WATERSHED
SCIENCE & ENGINEERING
110 Prefontaine Place South, Suite 508
Seattle, WA 98104
206-521-3000

# Memorandum

To: PACE Engineers, Inc.

From: Shaina Sabatine P.E., Larry Karpack P.E.

Date: May 28, 2015

Re: East Monroe Rezone Area -- Hydraulic Analysis

---

**Introduction**

The City of Monroe, on behalf of Heritage Baptist Fellowship, is requesting an amendment to the Monroe Comprehensive Plan that would change the zoning of five parcels of land located in East Monroe near the Skykomish River from "Limited Open Space" to "General Commercial" so that the land may be developed at some time in the future. This proposed rezone area is on the north side of State Route 2 (SR 2) in an area containing a slough that is connected to the Skykomish River at its western (downstream) end (Figure 1). Watershed Science & Engineering (WSE) was retained by PACE Engineers (PACE) to conduct the hydrologic and hydraulic analyses needed to address the Growth Management Hearings Board (GMHB) decision regarding the proposed rezone. Findings are intended for incorporation into the Supplemental Environmental Impact Statement (SEIS) for the East Monroe Rezone area. The GMHB has requested additional analysis regarding the effect of potential proposed fill and compensatory flood storage. WSE created a hydraulic model of the area in order to investigate the effects of potential future fill associated with development of the proposed rezone area.

**Project Setting**

As shown in Figure 1 the East Monroe Rezone area is bounded on its south by SR 2 and on its north and west by steep valley walls. East of the project site is relatively flat open land with limited existing development (driveways and a few structures). LiDAR topographic data for the project area clearly shows a remnant channel of the Skykomish River, traversing the site in an east to west arc. For purposes of this report this remnant channel is referred to as a slough. Initially it was thought that the remnant channel was still connected to the Skykomish River via culverts under the Burlington Northern/Santa Fe (BNSF) railroad tracks and SR 2 at its upstream (east) and downstream (west) ends. However, field investigations conducted by WSE found that there was no culvert under the BNSF tracks at the east end of the slough. The lack of a culvert connection at the east end of the slough was also verified by reviewing BNSF design drawings for the railroad berm. Currently, the only water entering the slough at its upstream end enters via roadside ditches from a local tributary area of about 273 acres, including areas north of SR 2 and areas between SR 2 and the BNSF tracks. The downstream (west) end of the slough is connected to the Skykomish River via culverts under the BNSF tracks and SR 2. These allow the slough to drain to the Skykomish at times when the river is low and also allow the Skykomish River to backwater onto the project site and areas east of the project during periods of high river flow.

Because the slough was formed by the Skykomish River it is greatly oversized for the current conditions flows. The slough is also densely vegetated with reed canary grass. This results in very low velocities in the slough (less than 0.25 feet per second) with the exception of localized stream velocities at the inlets and outlets to the existing culverts during major floods and at the existing beaver dam at times when there is a head drop (water fall) across the dam. Velocity considerations for the slough are discussed more fully in Attachment A.

**Model Development**

A 1-Dimensional HEC-RAS (version 4.1.0) hydraulic model was developed for the area in East Monroe for which the rezone is being proposed. An existing conditions model of the East Monroe Rezone area was built using a trimmed version of an existing FEMA model of the Snoqualmie and Skykomish Rivers which was developed by Northwest Hydraulic Consultants (NHC) for King and Snohomish Counties (NHC, 2006). The slough that traverses the East Monroe Rezone area was appended to the FEMA model as a tributary branch.

The FEMA model includes approximately 22 miles of the Skykomish River (17 miles upstream of the East Monroe site) and about 40 miles of the Snoqualmie River, plus numerous tributaries and overflow paths. Evaluating the effects of the East Monroe Rezone area does not require modeling this entire area, so the FEMA model was trimmed in order to reduce model run times and improve model stability. The Skykomish River reach of the model was trimmed approximately 2 miles upstream of the project site at a location sufficiently far from the project to ensure that any possible hydraulic effects of the project would be captured. The downstream extent of the Skykomish River reach of the model was kept intact because there are several significant overbank flow paths originating across the floodplain from the East Monroe site and there was no logical point to trim the model without potentially affecting these flow paths. The upstream extent of the model on the Snoqualmie River was trimmed far enough upstream to capture the return flows from these overbank flow paths. Flow inputs to the trimmed model were extracted directly from the FEMA modeling. The trimmed model was then run and compared to the original FEMA modeling to ensure that the trimmed model reproduced water surface elevations as simulated in the FEMA model.

*Model Topography*

The HEC-RAS model requires accurate topographic detail in the form of strategically placed cross sections. WSE obtained the most recent 3-ft gridded bare earth LiDAR data available from the Puget Sound LiDAR Consortium which was collected in February 2014. These data were used to define the ground surface for the overbank areas. LiDAR does not provide adequate detail for the channel, so a topographic survey of approximately 14 cross sections along the length of the slough was completed by PACE in February 2015. PACE also provided elevation data for key features along the slough including a beaver dam approximately 700 feet upstream of the slough's outlet and cross sections just upstream and downstream of all culverts along the slough. Additional survey points were also taken in overbank areas and used to ground truth the LiDAR data. Using these survey points it was determined that the LiDAR was consistently high by approximately 0.6-ft in the East Monroe Rezone area, most likely because of the density of tall grass and blackberry bushes in the area. WSE therefore adjusted the LiDAR elevation downward by 0.6 feet and merged the channel survey with the adjusted LiDAR data to create an accurate topographic surface for use in developing the model cross sections. The cross section layout and survey data used in development of the model are shown in Figure 1.

*Connection to FEMA Model*

The LiDAR data suggests that at one time the slough was connected to the Skykomish River at both its upstream and downstream ends. This was the assumption made by NHC in the mapping for the 2006 FEMA study. However, BNSF design drawings for the railroad show that there is no connection through the railroad berm at the slough's upstream end. Field investigations further confirmed that there does not appear to be any culvert under the railroad tracks near the upstream end of the slough between the slough and the Skykomish River. The slough is, however, connected to an upstream drainage ditch that runs between the railroad tracks and SR 2 via a 3-ft concrete culvert under SR 2. At its downstream end, the slough is connected to the Skykomish River via a 6-ft concrete culvert under the railroad tracks and a 5-ft x 6-ft concrete box culvert under SR 2 (see Figure 1). The Skykomish River is the downstream boundary of the Monroe Rezone reach of the model. No changes were made to the FEMA model of the Skykomish River other than to trim it upstream and downstream of the project site as described previously.

*Other Model Inputs and Parameters*

The 100-year flood modeled in the 2006 FEMA study was used as the basis for the current analysis. This event peaks at about 64,600 cubic feet per second (cfs) in the main channel of the Skykomish River just upstream of the connection to the slough, and backwaters into the slough through culverts under the railroad tracks and SR 2. Flow from a 273 acre local tributary area also enters the slough at its upstream end via several drainage ditches. The local drainage into the slough was estimated by scaling the 100-year hydrograph input for Cherry Creek (NHC, 2006) using the ratio of the contributing basin areas. This is the same method that was used to estimate all tributary inflows for the 2006 FEMA study.

The HEC-RAS model requires user defined Manning's n values. Manning's n is the parameter that accounts for roughness of the channel and overbank areas. A Manning's n roughness value of 0.05 was used for the channel portion of the slough, to account for the reed canary grass which fills the channel. A Manning's n roughness value of 0.10 was used for overbank areas to account for the dense vegetation including brush, tall grass, and blackberry bushes present along the overbanks.

**Model Application**

*Baseline Conditions*

The existing conditions model was run with the 100-year event flow inputs to obtain a baseline 100-year water surface elevation in the East Monroe Rezone area. In large floods such as this, the slough and its overbank areas act as an off channel storage area for flood waters from the Skykomish River. Flood waters from the Skykomish River backwater into the slough through the culverts at the western end of the slough. At the peak of the event, velocities in the slough are very slow, ranging from 0.01 feet per second (fps) to 0.07 fps. The baseline condition maximum water surface elevation across the Monroe Rezone site is essentially flat at an elevation of 65.31 feet, NAVD88. Water also fills the properties north of SR 2 to the east of the Monroe Rezone area to this same elevation. The extents of the baseline condition 100-year floodplain are shown in Figure 2.

*Proposed Development Conditions*

Figures 1 through 3 show an outline of the developable area as described in the East Monroe Rezone Final Environmental Impact Statement (FEIS) (PACE, 2013). The FEIS indicated that the developable area would be filled to an elevation above the 100-year water surface elevation. The perimeter of the fill pad would be sloped at 2H:1V down to the existing natural ground level. The developable area limit delineated on Figures 1 through 3 indicate the toe of the 2H:1V fill slope (i.e. the widest area). To provide compensatory storage for the loss of volume due to the fill, the FEIS proposed that the left bank of the slough be lowered to the estimated Ordinary High Water Mark (OHWM) of 59.8-ft and the overbank area be excavated as necessary to create a 1% grade up to the limit of the developable area. The existing conditions model geometry was edited to reflect these proposed development conditions and the 100-year event was rerun. The simulated maximum 100-year water surface elevation on the Monroe Rezone site and areas to the east of the site and north of SR 2 is 65.35 feet, NAVD88 (0.04-ft higher than the water surface elevation simulated with the baseline condition model). The higher water surface elevation is a result of the loss of storage volume in the project area due to differences between the proposed cuts and fills. The volume differences between existing and proposed conditions are summarized in Attachment B, Table B-1. Maximum water surface elevations offsite in the Skykomish River are unaffected by the proposed fill on the Monroe Rezone site. The 100-year flood extents for the proposed condition are shown on Figure 3. The development area, which will be filled above the 100-year water level, is not in the proposed condition 100-year floodplain.

Flow velocities simulated with the developed conditions model were compared to the existing conditions run and differences were found to be negligible. Attachment A shows the velocities at three points in time during the 100-year event; one on the rising limb of the hydrograph (as the slough is filling with water from the Skykomish River), one at the peak of the hydrograph, and one on the falling limb of the hydrograph (as the slough is draining back to the Skykomish River). As shown in Table A-1 flow velocities in the slough are generally very low (0-1 fps) and changes in velocities are very minor (less than 0.03 fps). The lone exception to this is near the culverts connecting the slough to the Skykomish River where velocities at the peak of the event are higher (± 2 fps) and the proposed condition velocities are lower than the existing condition velocities by about 0.1 fps (because there is less water flooding into the slough from the river). The FEIS proposes additional compensatory flood storage alternatives. If full compensatory storage were to be provided, any minor differences in flow velocities could be reduced or eliminated.

**Summary and Conclusion**

A summary of water surface elevations and representative velocities modeled for the existing and proposed conditions is provided in Table 1. Filling the proposed development area and providing compensatory storage as described above would raise the 100-year water surface elevation by about 0.04 feet in the slough and its surrounding floodplain, due to the loss of storage in the project area. Implementation of the alternative compensatory flood storage alternatives proposed in the FEIS could eliminate the potential increase in 100-year water surface elevation.

Velocity differences between the baseline condition and proposed condition throughout the 100-year event were determined to be negligible. The difference in maximum velocity between the baseline condition and the proposed condition at cross section 1861 is 0.01 fps as shown in Table 1. This section has the largest increase in maximum velocity seen at any channel cross section (not including culverts and the beaver dam as described in Attachment A). The maximum velocity results for cross section 2122 are also reported in Table 1. Cross section 2122 has the highest maximum velocity of any cross section in the model (again excluding the culvert inlets and outlets and the beaver dam). The locations of these cross sections are shown on Figures 1 through 3.

**Table 1** – Water Surface Elevation and Velocity Comparison

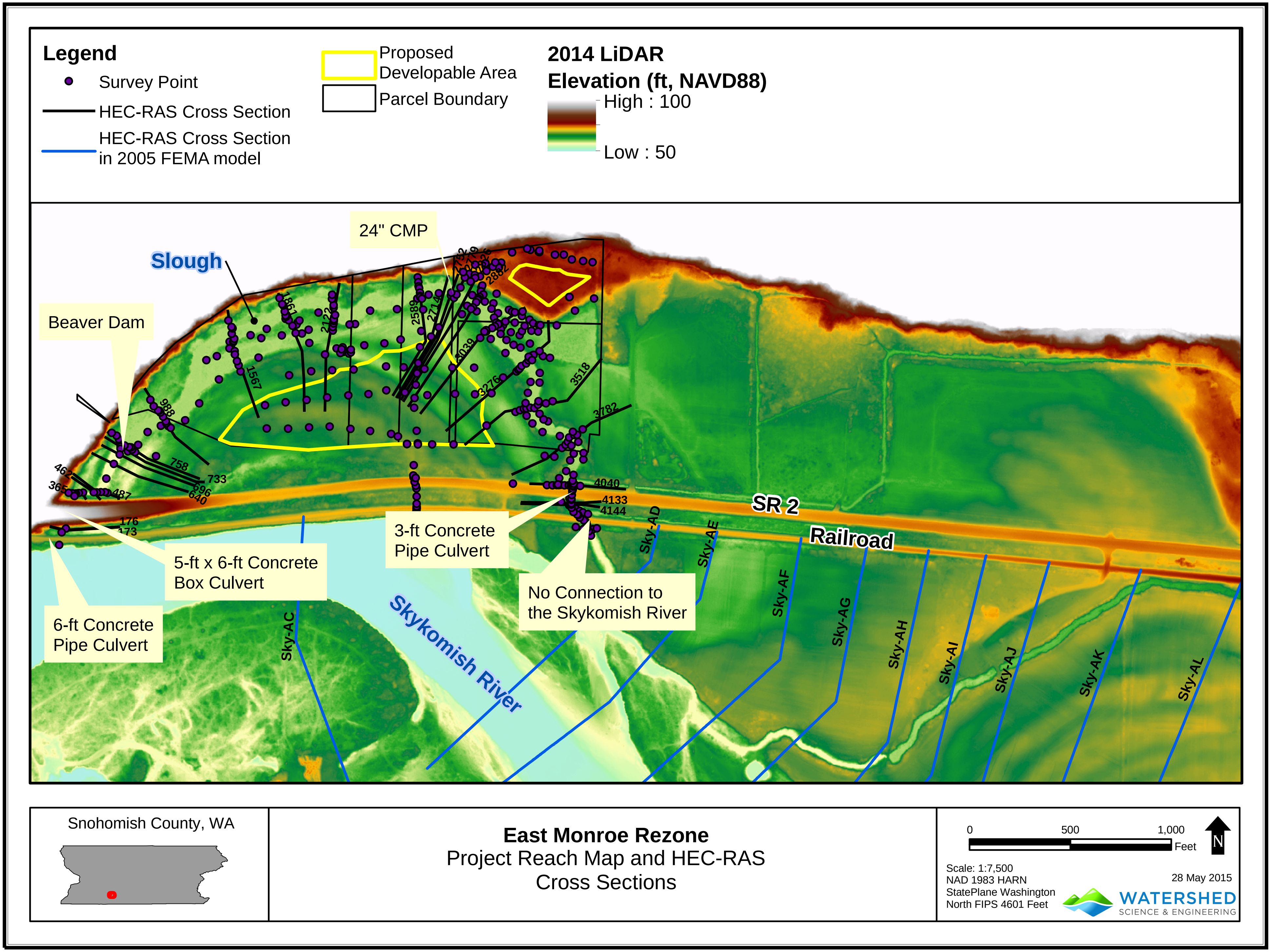
| ***Model Simulation*** | ***Water Surface Elevation in the Monroe Rezone Area (ft, NAVD88)*** | ***Difference from Existing Conditions (ft)*** | ***Maximum Velocity at Section 1861 (fps)*** | ***Difference from Existing Conditions (fps)*** | ***Maximum Velocity at Section 2122 (fps)*** | ***Difference from Existing Conditions (fps)*** |
|---|---|---|---|---|---|---|
| Existing Conditions | 65.31 | - | 0.17 | - | 0.24 | - |
| Proposed Conditions | 65.35 | +0.04 | 0.18 | +0.01 | 0.24 | 0.00 |

Based on the hydraulic analysis we believe that if an alternative compensatory flood storage strategy like those outlined in the FEIS or a smaller development footprint or some combination of these was implemented, water surface impacts could be reduced to zero. There are numerous possibilities for compensatory storage on the East Monroe Rezone site that can be explored under future development proposals as the site plan is refined.

**References**

Northwest Hydraulic Consultants, Inc., 2006. “Flood Insurance Mapping Study for the Snoqualmie River and Skykomish River”, Report prepared for King County and Snohomish County.

PACE Engineers, 2013. “Final Environmental Impact Statement: Volume I. East Monroe Comprehensive Plan Amendment and Rezone”.




