NE Manley Road Improvement Project

Hydraulic Report

Final Submittal

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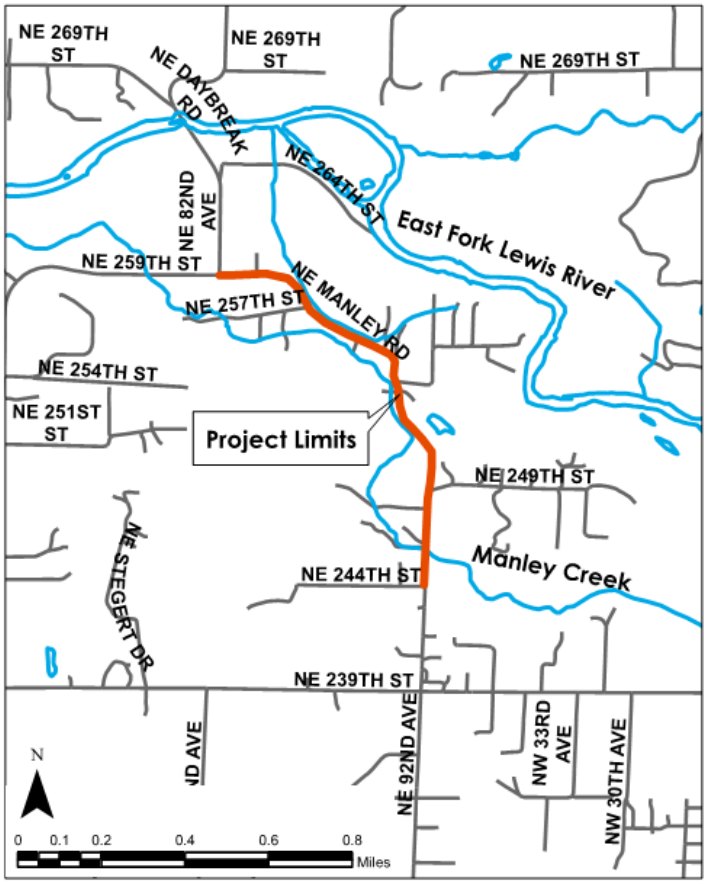
Section 1—Introduction

NE Manley Road Improvement Project is located northwest of the City of Battle Ground in Clark County, WA. It includes the length of NE Manley Road from its intersection with NE 82nd Avenue (at the north end) to its intersection with NE 244th Street (at the south end of the project) (Figure 1). The purpose of the project is to improve roadway safety by adding guardrail, adjusting the alignment, and improving the culvert crossings for Manley Creek. The project will replace four crossings of Manley Creek; three along NE Manley Road and one private driveway crossing. The existing culverts are undersized for the design flood event and are classified as fish barriers. This report documents the results of hydraulic engineering analyses carried out to support the design for the replacement of the existing culvert crossings.

The work reported here was carried out by Otak, Inc. (Otak) under contract with Clark County Public Works (County). This work included the following tasks:

- Review of background information including applicable design standards and regulations
- A field investigation to evaluate existing hydraulic conditions and channel stability
- Hydrologic analysis to establish design flows
- Hydraulic analyses to support the culvert designs
- Scour analyses to support the design of the culvert footings and any necessary scour countermeasures
- Design of stream channel realignment and reconstruction near the middle culvert
- Development of hydraulic design recommendations for temporary water management facilities to isolate in-stream work

Figure 1—Vicinity Map



Section 2 —Field Reconnaissance

A field reconnaissance of Manley Creek in the vicinity of the four culvert crossings was conducted by Otak staff on June 29, 2016. Observations were made of the general characteristics of the creek in the vicinity of the proposed culverts, the configuration and condition of the existing culverts, the lateral and vertical stability of the channel, evidence of general and local scour, and bed material characteristics. The field reconnaissance was followed up by a desktop review of available mapping and other information on the creek. Select photographs from the site visit are included in Appendix A.

General Observations

The Project crosses Manley Creek at four locations approximately 1.5 miles upstream of its confluence with the East Fork Lewis River. Manley Creek is trapezoidal in shape, sinuous and is a small creek without a functional floodplain for the majority of its length. At the south and middle culverts, the road crossings are well above the creek with steep embankments. The south crossing is the furthest upstream and at a higher elevation. The north crossing includes two culverts; North A is the road crossing and North B is the private driveway crossing. The north culverts are at a lower elevation and adjacent to the East Fork Lewis River floodplain (though not in the FEMA mapped floodplain). The north crossings have limited clearance.

The portion of the creek between the middle and north culverts was relocated prior to1950s. The creek was likely moved from flowing north to the East Fork Lewis River and instead was turned west to cross under the road (North A crossing). The channel at the upstream North A crossing was artificially constructed as evidenced by the creek elevation being higher than the adjacent floodplain beyond the creek's berm.

Existing Conditions

The south crossing is located at a meander bend in Manley Creek and the creek profile is relatively flat. Previous reports indicate that the existing culvert is prone to being clogged by debris and is classified as a partial fish passage barrier. The existing culvert is a 36-inch diameter round corrugated metal pipe and is approximately 74 feet long. The culvert follows the natural stream alignment skewed relative to the roadway by approximately 22 degrees. The inlet and outlet are both characterized by large pools within the stream channel. The culvert is in poor condition with visible corrosion below the springline and sag in the middle.

The middle crossing is on a steep and confined portion of the creek as it drops down the ridge that runs parallel to the East Fork Lewis River. The culvert outlet is perched above a small pool. The culvert is a 48-inch diameter round, smooth concrete culvert approximately 77 feet long. The stream channel upstream and downstream of the culvert closely parallels the roadway alignment and the channel turns sharply at the inlet and the outlet of the culvert. Some skew was constructed in the existing culvert to mitigate these bends; the culvert is skewed relative the roadway by approximately 26 degrees. The culvert is listed as fish passage barrier with an unknown percent passable.

The North A culvert is located where Manley Creek is in a shallow channel connected to the floodplain. A vegetated island is present immediately upstream of the crossing, separating the main channel from a high flow channel. A manmade berm exists along the north east edges of the stream and when the berm is overtopped water flows into the East Fork Lewis River floodplain area. There is a pool formed in the channel at the culvert outlet. The culvert is embedded and has limited access for observation and measurement. The culvert is a 36-inch diameter corrugated metal pipe and is approximately 44 feet long. The condition of the culvert could not be determined due to the embedment of the structure. The stream channel upstream of the culvert closely parallels the roadway alignment and turns sharply at the inlet of the culvert. The stream channel downstream is approximately perpendicular to the roadway's alignment. The existing culvert is skewed relative the roadway by approximately 5 degrees. The culvert is listed as a partial fish passage barrier.

The North B crossing is located 100 feet upstream of the North A crossing. At the North B crossing, Manley Creek crosses under the Brandreth's driveway in three culverts; two 30-inch and one 24-inch diameter culverts. One of the existing culverts is perched and all three are partially crushed.

Lateral Channel Stability

Under current conditions Manley Creek appears to be laterally stable within the vicinity of the culvert crossings, with the exception of the upstream side of the North A culvert. At this location the creek has two channels and it has switched from one side to the other multiple times since the project began. At the south crossing, the channel is vegetated with Reed Canary Grass and the banks are heavily vegetated with trees and underbrush. At the middle crossing, the banks are steep and well vegetated with large evergreen and deciduous trees. Between the North A and North B crossings, the banks are mowed grass with scattered trees. At the south and middle creek crossings, the side slopes limit any lateral movement in the creek channel. There is some channel side slope erosion at the downstream end of the middle crossing.

Vertical Channel Stability

Under current conditions Manley Creek appears to be vertically stable in the vicinity of the south culvert. At the North A culvert, the creek is in a state of aggradation and neighbors have reported a significant increase in sediment deposition at the crossing in recent years. The aggregation likely is a result of sediment deposit from the flattening channel slope near the crossing. It is unknown if the upstream mining operation is supplying additional sediment load to the creek. Also noteworthy, the existing culverts have pinned the creek at the crossings so channel may be less vertically stable than it appears.

One area of possible vertical channel instability is at the middle culvert. At the outfall of this culvert, there is a 3- to 4-foot drop and the creek has nearly vertical walls of a similar depth. The drop has been partially filled with rocks and logs to provide energy dissipation. It is expected that removing the culvert and installing a bottomless culvert will have an impact to the vertical channel stability. The proposed design takes into account the vertical channel instability.

Existing Culvert Scour

The existing south, middle, and North A culverts all have scour pools at the downstream ends. These scour pools are the result high velocities from the undersized culverts. The existing North B culverts do not have a downstream scour pool.

Bed Material

The existing culvert constriction at the south crossing results in upstream sediment accumulation. The bed material is primarily coarse gravel with some fine-grained sediment. A pebble count (Wolman, 1954) was conducted upstream of the south crossing, and it was found that there is in a median diameter of 24.6 mm (0.97 inches). Figure 2 is a plot of the resultant sediment gradation.

The bed in the vicinity of the north and middle crossings consists of a mix of gravel and cobble sized material with finer sand-sized material transported through the reach. It is unknown how much the upstream quarry operation that discharges stormwater runoff to the creek impacts the material gradation and loading. A pebble count was conducted upstream of the middle crossing, and it was found that there is a median diameter of 51.4 mm (2.02 inches). Figure 3 is a plot of the resultant sediment gradation.

A pebble count was also conducted downstream of the North A crossing, and it was found that there is a median diameter of 42.2 mm (1.66 inches). Figure 4 is a plot of the resultant sediment gradation. The bed material gradation for the North A culvert was also used for the North B culvert.

Figure 2—Upstream South Crossing Bed Material Gradation

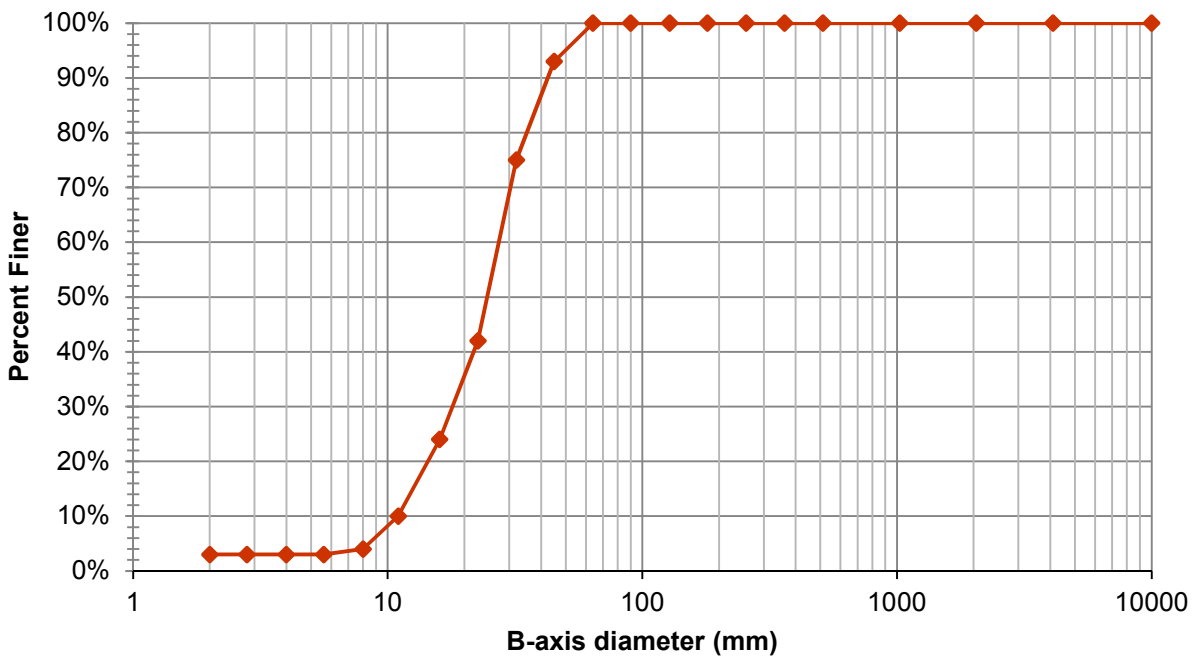


Figure 3—Downstream Middle Crossing Bed Material Gradation

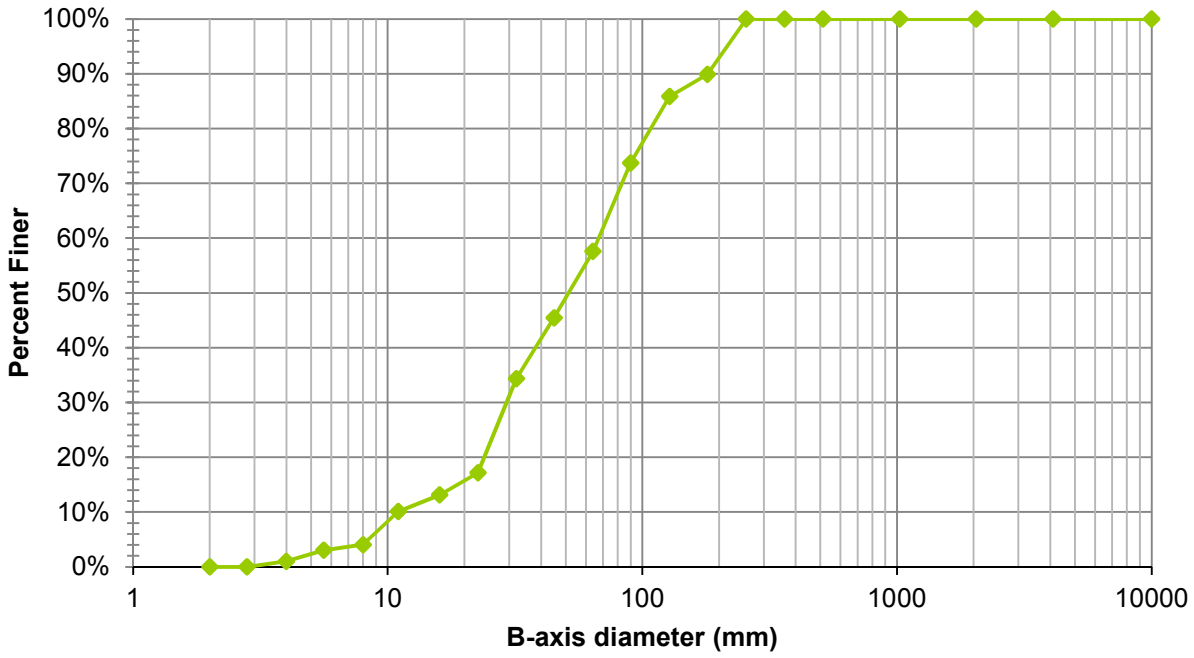
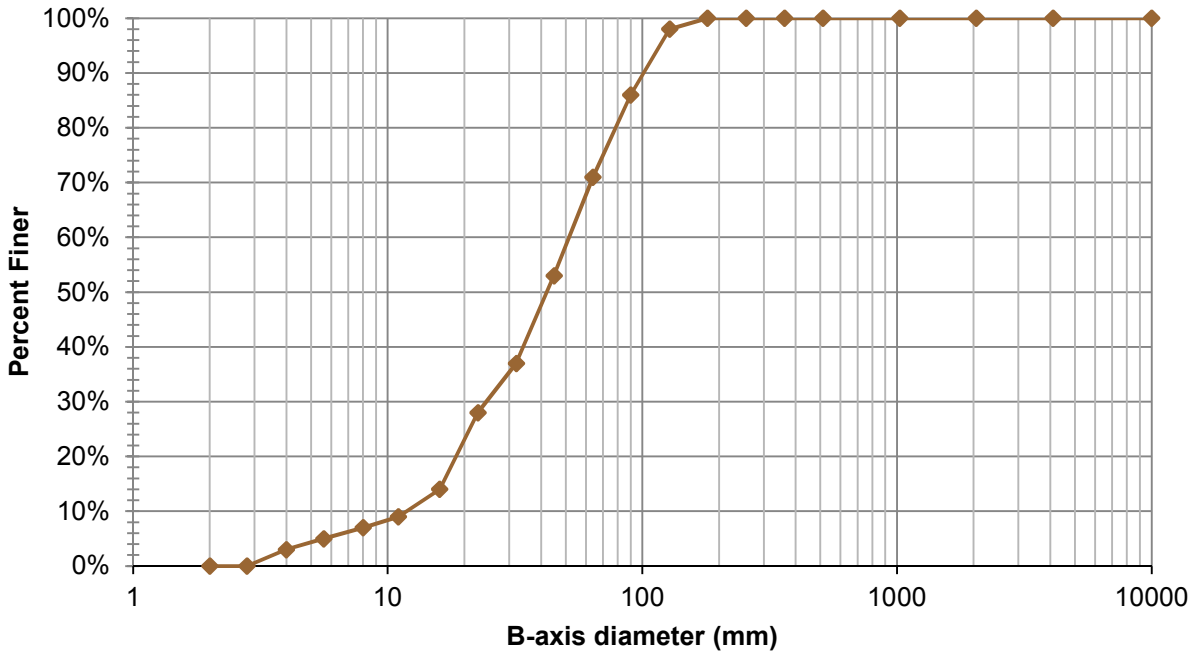


Figure 4—Downstream North A Crossing Bed Material Gradation



Section 3 —Hydrology

The Manley Creek catchment area is part of the East Fork Lewis River Watershed, located east of the Columbia River and west of the City of Battleground. The catchment drains into East Fork Lewis River Creek approximately 10 miles upstream of Lewis River confluence, which drains into the Columbia River near the Ridgefield National Wildlife Refuge. The Manley Creek catchment is approximately 1.28 square miles and largely comprised of rural housing and agriculture land, but also contains sections of densely forested land and wetlands.

The 2-, 10-, 25-, 50-, 100- and 500-year peak flows were estimated with the Flood Q Regression Tool based on the United States Geological Survey (USGS) Magnitude, Frequency, and Trends of Floods at Gaged and Ungaged Sites in Washington, Based on Data Through Water Year 2014 (USGS 2016). The tool uses a regional specific regression equation, the drainage basin area, and the annual precipitation to estimate the peak discharge for selected recurrence interval probabilities.

StreamStats is another USGS online tool that is commonly used to estimate flood and frequency for a particular basin area. The program is capable of auto-delineating a drainage basin. For the project, StreamStats calculated a basin area of 2.19 square-miles, which extended into an area that should not have been included given the County's contour information and Otak's field investigation. The additional 0.91 square-mile basin area is on the ridge along the East Fork Lewis River with well-draining soils. Runoff likely travels subterranean towards the river. StreamStats also used an older regression equation from USGS Magnitude and Frequency of Floods in Washington (USGS 2001) report completed in 2001, which only included data up to 1998. For these reasons, the results from StreamStats were not used in the hydraulic analysis.

Table 1 shows the peak flows for Manley Creek from the Flood Q Regression Tool for Washington. These flows were used at all four the culvert crossings. The Flood Q Regression Tool for Washington output is included in Appendix B.

Table 1—Comparison of Peak Discharge

Recurrence Interval (years)	Exceedance Probability (Percent)	Peak Discharge (cfs) Manley Creek at North A Crossing from Flood Q Regression Tool*
2	50	52.6
10	10	111
25	4	144
50	2	171
100	1	199
500	0.2	266

** Used at all four culvert crossings*

Section 4 —Hydraulics

Hydraulic Design Process and Description of Proposed Crossings

The hydraulic design process consisted of modeling the proposed culvert configurations with the goal of meeting the following specific design criteria:

- Passing the 100-year flood peak with adequate freeboard (1 foot minimum);
- Spanning 1.2 times the bankfull channel width plus 2 feet, and
- Ensuring no significant changes in hydraulic conditions that would affect channel stability or fish passage.

Scour calculations were carried out for all the proposed crossings to ensure protection of the culverts from scour (see Section 5 of this report).

Proposed South Culvert Crossing

The proposed culvert replacement at the south crossing will match the alignment of the existing culvert. The proposed culvert will be a 74-foot long, 22-foot span, and 11-foot rise structural plate arch. The culvert will be constructed with an open bottom and supported on spread footings. The spread footings will be embedded into the streambed material and protected with adequately sized riprap (WSDOT Class B riprap). The spread footings will be constructed flat but the channel through the culvert will have a 0.80% slope. The channel will be rebuilt to mimic the channel upstream and downstream of the crossing (details are provided in Section 6). Cast-in-place wing walls will be constructed at the inlet and outlet of the culvert.

Design drawings for the proposed south culvert replacement are included in Appendix C.

Proposed Middle Culvert Crossing

The proposed culvert replacement at the middle crossing will increase the skew relative to the roadway to 37.5 degrees. The increase in skew creates a longer culvert, but will reduce the degree of curvature the creek has to bend at the inlet and outlet of the culvert. Similar to the south culvert crossing, the proposed middle culvert crossing will be an 84-foot long, 22-foot span, and 11-foot rise structural plate arch. The culvert is also constructed with an open bottom and will be supported on spread footings. The spread footings will be embedded into the streambed material and protected with adequately sized riprap (WSDOT Class B riprap). The spread footings will constructed at a 6% slope to match the channel through the culvert. Cast-in-place wing walls will be constructed at the inlet and outlet of the culvert.

The existing channel is relatively steep, and the slope of the existing culvert is steeper than the upstream and downstream channels. Additionally, there is a 3- to 4-foot drop at the outlet of the existing culvert. The proposed

design will regraded the channel using cascades, pools, and runs to create a smooth transition from the upstream channel, though the culvert to the downstream channel (details are provided in Section 6). This channel configuration also helps to reduce the channel slope within the culvert. Downstream of the middle culvert, the alignment of the creek was slightly shifted to pull it away from the proposed roadway embankment retaining wall.

Design drawings for the proposed middle culvert replacement are included in Appendix C.

Proposed North A and North B Culvert Crossings

The proposed culverts at the North A and North B crossings will match the alignment of the existing culverts. The proposed culvert at the North A crossing will be a 40-foot long, 20-foot span, and 7-foot rise precast reinforced concrete three sided structure (with square corners). The North B crossing will have the same type and size of structure as the North A culvert crossing, except it will only be 16 feet long. The culverts will be open bottomed and supported on spread footings. The spread footings will be constructed flat but the channel through the culverts will have a 1% slope (North A) and a 5% slope (North B). The spread footings will be embedded into the streambed material and protected with adequately sized riprap (WSDOT Class B riprap). The channel will be rebuilt to mimic the channel upstream and downstream of the crossing (details are provided in Section 6).

Between the North A and the North B culvert crossings, the channel was regraded to remove the island between the main channel and the side channel. The channel furthest away from the road is the natural alignment of the creek and it was graded as the main channel. The side channel was turned into a backwater channel to provide fish habitat, particularly during high flows when it will fill up.

As part of the project, the small residential foot bridge and a portion of the concrete pad downstream of the North A crossing will be removed. After the removal, the channel bank will be restored with coir logs and matting.

Design drawings for the proposed North A and North B culvert replacements are included in Appendix C.

Hydraulic Model Development

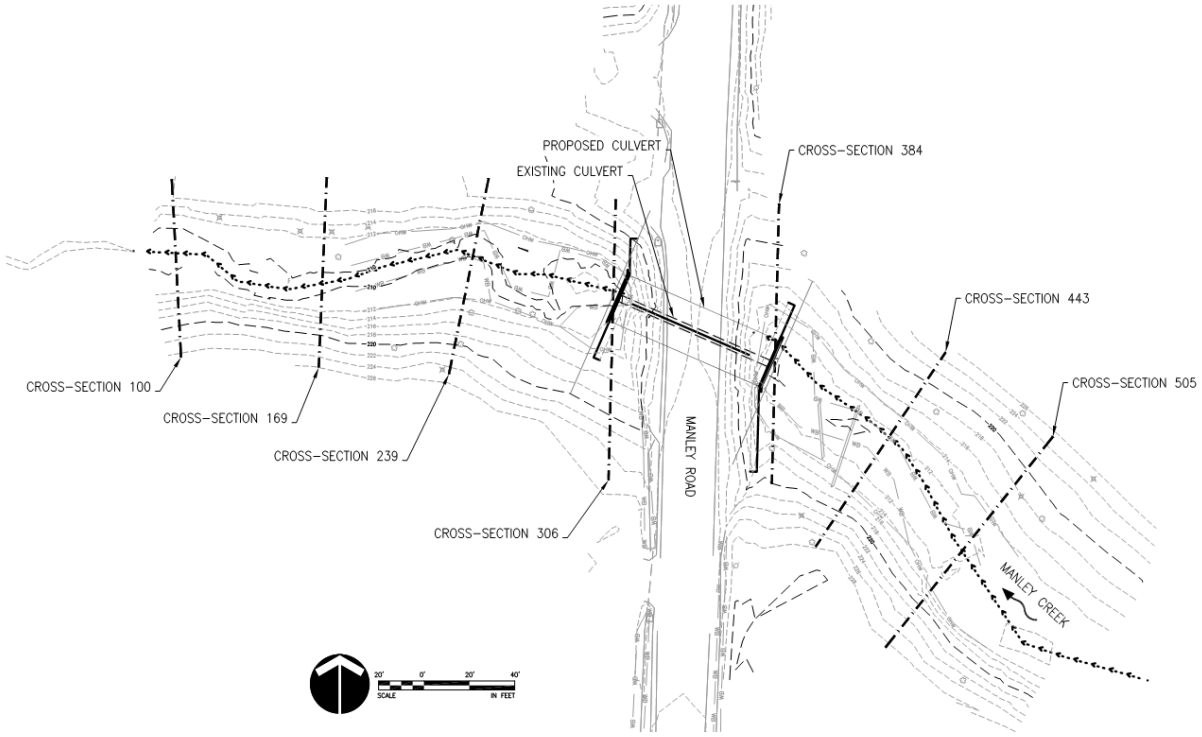
A one-dimensional hydraulic analysis of Manley Creek in the vicinity of each crossing was completed to provide a sound basis for the hydraulic design of the culvert replacements. The analysis was performed using the United States Army Corps of Engineers (USACE) HEC-RAS v5.0.3 computer software (USACE, 2016). Each crossing was modeled separately, except the North A and the North B crossings (which were combined given their close proximity).

South Crossing Model

Hydraulic models were developed for existing and proposed conditions at the south crossing. The modeled reach near the south crossing is about 400 feet long and extends from about 120 feet upstream of the culvert to about 200 feet downstream.

A total of seven user-input cross-sections were used to describe the geometry of the channel and side slopes through the modeled reach for the existing conditions model. The cross-sections were developed from survey data collected by Clark County surveyors for this project. The existing culvert configuration was coded into the model using survey data of the invert elevations and diameter. Ineffective flow areas were included on the cross-sections bounding the culvert to account for the contraction and expansion of flow into and out of the culvert. Figure 5 shows a plan view of the modeled reach and the seven cross-sections used within the model.

Figure 5—South Crossing Cross-Section Locations



The main channel and overbank roughness coefficients (Manning's n values) were estimated using engineering judgment based on field observation and standard references (Chow, 1959, Barnes, 1967). The main channel Manning's "n" value was set to 0.035 upstream and downstream of the crossing based on the relatively open middle of the channel. An overbank Manning's "n" value of 0.08 was used, representing the dense vegetation.

The flow is fairly uniform through the reach and lacks any significant hydraulic controls aside from the existing culvert crossing. The downstream boundary condition (starting water-surface elevation) for the hydraulic model was established using normal depth for a downstream longitudinal slope of 1.0%.

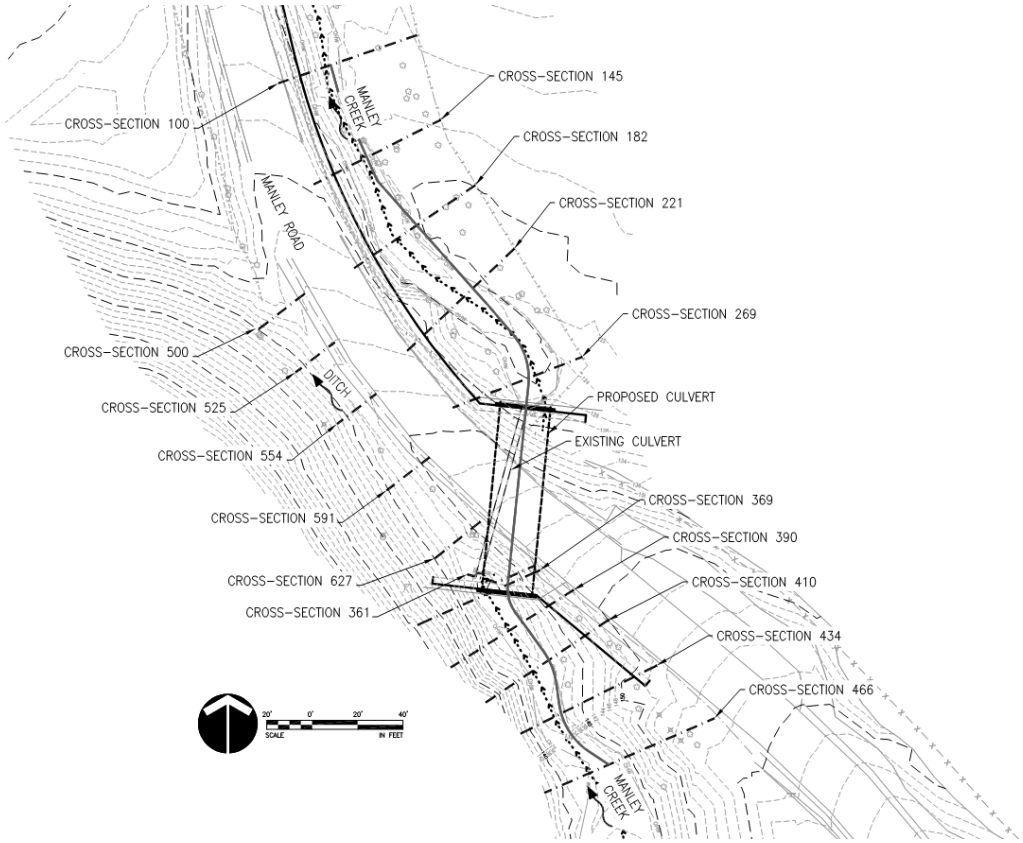
The proposed model was based on the existing conditions model. The existing culvert was replaced with the proposed culvert, which was modeled as a bridge given the width of the culvert in relation to the channel width. The upstream and downstream cross-sections near the new culvert were realigned to be parallel to the face of the proposed culvert. These cross-sections were modified to reflect the proposed channel grading and ineffective areas were adjusted for the wider culvert. The same Manning's "n" values were used for the proposed conditions as the existing conditions model.

Middle Crossing Model

Hydraulic models were developed for existing and proposed conditions at the middle crossing. The existing model required a more complex setup due to the fact that the existing culvert creates such a severe constriction in the flow that the flow overtops the roadway and some flow runs down the ditch on the west side of the road (split flow). The modeled reach near the middle crossing is about 360 feet long and extends 170 feet downstream the main channel, 130 feet downstream of the roadside ditch, and 130 feet upstream of the crossing.

A total of sixteen user-input cross-sections were used to describe the geometry of the channel, ditch, and side slopes through the modeled reach for the existing conditions model. The cross-sections were developed from survey data collected by Clark County surveyors for this project. A lateral structure was added along the roadway ditch to allow for the ditch flow to spill over the road and into the main channel on the other side of the road. The existing culvert configuration was coded into the model using survey data of the invert elevations and diameter of the pipe. Ineffective flow areas were included on the cross-sections bounding the culvert to account for the contraction and expansion of flow into and out of the culvert. Figure 6 shows a plan view of the modeled reach and the sixteen cross-sections used within the model.

Figure 6—Middle Crossing Cross-Section Locations



The main-channel, ditch, and overbank roughness coefficients (Manning's n values) were estimated using engineering judgment based on field observation and standard references (Chow, 1959, Barnes, 1967). The main channel Manning's "n" value was set to 0.045 upstream and downstream of the crossing based on the semi-roughened channel with riffles and pools. The ditch and overbank Manning's "n" values were set at 0.08 representing the dense vegetation.

With the split flow, several boundary conditions (starting water surface elevations) had to be set for the hydraulic model. For the ditch, the normal depth for the downstream longitudinal slope of 13.4 % was used and for Lower Manley Creek (Manley Creek downstream of the flow split), the normal depth for the downstream longitudinal

slope of 3.75% was used. Normal depth for a longitudinal slope of 4.58% was also used to set the starting water surface elevation at the upstream end of the hydraulic model.

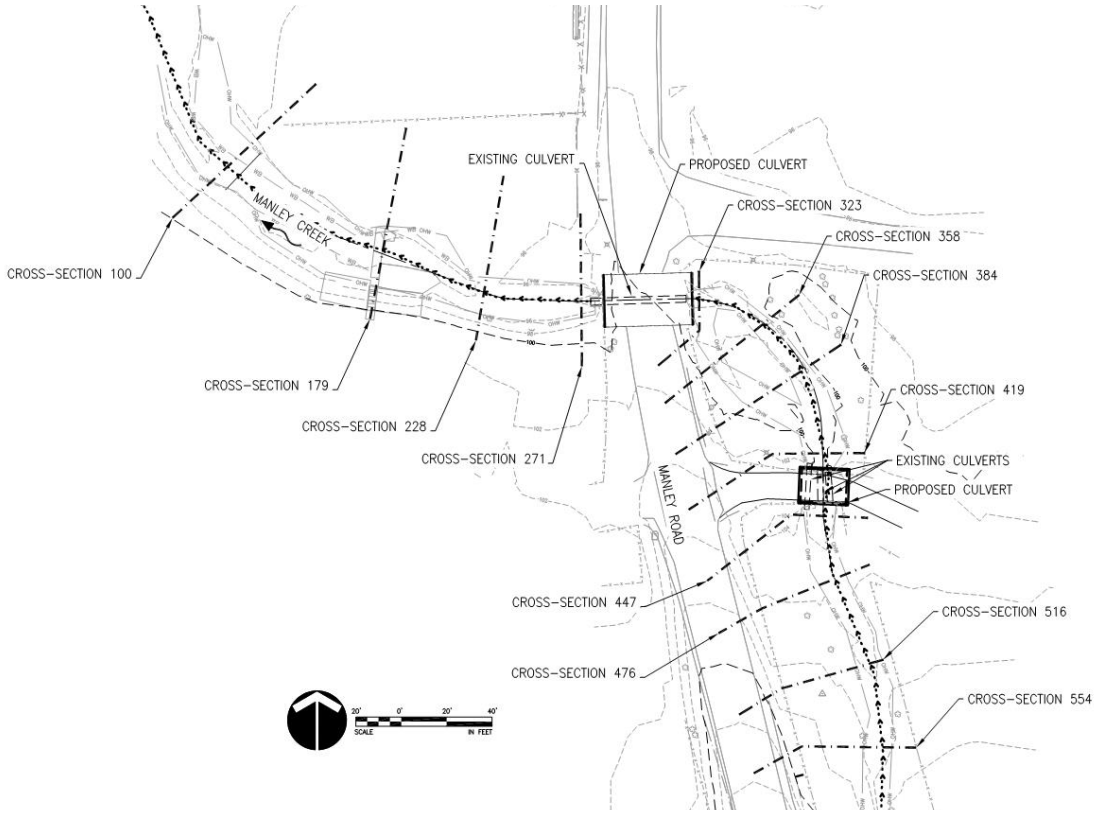
The proposed model was based on the existing conditions model but was simplified since the wider culvert eliminated any flow going down the roadside ditch or overtopping the road. The ditch cross-sections, the lateral structure, and split flow were removed from the proposed model. In the proposed conditions model, the flows downstream of the culvert are higher than existing conditions model since flow is no longer lost out of the system going down the ditch. The proposed conditions model has a total of eleven user-input cross-sections. The cross-sections near the culvert had to be moved to accurately model the new culvert alignment and geometry. The cross-sections were updated with the channel regrading that extended 230 feet downstream of the culvert (additional information on the channel design is in Section 6). The existing culvert was replaced with the proposed culvert, which was modeled as a bridge given the width of the culvert in relation to the channel width, and the ineffective areas were adjusted for the wider culvert. The same Manning's "n" values were used for the proposed conditions as the existing conditions model.

North A and North B Crossing Model

The North A and North B crossings were modeled together given their close proximity. Hydraulic models were developed for existing and proposed conditions at the north crossings. The modeled reach is about 450 feet long and extends 170 feet downstream of the North A crossing, 100 feet between the North A and the North B crossing, and 110 feet upstream from the North B crossing.

A total of twelve user-input cross-sections were used to describe the geometry of the channel and side slopes through the modeled reach for the existing conditions model. The cross-sections were developed from survey data collected by Clark County surveyors for this project. The first cross-section at 5+54 was placed far enough upstream that the 100-year flood event was fully contained in the channel. Going downstream from this cross-section, the channel becomes shallower and flow can overtop the east bank and connect into the East Fork Lewis River floodplain area. A lateral structure was added to the model to represent the berm along the bank of the creek that connects to the floodplain. Any flow that breaches the lateral structure is lost out of the system. The existing culvert configuration at North A and North B crossings was coded into the model using survey data of the invert elevations and diameters. Ineffective flow areas were included on the cross-sections bounding the culverts to account for the contraction and expansion of flow into and out of the culverts. Figure 7 shows a plan view of the modeled reach and the twelve cross-sections used within the model.

Figure 7—North A and North B Crossings Cross-Section Locations



The main-channel and overbank roughness coefficients (Manning's n values) were estimated using engineering judgment based on field observation and standard references (Chow, 1959, Barnes, 1967). The main channel Manning's "n" value was set to 0.040 upstream and downstream of the crossing based on the semi-roughened channel with riffles and pools. For dense vegetation, the overbank Manning's "n" values were set at 0.08. A Manning's "n" of 0.040 was used to represent mowed grass with scattered trees/bushes (the area between North A and North B crossings that is landscaped). A Manning's "n" of 0.030 was used to represent the open field downstream of the North A culvert. The downstream boundary condition (starting water-surface elevation) for the hydraulic model was established using normal depth for a downstream longitudinal slope of 1.60%.

The proposed conditions model was based on the existing conditions model. In the proposed conditions model, the flows are higher than the existing conditions model since no flow is lost out of the system at the middle crossing and less flow overtops the creek's berm (lateral weir). The existing culverts were replaced with the proposed culverts, which were modeled as a bridge given the width of the culverts in relation to the channel width. The upstream and downstream cross-sections near the new culverts were modified to reflect the proposed channel grading and ineffective areas were adjusted for the wider culvert. The same Manning's "n" values were used for the proposed conditions as the existing conditions model.

Model Results

South Crossing Results

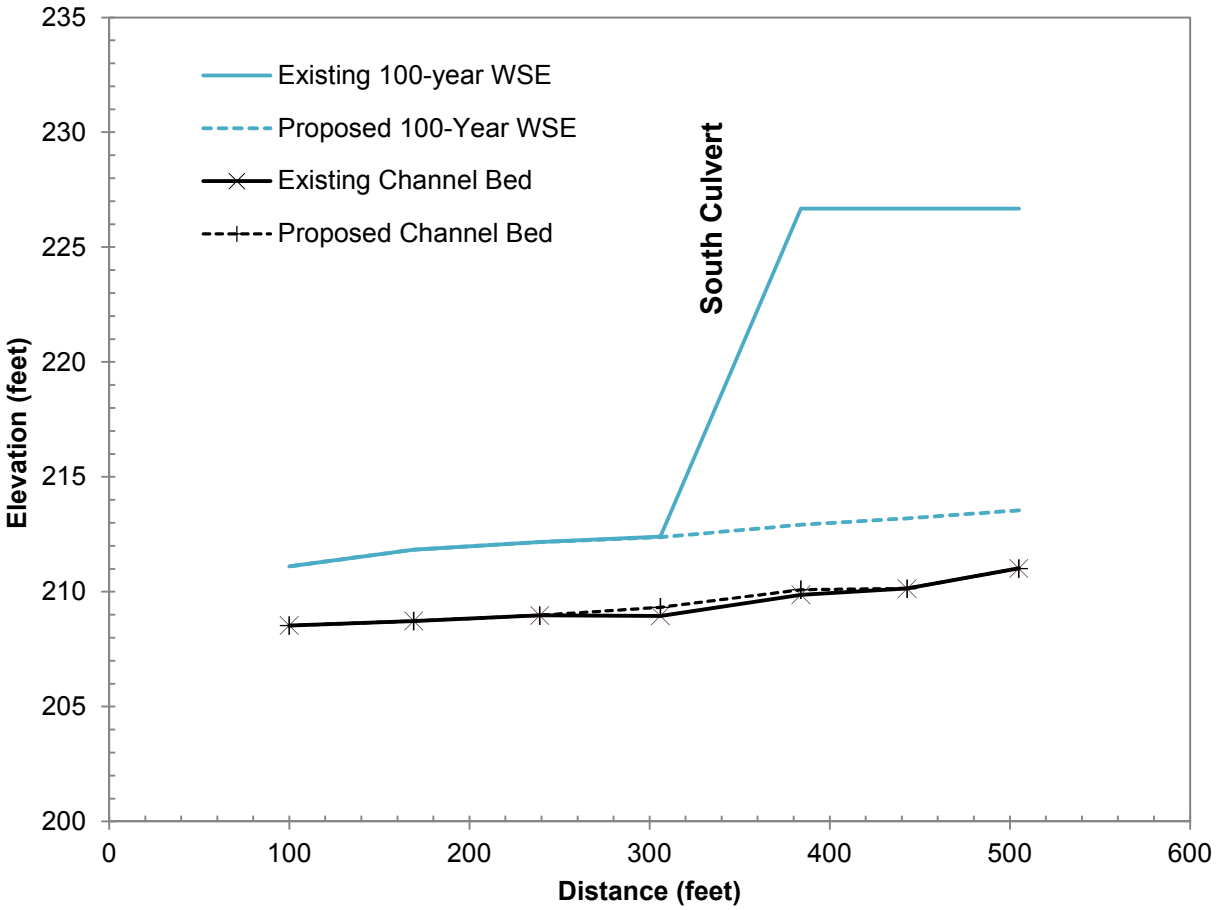
Figure 8 compares computed 100-year water-surface elevations for existing and proposed conditions. The plot shows that the proposed culvert will reduce upstream backwater by about 13 feet. Downstream of the culvert, computed water-surface elevations will remain the same after proposed conditions. Table 2 compares existing and proposed 100-year water surface elevations (WSE). At the upstream face of the culvert, the 100-year WSE is 212.74 feet. The upstream low chord of the culvert is 218.19 feet and the 100-year freeboard is 5.45 feet.

Table 2—South Crossing Comparison of 100-Year Water Surface Elevations (WSE)

Cross-Section	Existing Conditions WSE (feet)	Proposed Conditions WSE (feet)	Difference*
505	226.68	213.54	-13.14
443	226.68	213.19	-13.49
384	226.68	212.91	-13.77
South Culvert			
306	212.40	212.38	-0.02
239	212.17	212.17	0.00
169	211.83	211.83	0.00
100	211.11	211.11	0.00

** Change from existing conditions*

Figure 8—South Crossing 100-year WSE Profile



Comparison of existing and proposed conditions channel bed and computed 100-year water-surface elevation profile

Middle Crossing Results

The proposed culvert reduces the backwater effects at the upstream ends of the middle crossing as compared to the existing culvert. However, the increase in conveyance through the proposed culvert eliminates any water flowing down the ditch and leaving the system. The increase in the flow results in higher water surface elevations downstream of the crossing. The increased water surface elevations extend to the downstream limits of the model but are contained within the channel. The last cross-section in the model shows a rise of 1.70 ft. Table 3 compares existing and proposed 100-year water surface elevations (WSE). Figure 9 compares computed 100-year water-surface elevations for existing and project conditions. At the upstream face of the culvert, the 100-year WSE is 129.96 feet. The upstream low chord of the culvert is 137.10 feet and the 100-year freeboard is 7.14 feet.

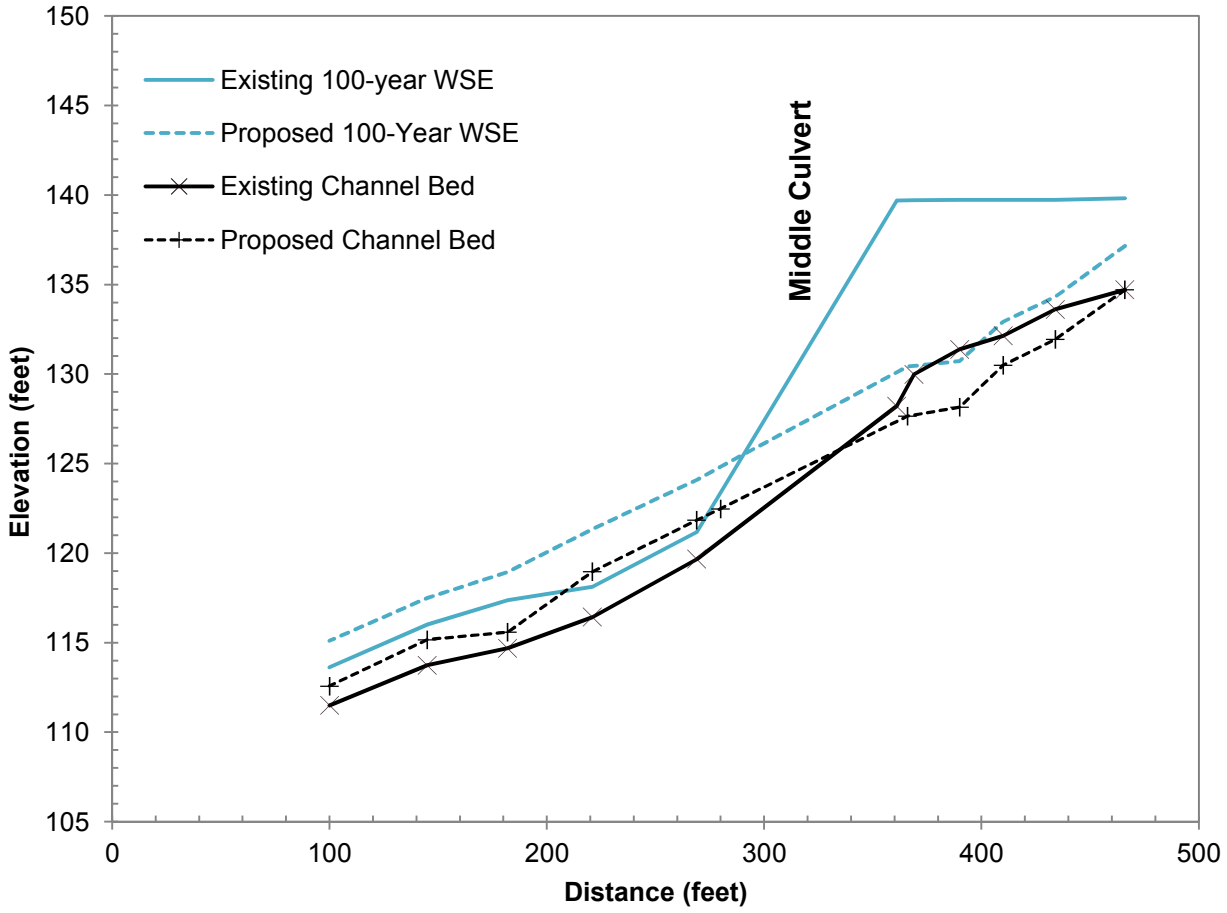
Table 3—Middle Crossing Comparison of 100-Year Water Surface Elevations (WSE)

Cross-Section*	Existing Conditions WSE (feet)	Proposed Conditions WSE (feet)	Difference**
466	139.86	137.16	-2.70
434	139.77	134.32	-5.45
410	139.77	132.91	-6.86
390	139.77	130.72	-9.05
Middle Culvert			
269	121.17	124.09	2.92
221	118.14	121.34	3.20
182	117.37	118.95	1.58
145	115.77	117.50	1.73
100	113.41	115.11	1.70

** Only cross-sections that apply to both the existing and proposed models are shown*

*** Change from existing conditions*

Figure 9—Middle Crossing 100-year WSE Profile



Comparison of existing and proposed conditions channel bed and computed 100-year water-surface elevation profile

North A and North B Crossing Results

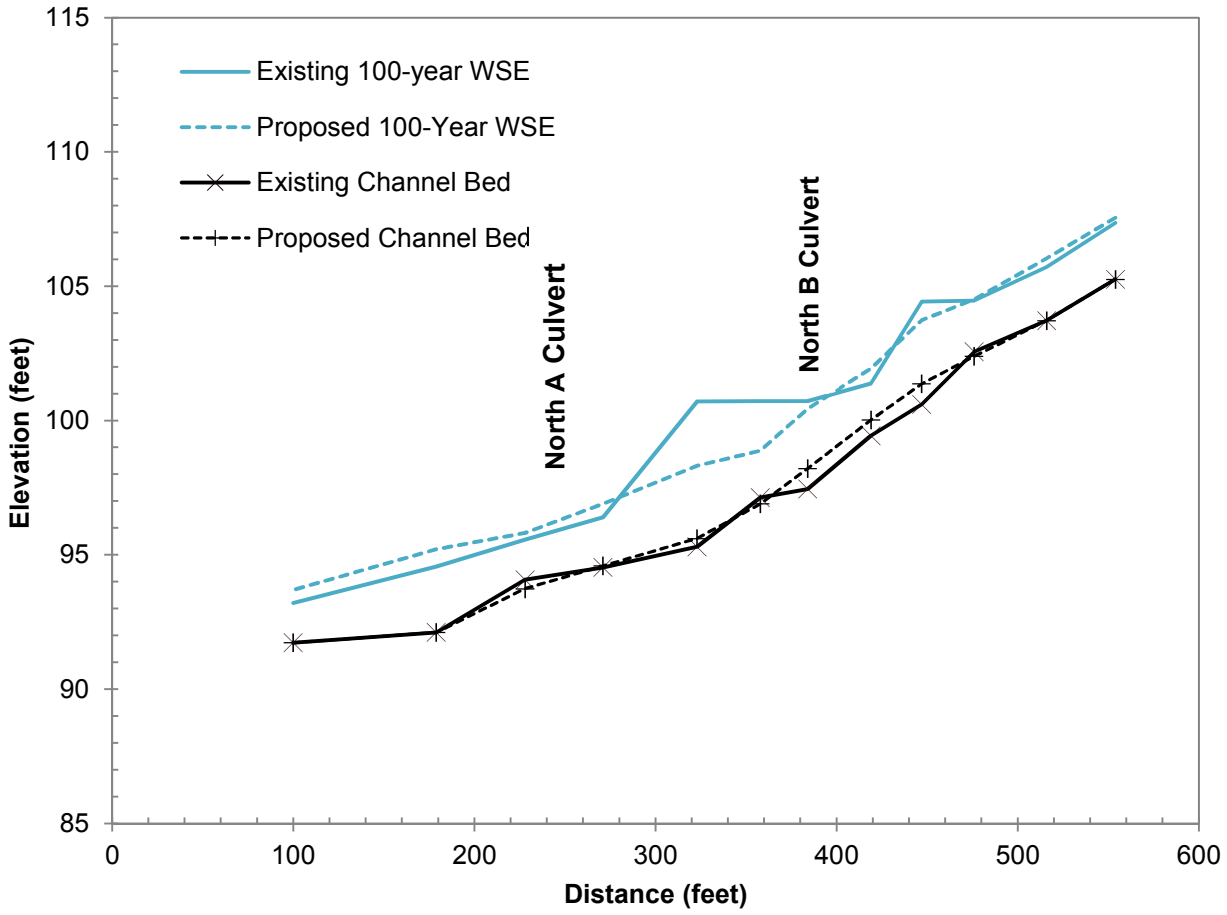
The proposed culverts reduce the backwater effects at the upstream ends of the North A and North B crossings as compared to the existing culverts. The proposed middle culvert eliminates any flow down the roadway ditch which increases the flow coming into the North A and North B culverts. However, the increased conveyance at the proposed North A and North B culverts results in less flow overtopping the creek's berm and leaving the system. The increase in the flows results in higher water surface elevation downstream of the crossings. For the North B culvert, the increased water surface elevation only impacts the immediate downstream cross-section. For North A culvert, the increased water surface elevation extends to the downstream limits of the model. Here the last cross-section in the model is showing a rise of 0.47 ft. Table 4 compares existing and proposed 100-year water surface elevations (WSE). Figure 10 compares computed 100-year water-surface elevations for existing and project conditions. At the upstream face of the North A culvert, the 100-year WSE is 97.89 feet. The low chord of the North A culvert is 99.00 feet and the 100-year freeboard is 1.11 feet. At the upstream face of the North B culvert, the 100-year WSE is 103.22 feet. The low chord of the North B culvert is 104.35 feet and the 100-year freeboard is 1.13 feet.

Table 4—North A and North B Crossing Comparison of 100-Year Water Surface Elevations (WSE)

Cross-Section	Existing Conditions WSE (feet)	Proposed Conditions WSE (feet)	Difference*
554	107.36	107.55	0.19
516	105.71	106.04	0.33
476	104.46	104.51	0.05
447	104.43	103.74	-0.69
North B Culvert			
419	101.38	101.94	0.56
384	100.72	100.43	-0.29
358	100.72	98.88	-1.84
323	100.71	98.32	-2.39
North A Culvert			
271	96.40	96.90	0.50
228	95.56	95.81	0.25
179	94.56	95.20	0.64
100	93.20	93.69	0.49

** Change from existing conditions*

Figure 10—North A and North B Crossings 100-year WSE Profile



Comparison of existing and proposed conditions channel bed and computed 100-year water-surface elevation profile

Section 5 —Scour

Methodology

A scour analysis of the four Manley Creek crossings was performed to determine the depth of the culvert footings and for environmental permitting. The analysis was carried out following the procedures outlined in the Federal Highway Administration (FHWA) document Evaluating Scour at Bridges, 5th Edition (HEC-18, FHWA, 2012). Scour components considered in the analysis include long-term degradation potential and general scour. Local scour was not computed since the culvert footings will be protected with adequately sized riprap (see Section 6 for a discussion of riprap calculations). Scour depths were estimated for the 100- and 500-year peak discharges.

As noted in the field reconnaissance (Section 2) there is little evidence of degradation the vicinity of the culverts. At the North A crossing there is evidence of aggregation. Removal of the culverts could result in potential degradation of the channel. However, at the north and south culverts this is accounted for in the proposed profile grading that results in a uniform slope through the proposed culverts matching the long profile of creek near the crossing (the estimated “equilibrium slope”). Therefore, the long-term degradation potential at these sites is assumed to equal zero. At the middle crossing, potential channel degradation is accounted for in the design though grade control, the cascades, pools, and runs (threshold channel design).

General scour consists of contraction scour, bend scour, planform characteristics (such as braided channels), and bedform passage (generally sand-bed channels). The creek turns right before it enters the middle and North A culverts. The bends are upstream of the culverts so the full bend scour inside the culverts is not expected. Bend scour calculations were not used as the proposed scour protection was designed to mitigate against this scour mechanism. Only contraction scour is reported in the scour calculations.

Results

South Culvert Results

Based on the coarse bed material represented by the pebble count (D_{50} = 24.6 mm) near the south culvert, the HEC-18 critical velocity equation indicates the upstream bed is immobile for both the 100-year and 500-year events, indicating clear-water contraction scour conditions. Using the coarse-gravel bed material, the resulting contraction scour is equal to zero for both flood events. The lack of contraction scour potential is consistent with the fact that the new culvert will be much wider than the existing culvert and there will be little constriction in the channel. Results of the scour calculations are summarized in Table 5. Complete scour calculations are summarized in Appendix E.

Middle Culvert Results

Based on the coarse-gravel bed material represented by the pebble count (D_{50} = 51.4 mm) near the middle culvert, the HEC-18 critical velocity equation indicates the upstream bed on the threshold between mobile and immobile for both the 100-year and 500-year events. Both contraction equations were checked and most conservative result reported. Using the coarse-gravel bed material the resulting contraction scour is 0.2 feet for the 100-year and 500-year flood event. The relatively low contraction scour potential is consistent with the fact that the new culvert will be much wider than the existing culvert and there will be little constriction in the channel. Results of the scour calculations are summarized in Table 5. Complete scour calculations are summarized in Appendix E.

North A and North B Culverts Results

Based on the coarse-gravel bed material represented by the pebble count (D_{50} = 42.2 mm) near the North A culvert, the HEC-18 critical velocity equation indicates the upstream bed is immobile for both the 100-year and 500-year events, indicating clear-water contraction scour conditions. Using the coarse-gravel bed material the resulting contraction scour is equal to 0.1 feet for both flood events. Near the North B culvert, the critical velocity equation indicates the upstream bed material is on the threshold between immobile and mobile and both contraction equations were checked and the most conservative result reported. At the North B culvert the 100-year and 500-year contraction scour was 0.3 feet. The relatively low contraction scour potential is consistent with the fact that the new culverts will be much wider than the existing culverts and there will be little constriction in the channel. Results of the scour calculations are summarized in Table 5. Complete scour calculations are summarized in Appendix E.

Table 5—Scour Depth Results

Culvert Crossing	Type of Scour	100-Year Scour Depth (feet)	500-Year Scour Depth (feet)
South	Clear-water	0.0	0.0
Middle	Live-bed*	0.2	0.2
North A	Clear-water	0.1	0.1
North B	Live-bed*	0.3	0.3

** Both types of contraction scour were checked and the most conservative reported*

Section 6 —Design of Stream Channel and Scour Countermeasure

Channel Design

The proposed channel will have a channel geometry and bed morphology that mimics relatively stable segments of the existing channel outside of the area altered by the stream crossings. In general, the existing channel bottom width is approximately 10 feet wide. The 100-year flow channel width is 20 feet and depth is 2 to 3 feet. The proposed stream cross-section area at the 100-year flow is approximately 40 square feet, which was designed to match the existing cross-section areas. The adjacent existing hillslopes are oversteepened (as steep as 1H:1V) throughout the majority of the reconstructed reach. To improve bank stability, the proposed grading at the toe of the upper hillslopes will have a side slope of 2H:1V or flatter.

Three different bed morphology designs are proposed to facilitate fish passage, enhance instream habitat complexity, improve stability of the bed and banks, and address the variability in the existing stream channel conditions throughout the project: (1) a standard constructed streambed, (2) a roughened constructed streambed, and (3) a cascade/pool constructed streambed.

Standard Constructed Streambed

The standard constructed streambed approach was taken for the North A crossing and south crossing where the existing longitudinal stream slope is less than 2% and the North B crossing where the upstream and downstream channel slopes are the same. The standard constructed streambed will consist of 1-inch to 6-inch streambed cobble and gravel mix.

Roughened Channel Constructed Streambed

The roughened channel approach was used within the middle crossing to provide stability and accommodate fish passage. The slope within the proposed culvert is 6%. The roughened channel constructed streambed will consist of 1-inch to 6-inch cobble and gravel mix, with one-man and two-man habitat boulders randomly placed throughout (approximately 4 per every 100 square feet) to dissipate energy and increase hydraulic diversity.

Cascade/Pool Constructed Streambed

The existing stream upstream and downstream of the middle crossing varies in slope from 4% to 12% with an overall slope of 7.4%. Using the Meyer-Peter & Muller method, an equilibrium bed slope for this stream reach was determined to be approximately 6%. In order to match the existing overall slope of 7.4% while maintaining overall stability, a series of cascades, pools, and runs are proposed.

The design of each cascade structure includes two distinct sections: a boulder crest and the cascade face. The crest of the cascade consists of a collection of larger boulders that serve as grade control and help shape the flow path through the riffle. The crest has a "V-shape" that points slightly upstream and slopes towards a low flow path in the center of the channel. This geometry directs flow away from the bank and helps maintain the shape of the cascade. The crest rock is keyed into the bed and upper banks to reduce the risk of the stream avulsing to a new flow path and/or flanking the structure. The cascade face was designed to be approximately 6-9 feet long, and the cascades for this project were designed to a have a bed gradient of 20-30%, defaulting to shorter, steeper cascade faces that would scour a deeper pool habitat at the base of the cascade face.

Pool excavations are proposed downstream of the cascades in areas where pools are expected to form naturally. These pools are designed to have a deeper water depth than the average channel and have a water surface with very little slope at low flow. The pools will likely shift position slightly in the future as the pool geometry will continuously be shaped by bed scour during high flows. At low flow, the pools will act as a depositional feature, temporarily storing fines, sediments, and organic matter. The depth and slope increases over the pools during larger flow events, increasing shear stress, and initiating scour that mobilizes fine materials.

Each cascade/pool feature is connected by a 30 to 46 foot long run. The runs were designed with streambed material similar to the native substrate. The streambed material proposed for the runs is the same 1-inch to 6-inch cobbles with gravel mix proposed for the standard constructed streambed. The runs will have a longitudinal bed slope close to the equilibrium bed slope so they are expected to remain stable. The proposed slope for the runs varies from 4-6%. The available sediment supply is expected to replenish the substrate that will be periodically transported out of the runs. Fine sediments will either deposit along the channel margins or will be able to pass through the stream as wash load.

Riprap Design

An analysis of the proposed culvert foundations was performed to assist with their design and to determine the required diameter of riprap to be placed. The analysis was carried out using the modified Isbash Relationship as outlined in the Federal Highway Administration document "Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance-Third Edition" (FHWA, 2009). The highest velocity at the culvert cross-section, the thickness of the riprap layer, and an applied factor of safety were used to determine the D_{50} necessary to ensure placed riprap remains stable. The D_{50} was determined for the 100- and 500-year flows and the larger of the two was used. Table 6 summarizes the D_{50} riprap size was determined for each crossing.

Table 6—Riprap Summary

Culvert Crossing	Calculated D_{50} (feet)
South	0.6
Middle	0.7
North A	0.7
North B	0.7

The closest Washington State Department of Transportation (WSDOT) standard specification for riprap is Class A, with a D_{50} of 1 foot. This project is proposing the use of Class B, which has a D_{50} of 1.83 feet, to be used throughout the project. The larger rock size increases the factor of safety as a scour countermeasure.

Section 7 —Temporary Water Management

All in-water work for this project will occur during the in-water work period from July 1 through September 1. Each of the crossings has a specific temporary water management plan that are shown in detail in Appendix C. However, the temporary water management approach at each of the crossings is the same. For the temporary water management, the work area will be isolated by diverting creek flows with a pump-around or gravity system and sandbags. When the culvert is removed, a bypass and sandbag coffer dam will be placed to direct the flow of Manley Creek to the downstream location shown on the permit plans. The bypass pipe at each crossing was sized to divert a minimum flow rate of 25 cubic-feet-per second (approximately half of the 2-year peak flow) and dewatering of the work areas shall occur at a rate slow enough to allow for safe capture and relocation of the fish species and other aquatic organisms to avoid stranding. A mesh screen will be installed at the pipe or pump inlet for fish protection.

Section 8 —References

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U.S. Army Corps of Engineers, 1994. Hydraulic Design of Flood Control Channels, EM 1110-2-1601, July 1991 with changes in June, 1994.

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Appendix A

Field Reconnaissance Photo Log

NE Manley Road Improvement Project
Hydraulic Report Photo Log

Photo 1 - Downstream of North A culvert

Photo 2 - North A culvert outlet

Photo 3 - North A culvert inlet

Photo 4 - Upstream of North A culvert

Photo 5 - North B culvert outlet

Photo 6 - North B culvert inlet

Photo 7 - Middle culvert upstream

Photo 8 - Middle culvert inlet

Photo 9 - Downstream middle culvert

Photo 10 - Middle culvert outlet

Photo 11 - Upstream of south culvert

Photo 12 - South culvert inlet

Photo 13 - Inside of south culvert

Photo 14 - South culvert outlet

Photo 15- Downstream of south culvert

Appendix B

Hydrologic Analysis

Flood Q Regression Tool. Use to estimate flood discharge in Washington State at ungaged sites

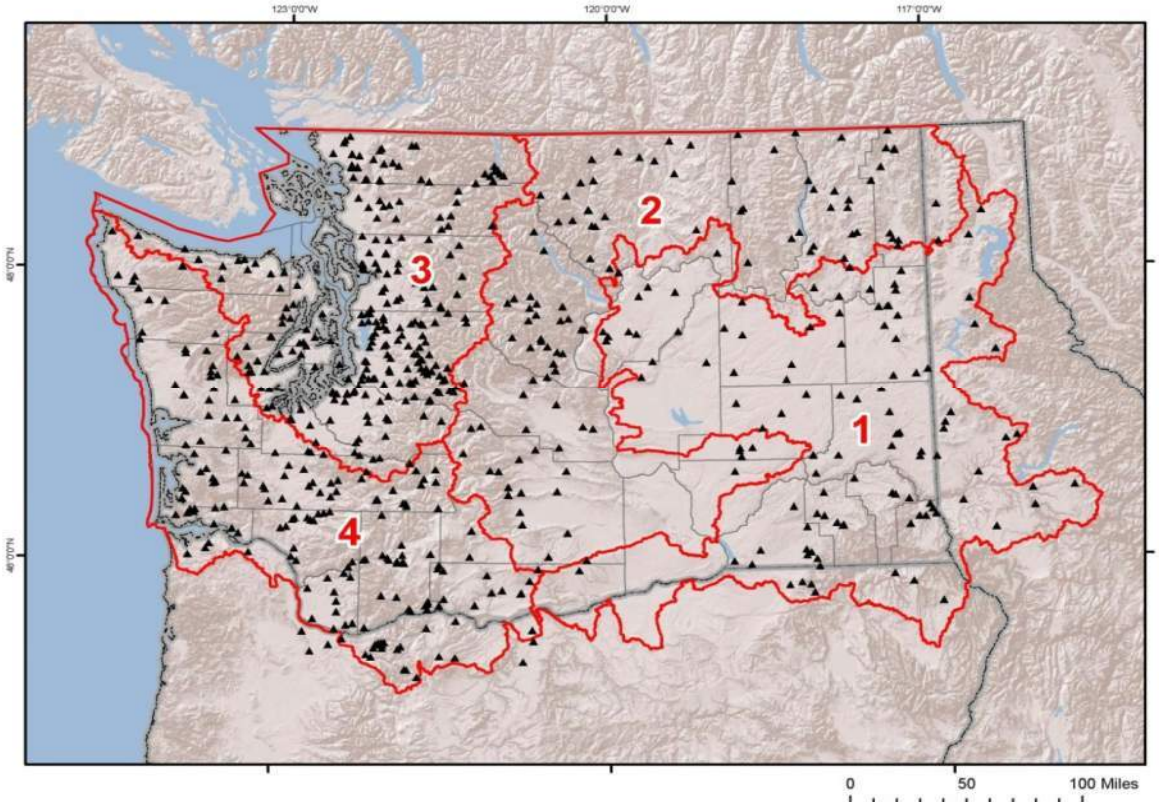
DA = Drainage Area, in square miles; P = Average Basin Annual Precipitation, in inches (from PRISM data set, years 1981-2010); CAN
Annual Exceedance Probability; Qu = Flood Discharge, in cubic feet per second at ungaged site for the indicated AEP;
Predition Intervals (L=Lower and U=Upper)

Instructions for using the Flood Q Tool to estimate Flood Discharges at Ungaged Sites using the regional regression equations

Steps	Instructions
1	Select the Regression Region below from the List Box
2	Determine the drainage area, *DA* and the Annual Precipitation, *P* for the ungage drainage basin. If you pick Regression Region 1 or 2, determine the percent canopy cover, *CAN*.
3	Enter these basin characteristic values in the green-shade cells. If the cell changes to red, than the value is outside the range of valid values for this regression. Valid value range listed to the right of the green cells.
4	Rows 23-30 will have the results. Estimated flood discharge, Qu, will be found in column O and the 90% prediction limits for these flood discharges will be found in columns R and T.

Regression Region 1
Regression Region 2
Regression Region 3
Regression Region 4

Regression Regions in Washington State



based on regional regression equations and user-determined basin characteristics.

