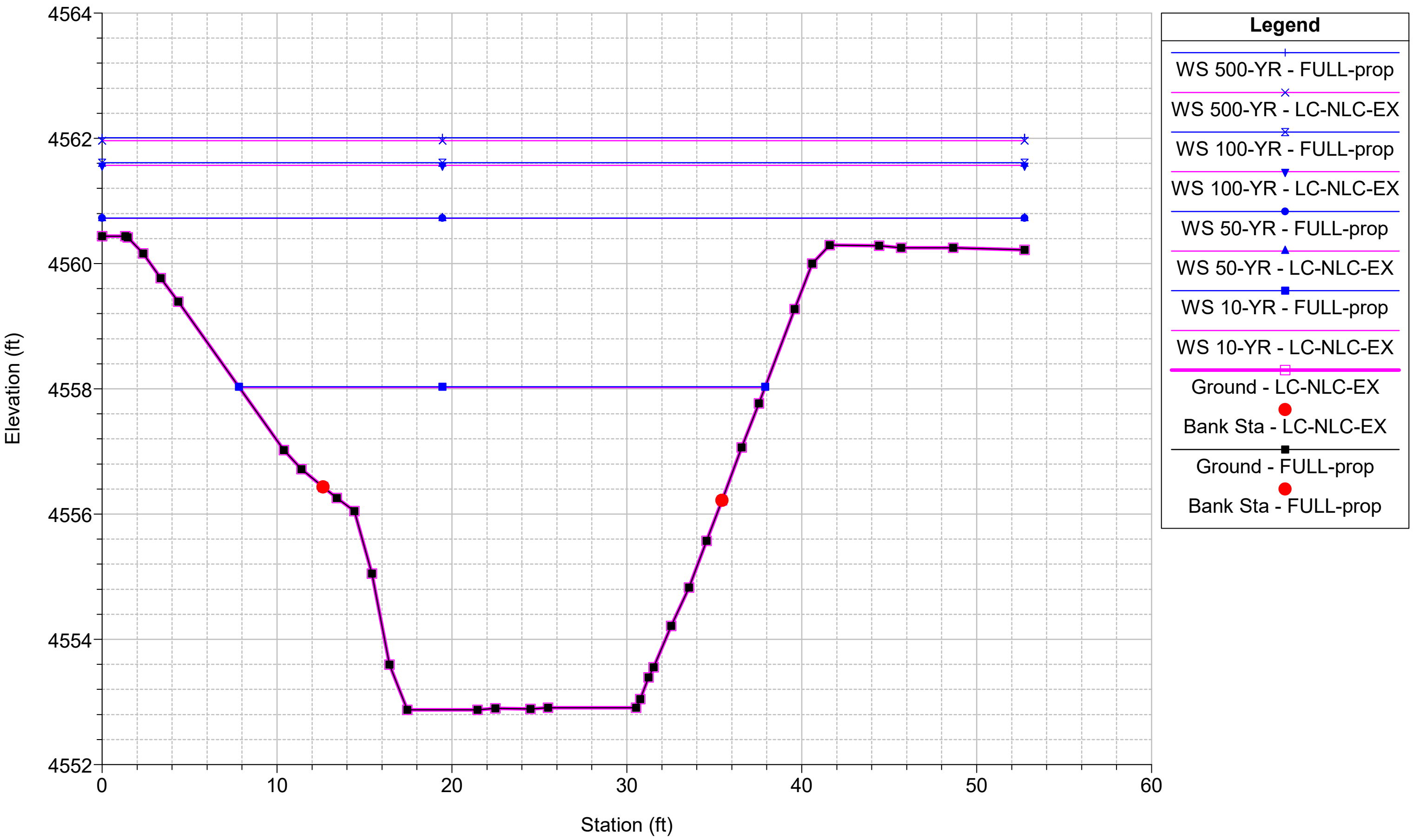
Appendix A – HEC-RAS Model Output

HEC-RAS Existing and Proposed Model Results and Cross Sections
HEC-RAS Existing and Proposed Conditions Flood Profile
HEC-RAS Bridge Results
HEC-RAS Scour Results