C:\Egnyte\Private\shaina\15-005 East Monroe Rezone\Memo\Figure 1 - Project Reach Map and HEC-RAS Cross Sections.mxd 5/28/2015 11:37:58 AM

Figure 1

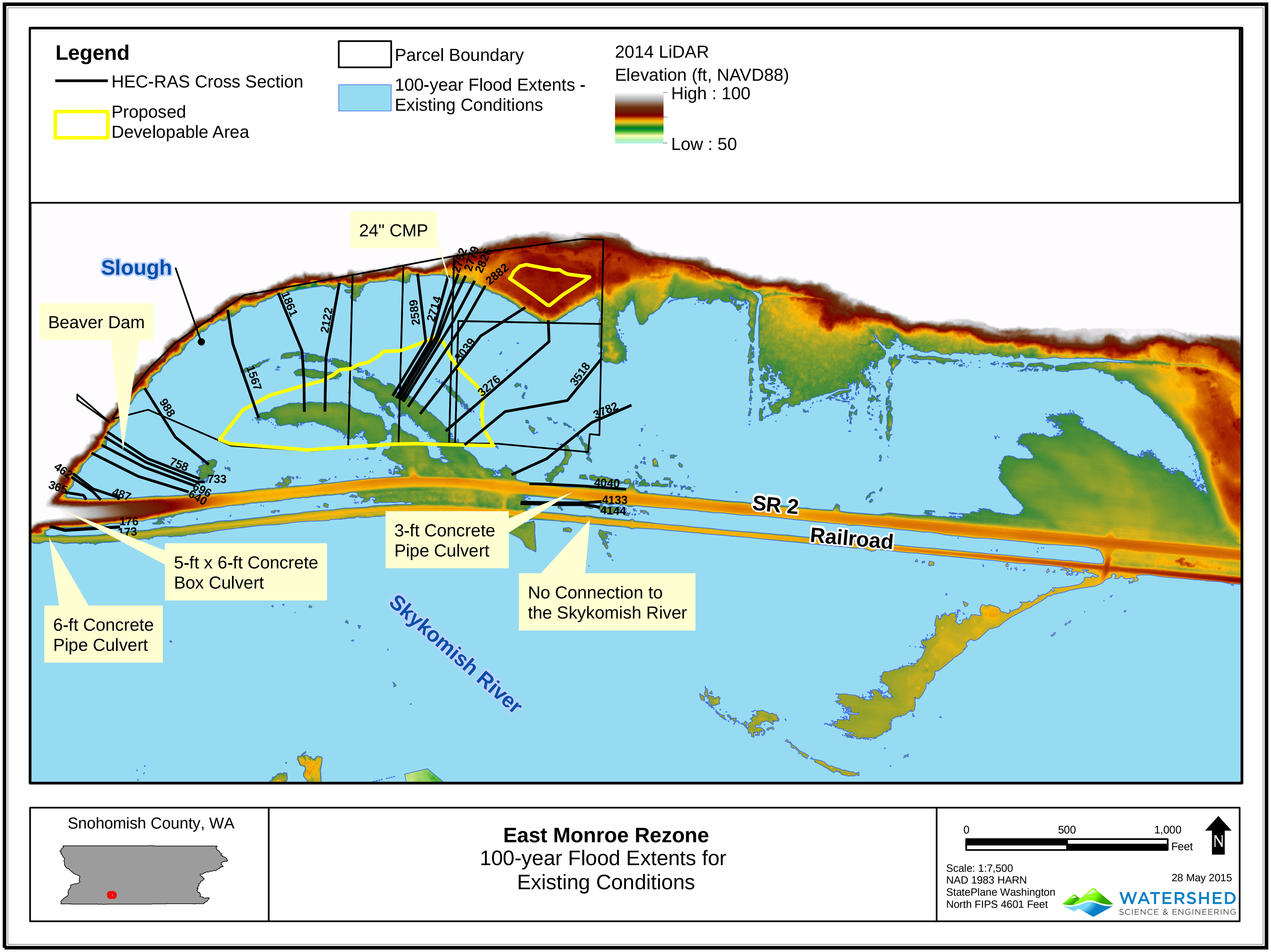
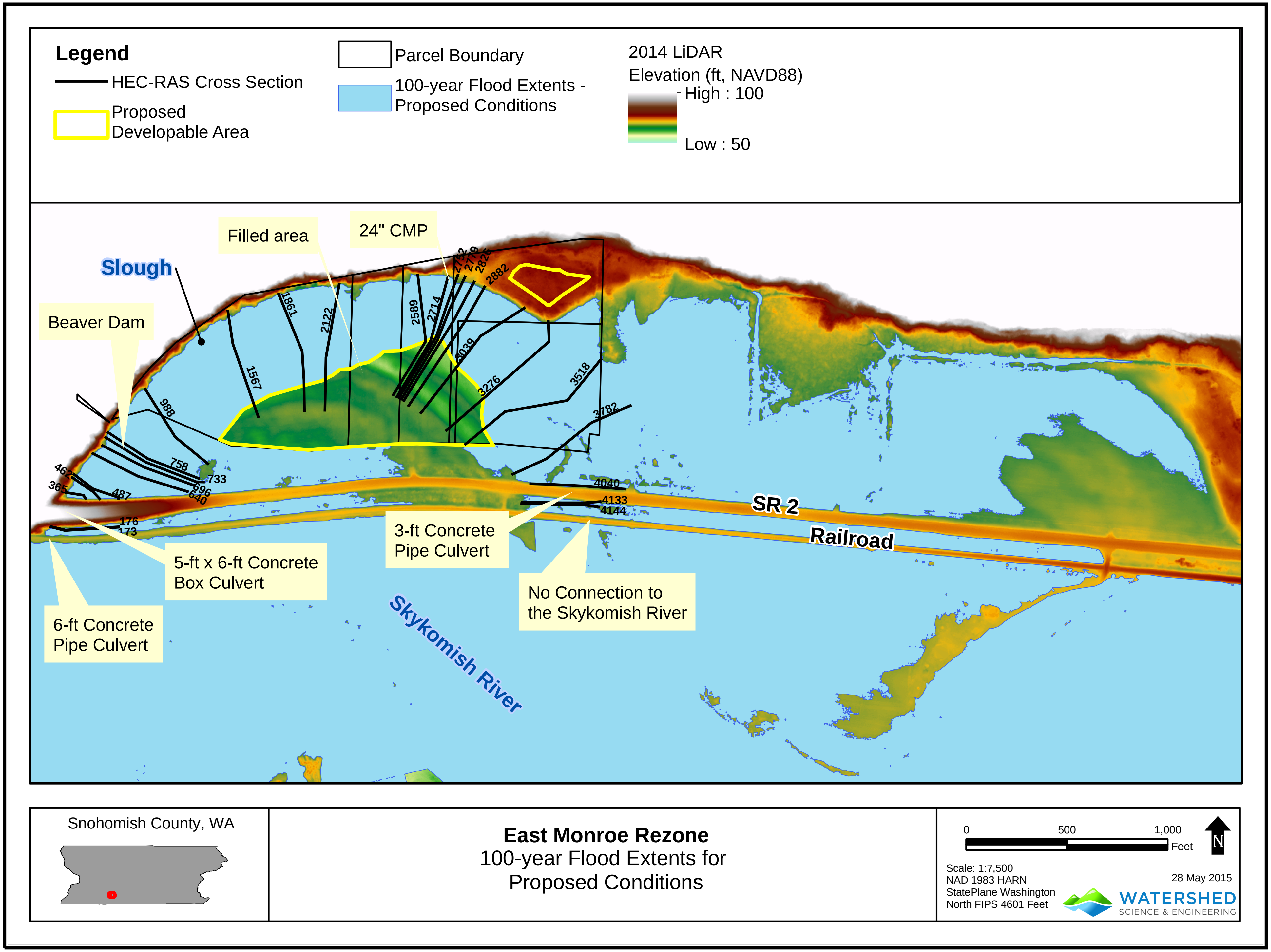

Legend
HEC-RAS Cross Section
Proposed Developable Area
Parcel Boundary
100-year Flood Extents - Existing Conditions
2014 LiDAR Elevation (ft, NAVD88)
High : 100
Low : 50
24" CMP
Slough
Beaver Dam
SR 2
Railroad
3-ft Concrete Pipe Culvert
5-ft x 6-ft Concrete Box Culvert
6-ft Concrete Pipe Culvert
No Connection to the Skykomish River
Skykomish River
Snohomish County, WA
East Monroe Rezone
100-year Flood Extents for Existing Conditions
0
500
1,000
Feet
N
Scale: 1:7,500
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
28 May 2015
WATERSHED
SCIENCE & ENGINEERING

Figure 2




C:\Egnyte\Private\shaina\15-005 East Monroe Rezone\Memo\Figure 3v2 - 100-year Flood Extents for Proposed Conditions.mxd 5/28/2015 11:38:23 AM

Figure 3

# Appendix

**Attachment A** – Flow Velocities on the Rising Limb, Near the Peak, and on the Falling Limb of the 100-year Flood Event for Existing and Proposed Conditions

**Attachment B** – Water Surface Elevations and Cumulative Volume of Water near the Peak for Existing and Proposed Conditions

**Attachment C** – Cross section plots comparing ground surface elevation and water surface elevation for the existing condition and proposed condition models

**Attachment A**

Table A-1 shows flow velocities at each cross section for three times during the simulated 100-year event: one that represents the rising limb of the hydrograph, one near the peak, and one that represents the falling limb of the hydrograph (see Figure A-1). Positive velocities indicate that flow is moving downstream in the slough (from the slough to the Skykomish River) while negative velocities indicate that water is backflowing into the slough from the Skykomish River. Flow velocities are generally low (less than 0.1 ft/s) throughout the reach at all times. Exceptions to this occur just upstream and downstream of culverts and at the beaver dam under certain conditions. Culverts constrict the flow area causing velocities to increase since the flow is being concentrated into a smaller area. This can be seen at cross sections 2779, 2752, 462, 365, 176, and 173 on the rising and falling limbs. The increased velocities, however, are localized in the center of the channel and very near the culvert. Higher velocities can also be seen on the rising and falling limbs at the beaver dam (near the downstream end of the slough at cross sections 733 and 696). The beaver dam causes a localized drop in the channel bottom, which leads to higher velocities at times when water is cascading over the dam. Once again this condition is localized towards the center of the channel and only affects the area just upstream of the dam. When water levels rise, the effects of culverts and the beaver dam on velocities get drowned out. Differences in velocities between the existing and proposed conditions are very small (less than 0.03 ft/s) except near the peak of the event and on the falling limb of the event at the downstream end of the slough near the culverts connecting the slough to the Skykomish River. Near the peak of the flood, a large volume of water is flowing from the Skykomish River into the slough, resulting in relatively high velocities upstream and downstream of the culverts under the railroad tracks and SR 2 (cross sections 365, 176, and 173). The absolute magnitude of the velocities is slightly lower (-0.08 fps) in the proposed conditions near the peak and on the falling limb as slightly less water is backflowing into the slough near the peak of the event and flowing out of the slough on the falling limb.

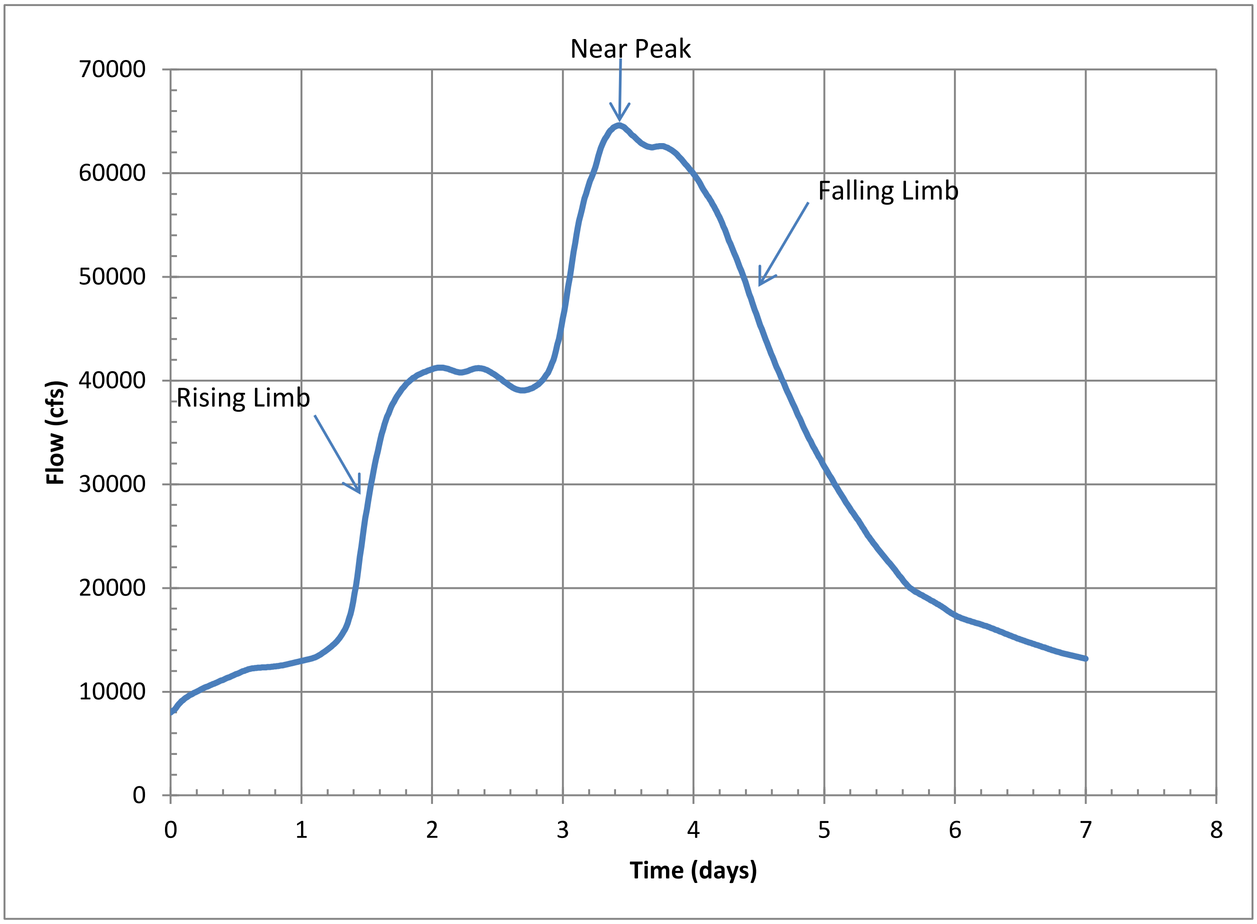
**Table A-1** – Flow Velocities on the Rising Limb, the Peak, and the Falling Limb of the 100-year Flood for Existing and Proposed Conditions

| ***Cross Section*** | ***Distance Along Channel from Upstream XS (ft)*** | ***Velocity (fps) - Rising Limb*** | | | ***Velocity (fps) near Peak*** | | | ***Velocity (fps) - Falling Limb*** | | | ***Note*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***Existing*** | ***Proposed*** | ***Diff*** | ***Existing*** | ***Proposed*** | ***Diff*** | ***Existing*** | ***Proposed*** | ***Diff*** | |
| 4144 | - | 0.02 | 0.02 | 0 | 0.05 | 0.05 | 0 | 0.03 | 0.03 | 0 | |
| 4133 | 11 | 0.02 | 0.02 | 0 | 0.05 | 0.05 | 0 | 0.03 | 0.04 | 0.01 | Culvert Inlet |
| 4040 | 93 | 0.03 | 0.03 | 0 | 0.05 | 0.05 | 0 | 0.04 | 0.04 | 0 | Culvert Outlet |
| 4039 | 1 | 0.03 | 0.03 | 0 | 0.05 | 0.05 | 0 | 0.04 | 0.04 | 0 | |
| 3782 | 257 | 0.04 | 0.04 | 0 | -0.02 | -0.02 | 0 | 0.03 | 0.03 | 0 | |