ٰ = Percent canopy cover (NLCD 2001); AEP =

$_L$, PI_U=

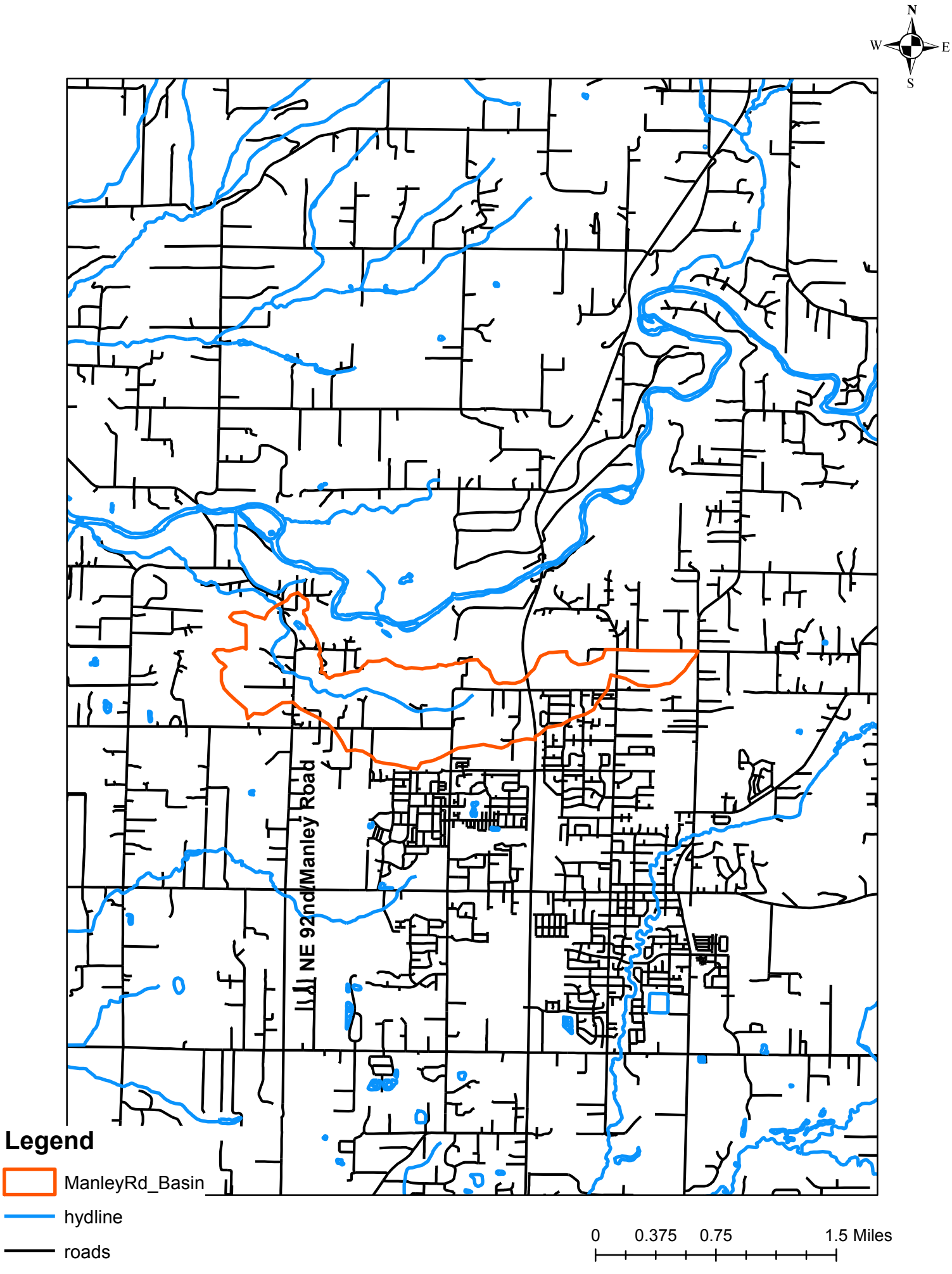
User determined basin characteristics for ungaged site				
Selected Region:	Regression Region 4			Range of values that are valid for the regression
Drainage Area, *DA*	=	1.28	square miles	0.18 - 2230
Annual Precipitation, *P*	=	59.90	inches	11.94 - 186.6
Percent Canopy, *CAN*	=	30	%	value not used in regression

Selected Region: Regression Region 4

Estimate of indicated flood discharge for Regression Region 4 using regional regression equations

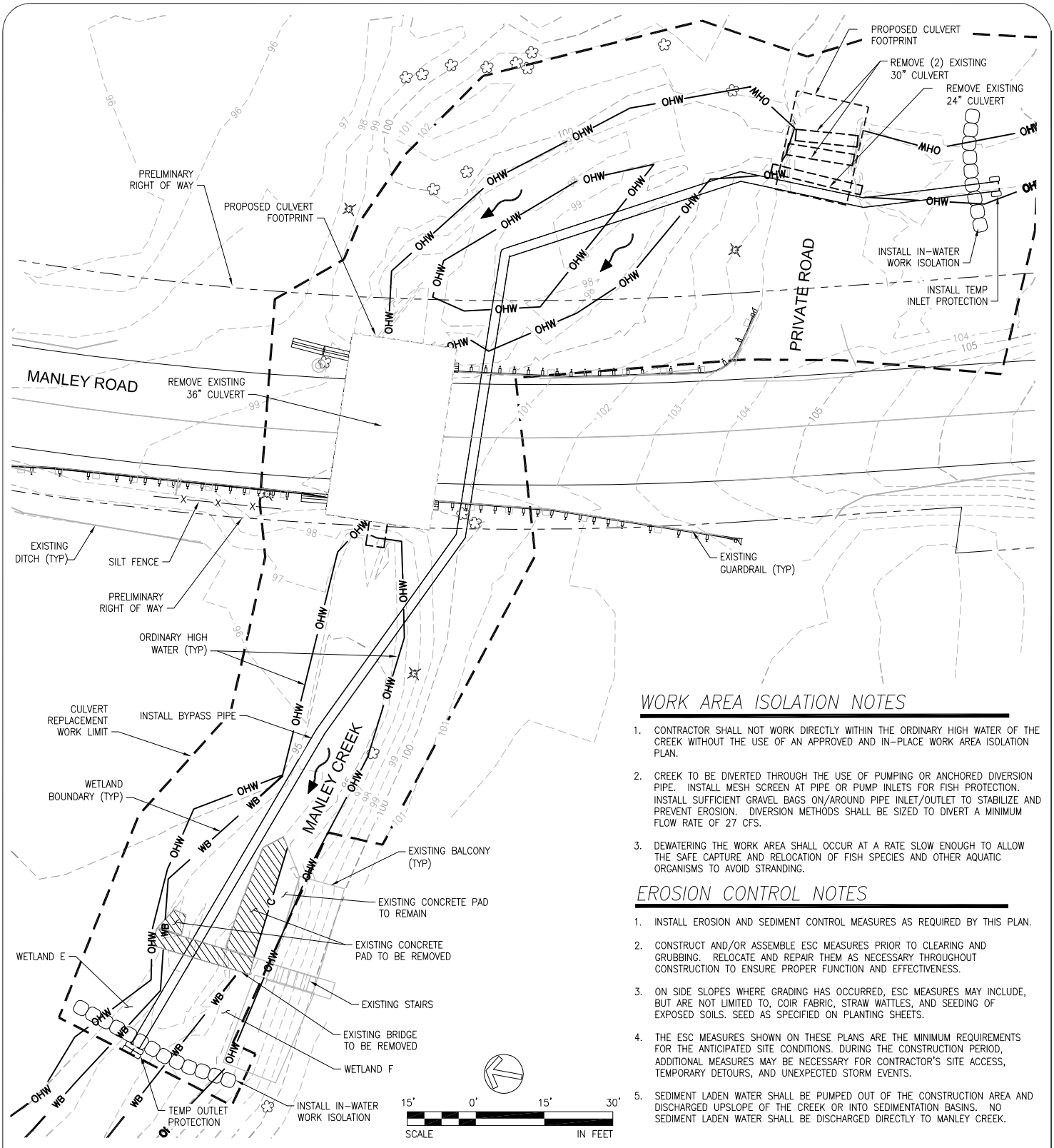
AEP		*Q_u, ft^3/s	Prediction Intervals, 90% confidence level PI_L, in ft^3/s	PI_U, in ft^3/s
0.5	=	52.6	13.5	204.9
0.2	=	85.4	22.5	324.7
0.1	=	111	28.8	427.2
0.04	=	144	35.5	584.0
0.02	=	171	40.3	726.1
0.01	=	199	44.8	883.4
0.005	=	225	48.5	1043.2
0.002	=	266	53.4	1325.4

*rounded to 3 significant figures


N
W
E
S
NE 92nd/Manley Road
Legend
ManleyRd_Basin
hydline
roads
0
0.375
0.75
1.5 Miles

Appendix C

Proposed Culvert Plans



WORK AREA ISOLATION NOTES

1. CONTRACTOR SHALL NOT WORK DIRECTLY WITHIN THE ORDINARY HIGH WATER OF THE CREEK WITHOUT THE USE OF AN APPROVED AND IN-PLACE WORK AREA ISOLATION PLAN.
2. CREEK TO BE DIVERTED THROUGH THE USE OF PUMPING OR ANCHORED DIVERSION PIPE. INSTALL MESH SCREEN AT PIPE OR PUMP INLETS FOR FISH PROTECTION. INSTALL SUFFICIENT GRAVEL BAGS ON/AROUND PIPE INLET/OUTLET TO STABILIZE AND PREVENT EROSION. DIVERSION METHODS SHALL BE SIZED TO DIVERT A MINIMUM FLOW RATE OF 27 CFS.
3. DEWATERING THE WORK AREA SHALL OCCUR AT A RATE SLOW ENOUGH TO ALLOW THE SAFE CAPTURE AND RELOCATION OF FISH SPECIES AND OTHER AQUATIC ORGANISMS TO AVOID STRANDING.

EROSION CONTROL NOTES

1. INSTALL EROSION AND SEDIMENT CONTROL MEASURES AS REQUIRED BY THIS PLAN.
2. CONSTRUCT AND/OR ASSEMBLE ESC MEASURES PRIOR TO CLEARING AND GRUBBING. RELOCATE AND REPAIR THEM AS NECESSARY THROUGHOUT CONSTRUCTION TO ENSURE PROPER FUNCTION AND EFFECTIVENESS.
3. ON SIDE SLOPES WHERE GRADING HAS OCCURRED, ESC MEASURES MAY INCLUDE, BUT ARE NOT LIMITED TO, COIR FABRIC, STRAW WATTLES, AND SEEDING OF EXPOSED SOILS. SEED AS SPECIFIED ON PLANTING SHEETS.
4. THE ESC MEASURES SHOWN ON THESE PLANS ARE THE MINIMUM REQUIREMENTS FOR THE ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, ADDITIONAL MEASURES MAY BE NECESSARY FOR CONTRACTOR'S SITE ACCESS, TEMPORARY DETOURS, AND UNEXPECTED STORM EVENTS.
5. SEDIMENT LADEN WATER SHALL BE PUMPED OUT OF THE CONSTRUCTION AREA AND DISCHARGED UPSLOPE OF THE CREEK OR INTO SEDIMENTATION BASINS. NO SEDIMENT LADEN WATER SHALL BE DISCHARGED DIRECTLY TO MANLEY CREEK.

NORTH CULVERTS-EXISTING CONDITION AND EROSION CONTROL

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*
NEAR: *BATTLE GROUND*
COUNTY: *CLARK* ***STATE:*** *WA*

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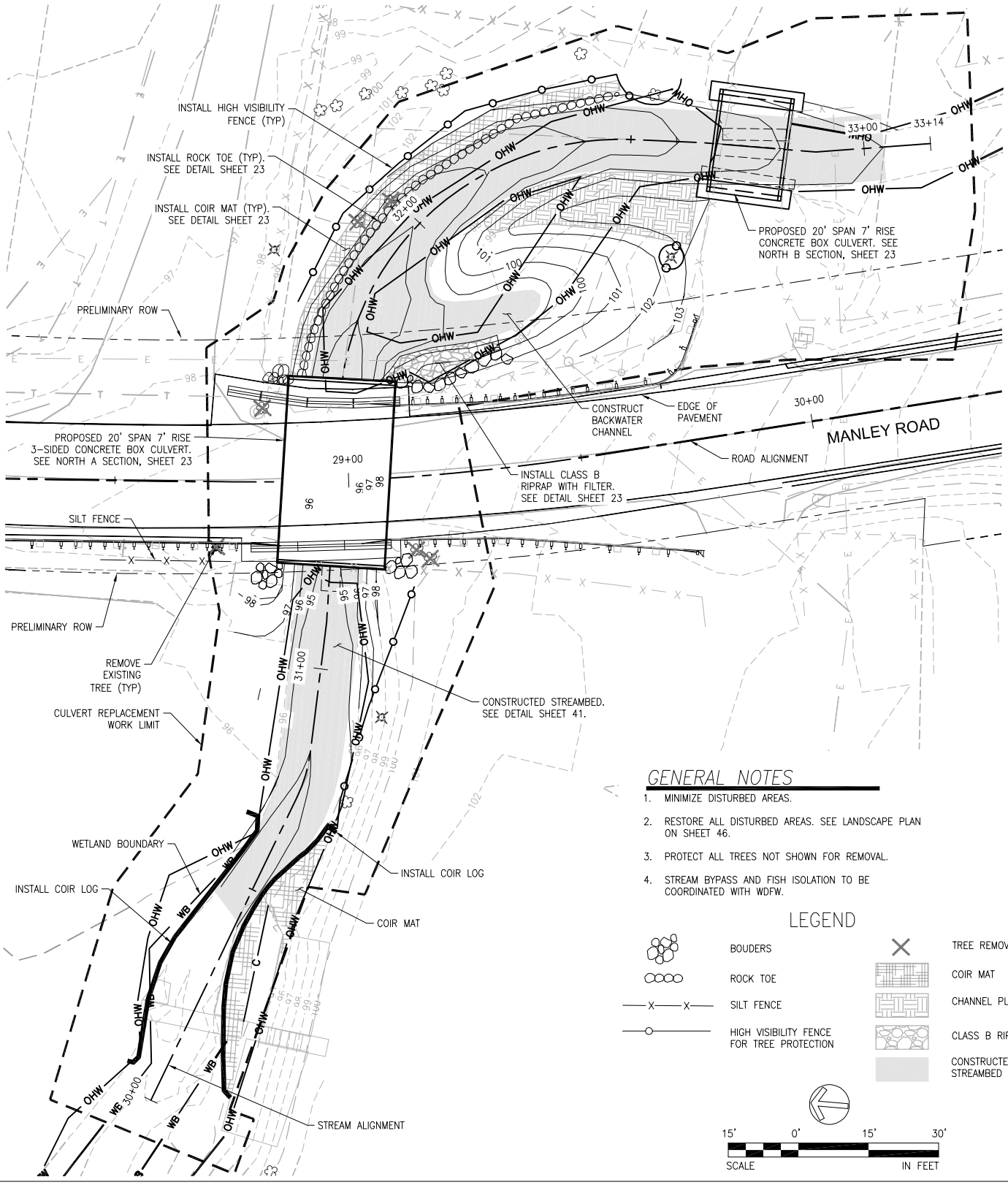

GENERAL NOTES

1. MINIMIZE DISTURBED AREAS.
2. RESTORE ALL DISTURBED AREAS. SEE LANDSCAPE PLAN ON SHEET 46.
3. PROTECT ALL TREES NOT SHOWN FOR REMOVAL.
4. STREAM BYPASS AND FISH ISOLATION TO BE COORDINATED WITH WDFW.

LEGEND

- BOUDERS
- ROCK TOE
- SILT FENCE
- HIGH VISIBILITY FENCE FOR TREE PROTECTION
- TREE REMOVAL
- COIR MAT
- CHANNEL PLUG
- CLASS B RIPRAP
- CONSTRUCTED STREAMBED

SCALE 15' 0' 15' 30' IN FEET

NORTH CULVERTS-SITE PLAN

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
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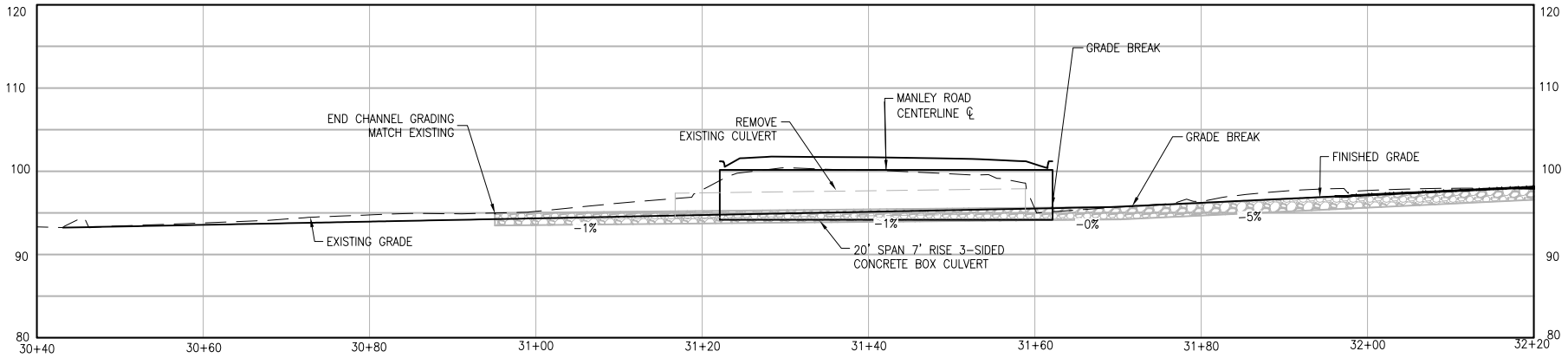

NORTH A CULVERT PROFILE

STAT: 30+40 TO 32+20
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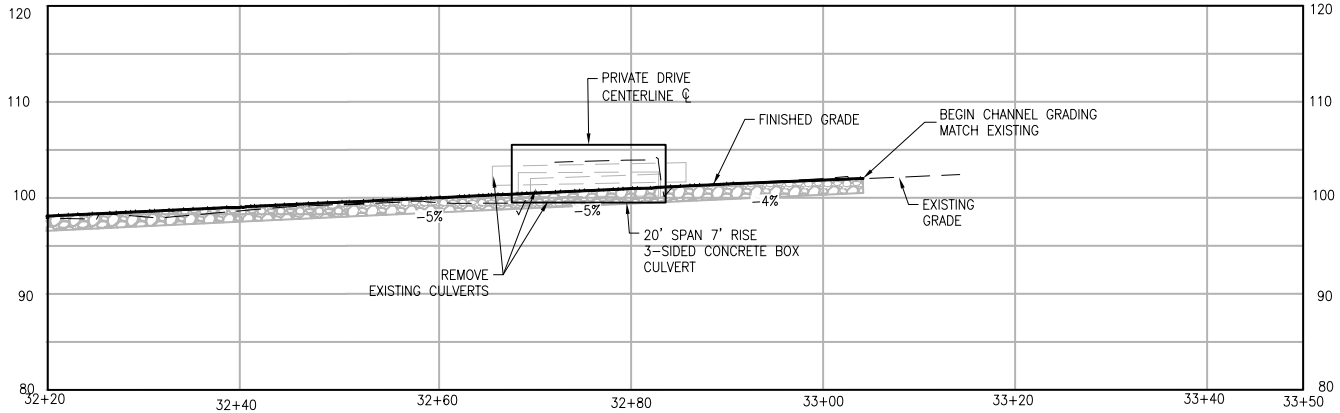
VERTI. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)



NORTH B CULVERT PROFILE

STAT.: 32+20 TO 33+50
HORIZ. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)
VERTI. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)

NORTH CULVERTS-STREAM PROFILE

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

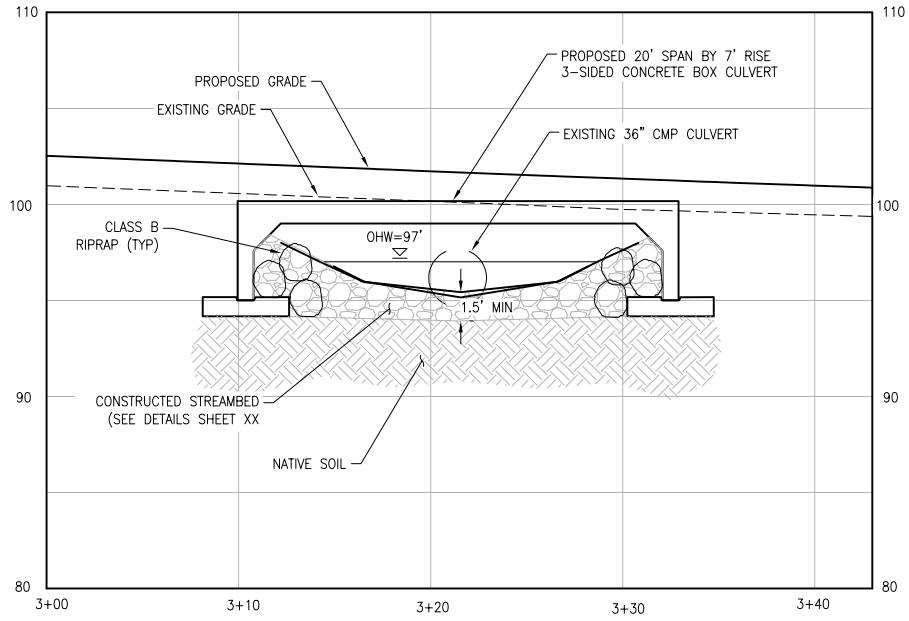
SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*



1/23 NORTH A CULVERT SECTION

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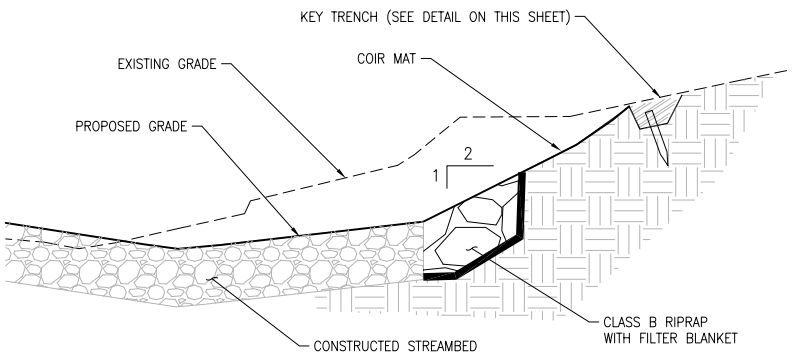

2/23 COIR AND ROCK TOE TREATMENT DETAIL

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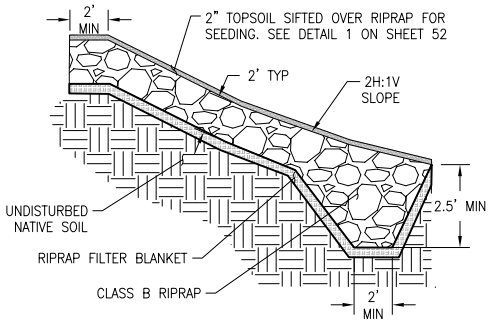

3/23 RIPRAP DETAIL

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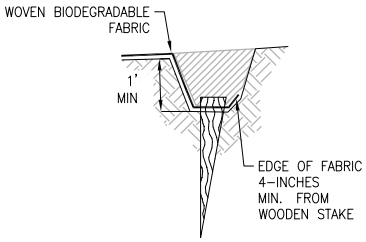
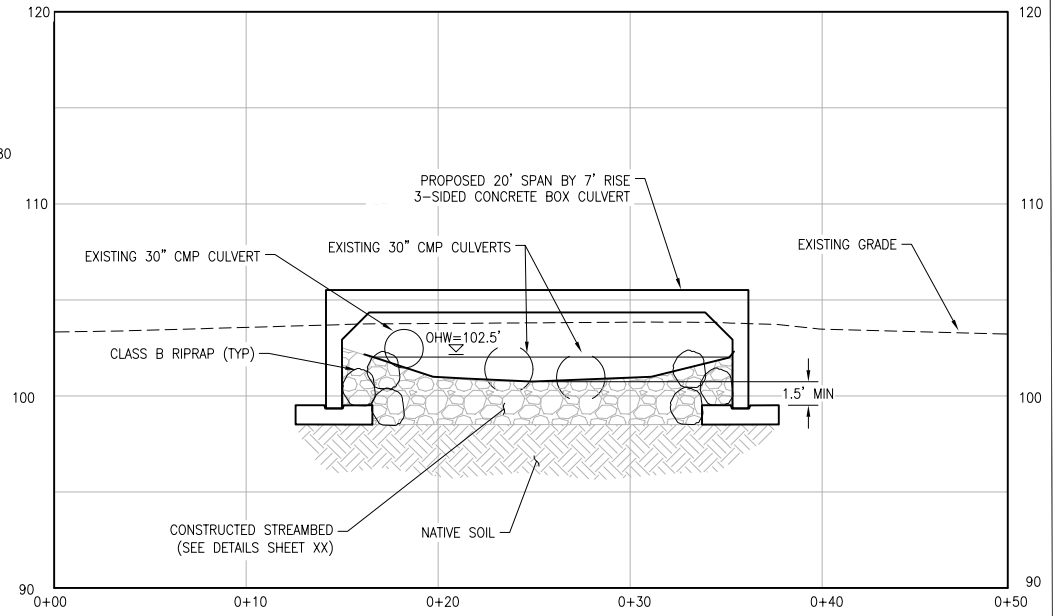


NOTES:
1. STAKE FABRIC TO BOTTOM OF KEY TRENCH, 1 STAKE PER 3 L.F.
2. FILL KEY TRENCH WITH TOPSOIL AND COMPACT. WHEN USED AT TOE, REPLACE TOPSOIL WITH STREAMBED GRAVEL

4/23 KEY TRENCH DETAIL

SCALE: N.T.S.



5/23 NORTH B CULVERT SECTION

SCALE: N.T.S.

NORTH CULVERTS- SECTION + DETAIL

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*

EROSION CONTROL NOTES

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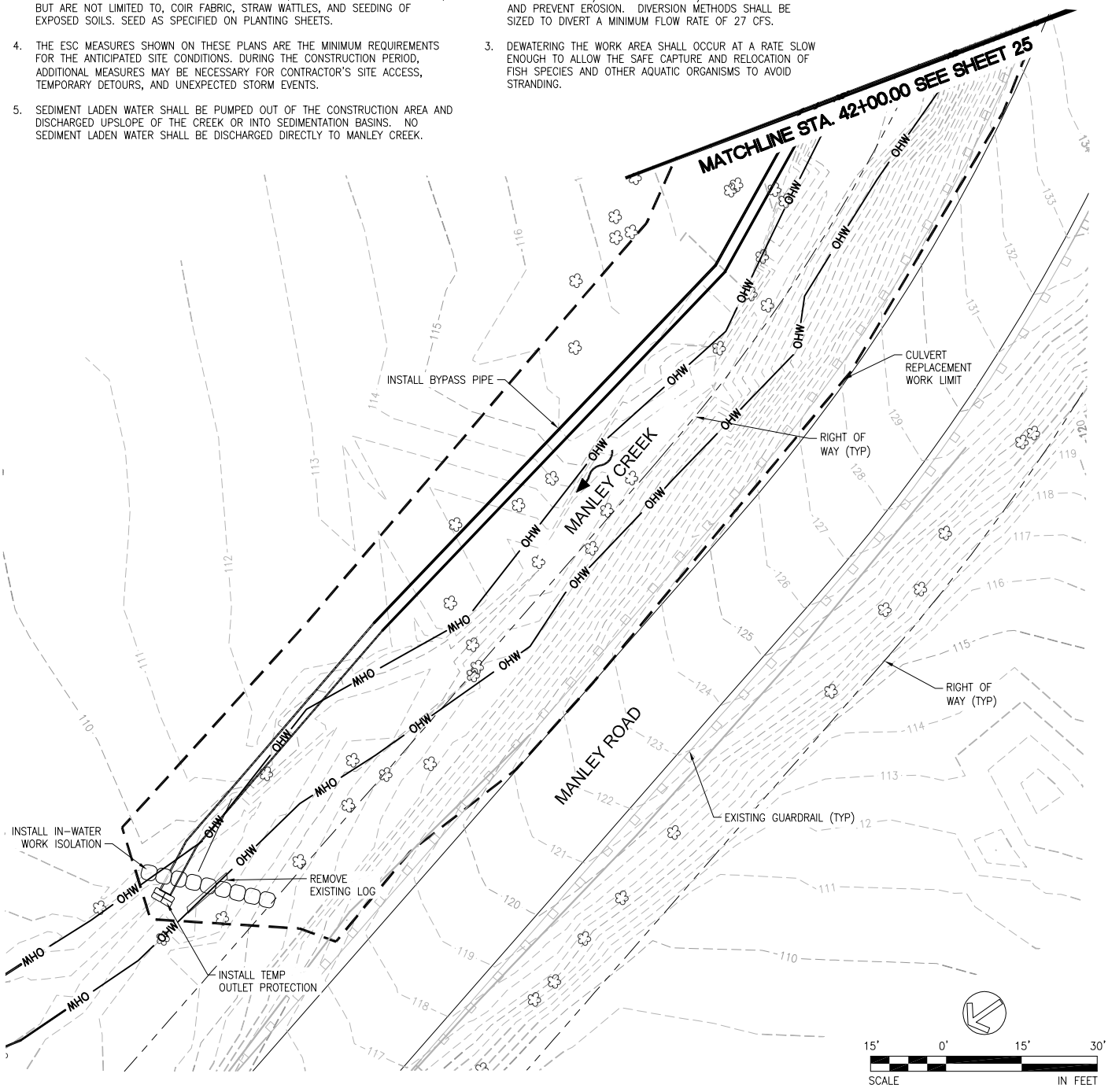
WORK AREA ISOLATION NOTES

1. CONTRACTOR SHALL NOT WORK DIRECTLY WITHIN THE ORDINARY HIGH WATER OF THE CREEK WITHOUT THE USE OF AN APPROVED AND IN-PLACE WORK AREA ISOLATION PLAN.
2. CREEK TO BE DIVERTED THROUGH THE USE OF PUMPING OR ANCHORED DIVERSION PIPE. INSTALL MESH SCREEN AT PIPE OR PUMP INLETS FOR FISH PROTECTION. INSTALL SUFFICIENT GRAVEL BAGS ON/AROUND PIPE INLET/OUTLET TO STABILIZE AND PREVENT EROSION. DIVERSION METHODS SHALL BE SIZED TO DIVERT A MINIMUM FLOW RATE OF 27 CFS.
3. DEWATERING THE WORK AREA SHALL OCCUR AT A RATE SLOW ENOUGH TO ALLOW THE SAFE CAPTURE AND RELOCATION OF FISH SPECIES AND OTHER AQUATIC ORGANISMS TO AVOID STRANDING.



MIDDLE CULVERT 1 - EXISTING CONDITION AND EROSION CONTROL

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*
NEAR: *BATTLE GROUND*
COUNTY: *CLARK* ***STATE:*** *WA*

Apr 20, 2018 - 3:18pm
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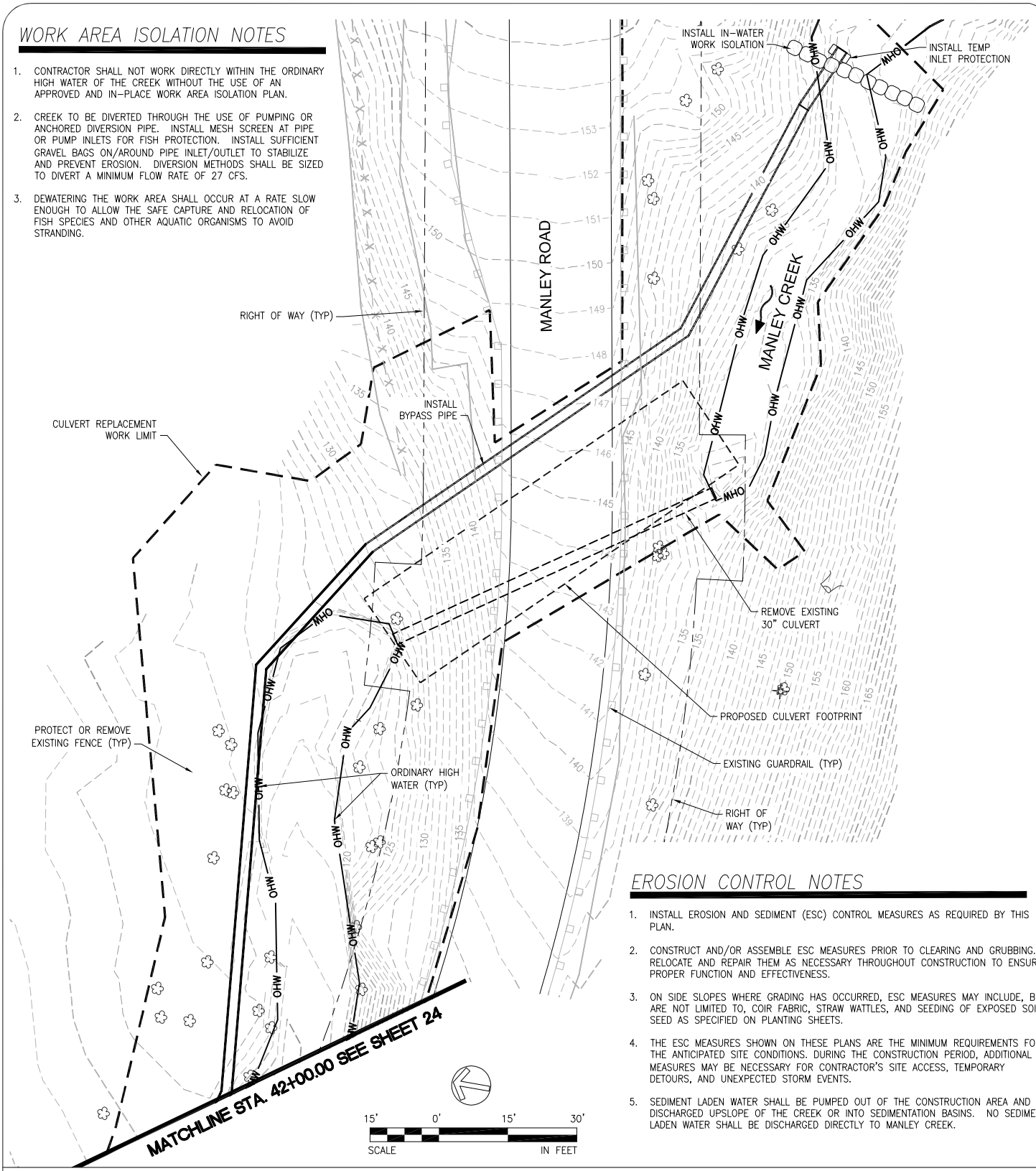
WORK AREA ISOLATION NOTES

1. CONTRACTOR SHALL NOT WORK DIRECTLY WITHIN THE ORDINARY HIGH WATER OF THE CREEK WITHOUT THE USE OF AN APPROVED AND IN-PLACE WORK AREA ISOLATION PLAN.
2. CREEK TO BE DIVERTED THROUGH THE USE OF PUMPING OR ANCHORED DIVERSION PIPE. INSTALL MESH SCREEN AT PIPE OR PUMP INLETS FOR FISH PROTECTION. INSTALL SUFFICIENT GRAVEL BAGS ON/AROUND PIPE INLET/OUTLET TO STABILIZE AND PREVENT EROSION. DIVERSION METHODS SHALL BE SIZED TO DIVERT A MINIMUM FLOW RATE OF 27 CFS.
3. DEWATERING THE WORK AREA SHALL OCCUR AT A RATE SLOW ENOUGH TO ALLOW THE SAFE CAPTURE AND RELOCATION OF FISH SPECIES AND OTHER AQUATIC ORGANISMS TO AVOID STRANDING.



EROSION CONTROL NOTES

1. INSTALL EROSION AND SEDIMENT (ESC) CONTROL MEASURES AS REQUIRED BY THIS PLAN.
2. CONSTRUCT AND/OR ASSEMBLE ESC MEASURES PRIOR TO CLEARING AND GRUBBING. RELOCATE AND REPAIR THEM AS NECESSARY THROUGHOUT CONSTRUCTION TO ENSURE PROPER FUNCTION AND EFFECTIVENESS.
3. ON SIDE SLOPES WHERE GRADING HAS OCCURRED, ESC MEASURES MAY INCLUDE, BUT ARE NOT LIMITED TO, COIR FABRIC, STRAW WATTLES, AND SEEDING OF EXPOSED SOILS. SEED AS SPECIFIED ON PLANTING SHEETS.
4. THE ESC MEASURES SHOWN ON THESE PLANS ARE THE MINIMUM REQUIREMENTS FOR THE ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, ADDITIONAL MEASURES MAY BE NECESSARY FOR CONTRACTOR'S SITE ACCESS, TEMPORARY DETOURS, AND UNEXPECTED STORM EVENTS.
5. SEDIMENT LADEN WATER SHALL BE PUMPED OUT OF THE CONSTRUCTION AREA AND DISCHARGED UPSLOPE OF THE CREEK OR INTO SEDIMENTATION BASINS. NO SEDIMENT LADEN WATER SHALL BE DISCHARGED DIRECTLY TO MANLEY CREEK.

MIDDLE CULVERT 2 - EXISTING CONDITION AND EROSION CONTROL

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

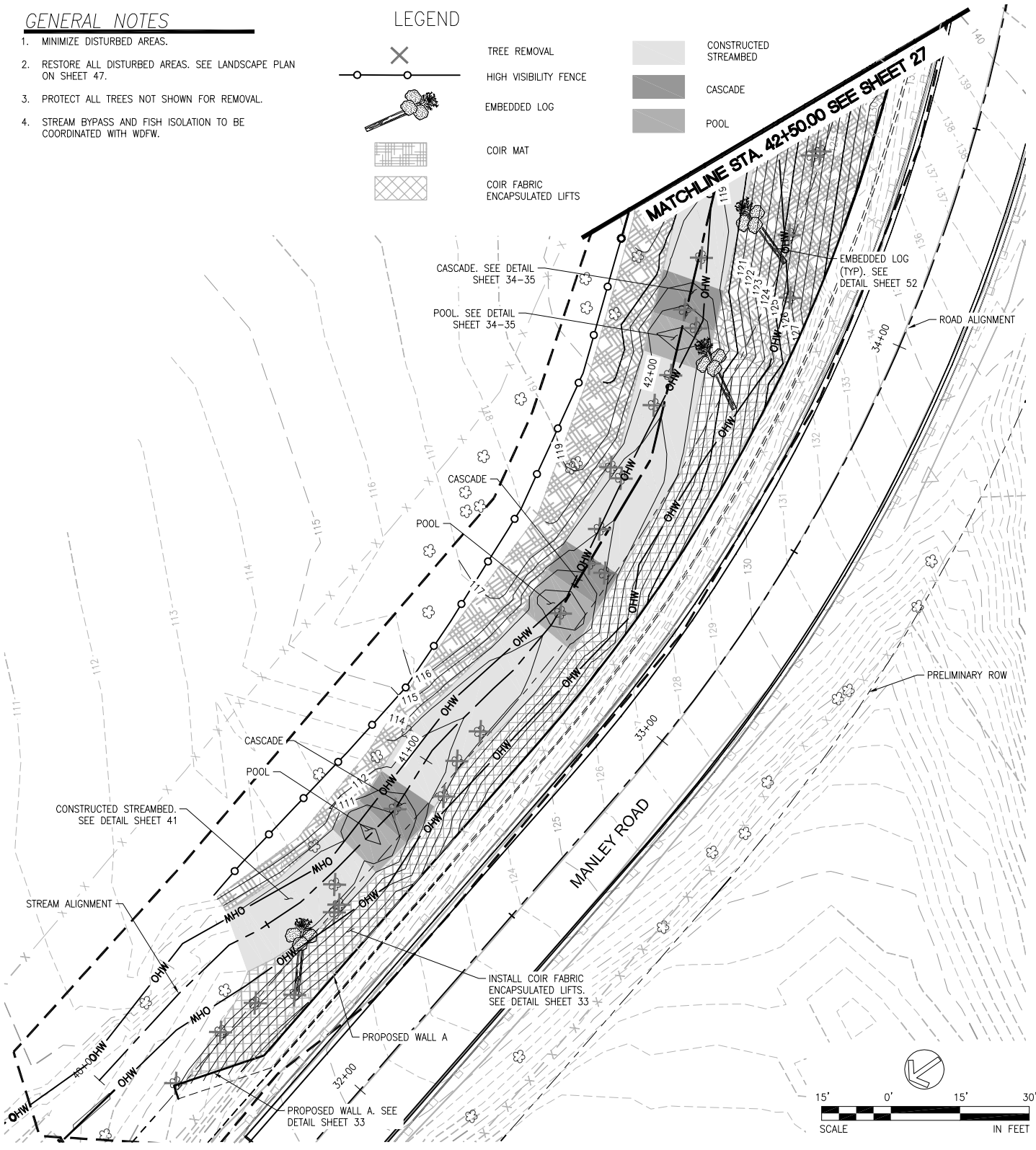
WATER BODY: *MANLEY CREEK*
NEAR: *BATTLE GROUND*
COUNTY: *CLARK* ***STATE:*** *WA*

GENERAL NOTES

1. MINIMIZE DISTURBED AREAS.
2. RESTORE ALL DISTURBED AREAS. SEE LANDSCAPE PLAN ON SHEET 47.
3. PROTECT ALL TREES NOT SHOWN FOR REMOVAL.
4. STREAM BYPASS AND FISH ISOLATION TO BE COORDINATED WITH WDFW.

LEGEND

TREE REMOVAL
HIGH VISIBILITY FENCE
EMBEDDED LOG
COIR MAT
COIR FABRIC ENCAPSULATED LIFTS
CONSTRUCTED STREAMBED
CASCADE
POOL



MIDDLE CULVERT 1 - SITE PLAN

DATE: FEBRUARY 2018

HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: 45.8067/122.5814

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: MANLEY CREEK
NEAR: BATTLE GROUND
COUNTY: CLARK ***STATE:*** WA

Apr 20, 2018 - 3:18pm
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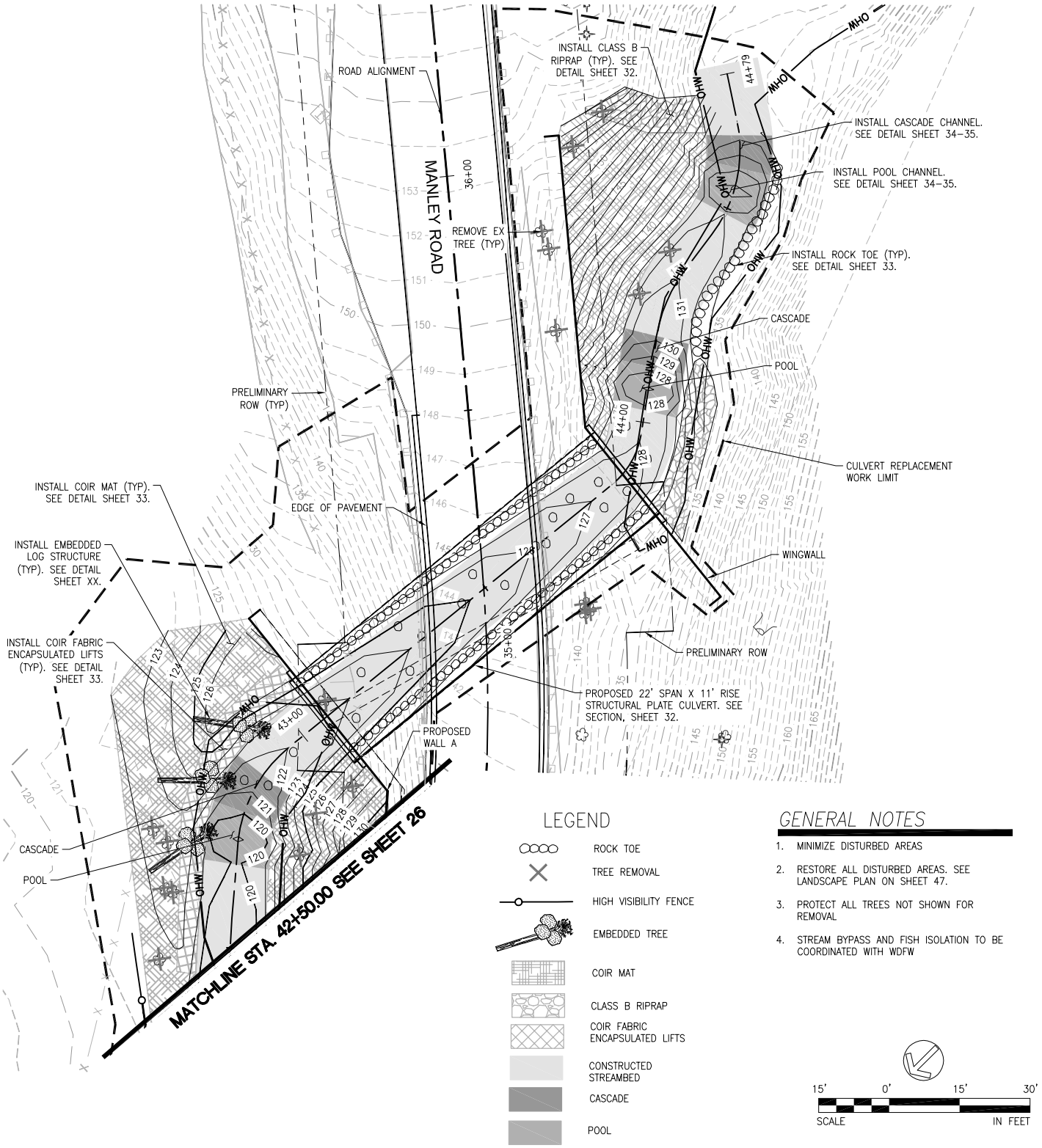

MIDDLE CULVERT 2 – SITE PLAN

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

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Apr 20, 2018 – 3:19pm
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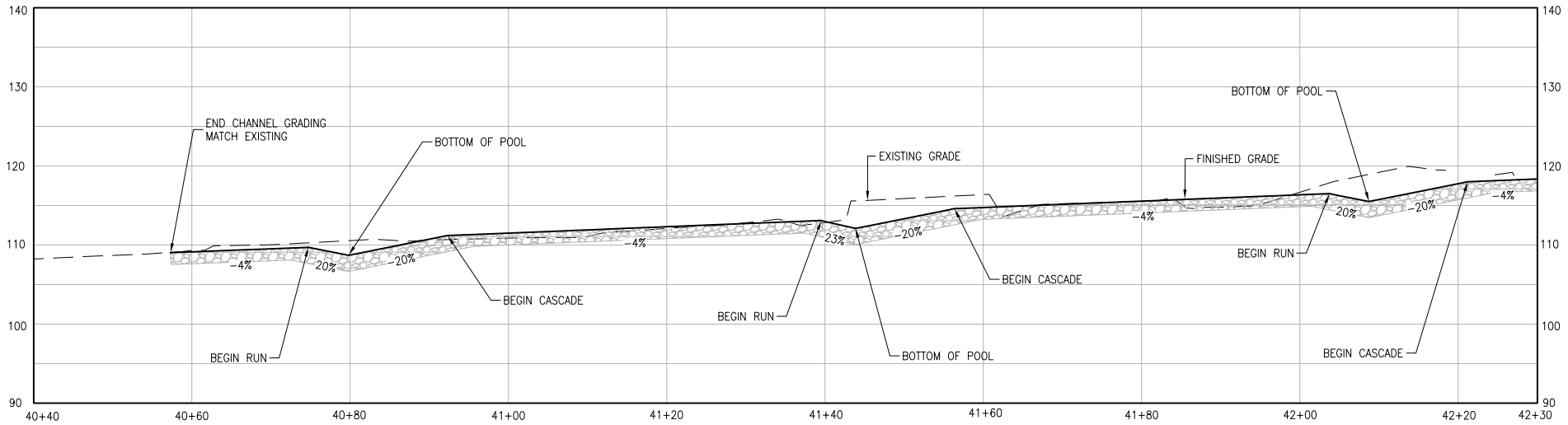


PROPOSED MIDDLE CULVERT PROFILE
(WALL SECTION)

STAT.: 40+40 TO 42+30
HORIZ. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)
VERTI. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)

MIDDLE CULVERT 1 - STREAM PROFILE

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

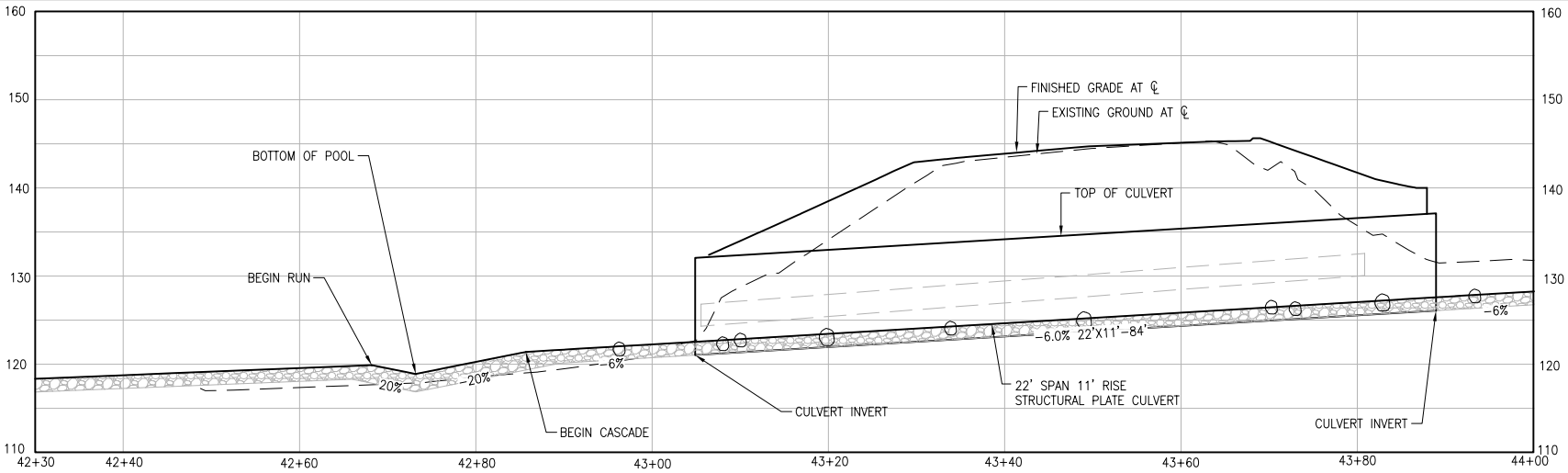
SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

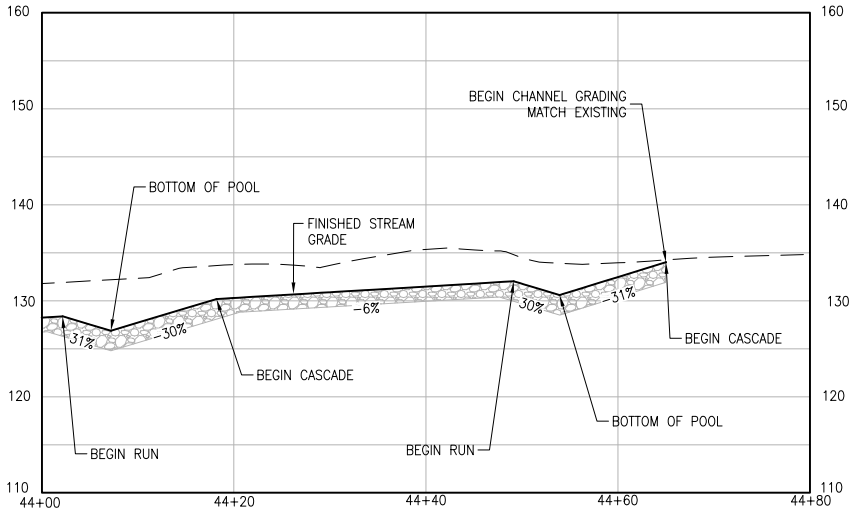
PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*





PROPOSED MIDDLE CULVERT PROFILE

STAT.: 42+30 TO 44+80
HORIZ. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)
VERTI. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)

MIDDLE CULVERT 2 - STREAM PROFILE

DATE: FEBRUARY 2018

HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

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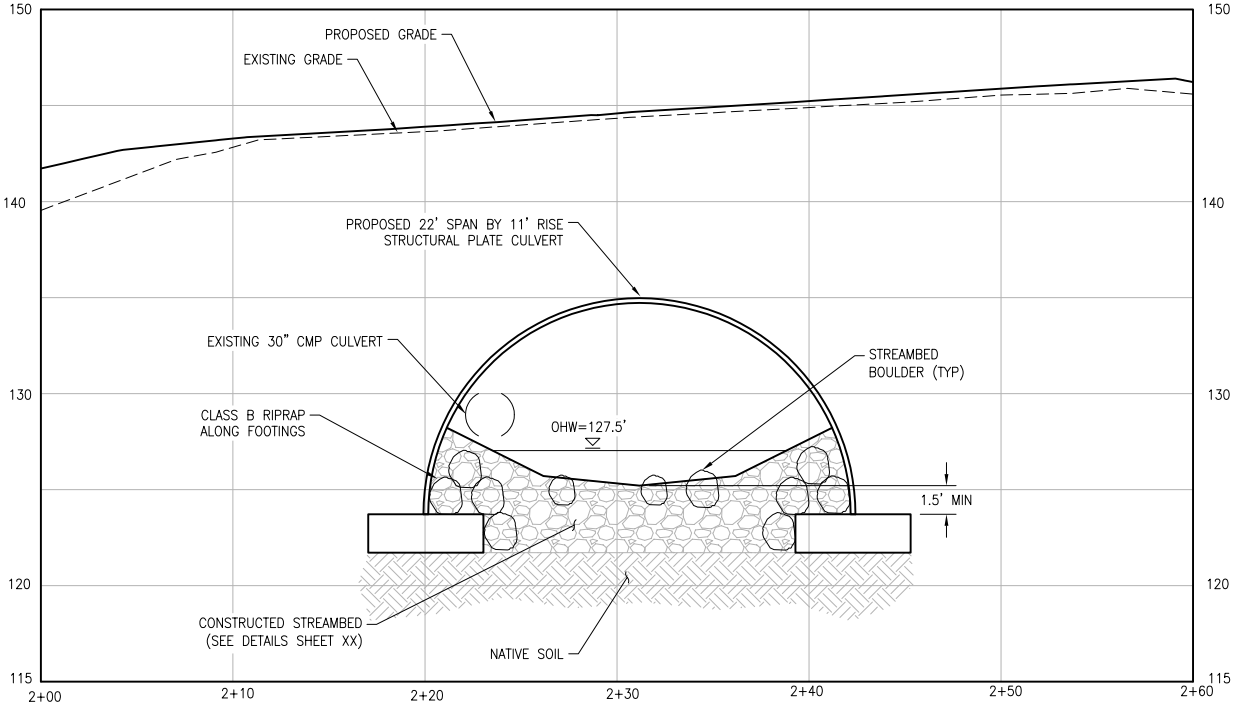
NE MANLEY ROAD IMPROVEMENT PROJECT

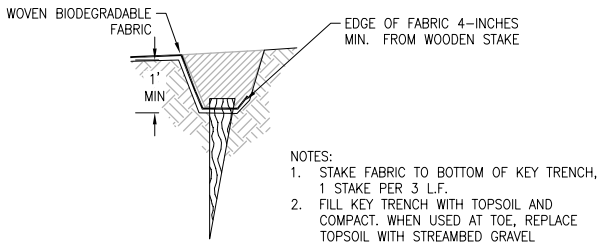
WATER BODY: *MANLEY CREEK*

NEAR: *BATTLE GROUND*

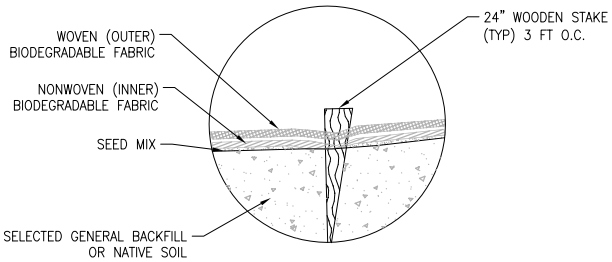
COUNTY: *CLARK* ***STATE:*** *WA*



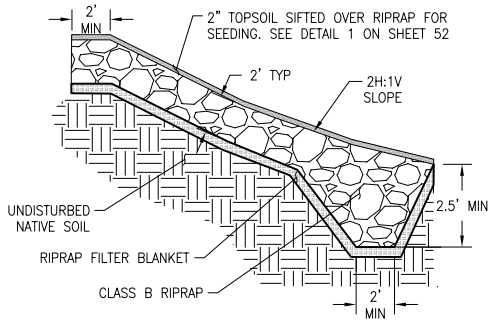
1/32 MIDDLE CULVERT SECTION
SCALE: N.T.S.



2/32 KEY TRENCH DETAIL
SCALE: N.T.S.



3/32 FABRICS AND STAKE DETAIL
SCALE: N.T.S.



4/32 RIPRAP DETAIL
SCALE: N.T.S.

MIDDLE CULVERT - CROSS SECTION + DETAILS

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

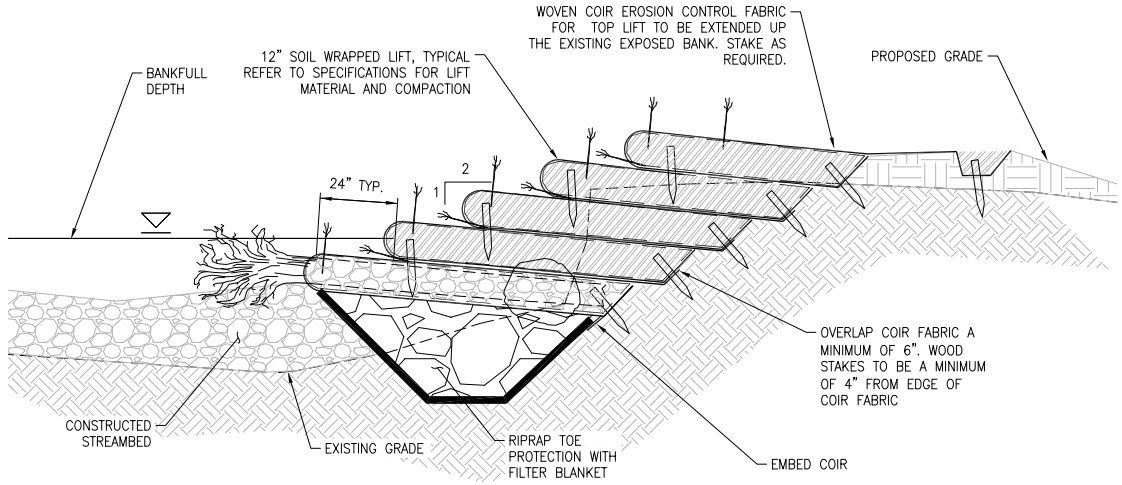
SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

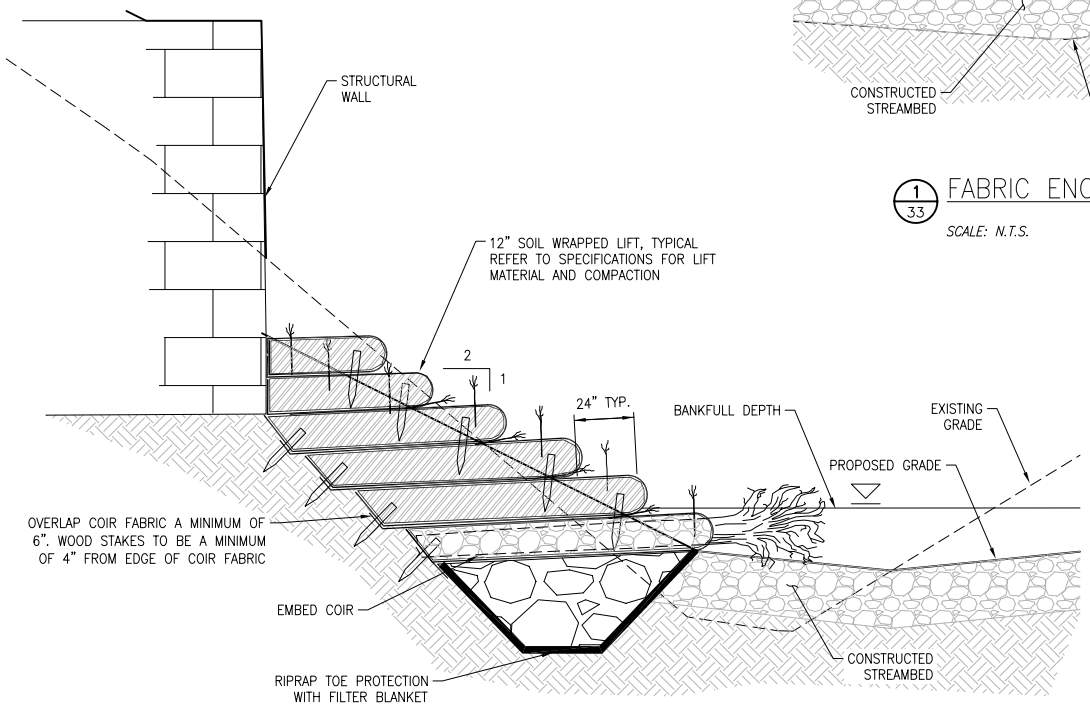
NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*



1/33 FABRIC ENCAPSULATED SOIL LIFTS AND ROCK TOE TREATMENT DETAIL

SCALE: N.T.S.



2/33 FABRIC ENCAPSULATED SOIL LIFTS AND WALL TREATMENT DETAIL

SCALE: N.T.S.