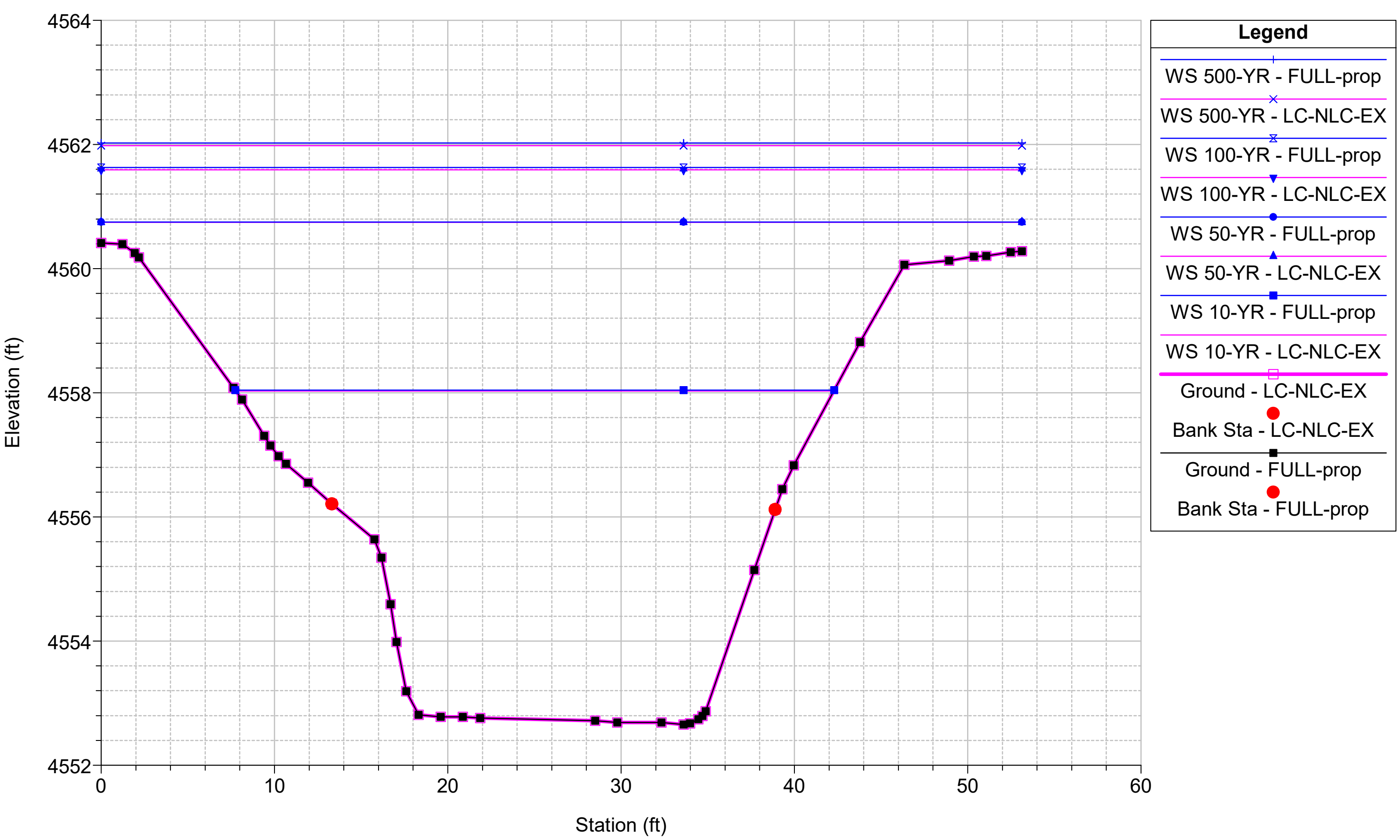
HEC-RAS

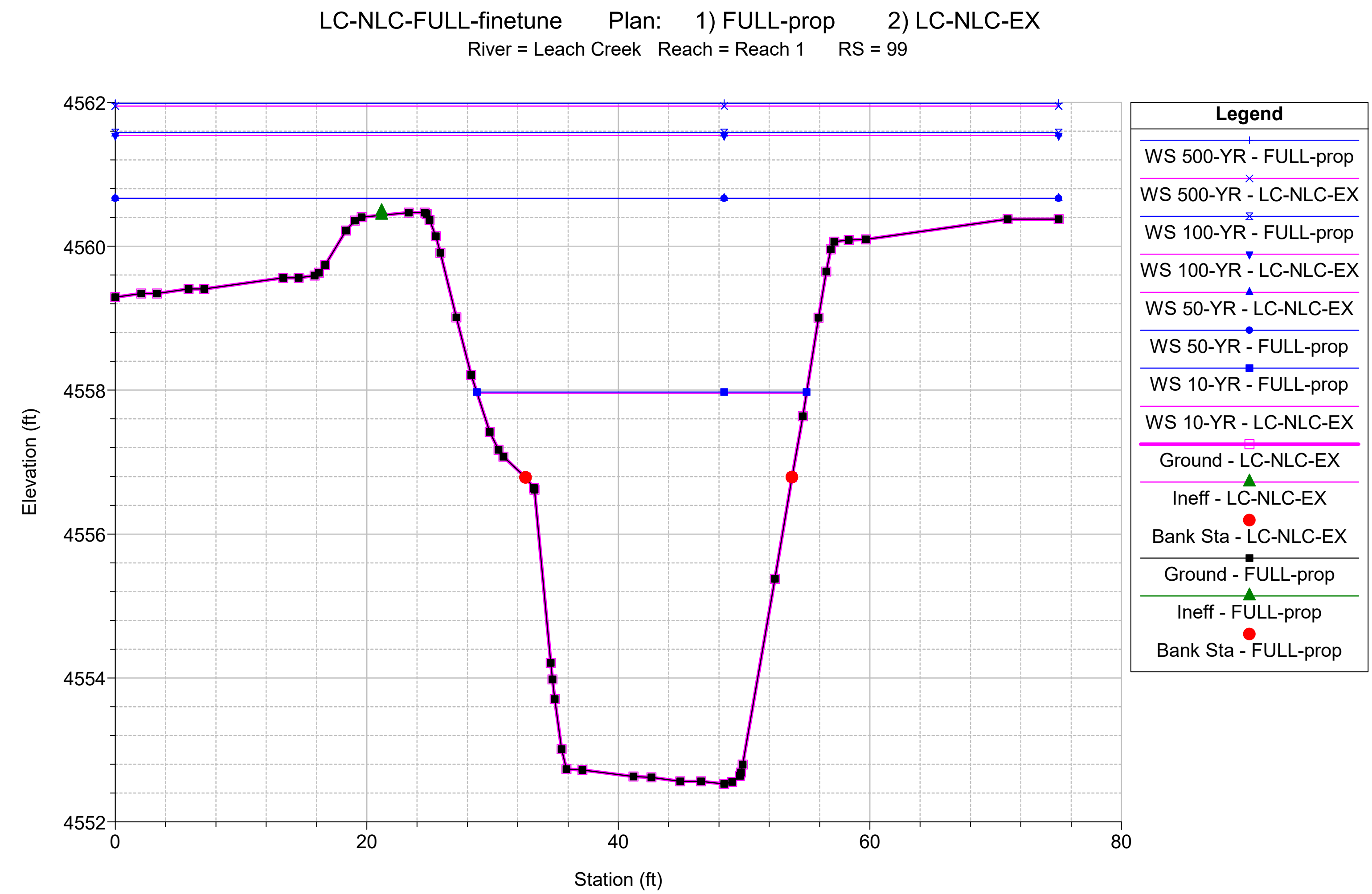
Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	145	10-YR	FULL-prop	312.00	4552.88	4558.03		4558.18	0.000833	3.07	106.70	30.66	0.26
Reach 1	145	10-YR	LC-NLC-EX	312.00	4552.88	4558.02		4558.17	0.000880	3.12	104.86	30.04	0.26
Reach 1	145	100-YR	FULL-prop	721.00	4552.88	4561.61		4561.78	0.000481	3.49	256.78	52.75	0.22
Reach 1	145	100-YR	LC-NLC-EX	721.00	4552.88	4561.57		4561.75	0.000517	3.57	250.97	52.75	0.22
Reach 1	119	10-YR	FULL-prop	312.00	4552.69	4558.04		4558.15	0.000550	2.60	126.59	34.82	0.21
Reach 1	119	10-YR	LC-NLC-EX	312.00	4552.66	4558.03		4558.14	0.000567	2.61	125.89	34.51	0.22
Reach 1	119	100-YR	FULL-prop	721.00	4552.69	4561.63		4561.76	0.000348	3.05	288.70	53.13	0.19
Reach 1	119	100-YR	LC-NLC-EX	721.00	4552.66	4561.59		4561.72	0.000366	3.08	285.29	53.13	0.19
Reach 1	99	10-YR	FULL-prop	312.00	4552.55	4557.97	4555.06	4558.13	0.000909	3.19	100.35	26.08	0.26
Reach 1	99	10-YR	LC-NLC-EX	312.00	4552.53	4557.96	4554.99	4558.12	0.000926	3.19	100.73	26.19	0.26
Reach 1	99	100-YR	FULL-prop	721.00	4552.55	4561.58	4556.71	4561.75	0.000512	3.54	278.27	75.01	0.22
Reach 1	99	100-YR	LC-NLC-EX	721.00	4552.53	4561.54	4556.62	4561.71	0.000536	3.56	276.72	75.01	0.22
Reach 1	76	10-YR	FULL-prop	312.00	4552.35	4557.84	4555.44	4558.09	0.001581	4.04	79.64	22.34	0.34
Reach 1	76	10-YR	LC-NLC-EX	312.00	4552.30	4557.83	4555.34	4558.08	0.001601	4.02	80.19	22.31	0.34
Reach 1	76	100-YR	FULL-prop	721.00	4552.35	4561.47	4557.29	4561.73	0.000826	4.37	218.32	63.47	0.27
Reach 1	76	100-YR	LC-NLC-EX	721.00	4552.30	4561.48	4557.22	4561.69	0.000738	4.07	262.71	80.42	0.25
Reach 1	66			Bridge									
Reach 1	51	10-YR	FULL-prop	312.00	4552.07	4557.80		4558.05	0.001599	4.06	80.19	23.93	0.35
Reach 1	51	10-YR	LC-NLC-EX	312.00	4552.17	4557.77	4555.59	4558.04	0.001677	4.13	79.00	24.03	0.36
Reach 1	51	100-YR	FULL-prop	721.00	4552.07	4561.41		4561.68	0.000820	4.41	208.29	46.83	0.28
Reach 1	51	100-YR	LC-NLC-EX	721.00	4552.17	4561.43	4557.42	4561.67	0.000786	4.31	234.65	64.53	0.27
Reach 1	36	10-YR	FULL-prop	312.00	4552.19	4557.70		4558.01	0.002044	4.50	72.57	22.19	0.39
Reach 1	36	10-YR	LC-NLC-EX	312.00	4552.11	4557.71	4555.68	4558.01	0.001966	4.41	73.81	22.00	0.38
Reach 1	36	100-YR	FULL-prop	721.00	4552.19	4561.44		4561.63	0.000710	4.08	272.77	78.63	0.26
Reach 1	36	100-YR	LC-NLC-EX	721.00	4552.11	4561.47	4557.48	4561.64	0.000609	3.77	307.21	88.42	0.24
Reach 2	-20	10-YR	FULL-prop	420.00	4552.01	4557.43	4555.68	4557.88	0.002690	5.44	83.62	26.51	0.46
Reach 2	-20	10-YR	LC-NLC-EX	420.00	4552.01	4557.43	4555.68	4557.88	0.002690	5.44	83.62	26.51	0.46
Reach 2	-20	100-YR	FULL-prop	1230.00	4552.01	4561.09	4558.81	4561.55	0.001644	6.37	336.42	134.02	0.40
Reach 2	-20	100-YR	LC-NLC-EX	1230.00	4552.01	4561.09	4558.81	4561.55	0.001644	6.37	336.42	134.02	0.40
Reach 2	-73	10-YR	FULL-prop	420.00	4552.01	4557.30		4557.73	0.002776	5.33	83.43	25.18	0.47
Reach 2	-73	10-YR	LC-NLC-EX	420.00	4552.01	4557.30		4557.73	0.002776	5.33	83.43	25.18	0.47
Reach 2	-73	100-YR	FULL-prop	1230.00	4552.01	4560.52	4558.33	4561.40	0.002754	7.91	220.72	101.18	0.52
Reach 2	-73	100-YR	LC-NLC-EX	1230.00	4552.01	4560.52	4558.33	4561.40	0.002754	7.91	220.72	101.18	0.52
Reach 2	-145	10-YR	FULL-prop	420.00	4551.81	4557.00		4557.51	0.003089	5.83	77.14	22.77	0.49
Reach 2	-145	10-YR	LC-NLC-EX	420.00	4551.81	4557.00		4557.51	0.003089	5.83	77.14	22.77	0.49
Reach 2	-145	100-YR	FULL-prop	1230.00	4551.81	4559.71	4558.34	4561.10	0.004677	9.89	161.29	65.12	0.65
Reach 2	-145	100-YR	LC-NLC-EX	1230.00	4551.81	4559.71	4558.34	4561.10	0.004677	9.89	161.29	65.12	0.65
Reach 2	-279	10-YR	FULL-prop	420.00	4550.56	4556.93		4557.18	0.001241	4.04	108.75	26.70	0.32
Reach 2	-279	10-YR	LC-NLC-EX	420.00	4550.56	4556.93		4557.18	0.001241	4.04	108.75	26.70	0.32
Reach 2	-279	100-YR	FULL-prop	1230.00	4550.56	4559.82		4560.50	0.001969	6.92	247.21	109.44	0.44
Reach 2	-279	100-YR	LC-NLC-EX	1230.00	4550.56	4559.82		4560.50	0.001969	6.92	247.21	109.44	0.44
Reach 2	-399	10-YR	FULL-prop	420.00	4551.32	4556.72		4557.01	0.001499	4.38	100.77	25.33	0.35
Reach 2	-399	10-YR	LC-NLC-EX	420.00	4551.32	4556.72		4557.01	0.001499	4.38	100.77	25.33	0.35
Reach 2	-399	100-YR	FULL-prop	1230.00	4551.32	4559.45		4560.23	0.002400	7.46	235.22	105.14	0.48
Reach 2	-399	100-YR	LC-NLC-EX	1230.00	4551.32	4559.45		4560.23	0.002400	7.46	235.22	105.14	0.48
Reach 2	-514	10-YR	FULL-prop	420.00	4550.66	4556.37		4556.79	0.002265	5.29	87.34	24.36	0.42
Reach 2	-514	10-YR	LC-NLC-EX	420.00	4550.66	4556.37		4556.79	0.002265	5.29	87.34	24.36	0.42
Reach 2	-514	100-YR	FULL-prop	1230.00	4550.66	4559.07	4557.34	4559.91	0.003057	8.23	248.86	115.40	0.53
Reach 2	-514	100-YR	LC-NLC-EX	1230.00	4550.66	4559.07	4557.34	4559.91	0.003057	8.23	248.86	115.40	0.53
Reach 2	-643	10-YR	FULL-prop	420.00	4549.97	4555.91	4553.96	4556.45	0.003001	5.97	76.67	22.05	0.47
Reach 2	-643	10-YR	LC-NLC-EX	420.00	4549.97	4555.91	4553.96	4556.45	0.003001	5.97	76.67	22.05	0.47
Reach 2	-643	100-YR	FULL-prop	1230.00	4549.97	4558.76	4558.49	4559.48	0.003002	8.04	281.60	128.98	0.50
Reach 2	-643	100-YR	LC-NLC-EX	1230.00	4549.97	4558.76	4558.49	4559.48	0.003002	8.04	281.60	128.98	0.50

LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 1 RS = 145

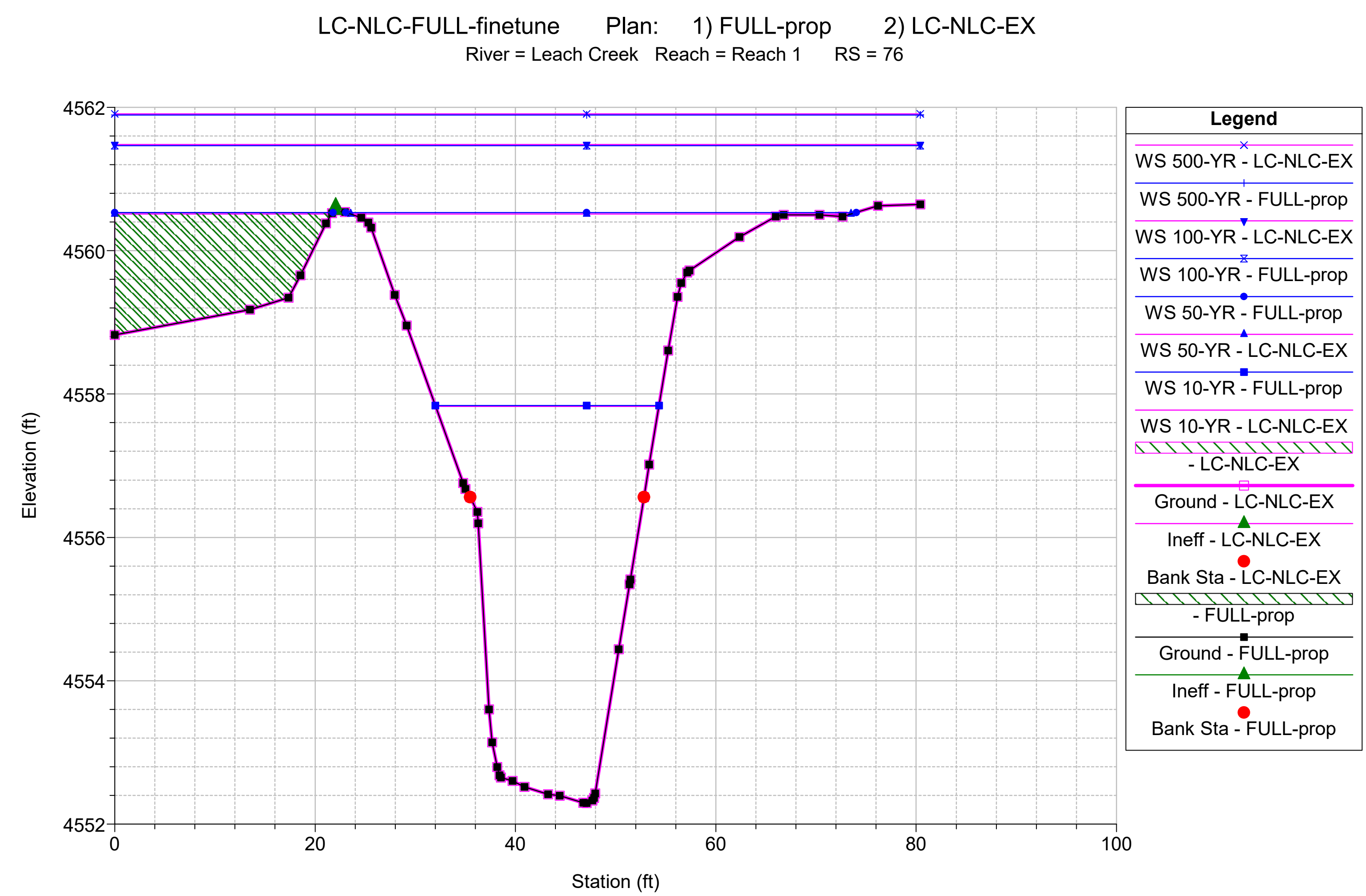


LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 1 RS = 119

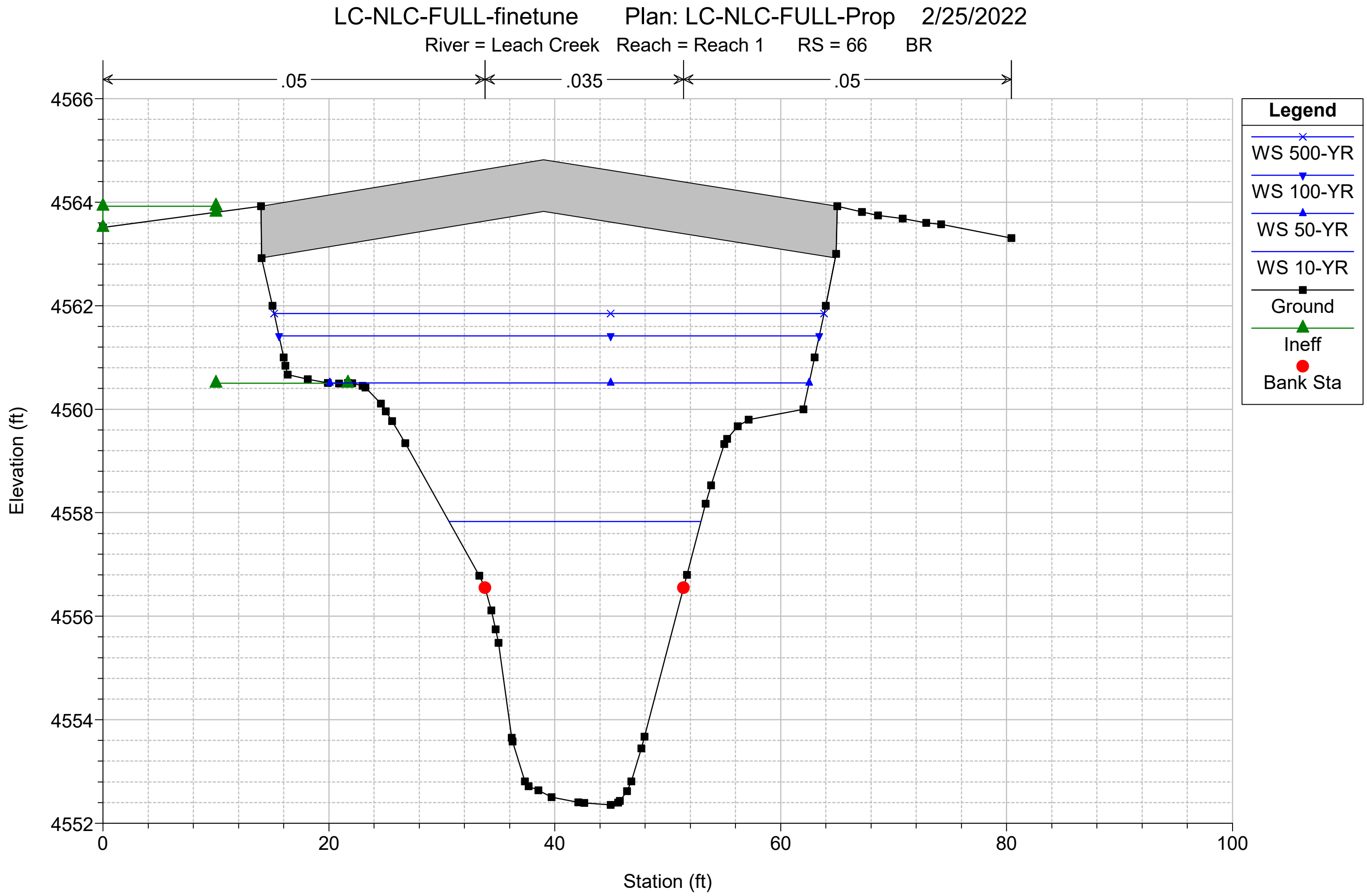




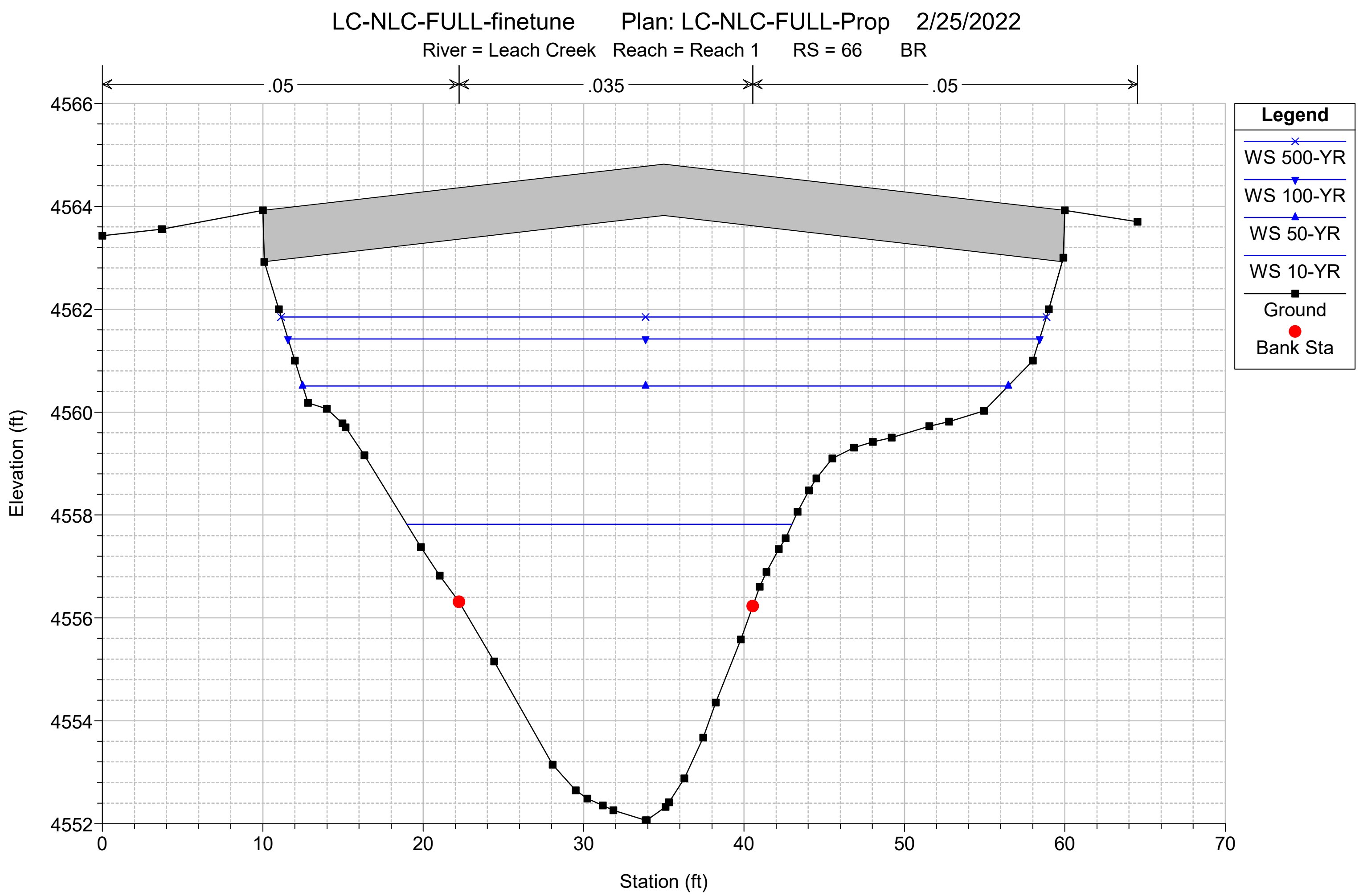
LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 1 RS = 99
Elevation (ft)
Station (ft)
4562
4560
4558
4556
4554
4552
0
20
40
60
80
Legend
WS 500-YR - FULL-prop
WS 500-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 50-YR - LC-NLC-EX
WS 50-YR - FULL-prop
WS 10-YR - FULL-prop
WS 10-YR - LC-NLC-EX
Ground - LC-NLC-EX
Ineff - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Ineff - FULL-prop
Bank Sta - FULL-prop



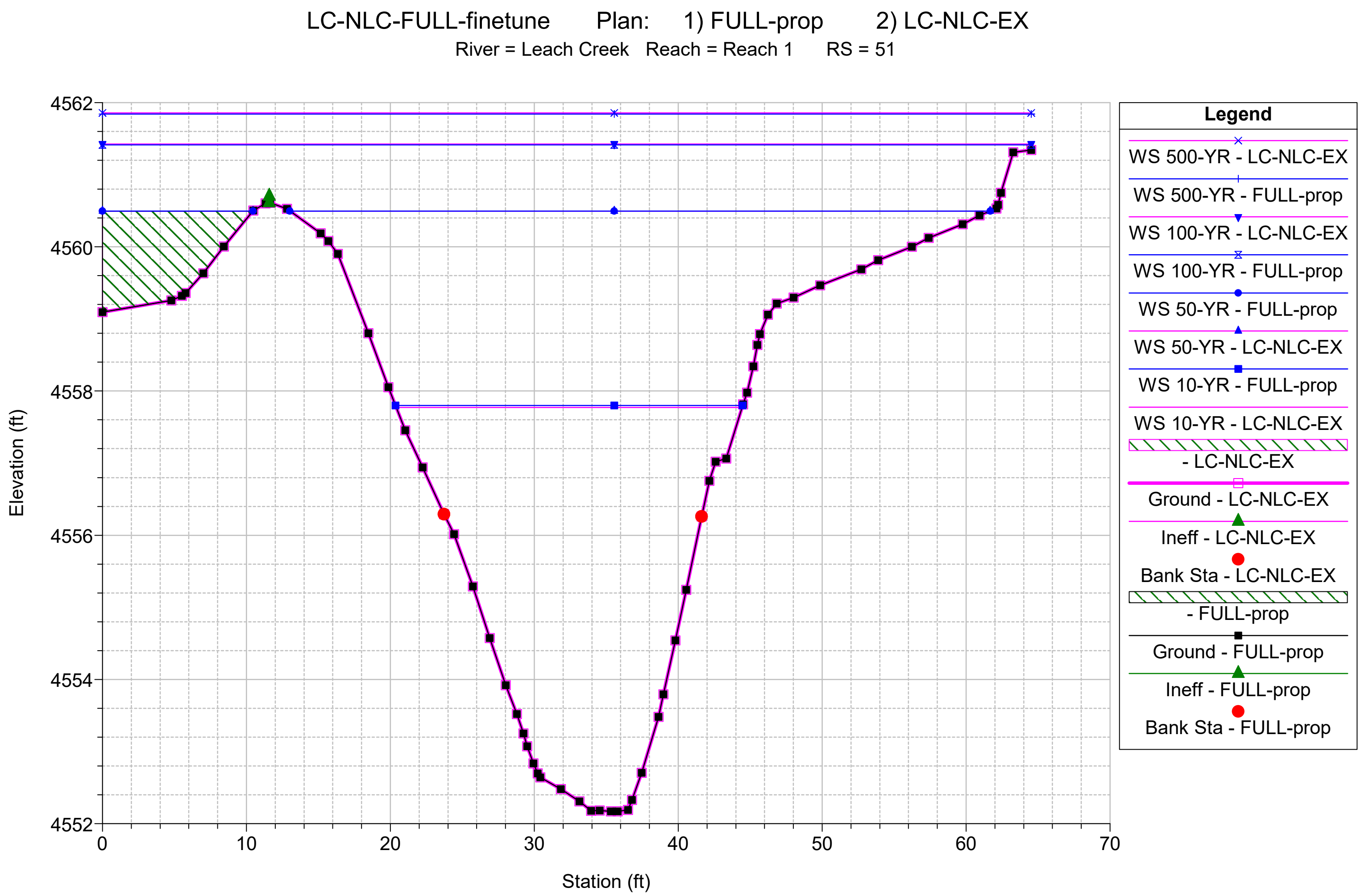
LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 1 RS = 76
Elevation (ft)
Station (ft)
4562
4560
4558
4556
4554
4552
0
20
40
60
80
100
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - FULL-prop
WS 10-YR - LC-NLC-EX
- LC-NLC-EX
Ground - LC-NLC-EX
Ineff - LC-NLC-EX
Bank Sta - LC-NLC-EX
- FULL-prop
Ground - FULL-prop
Ineff - FULL-prop
Bank Sta - FULL-prop