**Table A-1 (continued)** – Flow Velocities on the Rising Limb, the Peak, and the Falling Limb of the 100-year Flood for Existing and Proposed Conditions

| Cross Section | Distance Along Channel from Upstream XS (ft) | Velocity (fps) - Rising Limb | | | Velocity (fps) near Peak | | | Velocity (fps) - Falling Limb | | | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Existing | Proposed | Diff | Existing | Proposed | Diff | Existing | Proposed | Diff | |
| 3518 | 264 | 0.02 | 0.02 | 0 | -0.02 | -0.03 | 0.01 | 0.03 | 0.04 | 0.01 | |
| 3276 | 242 | 0.01 | 0.01 | 0 | -0.03 | -0.03 | 0 | 0.04 | 0.05 | 0.01 | |
| 3039 | 237 | 0.02 | 0.02 | 0 | -0.03 | -0.04 | 0.01 | 0.05 | 0.05 | 0 | |
| 2882 | 157 | 0.03 | 0.03 | 0 | -0.04 | -0.05 | 0.01 | 0.05 | 0.07 | 0.02 | |
| 2826 | 56 | 0.03 | 0.03 | 0 | -0.04 | -0.06 | 0.02 | 0.05 | 0.07 | 0.02 | |
| 2779 | 47 | 0.32 | 0.32 | 0 | -0.04 | -0.07 | 0.03 | 0.06 | 0.09 | 0.03 | Culvert Inlet |
| 2752 | 27 | 0.34 | 0.33 | -0.01 | -0.05 | -0.07 | 0.02 | 0.06 | 0.09 | 0.03 | Culvert Outlet |
| 2714 | 38 | 0.02 | 0.02 | 0 | -0.04 | -0.05 | 0.01 | 0.05 | 0.07 | 0.02 | |
| 2589 | 125 | 0.01 | 0.01 | 0 | -0.04 | -0.05 | 0.01 | 0.06 | 0.07 | 0.01 | |
| 2122 | 467 | -0.02 | -0.02 | 0 | -0.06 | -0.05 | -0.01 | 0.08 | 0.06 | -0.02 | |
| 1861 | 261 | -0.01 | -0.01 | 0 | -0.06 | -0.05 | -0.01 | 0.08 | 0.06 | -0.02 | |
| 1567 | 294 | -0.02 | -0.02 | 0 | -0.06 | -0.05 | -0.01 | 0.08 | 0.06 | -0.02 | |
| 988 | 579 | -0.04 | -0.04 | 0 | -0.08 | -0.07 | -0.01 | 0.09 | 0.09 | 0 | |
| 758 | 230 | -0.04 | -0.04 | 0 | -0.07 | -0.06 | -0.01 | 0.08 | 0.08 | 0 | |
| 733 | 25 | -1.74 | -1.73 | -0.01 | -0.09 | -0.09 | 0 | 0.11 | 0.11 | 0 | Beaver Dam |
| 696 | 37 | -0.05 | -0.05 | 0 | -0.08 | -0.08 | 0 | 0.1 | 0.1 | 0 | Beaver Dam |
| 640 | 56 | -0.03 | -0.03 | 0 | -0.08 | -0.07 | -0.01 | 0.09 | 0.09 | 0 | |
| 487 | 153 | -0.09 | -0.09 | 0 | -0.13 | -0.12 | -0.01 | 0.15 | 0.15 | 0 | |
| 462 | 25 | -0.28 | -0.28 | 0 | -0.23 | -0.22 | -0.01 | 0.27 | 0.27 | 0 | |
| 365 | 97 | -0.72 | -0.73 | 0.01 | -2.99 | -2.91 | -0.08 | 3.4 | 3.36 | -0.04 | Culvert Inlet |
| 176 | 189 | -0.8 | -0.8 | 0 | -2.83 | -2.77 | -0.06 | 4 | 3.94 | -0.06 | Culvert Outlet |
| 173 | 3 | -0.59 | -0.59 | 0 | -2.55 | -2.5 | -0.05 | 3.5 | 3.44 | -0.06 | Culvert Inlet |

**Figure A-1** – Hydrograph on the Skykomish River just upstream of its connection with the slough showing points in time where velocities in Table A-1 are reported



**Attachment B**

A hydrograph for the 100-year flood in the Skykomish River was simulated for existing and proposed conditions using the model developed for the East Monroe Rezone project area. Table B-1 shows model output (water surface elevation and volume of water) for the existing condition and proposed condition models at each cross section at a time near the peak of the hydrograph when water surface elevations in both models are approximately equal. This allows for the volume of water to be compared between the two models. The difference in volume between the existing and proposed conditions was calculated to determine whether there is a net increase or loss in storage area in the Monroe Rezone area. A positive difference indicates there is a net gain in storage area and a negative difference indicates there is a net loss in storage area. Volume differences in cross sections 2714 through 4144 indicate that there is a net loss in storage area between existing and proposed conditions.

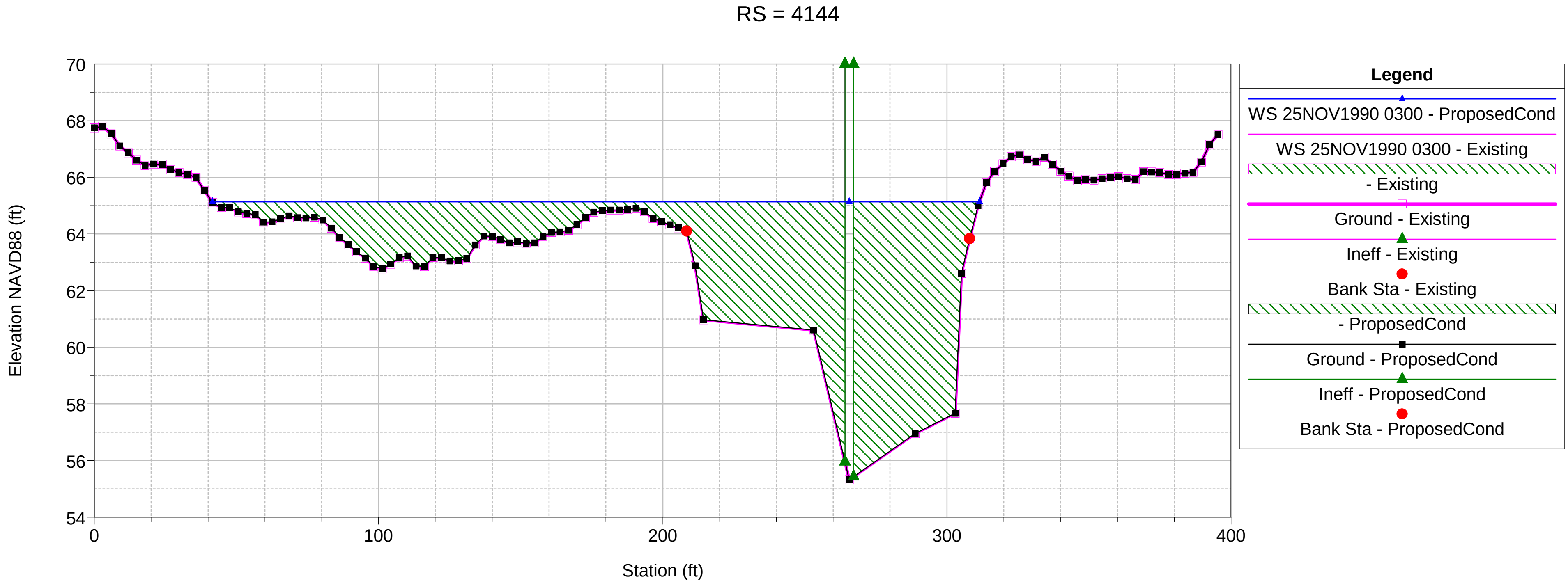
**Table B-1** – Water Surface Elevations and Cumulative Volume of Water in Storage near the Peak the Flood Event for Existing and Proposed Conditions

| Cross Section | Water Surface Elevation (ft) | | Cumulative Volume of Water (acre-ft) | | Volume Difference (acre-ft) |
|---|---|---|---|---|---|
| | Existing | Proposed | Existing | Proposed | |
| 4144 | 65.13 | 65.14 | 188.1 | 179.7 | -8.4 |
| 4133 | 65.13 | 65.14 | 187.9 | 179.5 | -8.4 |
| 4040 | 65.13 | 65.13 | 187.9 | 179.5 | -8.4 |
| 4039 | 65.13 | 65.13 | 187.8 | 179.4 | -8.4 |
| 3782 | 65.13 | 65.13 | 179.3 | 170.9 | -8.4 |
| 3518 | 65.13 | 65.13 | 162.8 | 154.4 | -8.4 |
| 3276 | 65.13 | 65.13 | 145.9 | 138.2 | -7.8 |
| 3039 | 65.13 | 65.13 | 130.2 | 124.3 | -5.9 |
| 2882 | 65.13 | 65.13 | 120.7 | 116.9 | -3.8 |
| 2826 | 65.13 | 65.13 | 117.3 | 114.5 | -2.8 |
| 2779 | 65.13 | 65.13 | 114.6 | 112.7 | -1.9 |
| 2752 | 65.13 | 65.13 | 113.1 | 111.8 | -1.3 |
| 2714 | 65.13 | 65.13 | 110.9 | 110.2 | -0.6 |
| 2589 | 65.13 | 65.13 | 103.6 | 104.9 | 1.3 |
| 2122 | 65.13 | 65.13 | 77.9 | 81.3 | 3.4 |
| 1861 | 65.13 | 65.13 | 67.8 | 69.9 | 2.2 |
| 1567 | 65.13 | 65.13 | 52.0 | 52.5 | 0.5 |
| 988 | 65.13 | 65.13 | 24.5 | 24.5 | 0.0 |
| 758 | 65.13 | 65.13 | 13.1 | 13.1 | 0.0 |
| 733 | 65.13 | 65.13 | 12.0 | 12.0 | 0.0 |
| 696 | 65.13 | 65.13 | 10.4 | 10.4 | 0.0 |

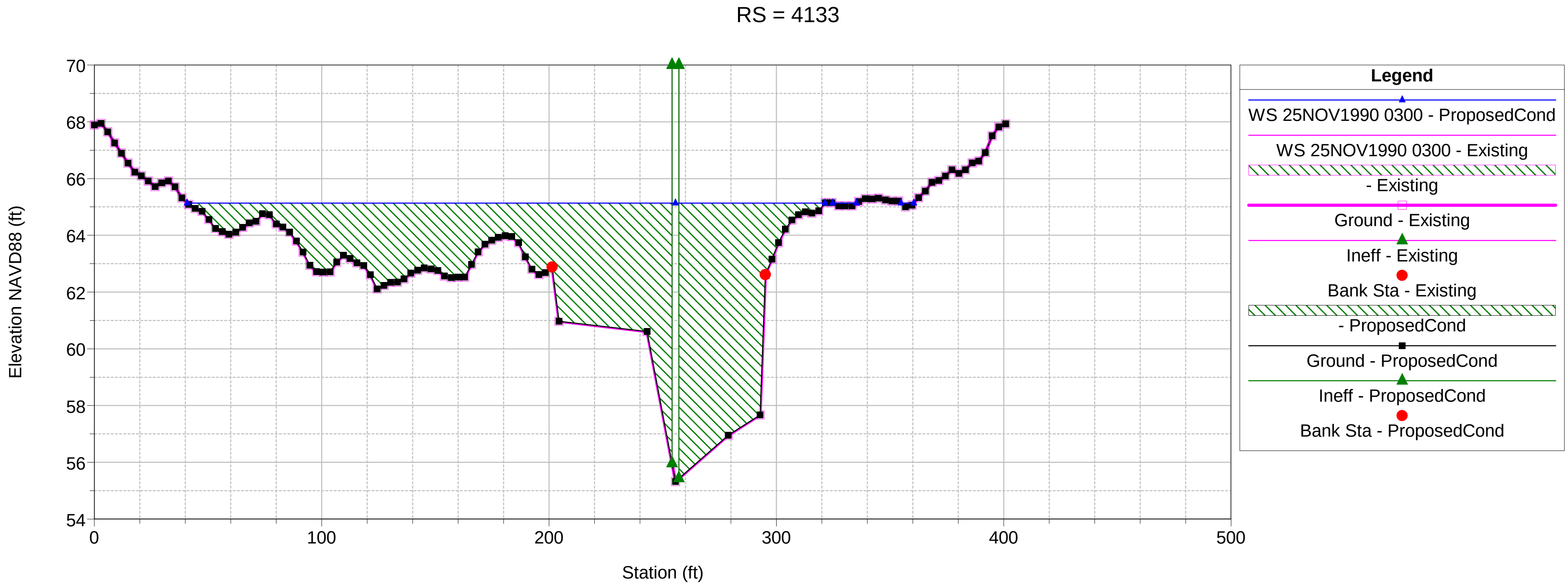
**Table B-1** – Water Surface Elevations and Cumulative Volume of Water in Storage near the Peak the Flood Event for Existing and Proposed Conditions

| Cross Section | Water Surface Elevation (ft) | | Cumulative Volume of Water (acre-ft) | | Volume Difference (acre-ft) |
|---|---|---|---|---|---|
| | Existing | Proposed | Existing | Proposed | |
| 640 | 65.13 | 65.13 | 7.7 | 7.7 | 0.0 |
| 487 | 65.13 | 65.13 | 1.9 | 1.9 | 0.0 |
| 462 | 65.13 | 65.13 | 1.4 | 1.4 | 0.0 |
| 365 | 65.11 | 65.11 | 0.2 | 0.2 | 0.0 |
| 176 | 64.87 | 64.87 | 0.1 | 0.1 | 0.0 |
| 173 | 64.88 | 64.88 | | | |

**Attachment C**

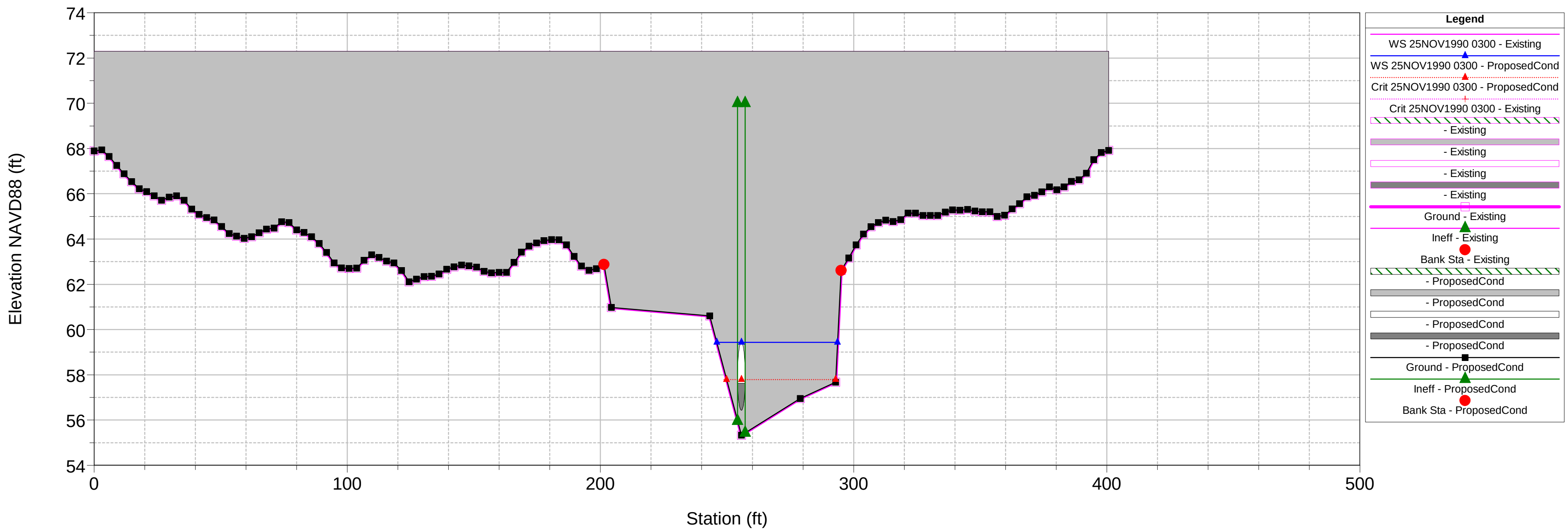


RS = 4144
70
68
66
64
62
60
58
56
54
Elevation NAVD88 (ft)
0
100
200
300
400
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