MIDDLE CULVERT - DETAILS

DATE: FEBRUARY 2018

HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

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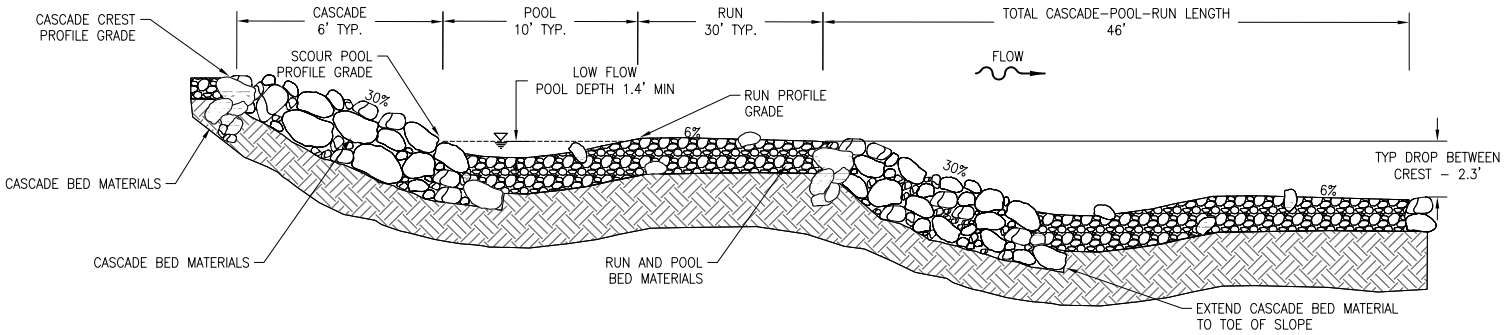
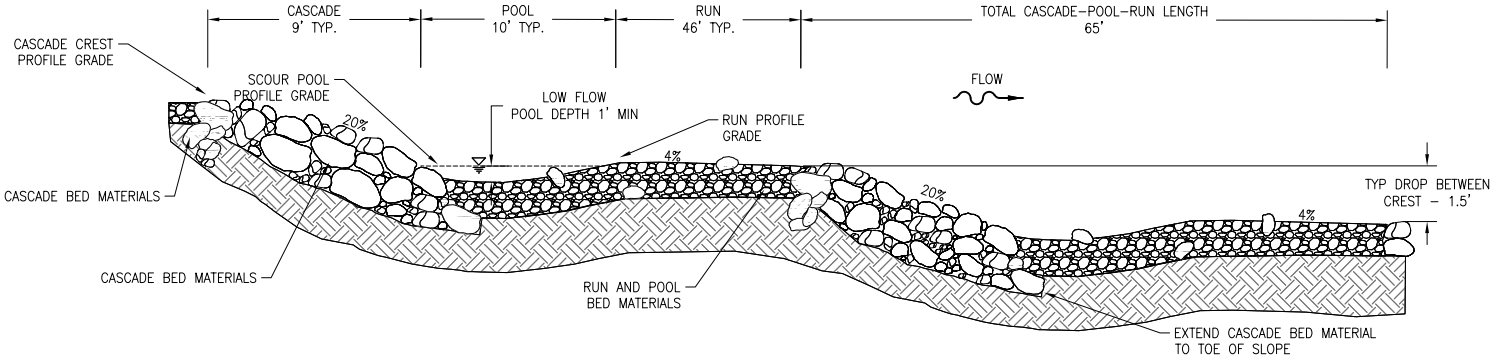
NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*



UPSTREAM CASCADE STREAMBED PROFILE



DOWNSTREAM CASCADE STREAMBED PROFILE

EXISTING BED MATERIAL GRADATION*
D_{min} = SAND
D_{16} = 0.8"
D_{50} = 2.2"
D_{84} = 4.8"
D_{max} = 9.8"

*FOR REFERENCE DURING POTENTIAL SALVAGE FOR REUSE

CASCADE CREST BED MATERIAL GRADATION
D_{min} = 12"
D_{max} = 30"

CASCADE BED MATERIAL GRADATION
D_{min} = SAND
D_{16} = 2.0"
D_{50} = 6.0"
D_{84} = 15.0"
D_{max} = 30"

RUN AND POOL BED MATERIAL GRADATION
D_{min} = SAND
D_{16} = 0.6"
D_{50} = 2.0"
D_{84} = 5.0"
D_{max} = 20"

GRADATION TABLES

MIDDLE CULVERT - DETAILS

DATE: FEBRUARY 2018

HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: 45.8067/122.5814

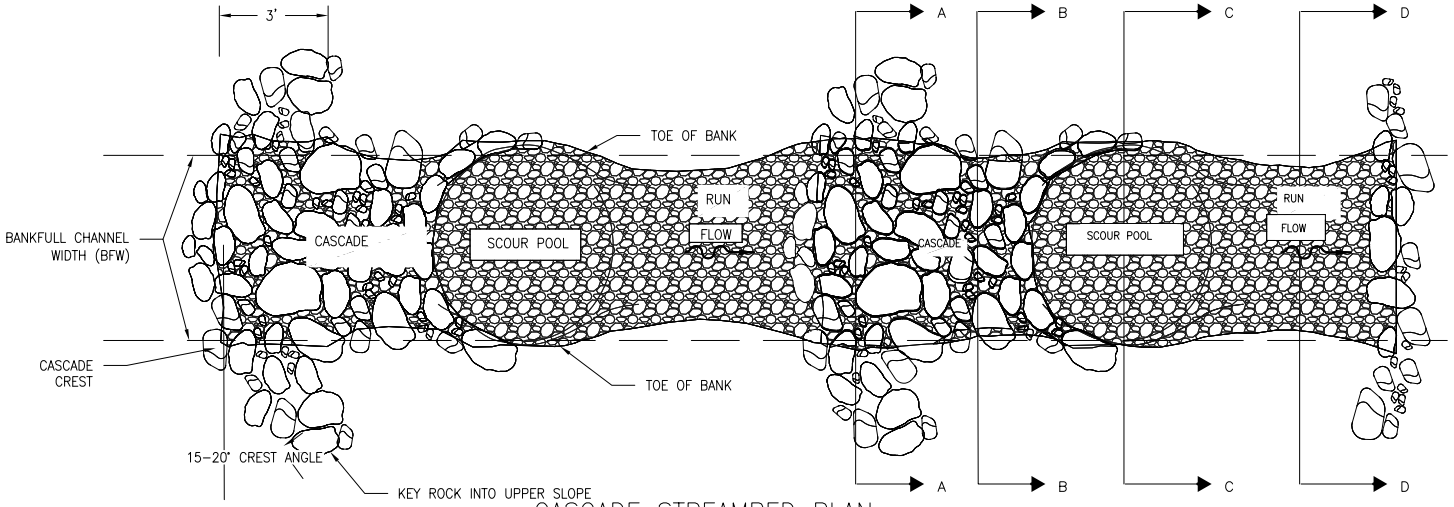
SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

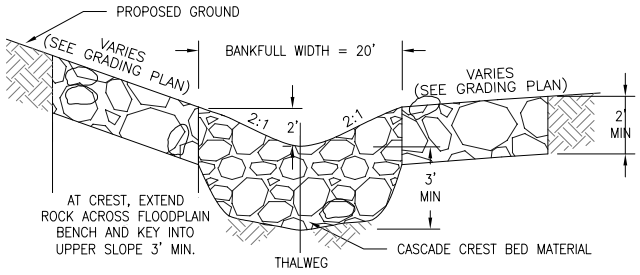
WATER BODY: MANLEY CREEK

NEAR: BATTLE GROUND

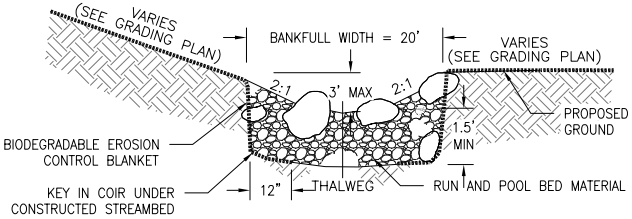
COUNTY: CLARK ***STATE:*** WA



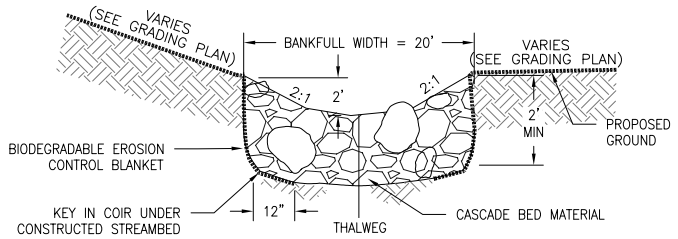
CASCADE STREAMBED PLAN



SECTION A



SECTION C



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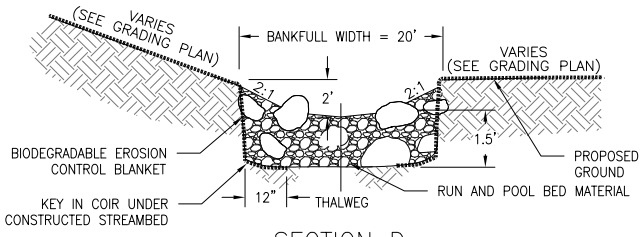


SECTION D

MIDDLE CULVERT - DETAILS

DATE: FEBRUARY 2018

HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

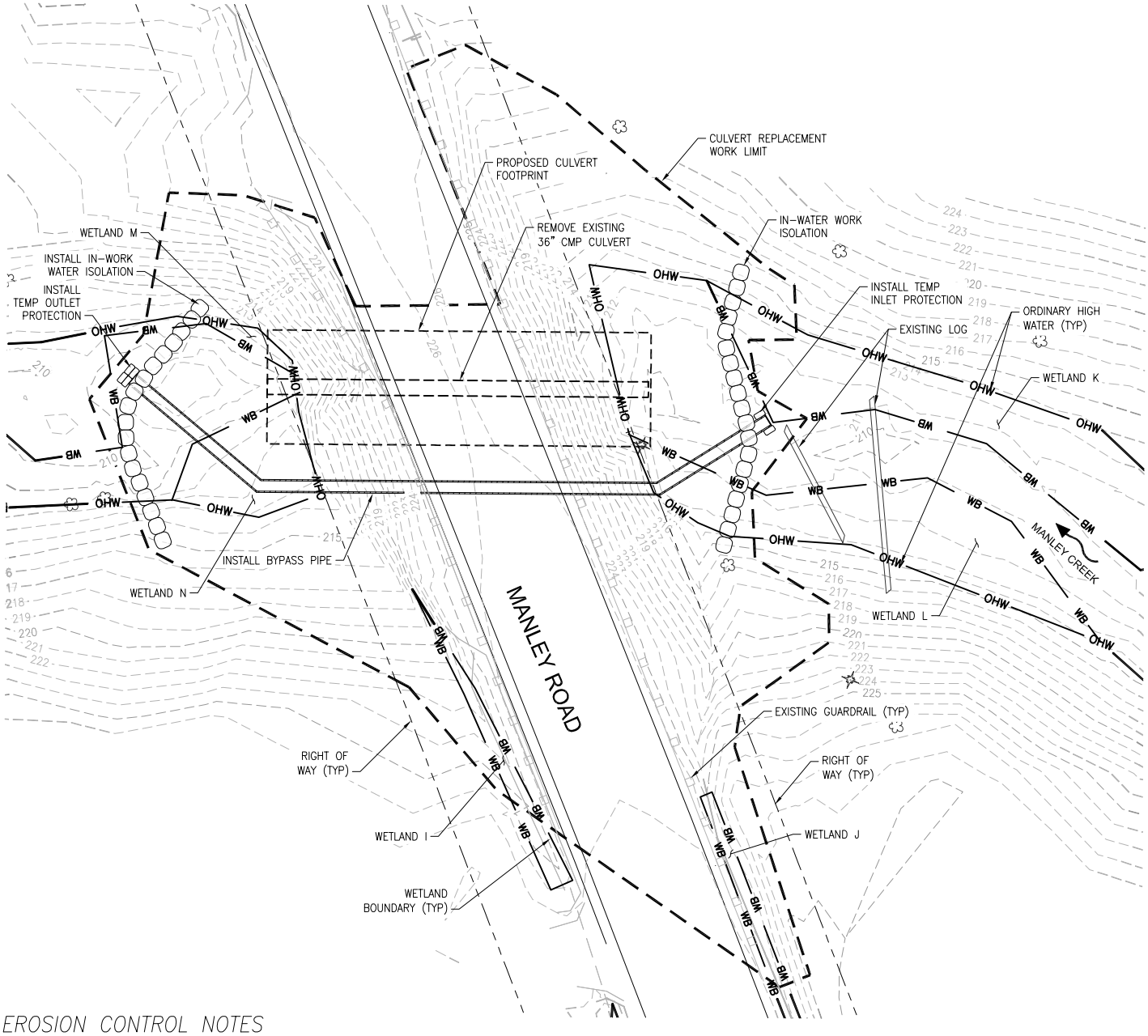
SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*



EROSION CONTROL NOTES

1. INSTALL EROSION AND SEDIMENT (ESC) CONTROL MEASURES AS REQUIRED BY THIS PLAN.
2. CONSTRUCT AND/OR ASSEMBLE ESC MEASURES PRIOR TO CLEARING AND GRUBBING. RELOCATE AND REPAIR THEM AS NECESSARY THROUGHOUT CONSTRUCTION TO ENSURE PROPER FUNCTION AND EFFECTIVENESS.
3. ON SIDE SLOPES WHERE GRADING HAS OCCURRED, ESC MEASURES MAY INCLUDE, BUT ARE NOT LIMITED TO, COIR FABRIC, STRAW WATTLES, AND SEEDING OF EXPOSED SOILS. SEED AS SPECIFIED ON PLANTING SHEETS.
4. THE ESC MEASURES SHOWN ON THESE PLANS ARE THE MINIMUM REQUIREMENTS FOR THE ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, ADDITIONAL MEASURES MAY BE NECESSARY FOR CONTRACTOR'S SITE ACCESS, TEMPORARY DETOURS, AND UNEXPECTED STORM EVENTS.
5. SEDIMENT LADEN WATER SHALL BE PUMPED OUT OF THE CONSTRUCTION AREA AND DISCHARGED UPSLOPE OF THE CREEK OR INTO SEDIMENTATION BASINS. NO SEDIMENT LADEN WATER SHALL BE DISCHARGED DIRECTLY TO MANLEY CREEK.

WORK AREA ISOLATION NOTES

1. CONTRACTOR SHALL NOT WORK DIRECTLY WITHIN THE ORDINARY HIGH WATER OF THE CREEK WITHOUT THE USE OF AN APPROVED AND IN-PLACE WORK AREA ISOLATION PLAN.
2. CREEK TO BE DIVERTED THROUGH THE USE OF PUMPING OR ANCHORED DIVERSION PIPE. INSTALL MESH SCREEN AT PIPE OR PUMP INLETS FOR FISH PROTECTION. INSTALL SUFFICIENT GRAVEL BAGS ON/AROUND PIPE INLET/OUTLET TO STABILIZE AND PREVENT EROSION. DIVERSION METHODS SHALL BE SIZED TO DIVERT A MINIMUM FLOW RATE OF 27 CFS.
3. DEWATERING THE WORK AREA SHALL OCCUR AT A RATE SLOW ENOUGH TO ALLOW THE SAFE CAPTURE AND RELOCATION OF FISH SPECIES AND OTHER AQUATIC ORGANISMS TO AVOID STRANDING.

15' 0' 15' 30'
SCALE IN FEET

SOUTH CULVERT - EXISTING CONDITION AND EROSION CONTROL

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*
NEAR: *BATTLE GROUND*
COUNTY: *CLARK* ***STATE:*** *WA*

Apr 20, 2018 - 3:19pm
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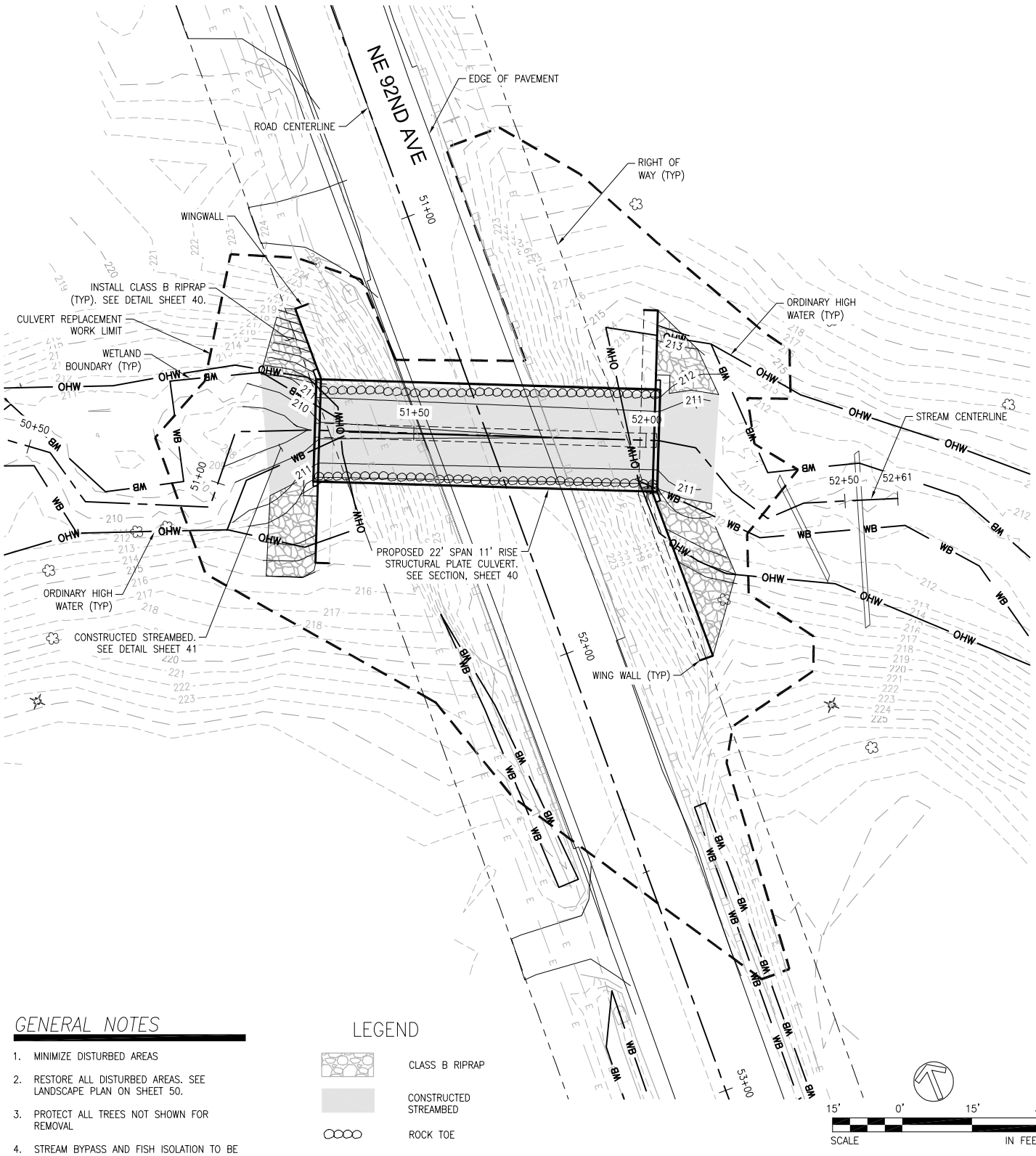

GENERAL NOTES

1. MINIMIZE DISTURBED AREAS
2. RESTORE ALL DISTURBED AREAS. SEE LANDSCAPE PLAN ON SHEET 50.
3. PROTECT ALL TREES NOT SHOWN FOR REMOVAL
4. STREAM BYPASS AND FISH ISOLATION TO BE COORDINATED WITH WDFW

LEGEND

- CLASS B RIPRAP
- CONSTRUCTED STREAMBED
- ROCK TOE

SOUTH CULVERT - SITE PLAN

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: 45.8067/122.5814

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: MANLEY CREEK
NEAR: BATTLE GROUND
COUNTY: CLARK ***STATE:*** WA

Apr 20, 2018 - 3:20pm
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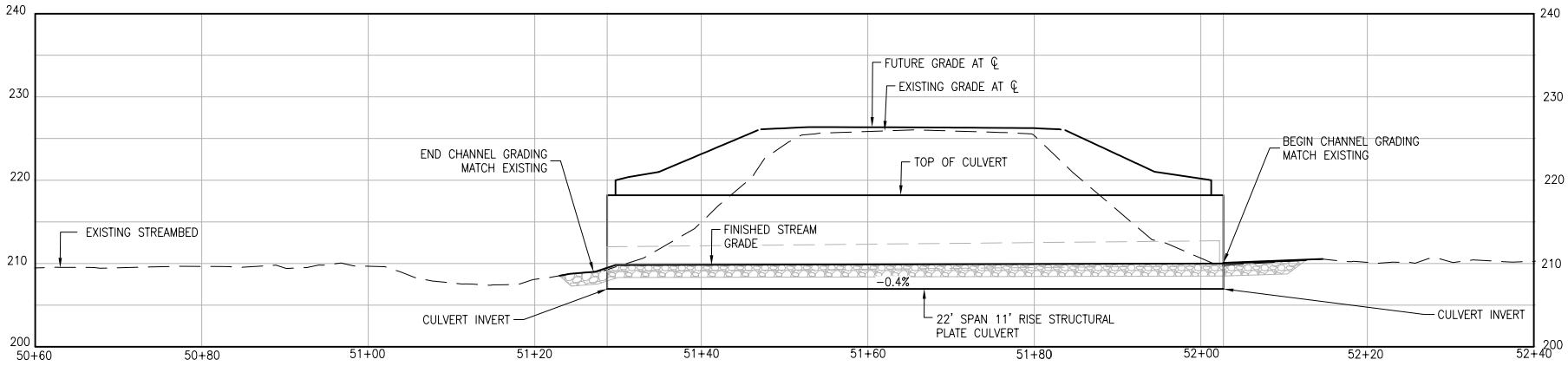


PROPOSED SOUTH CULVERT PROFILE

STAT.: 50+60 TO 52+40
HORIZ. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)
VERTI. SCALE: 1" : 20' (FOR 8.5" X 11" PAPER)

SOUTH CULVERT - STREAM PROFILE

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

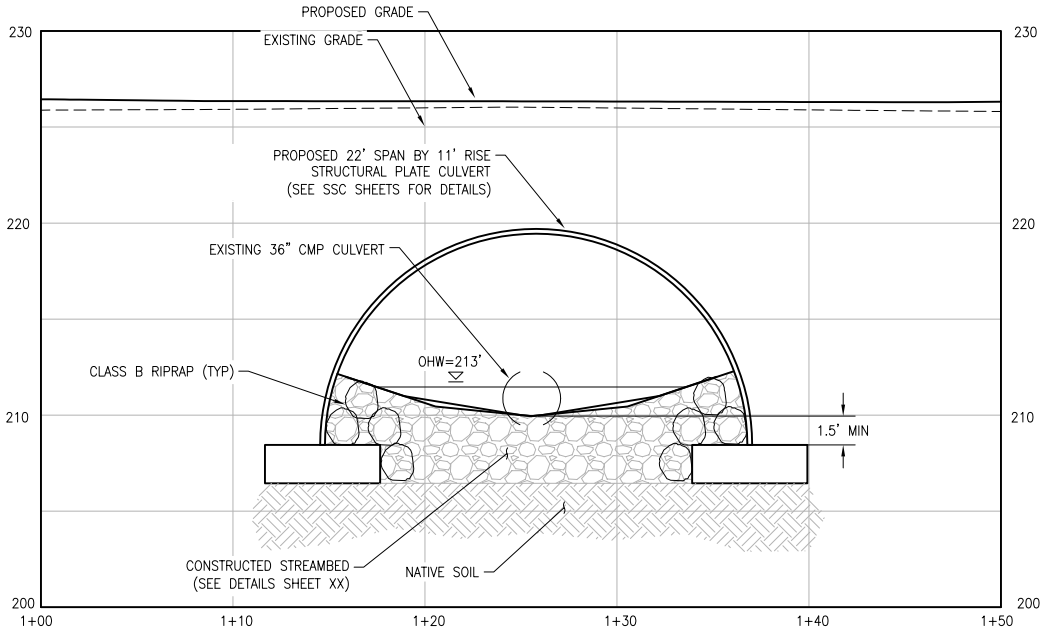
SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

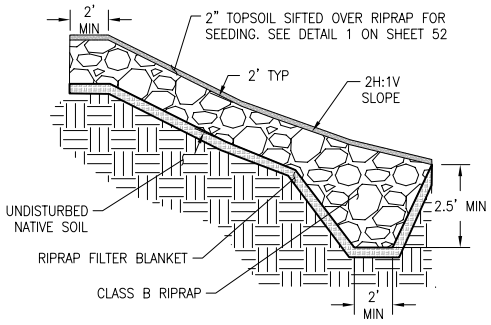
NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*



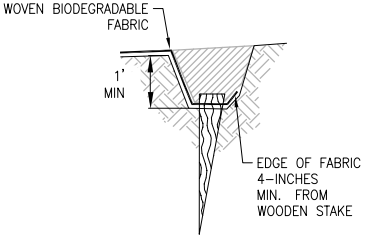
1/40 SOUTH CULVERT SECTION

SCALE: N.T.S.



2/40 RIPRAP DETAIL

SCALE: N.T.S.



NOTES:
1. STAKE FABRIC TO BOTTOM OF KEY TRENCH, 1 STAKE PER 3 L.F.
2. FILL KEY TRENCH WITH TOPSOIL AND COMPACT. WHEN USED AT TOE, REPLACE TOPSOIL WITH STREAMBED GRAVEL

3/40 KEY TRENCH DETAIL

SCALE: N.T.S.

SOUTH CULVERT - SECTION + DETAILS

DATE: FEBRUARY 2018

HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: *45.8067/122.5814*

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: *MANLEY CREEK*

NEAR: *BATTLE GROUND*

COUNTY: *CLARK* ***STATE:*** *WA*

CONSTRUCTED STREAMBED NOTES:

1. THIS PROJECT WILL REQUIRE A 'FIELD DIRECTED' APPROACH TO STREAMBED CONSTRUCTION. CONTRACTOR REQUIRED TO COORDINATE WORK ACTIVITIES WITH OWNER'S REPRESENTATIVE.
2. REMOVE UNSUITABLE MATERIALS FROM THE CHANNEL AREA. THESE MAY INCLUDE, BUT ARE NOT LIMITED TO THE FOLLOWING: CONCRETE, VEGETATION, GARBAGE, AND WOOD. COORDINATE WITH OWNER'S REPRESENTATIVES PRIOR TO REMOVING ANY LARGE BOULDERS.
3. CONSTRUCTED STREAMBED SHALL BE CONSTRUCTED WITH THE MATERIALS DESCRIBED IN THE TABLE BELOW IN ACCORDANCE WITH WSDOT SEPCIFICATIONS. STONE FOR CONSTRUCTED STREAMBED SHALL BE PLACED TO MATCH THE DESIGN GRADE SHOWN.
2. EXCAVATION CARRIED BELOW THE SUB-GRADE LINES SHOWN SHALL BE REPLACED WITH THE SPECIFIED OVERLAYING MATERIAL. THE CONTRACTOR SHALL BEAR ALL COSTS FOR CORRECTING OVER EXCAVATED AREAS.
3. PERFORM ALL SHAPING OF THE SUB-GRADE TO ELEVATIONS, LINES AND GRADES, AS SHOWN. SHAPE, TRIM, AND FINISH SLOPES OF CHANNELS TO CONFORM TO THE SUB-GRADE LINES, GRADES, AND CROSS SECTIONS AS SHOWN. THE FINISHED SUB-GRADE SHALL BE INSPECTED BY THE OWNER'S REPRESENTATIVE PRIOR TO PLACEMENT OF CONSTRUCTED STREAMBED.
4. PLACE STONE FOR CONSTRUCTED STREAMBED IN A MANNER THAT PREVENTS SEGREGATION OF STONE SIZES. CONSTRUCTED STREAMBED STONE SHALL BE PLACED IN A MANNER THAT PROMOTES MIXING OF STONE SIZES INTO A CONSOLIDATED LAYER AFTER EACH LIFT IS PLACED.
5. PLACE HABITAT BOULDERS AT THE DENSITY SPECIFIED FOR EACH CONSTRUCTED STREAMBED AREA. HABITAT BOULDERS SHALL BE PLACED SO THAT A 20-40% OF THE BOULDERS WILL BE EXPOSED ABOVE FINISH GRADE.
6. PLACE STREAMBED COBBLE MIX IN 8" LIFTS.
7. PLACE STREAMBED SEDIMENT MIX ON TOP OF EACH LIFT OF STREAMBED COBBLE MIX. USE WATER TO WASH THE STREAMBED SEDIMENT INTO THE VOIDS WITHIN THE STREAMBED COBBLE MIX LAYER. WASH WATER SHALL FLOW OVER THE TOP OF THE CONSTRUCTED STREAMBED (NOT SUBSURFACE) UPON COMPLETION OF THE CONSTRUCTED STREAMBED. ADDITIONAL HAND WORKING WITH ROCKBARS, SHOVELS, ETC. MAY BE REQUIRED TO ELIMINATE VOIDS IN CONSTRUCTED STREAMBED.
8. CONTINUE STREAMBED COBBLE MIX AND STREAMBED SEDIMENT MIX PLACEMENT UNTIL THE FINISH GRADE FOR THE STREAMBED CONSTRUCTION IS REACHED.
9. DO NOT ALLOW THE STREAMBED SEDIMENT MIX TO BUILD UP SUCH THAT ANY OF THE SUBSEQUENT LIFTS OF STONE WILL REST UPON GRAVEL MIX.

CONSTRUCTED STREAMBED MATERIAL TABLE

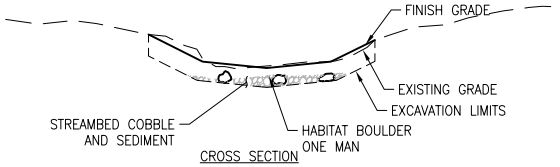
FILL MATERIAL	DIAM. RANGE* (IN)	PERCENT BY WEIGHT
HABITAT BOULDERS, TWO MAN	18-28	SEE HABITAT BOULDER DENSITY TABLE THIS SHEET
HABITAT BOULDERS, ONE MAN	12-18	
STREAMBED COBBLE**	2-6	80
STREAMBED SEDIMENT	2.5-NO. 200	20

* DIAMETER IN INCHES MEASURED ALONG INTERMEDIATE AXIS OF BOULDERS, AND COBBLE.
**STREAMBED COBBLE SHALL BE 2" STREAMBED COBBLE AS DESCRIBED IN WSDOT STANDARD SPECIFICATIONS.

HABITAT BOULDER DENSITY TABLE

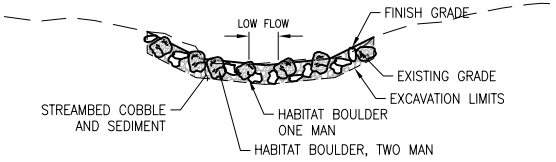
CROSSING ID	DENSITY (NUM OF STONES/SQ FT)
NORTHERN A CULVERT	4/100
NORTHERN B CULVERT	4/100
MIDDLE CULVERT	8/100
SOUTHERN CULVERT	4/100

STEP 1: EXCAVATE TO BEDROCK OR PREPARED SUBGRADE. MINIMUM DEPTH 18 INCHES BELOW FINISHED GRADE EXCEPT WHERE BEDROCK IS ENCOUNTERED.



CROSS SECTION

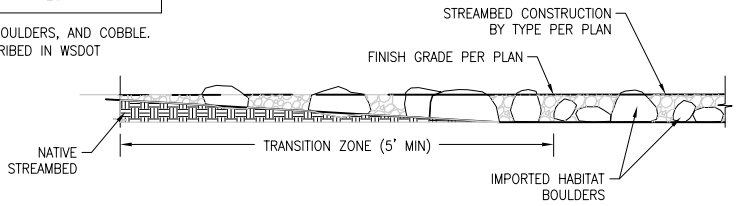
STEP 2: FOR AREAS WHERE PREPARED SUBGRADE IS LOCATED DEEPER THAN 18 INCHES FROM FINISH GRADE BACKFILL WITH COBBLE AND GRAVEL MIX. SEE SPECS FOR CONSTRUCTION REQUIREMENTS.



CROSS SECTION

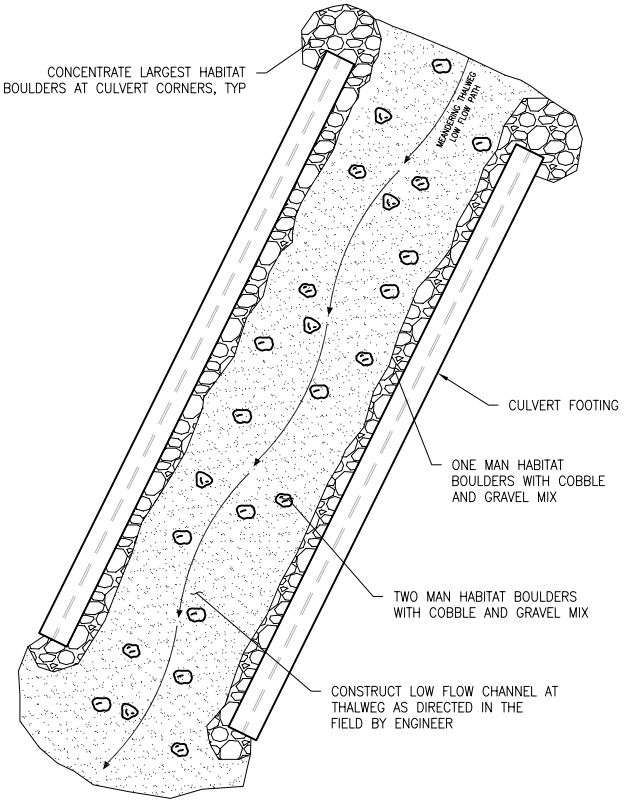
STEP 3: INDIVIDUALLY PLACE HABITAT BOULDERS AS SHOWN ON THE PLANS AND PER SPECS. BACKFILL WITH COBBLE AND GRAVEL MIX TO FINISH GRADE. WASH IN FINES AFTER PLACEMENT OF EACH LIFT OF COBBLE AND GRAVEL MIX TO SEAL STREAMBED SURFACE. SEE SPECS FOR ADDITIONAL REQUIREMENTS.

1/41 MATERIAL PLACEMENT DETAIL
SCALE: N.T.S.



NOTE: TRANSITION LINE EXTENDS FROM THE PROPOSED GRADE OF STREAMBED CONSTRUCTION TO NATIVE GROUND OVER TRANSITION LENGTH PER PLAN. TRANSITIONS CAN ALSO OCCUR FROM CUT SECTIONS TO NATIVE.

2/41 TRANSITION DETAIL
SCALE: N.T.S.



PLAN VIEW

3/41 INSIDE CULVERT DETAIL
SCALE: N.T.S.

CONSTRUCTED STREAMBED DETAILS

DATE: FEBRUARY 2018

otak
HanmiGlobal Partner

APPLICANT:
CLARK COUNTY PUBLIC WORKS

REFERENCE #:

ADJACENT PROPERTY OWNERS:
SEE JARPA ATTACHMENT C

PURPOSE:
IMPROVE TRAFFIC SAFETY AND FISH PASSAGE

LAT/LONG: 45.8067/122.5814

SITE LOCATION ADDRESS:
ALONG NE MANLEY ROAD

PROPOSED PROJECT:
NE MANLEY ROAD IMPROVEMENT PROJECT

WATER BODY: MANLEY CREEK

NEAR: BATTLE GROUND

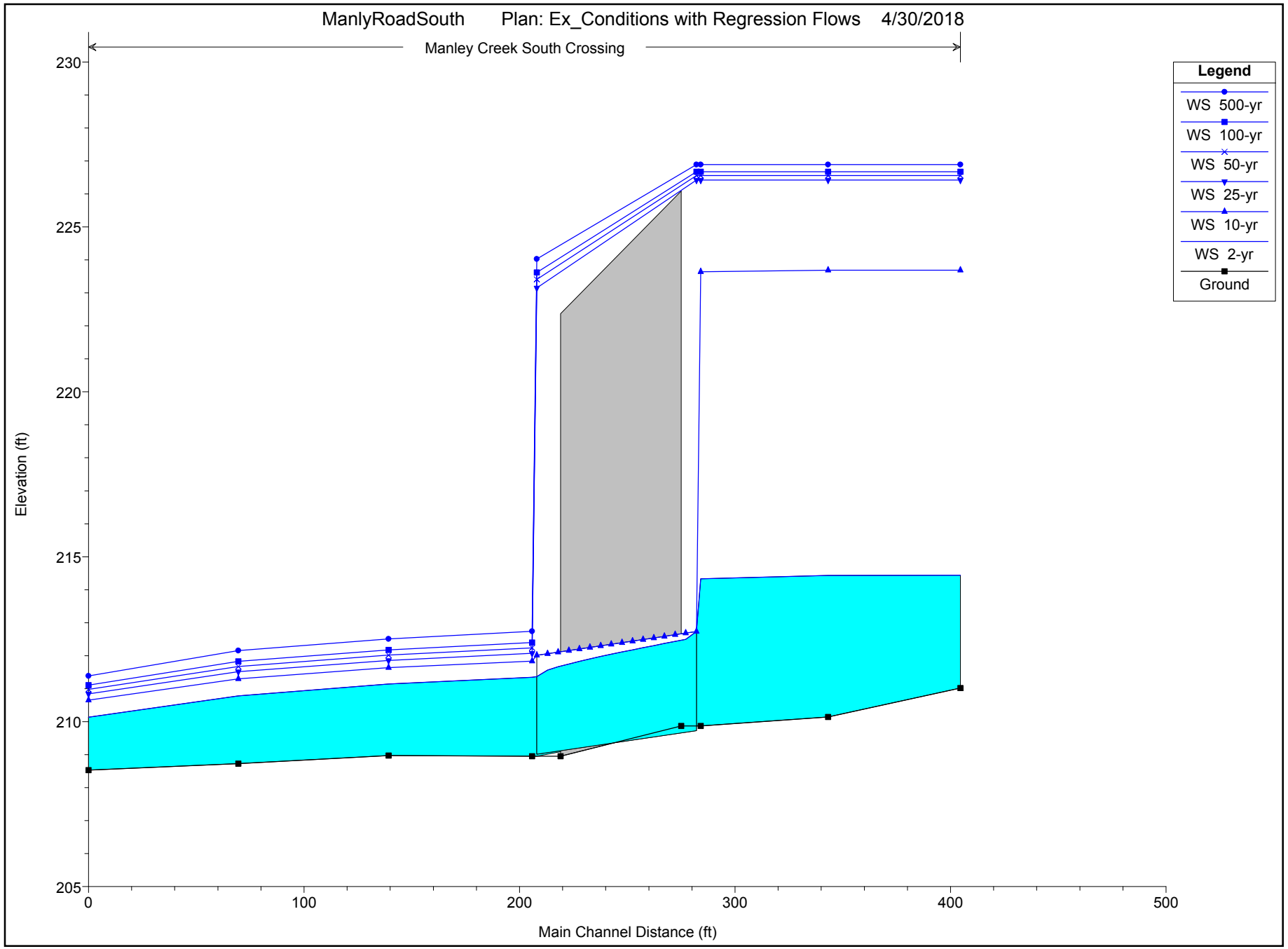
COUNTY: CLARK ***STATE:*** WA

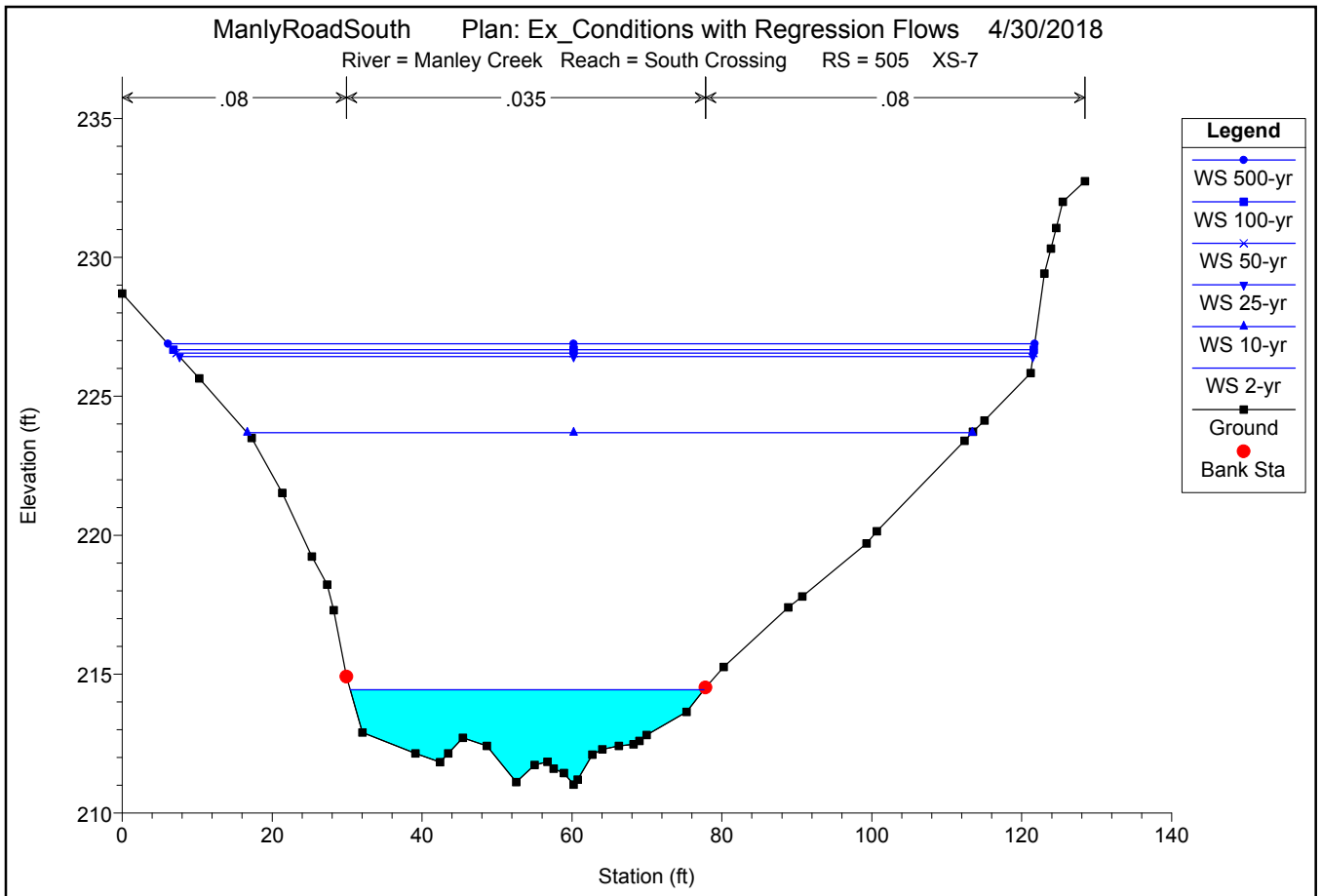
Appendix D

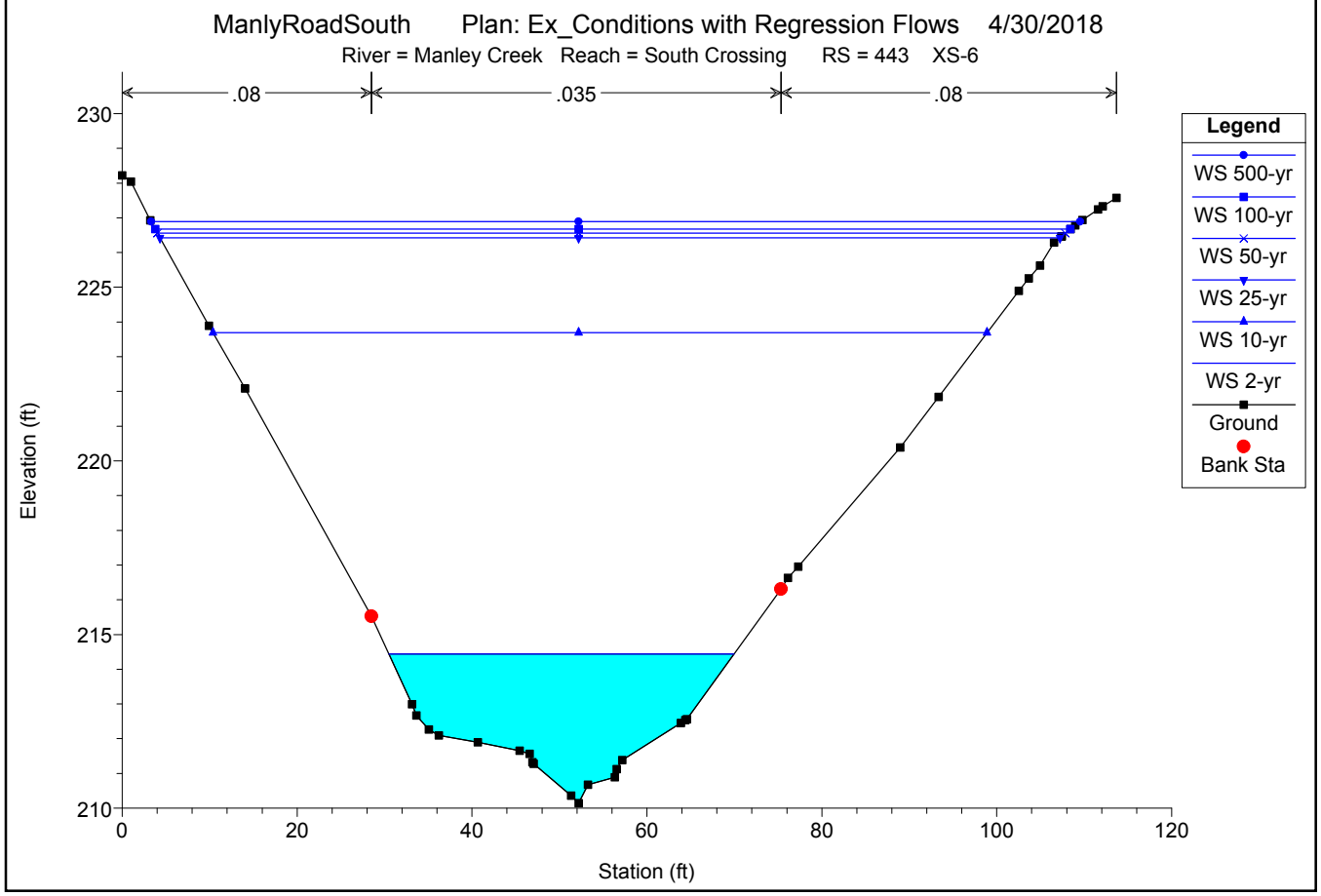
HEC-RAS Output

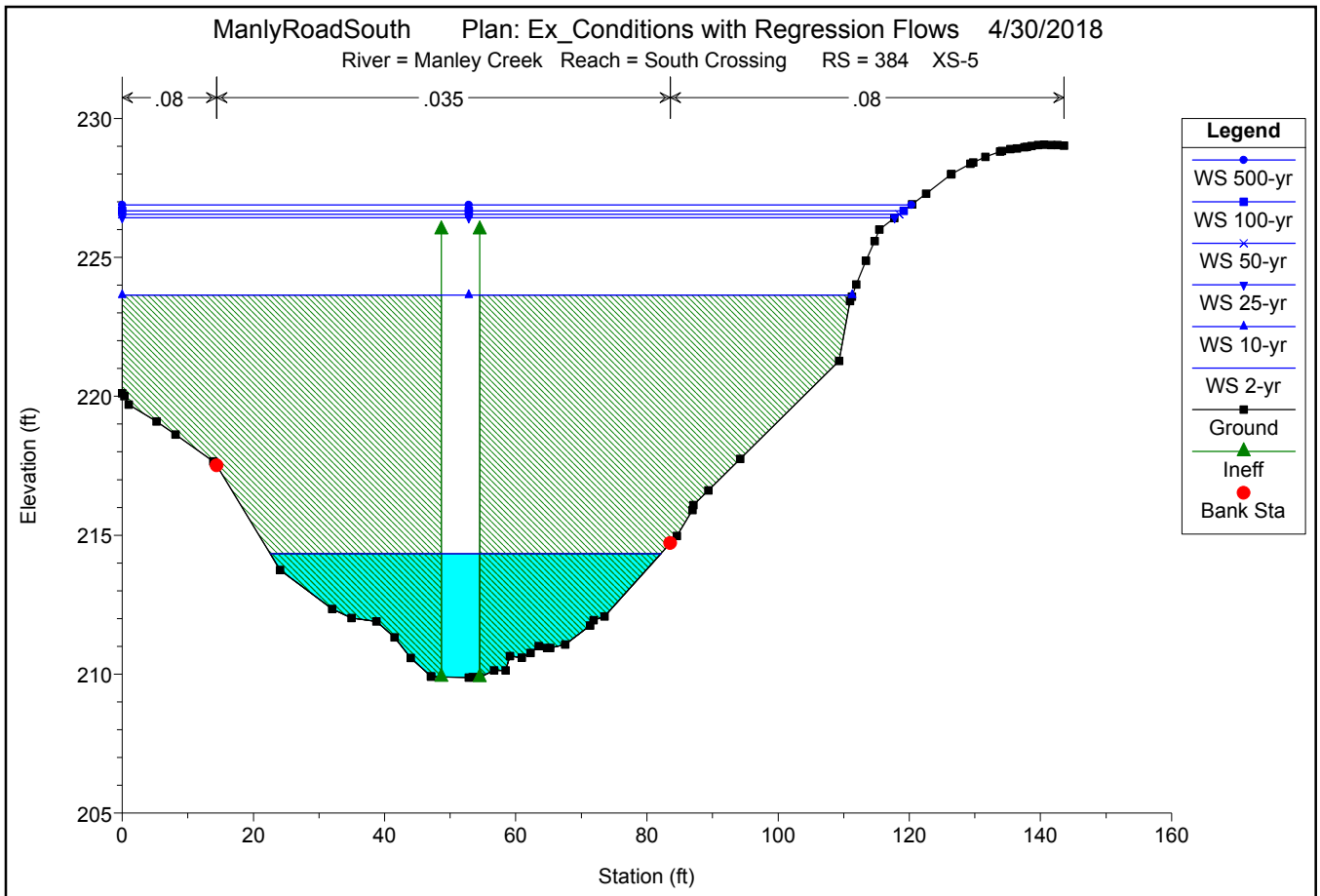
HEC-RAS Plan: South-Extg River: Manley Creek Reach: South Crossing

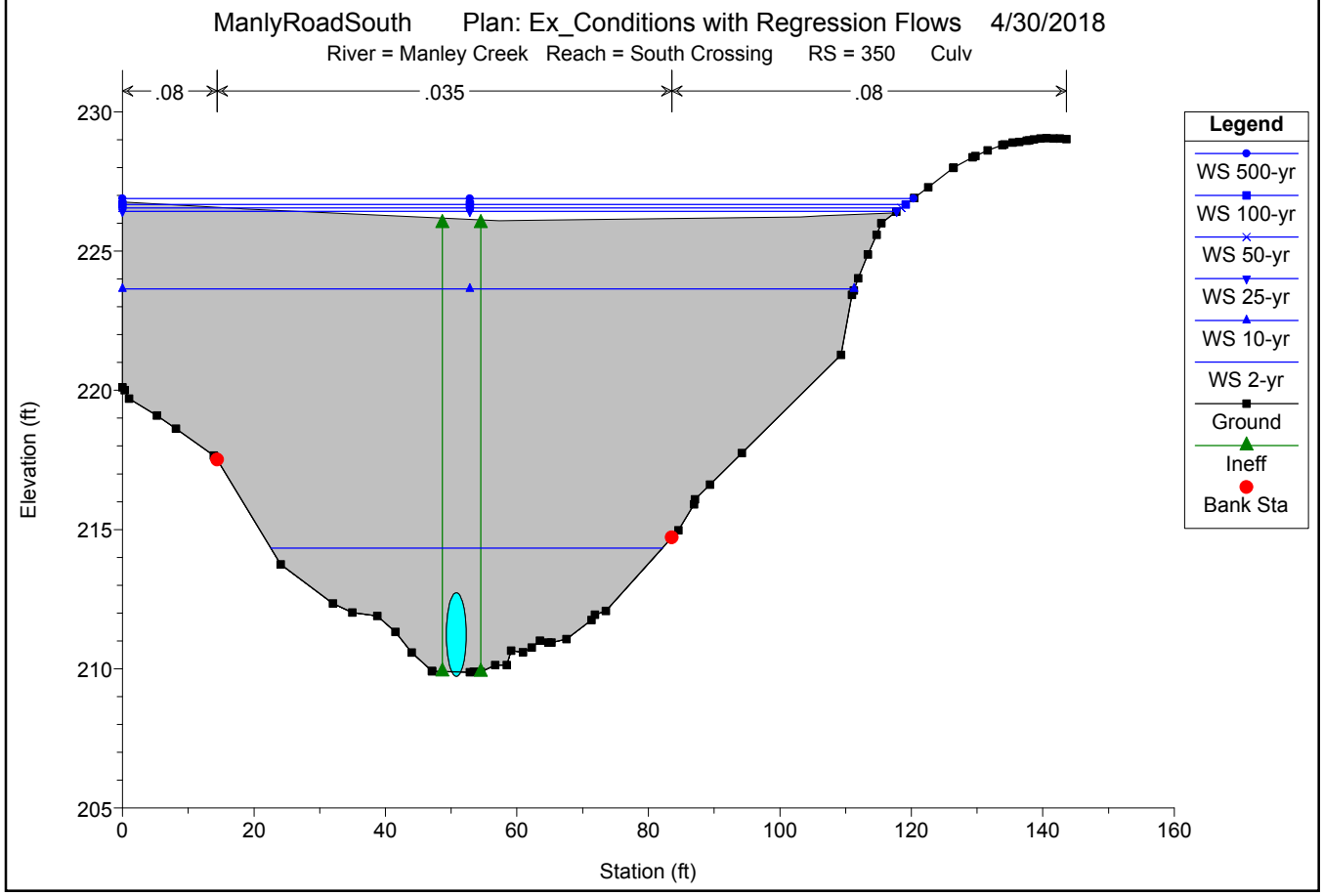
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
South Crossing	505	2-yr	52.60	211.02	214.44		214.44	0.000064	0.54	97.51	47.19	0.07
South Crossing	505	10-yr	111.00	211.02	223.69		223.69	0.000001	0.19	753.10	96.73	0.01
South Crossing	505	25-yr	144.00	211.02	226.43		226.43	0.000001	0.19	1043.03	113.82	0.01
South Crossing	505	50-yr	171.00	211.02	226.56		226.56	0.000001	0.22	1057.91	114.32	0.01
South Crossing	505	100-yr	199.00	211.02	226.68		226.68	0.000001	0.26	1071.70	114.79	0.01
South Crossing	505	500-yr	266.00	211.02	226.89		226.89	0.000002	0.34	1096.28	115.62	0.02
South Crossing	443	2-yr	52.60	210.14	214.43		214.44	0.000052	0.54	96.92	39.45	0.06
South Crossing	443	10-yr	111.00	210.14	223.69		223.69	0.000001	0.20	686.62	88.51	0.01
South Crossing	443	25-yr	144.00	210.14	226.43		226.43	0.000001	0.20	948.40	102.88	0.01
South Crossing	443	50-yr	171.00	210.14	226.56		226.56	0.000001	0.24	961.87	103.80	0.01
South Crossing	443	100-yr	199.00	210.14	226.68		226.68	0.000001	0.27	974.42	104.64	0.01
South Crossing	443	500-yr	266.00	210.14	226.89		226.89	0.000002	0.36	996.90	106.23	0.02
South Crossing	384	2-yr	52.60	209.87	214.33	211.25	214.40	0.000312	2.03	25.94	59.53	0.17
South Crossing	384	10-yr	111.00	209.87	223.64	212.12	223.67	0.000032	1.38	80.22	111.32	0.07
South Crossing	384	25-yr	144.00	209.87	226.43	212.55	226.43	0.000000	0.13	1321.92	117.74	0.01
South Crossing	384	50-yr	171.00	209.87	226.56	212.87	226.56	0.000000	0.16	1337.32	118.47	0.01
South Crossing	384	100-yr	199.00	209.87	226.68	213.19	226.68	0.000001	0.18	1351.62	119.14	0.01
South Crossing	384	500-yr	266.00	209.87	226.89	213.90	226.89	0.000001	0.24	1377.15	120.32	0.01
South Crossing	350		Culvert									
South Crossing	306	2-yr	52.60	208.95	211.35	210.63	211.65	0.004143	4.42	11.89	20.39	0.54
South Crossing	306	10-yr	111.00	208.95	211.84	211.52	211.98	0.002820	2.98	37.19	23.62	0.42
South Crossing	306	25-yr	144.00	208.95	212.07	211.80	212.25	0.003235	3.36	42.87	25.26	0.45
South Crossing	306	50-yr	171.00	208.95	212.24	211.80	212.44	0.003454	3.62	47.25	27.28	0.47
South Crossing	306	100-yr	199.00	208.95	212.40	211.80	212.63	0.003586	3.87	51.78	29.58	0.49
South Crossing	306	500-yr	266.00	208.95	212.74	211.85	213.04	0.003819	4.37	62.80	34.53	0.52
South Crossing	239	2-yr	52.60	208.97	211.14		211.22	0.003432	2.20	24.26	29.66	0.42
South Crossing	239	10-yr	111.00	208.97	211.64		211.77	0.003203	2.90	39.56	31.71	0.44
South Crossing	239	25-yr	144.00	208.97	211.86		212.02	0.003241	3.22	46.58	32.60	0.45
South Crossing	239	50-yr	171.00	208.97	212.02		212.20	0.003282	3.46	51.86	33.26	0.47
South Crossing	239	100-yr	199.00	208.97	212.17		212.38	0.003317	3.69	57.07	33.90	0.47
South Crossing	239	500-yr	266.00	208.97	212.51		212.77	0.003382	4.15	68.74	35.49	0.49
South Crossing	169	2-yr	52.60	208.73	210.78	210.30	210.90	0.006117	2.77	19.00	24.38	0.55
South Crossing	169	10-yr	111.00	208.73	211.30	210.86	211.48	0.005388	3.39	32.73	28.39	0.55
South Crossing	169	25-yr	144.00	208.73	211.52	211.03	211.73	0.005228	3.70	39.07	30.18	0.56
South Crossing	169	50-yr	171.00	208.73	211.67	211.17	211.91	0.005105	3.94	43.87	30.76	0.56
South Crossing	169	100-yr	199.00	208.73	211.83	211.29	212.09	0.005018	4.16	48.58	31.31	0.57
South Crossing	169	500-yr	266.00	208.73	212.15	211.54	212.48	0.004905	4.63	59.02	32.51	0.58
South Crossing	100	2-yr	52.60	208.53	210.14	209.92	210.35	0.010011	3.67	14.32	17.48	0.72
South Crossing	100	10-yr	111.00	208.53	210.65	210.42	210.97	0.010019	4.50	24.96	25.78	0.75
South Crossing	100	25-yr	144.00	208.53	210.84	210.63	211.22	0.010002	4.97	29.94	27.88	0.77
South Crossing	100	50-yr	171.00	208.53	210.98	210.77	211.41	0.010001	5.32	33.91	30.16	0.78
South Crossing	100	100-yr	199.00	208.53	211.11	210.91	211.59	0.010015	5.64	37.91	31.30	0.80
South Crossing	100	500-yr	266.00	208.53	211.39	211.22	211.99	0.010008	6.30	46.82	32.01	0.82

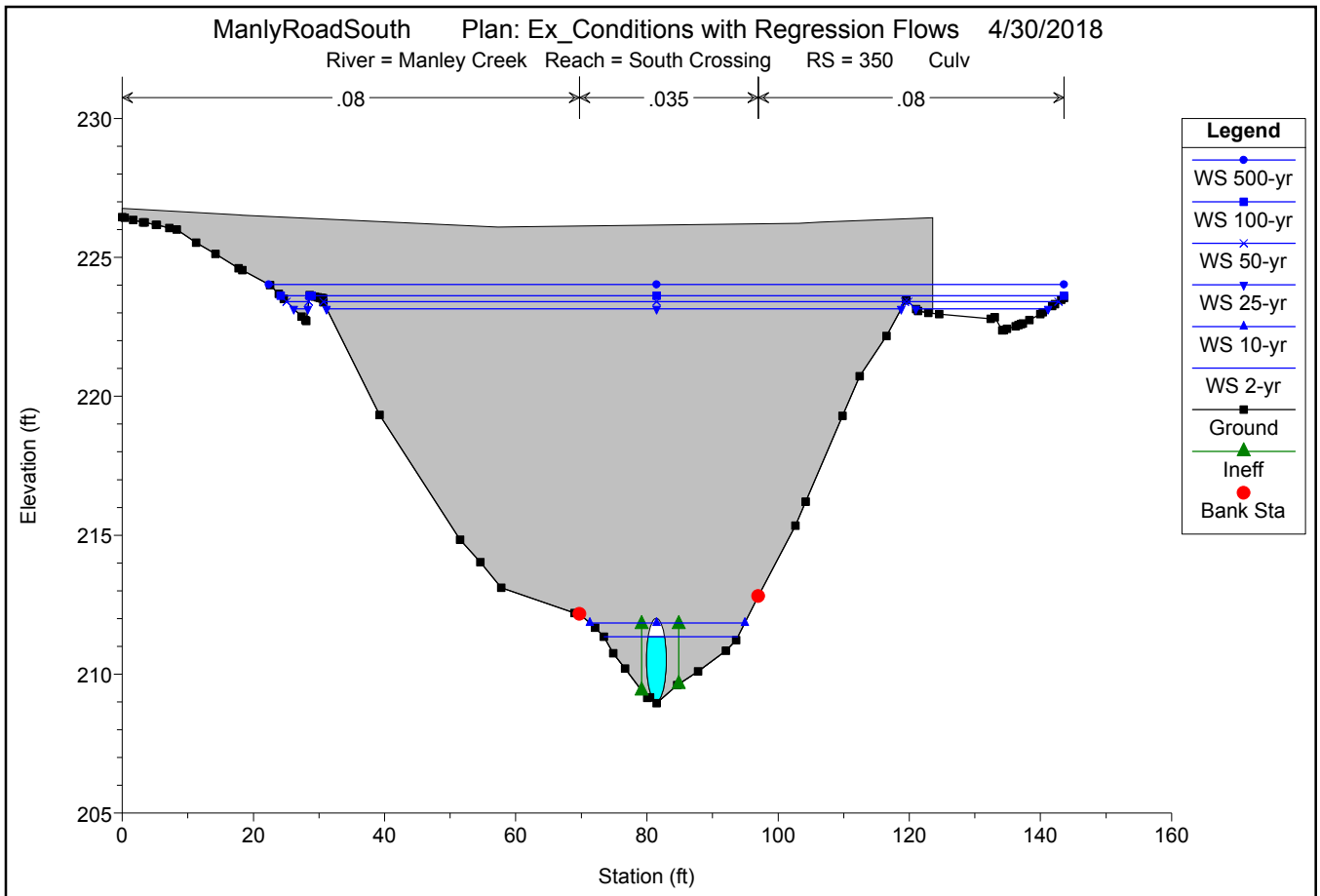

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
Manley Creek South Crossing
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Elevation (ft)
230
225
220
215
210
205
0
100
200
300
400
500
Main Channel Distance (ft)

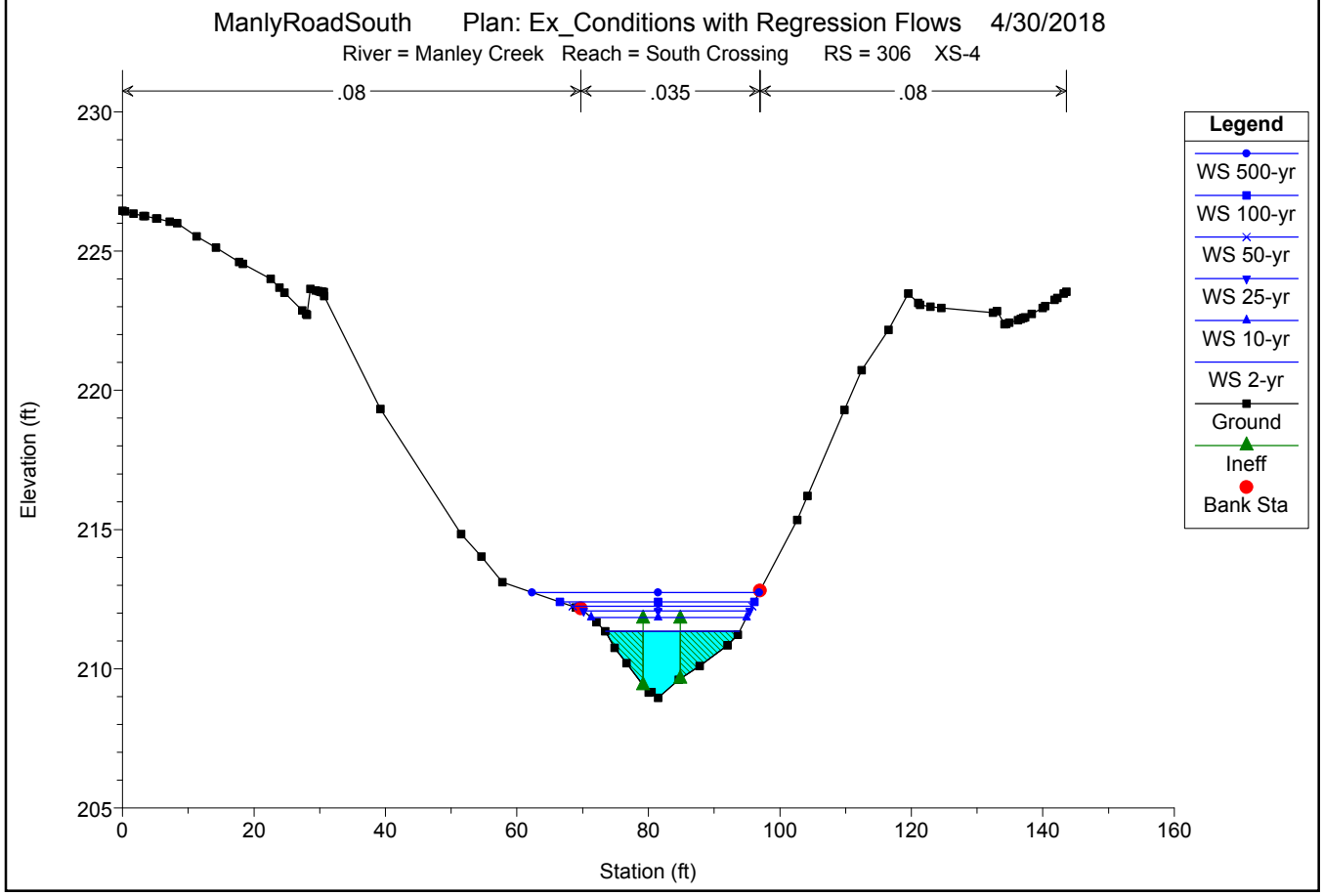

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 505 XS-7
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
210
215
220
225
230
235
0
20
40
60
80
100
120
140

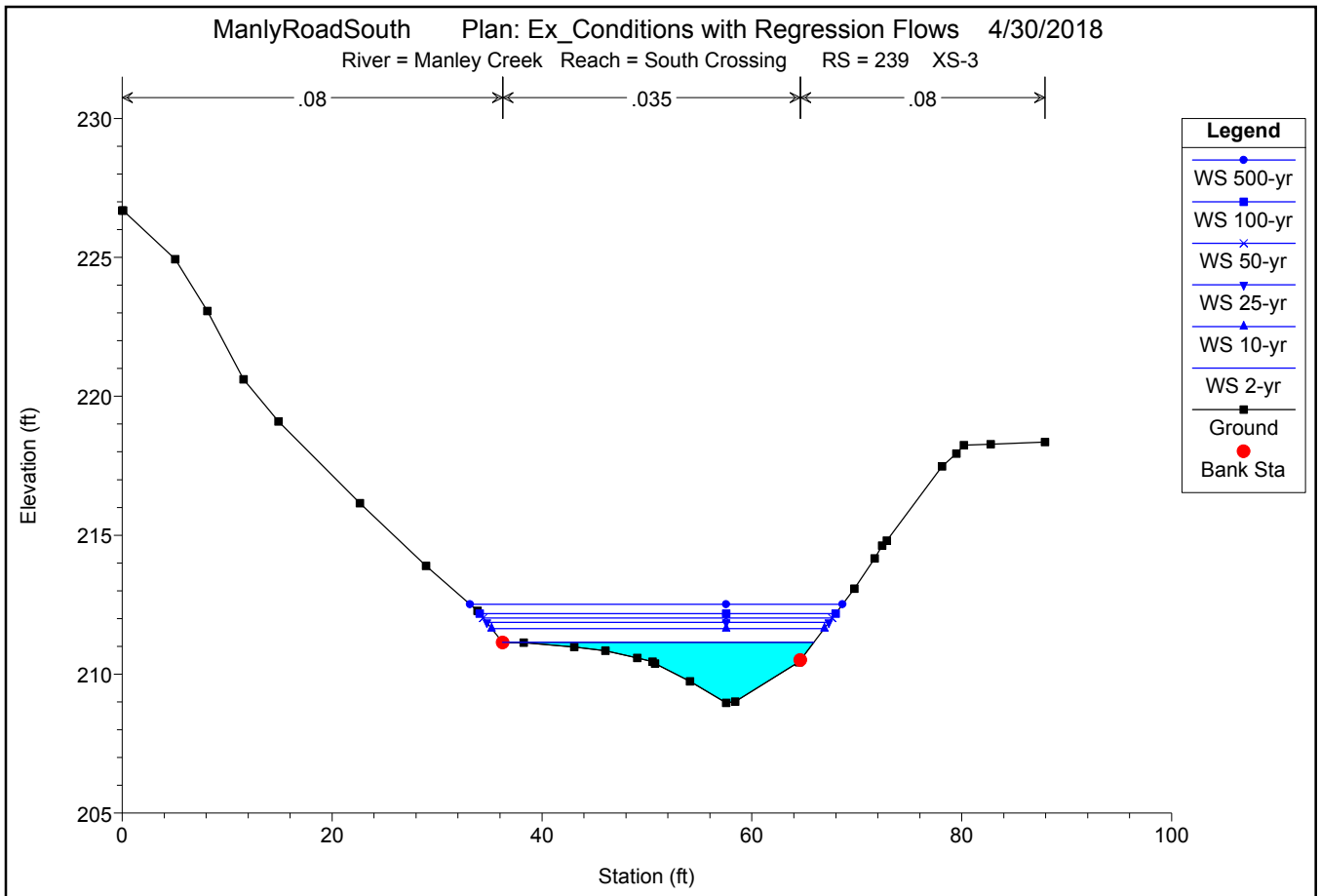

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 443 XS-6
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
210
215
220
225
230
0
20
40
60
80
100
120

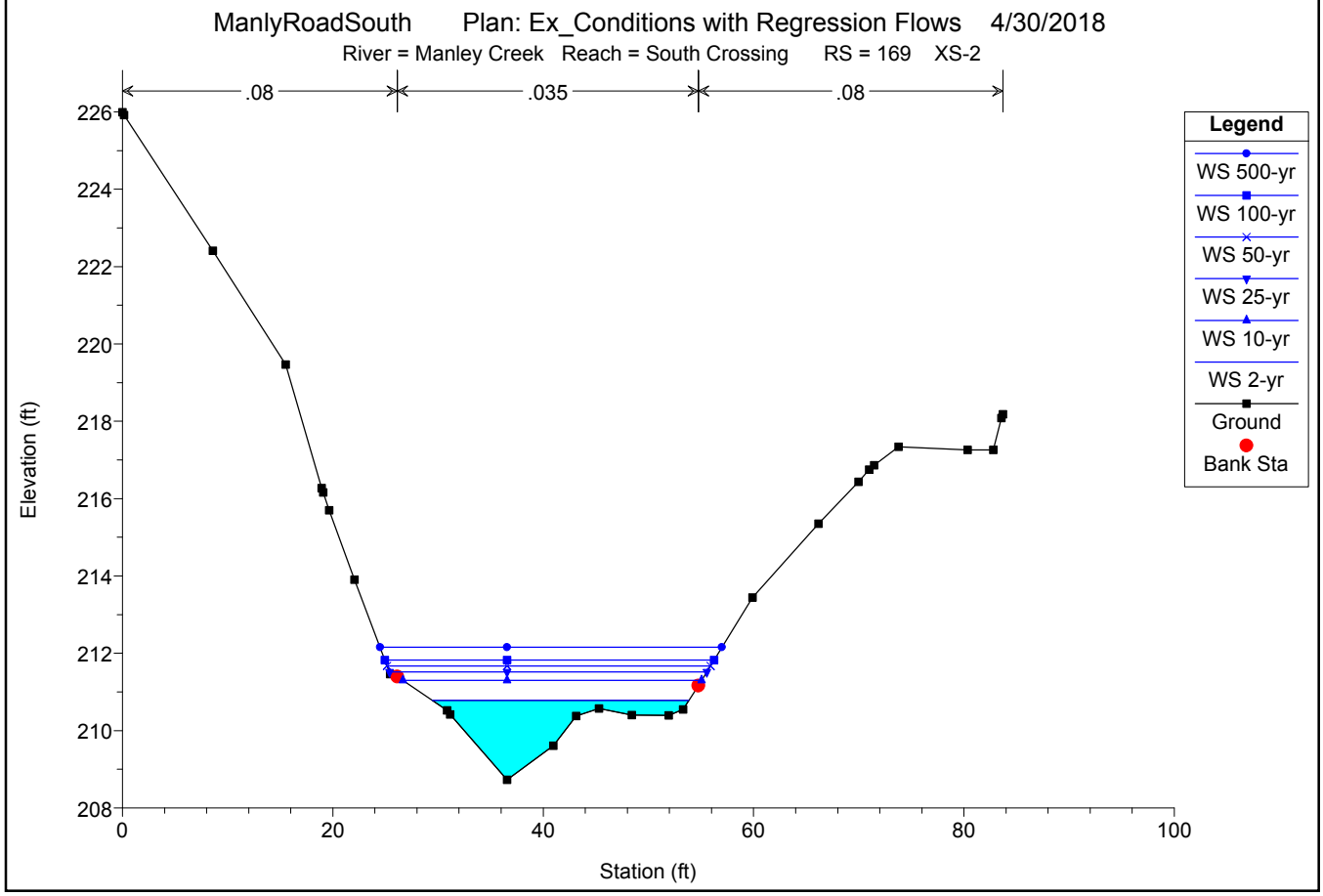

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 384 XS-5
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
230
225
220
215
210
205
0
20
40
60
80
100
120
140
160