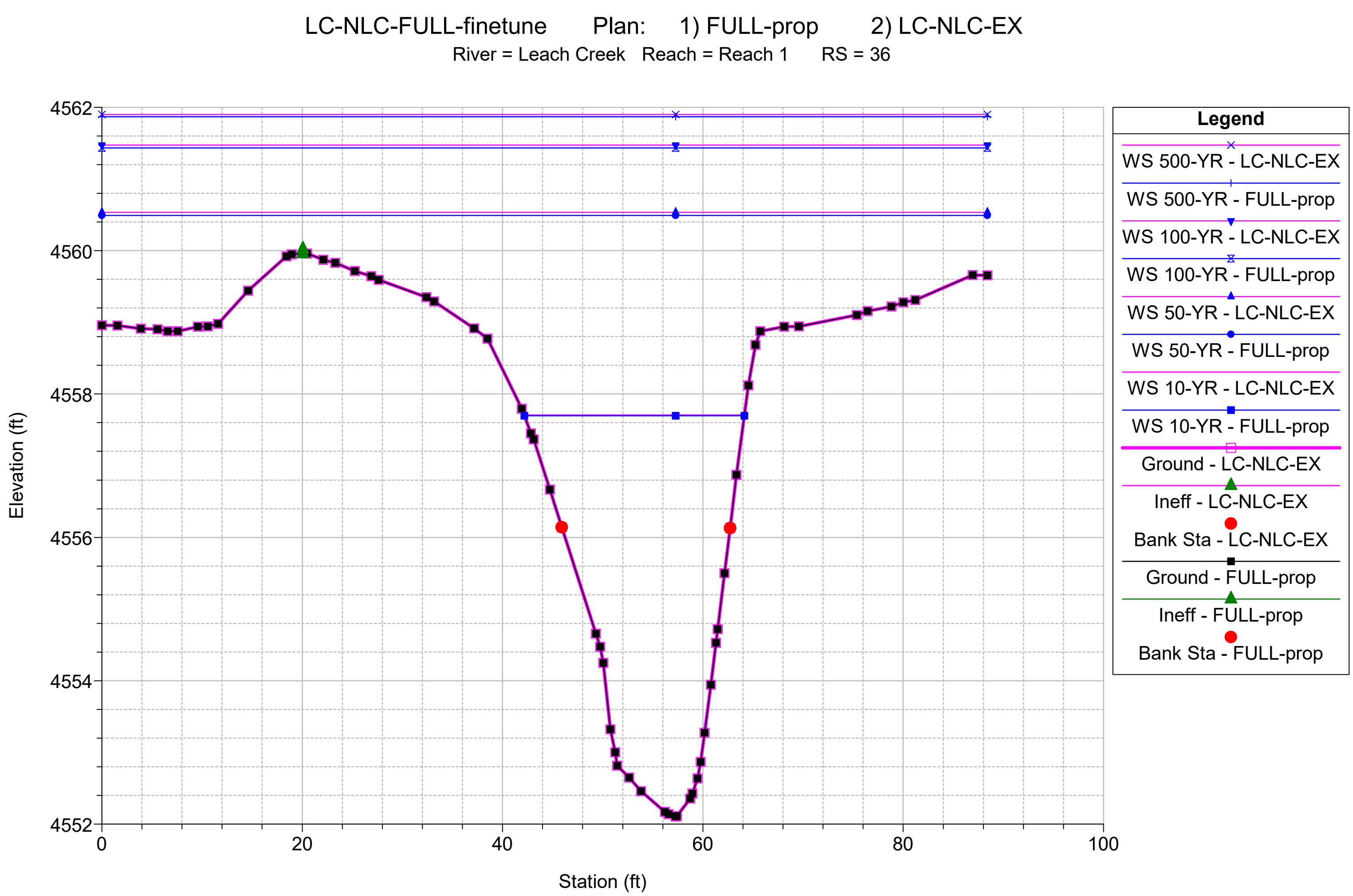


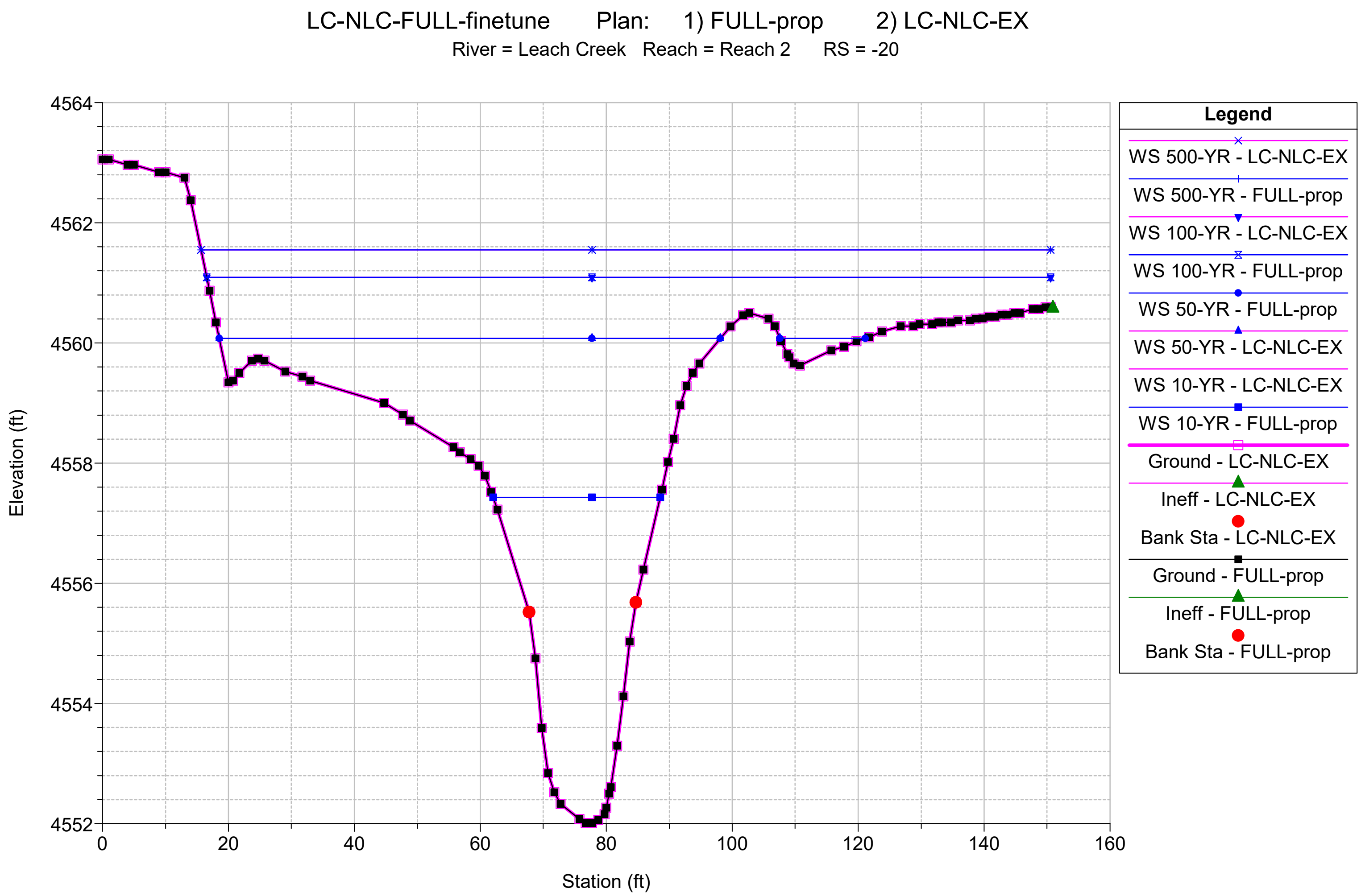
LC-NLC-FULL-finetune Plan: LC-NLC-FULL-Prop 2/25/2022
River = Leach Creek Reach = Reach 1 RS = 66 BR
.05
.035
.05
Legend
WS 500-YR
WS 100-YR
WS 50-YR
WS 10-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)



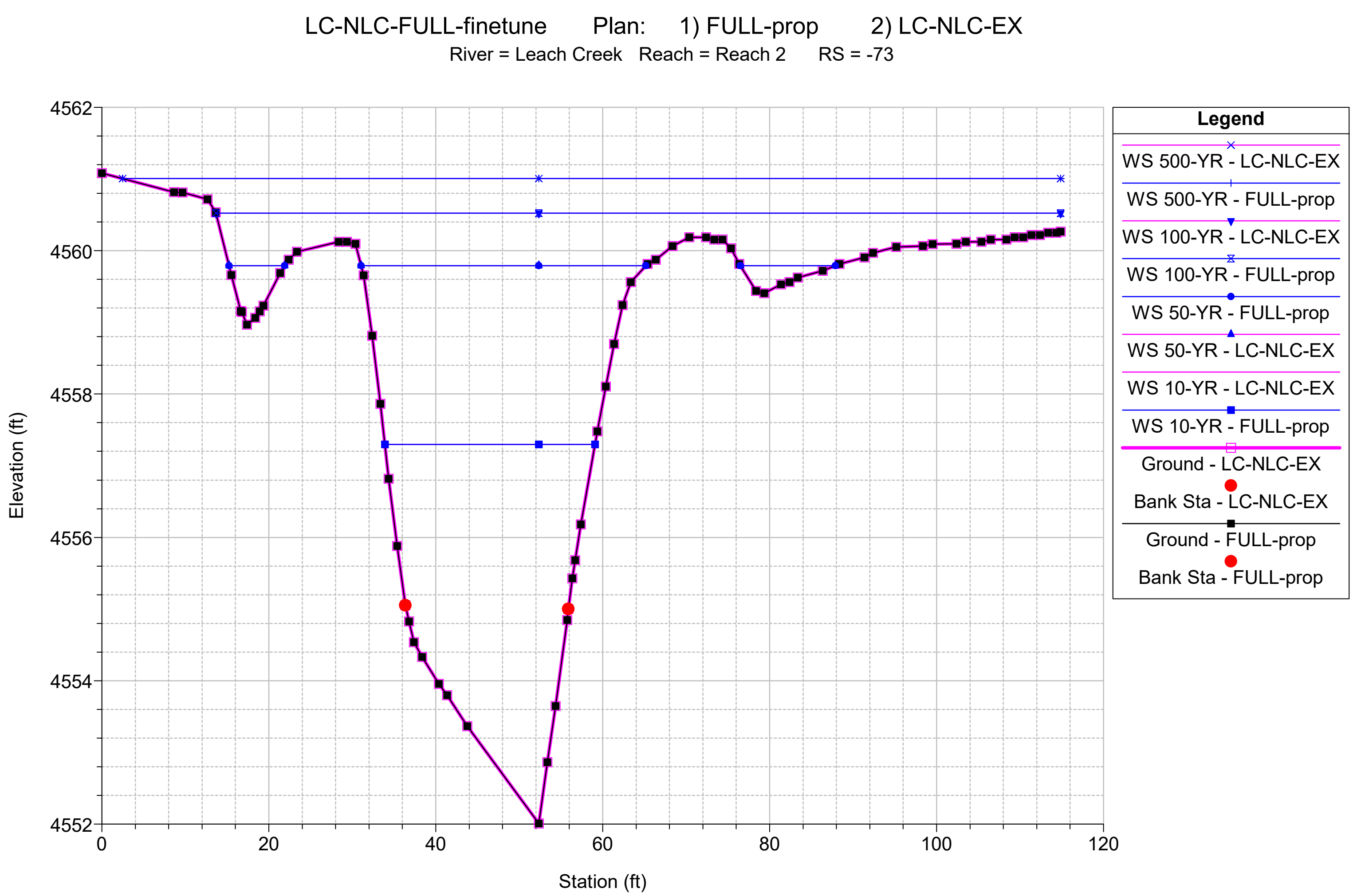
LC-NLC-FULL-finetune Plan: LC-NLC-FULL-Prop 2/25/2022
River = Leach Creek Reach = Reach 1 RS = 66 BR
.05
.035
.05
Legend
WS 500-YR
WS 100-YR
WS 50-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 1 RS = 51
Elevation (ft)
Station (ft)
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - FULL-prop
WS 10-YR - LC-NLC-EX
- LC-NLC-EX
Ground - LC-NLC-EX
Ineff - LC-NLC-EX
Bank Sta - LC-NLC-EX
- FULL-prop
Ground - FULL-prop
Ineff - FULL-prop
Bank Sta - FULL-prop
4562
4560
4558
4556
4554
4552
0
10
20
30
40
50
60
70