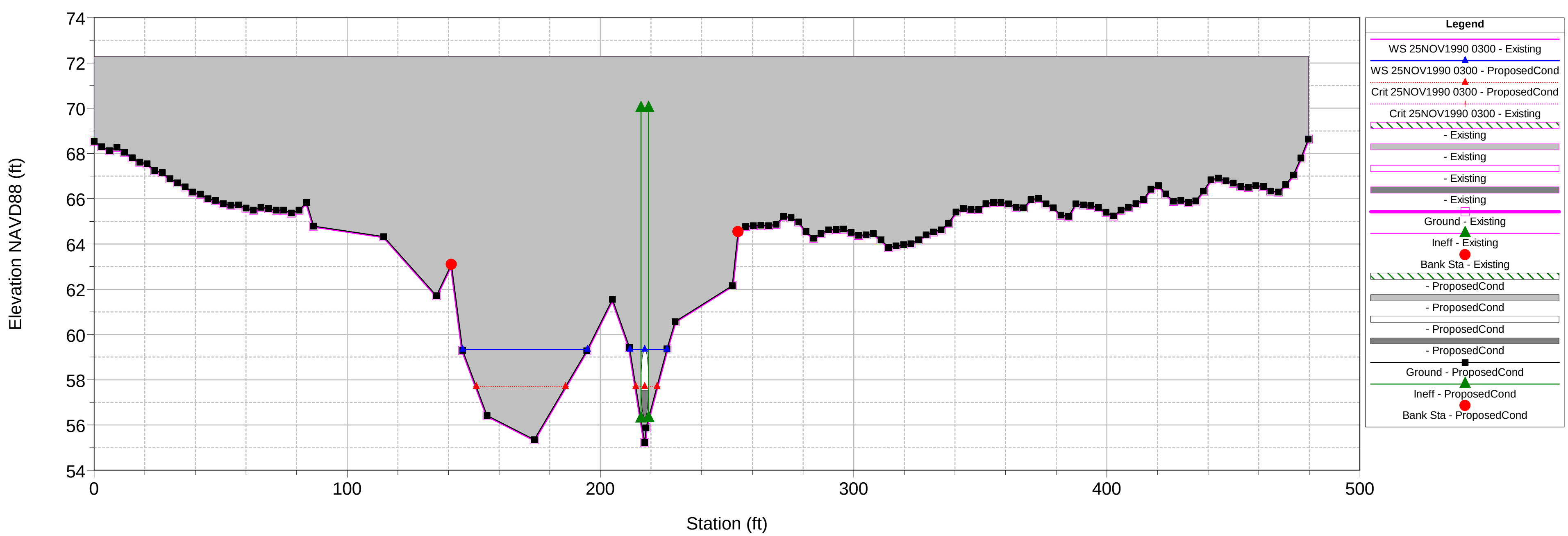



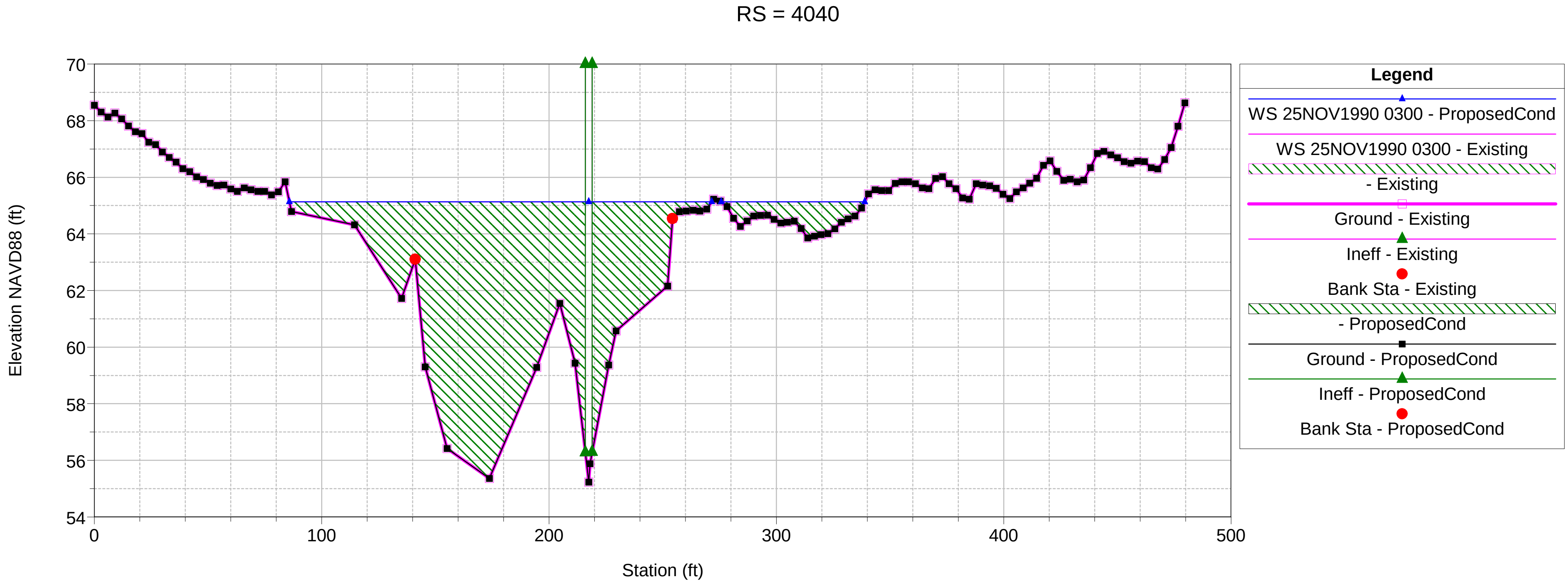
RS = 4133
70
68
66
64
62
60
58
56
54
Elevation NAVD88 (ft)
0
100
200
300
400
500
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

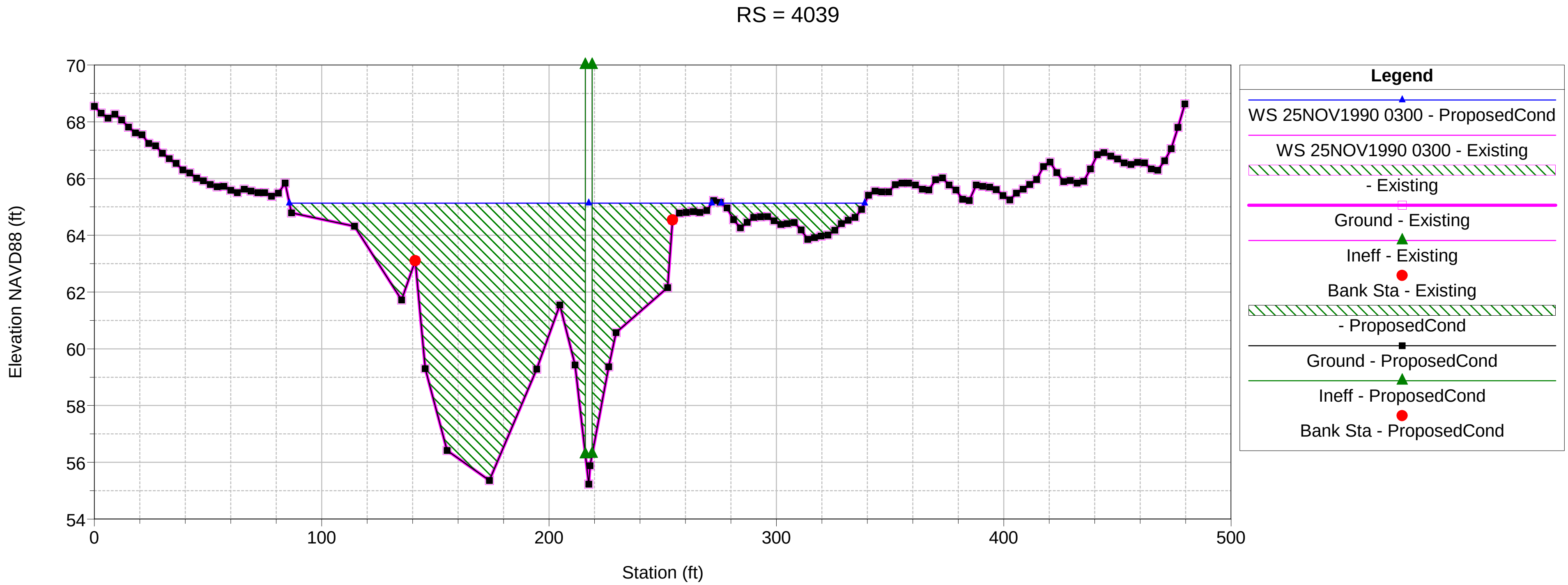
RS = 4132.9 Culv

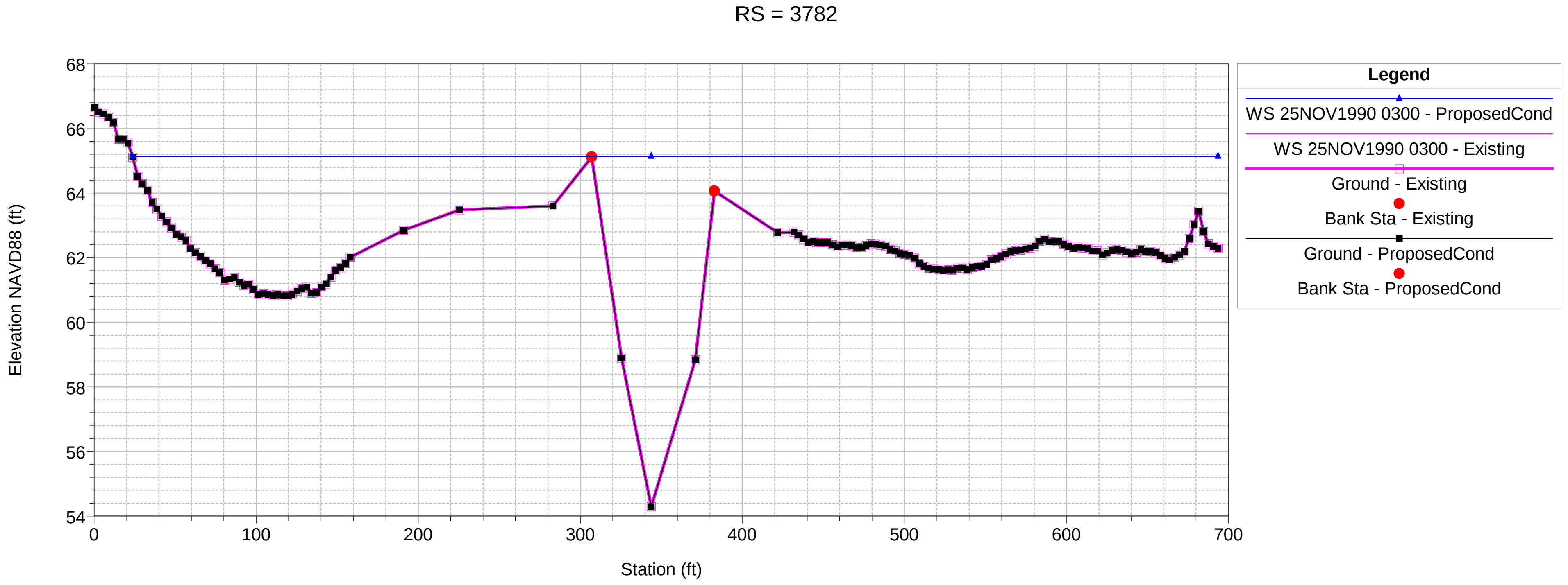


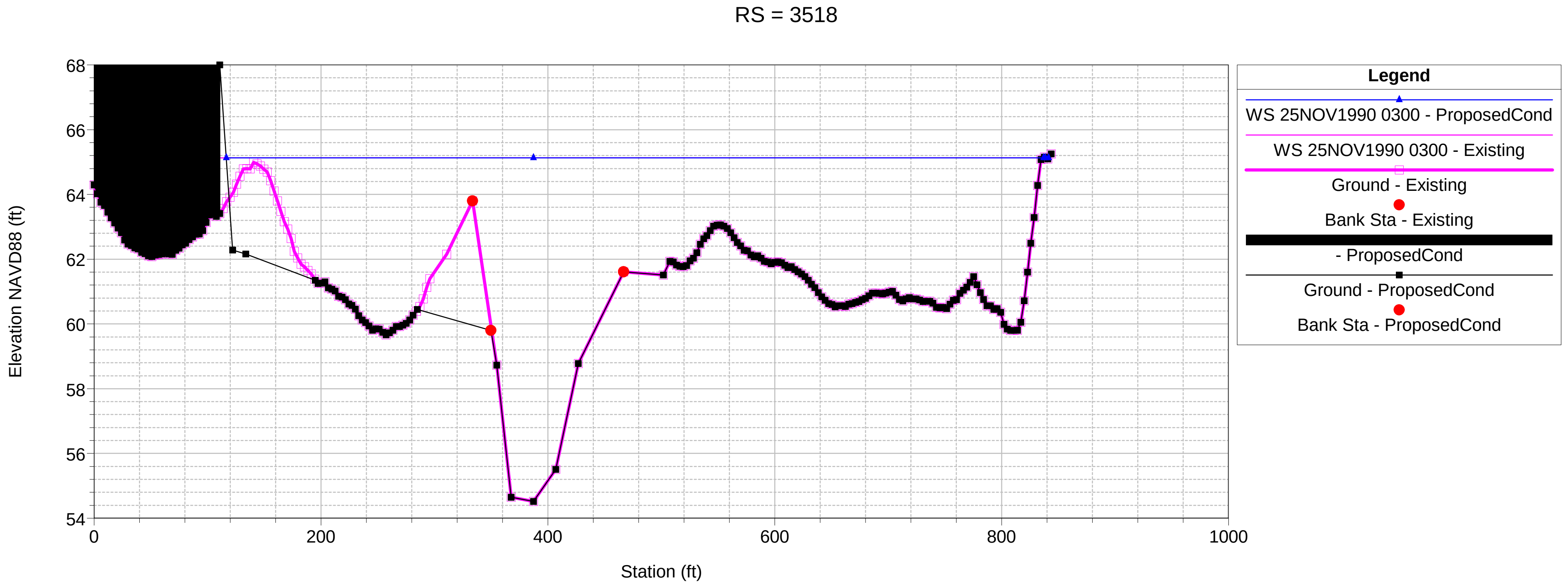

RS = 4132.9 Culv

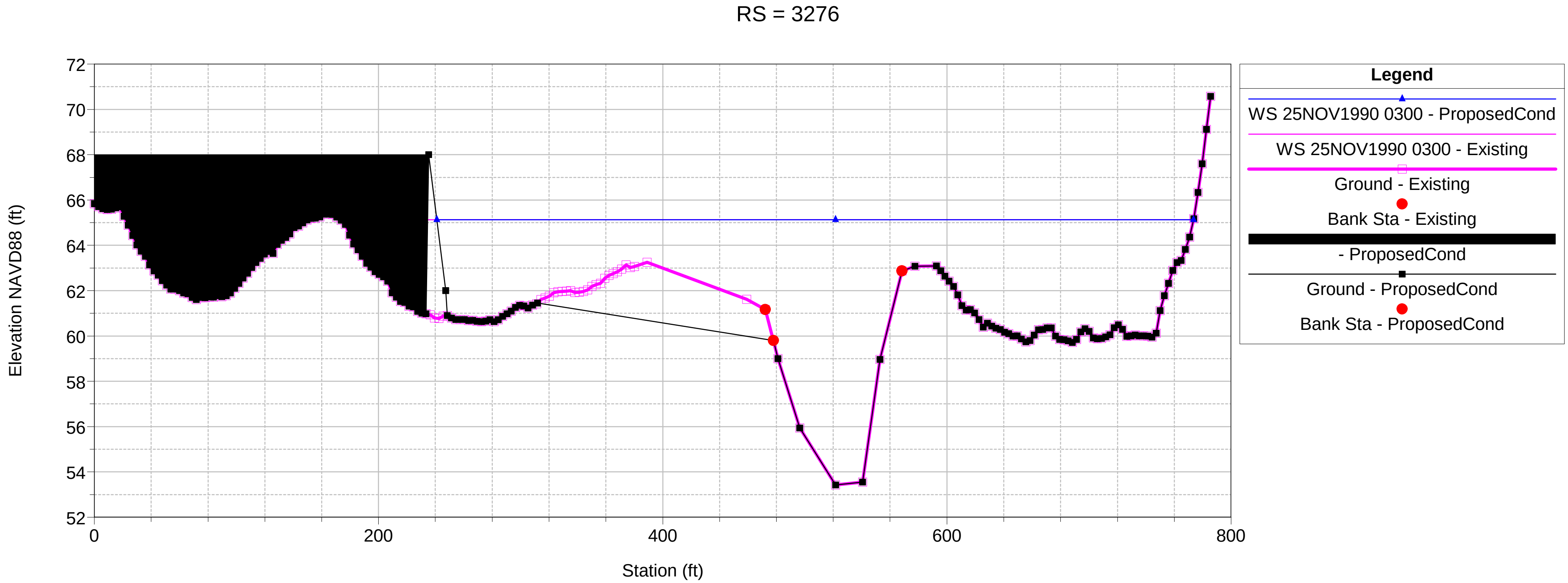


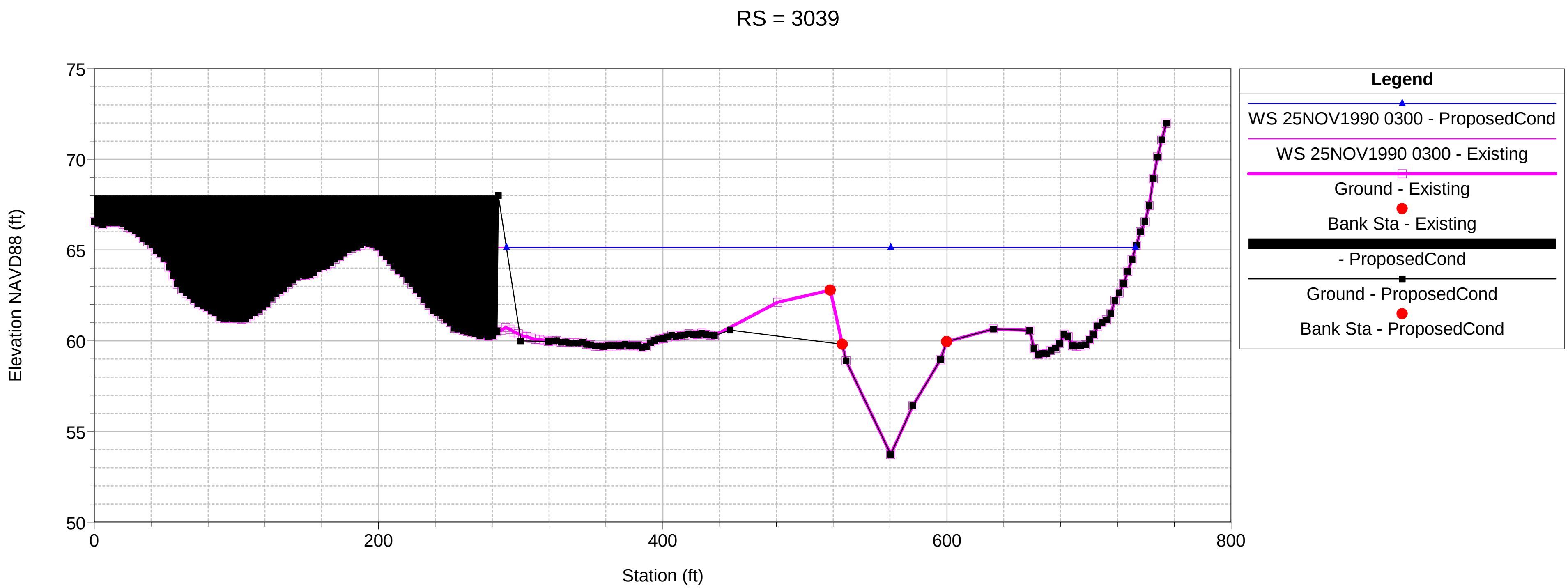

RS = 4040
Elevation NAVD88 (ft)
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