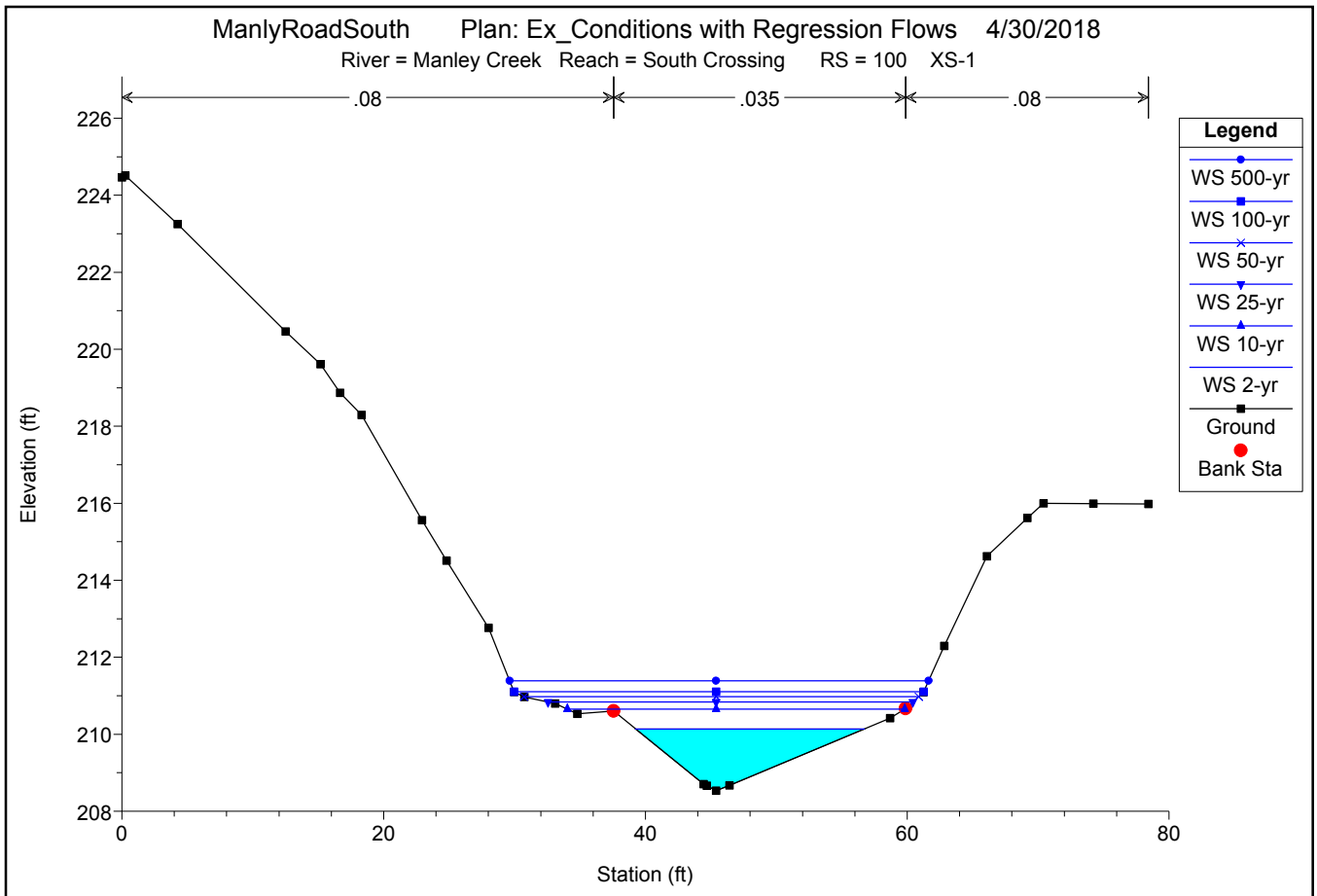

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 350 Culv
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
230
225
220
215
210
205
0
20
40
60
80
100
120
140
160


ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 350 Culv
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
230
225
220
215
210
205
0
20
40
60
80
100
120
140
160


ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 306 XS-4
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
230
225
220
215
210
205
0
20
40
60
80
100
120
140
160

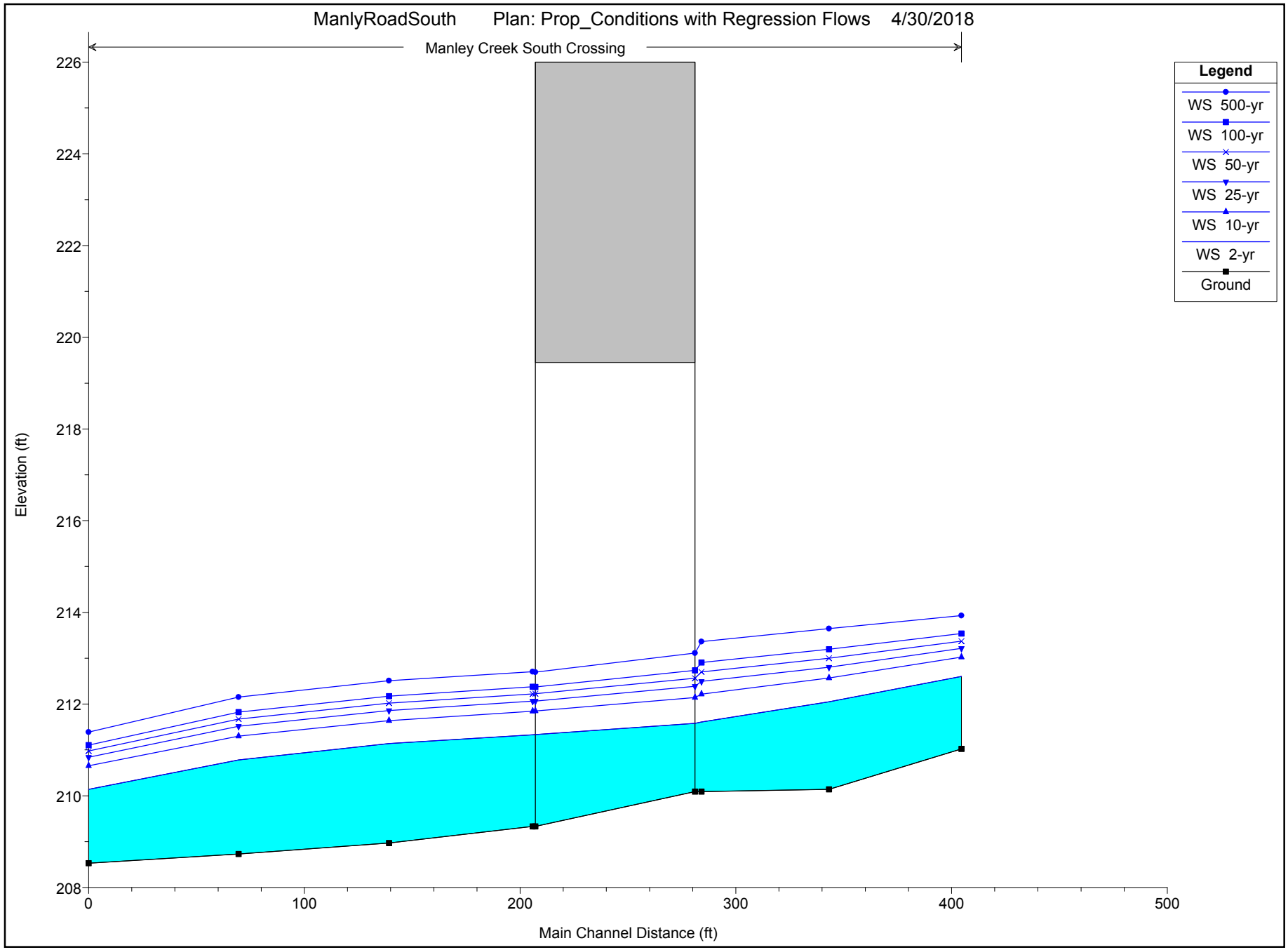

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 239 XS-3
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
230
225
220
215
210
205
0
20
40
60
80
100

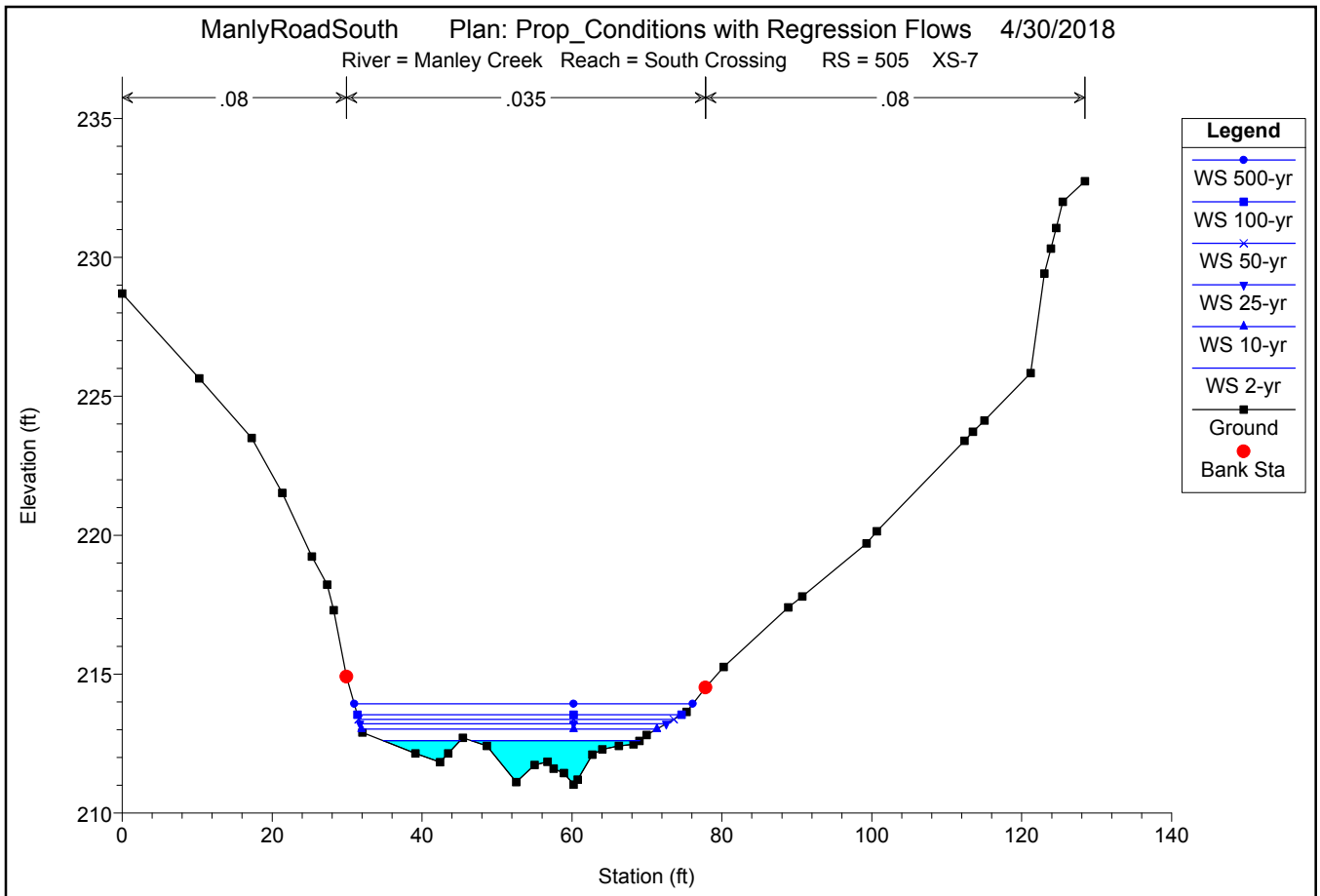

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 169 XS-2
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
226
224
222
220
218
216
214
212
210
208
0
20
40
60
80
100

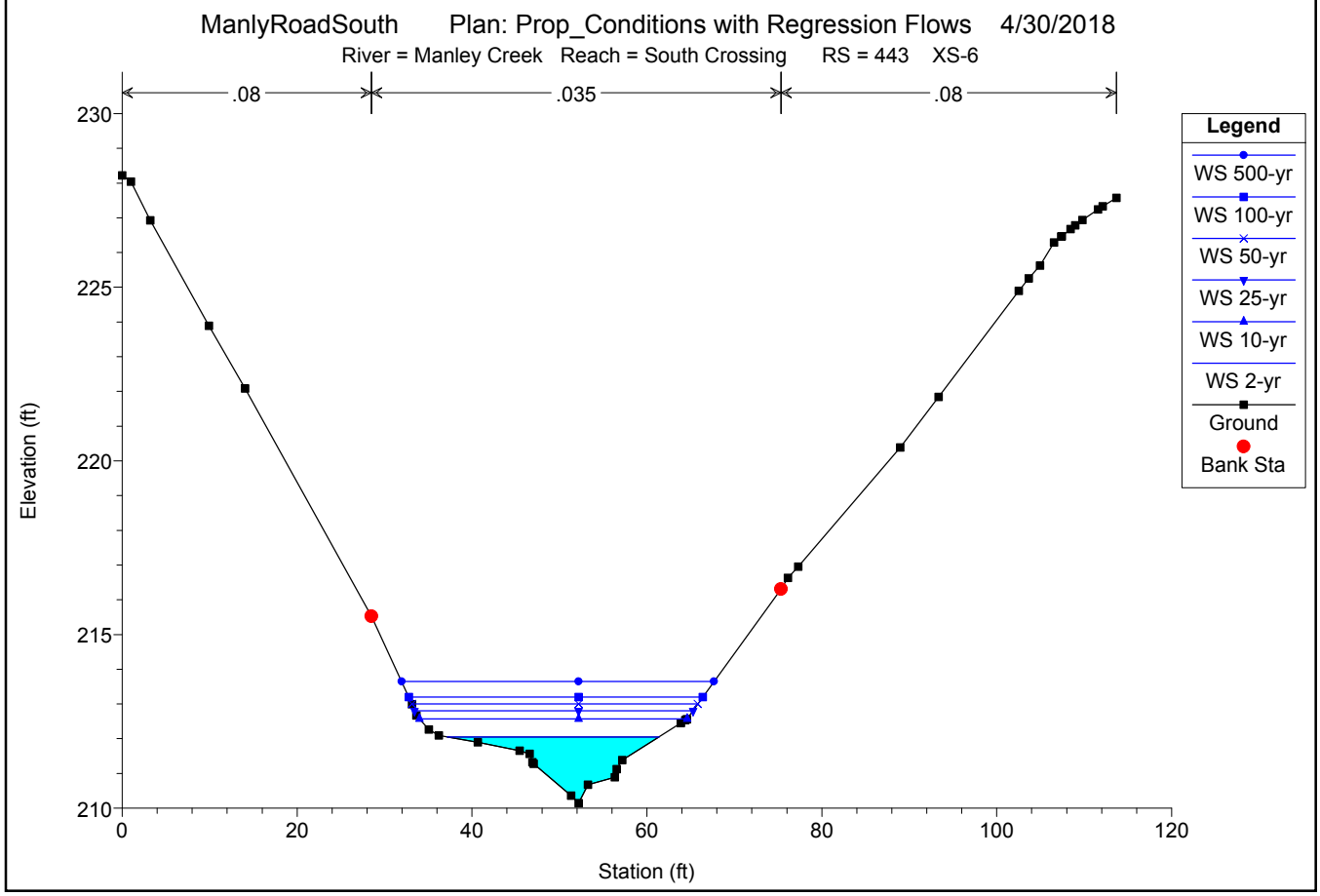

ManlyRoadSouth Plan: Ex_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 100 XS-1
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
226
224
222
220
218
216
214
212
210
208
0
20
40
60
80
Station (ft)

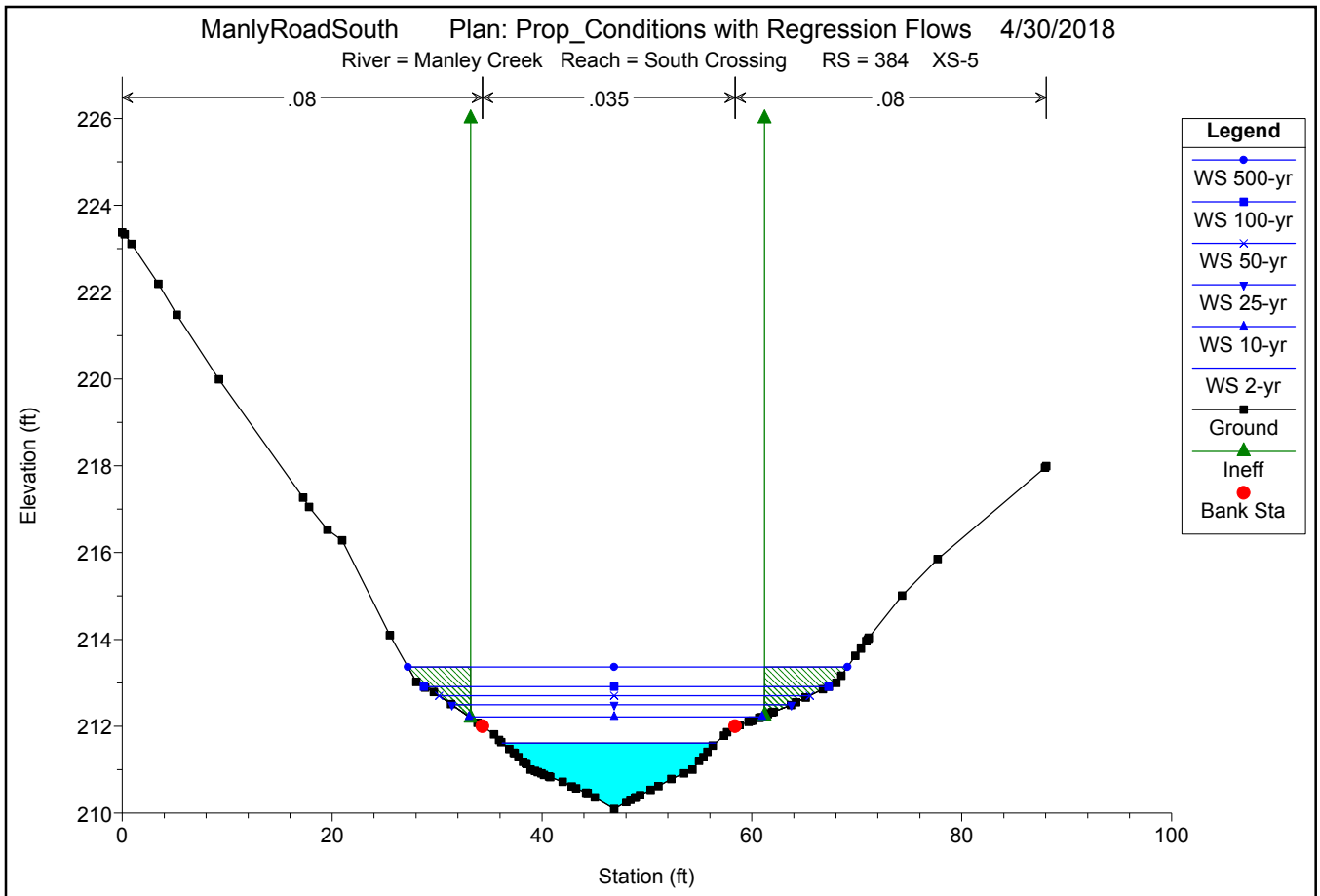
HEC-RAS Plan: South-Prop River: Manley Creek Reach: South Crossing

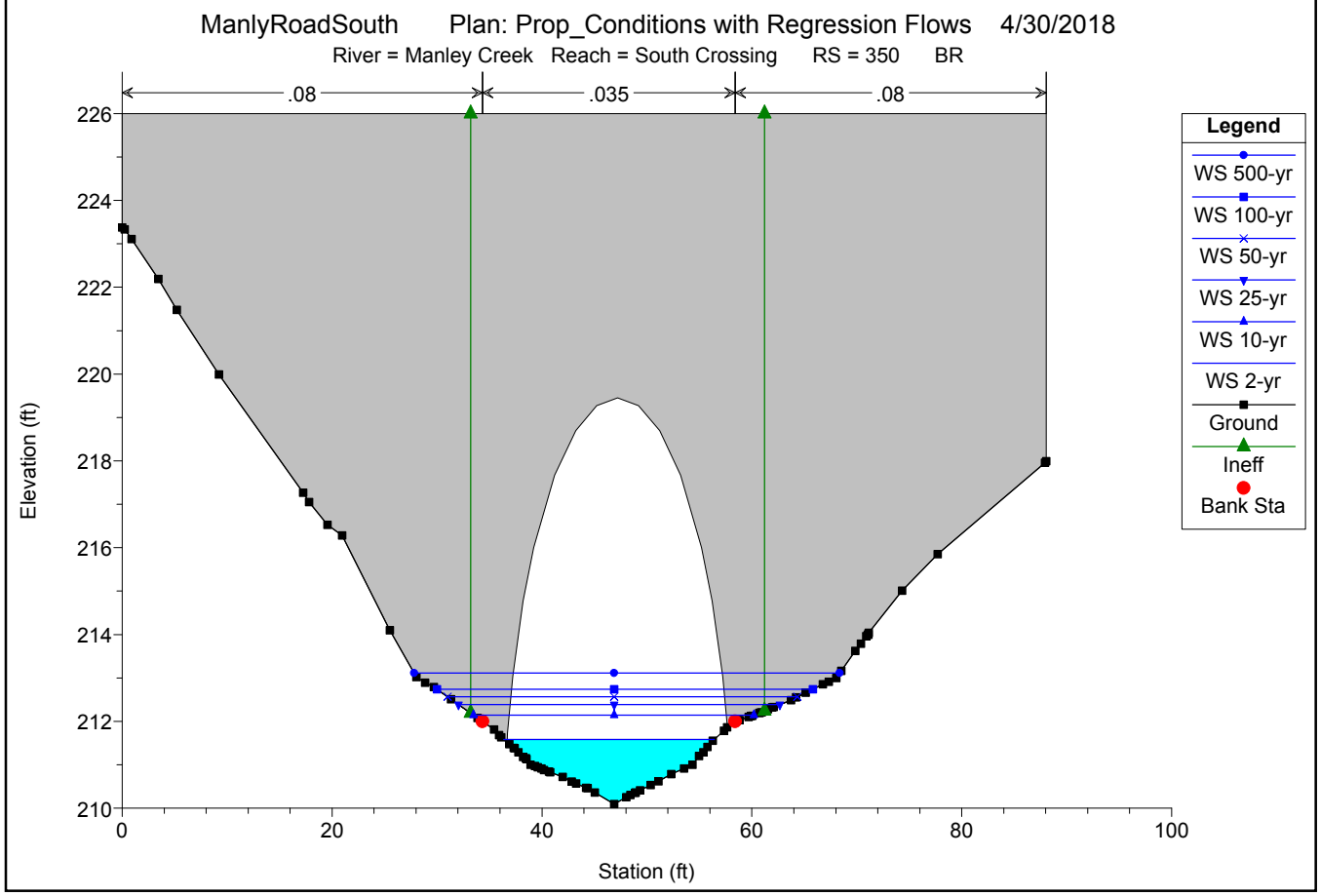
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
South Crossing	505	2-yr	52.60	211.02	212.61		212.71	0.007671	2.63	19.98	32.70	0.59
South Crossing	505	10-yr	111.00	211.02	213.02		213.18	0.006484	3.13	35.42	39.40	0.58
South Crossing	505	25-yr	144.00	211.02	213.22		213.39	0.005941	3.34	43.14	40.84	0.57
South Crossing	505	50-yr	171.00	211.02	213.37		213.56	0.005460	3.45	49.64	42.02	0.56
South Crossing	505	100-yr	199.00	211.02	213.54		213.73	0.004955	3.51	56.64	43.25	0.54
South Crossing	505	500-yr	266.00	211.02	213.93		214.13	0.003858	3.59	74.05	45.17	0.49
South Crossing	443	2-yr	52.60	210.14	212.05		212.20	0.008837	3.10	16.97	24.22	0.65
South Crossing	443	10-yr	111.00	210.14	212.57		212.76	0.006878	3.53	31.41	30.59	0.61
South Crossing	443	25-yr	144.00	210.14	212.81		213.02	0.006008	3.70	38.89	31.84	0.59
South Crossing	443	50-yr	171.00	210.14	213.00		213.22	0.005367	3.79	45.11	32.69	0.57
South Crossing	443	100-yr	199.00	210.14	213.19		213.43	0.004828	3.86	51.61	33.62	0.55
South Crossing	443	500-yr	266.00	210.14	213.64		213.89	0.003894	3.96	67.24	35.73	0.51
South Crossing	384	2-yr	52.60	210.09	211.61	211.30	211.75	0.006402	3.03	17.36	20.33	0.58
South Crossing	384	10-yr	111.00	210.09	212.22	211.75	212.41	0.005074	3.56	31.59	27.93	0.55
South Crossing	384	25-yr	144.00	210.09	212.49	211.94	212.71	0.004419	3.78	39.36	32.34	0.53
South Crossing	384	50-yr	171.00	210.09	212.70	212.09	212.94	0.004069	3.94	45.22	35.31	0.52
South Crossing	384	100-yr	199.00	210.09	212.91	212.22	213.16	0.003803	4.10	50.96	38.55	0.51
South Crossing	384	500-yr	266.00	210.09	213.36	212.49	213.66	0.003368	4.42	63.67	41.88	0.50
South Crossing	350		Bridge									
South Crossing	306	2-yr	52.60	209.33	211.33	210.61	211.41	0.002433	2.29	22.93	19.48	0.37
South Crossing	306	10-yr	111.00	209.33	211.84	211.13	212.01	0.003540	3.30	33.74	23.18	0.47
South Crossing	306	25-yr	144.00	209.33	212.06	211.34	212.28	0.003816	3.74	38.84	26.60	0.50
South Crossing	306	50-yr	171.00	209.33	212.22	211.51	212.48	0.004013	4.07	42.63	28.02	0.52
South Crossing	306	100-yr	199.00	209.33	212.38	211.66	212.67	0.004193	4.38	46.30	30.43	0.54
South Crossing	306	500-yr	266.00	209.33	212.71	211.97	213.10	0.004550	5.03	54.21	34.15	0.57
South Crossing	239	2-yr	52.60	208.97	211.14		211.22	0.003432	2.20	24.26	29.66	0.42
South Crossing	239	10-yr	111.00	208.97	211.64		211.77	0.003204	2.90	39.56	31.71	0.44
South Crossing	239	25-yr	144.00	208.97	211.86		212.02	0.003243	3.22	46.57	32.60	0.46
South Crossing	239	50-yr	171.00	208.97	212.02		212.20	0.003284	3.46	51.86	33.26	0.47
South Crossing	239	100-yr	199.00	208.97	212.17		212.38	0.003319	3.69	57.06	33.90	0.47
South Crossing	239	500-yr	266.00	208.97	212.51		212.77	0.003382	4.15	68.74	35.49	0.49
South Crossing	169	2-yr	52.60	208.73	210.78	210.30	210.90	0.006117	2.77	19.00	24.38	0.55
South Crossing	169	10-yr	111.00	208.73	211.30		211.48	0.005390	3.39	32.73	28.39	0.55
South Crossing	169	25-yr	144.00	208.73	211.52		211.73	0.005241	3.71	39.04	30.18	0.56
South Crossing	169	50-yr	171.00	208.73	211.67		211.91	0.005111	3.94	43.85	30.76	0.56
South Crossing	169	100-yr	199.00	208.73	211.83		212.09	0.005023	4.16	48.57	31.31	0.57
South Crossing	169	500-yr	266.00	208.73	212.15		212.48	0.004905	4.63	59.02	32.51	0.58
South Crossing	100	2-yr	52.60	208.53	210.14	209.92	210.35	0.010011	3.67	14.32	17.48	0.72
South Crossing	100	10-yr	111.00	208.53	210.65	210.42	210.97	0.010019	4.50	24.96	25.78	0.75
South Crossing	100	25-yr	144.00	208.53	210.84	210.63	211.22	0.010002	4.97	29.94	27.88	0.77
South Crossing	100	50-yr	171.00	208.53	210.98	210.78	211.41	0.010001	5.32	33.91	30.16	0.78
South Crossing	100	100-yr	199.00	208.53	211.11	210.91	211.59	0.010015	5.64	37.91	31.30	0.80
South Crossing	100	500-yr	266.00	208.53	211.39	211.21	211.99	0.010008	6.30	46.82	32.01	0.82

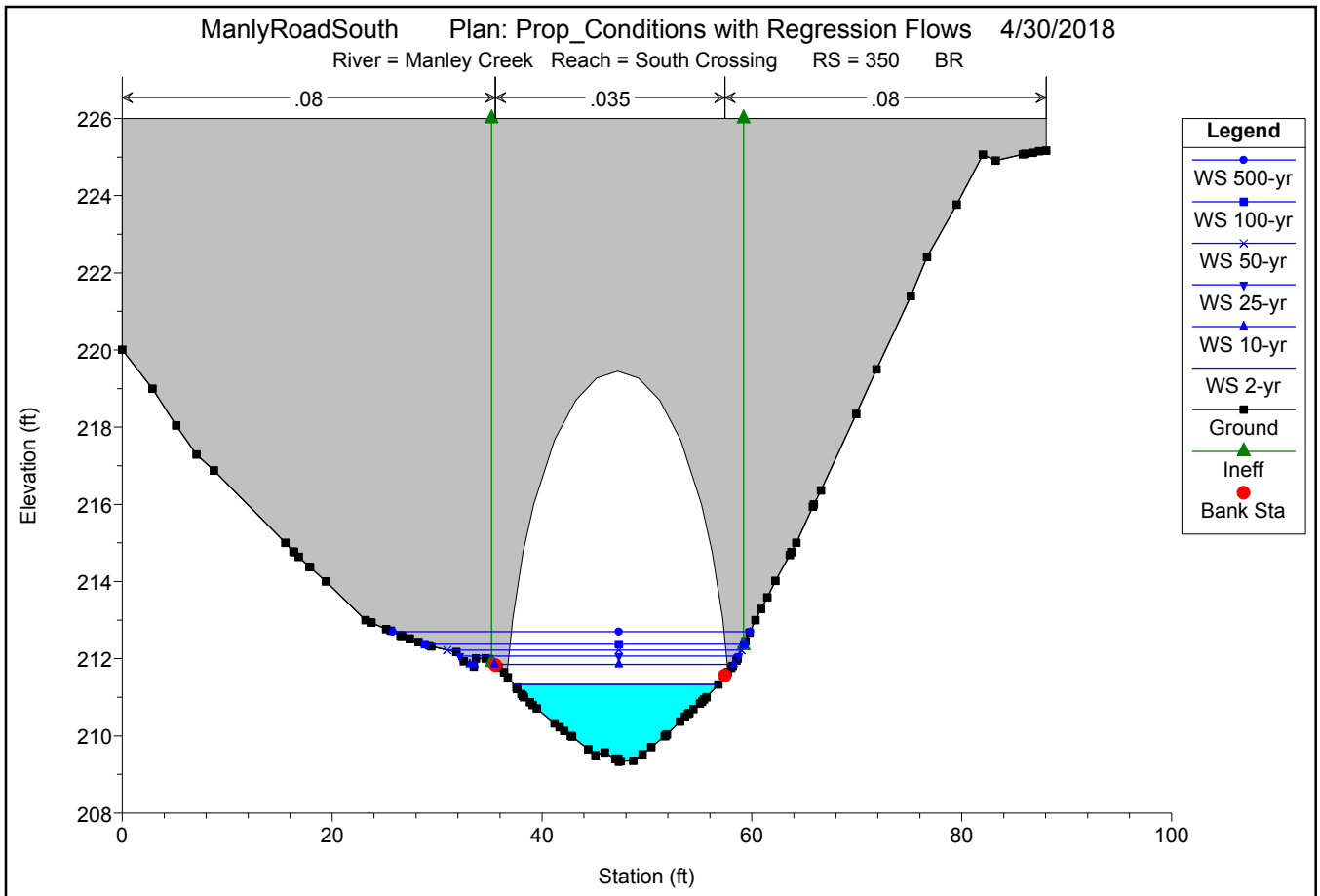

ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
Manley Creek South Crossing
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Elevation (ft)
226
224
222
220
218
216
214
212
210
208
0
100
200
300
400
500
Main Channel Distance (ft)

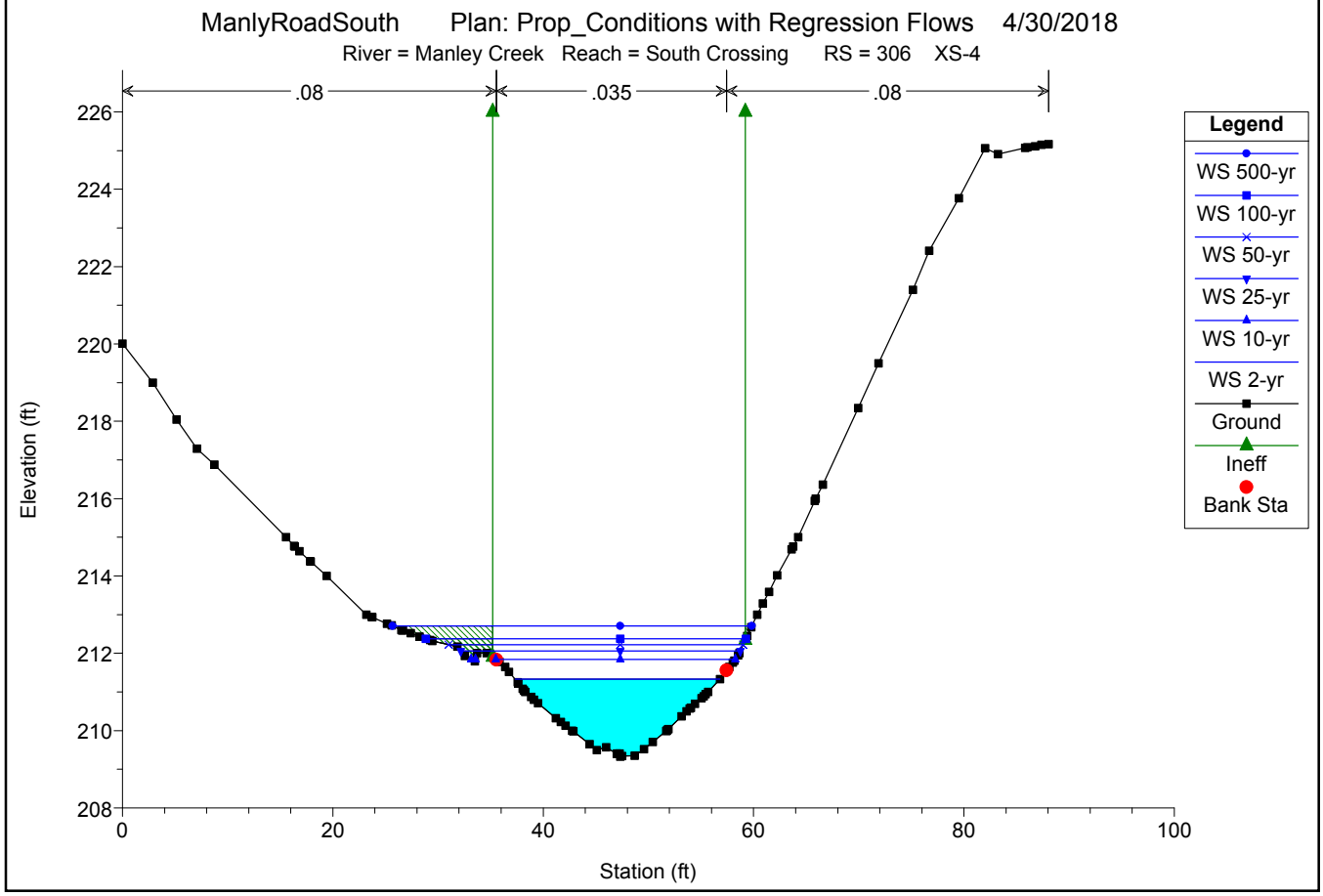

ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 505 XS-7
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
210
215
220
225
230
235
0
20
40
60
80
100
120
140

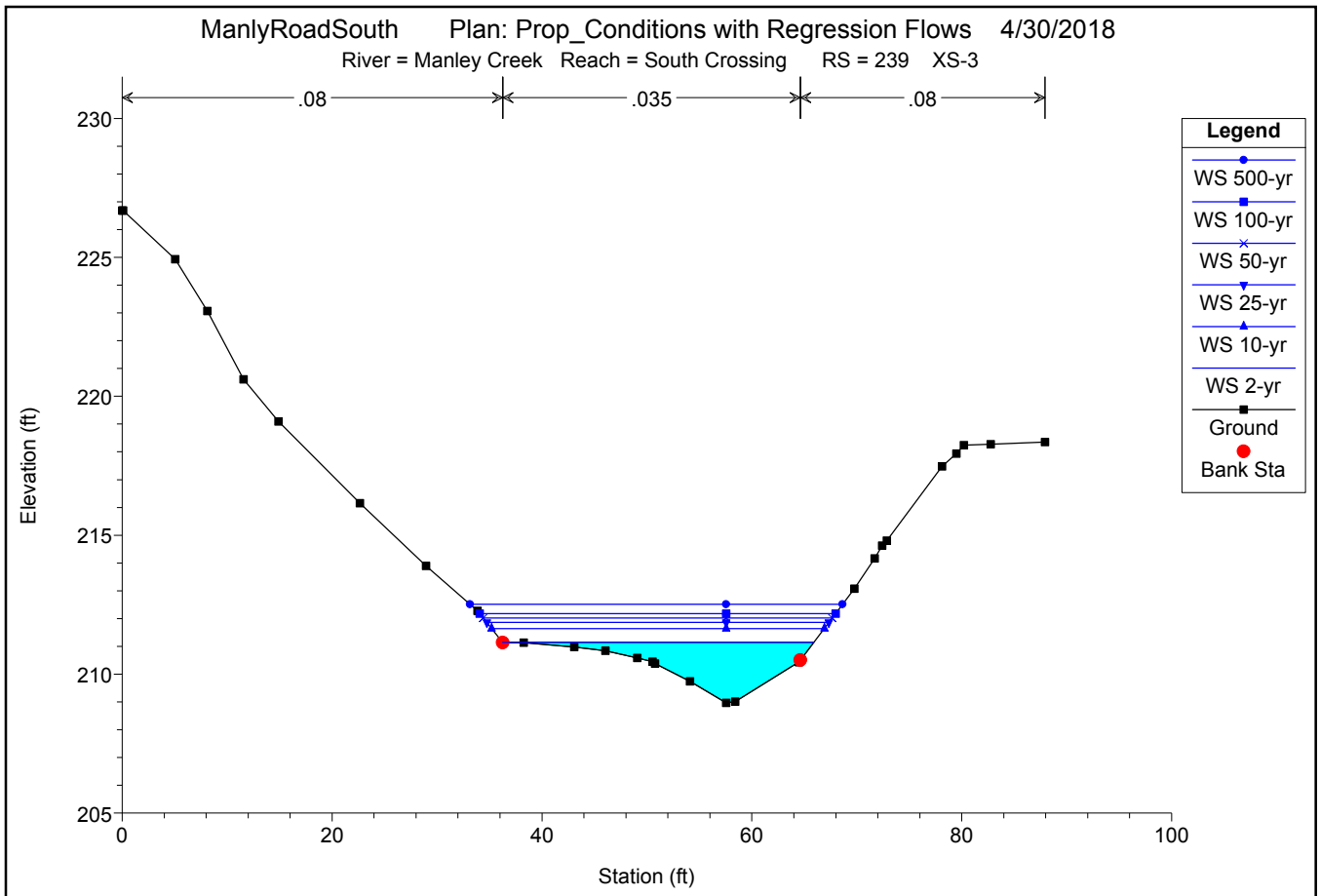

ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 443 XS-6
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
210
215
220
225
230
0
20
40
60
80
100
120

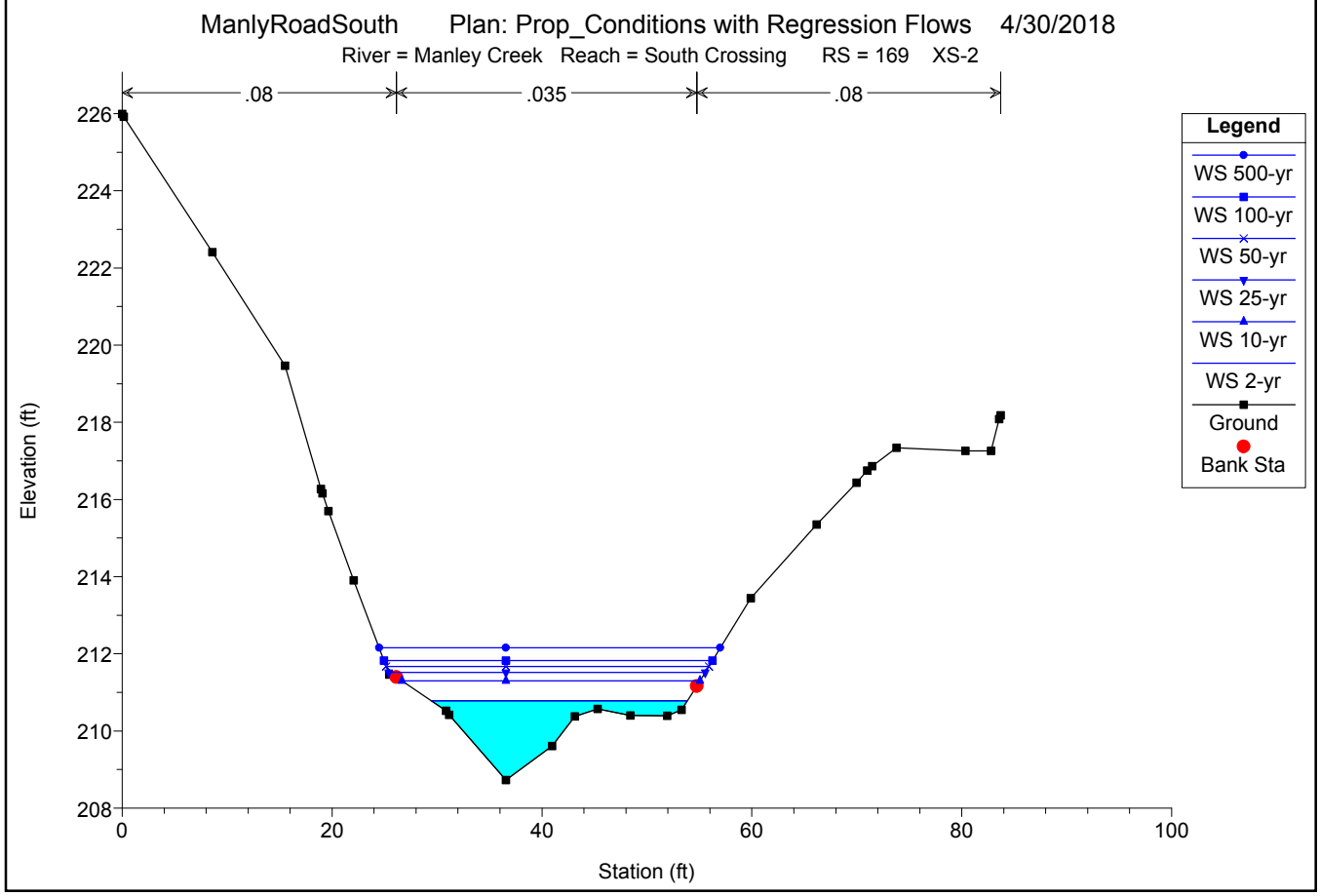

ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 384 XS-5
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
210
212
214
216
218
220
222
224
226
0
20
40
60
80
100

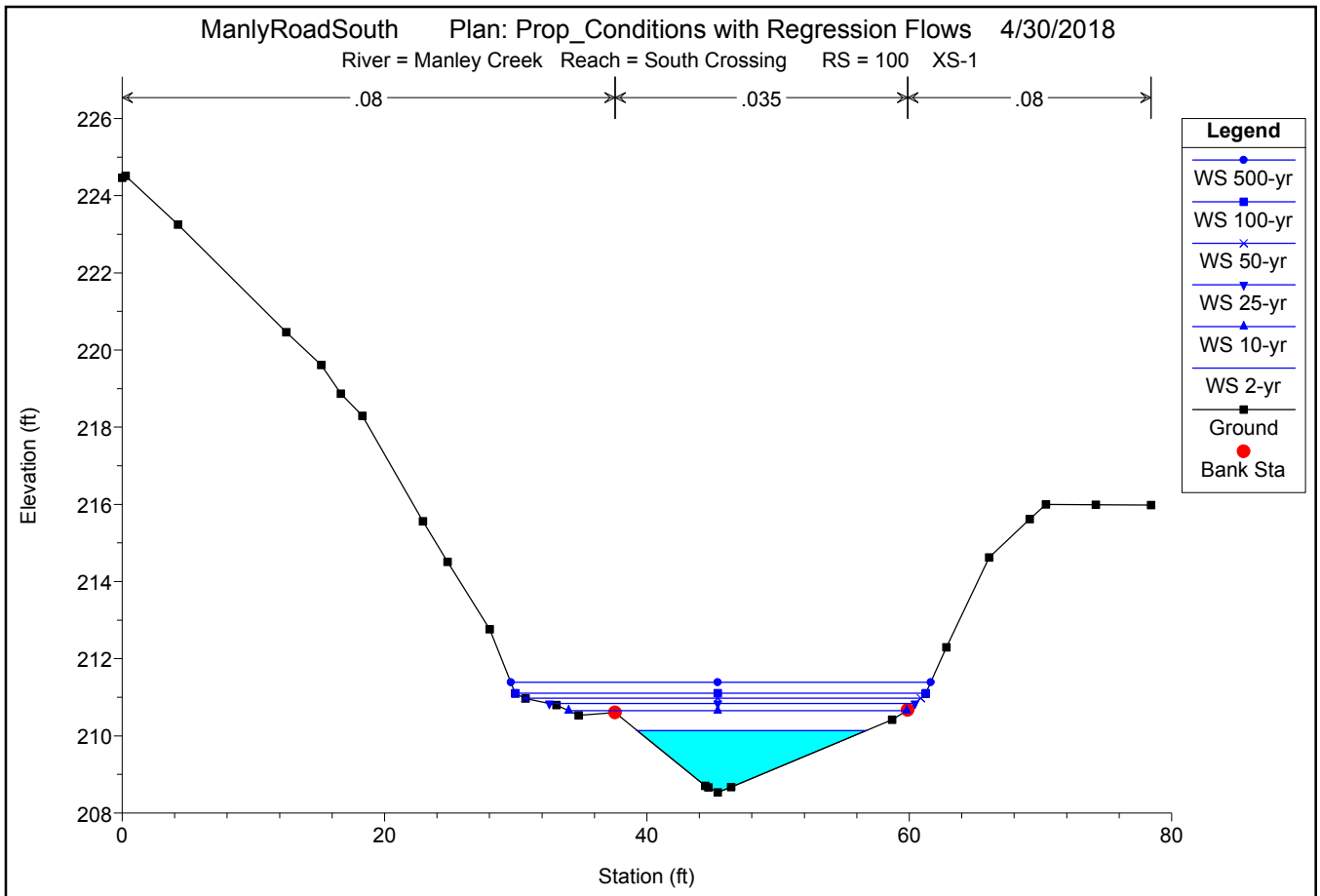

ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 350 BR
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
210
212
214
216
218
220
222
224
226
0
20
40
60
80
100


ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 350 BR
.08
.035
.08
Elevation (ft)
Station (ft)
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta


ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 306 XS-4
.08
.035
.08
Elevation (ft)
Station (ft)
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Ineff
Bank Sta


ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 239 XS-3
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
230
225
220
215
210
205
0
20
40
60
80
100


ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 169 XS-2
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
226
224
222
220
218
216
214
212
210
208
0
20
40
60
80
100

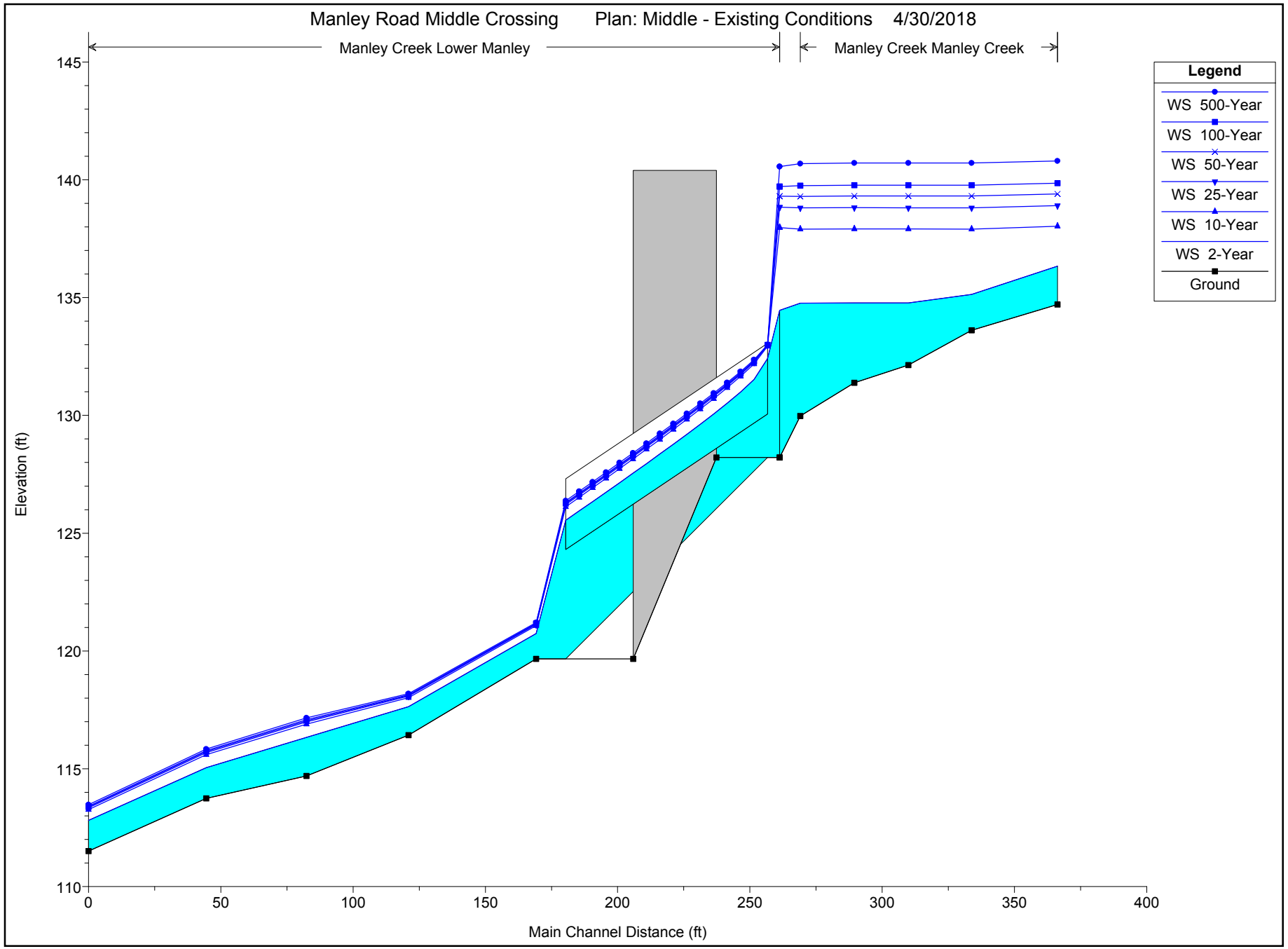

ManlyRoadSouth Plan: Prop_Conditions with Regression Flows 4/30/2018
River = Manley Creek Reach = South Crossing RS = 100 XS-1
.08
.035
.08
Legend
WS 500-yr
WS 100-yr
WS 50-yr
WS 25-yr
WS 10-yr
WS 2-yr
Ground
Bank Sta
Elevation (ft)
226
224
222
220
218
216
214
212
210
208
0
20
40
60
80
Station (ft)

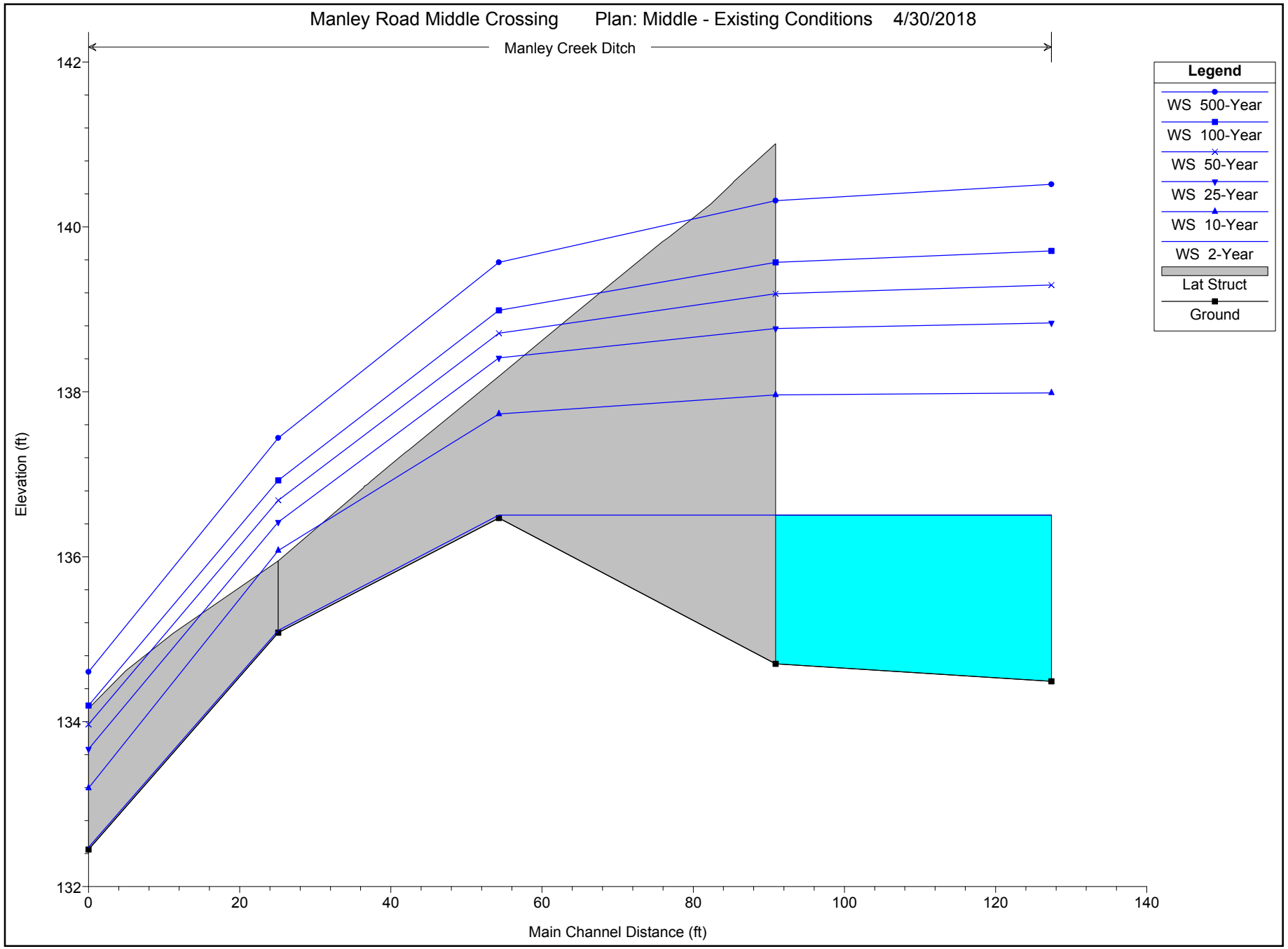
HEC-RAS Plan: MIDDLE-EXTG

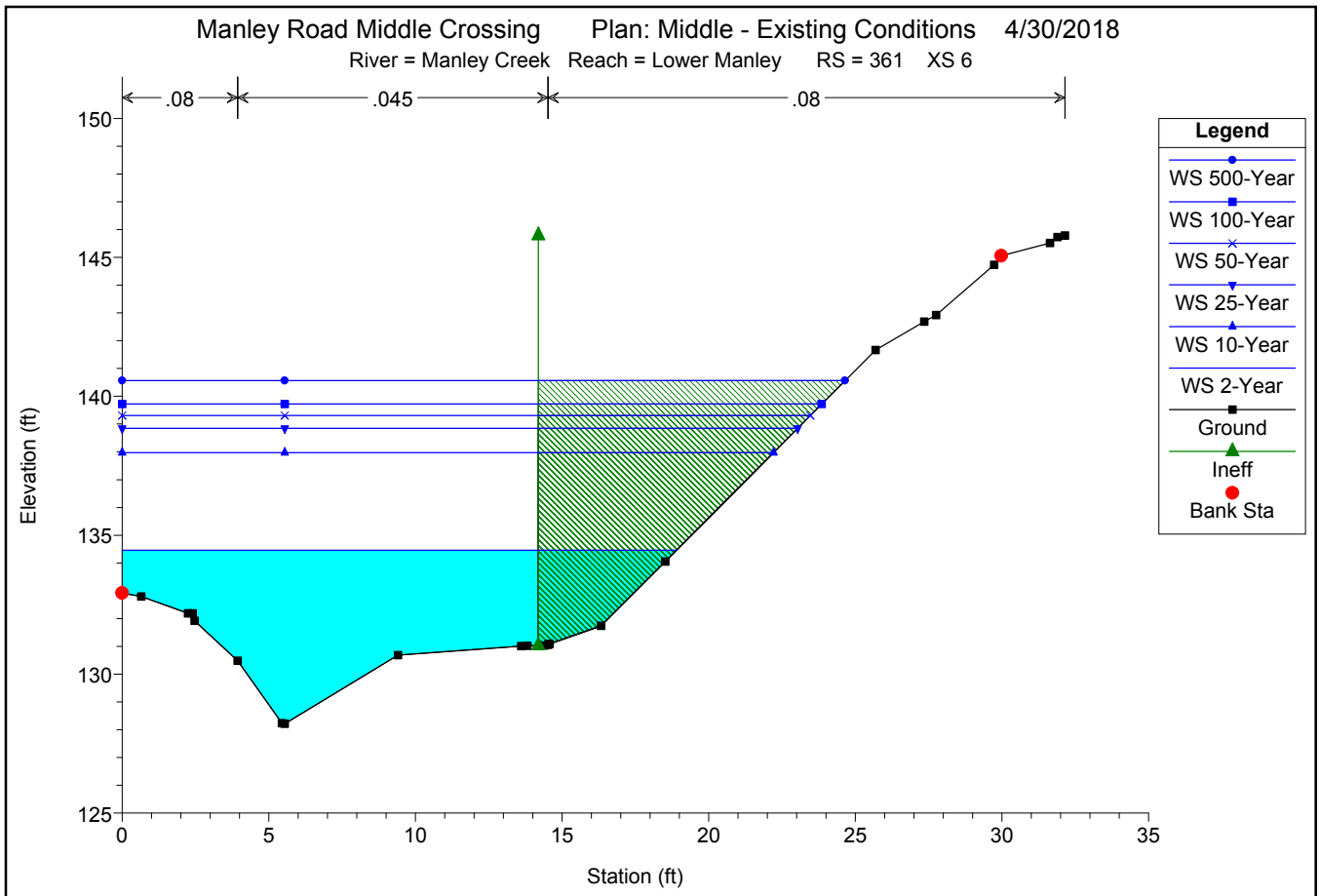
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Manley Creek	466	2-Year	52.60	134.71	136.33		136.59	0.021772	4.04	13.03	16.34	0.80
Manley Creek	466	10-Year	111.00	134.71	138.03		138.09	0.002584	2.06	53.93	27.75	0.26
Manley Creek	466	25-Year	144.00	134.71	138.90		138.96	0.001472	1.82	79.06	29.64	0.20
Manley Creek	466	50-Year	171.00	134.71	139.40		139.45	0.001288	1.82	94.00	30.75	0.18
Manley Creek	466	100-Year	199.00	134.71	139.86		139.91	0.001186	1.84	108.27	31.78	0.18
Manley Creek	466	500-Year	266.00	134.71	140.80		140.86	0.001076	1.91	139.27	33.90	0.17
Manley Creek	434	2-Year	52.60	133.61	135.14	135.14	135.64	0.038205	5.69	9.24	9.38	1.01
Manley Creek	434	10-Year	111.00	133.61	137.91		137.99	0.003586	2.35	47.31	18.45	0.26
Manley Creek	434	25-Year	144.00	133.61	138.81		138.89	0.002717	2.20	65.43	21.58	0.22
Manley Creek	434	50-Year	171.00	133.61	139.31		139.39	0.002597	2.23	76.63	23.35	0.22
Manley Creek	434	100-Year	199.00	133.61	139.77		139.85	0.002517	2.27	87.70	24.98	0.21
Manley Creek	434	500-Year	266.00	133.61	140.72		140.80	0.002390	2.36	112.92	28.34	0.21
Manley Creek	410	2-Year	52.60	132.14	134.77		134.83	0.002947	2.00	26.28	13.90	0.26
Manley Creek	410	10-Year	111.00	132.14	137.91		137.94	0.000805	1.33	83.21	22.99	0.12
Manley Creek	410	25-Year	144.00	132.14	138.82		138.85	0.000759	1.37	105.28	25.88	0.12
Manley Creek	410	50-Year	171.00	132.14	139.31		139.35	0.000797	1.44	118.54	27.47	0.12
Manley Creek	410	100-Year	199.00	132.14	139.77		139.81	0.000834	1.51	131.43	28.94	0.13
Manley Creek	410	500-Year	266.00	132.14	140.71		140.76	0.000907	1.66	160.18	31.96	0.13
Manley Creek	390	2-Year	52.60	131.38	134.77		134.79	0.000716	1.15	45.64	21.18	0.14
Manley Creek	390	10-Year	111.00	131.38	137.92		137.93	0.000239	0.88	125.84	29.52	0.08
Manley Creek	390	25-Year	144.00	131.38	138.82		138.83	0.000242	0.94	153.51	31.77	0.08
Manley Creek	390	50-Year	171.00	131.38	139.32		139.33	0.000263	1.01	169.56	32.78	0.08
Manley Creek	390	100-Year	199.00	131.38	139.77		139.79	0.000285	1.08	184.76	33.71	0.08
Manley Creek	390	500-Year	266.00	131.38	140.72		140.74	0.000333	1.22	217.50	35.63	0.09
Manley Creek	369	2-Year	52.60	129.98	134.77		134.78	0.000282	0.91	57.76	20.09	0.09
Manley Creek	369	10-Year	111.00	129.98	137.91		137.92	0.000192	0.96	115.23	26.02	0.07
Manley Creek	369	25-Year	144.00	129.98	138.81		138.82	0.000219	1.08	133.40	27.72	0.07
Manley Creek	369	50-Year	171.00	129.98	139.30		139.32	0.000254	1.19	143.70	28.65	0.08
Manley Creek	369	100-Year	199.00	129.98	139.75		139.78	0.000289	1.30	153.36	29.50	0.09
Manley Creek	369	500-Year	266.00	129.98	140.69		140.73	0.000372	1.53	173.89	31.26	0.10
Ditch	627	2-Year	0.00	134.49	136.50		136.50	0.000000	0.00	10.99	8.98	0.00
Ditch	627	10-Year	14.59	134.49	137.99		137.99	0.000369	0.52	27.94	13.87	0.06
Ditch	627	25-Year	39.41	134.49	138.84		138.85	0.000973	0.96	40.88	16.67	0.11
Ditch	627	50-Year	62.32	134.49	139.30		139.32	0.001548	1.27	49.00	18.74	0.14
Ditch	627	100-Year	86.75	134.49	139.71		139.75	0.002002	1.52	57.10	20.27	0.16
Ditch	627	500-Year	146.82	134.49	140.52		140.58	0.002763	1.97	74.49	22.52	0.19
Ditch	591	2-Year	0.00	134.70	136.50		136.50	0.000000	0.00	6.43	6.60	0.00
Ditch	591	10-Year	14.59	134.70	137.96		137.97	0.000962	0.75	19.45	11.25	0.10
Ditch	591	25-Year	39.41	134.70	138.77		138.80	0.002298	1.33	29.56	13.83	0.16
Ditch	591	50-Year	62.32	134.70	139.19		139.24	0.003482	1.75	35.68	15.19	0.20
Ditch	591	100-Year	86.75	134.70	139.57		139.64	0.004543	2.08	41.73	16.76	0.23
Ditch	591	500-Year	146.82	134.70	140.32		140.43	0.006372	2.64	55.62	20.33	0.28
Ditch	590		Lat Struct									
Ditch	554	2-Year	0.00	136.47	136.50		136.50	0.023962	0.19	0.01	0.32	0.25
Ditch	554	10-Year	14.59	136.47	137.73		137.86	0.038637	2.81	5.18	7.10	0.58
Ditch	554	25-Year	39.41	136.47	138.41	138.05	138.57	0.038910	3.16	12.47	14.51	0.60
Ditch	554	50-Year	62.32	136.47	138.71	138.38	138.92	0.038168	3.70	16.84	14.90	0.61
Ditch	554	100-Year	86.75	136.47	138.99		139.25	0.037236	4.12	21.06	15.26	0.62
Ditch	554	500-Year	146.82	136.47	139.57		139.94	0.036230	4.87	30.13	16.01	0.63
Ditch	525	2-Year	0.00	135.08	135.11	135.11	135.11	0.135302	0.38	0.00	0.20	0.57
Ditch	525	10-Year	14.59	135.08	136.07	136.07	136.26	0.082965	3.65	4.52	10.54	0.83
Ditch	525	25-Year	39.41	135.08	136.42	136.42	136.79	0.103412	5.22	8.27	11.08	0.98
Ditch	525	50-Year	62.32	135.08	136.68	136.68	137.17	0.103325	5.95	11.23	11.50	1.01
Ditch	525	100-Year	86.75	135.08	136.93	136.93	137.53	0.101984	6.52	14.09	11.88	1.03
Ditch	525	500-Year	146.82	135.08	137.44	137.44	138.25	0.098640	7.53	20.38	12.69	1.05
Ditch	524		Lat Struct									
Ditch	500	2-Year	0.00	132.45	132.48	132.48	132.48	0.009314	0.10	0.01	0.75	0.15
Ditch	500	10-Year	14.59	132.45	133.19	133.19	133.44	0.126075	3.96	3.68	7.67	1.01
Ditch	500	25-Year	39.41	132.45	133.67	133.67	134.03	0.109015	4.86	8.12	11.14	1.00
Ditch	500	50-Year	62.32	132.45	133.97	133.97	134.39	0.105772	5.21	11.96	14.46	1.01
Ditch	500	100-Year	86.75	132.45	134.20	134.20	134.68	0.103694	5.58	15.55	16.68	1.02
Ditch	500	500-Year	146.82	132.45	134.60	134.60	135.27	0.095301	6.53	22.49	17.43	1.01
Lower Manley	361	2-Year	52.60	128.21	134.46	131.00	134.48	0.000344	0.97	54.36	18.91	0.09
Lower Manley	361	10-Year	96.41	128.21	137.98	131.48	137.99	0.000188	0.92	104.24	22.21	0.06
Lower Manley	361	25-Year	104.59	128.21	138.84	131.56	138.86	0.000164	0.90	116.55	23.03	0.06
Lower Manley	361	50-Year	108.68	128.21	139.30	131.59	139.32	0.000154	0.88	123.07	23.46	0.05