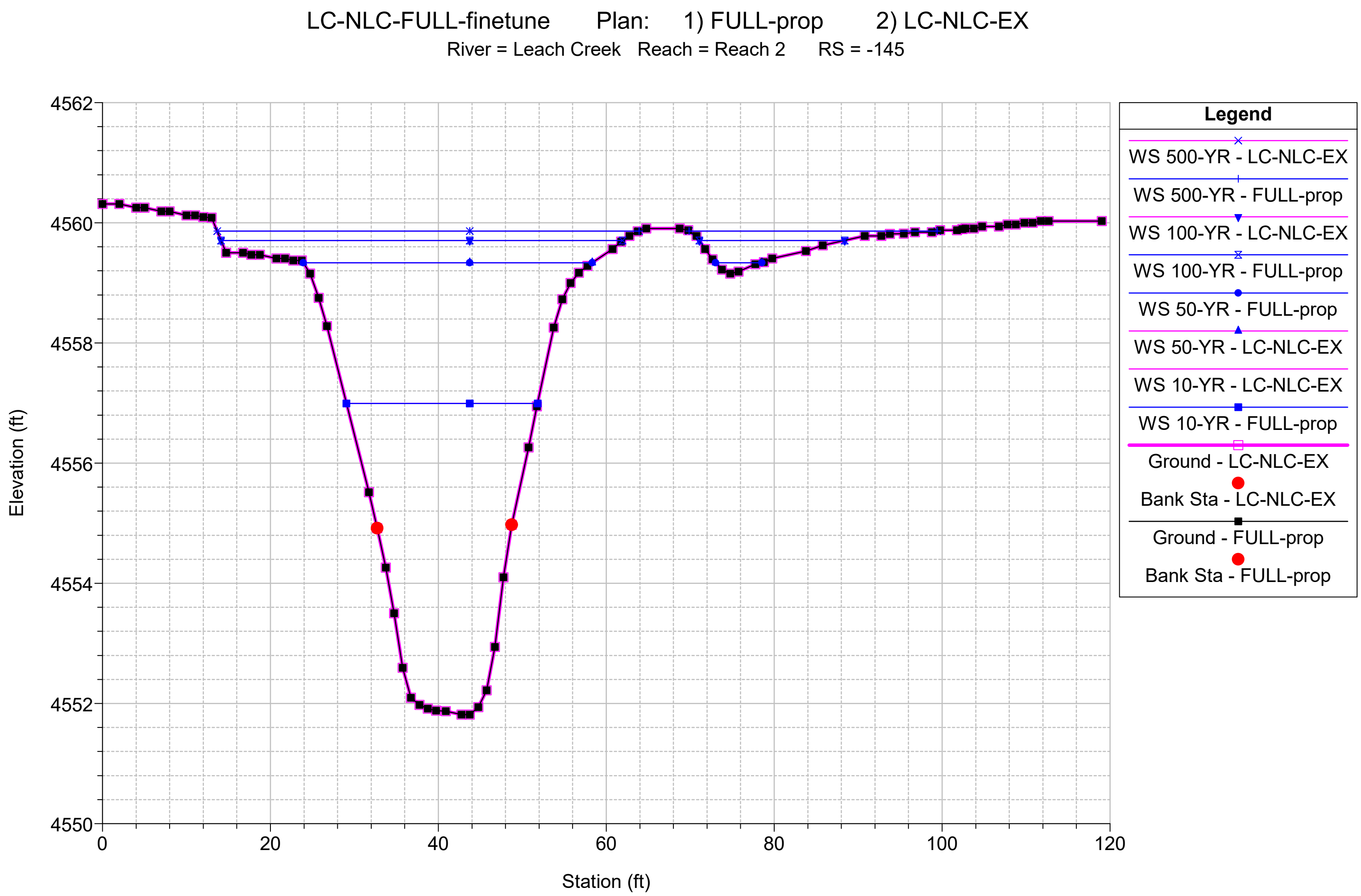

LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 1 RS = 36
Elevation (ft)
Station (ft)
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 50-YR - FULL-prop
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Ineff - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Ineff - FULL-prop
Bank Sta - FULL-prop
4562
4560
4558
4556
4554
4552
0
20
40
60
80
100

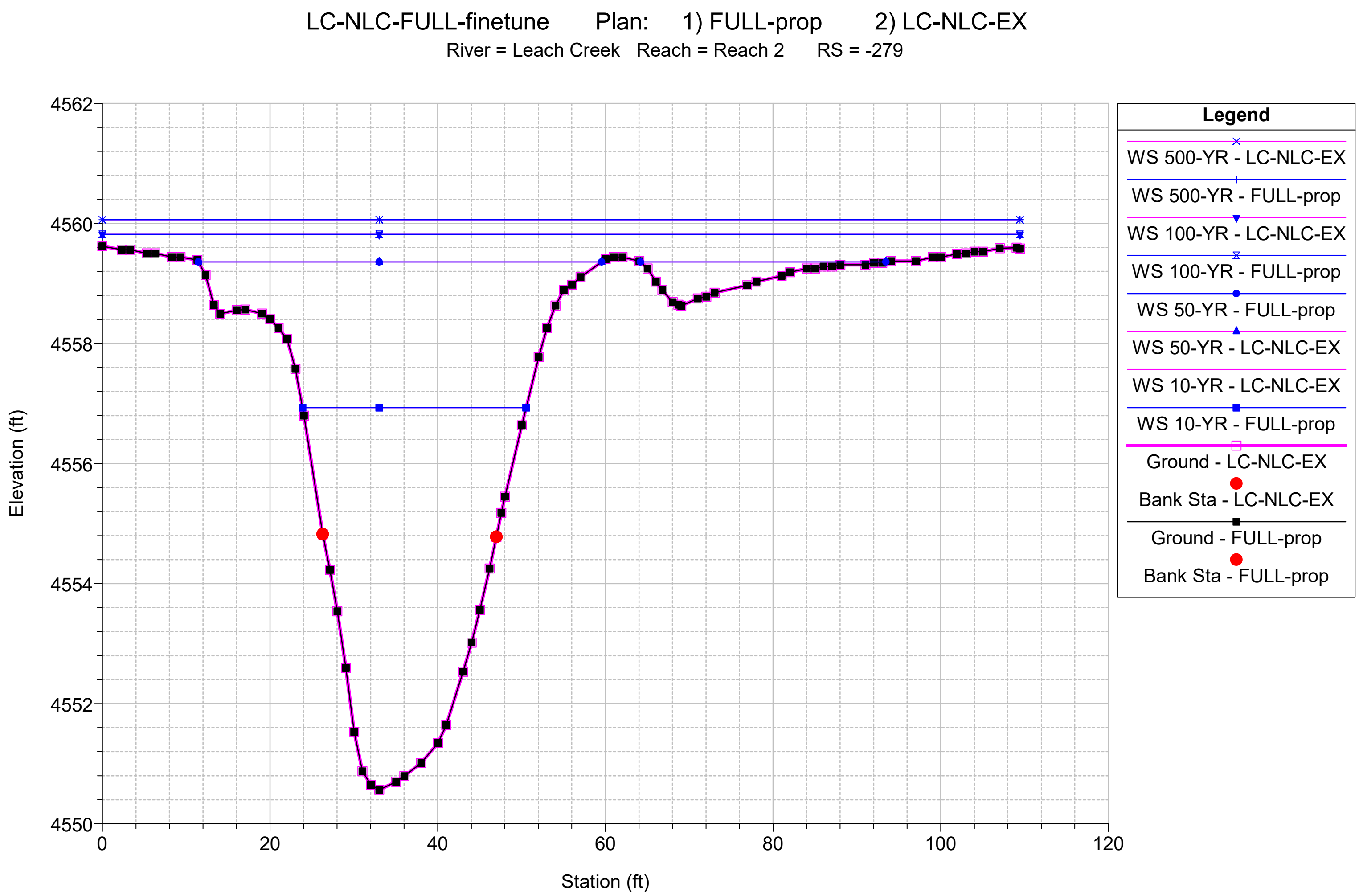


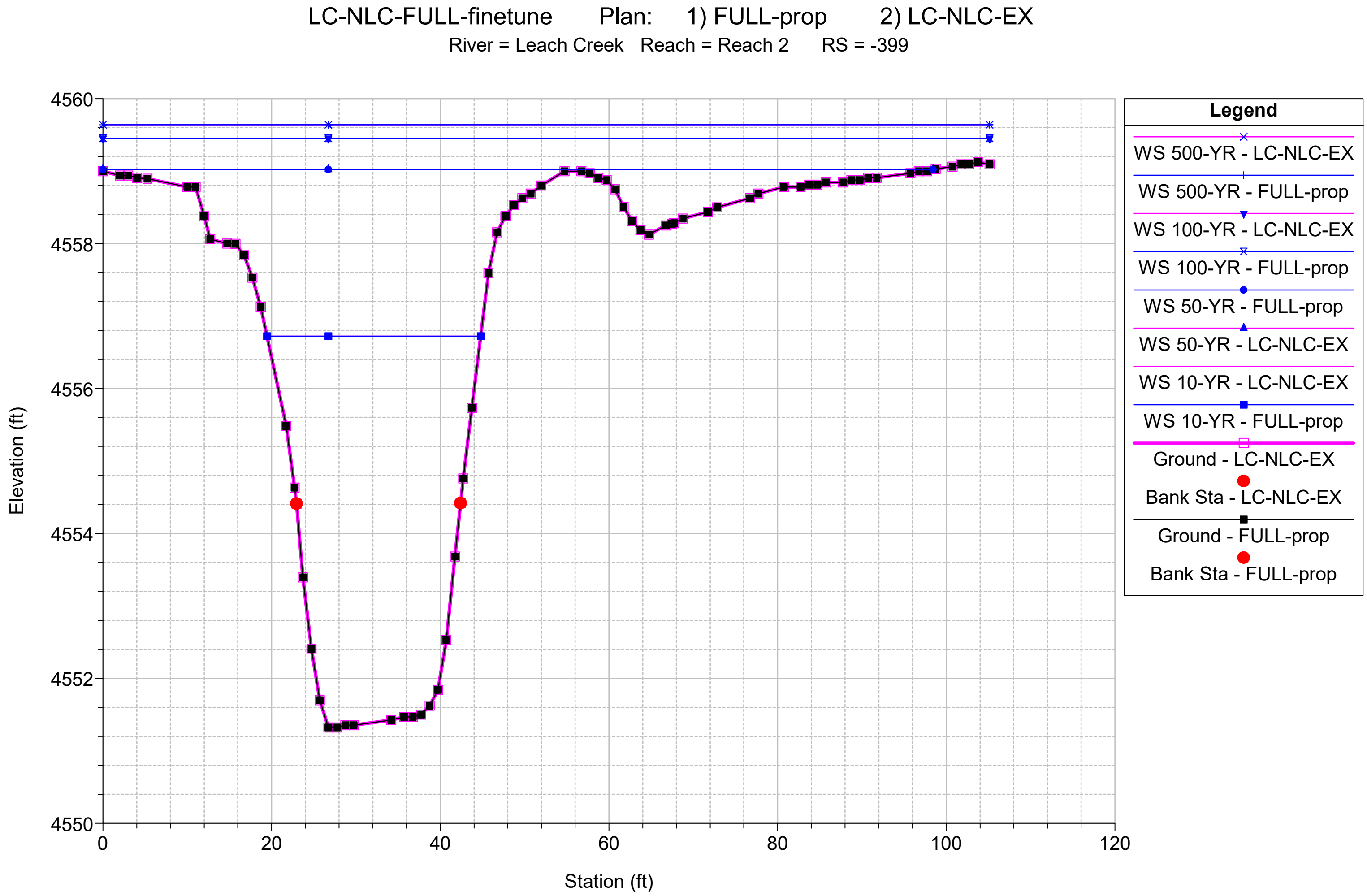
LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -20
Elevation (ft)
Station (ft)
4564
4562
4560
4558
4556
4554
4552
0
20
40
60
80
100
120
140
160
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Ineff - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Ineff - FULL-prop
Bank Sta - FULL-prop