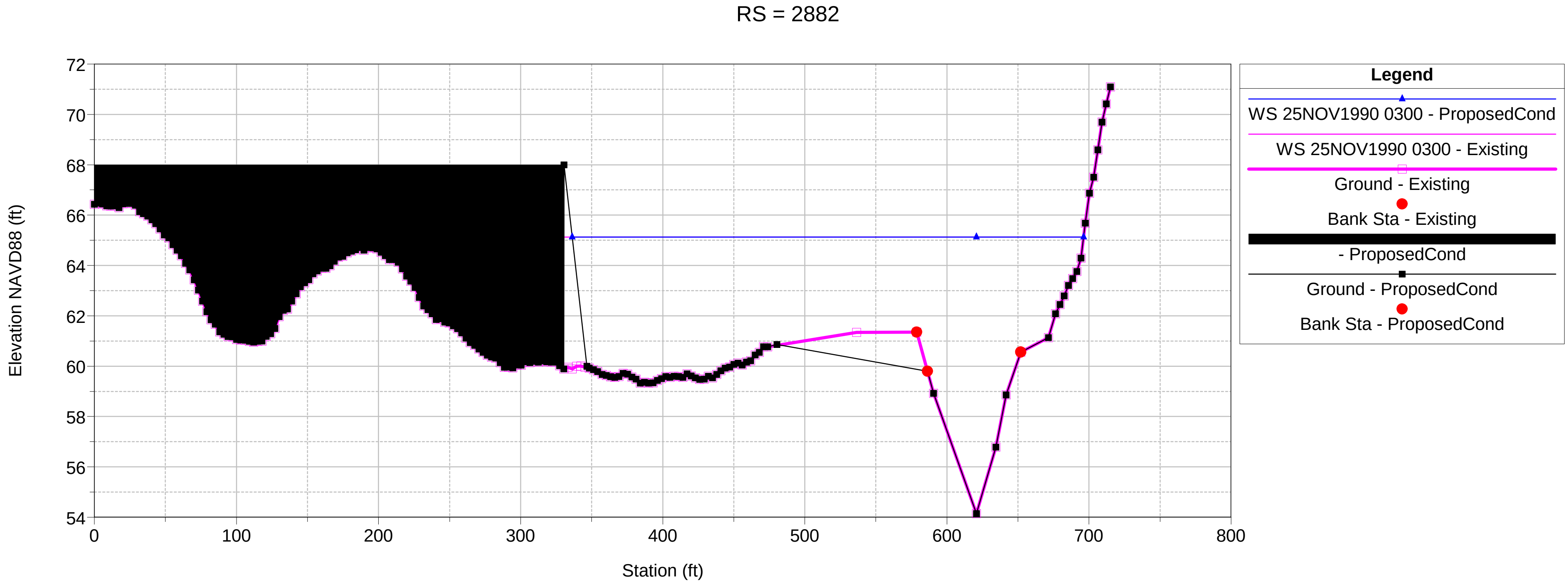

RS = 4039
Elevation NAVD88 (ft)
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

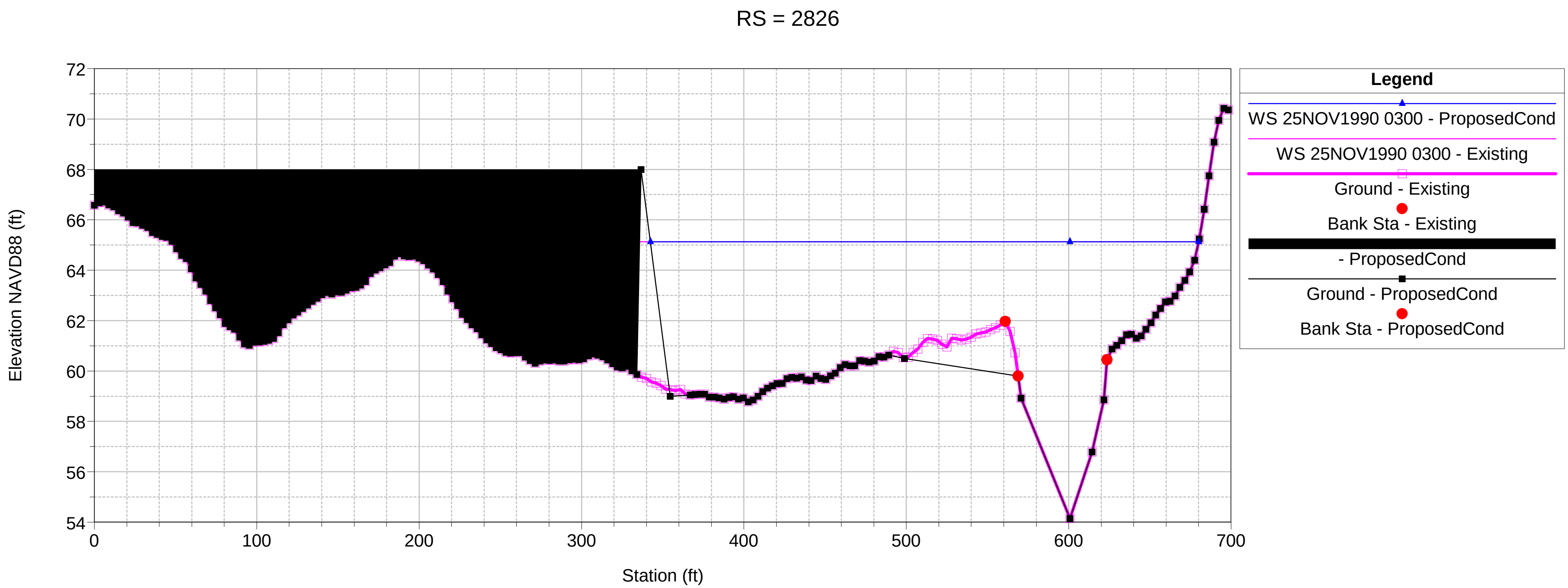

RS = 3782
68
66
64
62
60
58
56
54
Elevation NAVD88 (ft)
0
100
200
300
400
500
600
700
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
Ground - ProposedCond
Bank Sta - ProposedCond

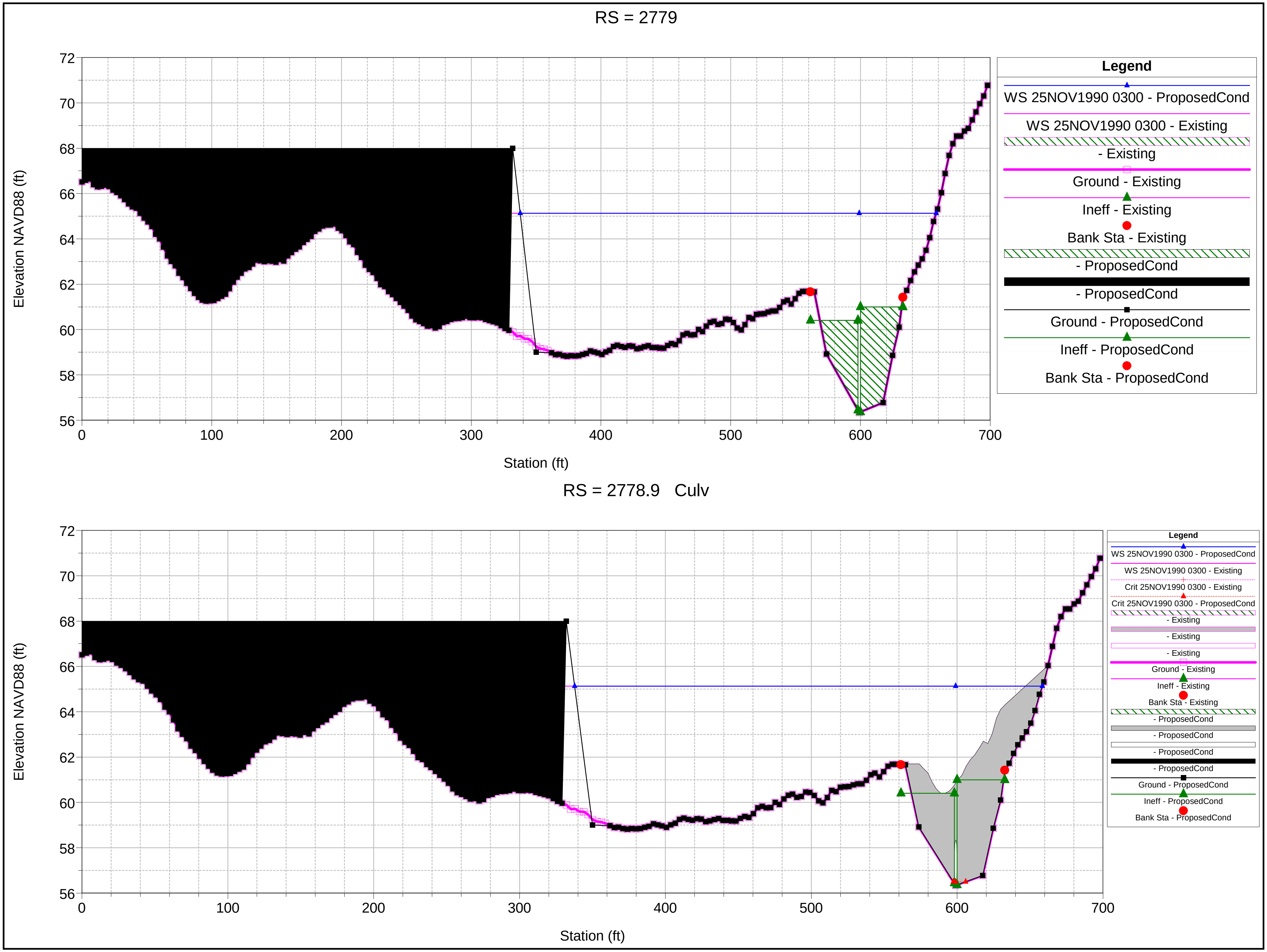

RS = 3518
68
66
64
62
60
58
56
54
Elevation NAVD88 (ft)
0
200
400
600
800
1000
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond


RS = 3276
Elevation NAVD88 (ft)
72
70
68
66
64
62
60
58
56
54
52
0
200
400
600
800
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond

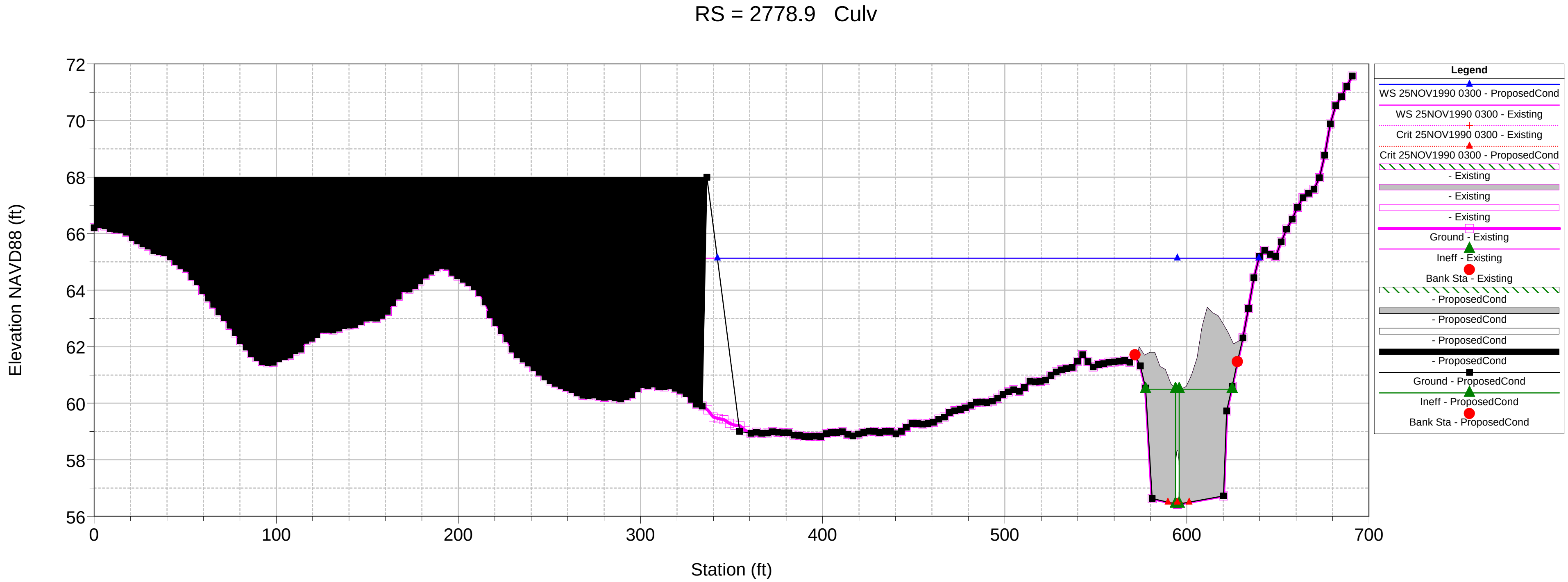

RS = 3039
Elevation NAVD88 (ft)
75
70
65
60
55
50
0
200
400
600
800
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond

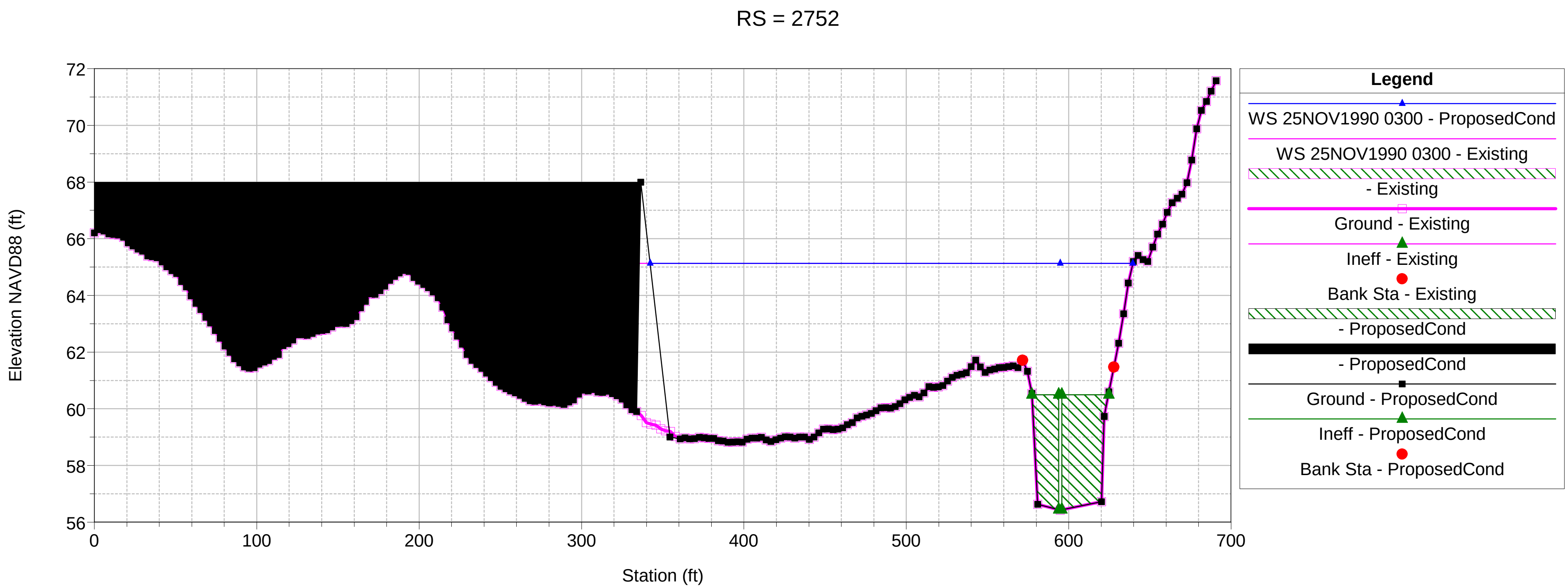

RS = 2882
Elevation NAVD88 (ft)
Station (ft)
72
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
600
700
800
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond