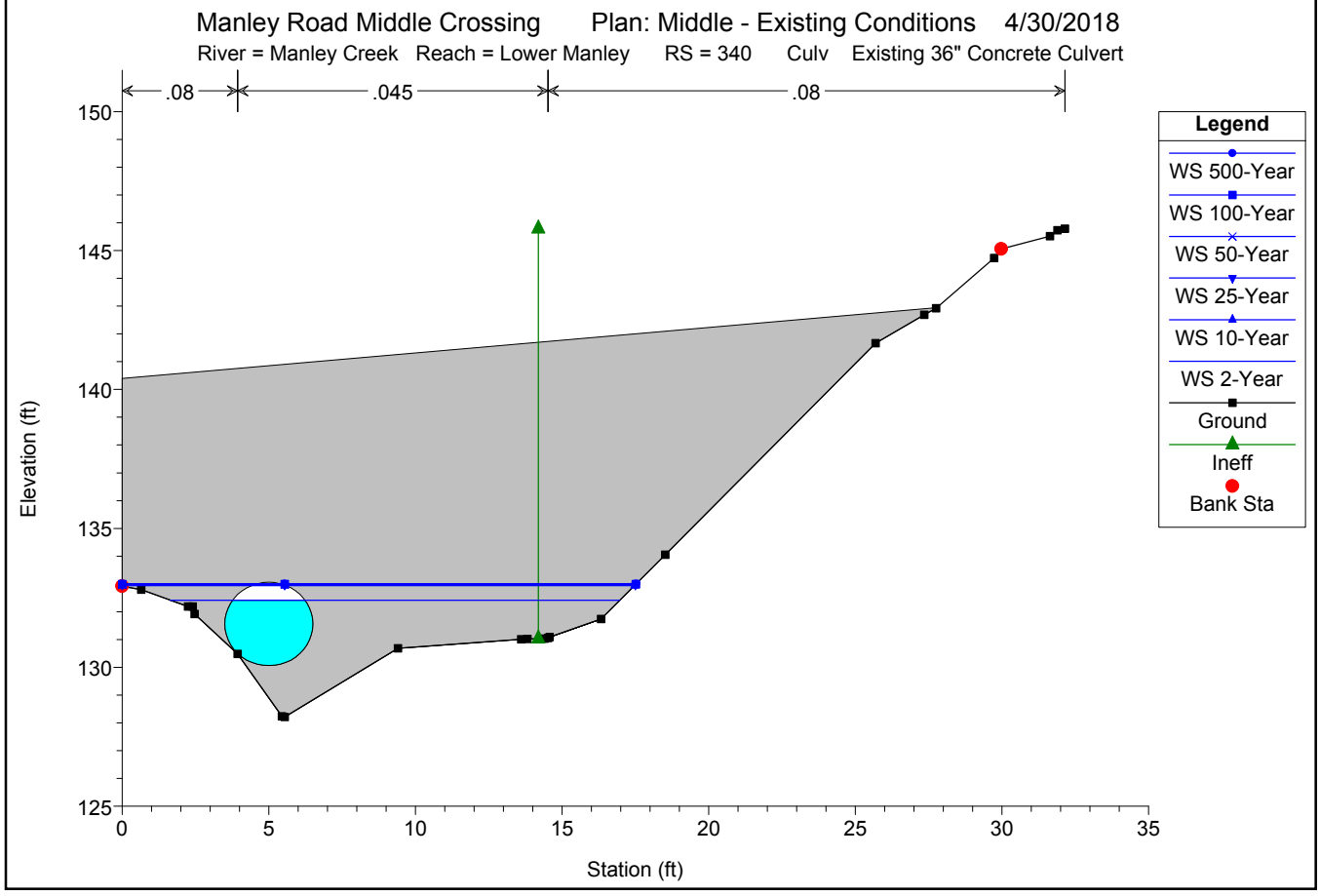
HEC-RAS Plan: MIDDLE-EXTG (Continued)

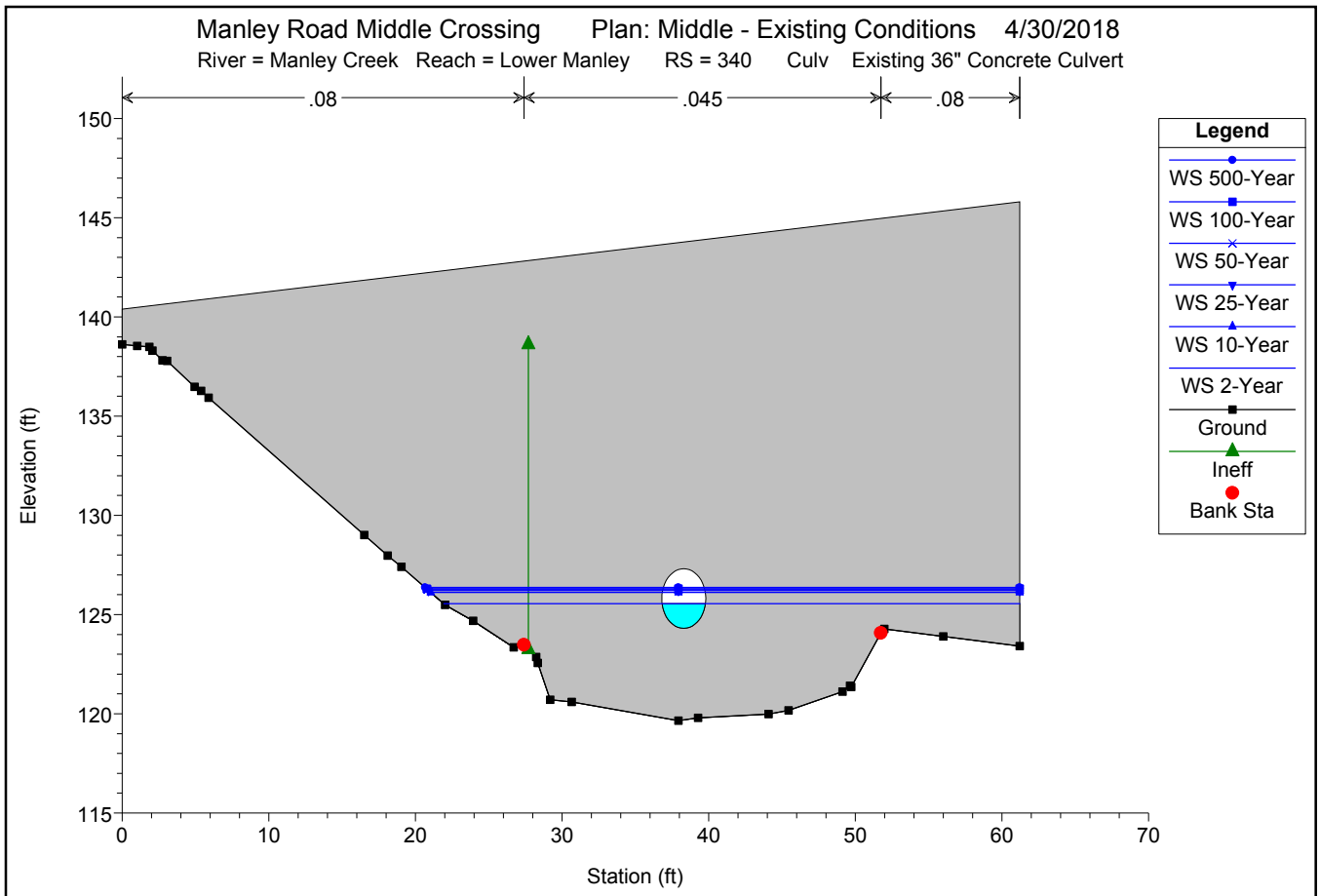
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Lower Manley	361	100-Year	112.25	128.21	139.72	131.64	139.73	0.000145	0.87	128.96	23.85	0.05
Lower Manley	361	500-Year	119.18	128.21	140.57	131.68	140.58	0.000130	0.85	141.00	24.65	0.05
Lower Manley	340		Culvert									
Lower Manley	269	2-Year	52.60	119.66	120.74	120.74	121.06	0.035521	4.53	11.60	18.47	1.01
Lower Manley	269	10-Year	96.41	119.66	121.07	121.07	121.52	0.031465	5.38	17.91	19.89	1.00
Lower Manley	269	25-Year	104.59	119.66	121.12	121.12	121.60	0.031413	5.53	18.91	20.11	1.01
Lower Manley	269	50-Year	108.68	119.66	121.15	121.15	121.63	0.030992	5.58	19.46	20.17	1.00
Lower Manley	269	100-Year	112.25	119.66	121.17	121.17	121.66	0.030984	5.65	19.87	20.22	1.00
Lower Manley	269	500-Year	119.18	119.66	121.21	121.21	121.72	0.030539	5.75	20.74	20.31	1.00
Lower Manley	221	2-Year	52.60	116.43	117.64	117.64	118.01	0.035224	4.93	10.68	14.54	1.01
Lower Manley	221	10-Year	96.41	116.43	118.02	118.02	118.55	0.031684	5.85	16.48	15.85	1.01
Lower Manley	221	25-Year	104.59	116.43	118.08	118.08	118.64	0.031177	5.98	17.48	16.02	1.01
Lower Manley	221	50-Year	108.68	116.43	118.11	118.11	118.68	0.031014	6.05	17.96	16.10	1.01
Lower Manley	221	100-Year	112.25	116.43	118.14	118.14	118.72	0.030924	6.11	18.37	16.17	1.01
Lower Manley	221	500-Year	119.18	116.43	118.18	118.18	118.79	0.030704	6.23	19.14	16.25	1.01
Lower Manley	182	2-Year	52.60	114.69	116.34		116.64	0.022073	4.45	11.81	12.47	0.81
Lower Manley	182	10-Year	96.41	114.69	116.89		117.29	0.018814	5.08	18.97	13.23	0.75
Lower Manley	182	25-Year	104.59	114.69	116.99		117.40	0.018393	5.16	20.27	13.42	0.74
Lower Manley	182	50-Year	108.68	114.69	117.04		117.46	0.018204	5.19	20.93	13.54	0.74
Lower Manley	182	100-Year	112.25	114.69	117.08		117.51	0.018041	5.22	21.50	13.63	0.73
Lower Manley	182	500-Year	119.18	114.69	117.16		117.59	0.017721	5.27	22.61	13.82	0.73
Lower Manley	145	2-Year	52.60	113.74	115.04	115.04	115.58	0.034508	5.88	8.95	8.50	1.01
Lower Manley	145	10-Year	96.41	113.74	115.60	115.60	116.34	0.032262	6.93	13.91	9.45	1.01
Lower Manley	145	25-Year	104.59	113.74	115.69	115.69	116.47	0.032028	7.08	14.77	9.60	1.01
Lower Manley	145	50-Year	108.68	113.74	115.73	115.73	116.53	0.031908	7.16	15.19	9.68	1.01
Lower Manley	145	100-Year	112.25	113.74	115.77	115.77	116.58	0.031818	7.22	15.55	9.74	1.01
Lower Manley	145	500-Year	119.18	113.74	115.84	115.84	116.67	0.031727	7.33	16.25	9.86	1.01
Lower Manley	100	2-Year	52.60	111.50	112.81	112.81	113.25	0.033358	5.32	9.88	11.45	1.01
Lower Manley	100	10-Year	96.41	111.50	113.27	113.27	113.87	0.030500	6.24	15.46	13.03	1.01
Lower Manley	100	25-Year	104.59	111.50	113.34	113.34	113.97	0.030149	6.37	16.43	13.29	1.01
Lower Manley	100	50-Year	108.68	111.50	113.38	113.38	114.02	0.029985	6.43	16.91	13.42	1.01
Lower Manley	100	100-Year	112.25	111.50	113.41	113.41	114.06	0.029854	6.48	17.32	13.52	1.01
Lower Manley	100	500-Year	119.18	111.50	113.47	113.47	114.14	0.029287	6.55	18.19	13.74	1.00

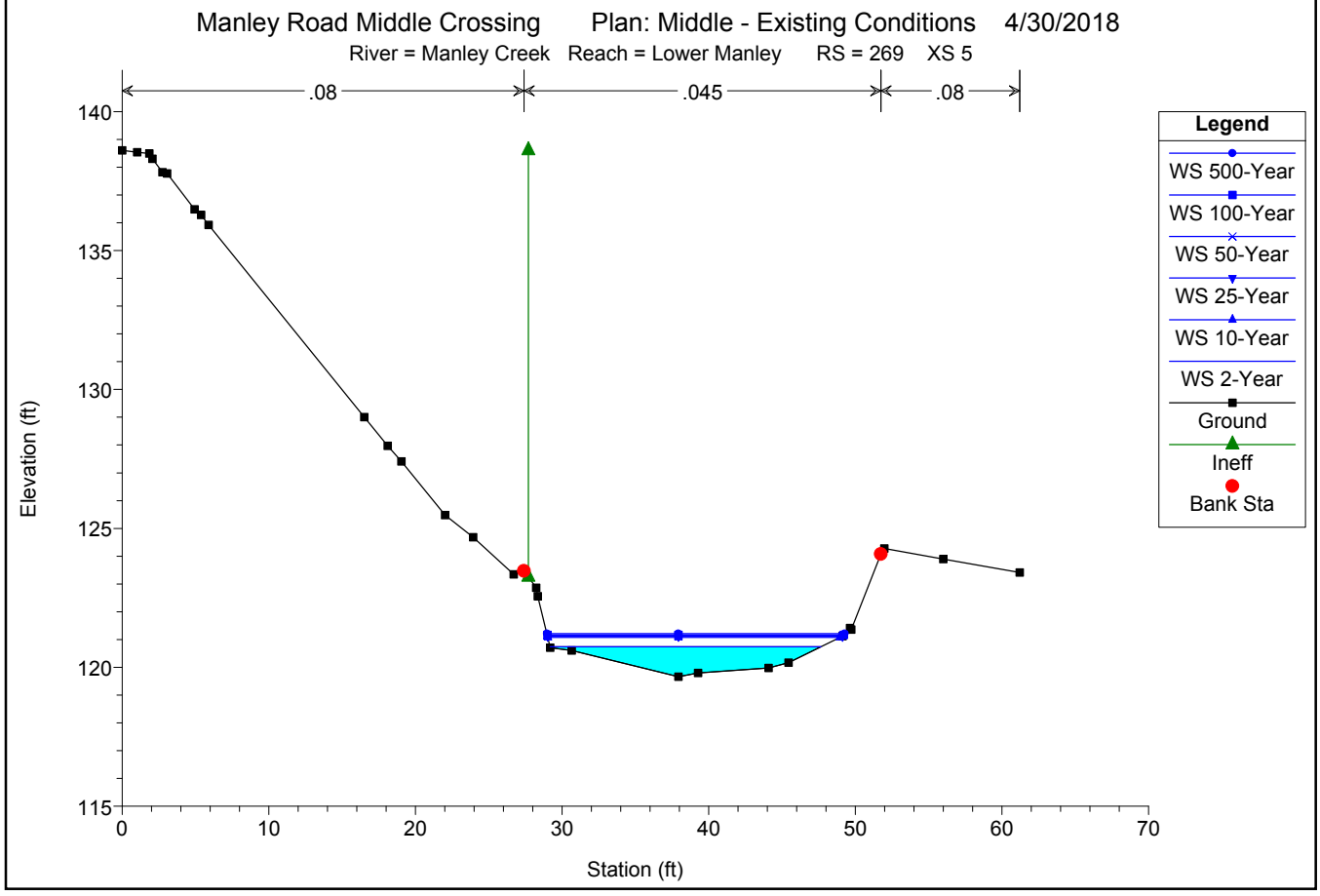

Manley Road Middle Crossing
Plan: Middle - Existing Conditions
4/30/2018
Manley Creek Lower Manley
Manley Creek Manley Creek
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
145
140
135
130
125
120
115
110
0
50
100
150
200
250
300
350
400

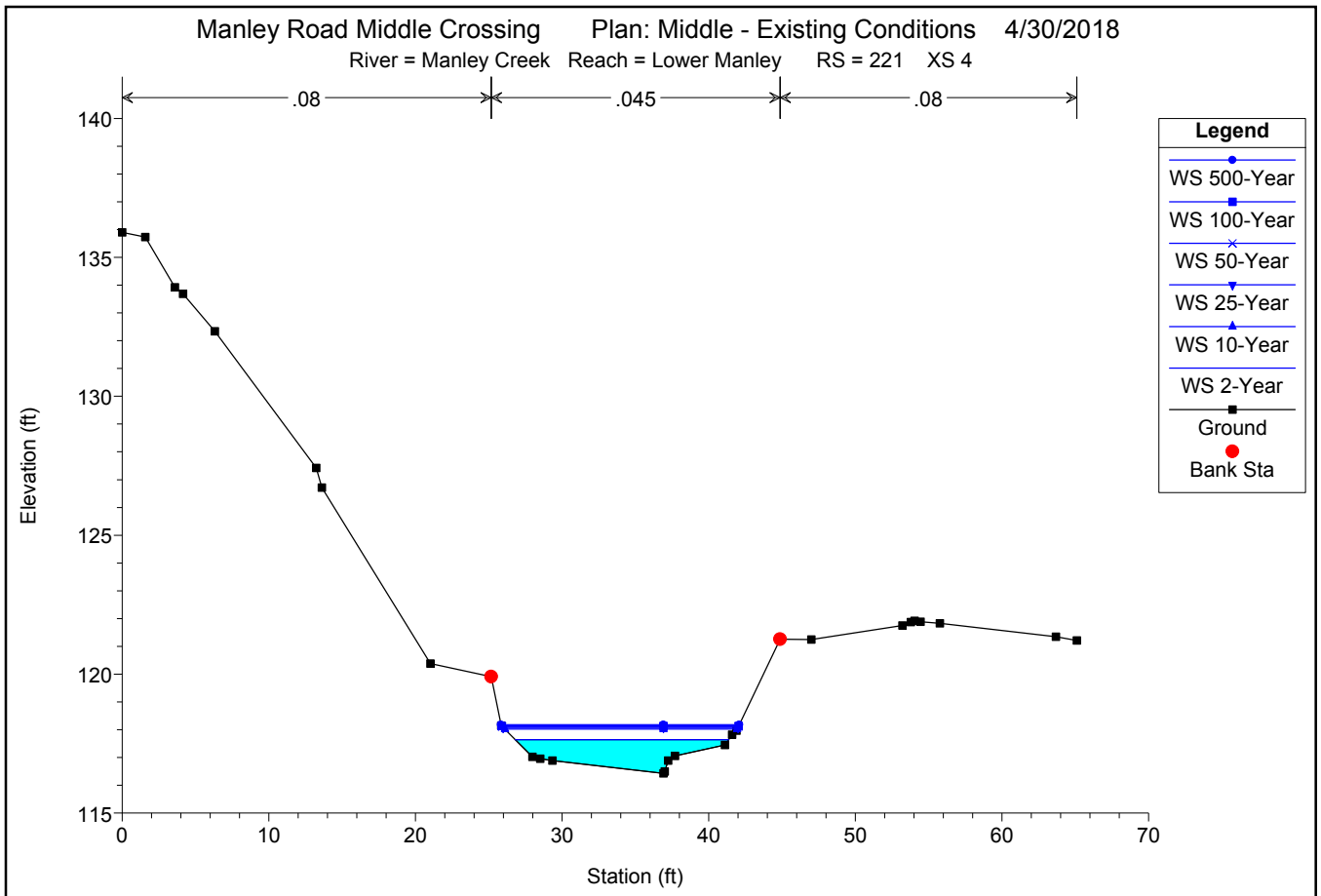

Manley Road Middle Crossing
Plan: Middle - Existing Conditions
4/30/2018
Manley Creek Ditch
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Lat Struct
Ground
Elevation (ft)
142
140
138
136
134
132
0
20
40
60
80
100
120
140
Main Channel Distance (ft)

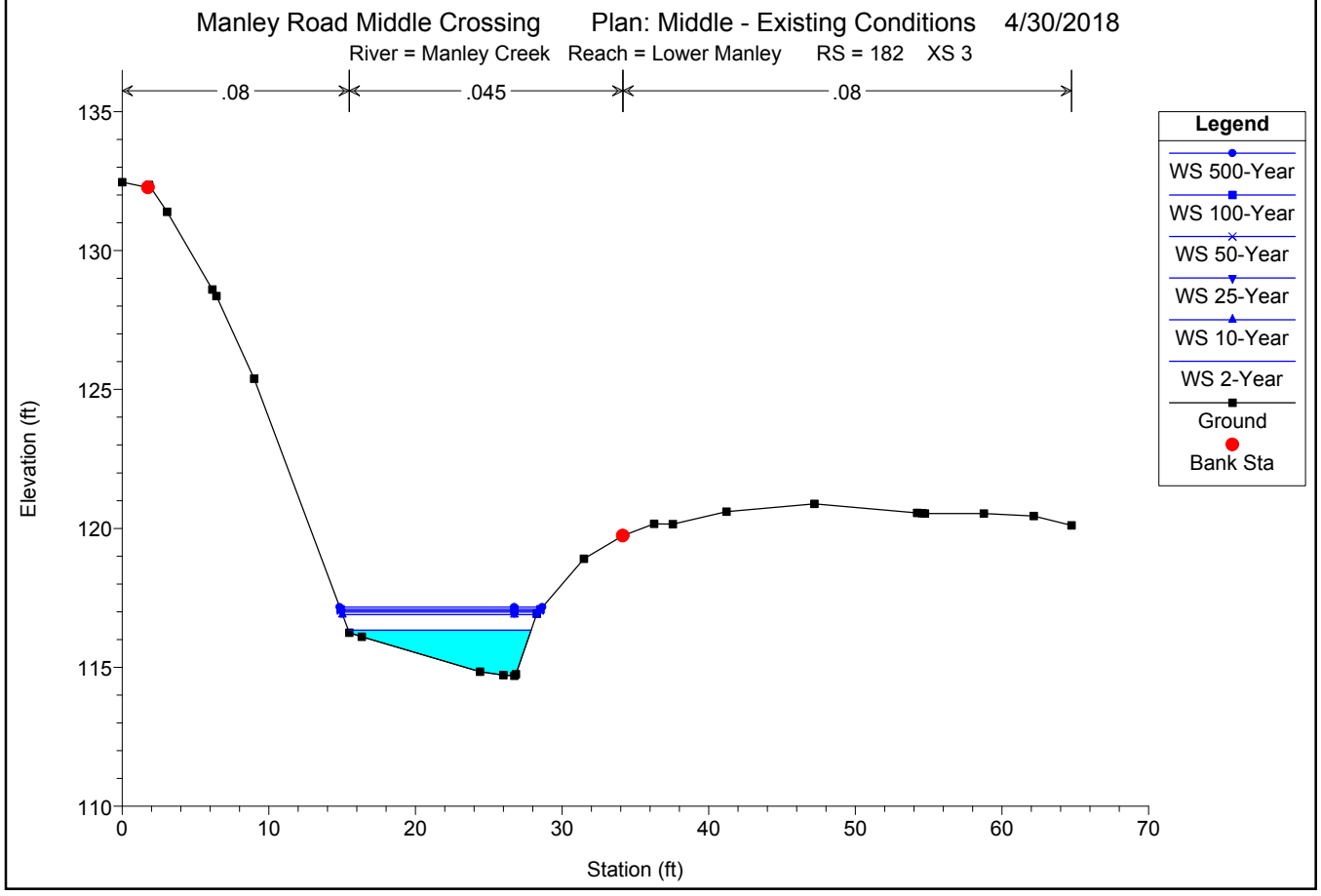

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 361 XS 6
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

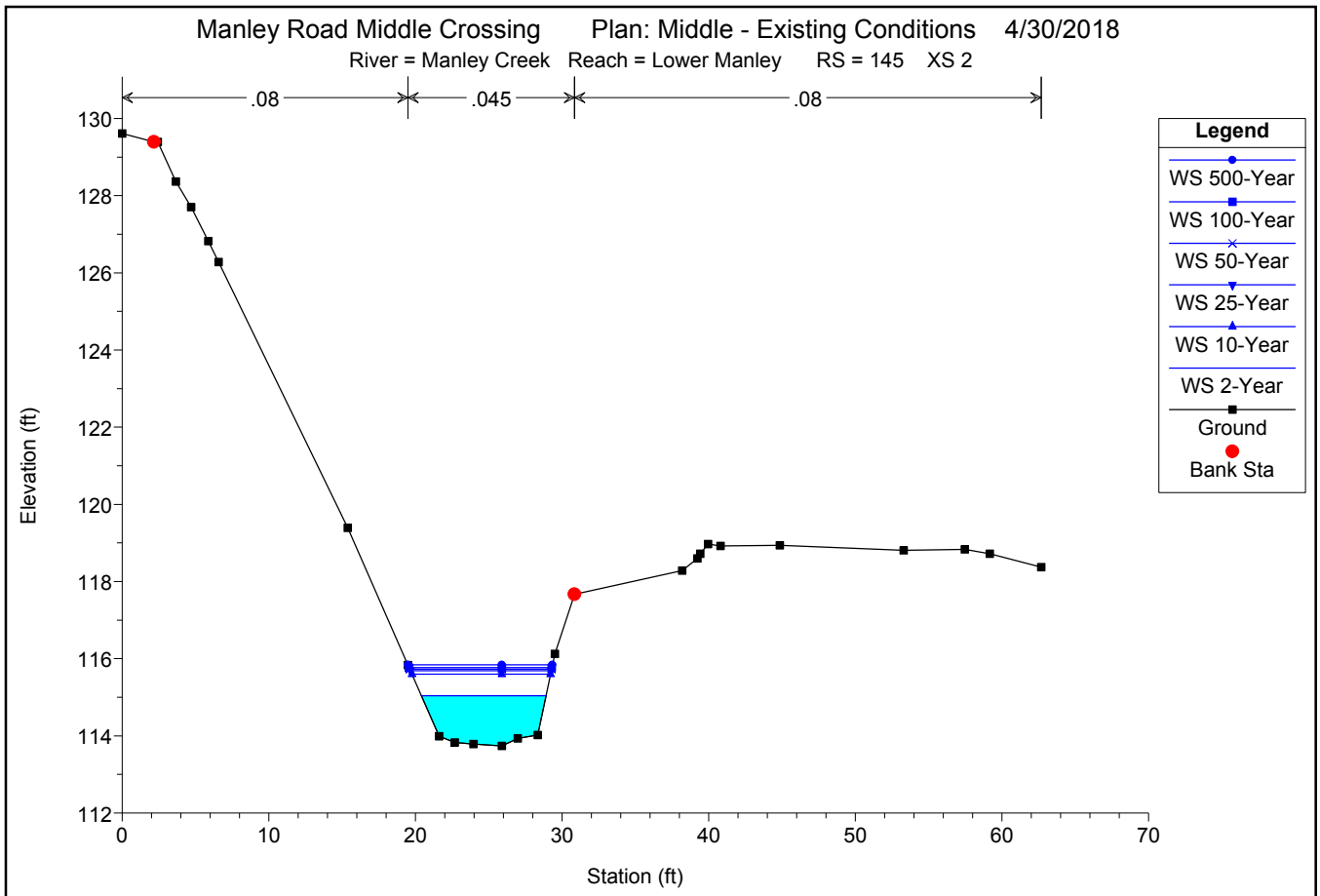

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 340 Culv Existing 36" Concrete Culvert
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

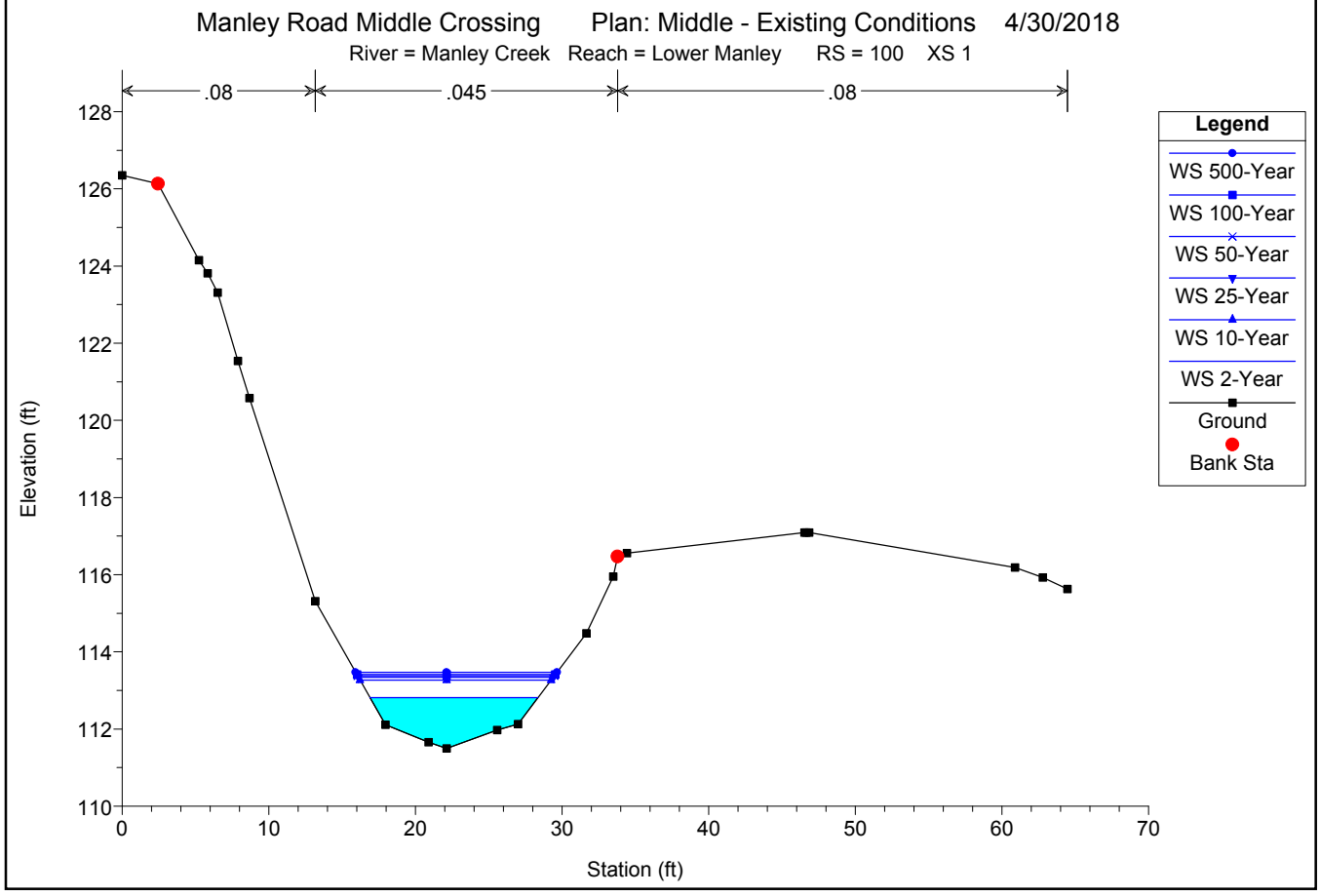

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 340 Culv Existing 36" Concrete Culvert
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

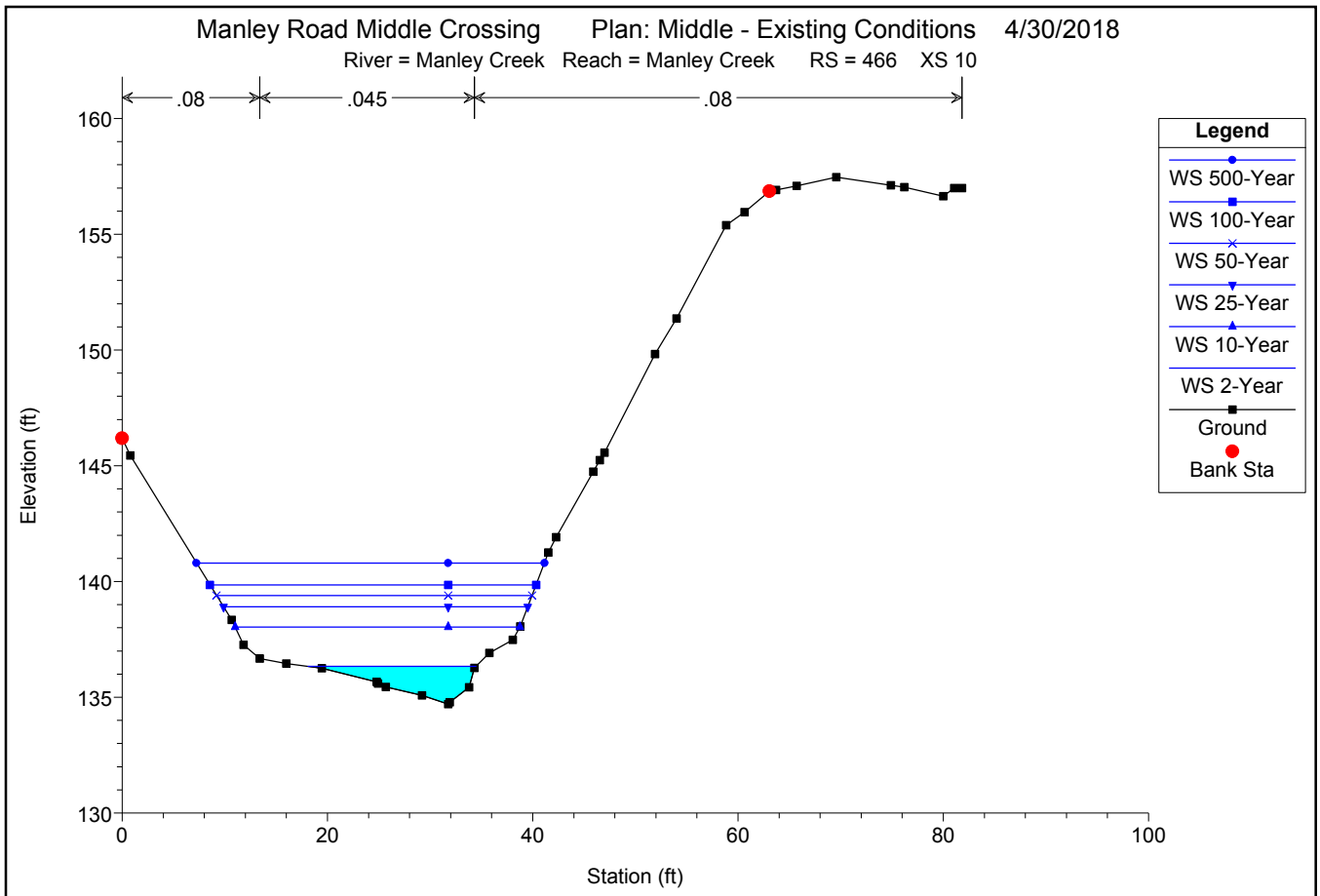

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 269 XS 5
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

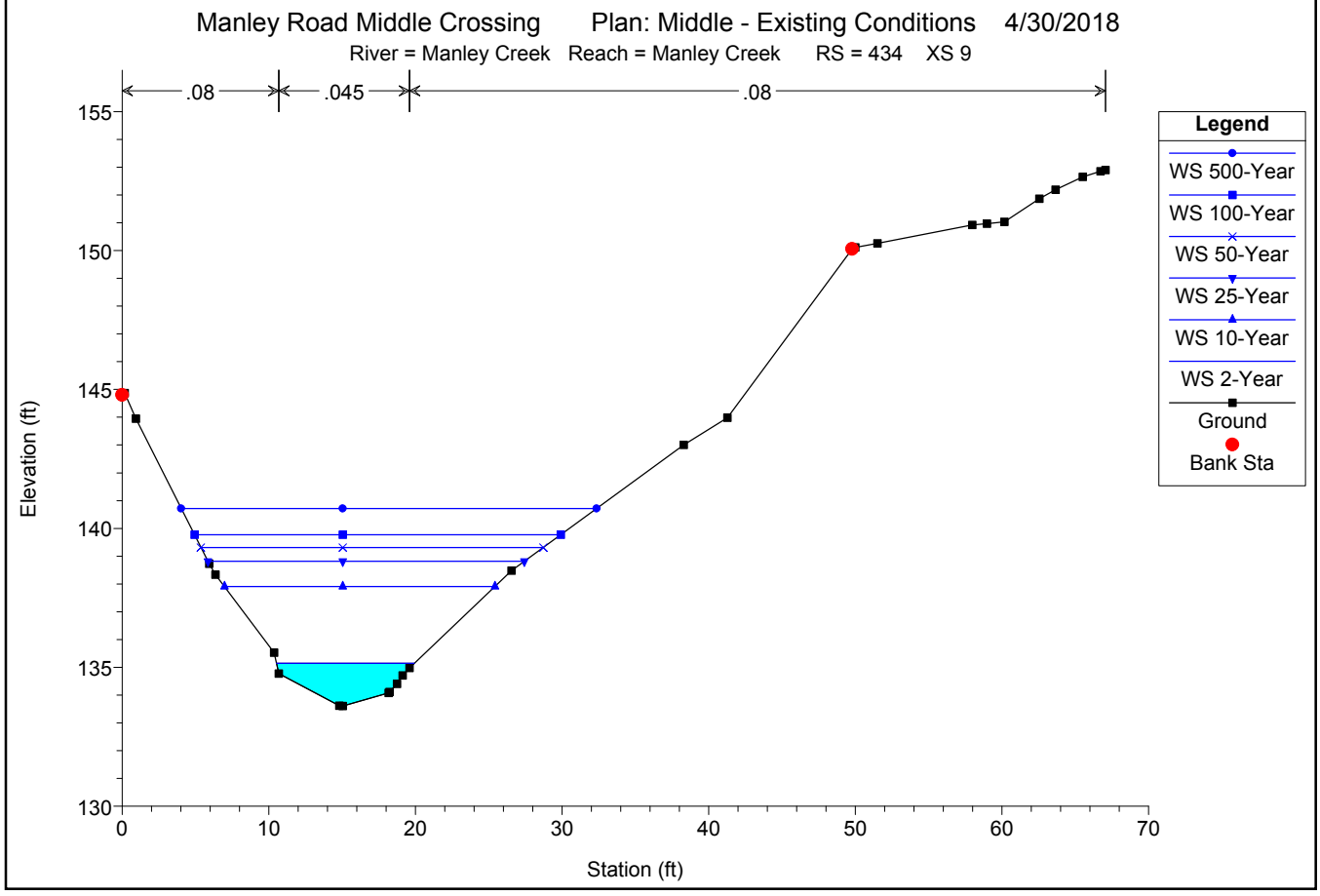

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 221 XS 4
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
140
135
130
125
120
115
0
10
20
30
40
50
60
70

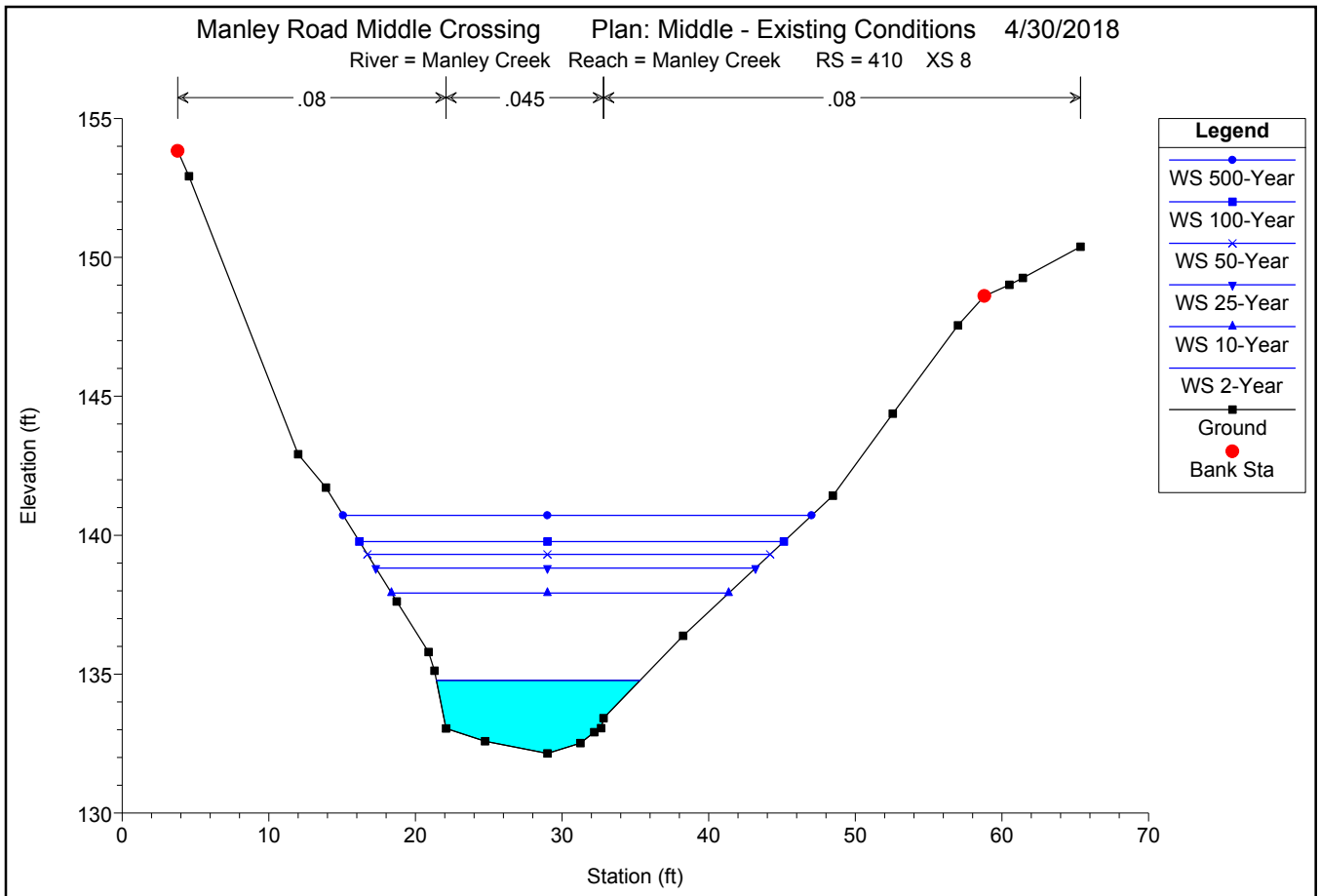

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 182 XS 3
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
135
130
125
120
115
110
0
10
20
30
40
50
60
70

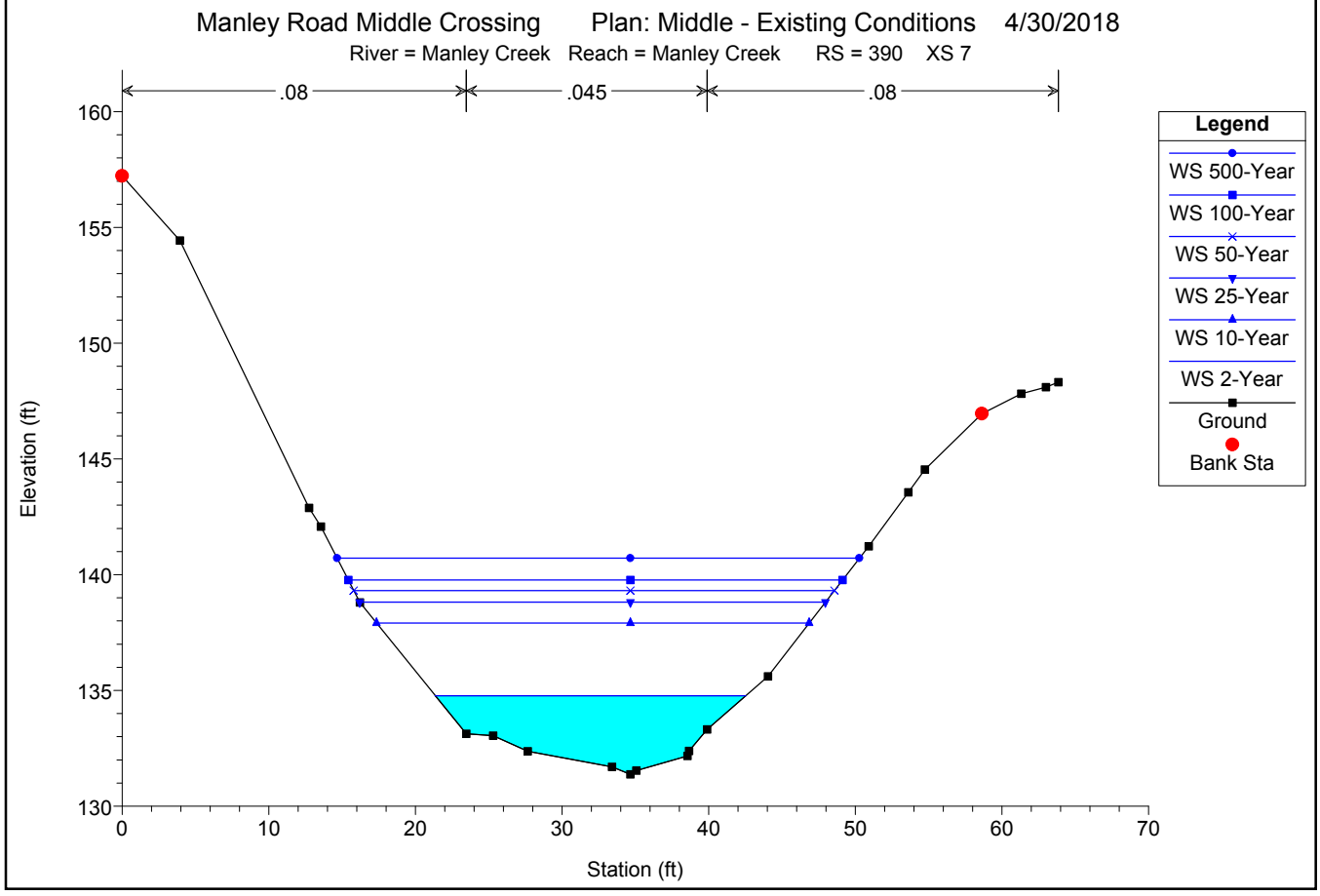

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 145 XS 2
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

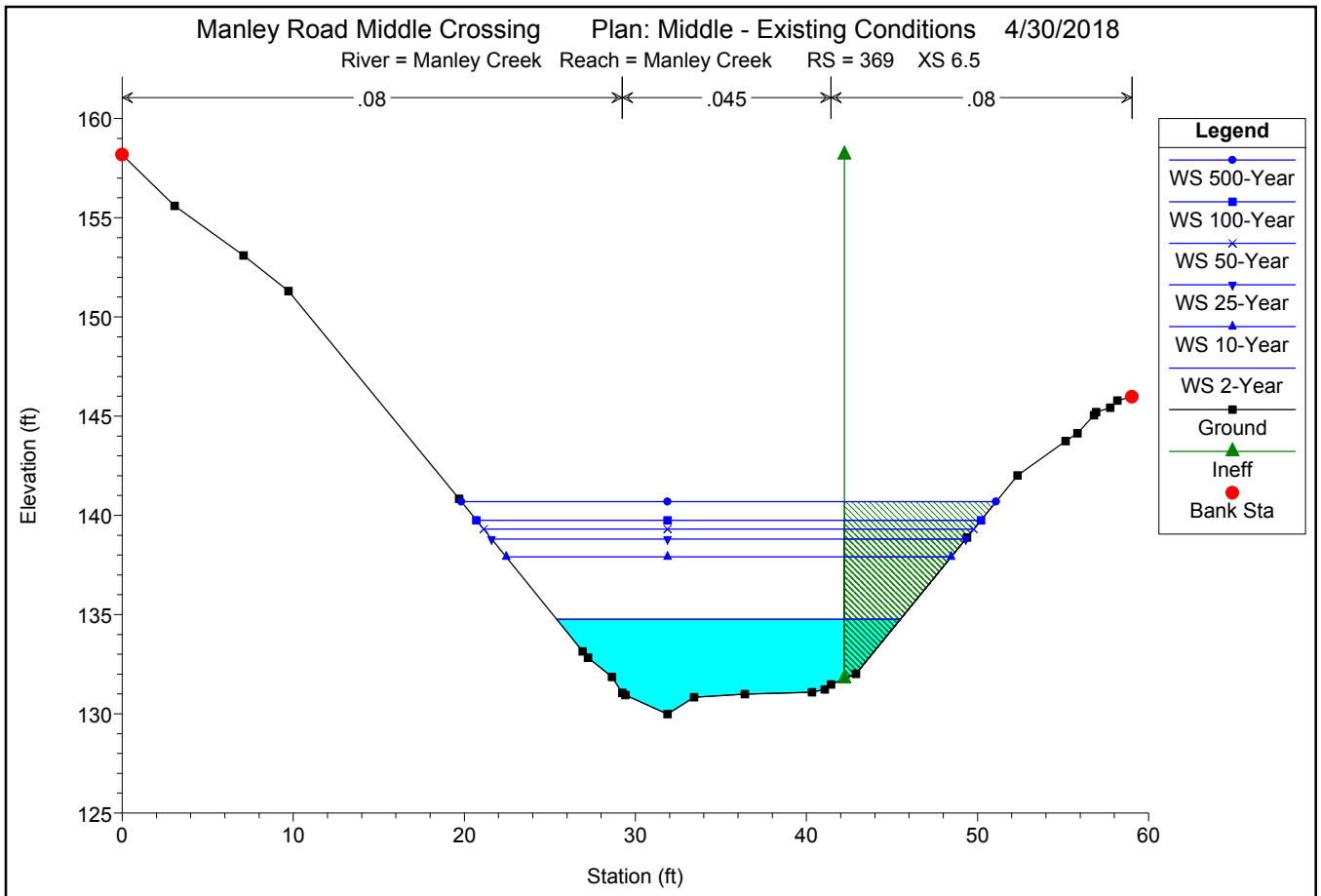

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Lower Manley RS = 100 XS 1
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

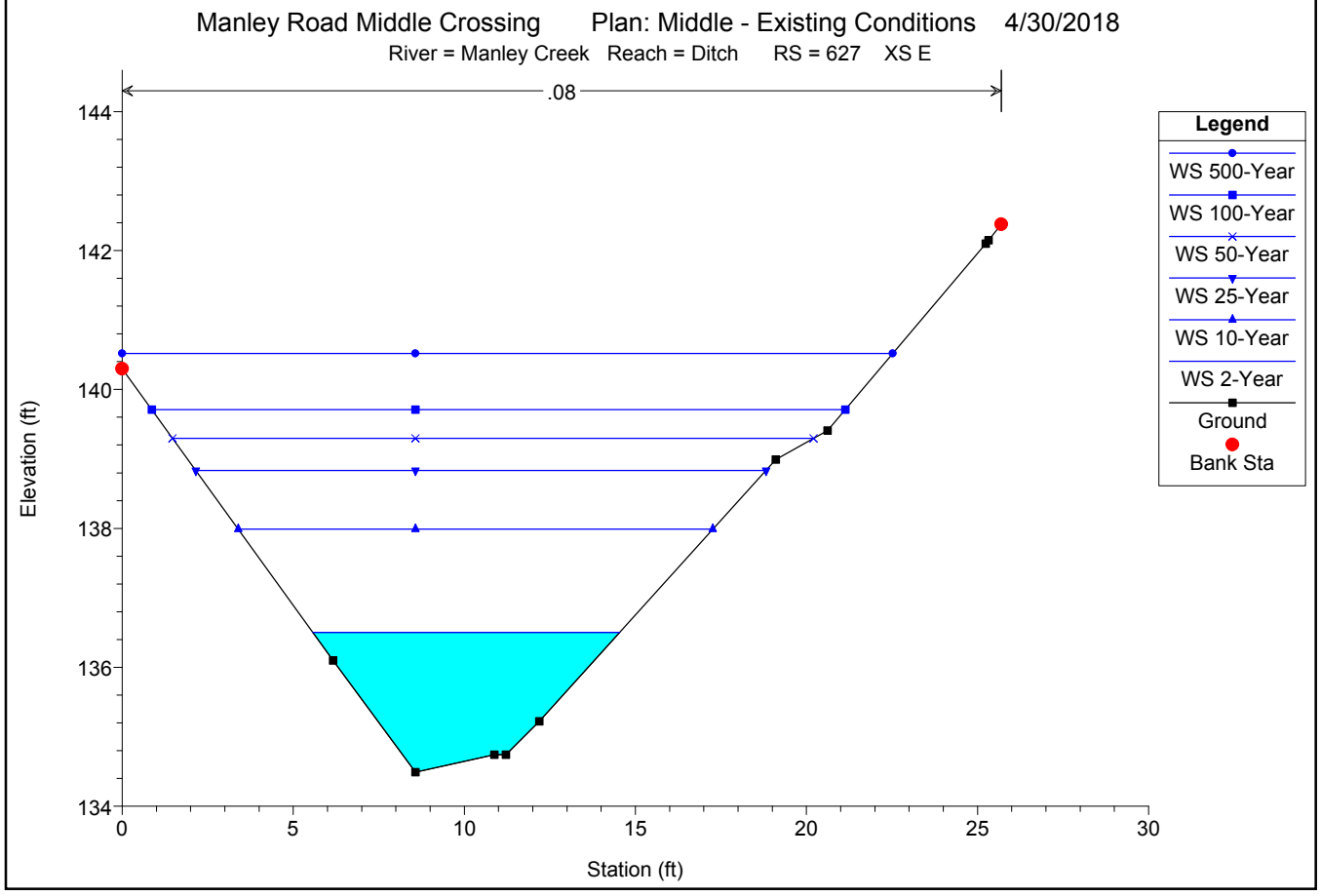

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Manley Creek RS = 466 XS 10
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
160
155
150
145
140
135
130
0
20
40
60
80
100

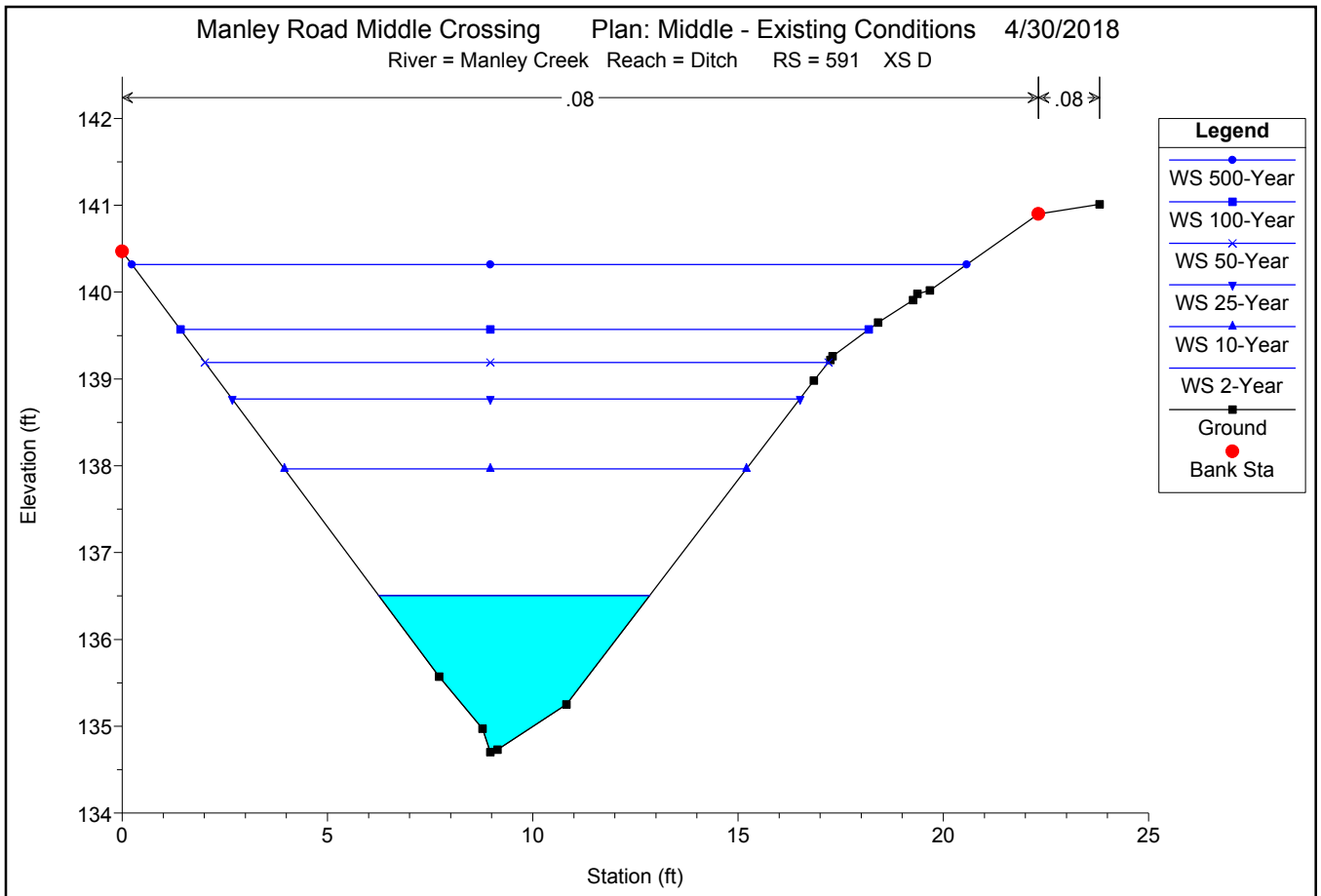

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Manley Creek RS = 434 XS 9
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
155
150
145
140
135
130
0
10
20
30
40
50
60
70

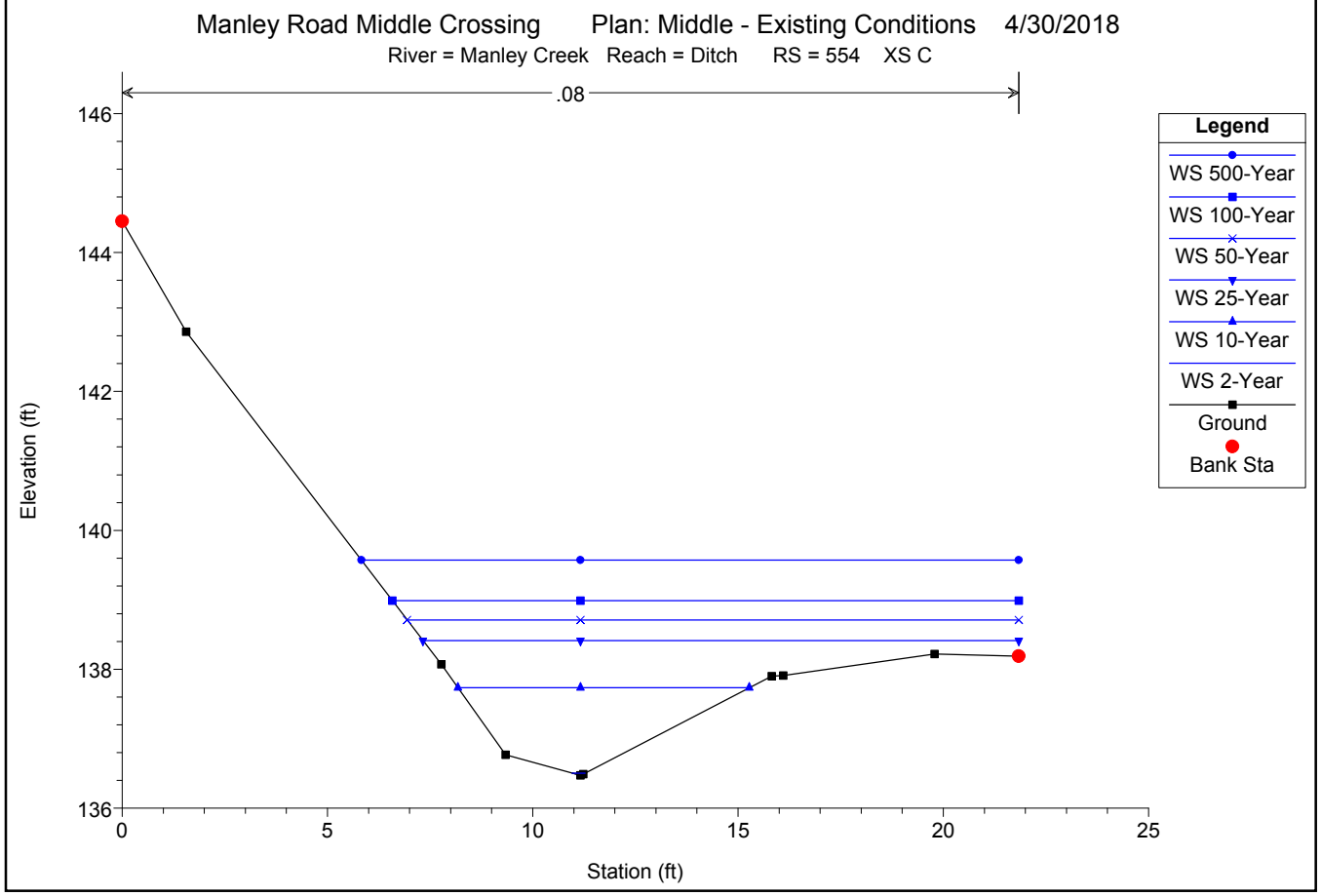

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Manley Creek RS = 410 XS 8
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
155
150
145
140
135
130
0
10
20
30
40
50
60
70

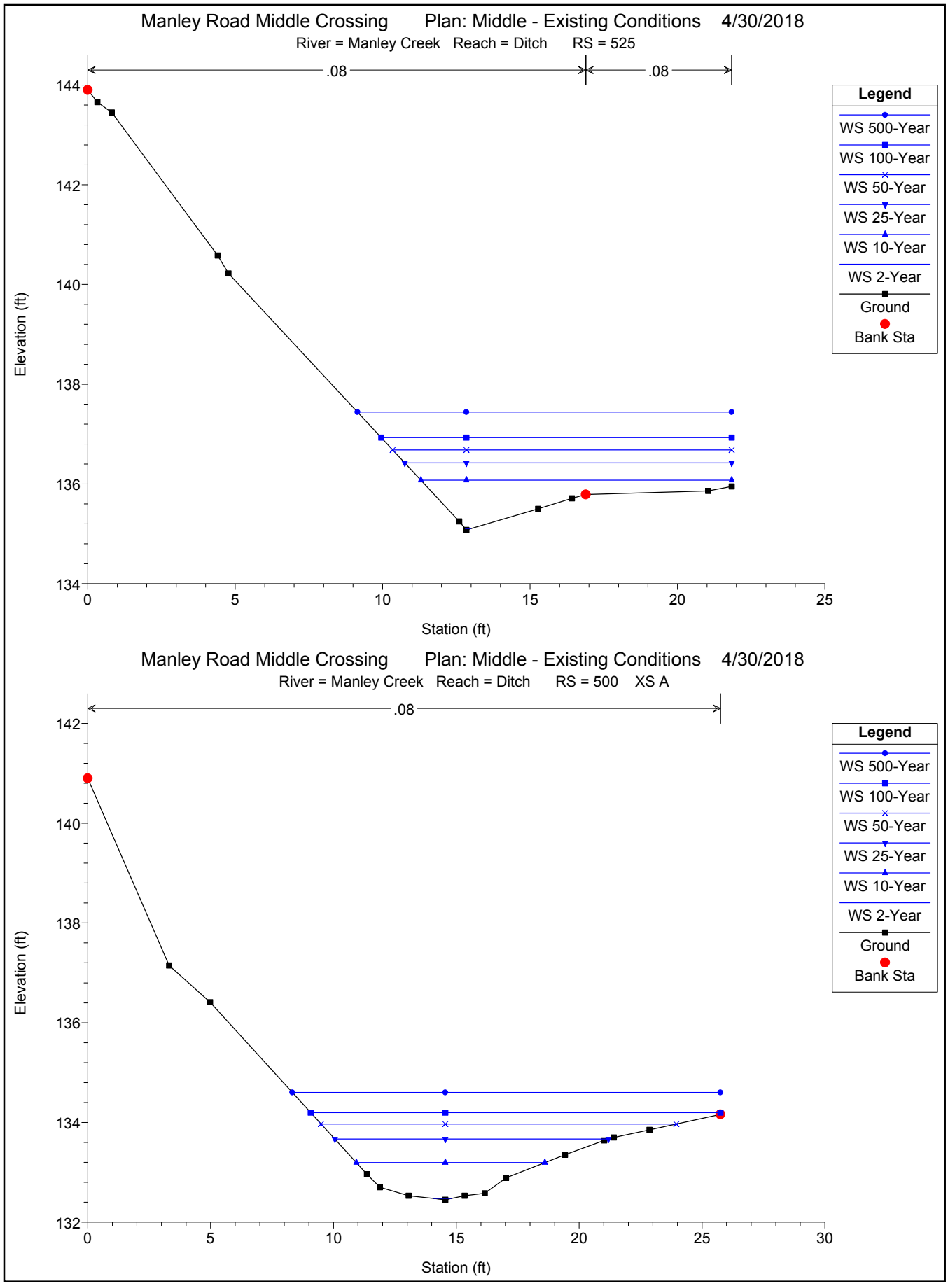

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Manley Creek RS = 390 XS 7
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
160
155
150
145
140
135
130
0
10
20
30
40
50
60
70


Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Manley Creek RS = 369 XS 6.5
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
160
155
150
145
140
135
130
125
0
10
20
30
40
50
60


Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Ditch RS = 627 XS E
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
144
142
140
138
136
134
0
5
10
15
20
25
30


Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Ditch RS = 591 XS D
.08
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
142
141
140
139
138
137
136
135
134
0
5
10
15
20
25


Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Ditch RS = 554 XS C
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
146
144
142
140
138
136
0
5
10
15
20
25