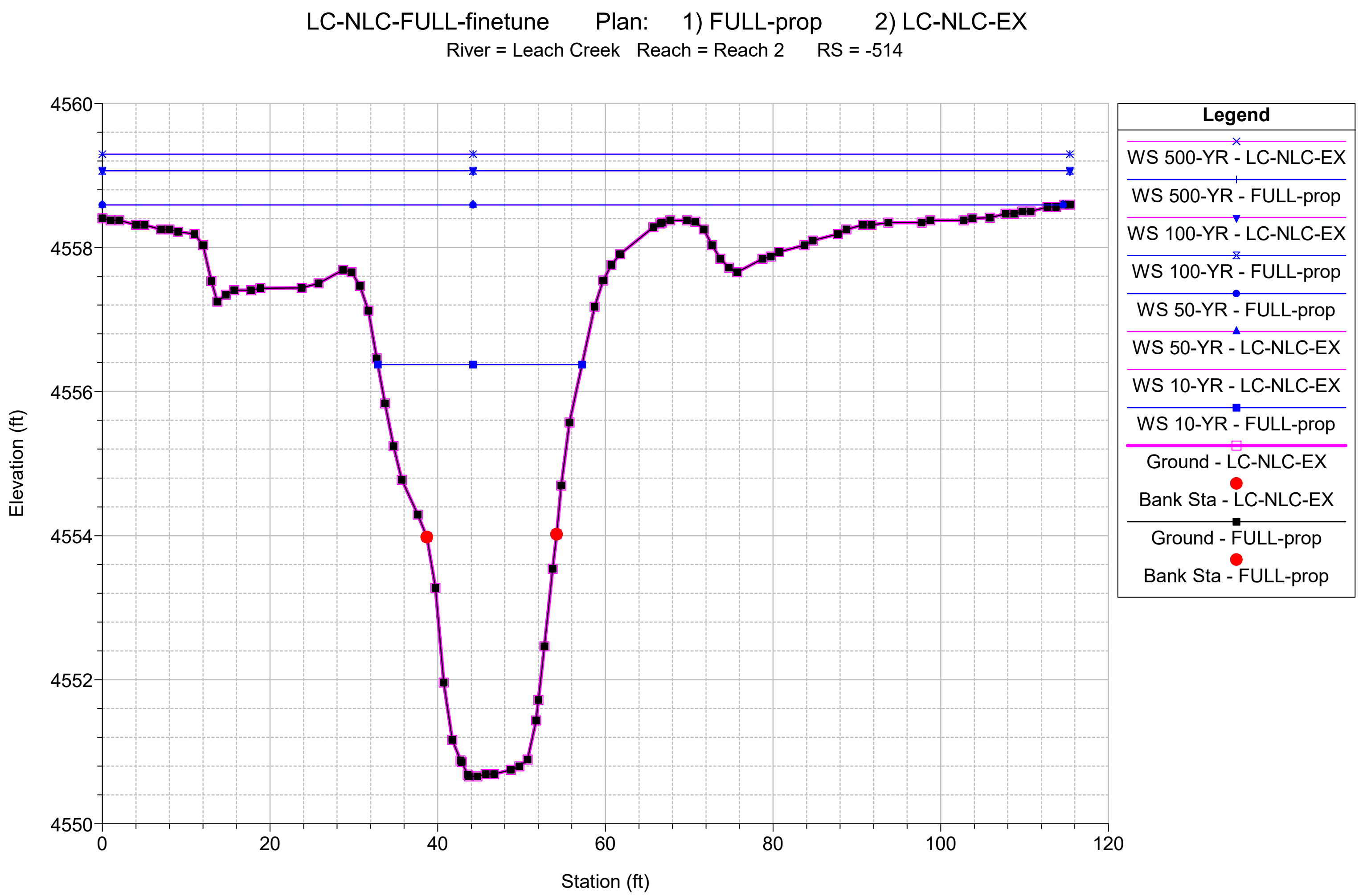


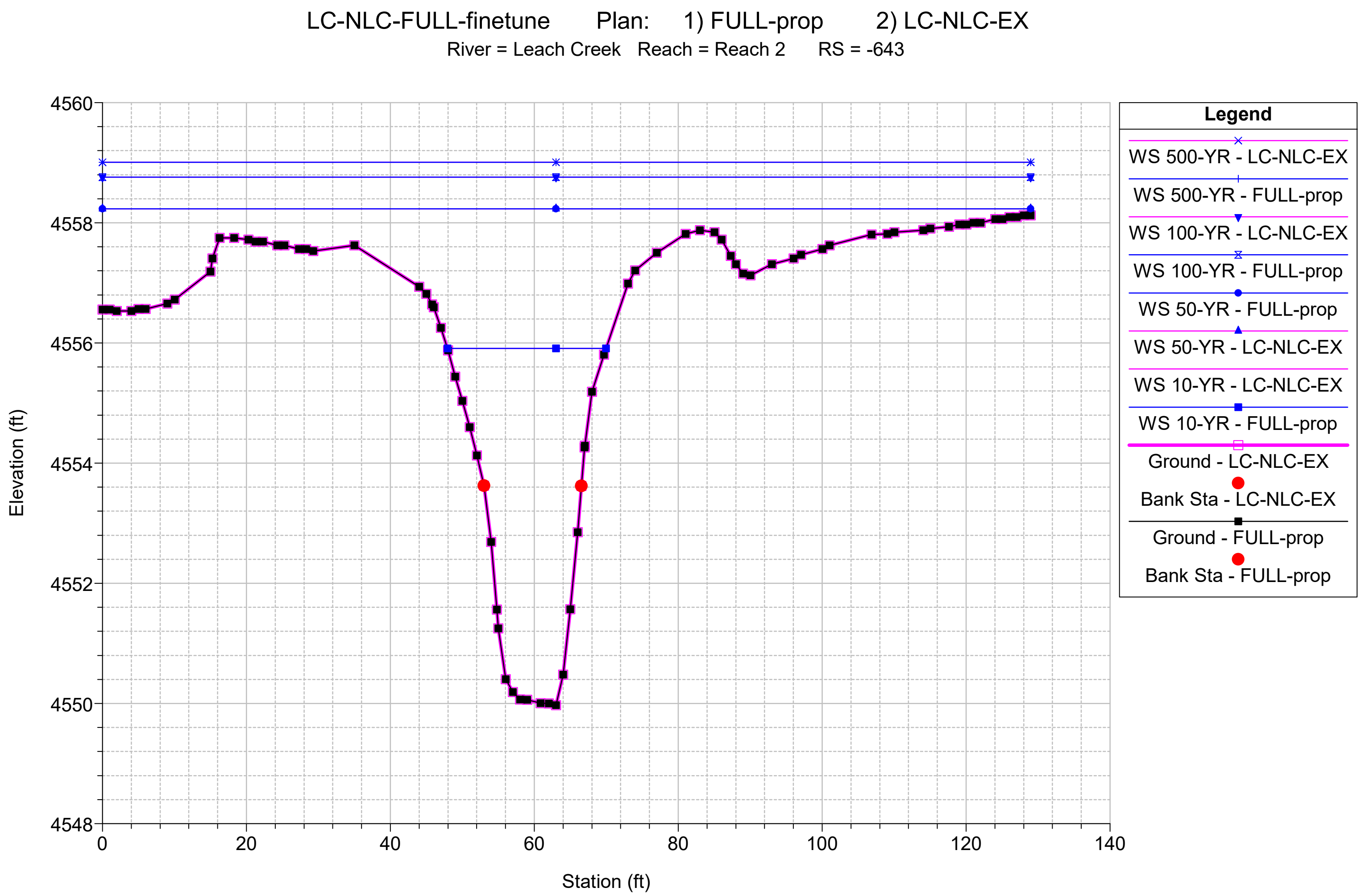
LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -73
Elevation (ft)
Station (ft)
4562
4560
4558
4556
4554
4552
0
20
40
60
80
100
120
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Bank Sta - FULL-prop


LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -145
Elevation (ft)
Station (ft)
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Bank Sta - FULL-prop

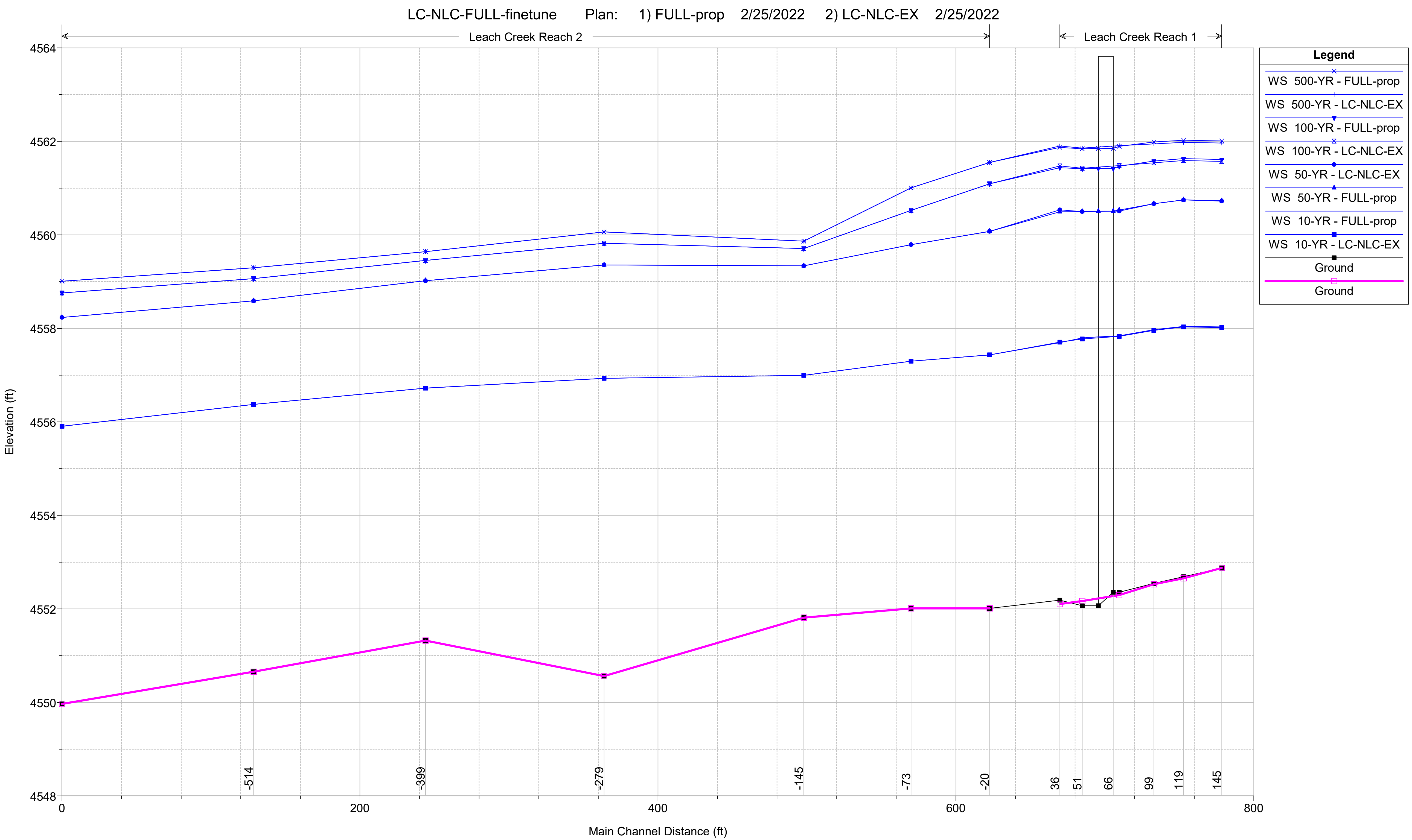

LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -279
Elevation (ft)
Station (ft)
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Bank Sta - FULL-prop


LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -399
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Bank Sta - FULL-prop
Elevation (ft)
Station (ft)
4560
4558
4556
4554
4552
4550
0
20
40
60
80
100
120


LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -514
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Bank Sta - FULL-prop
Elevation (ft)
Station (ft)
4560
4558
4556
4554
4552
4550
0
20
40
60
80
100
120



LC-NLC-FULL-finetune Plan: 1) FULL-prop 2) LC-NLC-EX
River = Leach Creek Reach = Reach 2 RS = -643
Elevation (ft)
4560
4558
4556
4554
4552
4550
4548
Station (ft)
0
20
40
60
80
100
120
140
Legend
WS 500-YR - LC-NLC-EX
WS 500-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 50-YR - FULL-prop
WS 50-YR - LC-NLC-EX
WS 10-YR - LC-NLC-EX
WS 10-YR - FULL-prop
Ground - LC-NLC-EX
Bank Sta - LC-NLC-EX
Ground - FULL-prop
Bank Sta - FULL-prop



LC-NLC-FULL-finetune Plan: 1) FULL-prop 2/25/2022 2) LC-NLC-EX 2/25/2022
Leach Creek Reach 2
Leach Creek Reach 1
Legend
WS 500-YR - FULL-prop
WS 500-YR - LC-NLC-EX
WS 100-YR - FULL-prop
WS 100-YR - LC-NLC-EX
WS 50-YR - LC-NLC-EX
WS 50-YR - FULL-prop
WS 10-YR - FULL-prop
WS 10-YR - LC-NLC-EX
Ground
Ground
Elevation (ft)
4564
4562
4560
4558
4556
4554
4552
4550
4548
-514
-399
-279
-145
-73
-20
36
51
66
99
119
145
0
200
400
600
800
Main Channel Distance (ft)

Plan: FULL-prop Leach Creek Reach 1 RS: 66 Profile: 10-YR

E.G. US. (ft)	4558.09	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	4557.84	E.G. Elev (ft)	4558.09	4558.07
Q Total (cfs)	312.00	W.S. Elev (ft)	4557.83	4557.82
Q Bridge (cfs)	312.00	Crit W.S. (ft)	4555.44	4555.63
Q Weir (cfs)		Max Chl Dpth (ft)	5.48	5.75
Weir Sta Lft (ft)		Vel Total (ft/s)	3.93	3.87
Weir Sta Rgt (ft)		Flow Area (sq ft)	79.47	80.69
Weir Submerg		Froude # Chl	0.34	0.35
Weir Max Depth (ft)		Specif Force (cu ft)	222.18	215.95
Min El Weir Flow (ft)	4563.44	Hydr Depth (ft)	3.56	3.36
Min El Prs (ft)	4563.82	W.P. Total (ft)	26.14	27.06
Delta EG (ft)	0.04	Conv. Total (cfs)	7823.8	7870.9
Delta WS (ft)	0.04	Top Width (ft)	22.31	24.00
BR Open Area (sq ft)	297.02	Frctn Loss (ft)	0.02	0.02
BR Open Vel (ft/s)	3.93	C & E Loss (ft)	0.00	0.00
BR Sluice Coef		Shear Total (lb/sq ft)	0.30	0.29
BR Sel Method	Energy only	Power Total (lb/ft s)	1.19	1.13

Plan: FULL-prop Leach Creek Reach 1 RS: 66 Profile: 50-YR

E.G. US. (ft)	4560.83	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	4560.53	E.G. Elev (ft)	4560.83	4560.80
Q Total (cfs)	617.00	W.S. Elev (ft)	4560.51	4560.51
Q Bridge (cfs)	617.00	Crit W.S. (ft)	4556.88	4556.97
Q Weir (cfs)		Max Chl Dpth (ft)	8.15	8.44
Weir Sta Lft (ft)		Vel Total (ft/s)	3.92	3.69
Weir Sta Rgt (ft)		Flow Area (sq ft)	157.53	167.08
Weir Submerg		Froude # Chl	0.31	0.30
Weir Max Depth (ft)		Specif Force (cu ft)	574.70	578.25
Min El Weir Flow (ft)	4563.44	Hydr Depth (ft)	3.71	3.80
Min El Prs (ft)	4563.82	W.P. Total (ft)	47.46	48.13
Delta EG (ft)	0.05	Conv. Total (cfs)	18442.3	19461.0
Delta WS (ft)	0.04	Top Width (ft)	42.42	43.99
BR Open Area (sq ft)	297.02	Frctn Loss (ft)	0.01	0.01
BR Open Vel (ft/s)	3.92	C & E Loss (ft)	0.01	0.00
BR Sluice Coef		Shear Total (lb/sq ft)	0.23	0.22
BR Sel Method	Energy only	Power Total (lb/ft s)	0.91	0.80

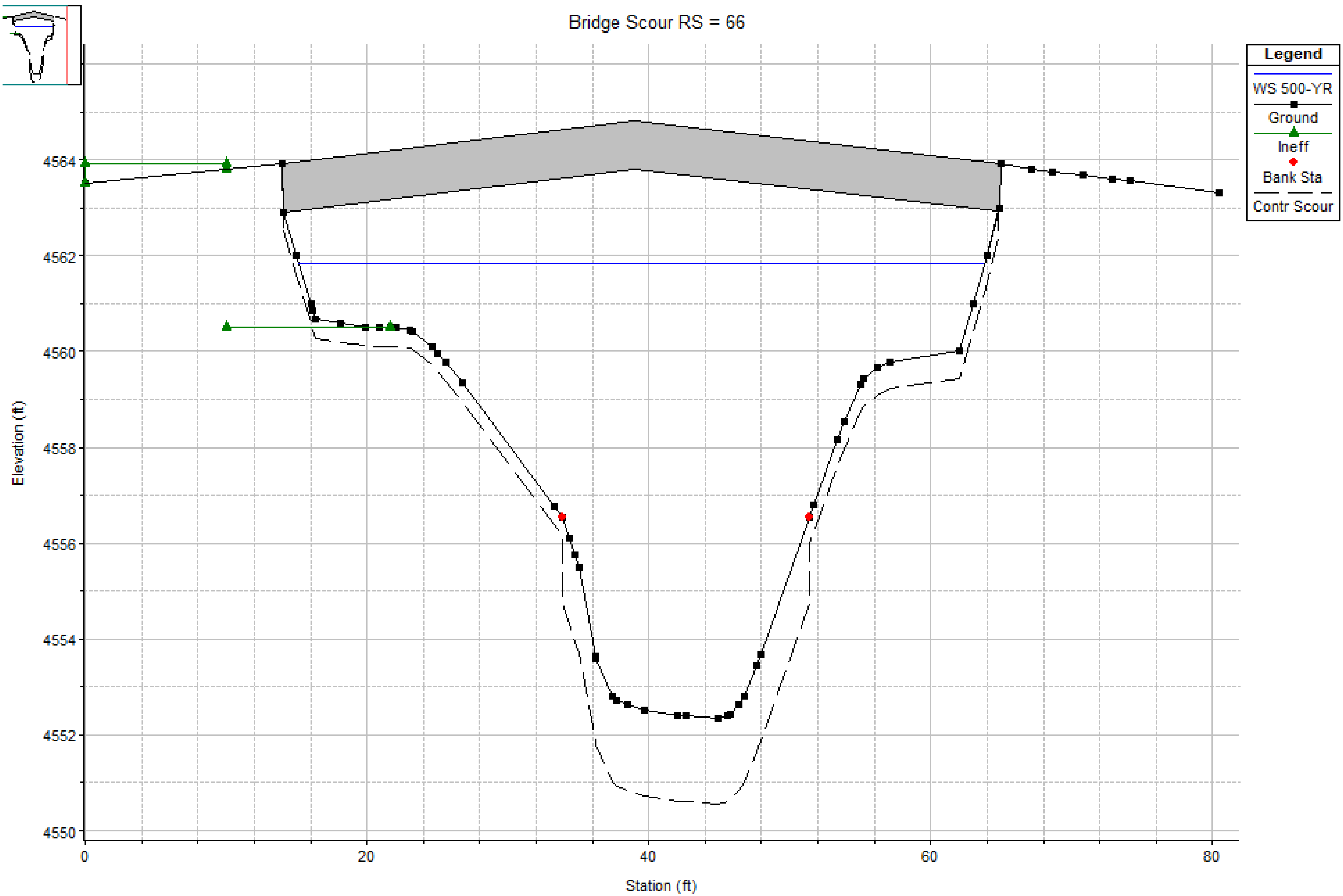
Plan: FULL-prop   Leach Creek   Reach 1 RS: 66   Profile: 100-YR

E.G. US. (ft)	4561.73	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	4561.47	E.G. Elev (ft)	4561.71	4561.69
Q Total (cfs)	721.00	W.S. Elev (ft)	4561.42	4561.42
Q Bridge (cfs)	721.00	Crit W.S. (ft)	4557.29	4557.37
Q Weir (cfs)		Max Chl Dpth (ft)	9.06	9.36
Weir Sta Lft (ft)		Vel Total (ft/s)	3.61	3.45
Weir Sta Rgt (ft)		Flow Area (sq ft)	200.00	208.77
Weir Submerg		Froude # Chl	0.29	0.28
Weir Max Depth (ft)		Specif Force (cu ft)	746.47	758.59
Min El Weir Flow (ft)	4563.44	Hydr Depth (ft)	4.18	4.46
Min El Prs (ft)	4563.82	W.P. Total (ft)	53.56	51.62
Delta EG (ft)	0.04	Conv. Total (cfs)	23833.7	25241.1
Delta WS (ft)	0.05	Top Width (ft)	47.84	46.85
BR Open Area (sq ft)	297.02	Frctn Loss (ft)	0.01	0.01
BR Open Vel (ft/s)	3.61	C & E Loss (ft)	0.01	0.00
BR Sluice Coef		Shear Total (lb/sq ft)	0.21	0.21
BR Sel Method	Energy only	Power Total (lb/ft s)	0.77	0.71

Plan: FULL-prop   Leach Creek   Reach 1 RS: 66   Profile: 500-YR

E.G. US. (ft)	4562.11	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	4561.89	E.G. Elev (ft)	4562.10	4562.08
Q Total (cfs)	730.00	W.S. Elev (ft)	4561.85	4561.85
Q Bridge (cfs)	730.00	Crit W.S. (ft)	4557.29	4557.41
Q Weir (cfs)		Max Chl Dpth (ft)	9.49	9.78
Weir Sta Lft (ft)		Vel Total (ft/s)	3.31	3.19
Weir Sta Rgt (ft)		Flow Area (sq ft)	220.71	228.99
Weir Submerg		Froude # Chl	0.26	0.25
Weir Max Depth (ft)		Specif Force (cu ft)	830.36	846.55
Min El Weir Flow (ft)	4563.44	Hydr Depth (ft)	4.53	4.80
Min El Prs (ft)	4563.82	W.P. Total (ft)	54.78	52.83
Delta EG (ft)	0.04	Conv. Total (cfs)	26733.0	28257.1
Delta WS (ft)	0.05	Top Width (ft)	48.69	47.70
BR Open Area (sq ft)	297.02	Frctn Loss (ft)	0.01	0.01
BR Open Vel (ft/s)	3.31	C & E Loss (ft)	0.01	0.00
BR Sluice Coef		Shear Total (lb/sq ft)	0.19	0.18
BR Sel Method	Energy only	Power Total (lb/ft s)	0.62	0.58