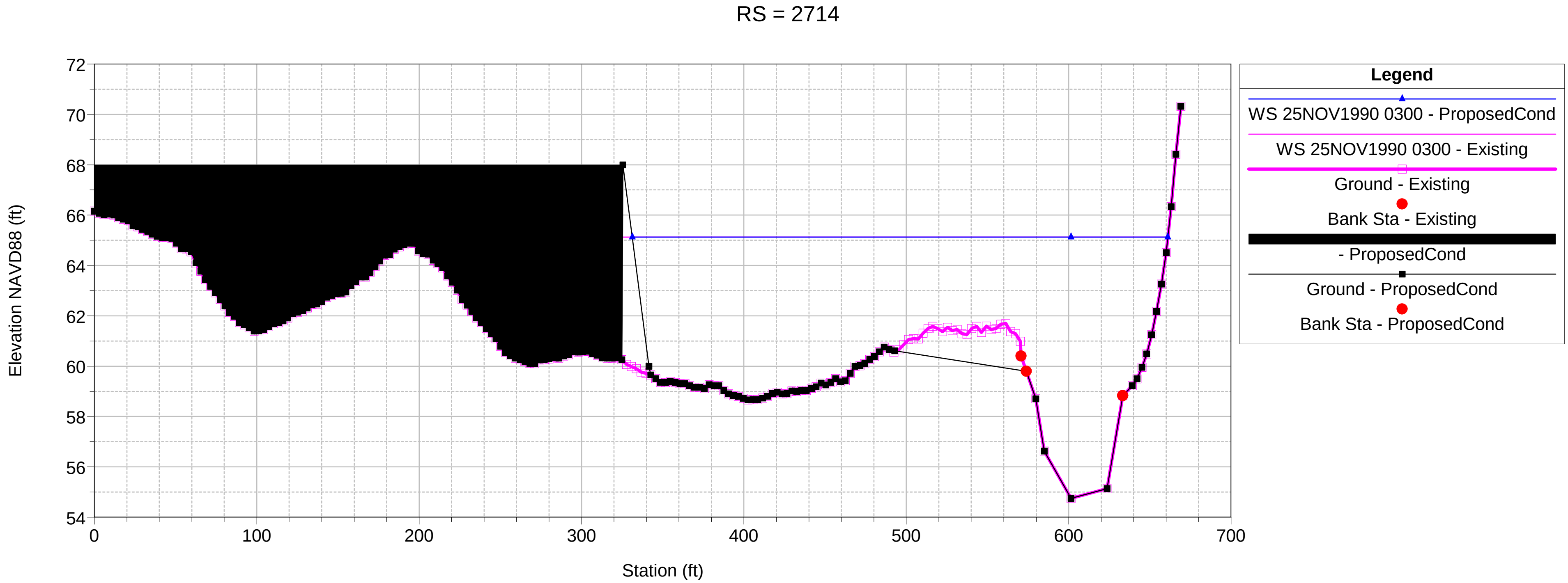

RS = 2826
Elevation NAVD88 (ft)
Station (ft)
72
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
600
700
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond

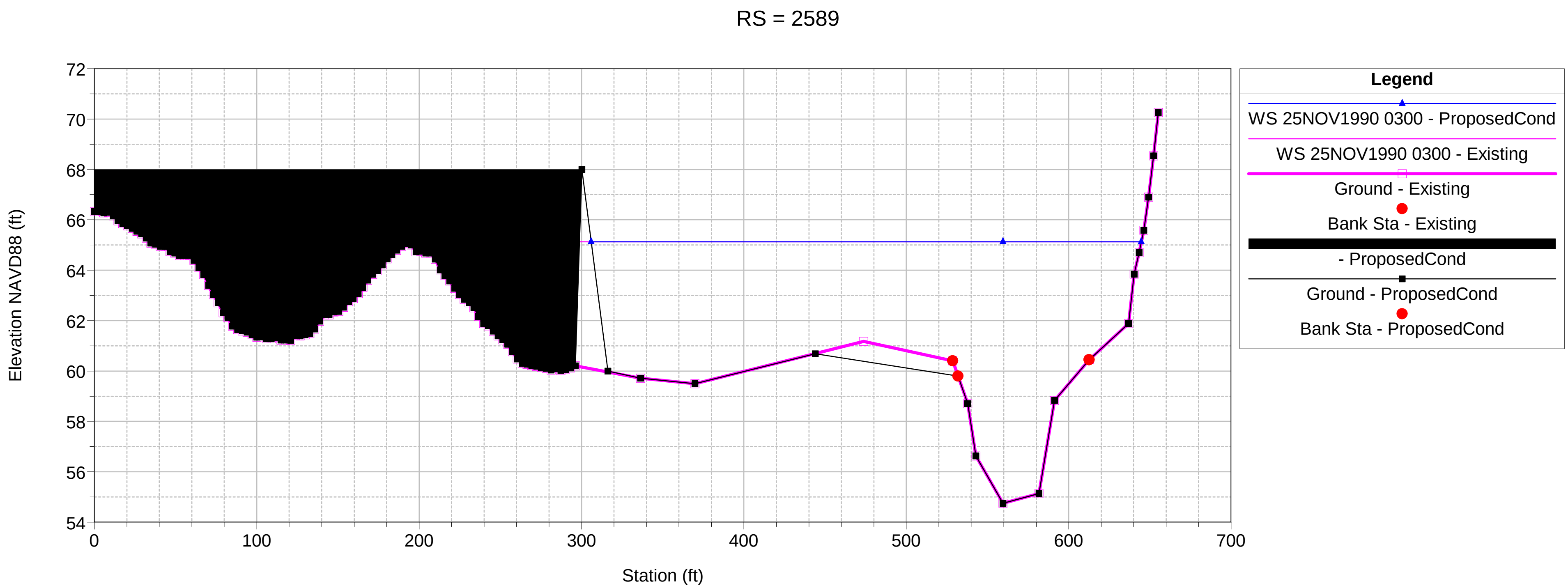


RS = 2779
Elevation NAVD88 (ft)
72
70
68
66
64
62
60
58
56
0
100
200
300
400
500
600
700
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond
RS = 2778.9 Culv
Elevation NAVD88 (ft)
72
70
68
66
64
62
60
58
56
0
100
200
300
400
500
600
700
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Crit 25NOV1990 0300 - Existing
Crit 25NOV1990 0300 - ProposedCond
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
- ProposedCond
- ProposedCond
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

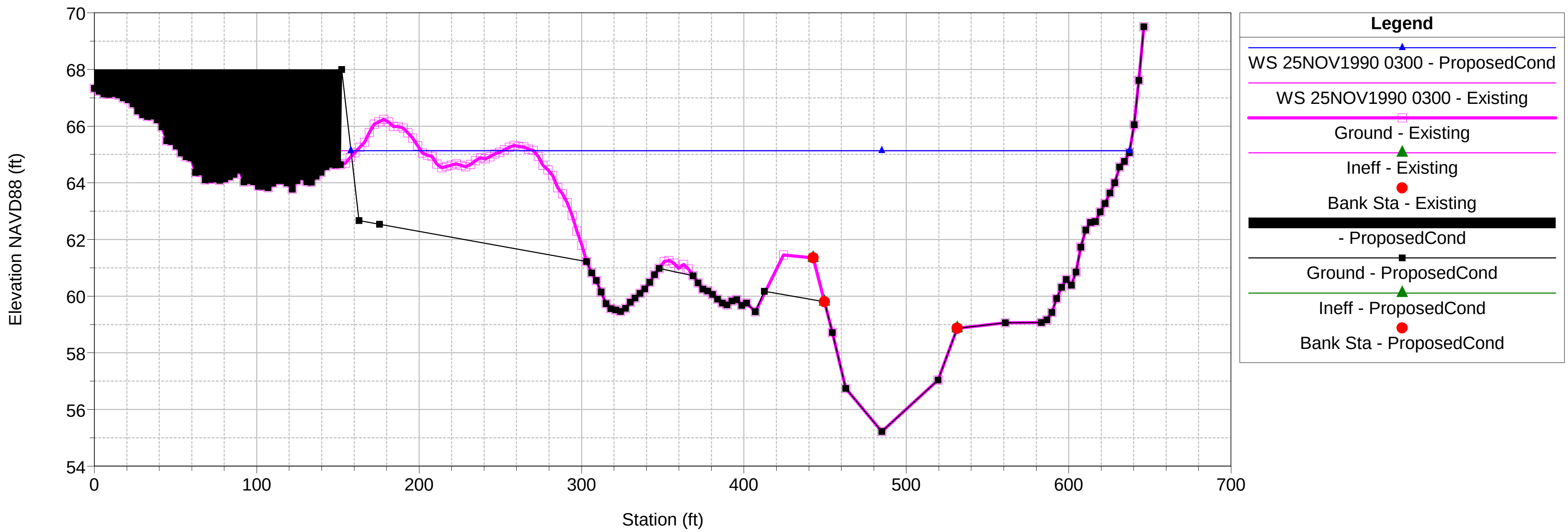

RS = 2778.9 Culv
Elevation NAVD88 (ft)
Station (ft)
72
70
68
66
64
62
60
58
56
0
100
200
300
400
500
600
700
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Crit 25NOV1990 0300 - Existing
Crit 25NOV1990 0300 - ProposedCond
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
- ProposedCond
- ProposedCond
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond


RS = 2752
Elevation NAVD88 (ft)
Station (ft)
72
70
68
66
64
62
60
58
56
0
100
200
300
400
500
600
700
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

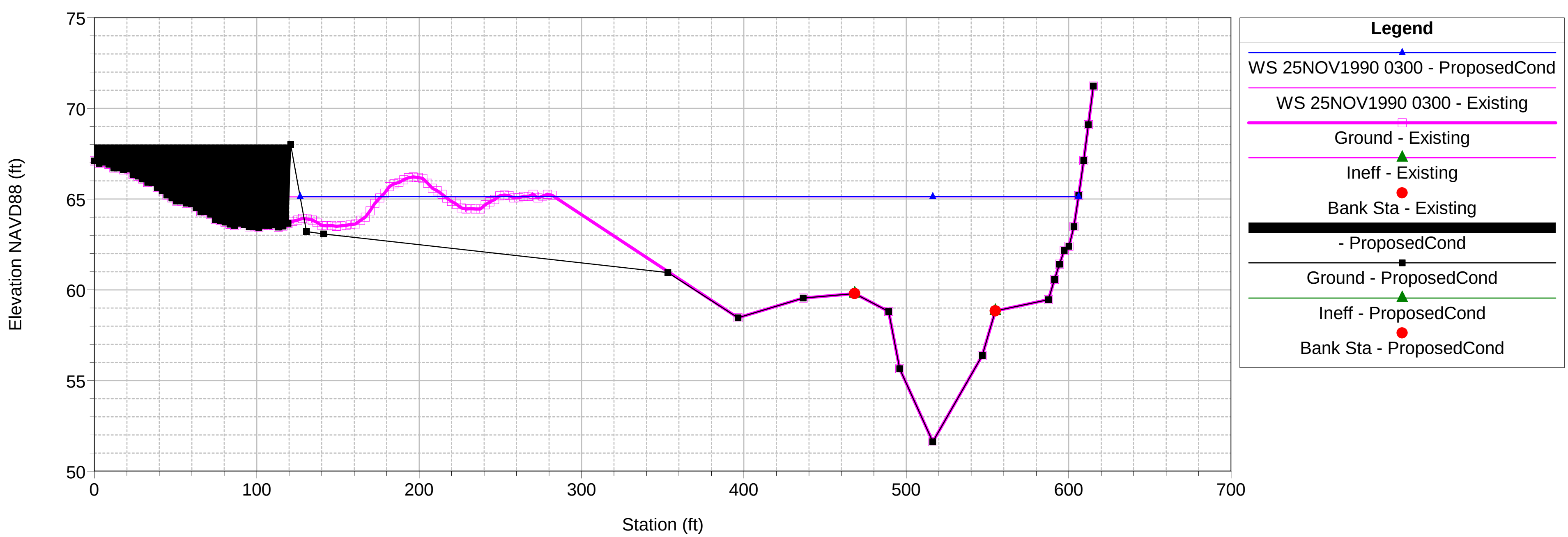

RS = 2714
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)
72
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
600
700

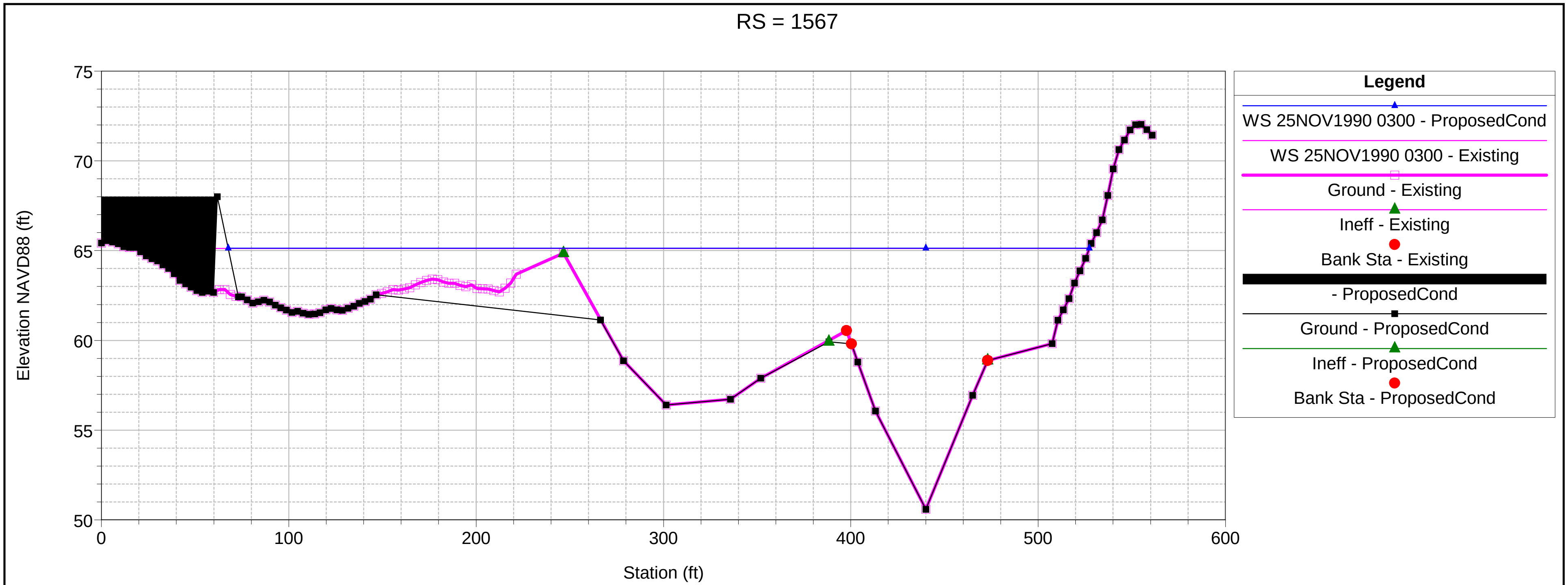

RS = 2589
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)
72
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
600
700