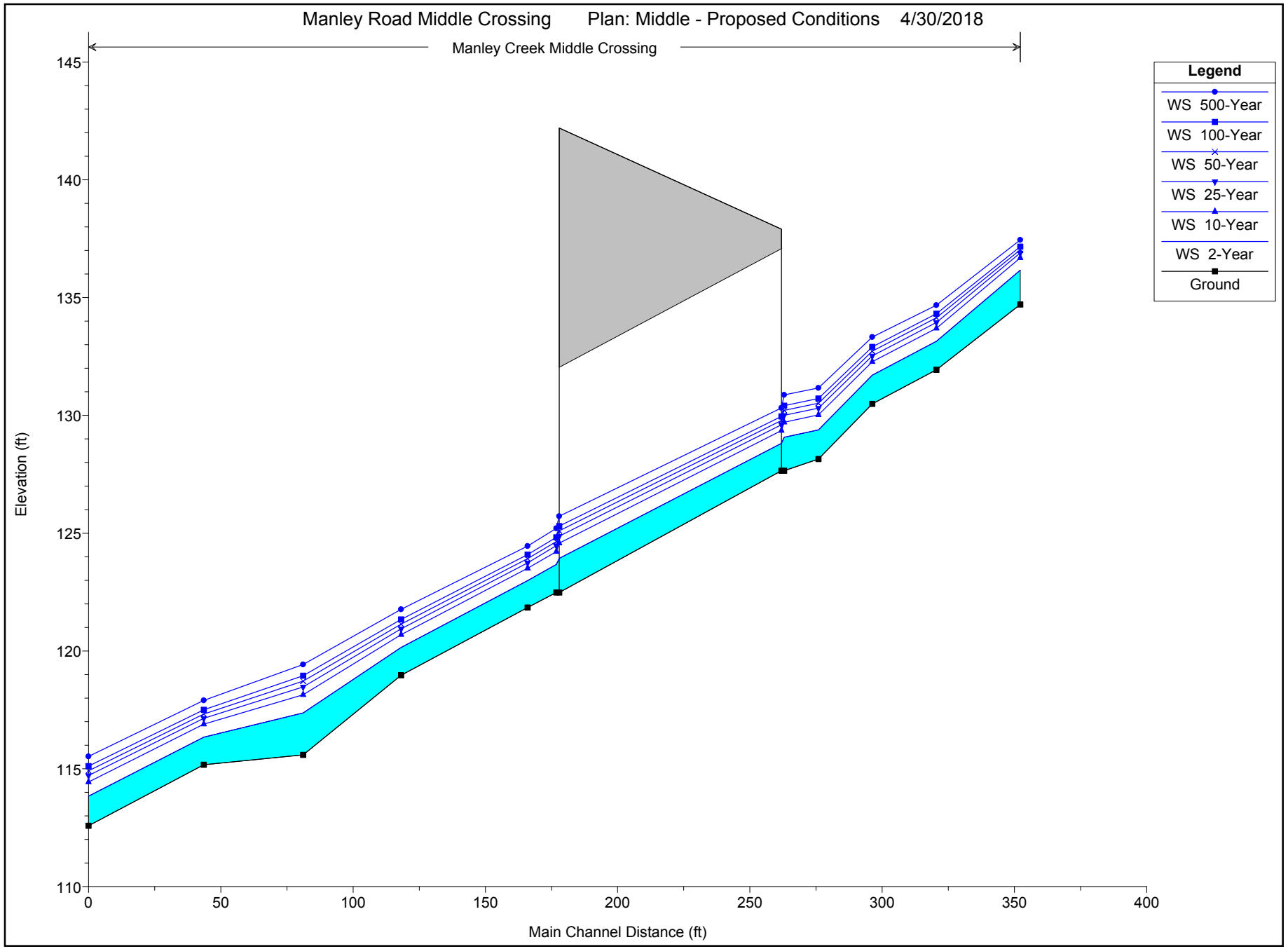

Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Ditch RS = 525
.08
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
Manley Road Middle Crossing Plan: Middle - Existing Conditions 4/30/2018
River = Manley Creek Reach = Ditch RS = 500 XS A
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

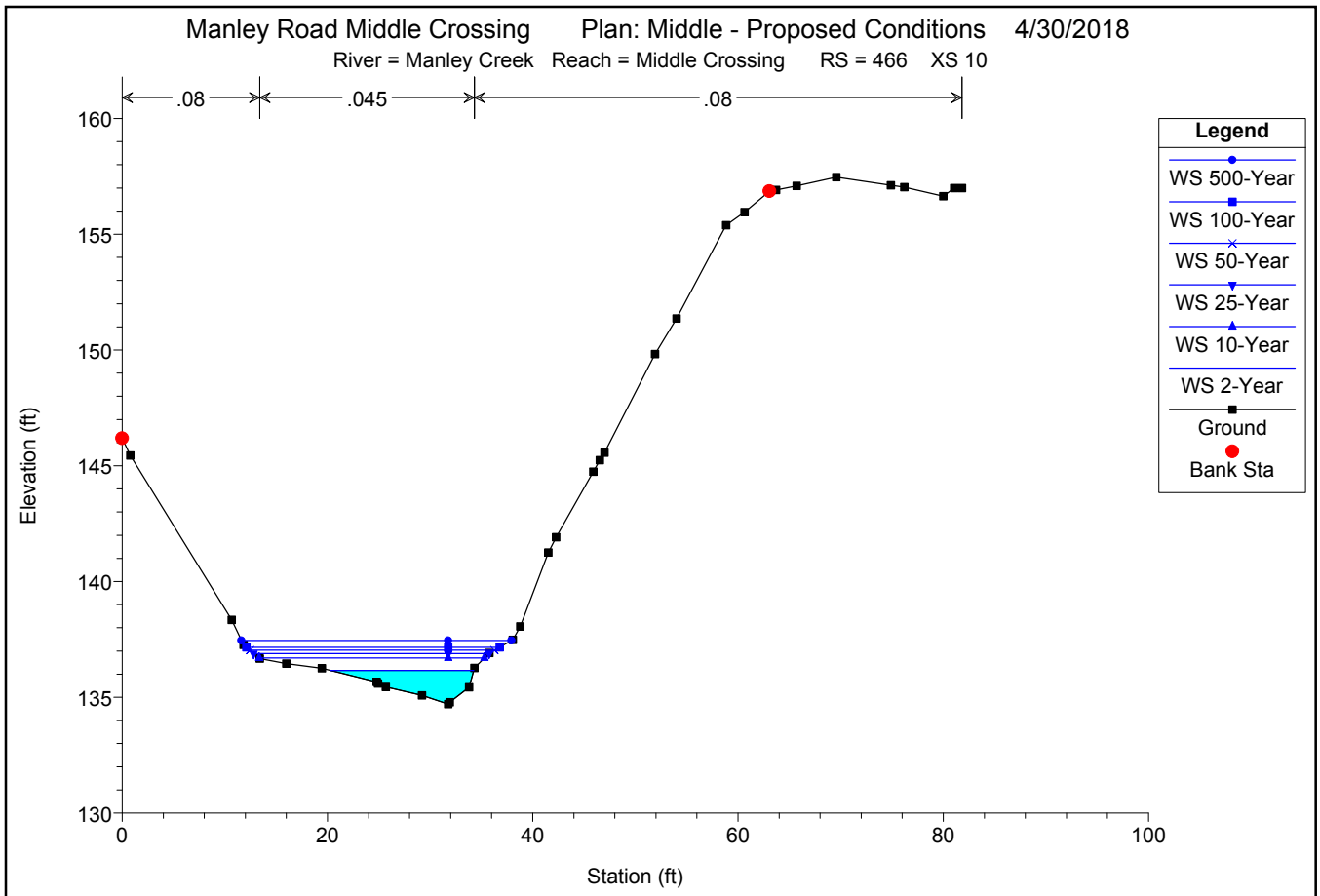
HEC-RAS Plan: MIDDLE-PROP River: Manley Creek Reach: Middle Crossing

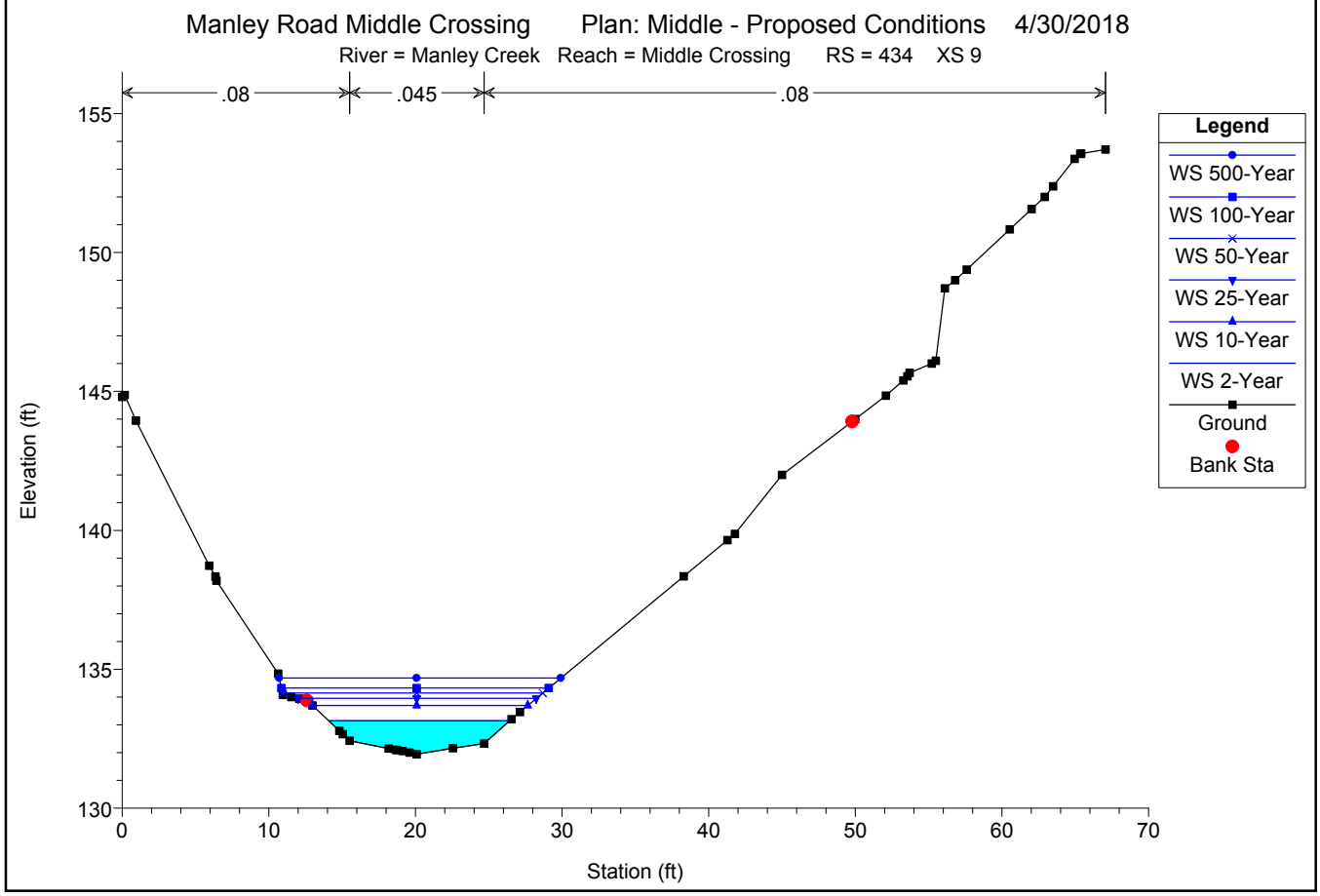
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Middle Crossing	466	2-Year	52.60	134.71	136.16	136.16	136.55	0.035629	5.01	10.51	13.95	1.02
Middle Crossing	466	10-Year	111.00	134.71	136.69	136.69	137.17	0.036441	5.54	20.02	21.94	1.02
Middle Crossing	466	25-Year	144.00	134.71	136.89	136.89	137.43	0.035540	5.87	24.53	22.93	1.00
Middle Crossing	466	50-Year	171.00	134.71	137.03	137.03	137.62	0.036998	6.17	27.72	23.80	1.01
Middle Crossing	466	100-Year	199.00	134.71	137.16	137.16	137.81	0.038432	6.44	30.89	24.66	1.01
Middle Crossing	466	500-Year	266.00	134.71	137.45	137.45	138.20	0.039569	6.94	38.34	26.32	1.01
Middle Crossing	434	2-Year	52.60	131.94	133.14	133.14	133.56	0.050689	5.17	10.18	12.35	1.00
Middle Crossing	434	10-Year	111.00	131.94	133.70	133.70	134.31	0.053148	6.26	17.73	14.72	1.01
Middle Crossing	434	25-Year	144.00	131.94	133.95	133.95	134.64	0.053384	6.69	21.53	16.23	1.01
Middle Crossing	434	50-Year	171.00	131.94	134.14	134.14	134.89	0.050935	6.94	24.85	17.75	0.99
Middle Crossing	434	100-Year	199.00	131.94	134.32	134.32	135.12	0.049750	7.21	28.04	18.23	0.98
Middle Crossing	434	500-Year	266.00	131.94	134.68	134.68	135.62	0.049301	7.82	34.84	19.22	0.99
Middle Crossing	410	2-Year	52.60	130.49	131.71	131.71	132.13	0.051019	5.24	10.05	12.02	1.01
Middle Crossing	410	10-Year	111.00	130.49	132.28	132.28	132.90	0.053105	6.34	17.52	14.27	1.01
Middle Crossing	410	25-Year	144.00	130.49	132.53	132.53	133.24	0.052616	6.76	21.32	15.73	1.00
Middle Crossing	410	50-Year	171.00	130.49	132.73	132.73	133.49	0.050422	7.03	24.51	16.93	0.99
Middle Crossing	410	100-Year	199.00	130.49	132.91	132.91	133.73	0.048879	7.29	27.77	18.28	0.98
Middle Crossing	410	500-Year	266.00	130.49	133.32	133.32	134.23	0.045233	7.71	35.97	21.00	0.95
Middle Crossing	390	2-Year	52.60	128.15	129.38	129.37	129.79	0.046632	5.11	10.30	11.96	0.97
Middle Crossing	390	10-Year	111.00	128.15	130.02	129.94	130.57	0.043737	5.94	18.68	14.35	0.92
Middle Crossing	390	25-Year	144.00	128.15	130.31	130.20	130.92	0.043251	6.27	22.96	15.43	0.91
Middle Crossing	390	50-Year	171.00	128.15	130.52	130.39	131.18	0.043115	6.51	26.28	16.21	0.90
Middle Crossing	390	100-Year	199.00	128.15	130.72	130.58	131.42	0.042932	6.72	29.62	16.97	0.90
Middle Crossing	390	500-Year	266.00	128.15	131.16	130.98	131.95	0.041825	7.09	37.54	18.64	0.88
Middle Crossing	366	2-Year	52.60	127.65	129.07	128.82	129.30	0.022017	3.79	13.86	14.12	0.68
Middle Crossing	366	10-Year	111.00	127.65	129.71	129.35	130.05	0.024111	4.68	23.73	16.72	0.69
Middle Crossing	366	25-Year	144.00	127.65	130.00	129.60	130.39	0.024779	5.01	28.73	17.90	0.70
Middle Crossing	366	50-Year	171.00	127.65	130.21	129.78	130.64	0.025375	5.25	32.56	18.77	0.70
Middle Crossing	366	100-Year	199.00	127.65	130.41	129.95	130.88	0.025712	5.46	36.47	19.63	0.71
Middle Crossing	366	500-Year	266.00	127.65	130.87	130.33	131.39	0.025966	5.79	45.92	21.78	0.70
Middle Crossing	320		Bridge									
Middle Crossing	280	2-Year	52.60	122.48	123.67	123.67	124.07	0.047619	5.10	10.32	12.75	1.00
Middle Crossing	280	10-Year	111.00	122.48	124.21	124.21	124.81	0.050052	6.22	17.84	14.91	1.00
Middle Crossing	280	25-Year	144.00	122.48	124.47	124.47	125.15	0.050123	6.61	21.80	15.94	1.00
Middle Crossing	280	50-Year	171.00	122.48	124.65	124.65	125.39	0.051128	6.92	24.72	16.67	1.00
Middle Crossing	280	100-Year	199.00	122.48	124.82	124.82	125.62	0.051781	7.19	27.69	17.38	1.00
Middle Crossing	280	500-Year	266.00	122.48	125.20	125.20	126.12	0.052196	7.69	34.58	18.88	1.00
Middle Crossing	269	2-Year	52.60	121.84	122.99	122.99	123.37	0.047757	4.97	10.58	13.71	1.00
Middle Crossing	269	10-Year	111.00	121.84	123.51	123.51	124.08	0.049561	6.07	18.28	15.94	1.00
Middle Crossing	269	25-Year	144.00	121.84	123.74	123.74	124.40	0.050491	6.50	22.14	16.95	1.00
Middle Crossing	269	50-Year	171.00	121.84	123.92	123.92	124.63	0.050501	6.77	25.27	17.72	1.00
Middle Crossing	269	100-Year	199.00	121.84	124.09	124.09	124.86	0.050632	7.01	28.37	18.45	1.00
Middle Crossing	269	500-Year	266.00	121.84	124.45	124.45	125.34	0.051655	7.55	35.24	19.99	1.00
Middle Crossing	221	2-Year	52.60	118.97	120.15	120.15	120.56	0.048685	5.14	10.24	12.74	1.01
Middle Crossing	221	10-Year	111.00	118.97	120.69	120.69	121.30	0.050650	6.25	17.77	14.92	1.01
Middle Crossing	221	25-Year	144.00	118.97	120.94	120.94	121.63	0.051572	6.68	21.57	15.90	1.01
Middle Crossing	221	50-Year	171.00	118.97	121.14	121.14	121.87	0.050777	6.90	24.87	18.23	1.00
Middle Crossing	221	100-Year	199.00	118.97	121.34	121.34	122.10	0.048743	7.02	28.92	21.73	0.97
Middle Crossing	221	500-Year	266.00	118.97	121.77	121.77	122.54	0.044935	7.16	39.99	30.72	0.92
Middle Crossing	182	2-Year	52.60	115.59	117.37		117.50	0.010048	2.85	18.44	14.91	0.45
Middle Crossing	182	10-Year	111.00	115.59	118.14		118.34	0.011706	3.58	31.01	17.86	0.48
Middle Crossing	182	25-Year	144.00	115.59	118.48		118.71	0.012314	3.86	37.26	19.15	0.49
Middle Crossing	182	50-Year	171.00	115.59	118.72		118.98	0.012782	4.07	42.00	20.08	0.50
Middle Crossing	182	100-Year	199.00	115.59	118.95		119.23	0.013127	4.25	46.80	20.98	0.50
Middle Crossing	182	500-Year	266.00	115.59	119.43		119.76	0.014004	4.65	57.26	22.81	0.52
Middle Crossing	145	2-Year	52.60	115.17	116.35	116.35	116.76	0.048707	5.14	10.24	12.74	1.01
Middle Crossing	145	10-Year	111.00	115.17	116.89	116.89	117.50	0.050487	6.24	17.79	14.93	1.01
Middle Crossing	145	25-Year	144.00	115.17	117.14	117.14	117.83	0.051260	6.66	21.62	15.92	1.01
Middle Crossing	145	50-Year	171.00	115.17	117.32	117.32	118.07	0.051723	6.95	24.61	16.66	1.01
Middle Crossing	145	100-Year	199.00	115.17	117.50	117.50	118.31	0.051965	7.20	27.64	17.37	1.01
Middle Crossing	145	500-Year	266.00	115.17	117.90	117.90	118.80	0.051103	7.63	35.09	21.89	0.99
Middle Crossing	100	2-Year	52.60	112.58	113.83	113.76	114.17	0.037513	4.65	11.32	13.18	0.88
Middle Crossing	100	10-Year	111.00	112.58	114.44	114.30	114.92	0.037535	5.55	20.00	15.64	0.87
Middle Crossing	100	25-Year	144.00	112.58	114.71	114.55	115.25	0.037523	5.89	24.46	16.76	0.86
Middle Crossing	100	50-Year	171.00	112.58	114.92	114.73	115.50	0.037514	6.12	27.96	17.59	0.86

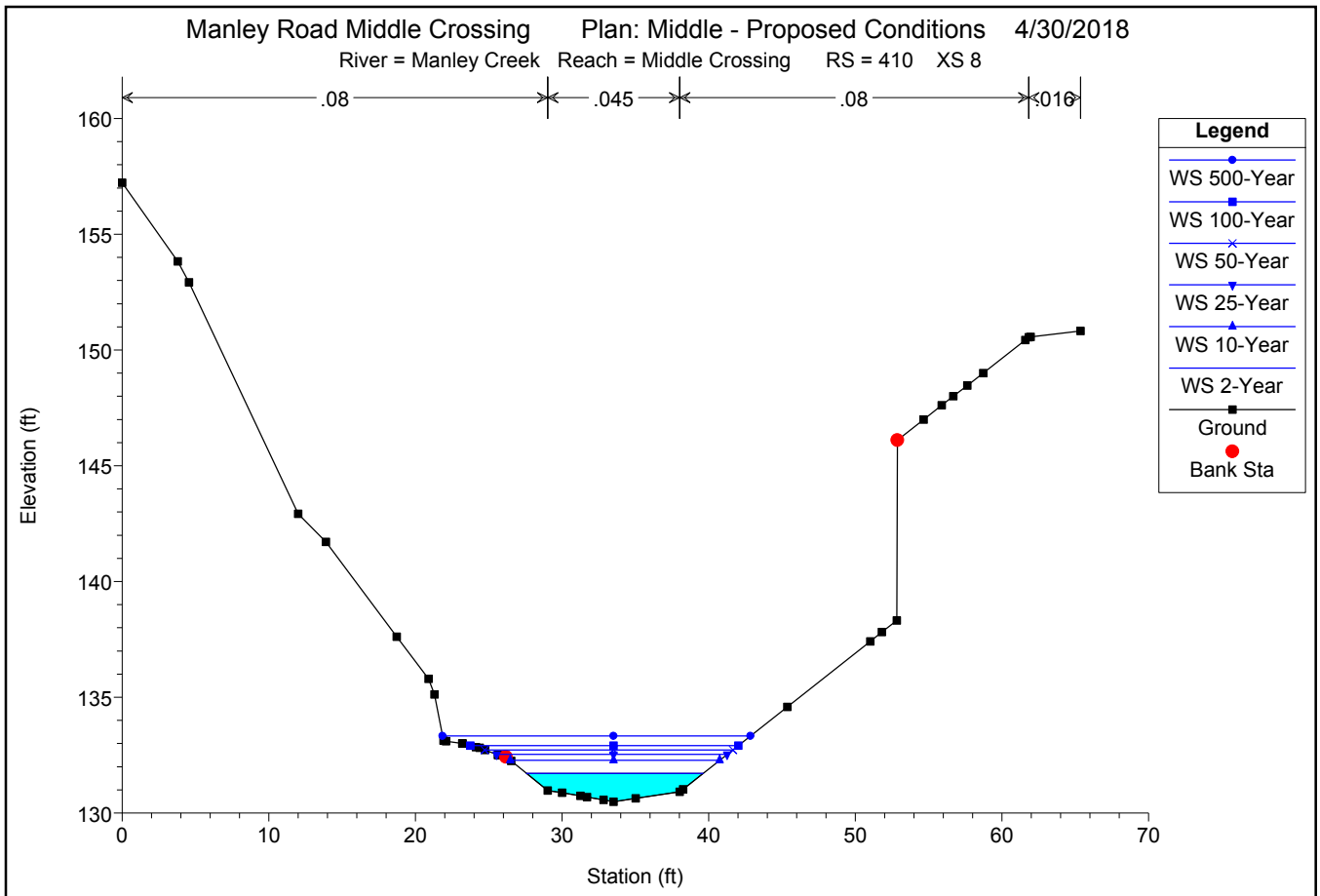
HEC-RAS Plan: MIDDLE-PROP River: Manley Creek Reach: Middle Crossing (Continued)

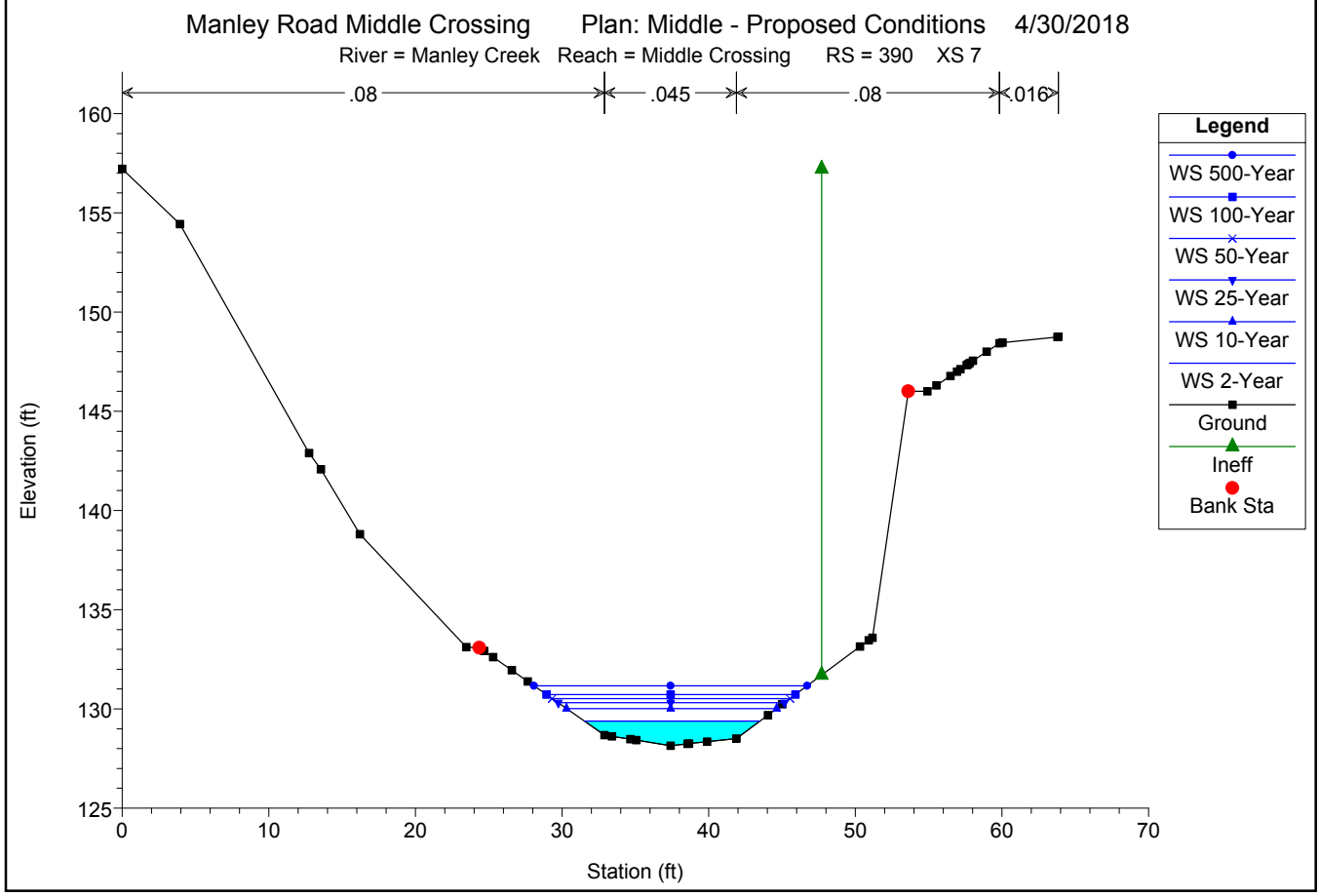
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Middle Crossing	100	100-Year	199.00	112.58	115.11	114.90	115.73	0.037512	6.33	31.46	18.38	0.85
Middle Crossing	100	500-Year	266.00	112.58	115.52	115.28	116.23	0.037571	6.75	39.39	20.02	0.85

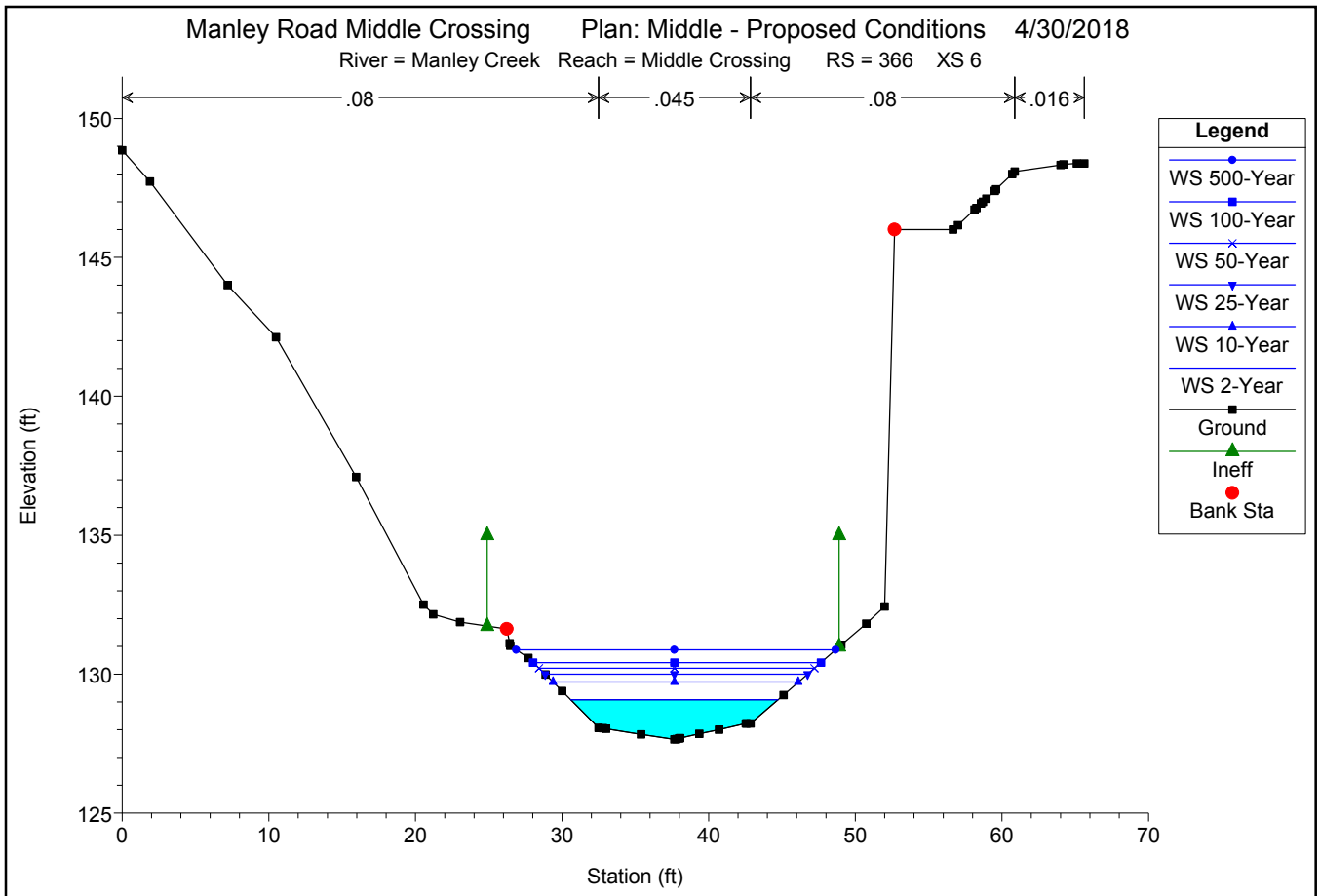

Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
Manley Creek Middle Crossing
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
145
140
135
130
125
120
115
110
0
50
100
150
200
250
300
350
400

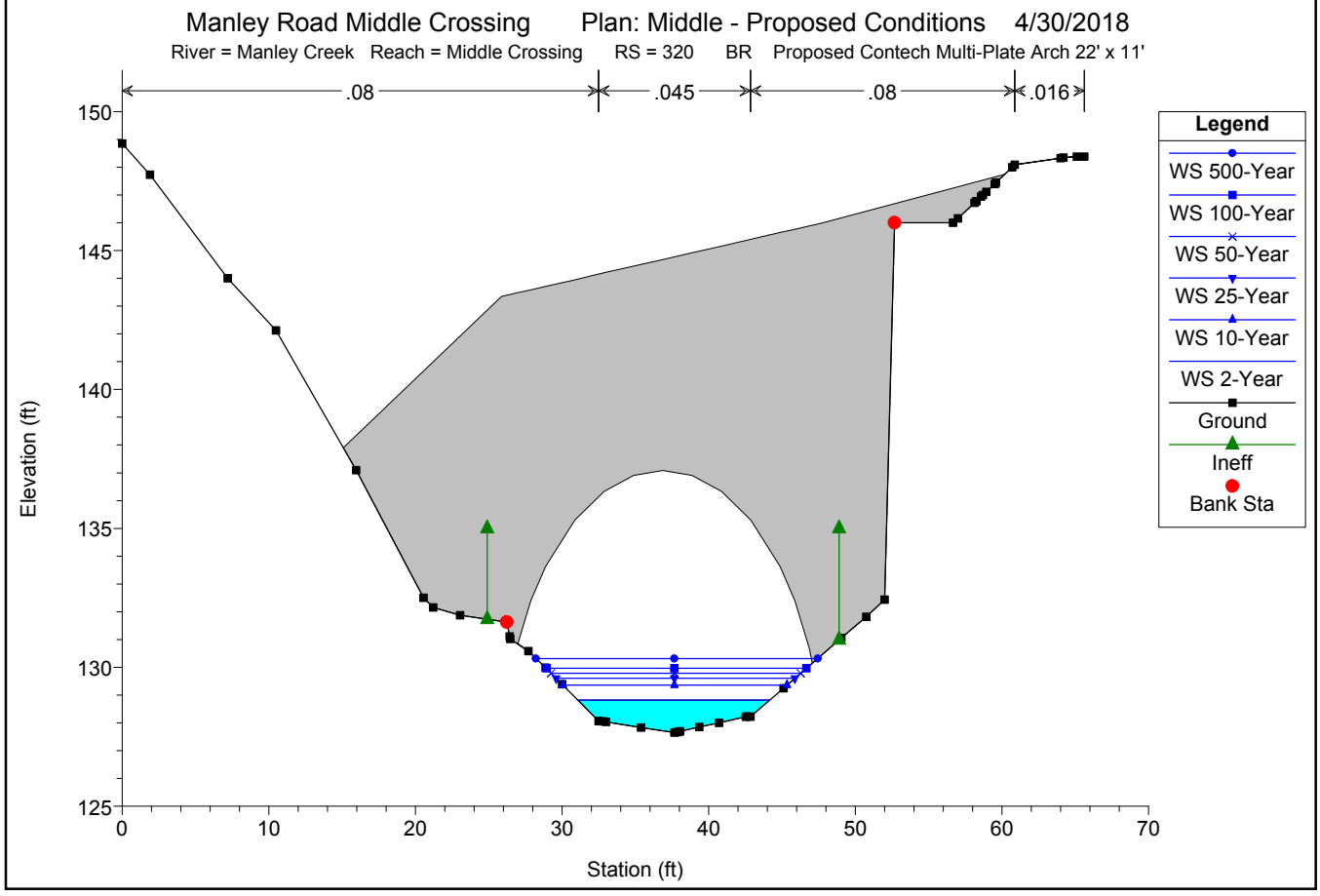

Manley Road Middle Crossing
Plan: Middle - Proposed Conditions
4/30/2018
River = Manley Creek
Reach = Middle Crossing
RS = 466
XS 10
.08
.045
.08
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta

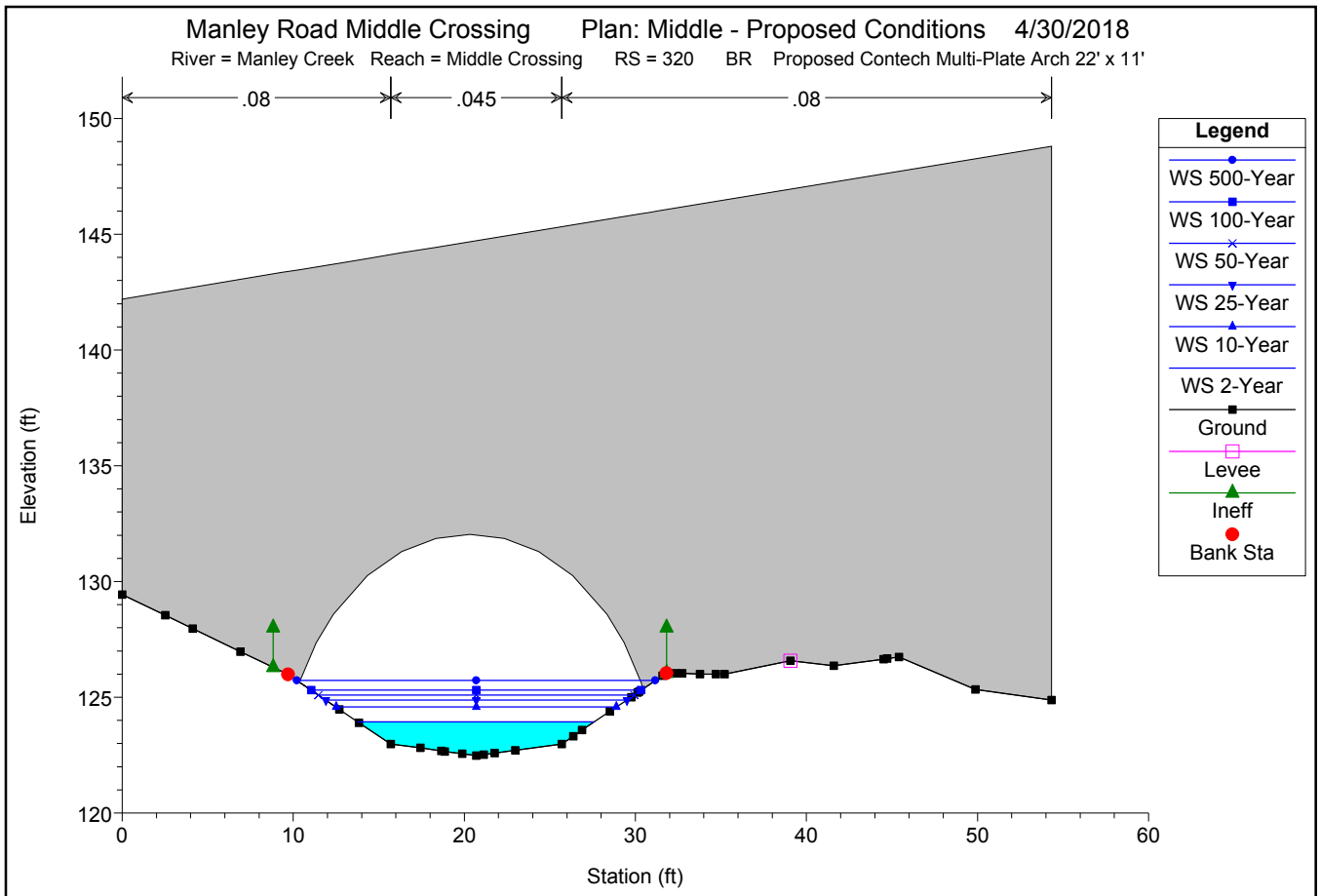

Manley Road Middle Crossing
Plan: Middle - Proposed Conditions
4/30/2018
River = Manley Creek
Reach = Middle Crossing
RS = 434
XS 9
.08
.045
.08
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta

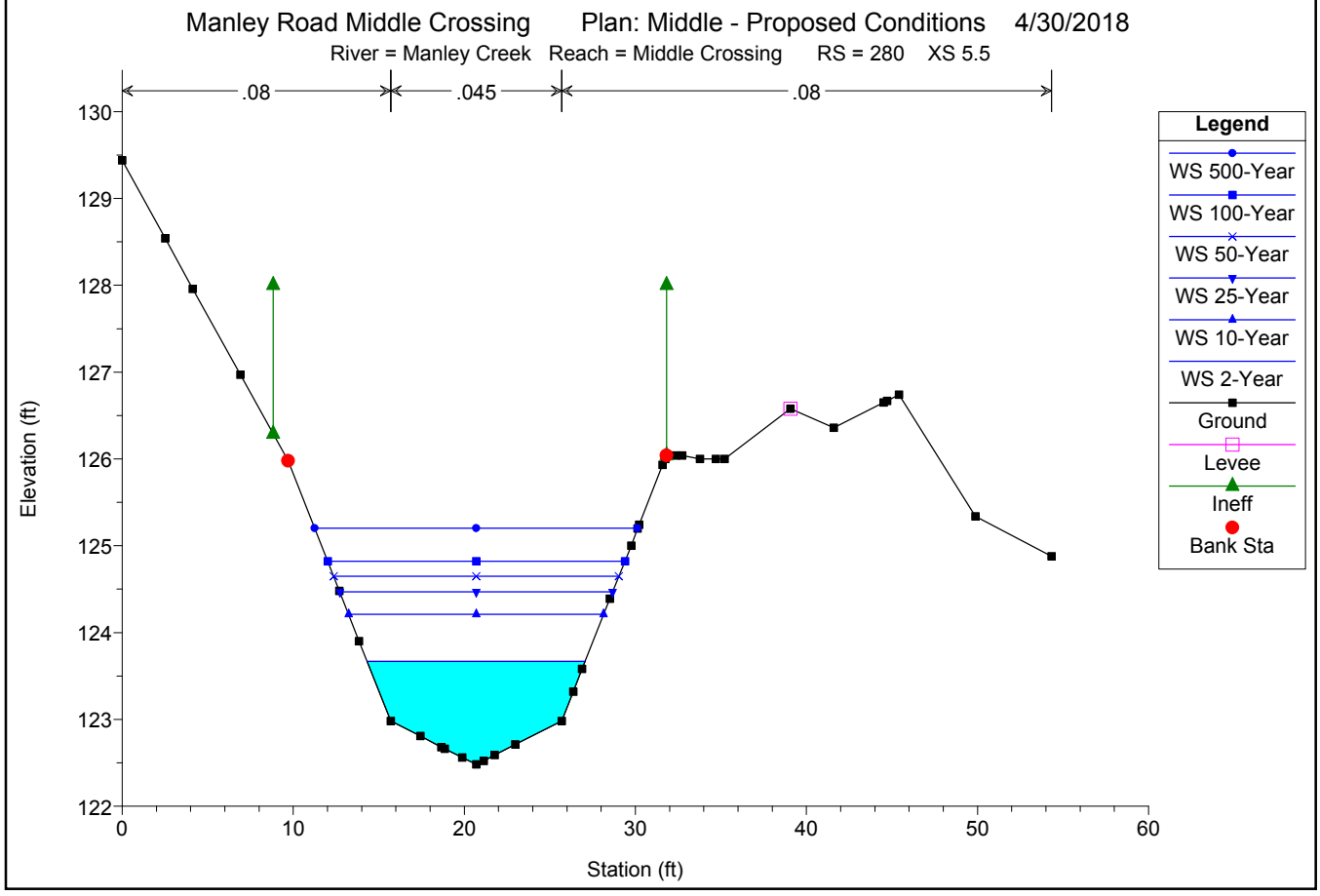

Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 410 XS 8
.08
.045
.08
.016
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta

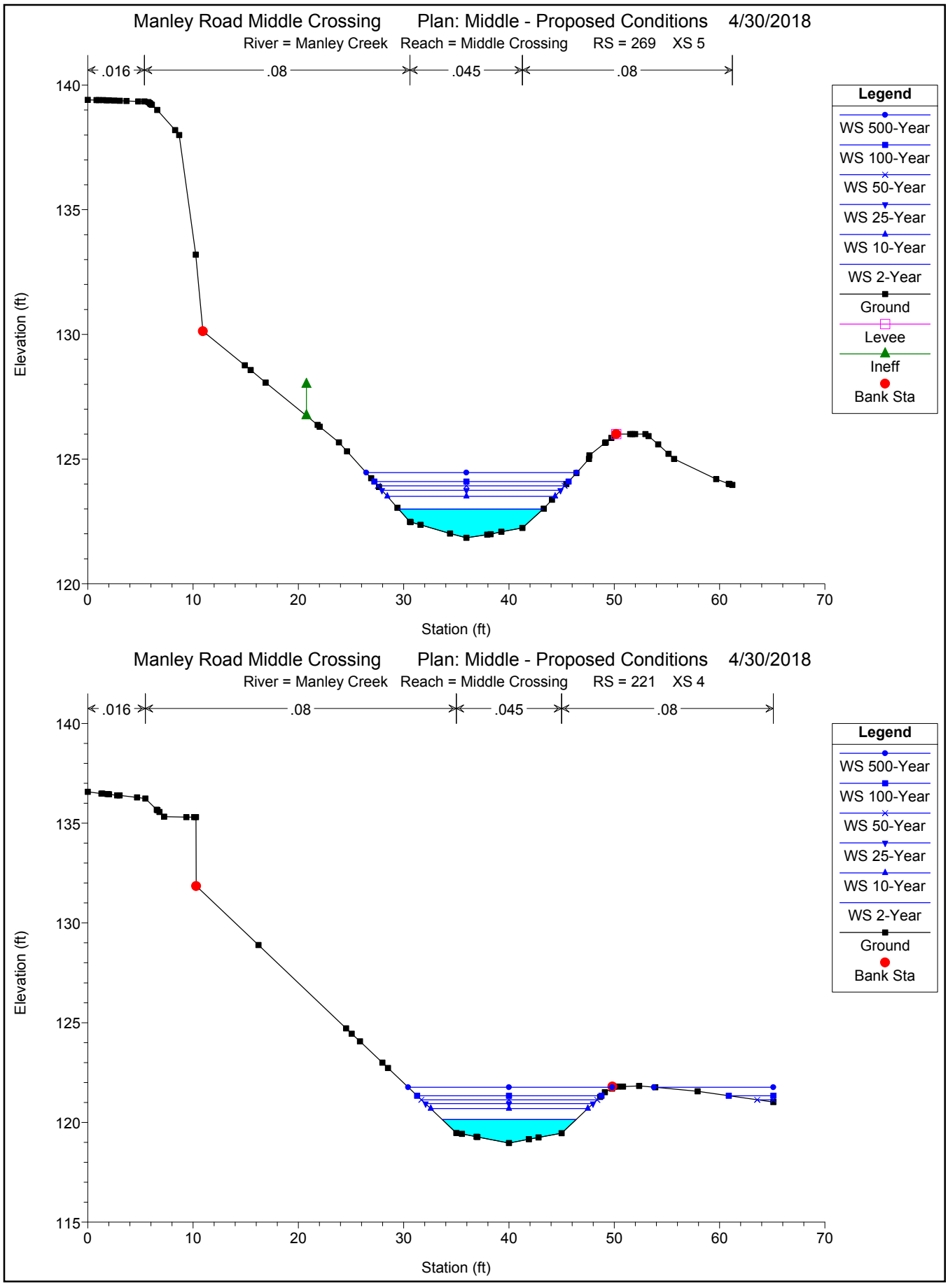

Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 390 XS 7
.08
.045
.08
.016
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta

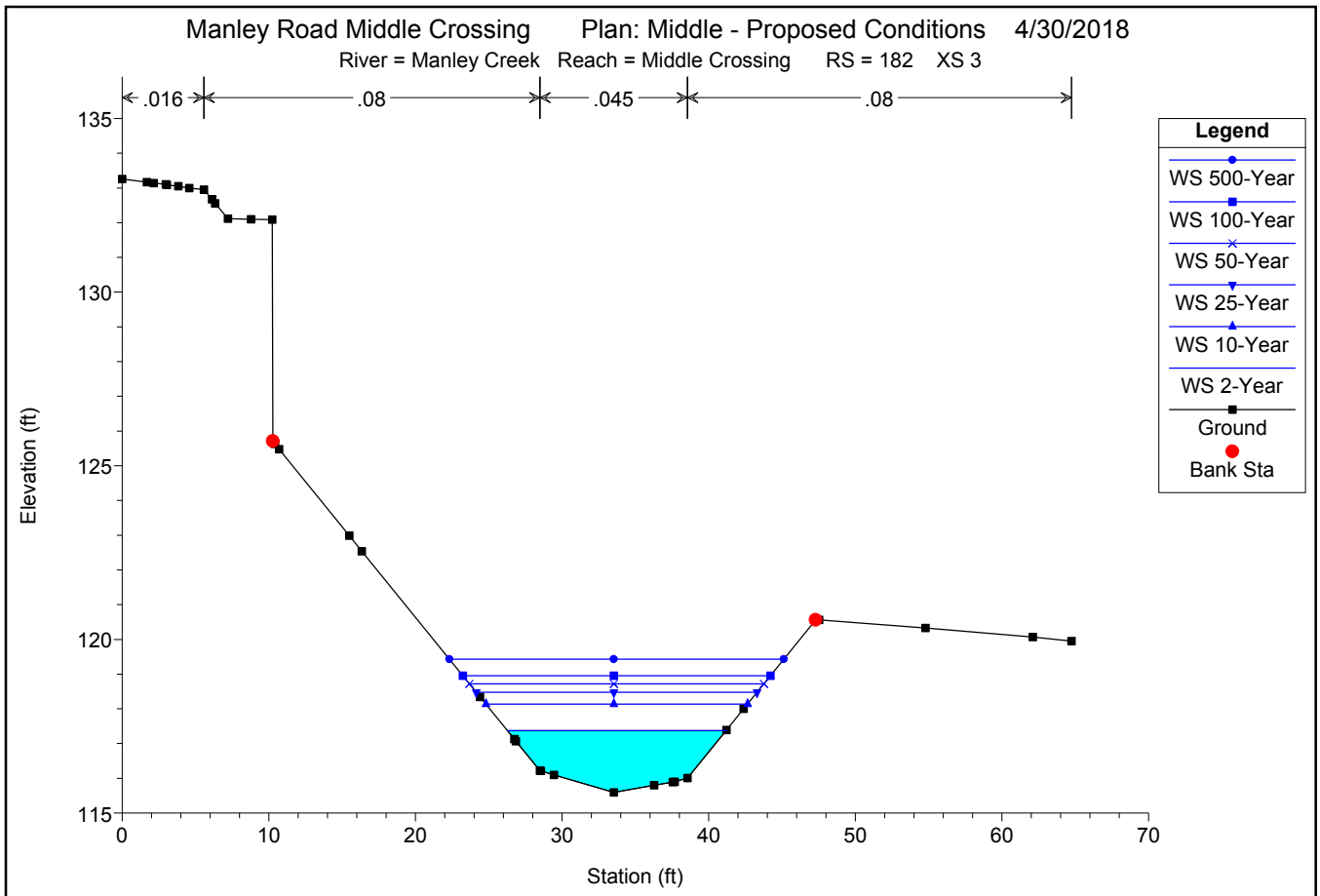

Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 366 XS 6
.08
.045
.08
.016
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

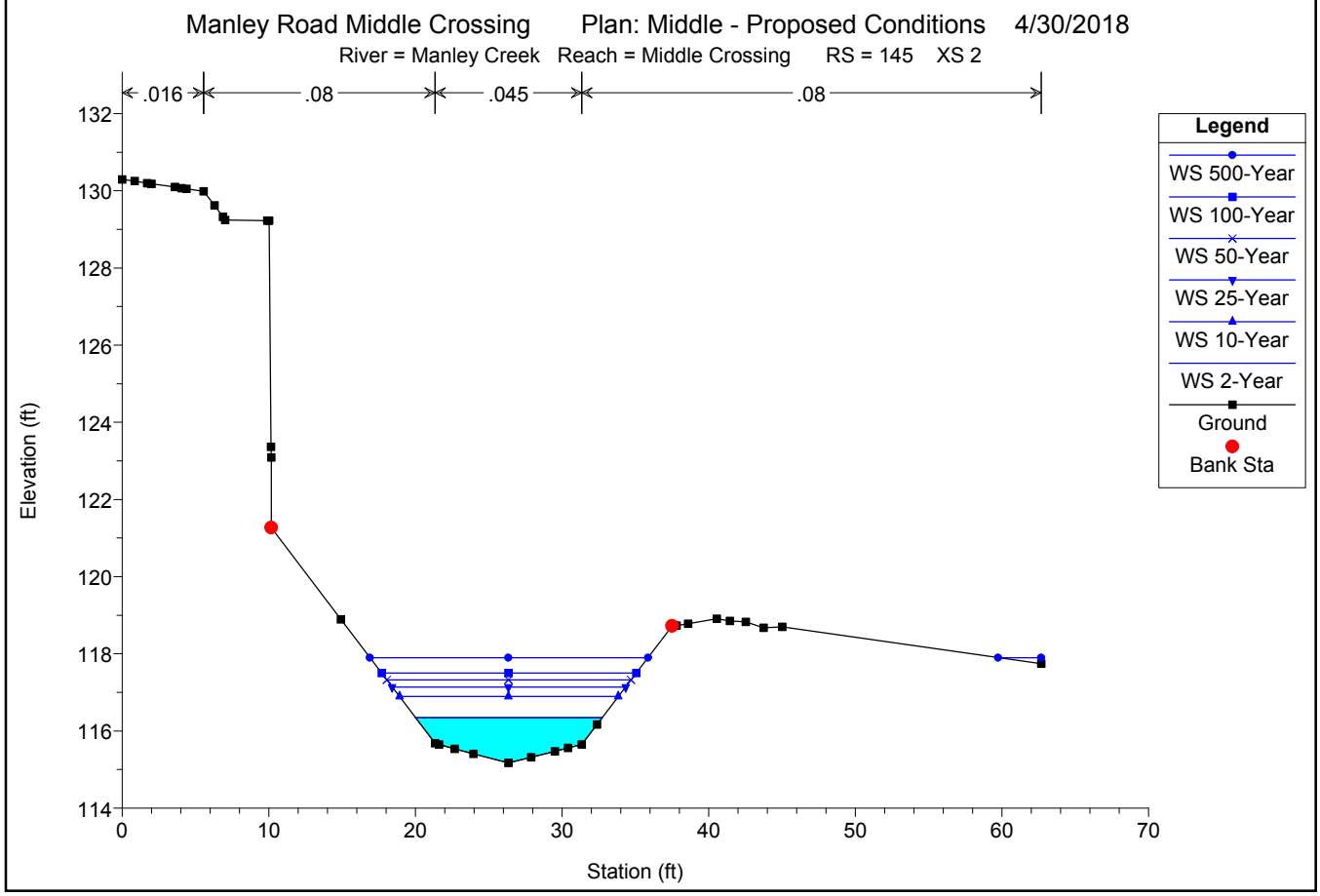

Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 320 BR Proposed Contech Multi-Plate Arch 22' x 11'
.08
.045
.08
.016
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

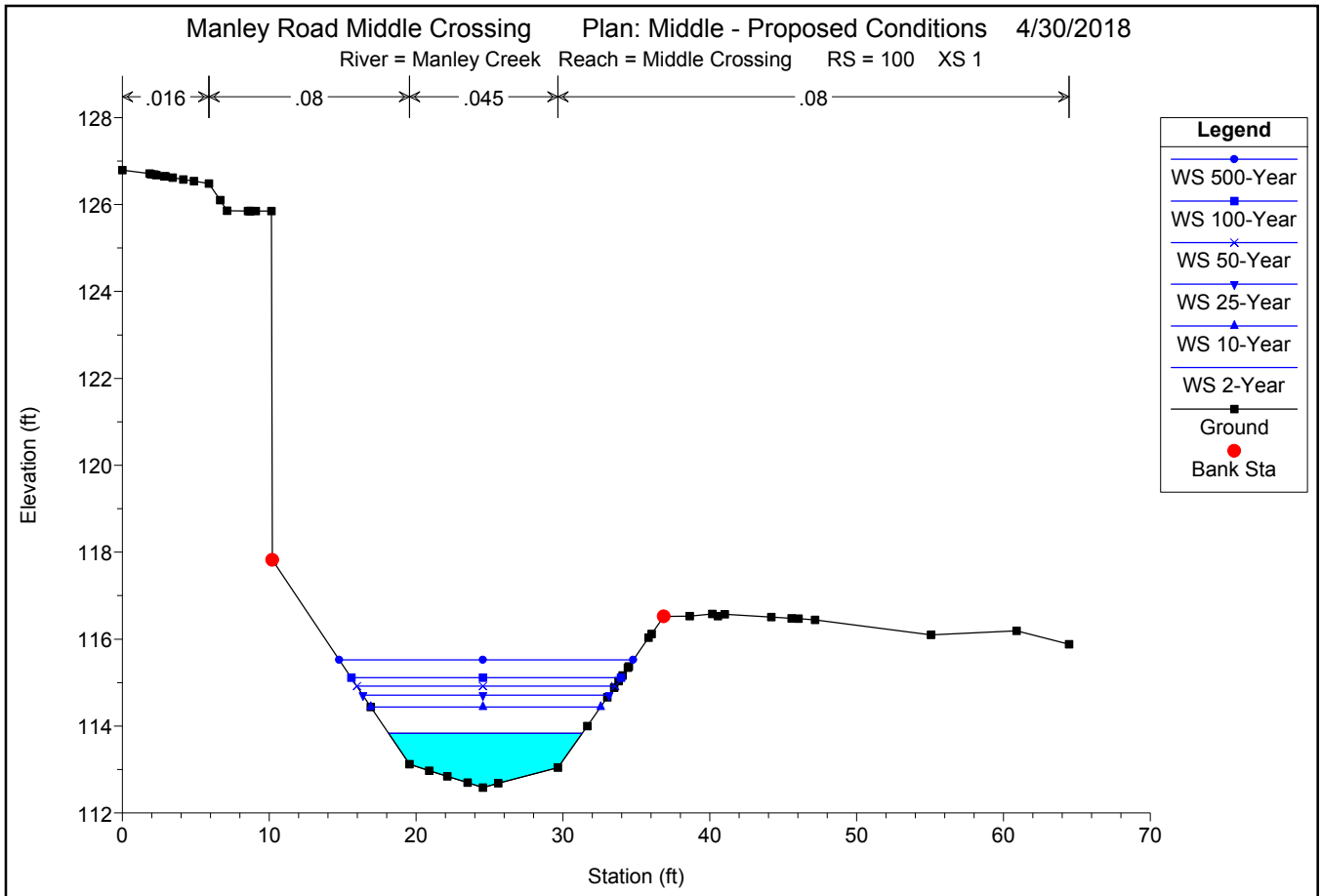

Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 320 BR Proposed Contech Multi-Plate Arch 22' x 11'
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Levee
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 280 XS 5.5
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Levee
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 269 XS 5
.016
.08
.045
.08
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Levee
Ineff
Bank Sta
Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 221 XS 4
.016
.08
.045
.08
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta


Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 182 XS 3
.016
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)


Manley Road Middle Crossing Plan: Middle - Proposed Conditions 4/30/2018
River = Manley Creek Reach = Middle Crossing RS = 145 XS 2
.016
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

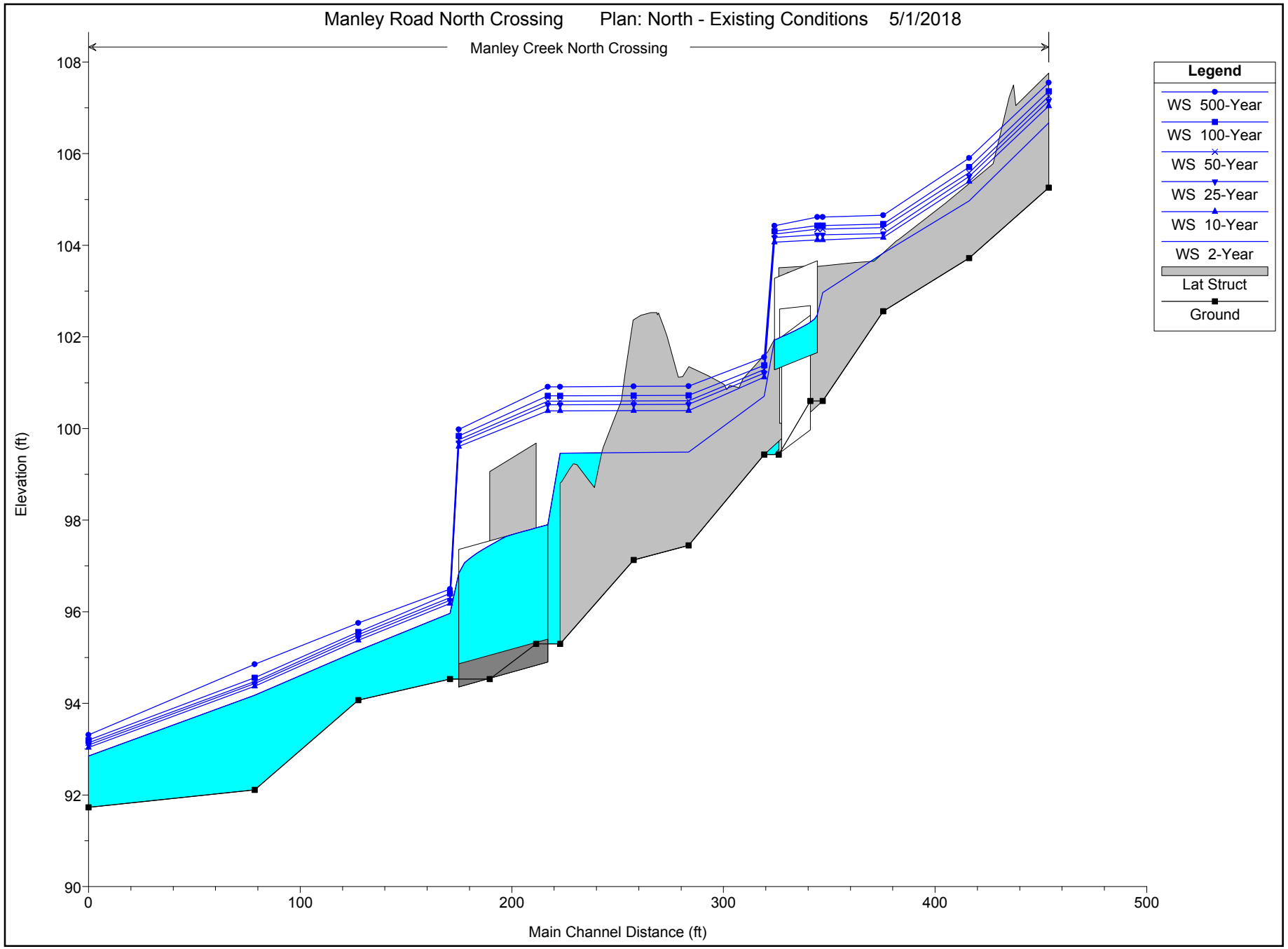

Manley Road Middle Crossing
Plan: Middle - Proposed Conditions
4/30/2018
River = Manley Creek
Reach = Middle Crossing
RS = 100
XS 1
.016
.08
.045
.08
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
128
126
124
122
120
118
116
114
112
0
10
20
30
40
50
60
70

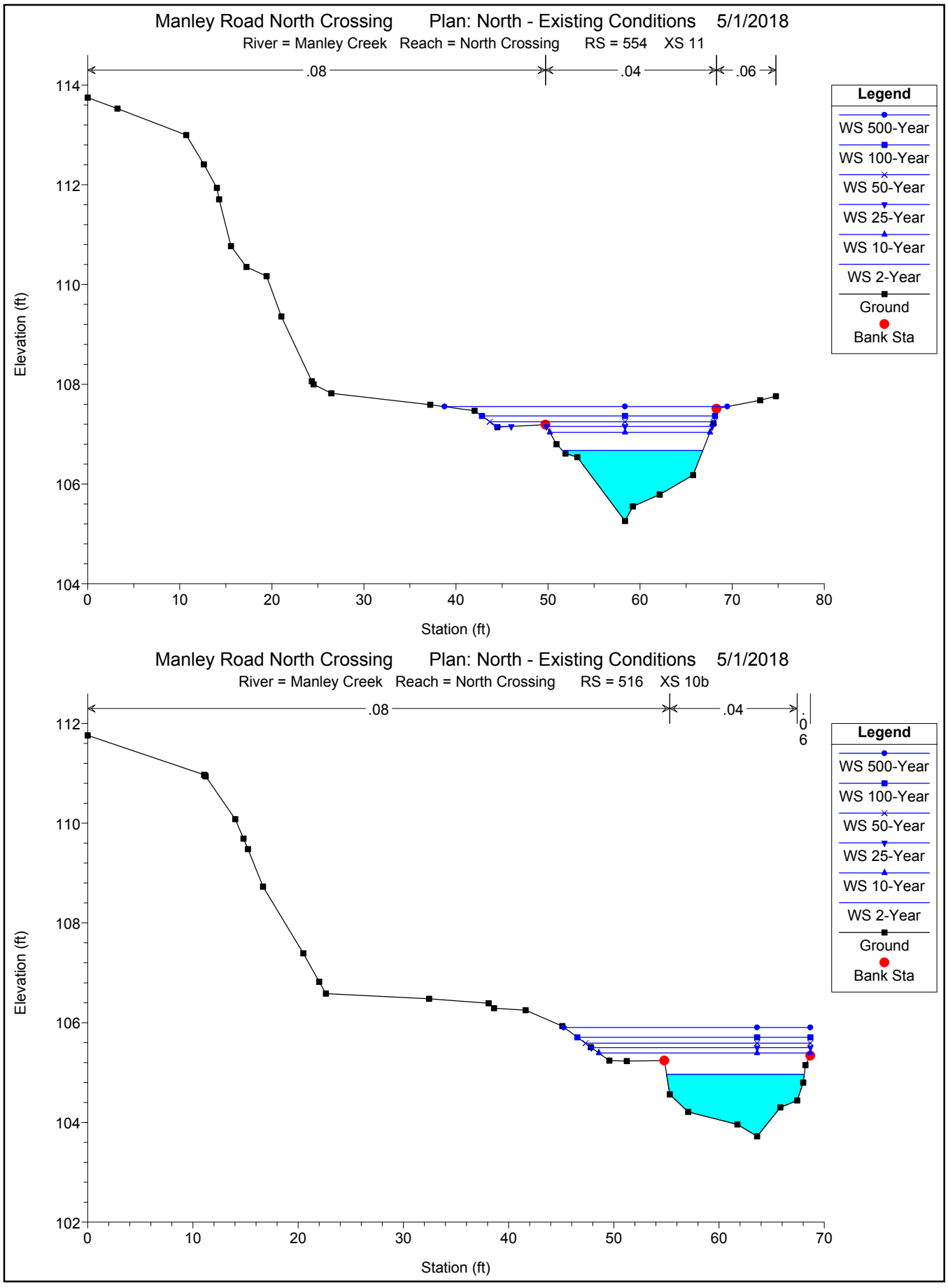
HEC-RAS Plan: NORTH-EXTG River: Manley Creek Reach: North Crossing