500-YEAR SCOUR CALCULATED AT CROSS SECTION 99



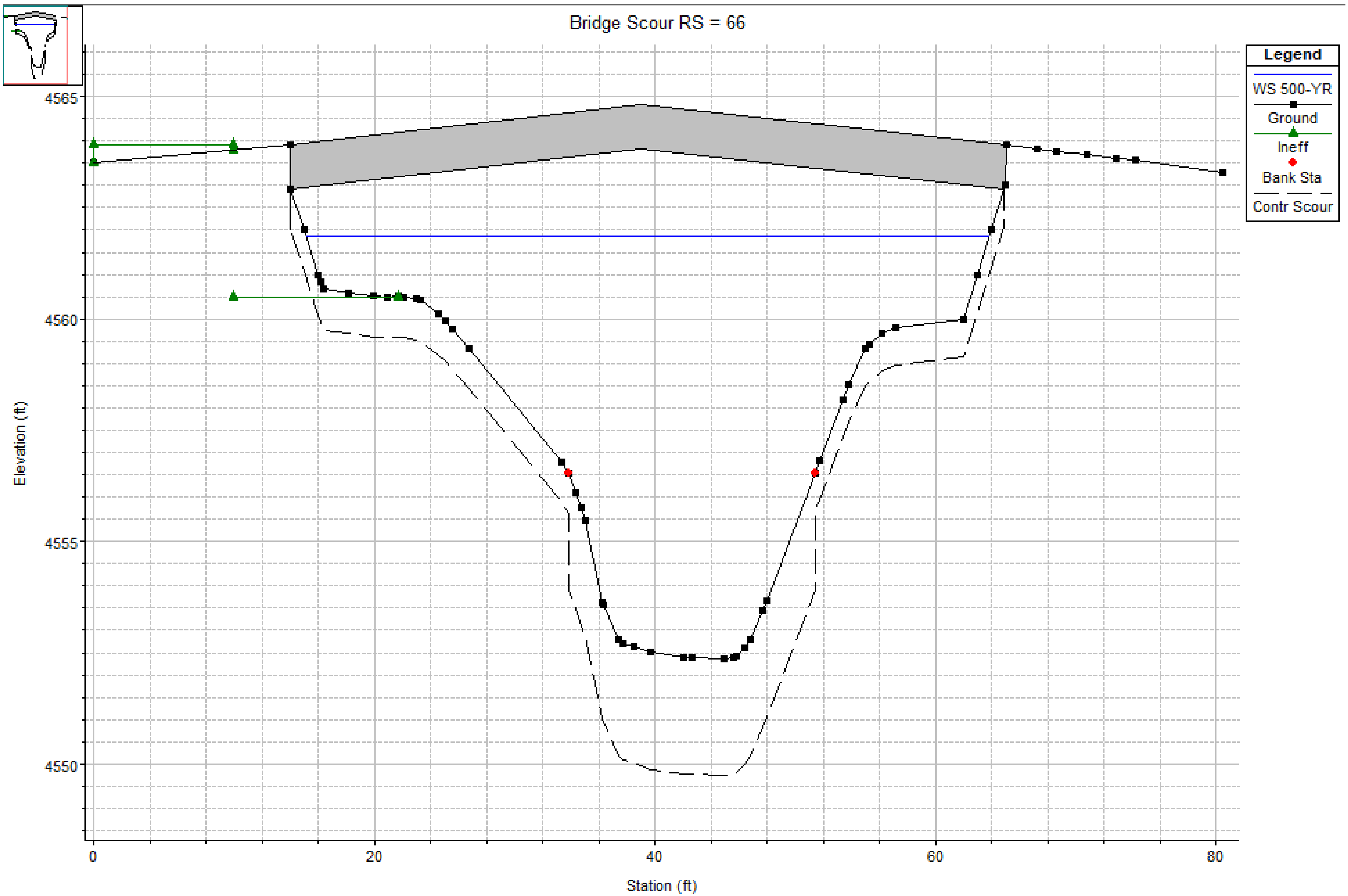
LEACH CREEK REACH 1 - 500 YEAR SCOUR RESULTS AT XS 99

Contraction Scour

	Left	Channel	Right
Input Data			
Average Depth (ft):	2.57	8.53	2.01
Approach Velocity (ft/s):	1.06	3.29	0.89
Br Average Depth (ft):	2.35	8.37	2.40
BR Opening Flow (cfs):	60.45	629.91	39.65
BR Top WD (ft):	18.68	17.57	12.45
Grain Size D50 (mm):	0.01	0.01	0.01
Approach Flow (cfs):	84.06	605.34	40.60
Approach Top WD (ft):	30.87	21.57	22.57
K1 Coefficient:	0.690	0.690	0.690
Results			
Scour Depth Ys (ft):	0.39	1.80	0.57
Critical Velocity (ft/s):	0.42	0.51	0.40
Equation:	Live	Live	Live

Combined Scour Depths

500-YEAR SCOUR CALCULATED AT CROSS SECTION 119



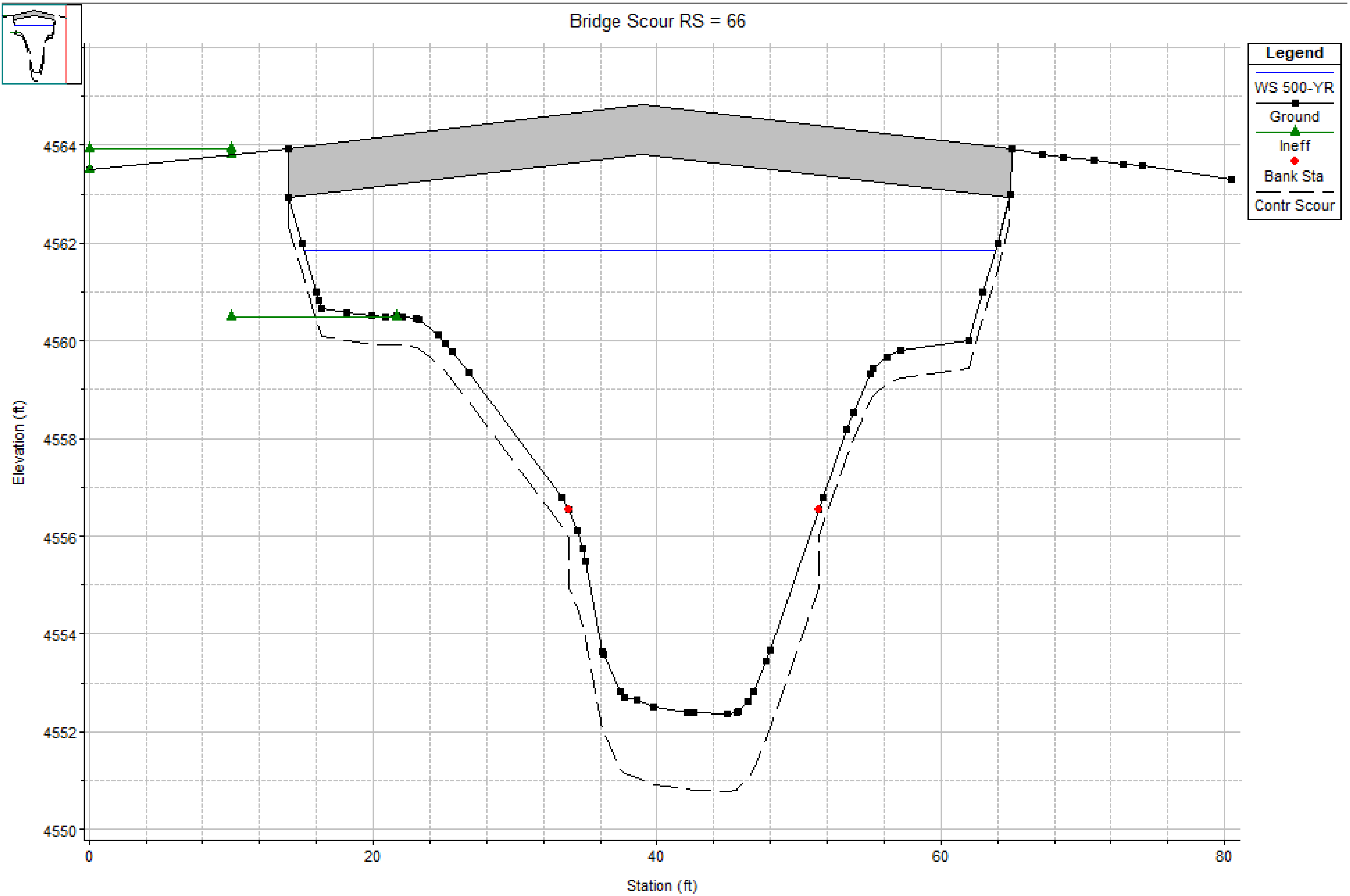
LEACH CREEK REACH 1 - 500 YEAR SCOUR RESULTS AT XS 119

Contraction Scour

	Left	Channel	Right
Input Data			
Average Depth (ft):	3.85	8.55	2.81
Approach Velocity (ft/s):	1.11	2.90	0.92
Br Average Depth (ft):	2.35	8.37	2.40
BR Opening Flow (cfs):	60.45	629.91	39.65
BR Top WD (ft):	18.68	17.57	12.45
Grain Size D50 (mm):	0.01	0.01	0.01
Approach Flow (cfs):	51.14	638.96	39.90
Approach Top WD (ft):	11.95	25.74	15.44
K1 Coefficient:	0.690	0.690	0.690
Results			
Scour Depth Ys (ft):	0.91	2.62	0.84
Critical Velocity (ft/s):	0.45	0.51	0.43
Equation:	Live	Live	Live

Combined Scour Depths

500-YEAR SCOUR CALCULATED AT CROSS SECTION 145



LEACH CREEK REACH 1 - 500 YEAR SCOUR RESULTS AT XS 145

Contraction Scour

	Left	Channel	Right
Input Data			
Average Depth (ft):	3.69	8.29	2.39
Approach Velocity (ft/s):	1.26	3.31	0.97
Br Average Depth (ft):	2.35	8.37	2.40
BR Opening Flow (cfs):	60.45	629.91	39.65
BR Top WD (ft):	18.68	17.57	12.45
Grain Size D50 (mm):	0.01	0.01	0.01
Approach Flow (cfs):	52.96	635.01	42.03
Approach Top WD (ft):	11.40	23.15	18.19
K1 Coefficient:	0.690	0.690	0.690
Results			
Scour Depth Ys (ft):	0.59	1.59	0.55
Critical Velocity (ft/s):	0.45	0.51	0.41
Equation:	Live	Live	Live

Combined Scour Depths

Appendix B – Riprap Sizing Calculations

USDA - NEH - technical supplement 14-c - stone sizing criteria

water density	62.4	lb/cf
riprap density	165	lb/cf
mean channel velocity (fps)	5	
500 year storm peak flow (cfs)	730	
channel bottom width (ft)	10	
q, unit discharge (cf/s/ft)	73	
S, channel slope (ft/ft)	0.004	
ISBASH METHOD		
d50, ft	0.35	ft
=V^2/(2*g*C^2*(Gs-1)	4.20	in
V, mean ch vel (fps)	5	
Gs, specific gravity of stone (2.5-2.7)	2.5	
g, grav constant	32.2	ft/s2
C, 0.86 high turbulence zones	0.86	
USBR METHOD		
d50, ft	0.34	ft
=.0122*V^2.06	4.03	in
V, mean ch vel (fps)	5	
ABS rock chutes on steep slopes		
d50, in		
for S<0.1 : d50=12*(1.923*q*S^1.5)^0.529	2.05	in
q, unit discharge (cf/s/ft)	73	
S, channel slope (ft/ft)	0.004	
USGS METHOD		
d50, ft	0.51	FT
=.01*V^2.44	6.09	in
V, mean ch vel (fps)	5	
USACE - Maynord method		
D30 (Ft)	0.12	ft
D30 (in)	1.46	in
d, water depth (ft)	9.5	
FS, factor of safety 1.2	1.2	
Cs, stability coeff, =0.3	0.3	
Cv, velocity distribution coeff, 1.0 straight chann	1	
CT, thickness coeff, =1.0	1	
yw, specific wt of water (lb/cf)	62.4	
ys, specific wt of stone (lb/cf)	165	
V, local velocity (fps)	5	
g, gravity (ft/s^2)	32.2	
K1, side slope correction	0.71747	
theta, angle of rock from horizontal (deg)	26.6	2:1 slope
phi, angle of repose = 40 deg	40	