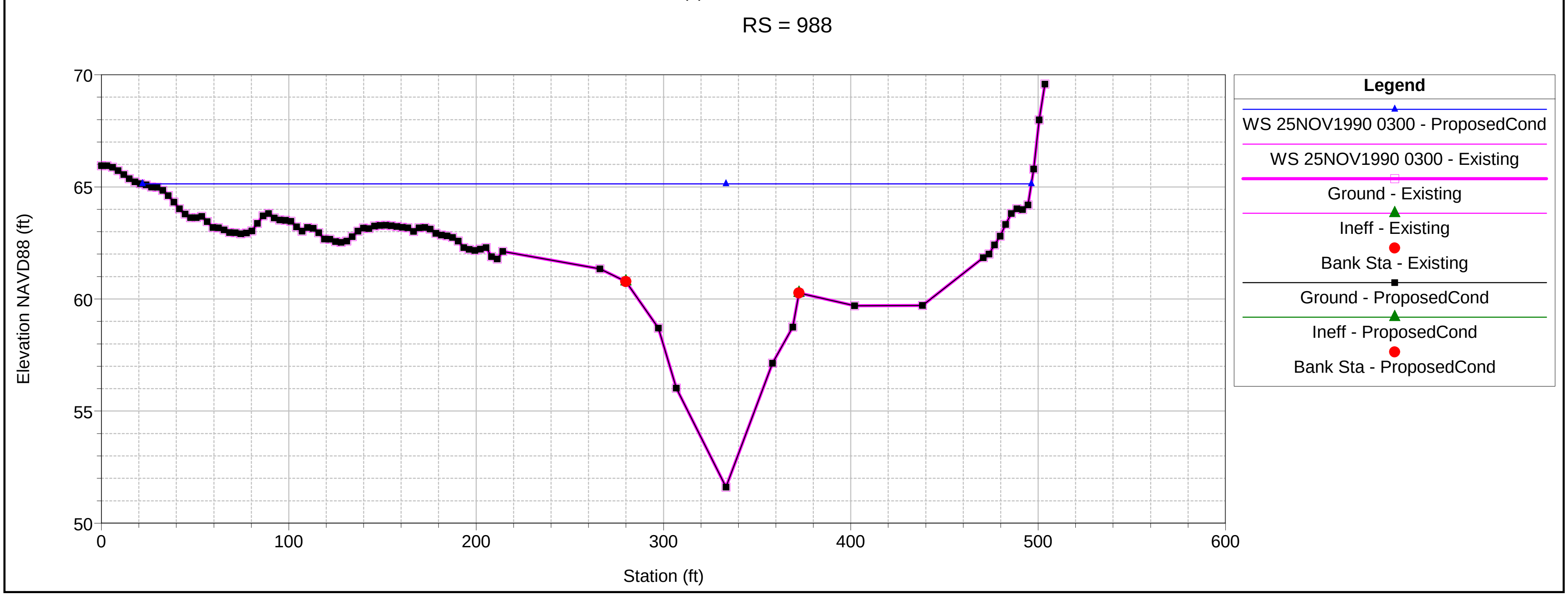
RS = 2122

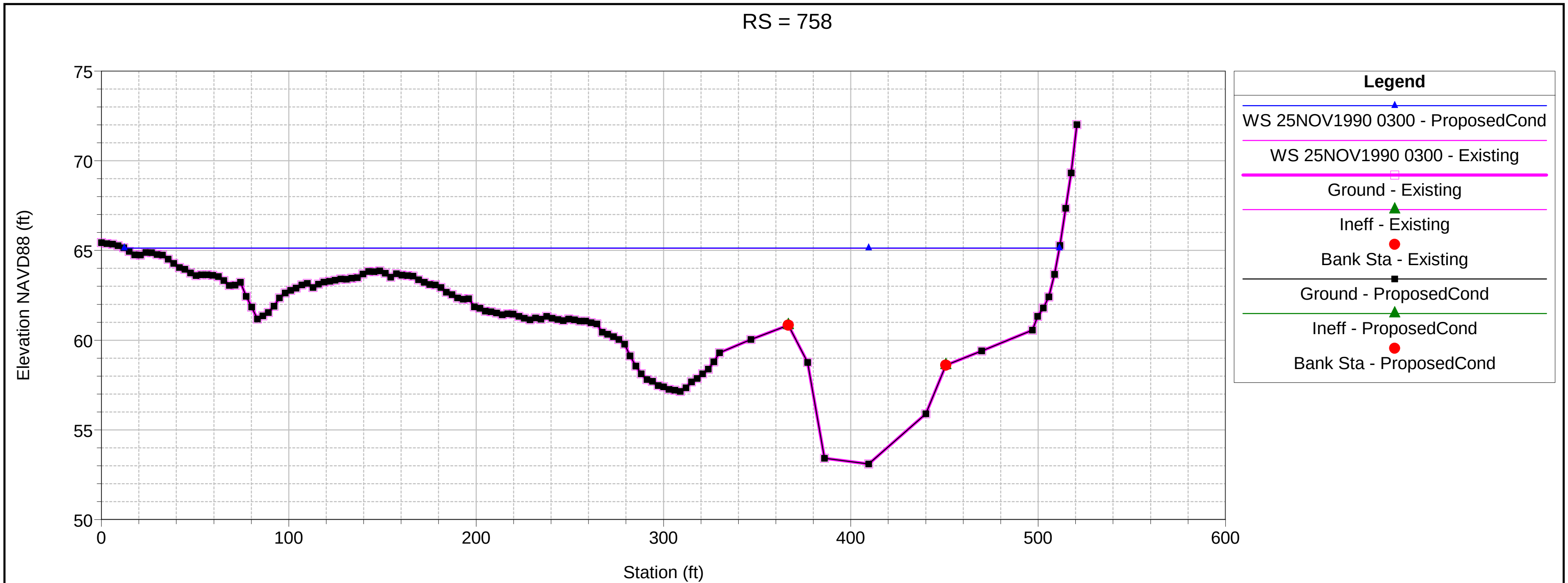


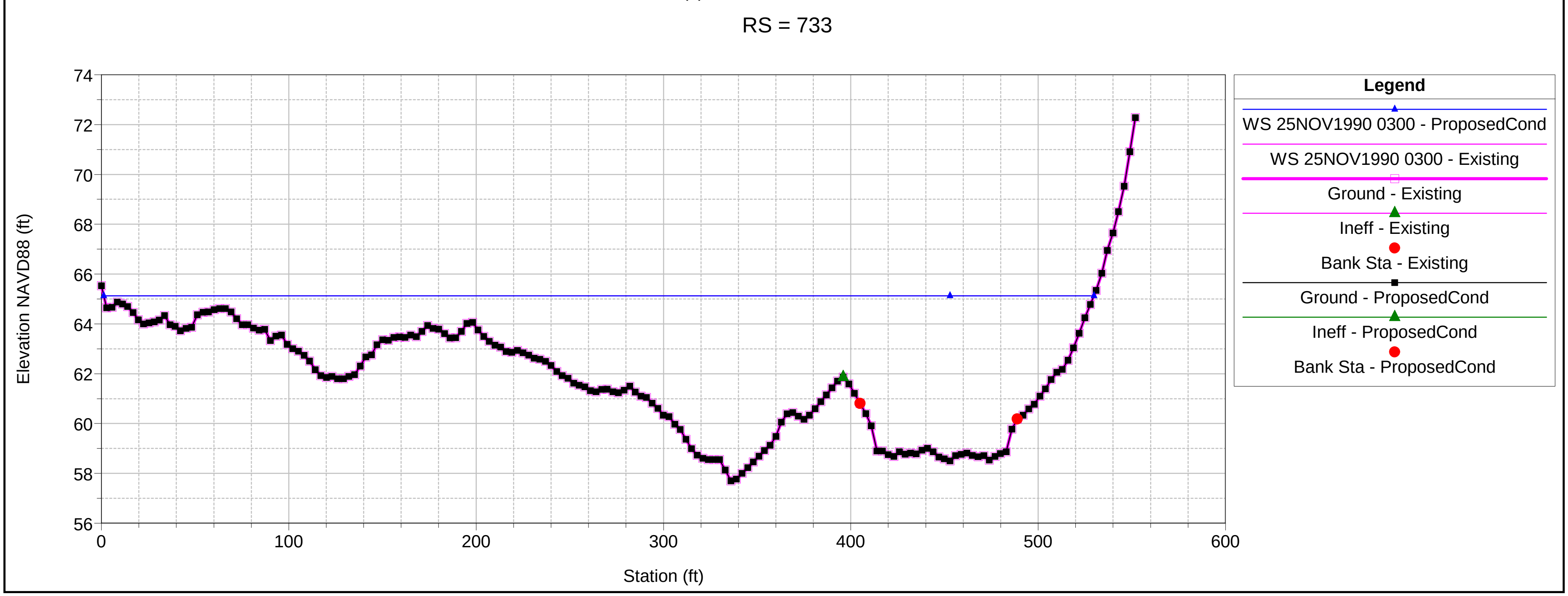

RS = 1861



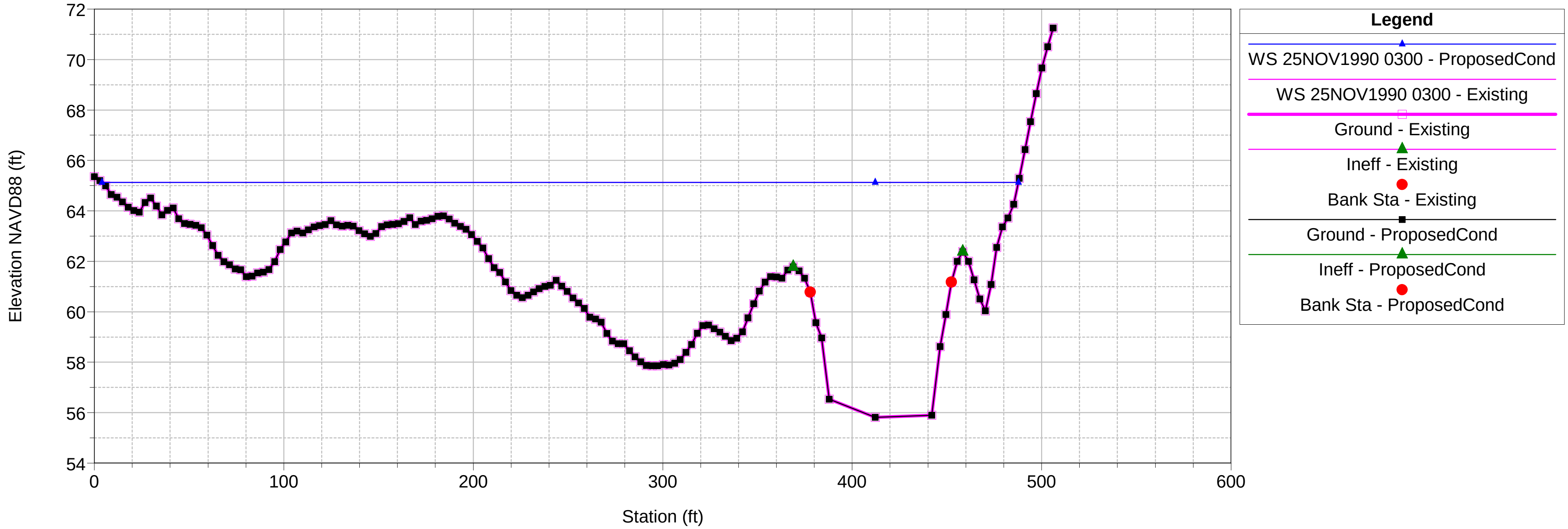

RS = 1567
Elevation NAVD88 (ft)
75
70
65
60
55
50
0
100
200
300
400
500
600
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond


RS = 988
Elevation NAVD88 (ft)
70
65
60
55
50
0
100
200
300
400
500
600
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond


RS = 758
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)
75
70
65
60
55
50
0
100
200
300
400
500
600

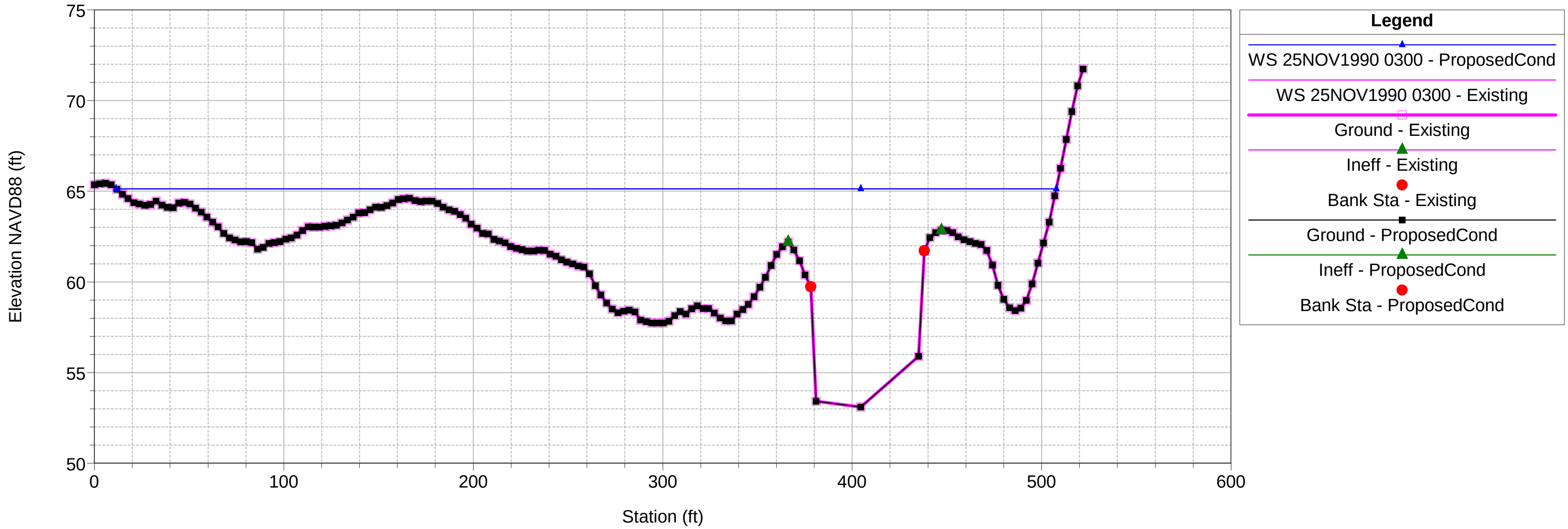

RS = 733
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)
74
72
70
68
66
64
62
60
58
56
0
100
200
300
400
500
600

RS = 696

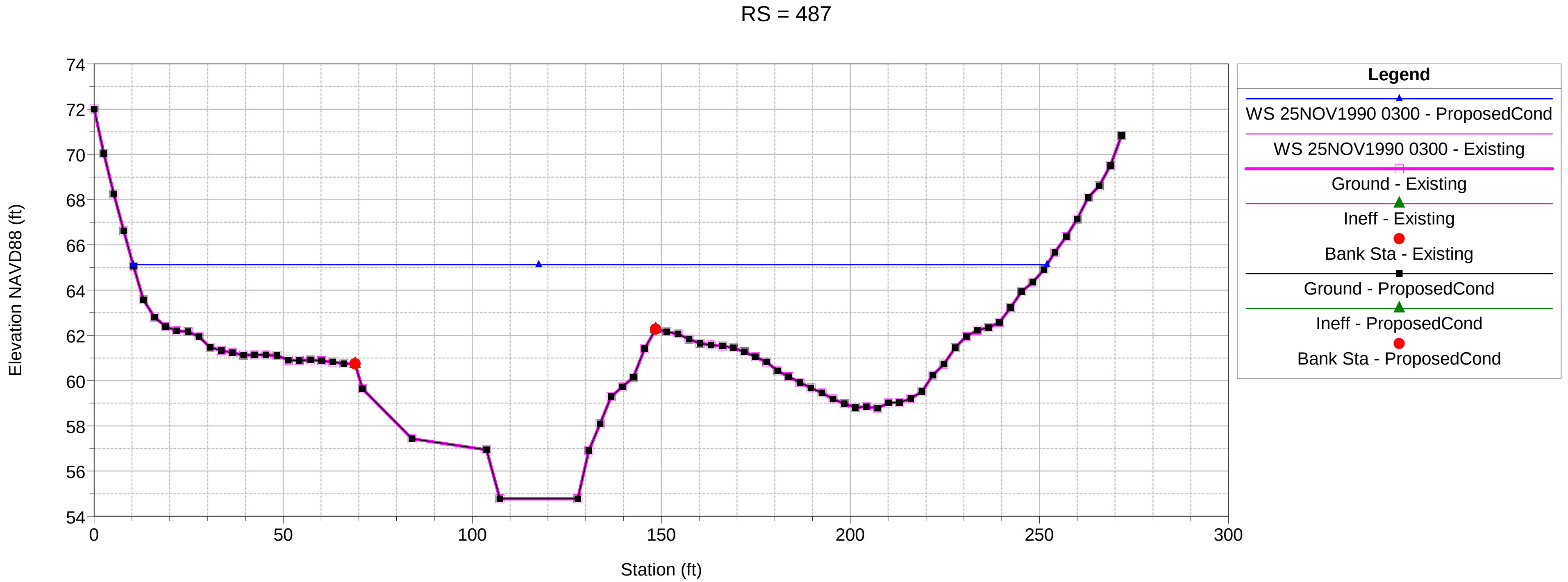


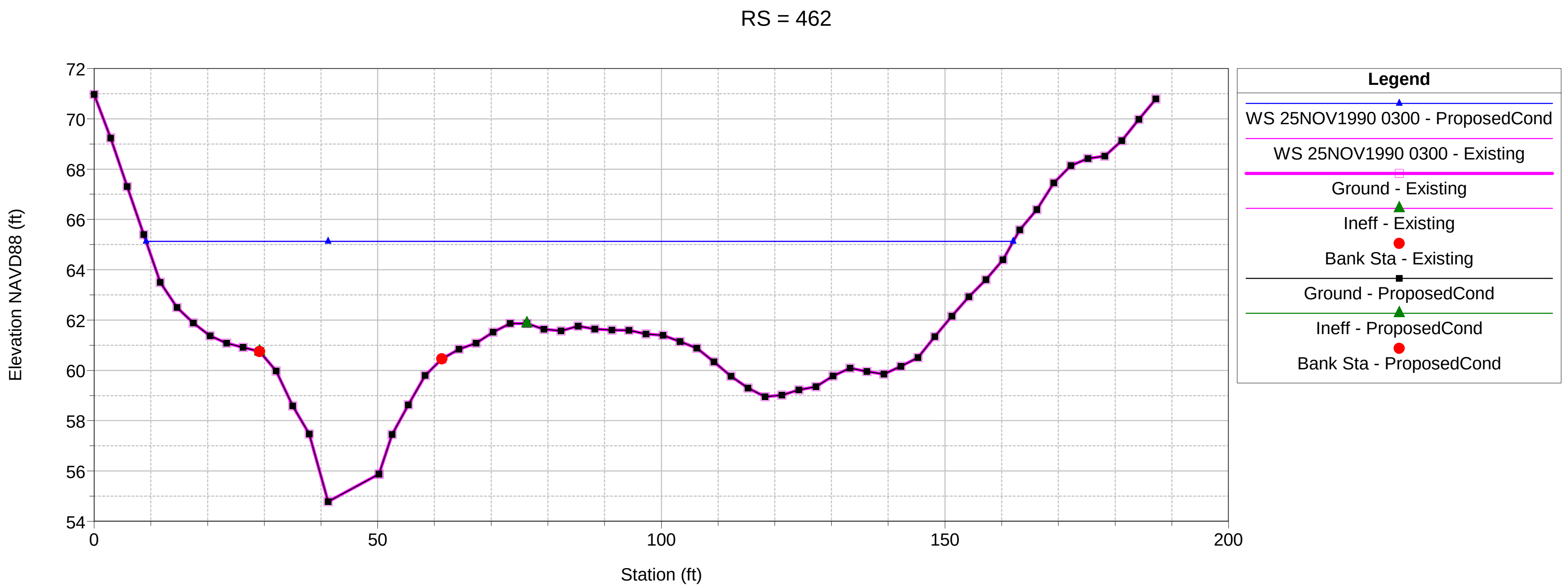
Elevation NAVD88 (ft)
72
70
68
66
64
62
60
58
56
54
0
100
200
300
400
500
600
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