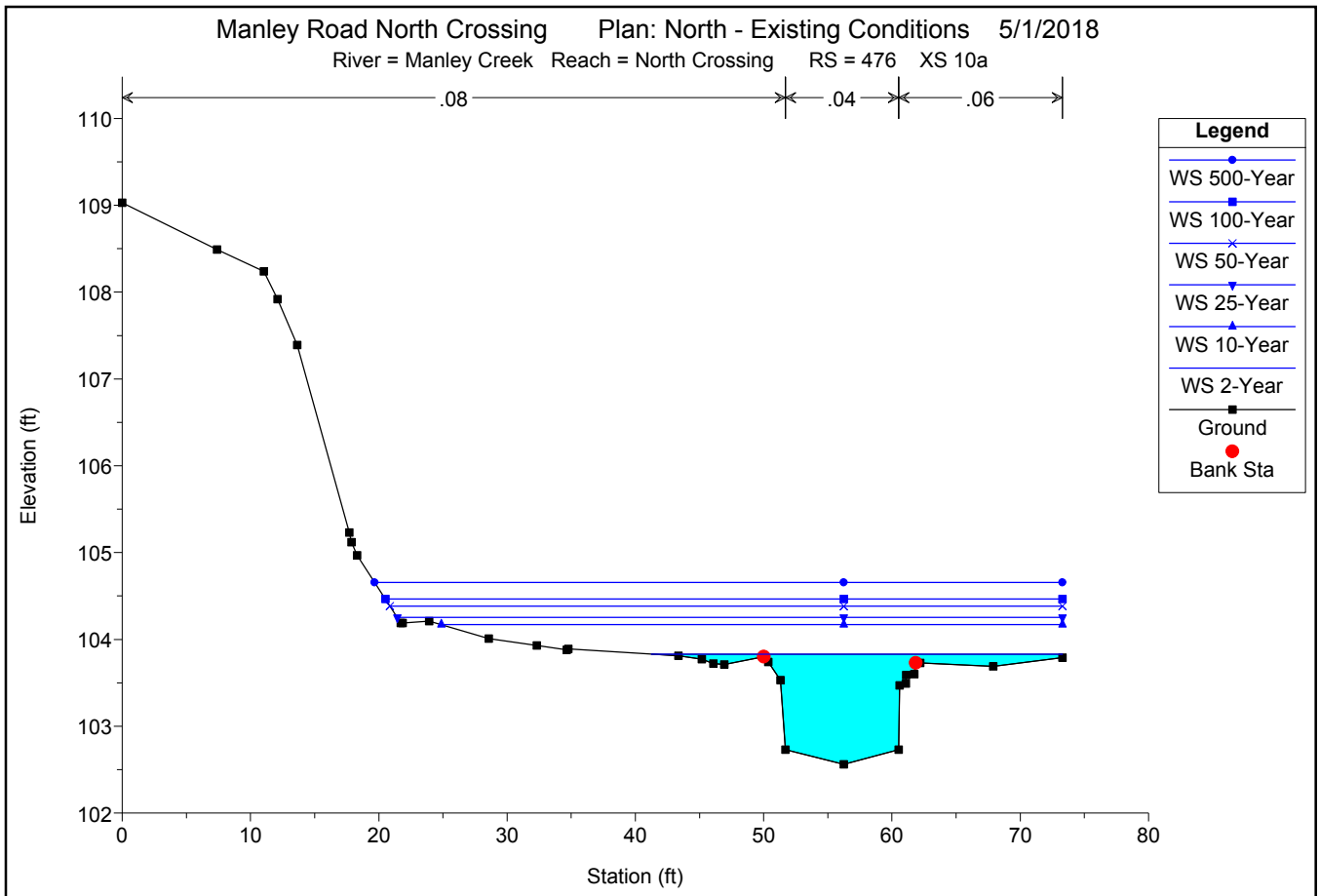
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
North Crossing	554	2-Year	52.60	105.26	106.67	106.67	107.03	0.027245	4.83	10.89	15.23	1.01
North Crossing	554	10-Year	96.58	105.26	107.04	107.04	107.55	0.025552	5.72	16.90	17.41	1.02
North Crossing	554	25-Year	110.14	105.26	107.15	107.15	107.68	0.023760	5.81	18.96	19.63	1.00
North Crossing	554	50-Year	122.51	105.26	107.25	107.25	107.79	0.022371	5.91	21.17	24.33	0.98
North Crossing	554	100-Year	139.69	105.26	107.36	107.36	107.94	0.021171	6.09	23.98	25.31	0.97
North Crossing	554	500-Year	173.22	105.26	107.55	107.55	108.19	0.020164	6.49	29.03	30.70	0.96
North Crossing	553		Lat Struct									
North Crossing	516	2-Year	52.60	103.72	104.97	104.95	105.35	0.029172	4.97	10.59	13.09	0.97
North Crossing	516	10-Year	96.43	103.72	105.39	105.39	105.92	0.027634	5.86	17.24	20.12	0.95
North Crossing	516	25-Year	109.58	103.72	105.50	105.50	106.06	0.026579	6.04	19.44	20.82	0.94
North Crossing	516	50-Year	121.47	103.72	105.59	105.59	106.18	0.026162	6.22	21.27	21.38	0.94
North Crossing	516	100-Year	137.91	103.72	105.71	105.71	106.33	0.025330	6.42	23.87	22.15	0.93
North Crossing	516	500-Year	169.86	103.72	105.90	105.90	106.60	0.025034	6.85	28.38	23.43	0.93
North Crossing	476	2-Year	52.60	102.56	103.83	103.83	104.14	0.029429	4.52	13.03	32.05	0.81
North Crossing	476	10-Year	94.63	102.56	104.17	104.17	104.47	0.022917	4.88	27.63	48.42	0.76
North Crossing	476	25-Year	106.16	102.56	104.26	104.24	104.55	0.021051	4.88	31.95	51.84	0.73
North Crossing	476	50-Year	116.45	102.56	104.38		104.62	0.015984	4.52	38.68	52.41	0.65
North Crossing	476	100-Year	130.16	102.56	104.46		104.70	0.015342	4.58	42.90	52.76	0.64
North Crossing	476	500-Year	157.26	102.56	104.66		104.87	0.012673	4.49	53.16	53.60	0.59
North Crossing	447	2-Year	52.58	100.60	102.97	102.15	103.05	0.003133	2.38	22.10	23.05	0.36
North Crossing	447	10-Year	90.90	100.60	104.12	102.60	104.16	0.000919	1.85	71.11	63.69	0.21
North Crossing	447	25-Year	101.07	100.60	104.23	102.67	104.28	0.000921	1.91	78.15	63.89	0.21
North Crossing	447	50-Year	110.36	100.60	104.35	102.75	104.40	0.000876	1.93	86.16	64.11	0.21
North Crossing	447	100-Year	122.18	100.60	104.43	102.83	104.48	0.000941	2.04	91.02	64.24	0.22
North Crossing	447	500-Year	146.41	100.60	104.62	102.98	104.67	0.000994	2.19	103.06	64.57	0.23
North Crossing	433		Culvert									
North Crossing	419	2-Year	52.58	99.43	100.70	100.70	101.13	0.026914	5.23	10.06	12.09	1.01
North Crossing	419	10-Year	90.90	99.43	101.12	101.12	101.64	0.024913	5.80	15.68	15.23	1.01
North Crossing	419	25-Year	101.07	99.43	101.21	101.21	101.75	0.024664	5.91	17.09	16.00	1.01
North Crossing	419	50-Year	110.36	99.43	101.29	101.29	101.85	0.024408	6.01	18.37	16.67	1.01
North Crossing	419	100-Year	122.18	99.43	101.38	101.38	101.96	0.024023	6.11	19.99	17.49	1.01
North Crossing	419	500-Year	146.41	99.43	101.56	101.56	102.18	0.023233	6.33	23.17	20.53	1.00
North Crossing	384	2-Year	52.58	97.45	99.48		99.54	0.004279	1.94	27.05	28.63	0.35
North Crossing	384	10-Year	90.90	97.45	100.39		100.43	0.001322	1.53	62.31	48.70	0.21
North Crossing	384	25-Year	101.04	97.45	100.53		100.56	0.001220	1.55	69.12	51.32	0.20
North Crossing	384	50-Year	110.20	97.45	100.61		100.64	0.001239	1.61	73.15	52.81	0.21
North Crossing	384	100-Year	121.69	97.45	100.72		100.76	0.001199	1.65	79.46	55.06	0.20
North Crossing	384	500-Year	144.61	97.45	100.92		100.97	0.001163	1.73	90.90	58.31	0.20
North Crossing	358	2-Year	52.58	97.13	99.48		99.49	0.000674	1.02	51.53	36.78	0.15
North Crossing	358	10-Year	90.90	97.13	100.39		100.41	0.000390	1.06	88.76	44.28	0.12
North Crossing	358	25-Year	101.04	97.13	100.52		100.54	0.000396	1.10	94.84	45.21	0.12
North Crossing	358	50-Year	110.20	97.13	100.60		100.62	0.000423	1.16	98.33	45.72	0.13
North Crossing	358	100-Year	121.69	97.13	100.72		100.74	0.000440	1.22	103.71	46.83	0.13
North Crossing	358	500-Year	144.61	97.13	100.92		100.94	0.000476	1.33	113.32	49.18	0.14
North Crossing	323	2-Year	48.19	95.30	99.46	96.57	99.48	0.000200	1.08	46.27	30.49	0.10
North Crossing	323	10-Year	68.31	95.30	100.38	96.87	100.39	0.000086	0.80	98.32	36.34	0.07
North Crossing	323	25-Year	74.82	95.30	100.52	96.93	100.53	0.000090	0.84	103.32	38.17	0.07
North Crossing	323	50-Year	81.08	95.30	100.60	96.99	100.61	0.000098	0.88	106.28	39.15	0.07
North Crossing	323	100-Year	89.69	95.30	100.71	97.07	100.72	0.000107	0.94	110.92	40.73	0.08
North Crossing	323	500-Year	105.78	95.30	100.91	97.21	100.93	0.000123	1.03	119.32	43.53	0.08
North Crossing	297		Culvert									
North Crossing	271	2-Year	48.19	94.53	95.96	95.84	96.38	0.017936	5.15	9.35	11.53	0.85
North Crossing	271	10-Year	68.31	94.53	96.18	96.00	96.55	0.017133	4.86	14.06	12.32	0.80
North Crossing	271	25-Year	74.82	94.53	96.25	96.07	96.64	0.017577	5.02	14.90	12.56	0.81
North Crossing	271	50-Year	81.08	94.53	96.31	96.14	96.72	0.018150	5.19	15.62	12.77	0.83
North Crossing	271	100-Year	89.69	94.53	96.40	96.23	96.84	0.018206	5.33	16.82	13.10	0.83
North Crossing	271	500-Year	105.78	94.53	96.49	96.38	97.02	0.020908	5.86	18.06	13.44	0.89
North Crossing	228	2-Year	48.19	94.07	95.15	95.08	95.46	0.020700	4.45	10.83	13.41	0.87
North Crossing	228	10-Year	68.31	94.07	95.37	95.28	95.75	0.019316	4.94	13.84	16.89	0.86
North Crossing	228	25-Year	74.82	94.07	95.44	95.34	95.84	0.019172	5.08	14.76	25.59	0.87
North Crossing	228	50-Year	81.08	94.07	95.50	95.39	95.92	0.019012	5.19	15.80	33.95	0.87
North Crossing	228	100-Year	89.69	94.07	95.56	95.52	96.01	0.019675	5.42	17.02	47.42	0.89
North Crossing	228	500-Year	105.78	94.07	95.75	95.75	96.15	0.015157	5.17	22.11	61.44	0.79

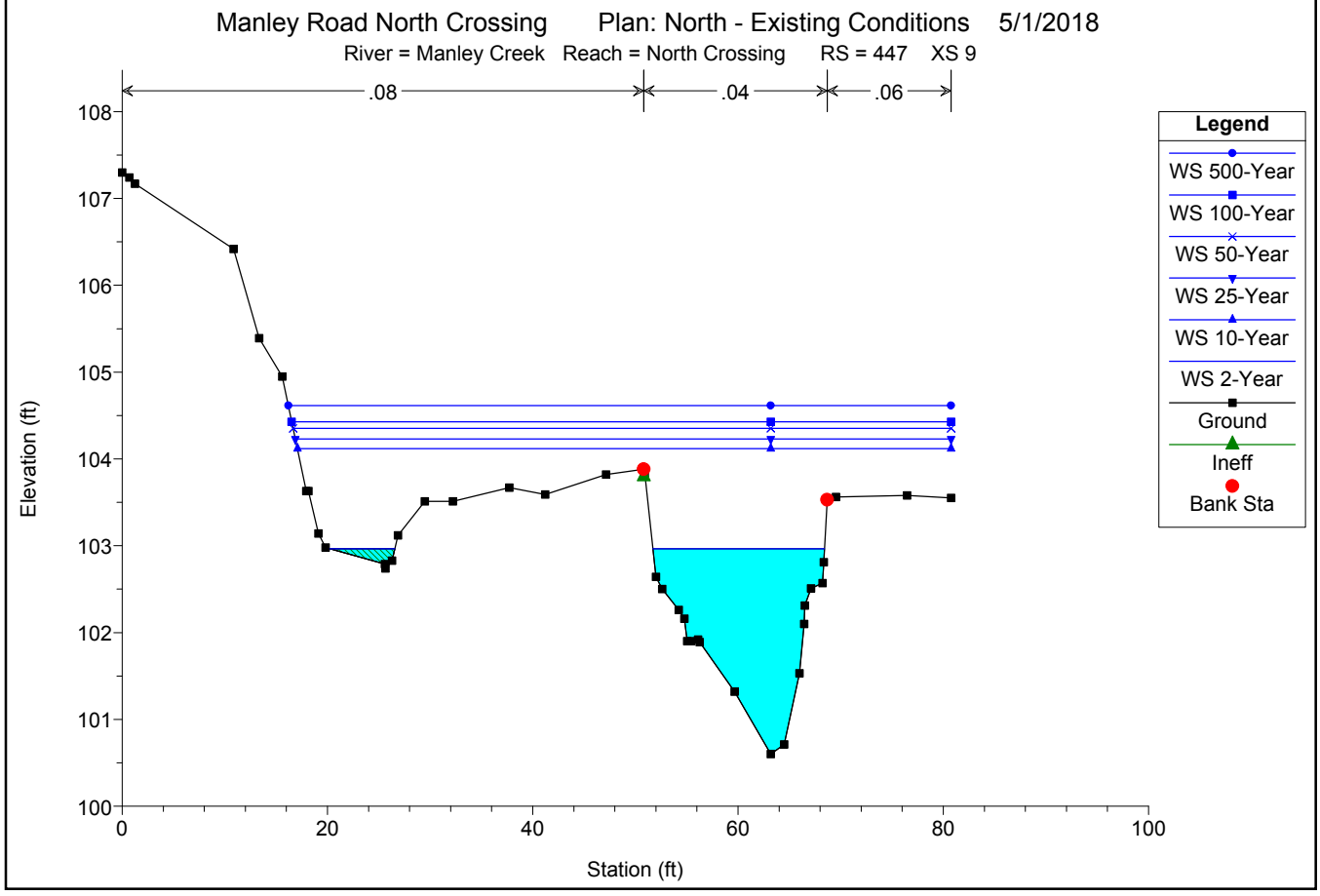
HEC-RAS Plan: NORTH-EXTG River: Manley Creek Reach: North Crossing (Continued)

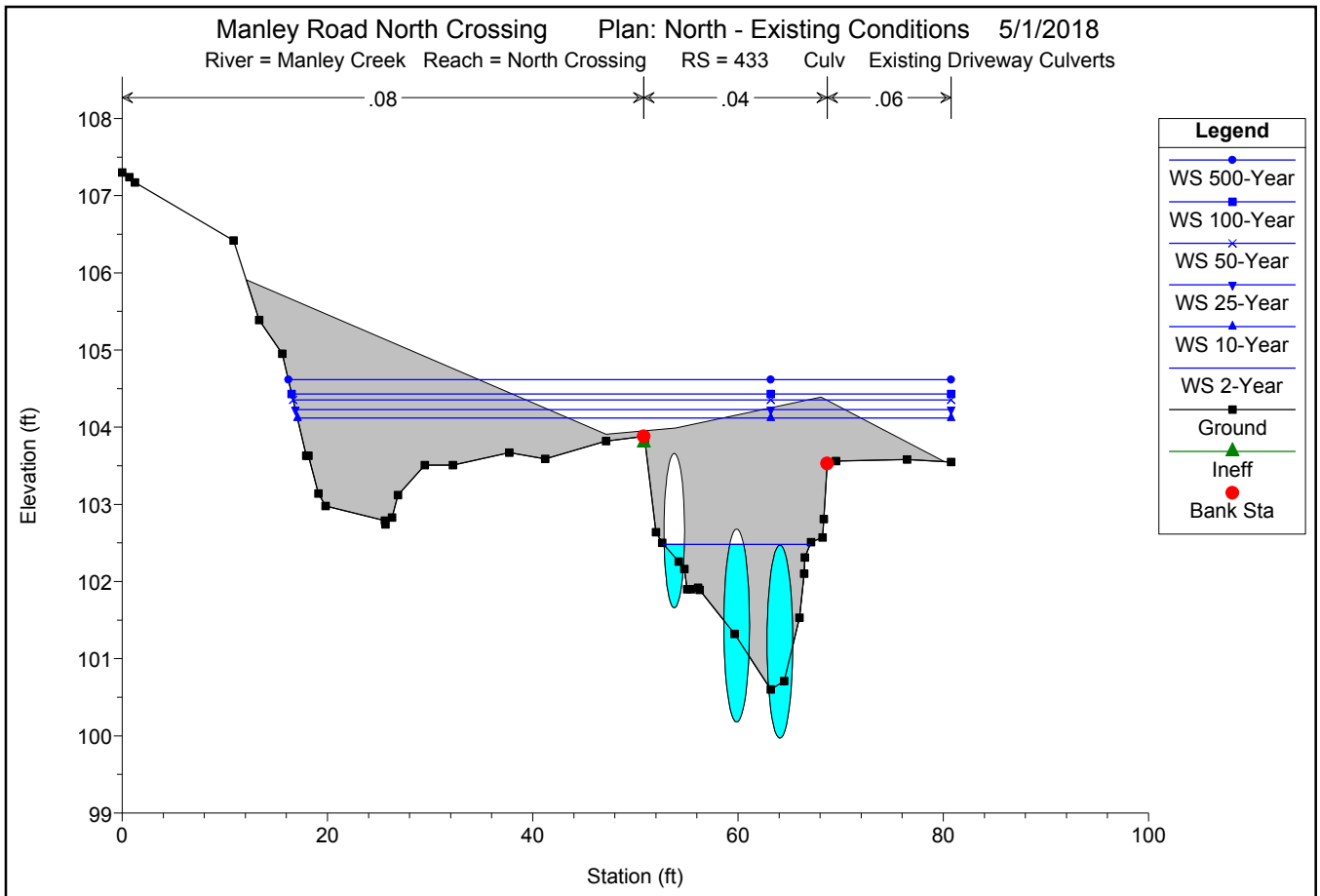
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
North Crossing	179	2-Year	48.19	92.11	94.18	94.02	94.49	0.019017	4.51	10.89	13.46	0.79
North Crossing	179	10-Year	68.31	92.11	94.37	94.31	94.79	0.020168	5.23	13.87	16.77	0.84
North Crossing	179	25-Year	74.82	92.11	94.43	94.38	94.87	0.020395	5.42	14.84	17.71	0.85
North Crossing	179	50-Year	81.08	92.11	94.48	94.46	94.94	0.020793	5.61	15.70	18.51	0.86
North Crossing	179	100-Year	89.69	92.11	94.56	94.56	95.04	0.019988	5.73	17.30	19.91	0.85
North Crossing	179	500-Year	105.78	92.11	94.85	94.85	95.17	0.011295	4.88	26.85	44.01	0.66
North Crossing	100	2-Year	48.19	91.73	92.85	92.75	93.10	0.016030	4.11	12.14	16.85	0.78
North Crossing	100	10-Year	68.31	91.73	93.03	92.94	93.35	0.016018	4.64	15.39	18.39	0.80
North Crossing	100	25-Year	74.82	91.73	93.09	93.00	93.42	0.016020	4.78	16.37	18.83	0.80
North Crossing	100	50-Year	81.08	91.73	93.14	93.05	93.49	0.016021	4.92	17.30	19.24	0.81
North Crossing	100	100-Year	89.69	91.73	93.20	93.12	93.58	0.016016	5.09	18.53	19.88	0.81
North Crossing	100	500-Year	105.78	91.73	93.31	93.24	93.73	0.016012	5.39	20.75	21.05	0.82

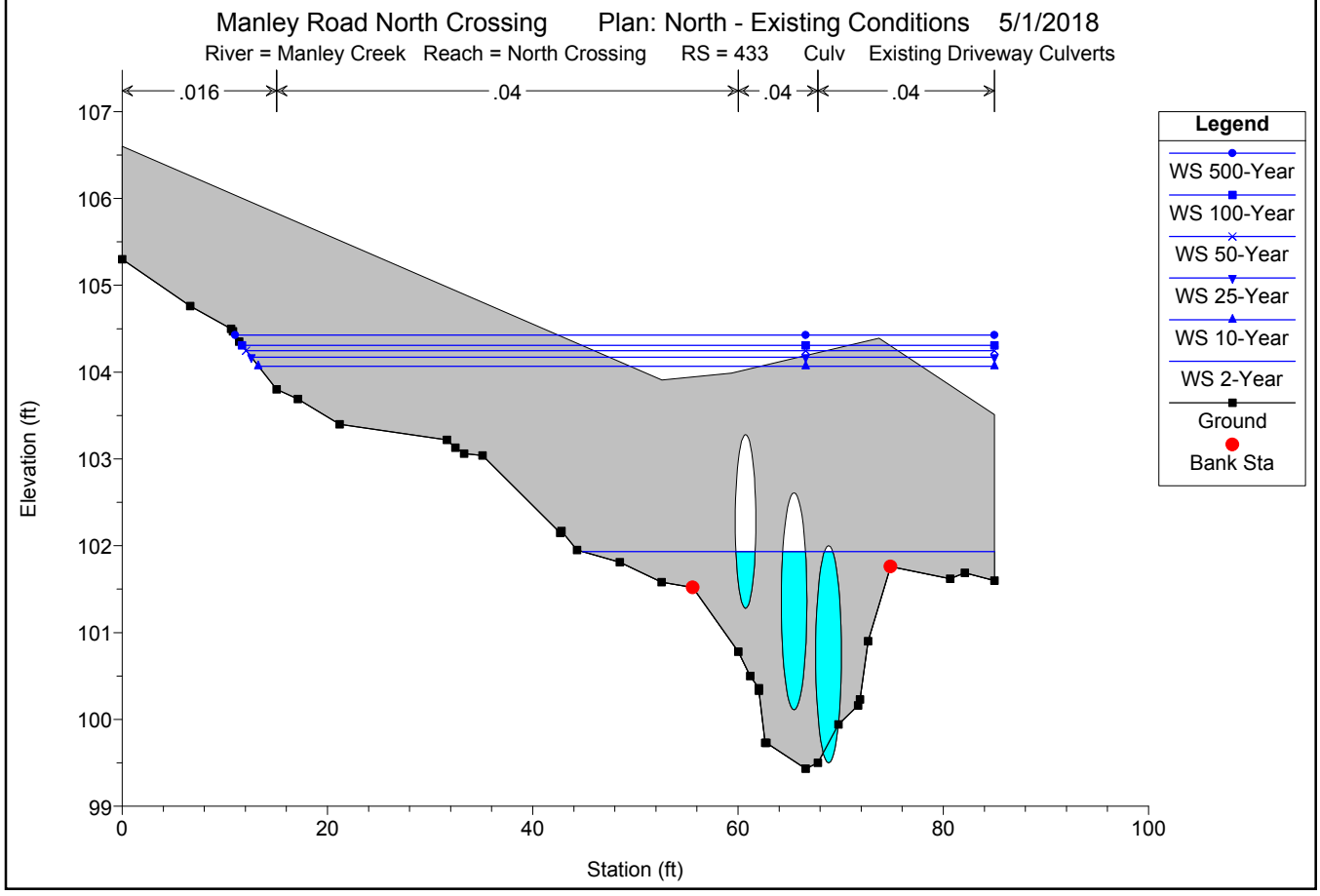

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
Manley Creek North Crossing
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Lat Struct
Ground
Elevation (ft)
Main Channel Distance (ft)
90
92
94
96
98
100
102
104
106
108
0
100
200
300
400
500

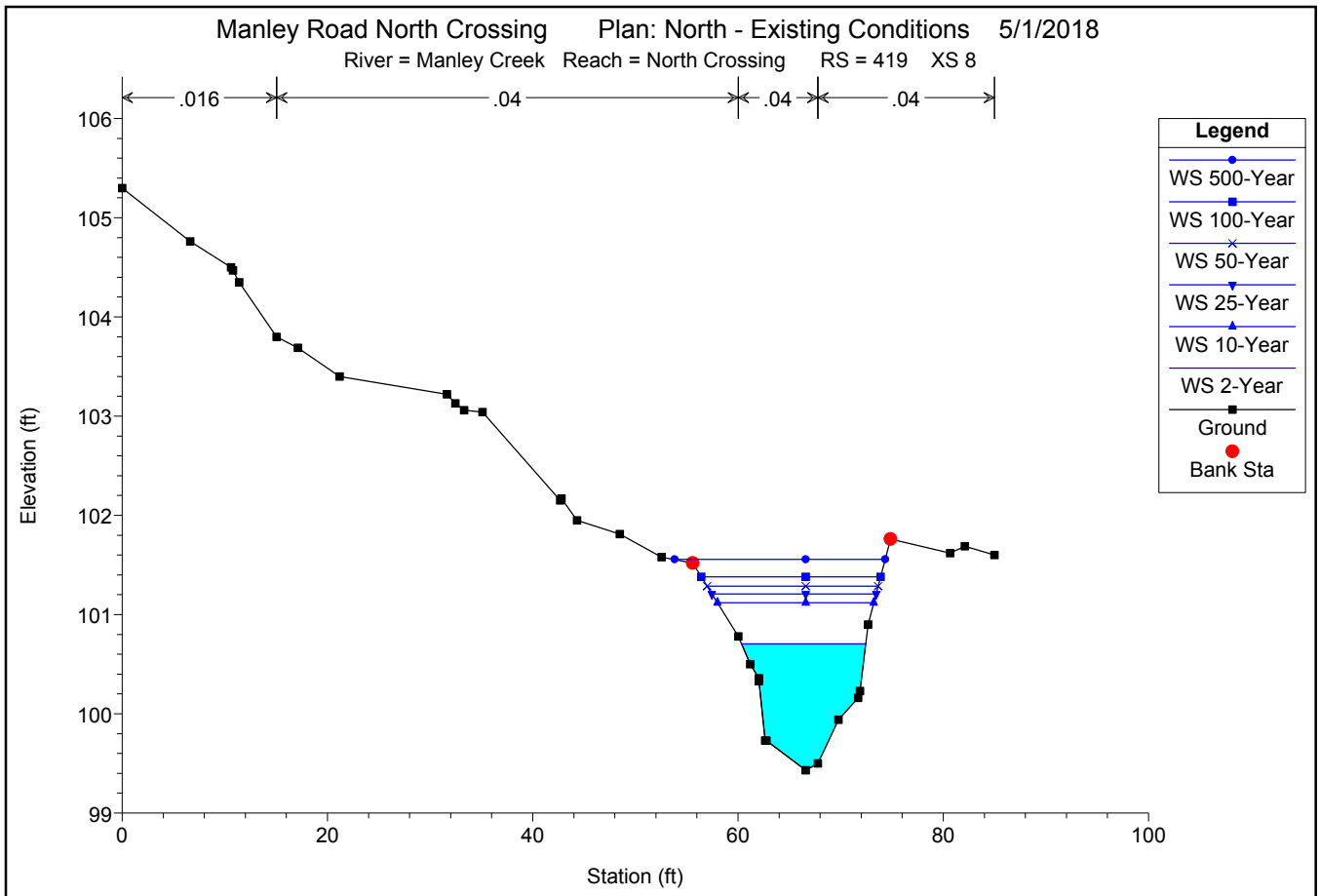

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 554 XS 11
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 516 XS 10b
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

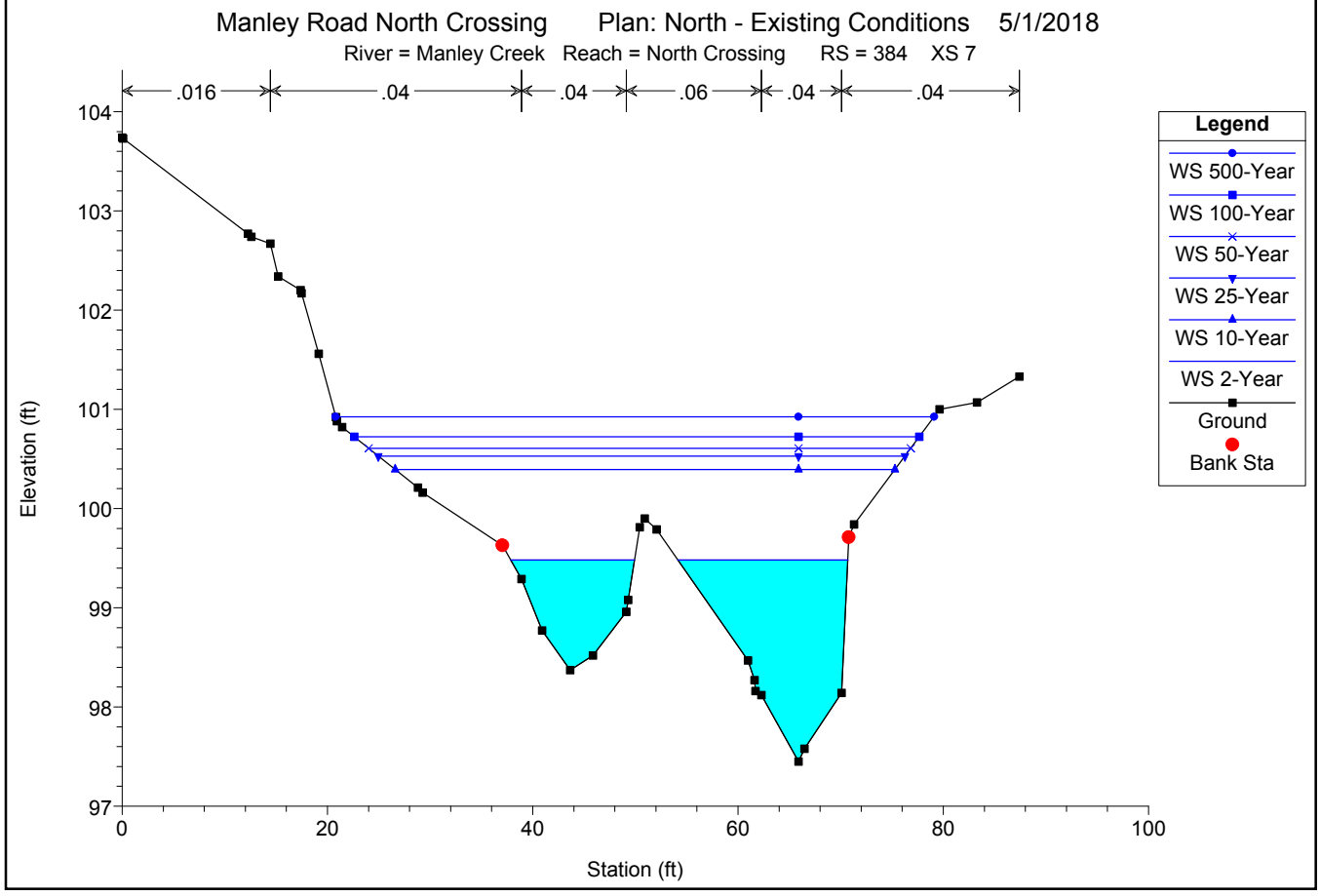

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 476 XS 10a
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

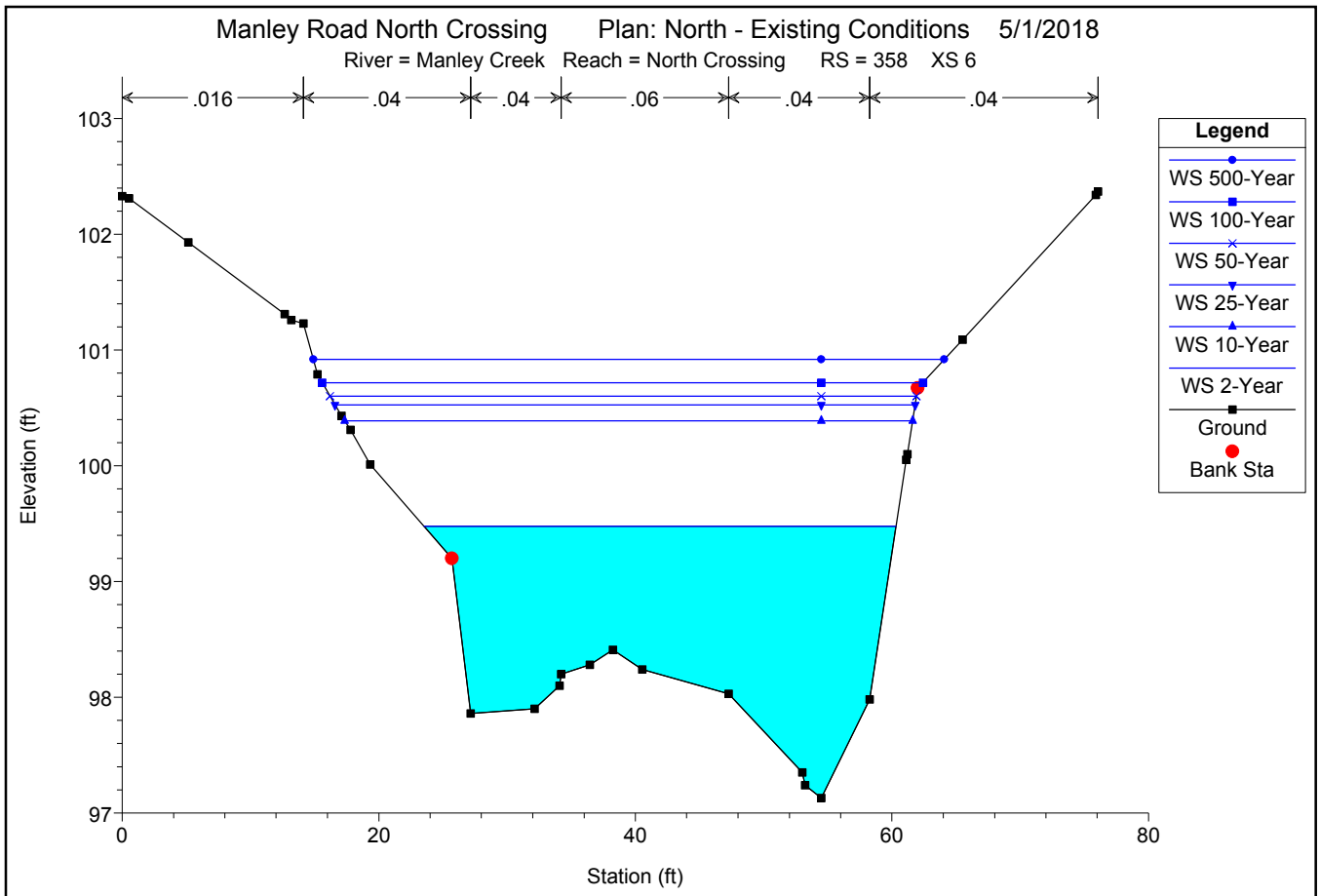

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 447 XS 9
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

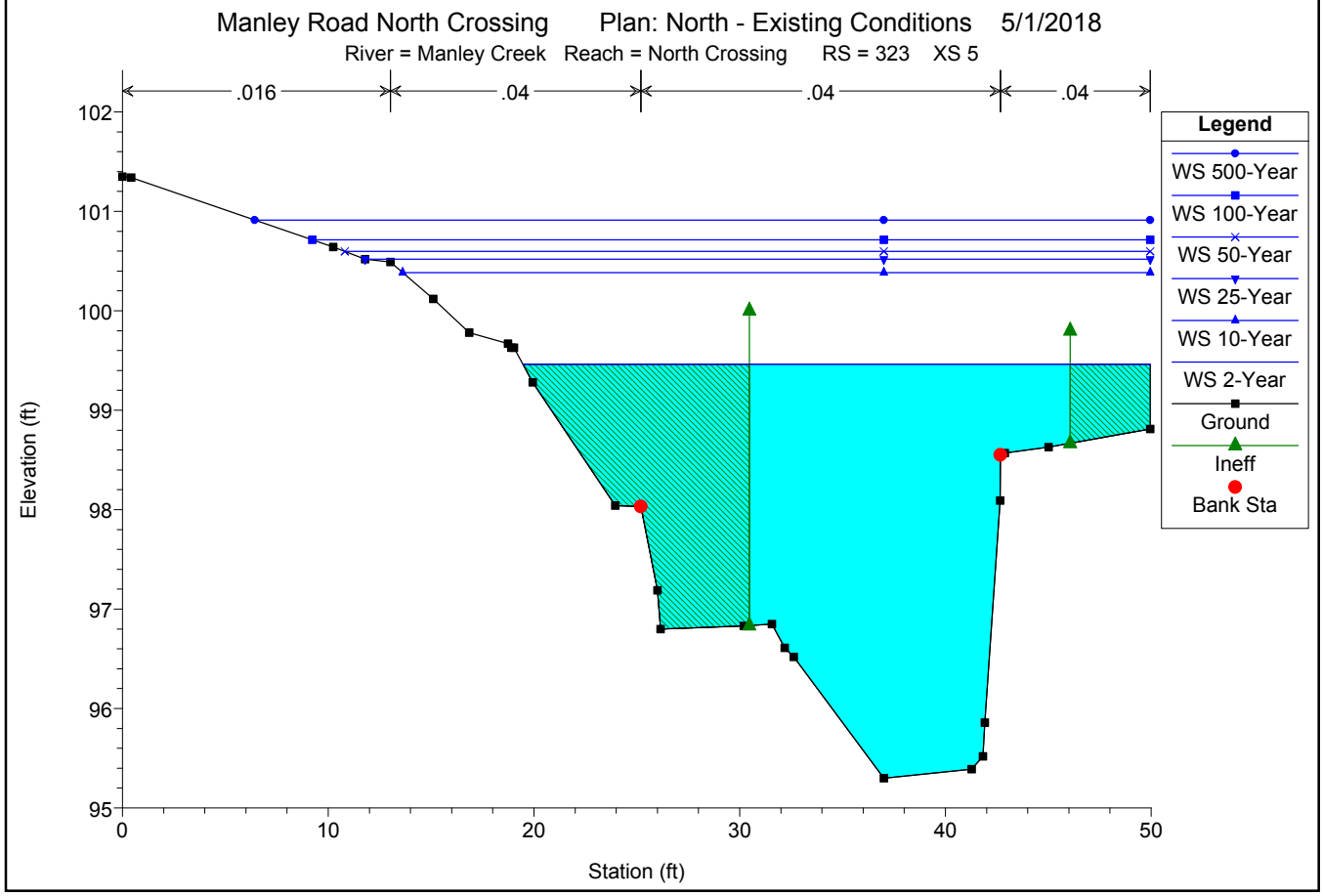

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 433 Culv Existing Driveway Culverts
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
108
107
106
105
104
103
102
101
100
99
0
20
40
60
80
100

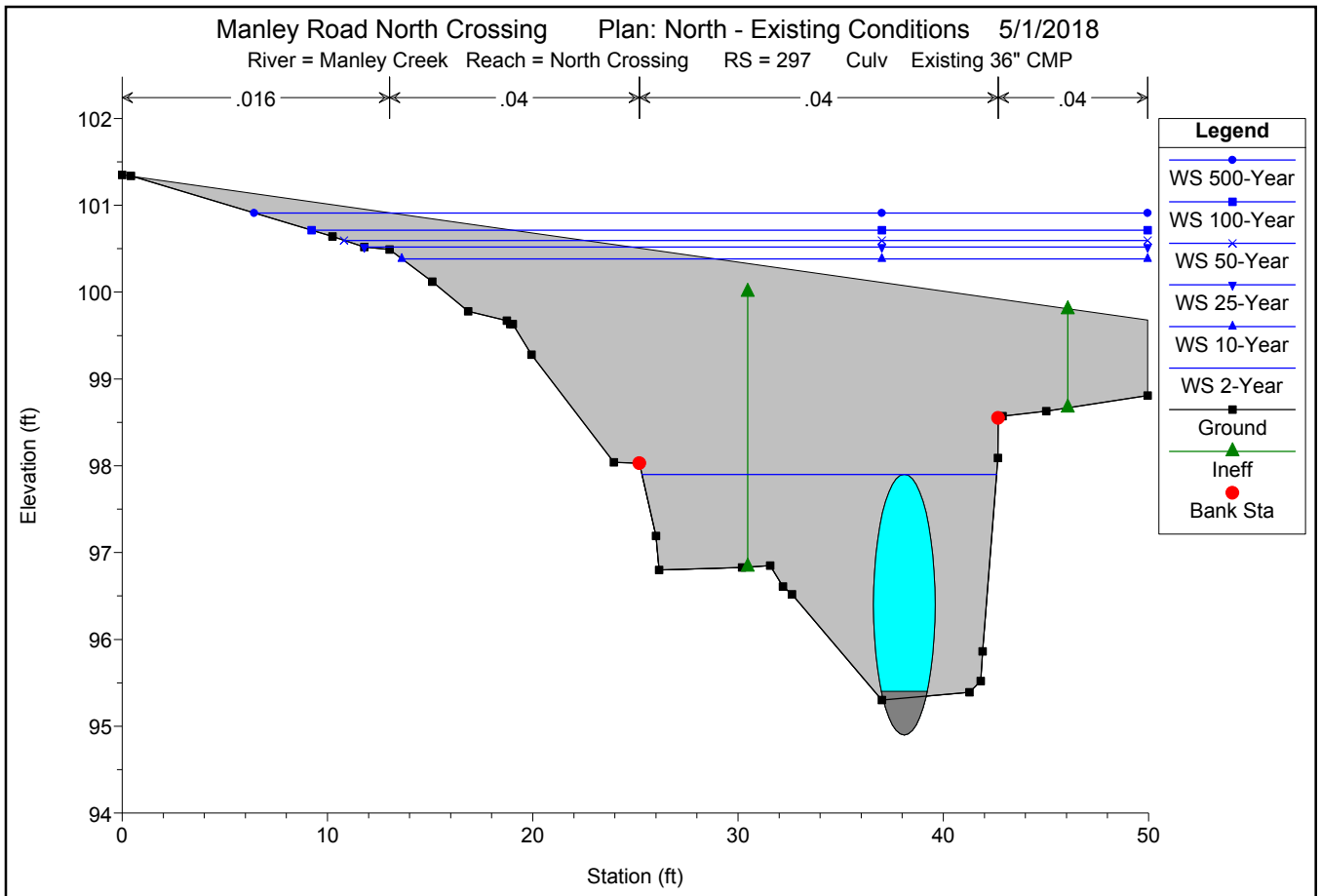

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 433 Culv Existing Driveway Culverts
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
107
106
105
104
103
102
101
100
99
0
20
40
60
80
100

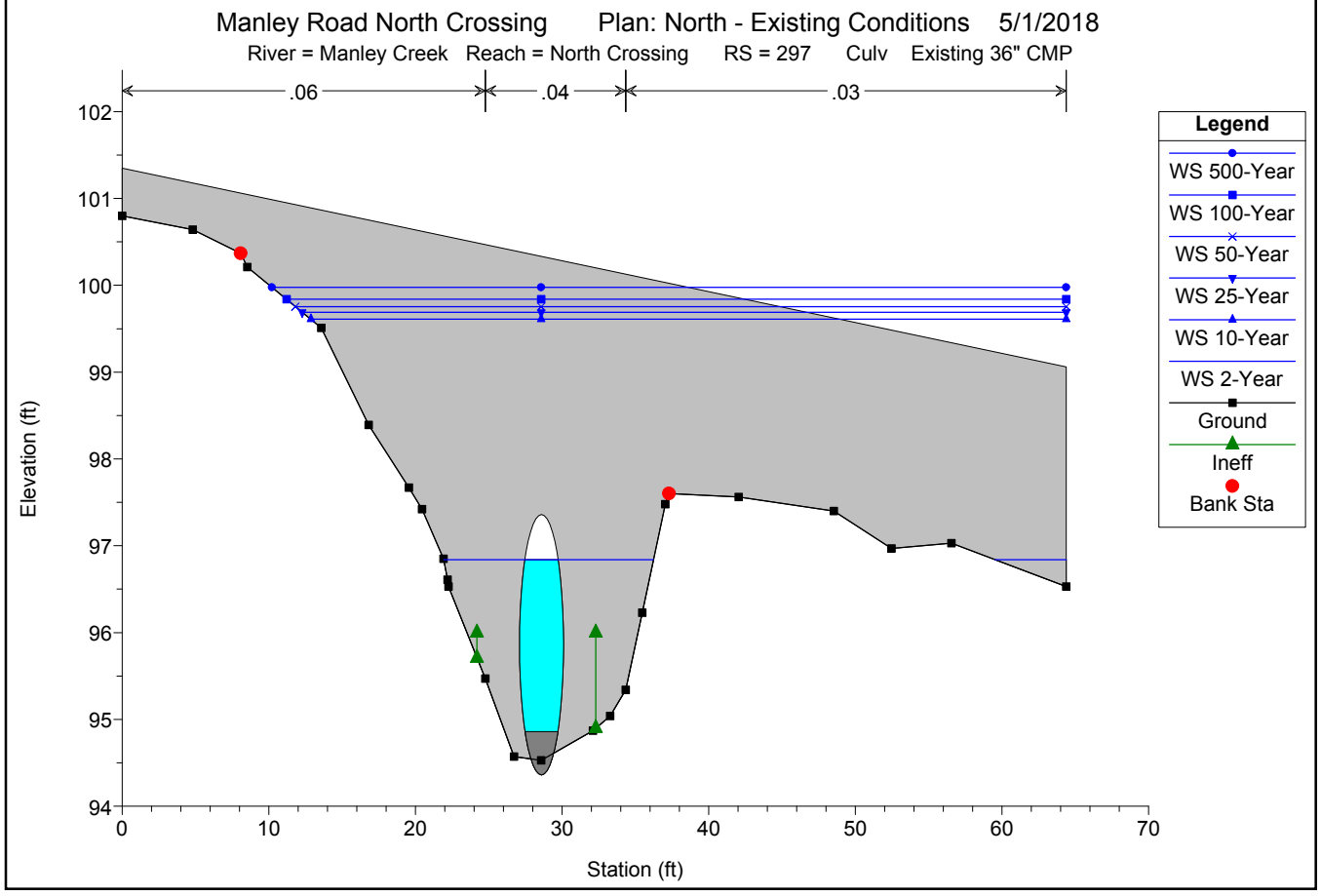

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 419 XS 8
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
106
105
104
103
102
101
100
99
0
20
40
60
80
100

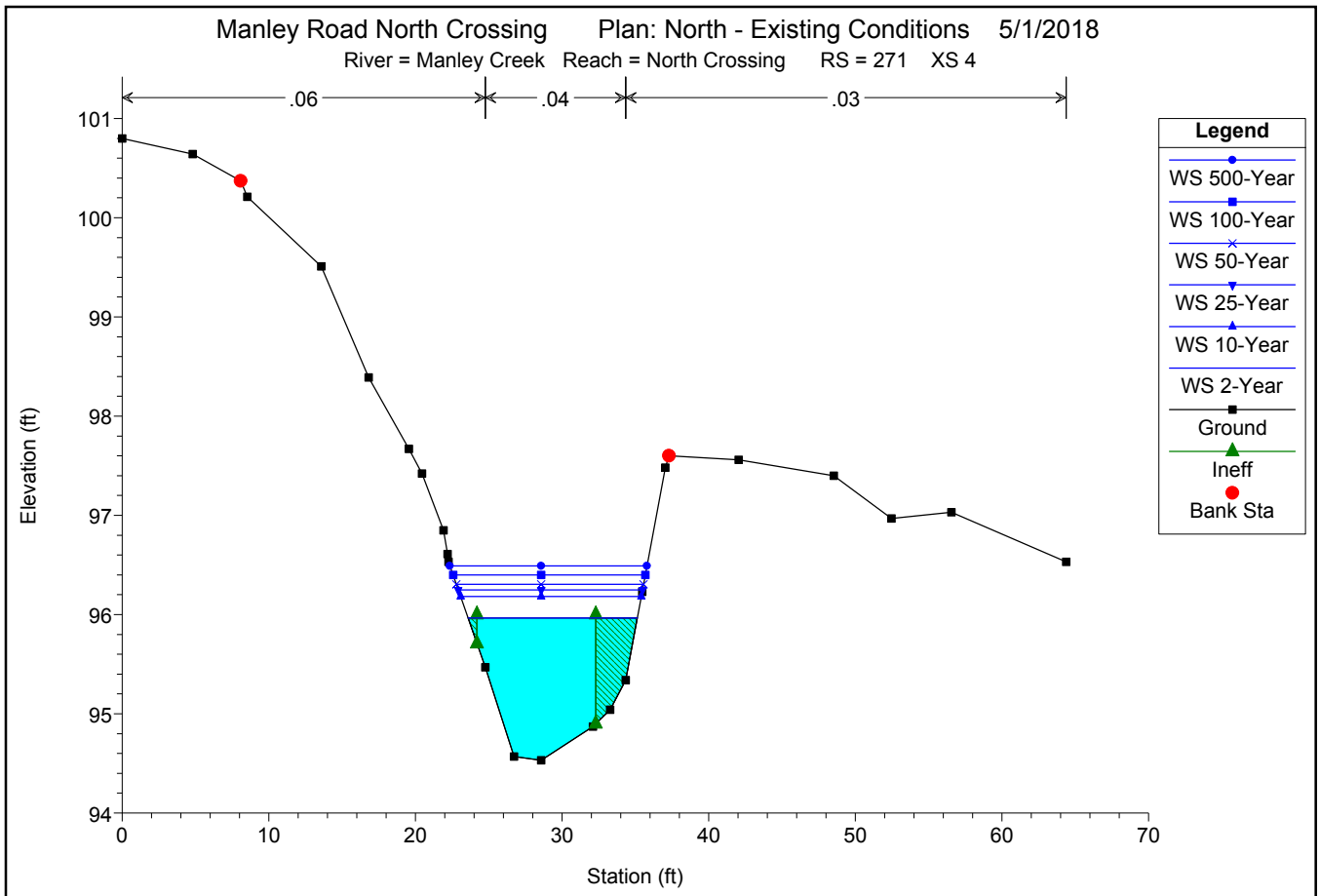

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 384 XS 7
.016
.04
.04
.06
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
104
103
102
101
100
99
98
97
0
20
40
60
80
100

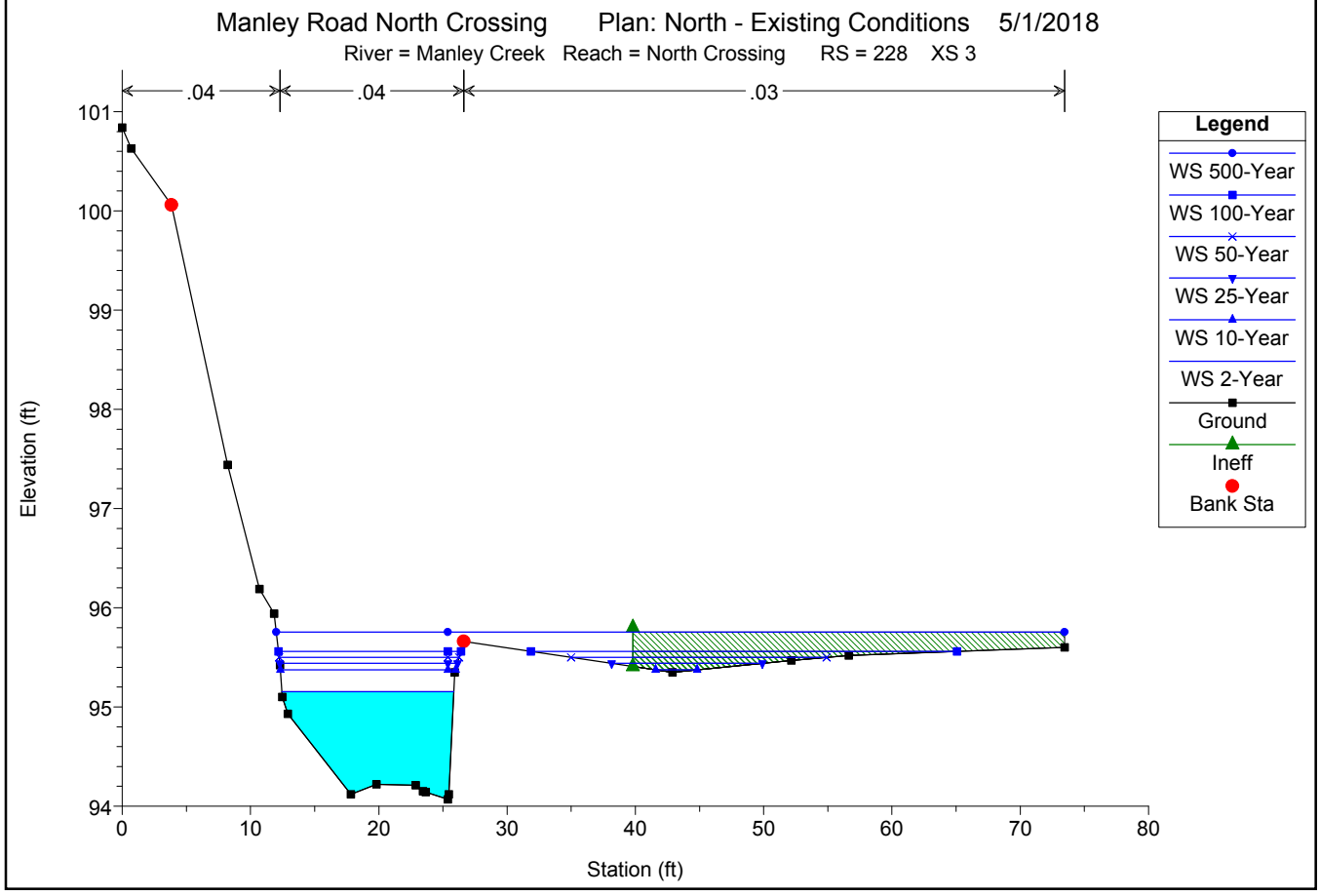

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 358 XS 6
.016
.04
.04
.06
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

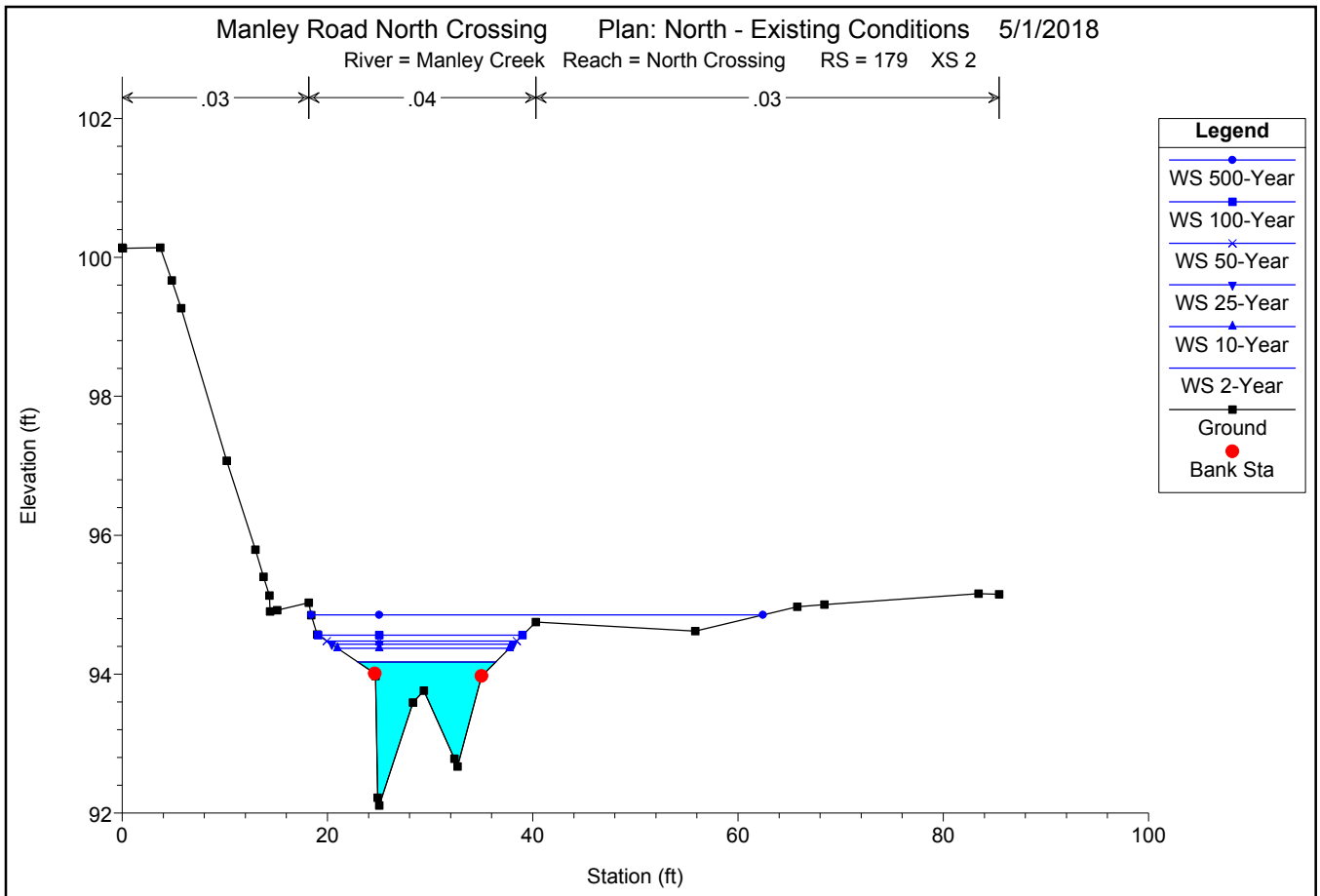

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 323 XS 5
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

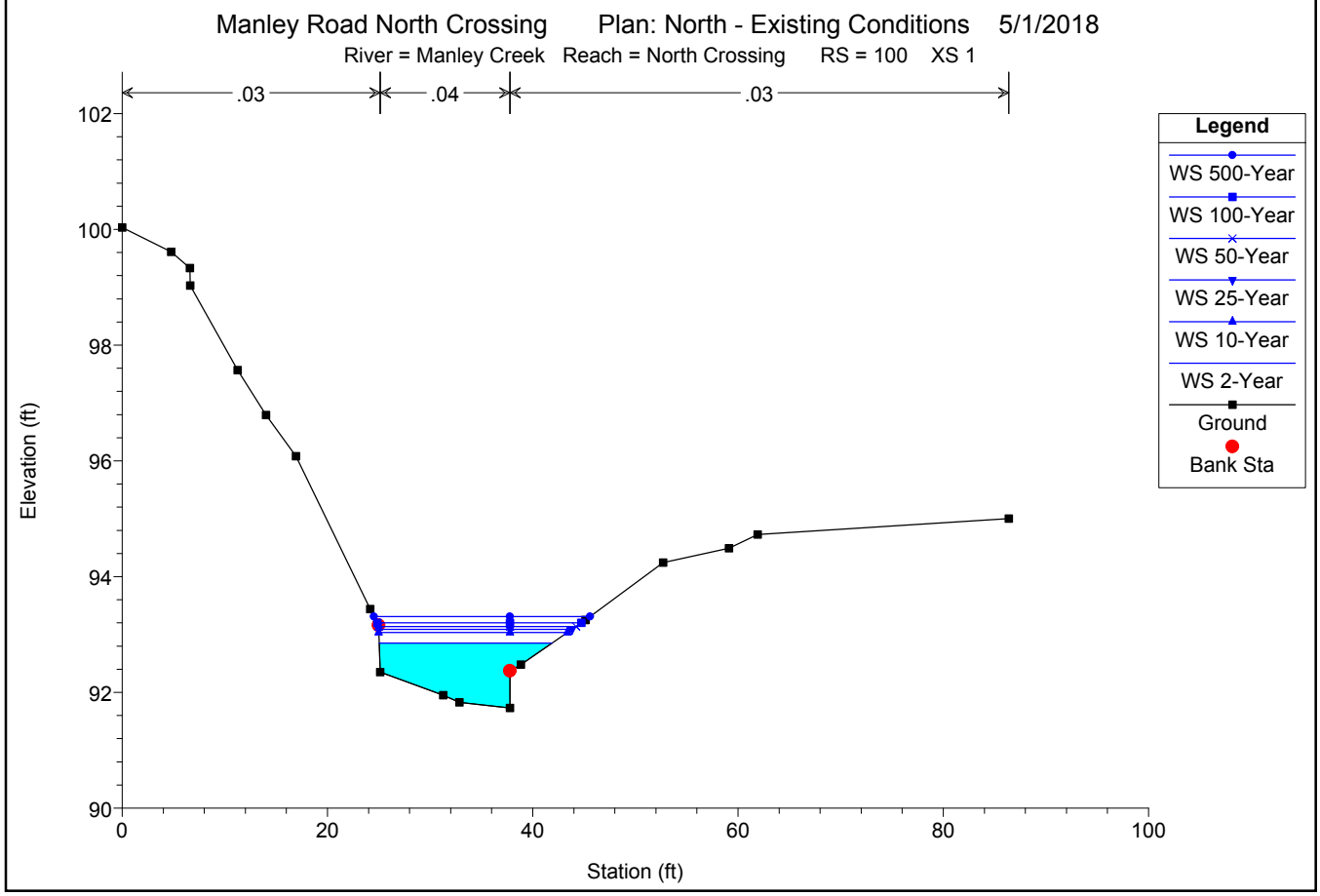

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 297 Culv Existing 36" CMP
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 297 Culv Existing 36" CMP
.06
.04
.03
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 271 XS 4
.06
.04
.03
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta


Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 228 XS 3
.04
.04
.03
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta


Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 179 XS 2
.03
.04
.03
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
102
100
98
96
94
92
0
20
40
60
80
100

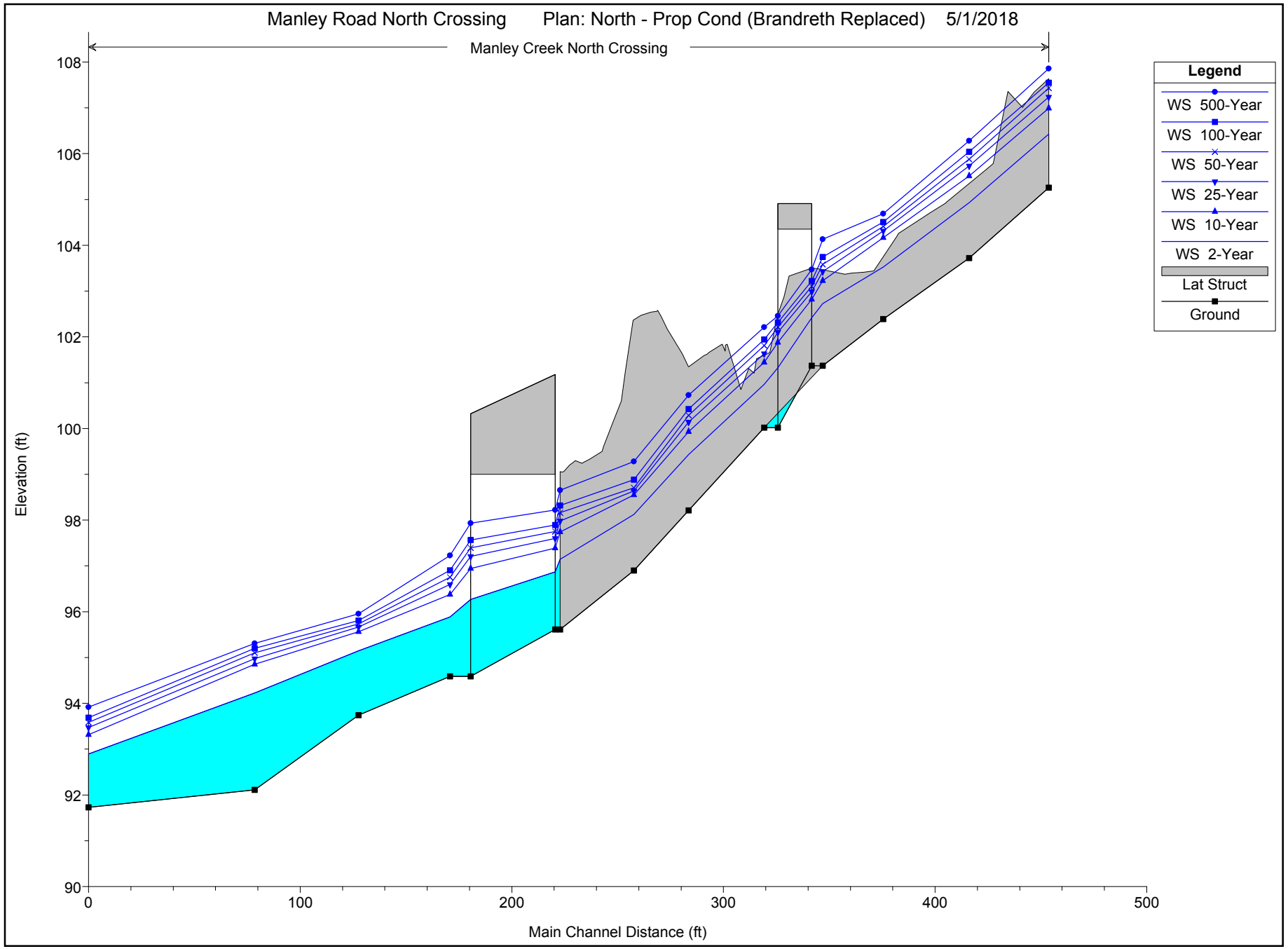

Manley Road North Crossing Plan: North - Existing Conditions 5/1/2018
River = Manley Creek Reach = North Crossing RS = 100 XS 1
.03
.04
.03
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
102
100
98
96
94
92
90
0
20
40
60
80
100

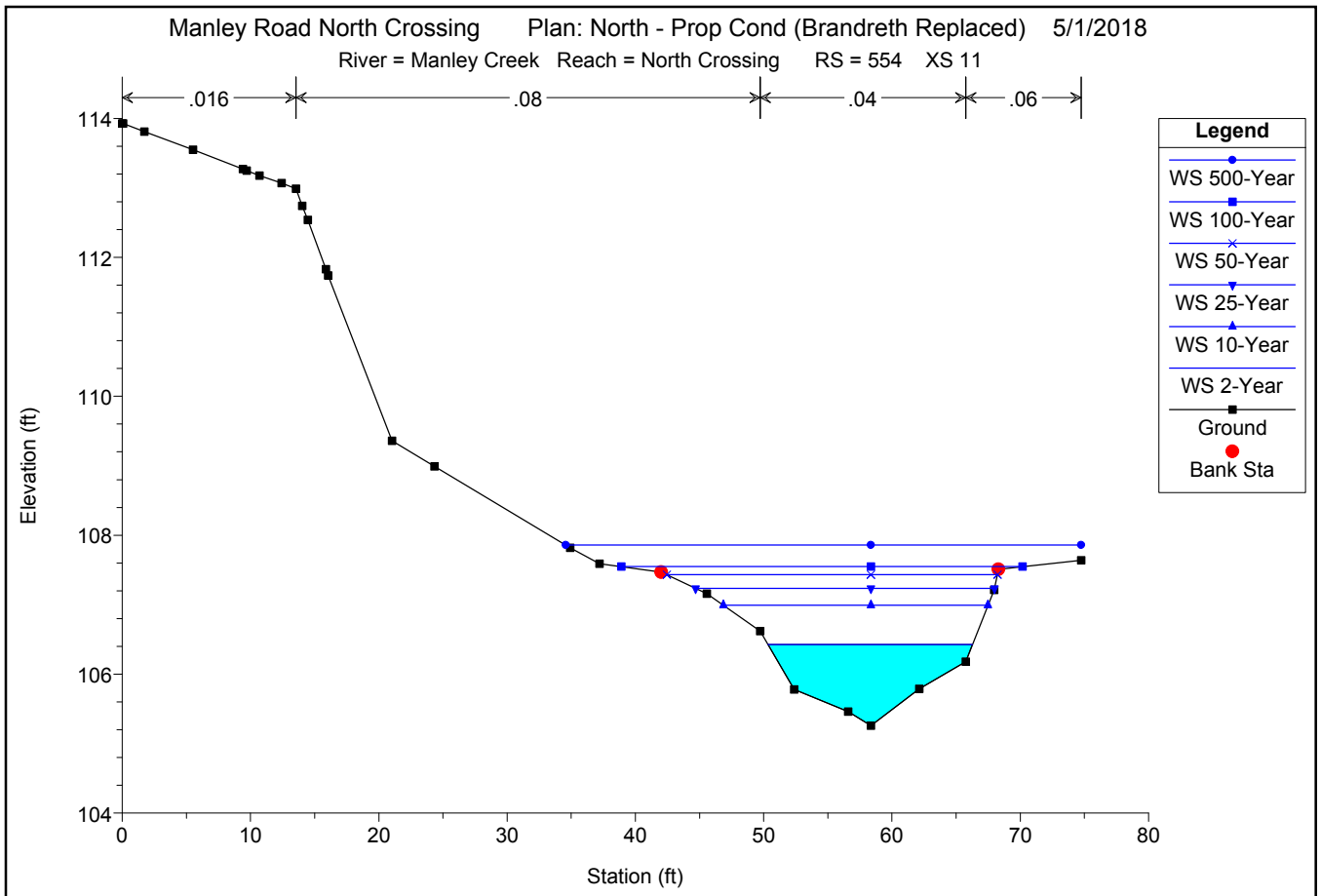
HEC-RAS Plan: PROP-BRANDRETH River: Manley Creek Reach: North Crossing