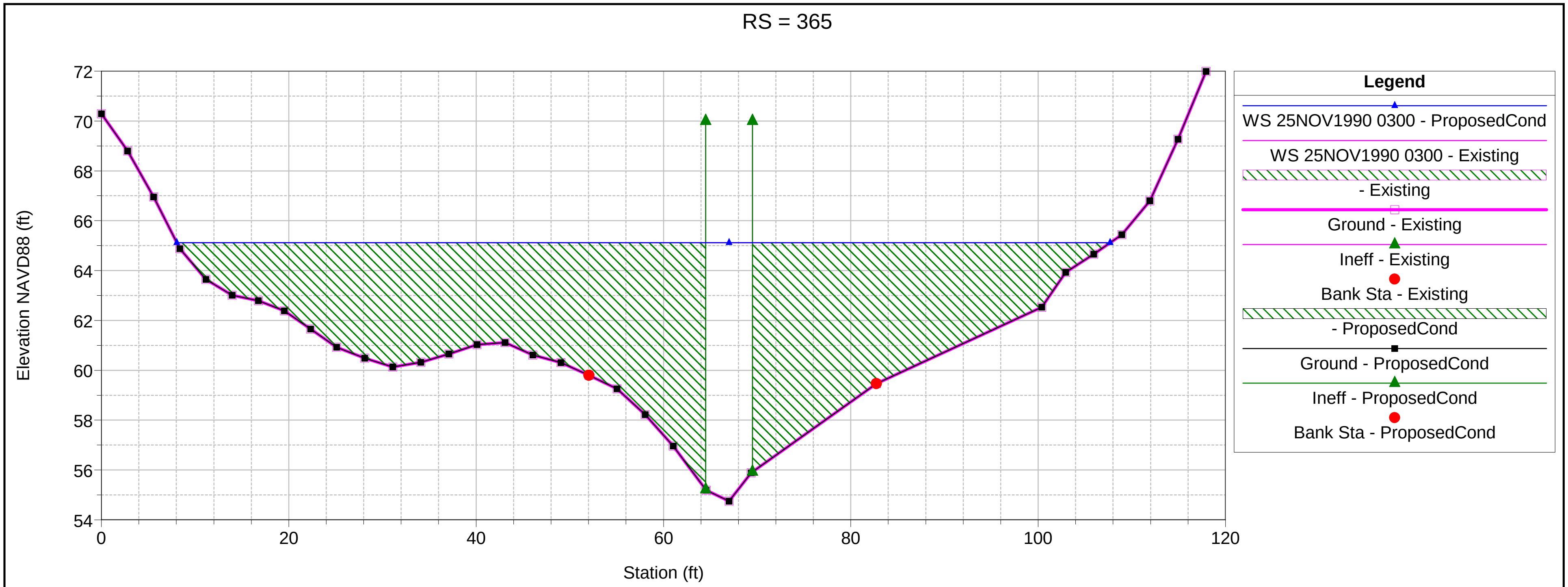

RS = 640



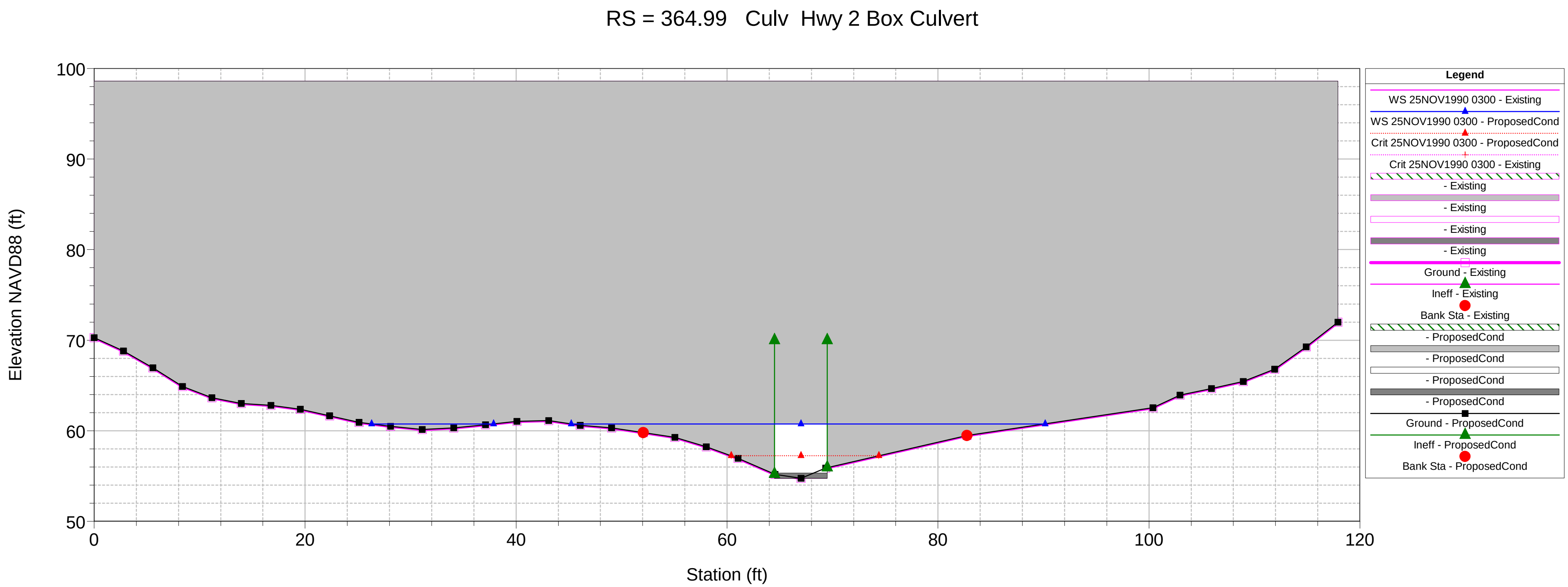
Elevation NAVD88 (ft)
75
70
65
60
55
50
0
100
200
300
400
500
600
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond


RS = 487
Elevation NAVD88 (ft)
74
72
70
68
66
64
62
60
58
56
54
0
50
100
150
200
250
300
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond


RS = 462
Elevation NAVD88 (ft)
72
70
68
66
64
62
60
58
56
54
0
50
100
150
200
Station (ft)
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond

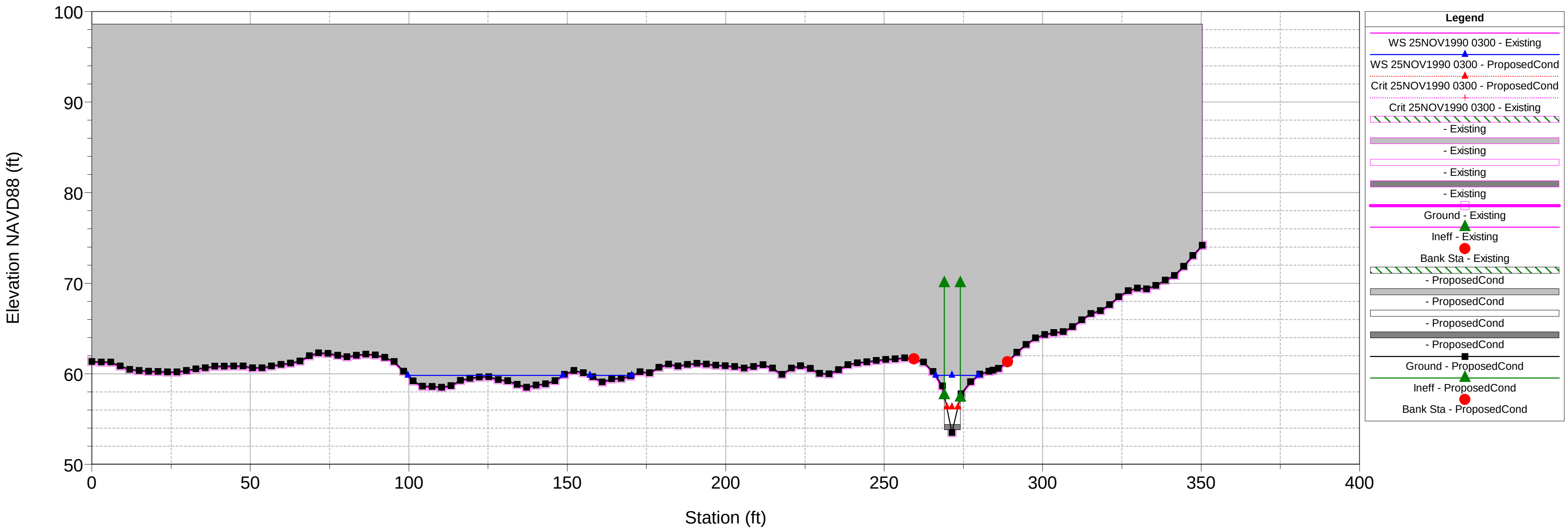


RS = 365
Legend
WS 25NOV1990 0300 - ProposedCond
WS 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)

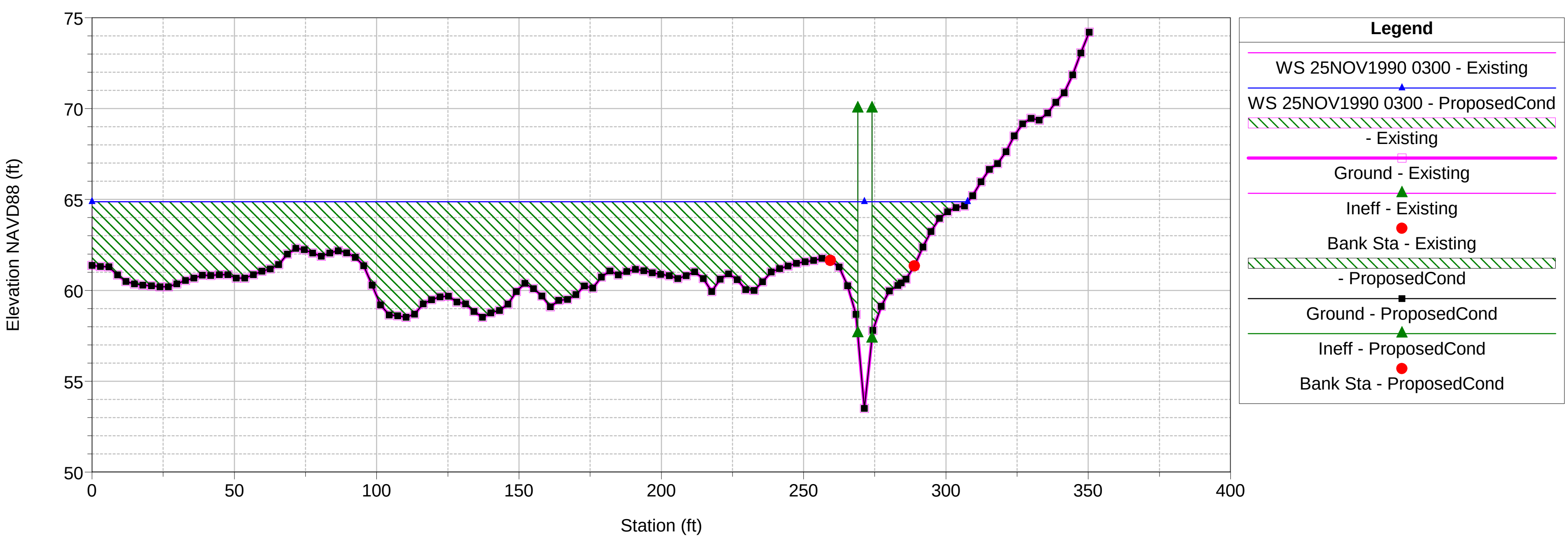



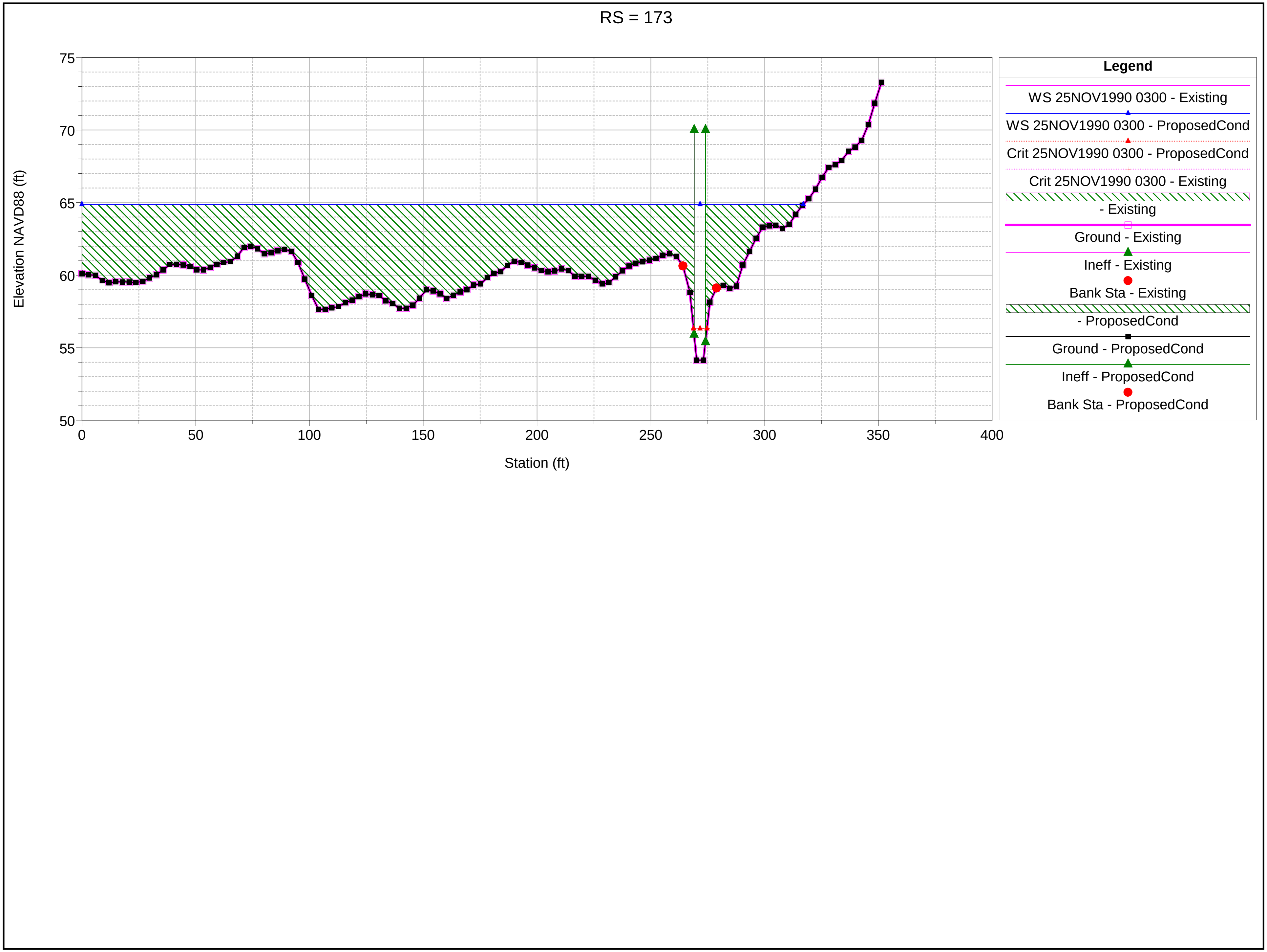
RS = 364.99 Culv Hwy 2 Box Culvert
Legend
WS 25NOV1990 0300 - Existing
WS 25NOV1990 0300 - ProposedCond
Crit 25NOV1990 0300 - ProposedCond
Crit 25NOV1990 0300 - Existing
- Existing
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
- ProposedCond
- ProposedCond
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)

RS = 364.99 Culv Hwy 2 Box Culvert




RS = 176




RS = 173
Legend
WS 25NOV1990 0300 - Existing
WS 25NOV1990 0300 - ProposedCond
Crit 25NOV1990 0300 - ProposedCond
Crit 25NOV1990 0300 - Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- ProposedCond
Ground - ProposedCond
Ineff - ProposedCond
Bank Sta - ProposedCond
Elevation NAVD88 (ft)
Station (ft)
75
70
65
60
55
50
0
50
100
150
200
250
300
350
400