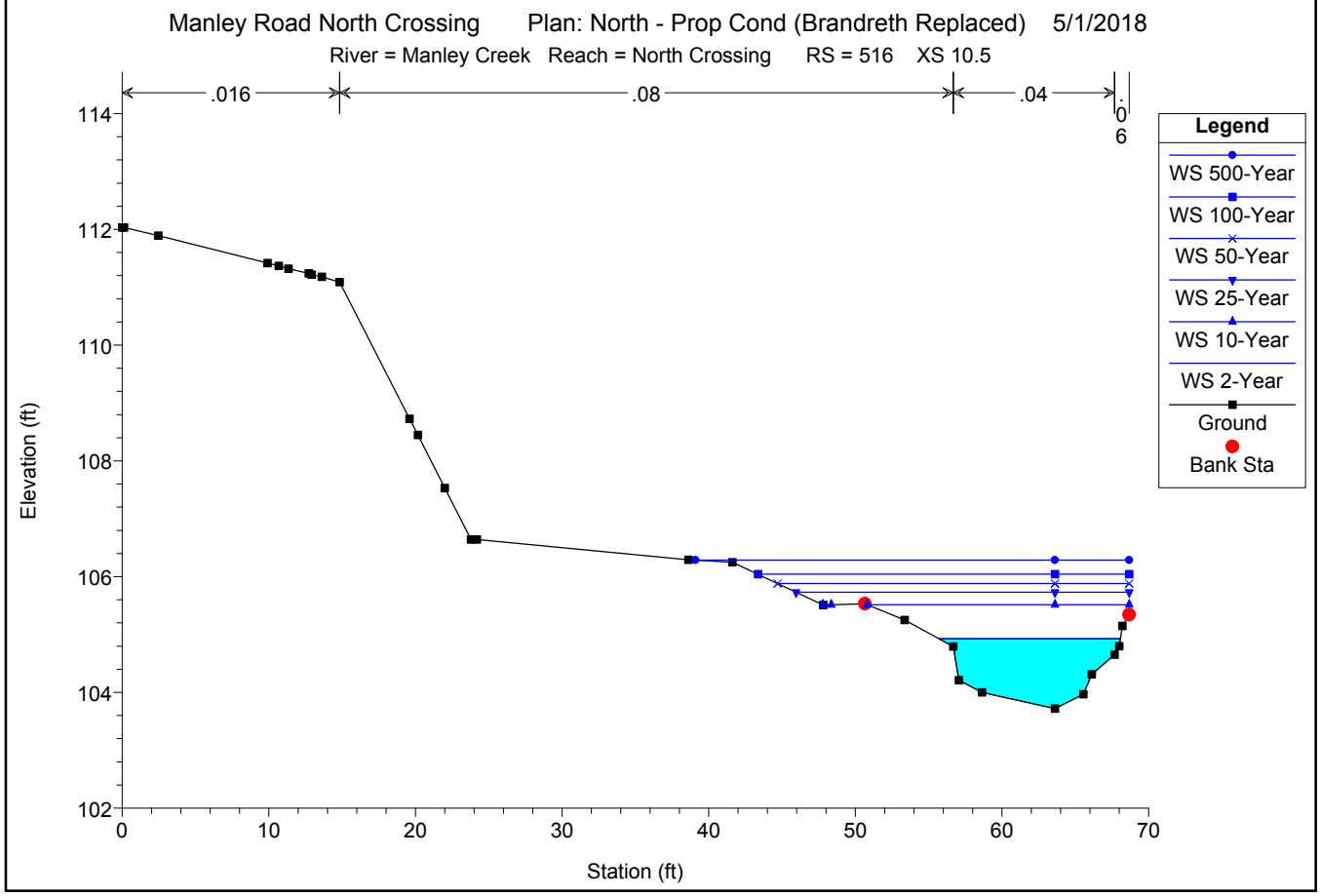
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
North Crossing	554	2-Year	52.60	105.26	106.43	106.43	106.78	0.028683	4.77	11.02	15.94	1.01
North Crossing	554	10-Year	111.00	105.26	106.99	106.91	107.42	0.028768	5.24	21.18	20.63	0.91
North Crossing	554	25-Year	144.00	105.26	107.24	107.12	107.69	0.031011	5.43	26.53	23.29	0.90
North Crossing	554	50-Year	171.00	105.26	107.43		107.90	0.031858	5.45	31.36	25.77	0.87
North Crossing	554	100-Year	199.00	105.26	107.55	107.43	108.07	0.033223	5.79	34.52	31.28	0.89
North Crossing	554	500-Year	266.00	105.26	107.86	107.77	108.43	0.028049	6.13	46.24	40.15	0.85
North Crossing	553		Lat Struct									
North Crossing	516	2-Year	52.60	103.72	104.93	104.93	105.34	0.033276	5.18	10.16	12.39	1.01
North Crossing	516	10-Year	110.53	103.72	105.51	105.51	106.04	0.047294	5.84	18.94	18.45	1.00
North Crossing	516	25-Year	142.32	103.72	105.73	105.73	106.32	0.042827	6.18	23.67	22.74	0.97
North Crossing	516	50-Year	168.15	103.72	105.88	105.88	106.52	0.041006	6.48	27.17	23.99	0.96
North Crossing	516	100-Year	194.80	103.72	106.04	106.04	106.72	0.038137	6.67	31.13	25.33	0.94
North Crossing	516	500-Year	258.04	103.72	106.28	106.28	107.14	0.041298	7.57	37.53	29.59	0.99
North Crossing	476	2-Year	52.60	102.39	103.52	103.52	103.99	0.029376	5.47	9.61	10.91	1.03
North Crossing	476	10-Year	108.43	102.39	104.17	104.17	104.54	0.014552	5.32	29.67	48.17	0.78
North Crossing	476	25-Year	137.09	102.39	104.31	104.31	104.72	0.014694	5.70	36.89	49.61	0.80
North Crossing	476	50-Year	160.31	102.39	104.41	104.41	104.85	0.015115	6.02	41.74	49.81	0.82
North Crossing	476	100-Year	183.85	102.39	104.51	104.51	104.97	0.015111	6.26	46.75	50.01	0.83
North Crossing	476	500-Year	241.23	102.39	104.69	104.69	105.24	0.016598	6.99	55.82	50.37	0.88
North Crossing	447	2-Year	52.60	101.37	102.73	102.42	102.87	0.009109	3.06	17.18	18.96	0.57
North Crossing	447	10-Year	106.53	101.37	103.23	102.82	103.47	0.010245	3.93	27.08	24.62	0.60
North Crossing	447	25-Year	133.80	101.37	103.43	102.99	103.71	0.010653	4.30	31.14	26.47	0.61
North Crossing	447	50-Year	155.73	101.37	103.58	103.12	103.90	0.010861	4.54	34.37	34.87	0.62
North Crossing	447	100-Year	177.76	101.37	103.74	103.22	104.09	0.010680	4.72	38.33	38.73	0.61
North Crossing	447	500-Year	231.25	101.37	104.13	103.49	104.51	0.009779	4.99	48.28	55.51	0.59
North Crossing	433		Bridge									
North Crossing	419	2-Year	52.60	100.02	100.97	100.97	101.34	0.026401	4.91	10.72	14.33	1.00
North Crossing	419	10-Year	106.53	100.02	101.44	101.44	101.97	0.023698	5.83	18.26	17.26	1.00
North Crossing	419	25-Year	133.80	100.02	101.63	101.63	102.23	0.022536	6.17	21.74	20.46	0.99
North Crossing	419	50-Year	155.73	100.02	101.81	101.81	102.41	0.019479	6.21	25.63	26.92	0.94
North Crossing	419	100-Year	177.76	100.02	101.94	101.94	102.57	0.018640	6.39	28.74	27.24	0.93
North Crossing	419	500-Year	231.25	100.02	102.21	102.21	102.92	0.018050	6.83	35.24	28.14	0.94
North Crossing	384	2-Year	52.60	98.21	99.43	99.43	99.83	0.026520	5.06	10.39	13.23	1.01
North Crossing	384	10-Year	106.50	98.21	99.93	99.93	100.51	0.023580	6.10	17.46	15.20	1.00
North Crossing	384	25-Year	133.38	98.21	100.14	100.14	100.78	0.022553	6.43	20.74	16.08	1.00
North Crossing	384	50-Year	154.37	98.21	100.29	100.29	100.98	0.022047	6.65	23.21	16.79	1.00
North Crossing	384	100-Year	175.36	98.21	100.43	100.43	101.16	0.022016	6.86	25.56	17.45	1.00
North Crossing	384	500-Year	225.93	98.21	100.73	100.73	101.55	0.022081	7.27	31.07	18.91	1.00
North Crossing	358	2-Year	52.60	96.90	98.12	98.12	98.48	0.026704	4.78	11.00	23.66	1.00
North Crossing	358	10-Year	106.50	96.90	98.55	98.55	98.86	0.023346	4.43	24.02	34.29	0.93
North Crossing	358	25-Year	133.38	96.90	98.64	98.64	99.02	0.024986	4.93	27.08	34.71	0.98
North Crossing	358	50-Year	154.37	96.90	98.71	98.71	99.13	0.025615	5.24	29.46	35.02	1.01
North Crossing	358	100-Year	175.36	96.90	98.88	98.79	99.26	0.018165	4.93	35.59	35.81	0.87
North Crossing	358	500-Year	225.93	96.90	99.28	98.97	99.59	0.010310	4.49	50.36	38.04	0.69
North Crossing	323	2-Year	52.60	95.61	97.15	96.86	97.37	0.010767	3.80	13.84	13.68	0.67
North Crossing	323	10-Year	106.50	95.61	97.74	97.39	98.08	0.010730	4.69	22.73	16.18	0.70
North Crossing	323	25-Year	133.38	95.61	97.98	97.60	98.37	0.010639	4.98	26.76	17.19	0.70
North Crossing	323	50-Year	154.37	95.61	98.16	97.75	98.58	0.010480	5.17	29.87	17.93	0.71
North Crossing	323	100-Year	175.36	95.61	98.32	97.89	98.76	0.010463	5.36	32.74	18.57	0.71
North Crossing	323	500-Year	225.93	95.61	98.65	98.19	99.17	0.010554	5.77	39.18	19.94	0.73
North Crossing	297		Bridge									
North Crossing	271	2-Year	52.60	94.59	95.89	95.84	96.27	0.022212	4.96	10.61	12.12	0.93
North Crossing	271	10-Year	106.50	94.59	96.38	96.38	96.98	0.024168	6.25	17.04	14.11	1.00
North Crossing	271	25-Year	133.38	94.59	96.59	96.59	97.27	0.023812	6.60	20.22	15.03	1.00
North Crossing	271	50-Year	154.37	94.59	96.75	96.75	97.48	0.023510	6.82	22.63	15.69	1.00
North Crossing	271	100-Year	175.36	94.59	96.90	96.90	97.66	0.023059	7.00	25.06	16.33	1.00
North Crossing	271	500-Year	225.93	94.59	97.23	97.23	98.07	0.022823	7.38	30.60	18.07	1.00
North Crossing	228	2-Year	52.60	93.74	95.15	95.03	95.41	0.015536	4.15	13.05	21.33	0.79
North Crossing	228	10-Year	106.50	93.74	95.56	95.56	95.86	0.012405	4.72	25.95	52.98	0.74
North Crossing	228	25-Year	133.38	93.74	95.67	95.67	96.01	0.013017	5.07	30.00	61.36	0.77
North Crossing	228	50-Year	154.37	93.74	95.74	95.74	96.11	0.013579	5.34	32.70	61.42	0.79
North Crossing	228	100-Year	175.36	93.74	95.81	95.81	96.21	0.013881	5.55	35.36	61.48	0.81
North Crossing	228	500-Year	225.93	93.74	95.95	95.95	96.44	0.014568	6.01	41.10	61.63	0.83

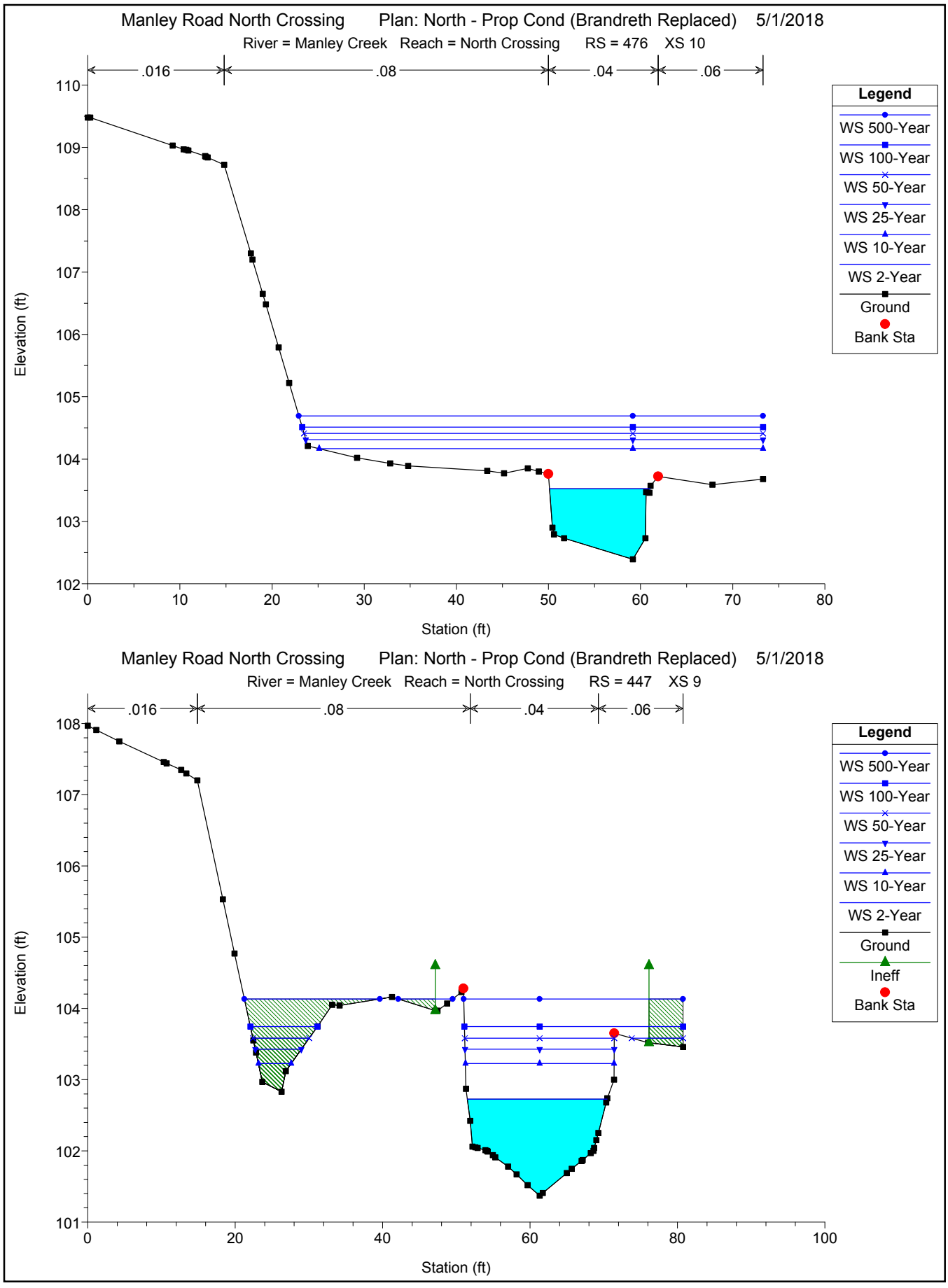
HEC-RAS Plan: PROP-BRANDRETH River: Manley Creek Reach: North Crossing (Continued)

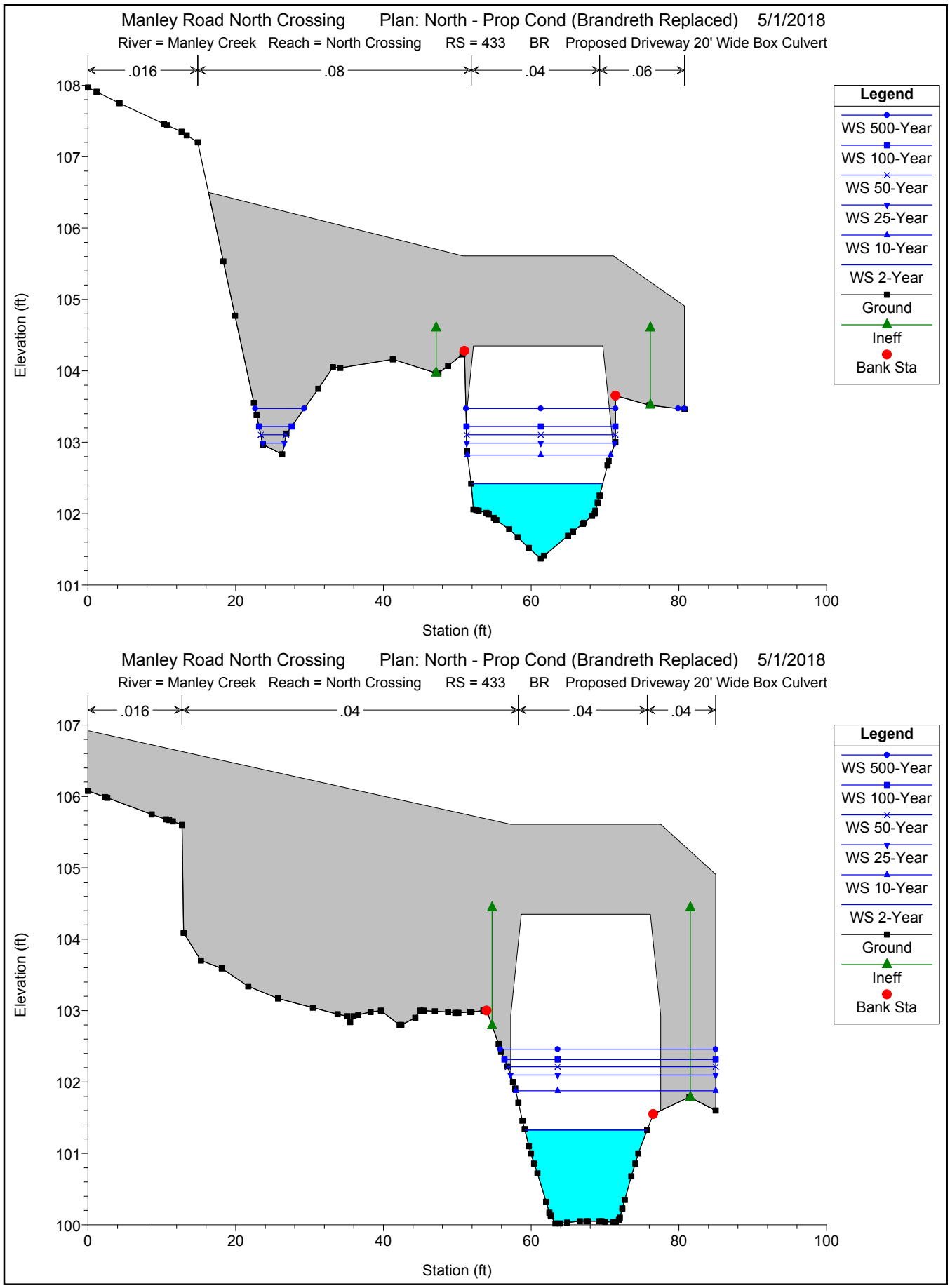
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
North Crossing	179	2-Year	52.60	92.11	94.22	94.09	94.56	0.019272	4.69	11.56	14.27	0.80
North Crossing	179	10-Year	106.50	92.11	94.85	94.85	95.17	0.011452	4.92	26.85	44.01	0.67
North Crossing	179	25-Year	133.38	92.11	94.97	94.97	95.32	0.011907	5.25	32.44	49.92	0.69
North Crossing	179	50-Year	154.37	92.11	95.10	95.10	95.42	0.010520	5.16	39.83	63.61	0.65
North Crossing	179	100-Year	175.36	92.11	95.20	95.20	95.49	0.009730	5.13	46.45	71.23	0.63
North Crossing	179	500-Year	225.93	92.11	95.31	95.31	95.65	0.010871	5.61	54.09	71.46	0.67
North Crossing	100	2-Year	52.60	91.73	92.89	92.80	93.16	0.016026	4.23	12.88	17.21	0.78
North Crossing	100	10-Year	106.50	91.73	93.31	93.24	93.73	0.016012	5.40	20.85	21.10	0.83
North Crossing	100	25-Year	133.38	91.73	93.47	93.42	93.96	0.016008	5.82	24.37	22.79	0.84
North Crossing	100	50-Year	154.37	91.73	93.59	93.55	94.12	0.016005	6.11	27.00	23.96	0.85
North Crossing	100	100-Year	175.36	91.73	93.69	93.67	94.26	0.016003	6.37	29.54	25.03	0.86
North Crossing	100	500-Year	225.93	91.73	93.92	93.92	94.58	0.015755	6.88	35.55	27.41	0.87

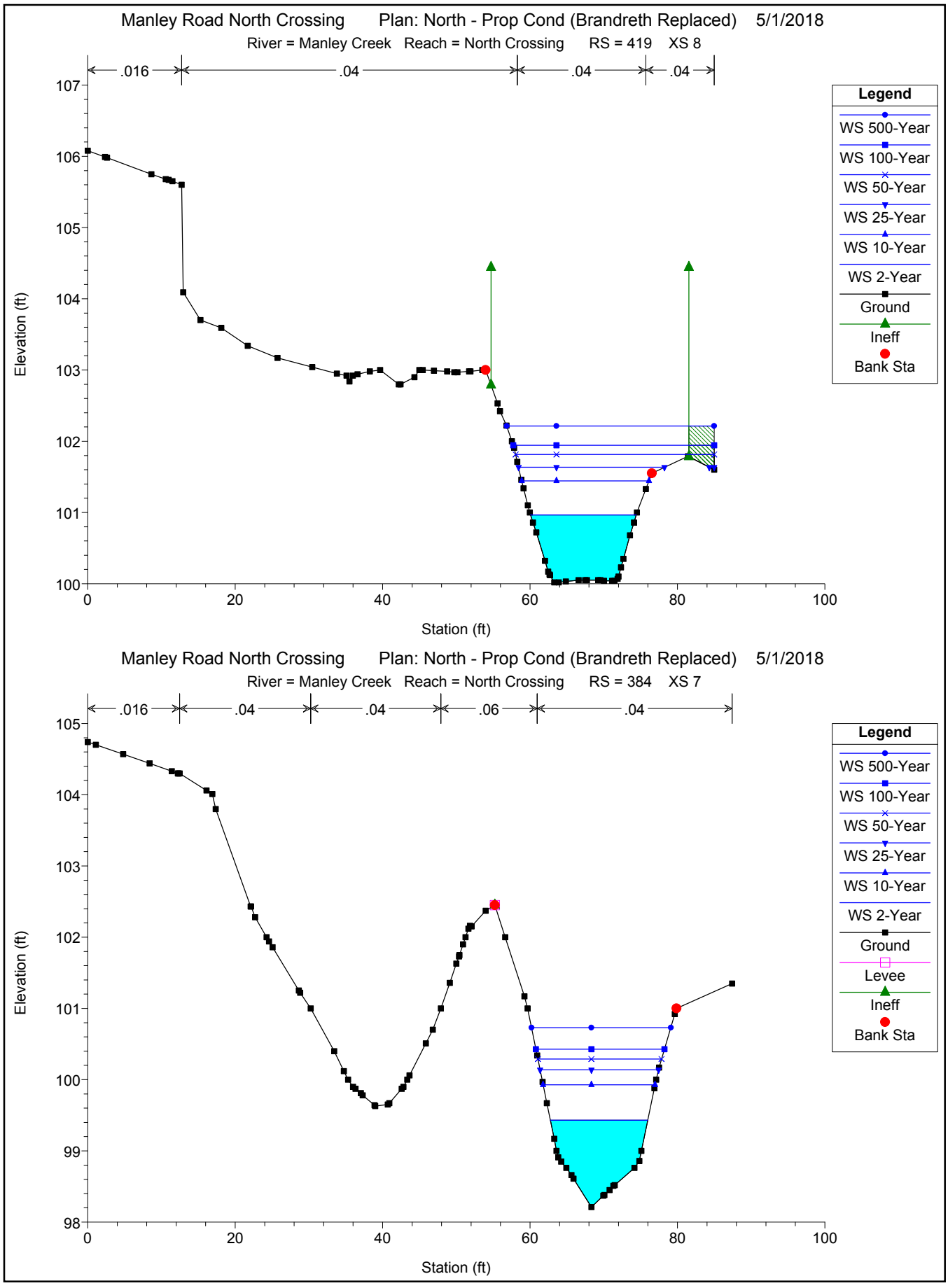

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
Manley Creek North Crossing
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Lat Struct
Ground
Elevation (ft)
Main Channel Distance (ft)
90
92
94
96
98
100
102
104
106
108
0
100
200
300
400
500

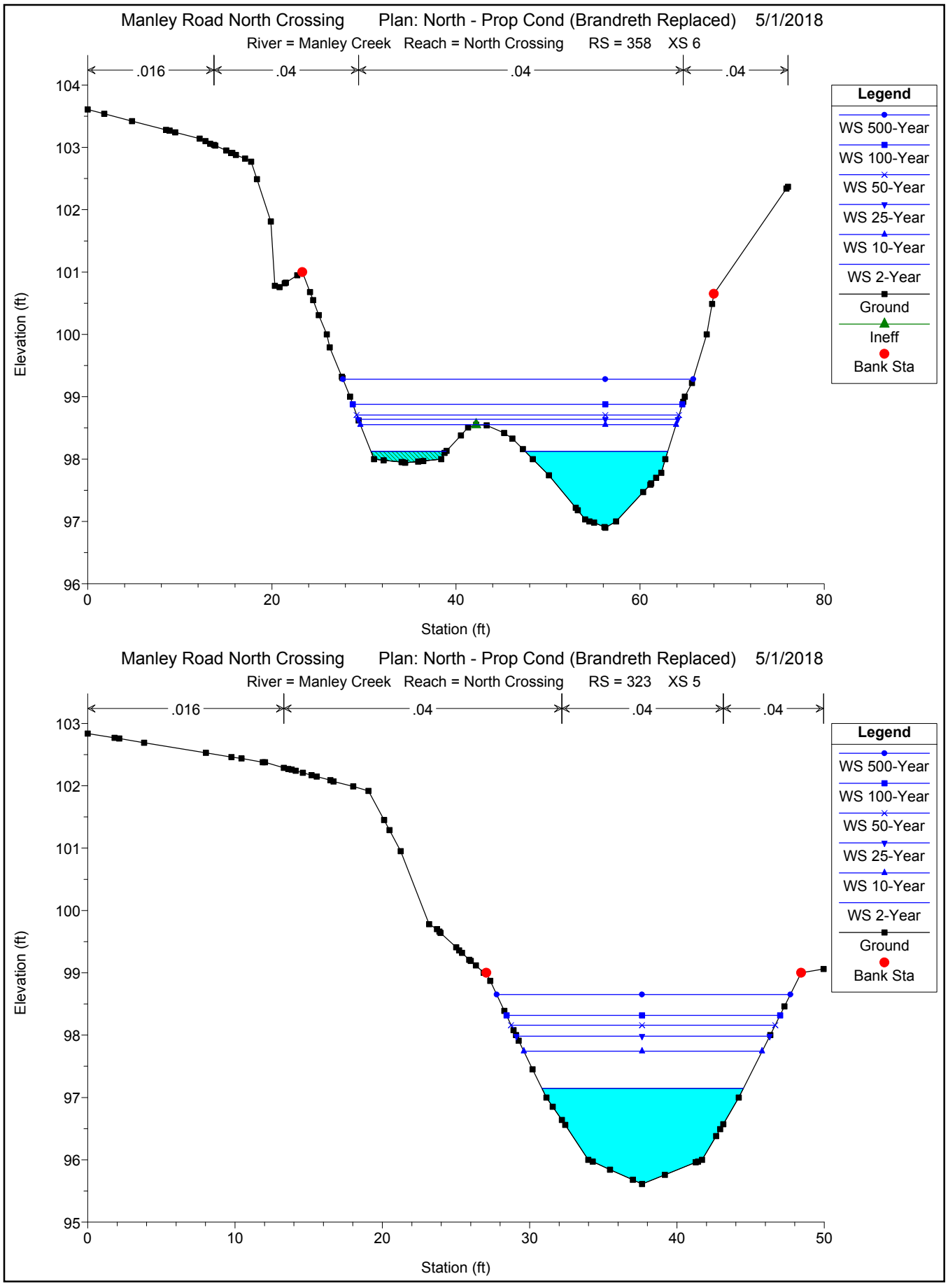

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 554 XS 11
.016
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
114
112
110
108
106
104
0
10
20
30
40
50
60
70
80

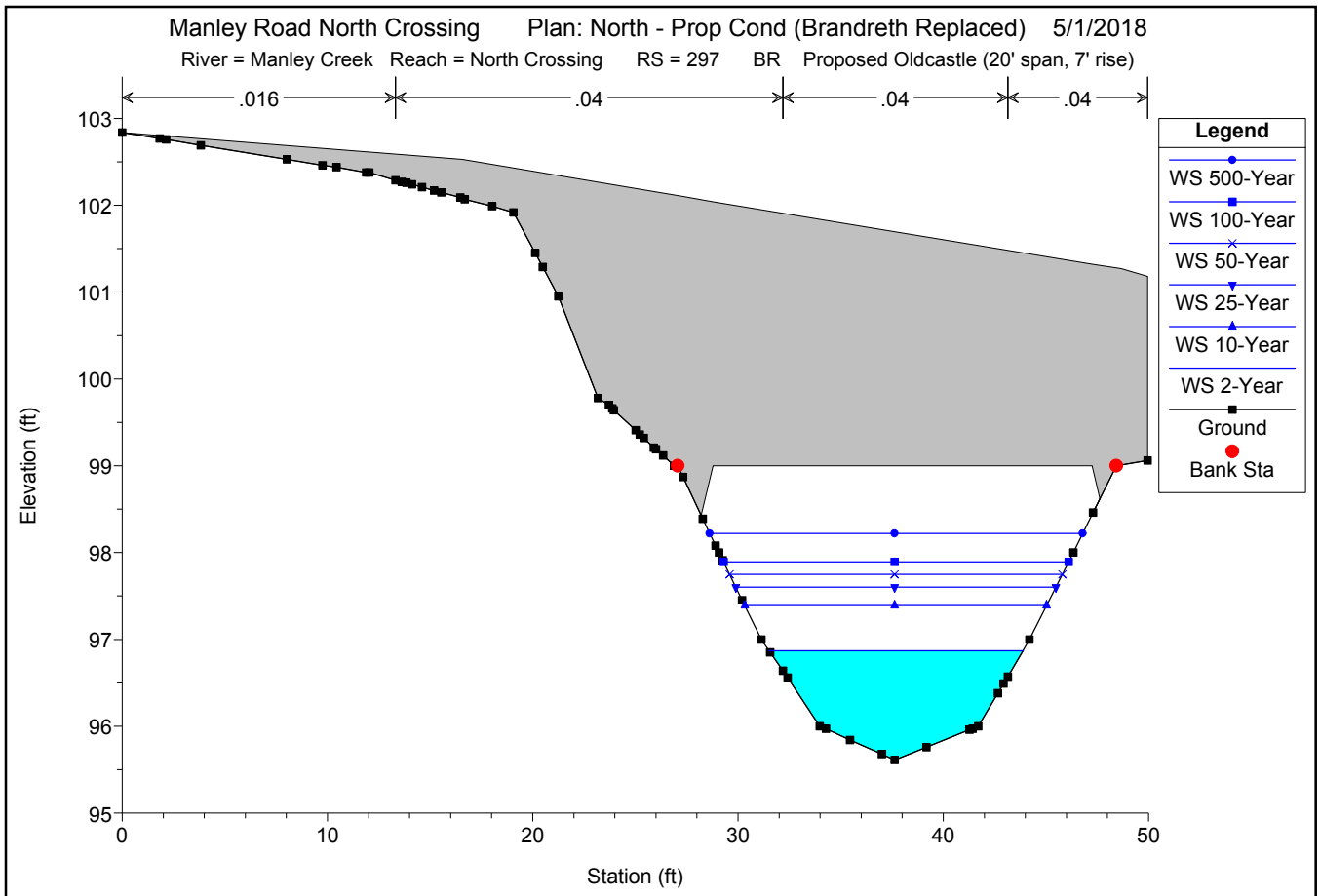

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 516 XS 10.5
.016
.08
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
114
112
110
108
106
104
102
0
10
20
30
40
50
60
70

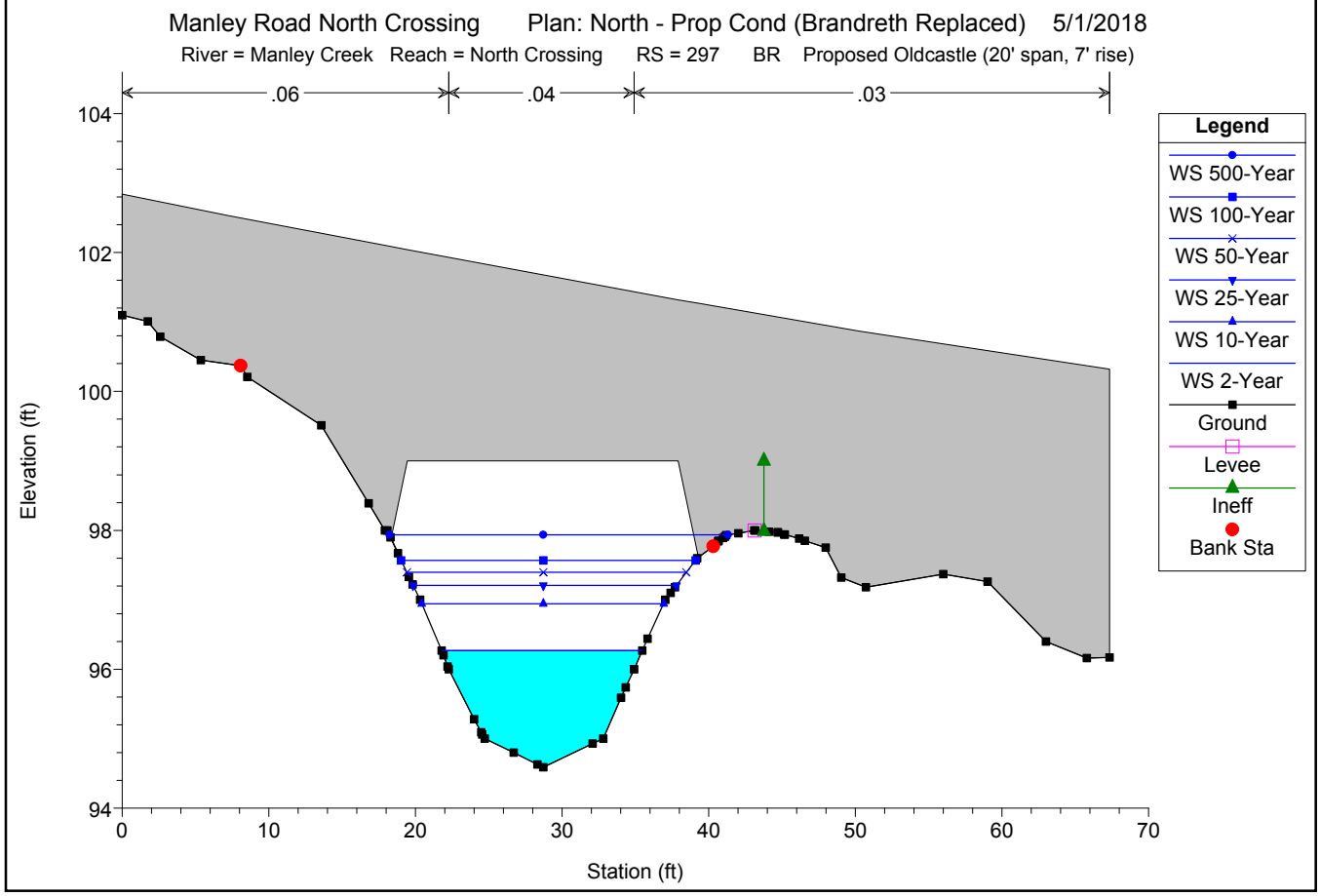

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 476 XS 10
.016
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 447 XS 9
.016
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

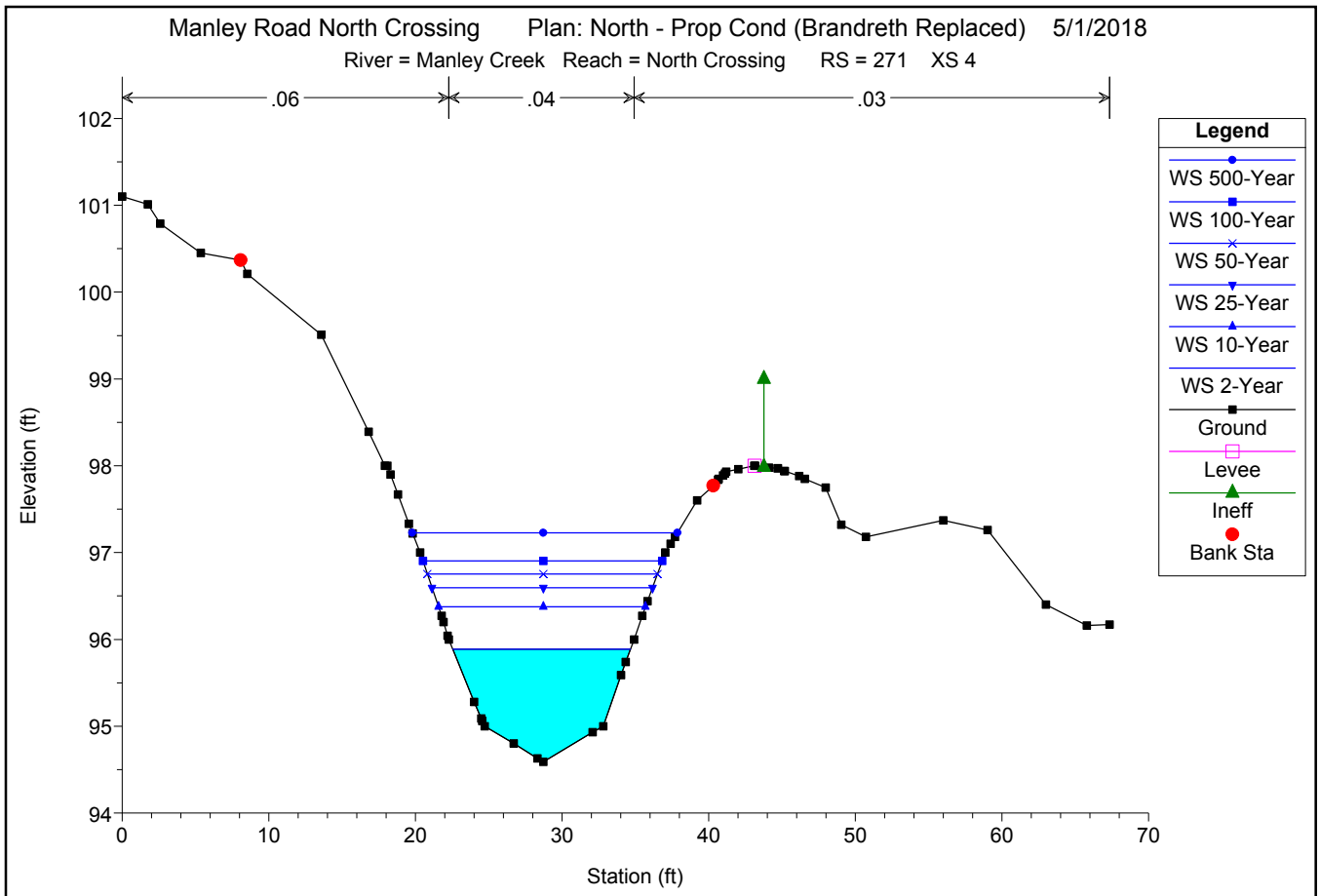

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 433 BR Proposed Driveway 20' Wide Box Culvert
.016
.08
.04
.06
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 433 BR Proposed Driveway 20' Wide Box Culvert
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

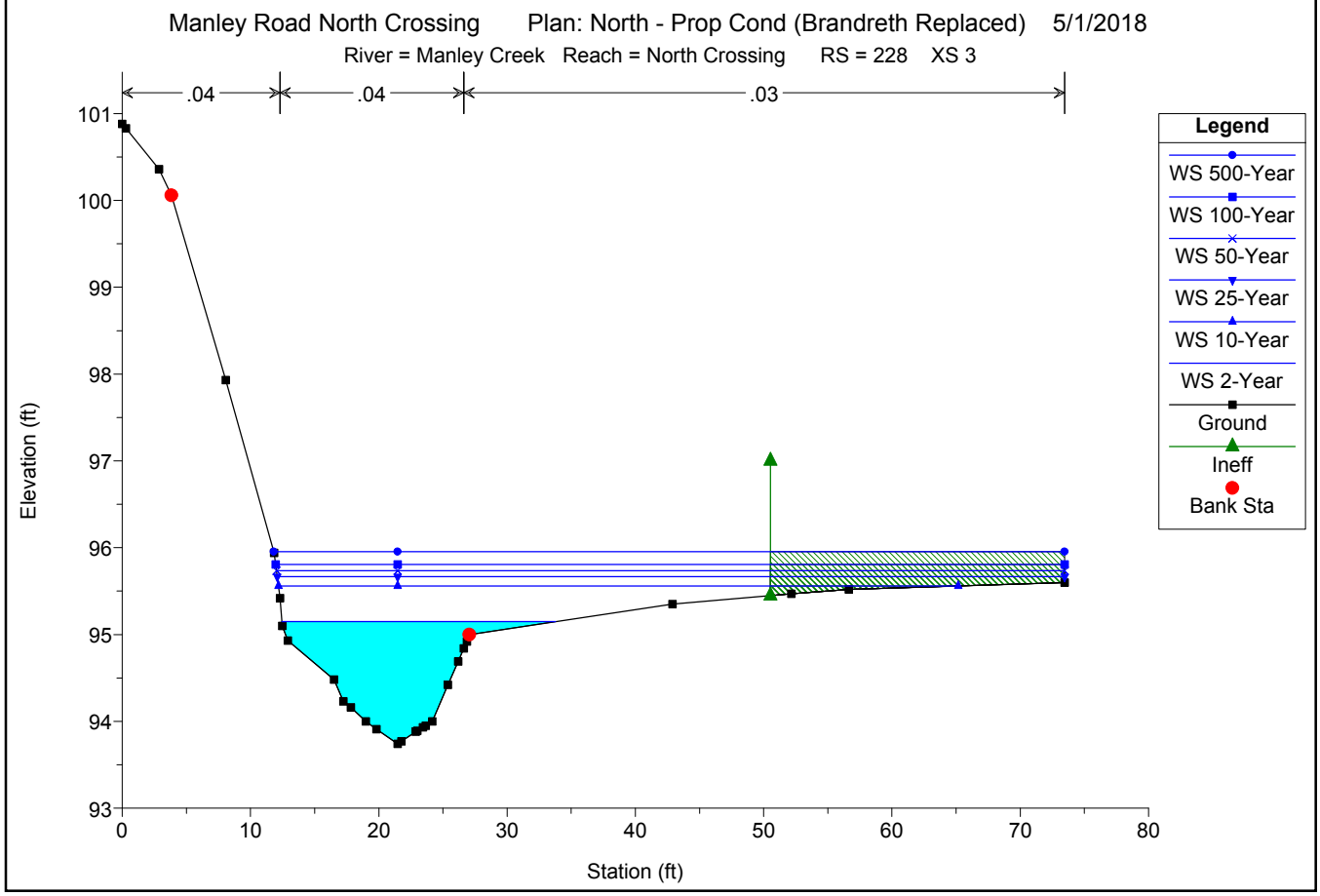

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 419 XS 8
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 384 XS 7
.016
.04
.04
.06
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Levee
Ineff
Bank Sta
Elevation (ft)
Station (ft)

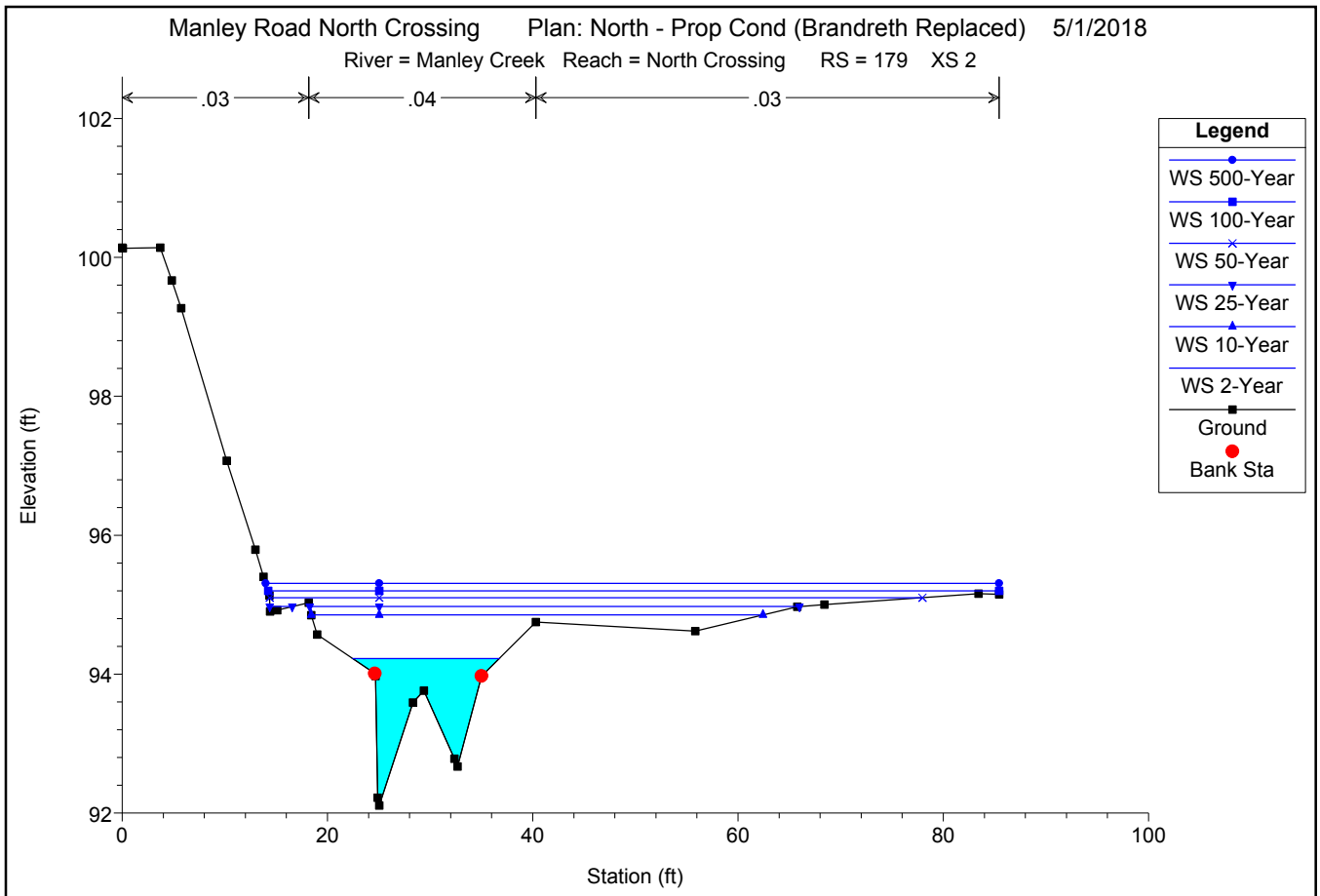

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 358 XS 6
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 323 XS 5
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)

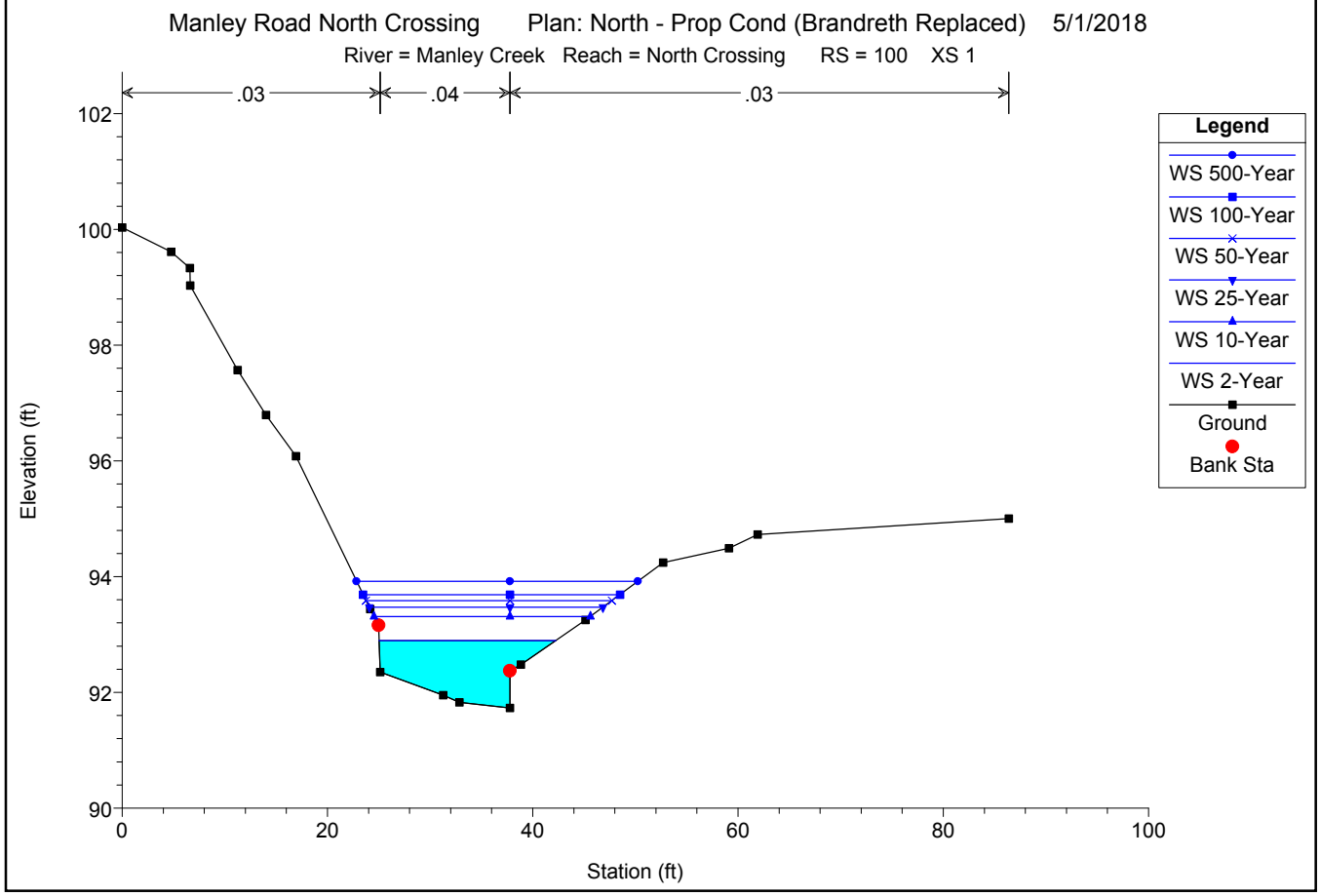

Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 297 BR Proposed Oldcastle (20' span, 7' rise)
.016
.04
.04
.04
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)


Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 297 BR Proposed Oldcastle (20' span, 7' rise)
.06
.04
.03
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Levee
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 271 XS 4
.06
.04
.03
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Levee
Ineff
Bank Sta


Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 228 XS 3
.04
.04
.03
Elevation (ft)
Station (ft)
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Ineff
Bank Sta


Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 179 XS 2
.03
.04
.03
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
102
100
98
96
94
92
0
20
40
60
80
100


Manley Road North Crossing Plan: North - Prop Cond (Brandreth Replaced) 5/1/2018
River = Manley Creek Reach = North Crossing RS = 100 XS 1
.03
.04
.03
Legend
WS 500-Year
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 2-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
102
100
98
96
94
92
90
0
20
40
60
80
100

Appendix E

Scour Calculations

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Southern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Morgan Clay
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17		
y=	1.31	ft	
D=	0.08071	ft	24.6 mm
V_c=	5.05	ft/s	

Avg. velocity in main channel, V= 3.51 ft/s

$V>V_c$? No, therefore clear-water contraction scour occurs

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Southern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Morgan Clay
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	2.02	ft
K_u=	0.0077	
Q =	195	ft3/s
D_{50} =	0.0807	ft
D_m =	0.101	ft
W =	19	ft
y_2 =	1.7	ft
y_s =	0.0	ft

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Southern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Morgan Clay
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17		
y=	1.64	ft	
D=	0.08071	ft	24.6 mm
V_c=	5.24	ft/s	

Avg. velocity in main channel, V= 3.59 ft/s

$V>V_c$? No, therefore clear-water contraction scour occurs

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Southern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Morgan Clay
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	2.38	ft
K_u=	0.0077	
Q =	261	ft3/s
D_{50} =	0.0807	ft
D_m =	0.101	ft
W =	19	ft
y_2 =	2.2	ft
y_s =	0.0	ft

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17	
y=	1.75 ft	
D=	0.16864 ft	51.4 mm
V_c=	6.77 ft/s	

Avg. velocity in main channel, V= 6.72 ft/s

$V>V_c$? No, therefore clear-water contraction scour occurs

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

LIVE-BED SCOUR

$y_2/y_1 = (Q_2/Q_1)^{6/7}(W_1/W_2)^{k1}$ Eq. 6.2, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_1 = average depth in the upstream main channel, ft (m)
y_2 = average depth in the contracted section, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
Q_1 = flow in the upstream channel transporting sediment, ft^3/s (m^3/s)
Q_2 = flow in the contracted channel, ft^3/s (m^3/s)
W_1 = bottom or top width of the upstream main channel that is transporting bed material, ft (m)
W_2 = bottom or top width of the main channel in the contracted section less pier width(s), ft (m)
k_1 = exponent (Refer to the table on page 6.11 of HEC-18 "Evaluating Scour at Bridges", April 2012)
V_* = shear velocity in the upstream section, ft/s (m/s)
ω = fall velocity of bed material based on the D_{50}, ft/s (m/s)
for fall velocity in SI units (m/s) divide ω in ft/s by 3.28
g = acceleration of gravity (32.2 ft/s) (9.81 ft/s)
S_1 = slope of energy grade line of main channel, ft/ft (m/m)

Design Case:

y_o =	2.0	ft	
g=	32.2	ft/s/s	
y_1 =	1.98	ft	
S_1=	0.042932	ft/ft	
V_* =	1.65	ft/s	
ω =	0.00012	ft/s	0.037 mm/s
V_*/ω =	13625.61		
k_1 =	0.69		
Q_1 =	198	ft3/s	
Q_2 =	192	ft3/s	
W_1 =	15	ft	
W_2 =	13	ft	
y_2 =	2.1	ft	
y_s =	0.17	ft	

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	1.96	ft
K_u=	0.0077	
Q =	192	ft3/s
D_{50} =	0.1686	ft
D_m =	0.211	ft
W =	13	ft
y_2 =	2.0	ft
y_s =	0.0	ft

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17	
y=	2.03 ft	
D=	0.16864 ft	51.4 mm
V_c=	6.94 ft/s	

Avg. velocity in main channel, V= 7.71 ft/s

$V>V_c$? Yes, therefore live-bed contraction scour occurs

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

LIVE-BED SCOUR

$y_2/y_1 = (Q_2/Q_1)^{6/7}(W_1/W_2)^{k1}$ Eq. 6.2, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_1 = average depth in the upstream main channel, ft (m)
y_2 = average depth in the contracted section, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
Q_1 = flow in the upstream channel transporting sediment, ft^3/s (m^3/s)
Q_2 = flow in the contracted channel, ft^3/s (m^3/s)
W_1 = bottom or top width of the upstream main channel that is transporting bed material, ft (m)
W_2 = bottom or top width of the main channel in the contracted section less pier width(s), ft (m)
k_1 = exponent (Refer to the table on page 6.11 of HEC-18 "Evaluating Scour at Bridges", April 2012)
V_* = shear velocity in the upstream section, ft/s (m/s)
ω = fall velocity of bed material based on the D_{50}, ft/s (m/s)
for fall velocity in SI units (m/s) divide ω in ft/s by 3.28
g = acceleration of gravity (32.2 ft/s) (9.81 ft/s)
S_1 = slope of energy grade line of main channel, ft/ft (m/m)

Design Case:

y_o =	1.9	ft	
g=	32.2	ft/s/s	
y_1 =	2.42	ft	
S_1=	0.045233	ft/ft	
V_* =	1.88	ft/s	
ω =	0.00012	ft/s	0.037 mm/s
V_*/ω =	15482.69		
k_1 =	0.69		
Q_1 =	263	ft3/s	
Q_2 =	266	ft3/s	
W_1 =	15	ft	
W_2 =	18	ft	
y_2 =	2.1	ft	
y_s =	0.20	ft	

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	1.94	ft
K_u=	0.0077	
Q =	266	ft3/s
D_{50} =	0.1686	ft
D_m =	0.211	ft
W =	18	ft
y_2 =	2.0	ft
y_s =	0.0	ft

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17	
y=	1.78 ft	
D=	0.13850 ft	42.2 mm
V_c=	6.36 ft/s	

Avg. velocity in main channel, V= 6.26 ft/s

$V>V_c$? No, therefore clear-water contraction scour occurs

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

LIVE-BED SCOUR

$y_2/y_1 = (Q_2/Q_1)^{6/7}(W_1/W_2)^{k1}$ Eq. 6.2, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_1 = average depth in the upstream main channel, ft (m)
y_2 = average depth in the contracted section, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
Q_1 = flow in the upstream channel transporting sediment, ft^3/s (m^3/s)
Q_2 = flow in the contracted channel, ft^3/s (m^3/s)
W_1 = bottom or top width of the upstream main channel that is transporting bed material, ft (m)
W_2 = bottom or top width of the main channel in the contracted section less pier width(s), ft (m)
k_1 = exponent (Refer to the table on page 6.11 of HEC-18 "Evaluating Scour at Bridges", April 2012)
V_* = shear velocity in the upstream section, ft/s (m/s)
ω = fall velocity of bed material based on the D_{50}, ft/s (m/s)
for fall velocity in SI units (m/s) divide ω in ft/s by 3.28
g = acceleration of gravity (32.2 ft/s) (9.81 ft/s)
S_1 = slope of energy grade line of main channel, ft/ft (m/m)

Design Case:

y_o =	1.4	ft	
g=	32.2	ft/s/s	
y_1 =	1.78	ft	
S_1=	0.015111	ft/ft	
V_* =	0.93	ft/s	
ω =	0.00012	ft/s	0.037 mm/s
V_*/ω =	7674.93		
k_1 =	0.69		
Q_1 =	133	ft3/s	
Q_2 =	176	ft3/s	
W_1 =	12	ft	
W_2 =	18	ft	
y_2 =	1.7	ft	
y_s =	0.3	ft	

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	1.42	ft
K_u=	0.0077	
Q =	176	ft3/s
D_{50} =	0.1385	ft
D_m =	0.173	ft
W =	18	ft
y_2 =	1.4	ft
y_s =	0.0	ft

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17	
y=	1.65 ft	
D=	0.13850 ft	42.2 mm
V_c=	6.28 ft/s	

Avg. velocity in main channel, V= 7.29 ft/s

$V>V_c$? Yes, therefore live-bed contraction scour occurs

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

LIVE-BED SCOUR

$y_2/y_1 = (Q_2/Q_1)^{6/7}(W_1/W_2)^{k1}$ Eq. 6.2, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_1 = average depth in the upstream main channel, ft (m)
y_2 = average depth in the contracted section, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
Q_1 = flow in the upstream channel transporting sediment, ft^3/s (m^3/s)
Q_2 = flow in the contracted channel, ft^3/s (m^3/s)
W_1 = bottom or top width of the upstream main channel that is transporting bed material, ft (m)
W_2 = bottom or top width of the main channel in the contracted section less pier width(s), ft (m)
k_1 = exponent (Refer to the table on page 6.11 of HEC-18 "Evaluating Scour at Bridges", April 2012)
V_* = shear velocity in the upstream section, ft/s (m/s)
ω = fall velocity of bed material based on the D_{50}, ft/s (m/s)
for fall velocity in SI units (m/s) divide ω in ft/s by 3.28
g = acceleration of gravity (32.2 ft/s) (9.81 ft/s)
S_1 = slope of energy grade line of main channel, ft/ft (m/m)

Design Case:

y_o =	1.7	ft	
g=	32.2	ft/s/s	
y_1 =	1.96	ft	
S_1=	0.029321	ft/ft	
V_* =	1.36	ft/s	
ω =	0.00012	ft/s	0.037 mm/s
V_*/ω =	11220.51		
k_1 =	0.69		
Q_1 =	164	ft3/s	
Q_2 =	228	ft3/s	
W_1 =	12	ft	
W_2 =	18	ft	
y_2 =	1.9	ft	
y_s =	0.3	ft	

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	1.67	ft
K_u=	0.0077	
Q =	228	ft3/s
D_{50} =	0.1385	ft
D_m =	0.173	ft
W =	18	ft
y_2 =	1.8	ft
y_s =	0.1	ft

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Northern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17		
y=	0.99	ft	
D=	0.13845	ft	42.2 mm
V_c=	5.77	ft/s	

Avg. velocity in main channel, V= 4.93 ft/s

$V>V_c$? No, therefore clear-water contraction scour occurs

100-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Northern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	1.82	ft
K_u=	0.0077	
Q =	170	ft3/s
D_{50} =	0.1385	ft
D_m =	0.173	ft
W =	13	ft
y_2 =	1.9	ft
y_s =	0.1	ft

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Northern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

DETERMINATION OF TRANSPORT REGIME UPSTREAM OF BRIDGE

$V_c=K_u y^{1/6} D^{1/3}$ Eq. 6.1, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, ft/s (m/s)
y = Average depth of flow upstream of the bridge, ft (m)
D = particle size for V_c, ft (m)
D_{50} = Particle size in a mixture of which 50 percent are smaller, ft (m)
K_u = 11.17 English units
K_u = 6.19 SI units

Design Case:

K_u=	11.17	
y=	1.35 ft	
D=	0.13845 ft	42.2 mm
V_c=	6.07 ft/s	

Avg. velocity in main channel, V= 4.37 ft/s

$V>V_c$? No, therefore clear-water contraction scour occurs

500-YR CONTRACTION SCOUR COMPUTATIONS

Project: Manley Road Northern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

CONTRACTION SCOUR

CLEAR-WATER SCOUR

$y_2 = [(K_u Q^2)/(D_m^{2/3} W^2)]^{3/7}$ Eq. 6.4, HEC-18 "Evaluating Scour at Bridges", Fifth Edition, 2012

where:

y_2 = average equilibrium depth in the contracted section after contraction scour
K_u = 0.0077 English units
K_u = 0.025 SI units
Q = discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
D_m = diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft (m)
D_{50} = median diameter of bed material, ft (m)
W = bottom width of the contracted section less pier widths, ft (m)
y_o = existing depth in the contracted section before scour, ft (m)
y_s = average contraction scour depth (if value is <= zero, then contraction scour = 0)

Design Case:

y_o =	1.80	ft
K_u=	0.0077	
Q =	226	ft3/s
D_{50} =	0.1385	ft
D_m =	0.173	ft
W =	17	ft
y_2 =	1.9	ft
y_s =	0.1	ft

Appendix F

Riprap Calculations

500-YR DESIGN OF RIPRAP PROTECTION AT BRIDGE

Project: Manley Road Southern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Morgan Clay
Company: Otak, Inc.

RIPRAP AT BRIDGE ABUTMENTS

For Froude Numbers < or = 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]$ Eq. 14.1, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

D_{50} = median stone diameter, m (ft)
V = characteristic average velocity in the contracted section, m/s (ft/s)
S_S = specific gravity of riprap (normally 2.8 for Basalt)
g= 9.81 m/s/s (32.2 ft/s/s)
y = depth of flow in the contracted bridge opening, m (ft)
K = 0.89 for a spill-through abutment or 1.02 for a vertical wall abutment

For Froude Numbers > 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]^{0.14}$ Eq. 14.2, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

K = 0.61 for a spill-through abutment or 0.69 for a vertical wall abutment

Design Case:

Fr=	0.63
V=	5.55 ft/s
S_S=	2.65
g=	32.2 ft/s2
y=	2.41 ft
K=	1.02
D_{50}=	**0.6 ft**

500-YR DESIGN OF RIPRAP PROTECTION AT BRIDGE

Project: Manley Road Middle Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

RIPRAP AT BRIDGE ABUTMENTS

For Froude Numbers < or = 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]$ Eq. 14.1, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

D_{50} = median stone diameter, m (ft)
V = characteristic average velocity in the contracted section, m/s (ft/s)
S_S = specific gravity of riprap (normally 2.8 for Basalt)
g= 9.81 m/s/s (32.2 ft/s/s)
y = depth of flow in the contracted bridge opening, m (ft)
K = 0.89 for a spill-through abutment or 1.02 for a vertical wall abutment

For Froude Numbers > 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]^{0.14}$ Eq. 14.2, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

K = 0.61 for a spill-through abutment or 0.69 for a vertical wall abutment

Design Case:

Fr=	1.00
V=	7.7 ft/s
S_S=	2.7
g=	32.2 ft/s2
y=	1.84 ft
K=	0.69
D_{50}=	**0.7 ft**

500-YR DESIGN OF RIPRAP PROTECTION AT BRIDGE

Project: Manley Road Brandreth Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

RIPRAP AT BRIDGE ABUTMENTS

For Froude Numbers < or = 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]$ Eq. 14.1, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

D_{50} = median stone diameter, m (ft)
V = characteristic average velocity in the contracted section, m/s (ft/s)
S_S = specific gravity of riprap (normally 2.8 for Basalt)
g= 9.81 m/s/s (32.2 ft/s/s)
y = depth of flow in the contracted bridge opening, m (ft)
K = 0.89 for a spill-through abutment or 1.02 for a vertical wall abutment

For Froude Numbers > 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]^{0.14}$ Eq. 14.2, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

K = 0.61 for a spill-through abutment or 0.69 for a vertical wall abutment

Design Case:

Fr=	1.00
V=	7.29 ft/s
S_S=	2.7
g=	32.2 ft/s2
y=	1.65 ft
K=	0.69
D_{50}=	**0.7 ft**

500-YR DESIGN OF RIPRAP PROTECTION AT BRIDGE

Project: Manley Road Northern Crossing
Project No.: 17532
Location: Clark County, Washington
Designer: Karina Nordahl
Company: Otak, Inc.

RIPRAP AT BRIDGE ABUTMENTS

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g= 9.81 m/s/s (32.2 ft/s/s)
y = depth of flow in the contracted bridge opening, m (ft)
K = 0.89 for a spill-through abutment or 1.02 for a vertical wall abutment

For Froude Numbers > 0.80:

$D_{50}/y = [K/(S_S-1)][V^2/gy]^{0.14}$ Eq. 14.2, HEC-23 "Bridge Scour and Stream Instability Measures", Sept, 2009

where:

K = 0.61 for a spill-through abutment or 0.69 for a vertical wall abutment

Design Case:

Fr=	0.99
V=	7.3 ft/s
S_S=	2.7
g=	32.2 ft/s2
y=	1.7 ft
K=	0.69
D_{50}=	**0.7 ft**