PULGAS CREEK FLOODING: PROPOSED MITIGATED PROJECT

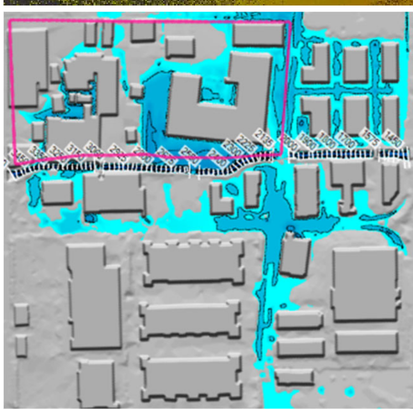
APPENDIX F

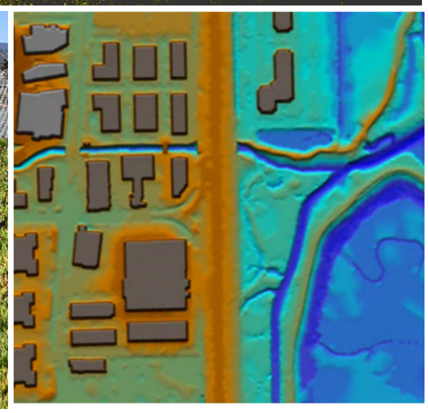
to the
Alexandria Center for Life Science Project Draft EIR

Alexandria Center for Science & Technology at San Carlos (ACST)

Pulgas Creek Flooding: Proposed Mitigated Project

San Carlos, California





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WRA #30042-1
November 2020

wra
ENVIRONMENTAL CONSULTANTS

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LIST OF ACRONYMS

Acronym	Full Name
1D	One-dimensional
2D	Two -Dimensional
ACST	Alexandria Center for Science & Technology at San Carlos
AF	acre-feet
cfs	Cubic Feet per Second
CLOMR	Conditional Letter of Map Revision
F&L	Freyer & Laureta, Inc.
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
ft	Feet
HEC-RAS	Hydrologic Engineering Center – River Analysis System
LiDAR	Light Detection and Ranging
MHHW	Mean Higher High Water
lb/sf	Pounds per Square Foot
n	Manning's roughness coefficient
NOAA	National Oceanic and Atmospheric Administration
PLS	Professional Land Surveyor
Q	Discharge or Streamflow
Q10	Discharge or Streamflow of a 10-year flood event
Q100	Discharge or Streamflow of a 100-year flood event
RS	River Station
TOB	Top of Bank
WSEL	Water Surface Elevation

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1.0 Executive Summary

WRA, Inc. has conducted hydraulic studies for the Alexandria Center for Science and Technology (ACST) project (Project) in the City of San Carlos, San Mateo County (City Planning submission #PLN2020-00032). The Project site is adjacent to the north side of Pulgas Creek, south of Commercial Street between Old County Road and Industrial Road

WRA performed iterative hydraulic modeling of potential project mitigation features to eliminate or minimize increases to off-site flooding extent and depth and local shear stresses in the creek. *Based on our understanding of the site hydraulics from modeling several possible mitigation features and combinations, this memo presents results for a Mitigated Project whose final design would reduce the potential adverse offsite impacts for the 100-year and 10-year floods to a less-than-significant impact.* Modeling indicates that the Mitigated Project will reduce the 100-year flood conditions on site and be protective of the proposed buildings.

The Mitigated Project can successfully address the potential flood issues of the Project without mitigation that were assessed in our October memo (Appendix A).

The hydraulic modeling for the 10-year event and the mitigation scenarios was performed using the same modeling software and version (HEC-RAS version 5.0.7) and combination of creek and study area model types one-dimensional [1D] model of the Pulgas Creek channel and two-dimensional [2D] model of surrounding areas) as the 100-year event modeling by WRA (October 2020).

The hydraulic analysis of Project mitigation features and scenarios was performed by modifying specific characteristics in the model such as the topographic surface, building layouts, bridge structures, surface swales or culverts, that would reflect the hydraulic effect of possible final design features for the Project.

No changes to any off-site areas were made in the model set-up (since the Project would not have the authority or responsibility to directly change off-site property), and the model's boundary conditions and hydrologic inputs were held constant.

The potential mitigation features and combinations as mitigated Project scenarios were developed with the intent of successfully meeting key performance targets:

- Offsite flooding would be no worse than under existing conditions.
- The Project building layout would be preserved.
- Project operational impacts and flood cleanup needs within the Project site would be minimized.

Several potential mitigation features in varying combinations were evaluated by iterative hydraulic modeling to identify the preferred mitigation strategy.

The individual key design features within the identified Mitigated Project are:

1. Allowing inflow of flood waters to the site in a predictable, controlled fashion via a surface swale or culvert off the north bank of Pulgas Creek upstream of the dual container crossing.
2. Allowing inflow of flood waters to the site in a predictable, controlled fashion via a surface swale or culvert off the north bank of Pulgas Creek upstream of the parking lot bridge.

3. Facilitating the outflow of water to return from the landscape depression to the creek via the downstream swale or culvert as the flood hydrograph peak passes.
4. Directing flood water into the enlarged lowered landscape depression for temporary storage.
5. Maintaining a floodplain flow path on the creek side portion of the south parking lot at a finished grade elevation that allows water to flow overbank, be slowed down and detained, but follow their existing route across Industrial Road.

Each of these design features will be further optimized for the Mitigated Project during final design to fully realize their functionality and verify their performance relative to the flood impact requirements of the City and the project layout and project operations targets.

2.0 Introduction

2.1 Project Understanding and Site Overview

The proposed *Alexandria Center for Science & Technology at San Carlos* (ACST) (Project) is adjacent to the north side of Pulgas Creek in the City of San Carlos, San Mateo County, south of Commercial Street between Old County Road and Industrial Road (City Planning submission #PLN2020-00032).

2.2 Purpose, Scope and Limitation

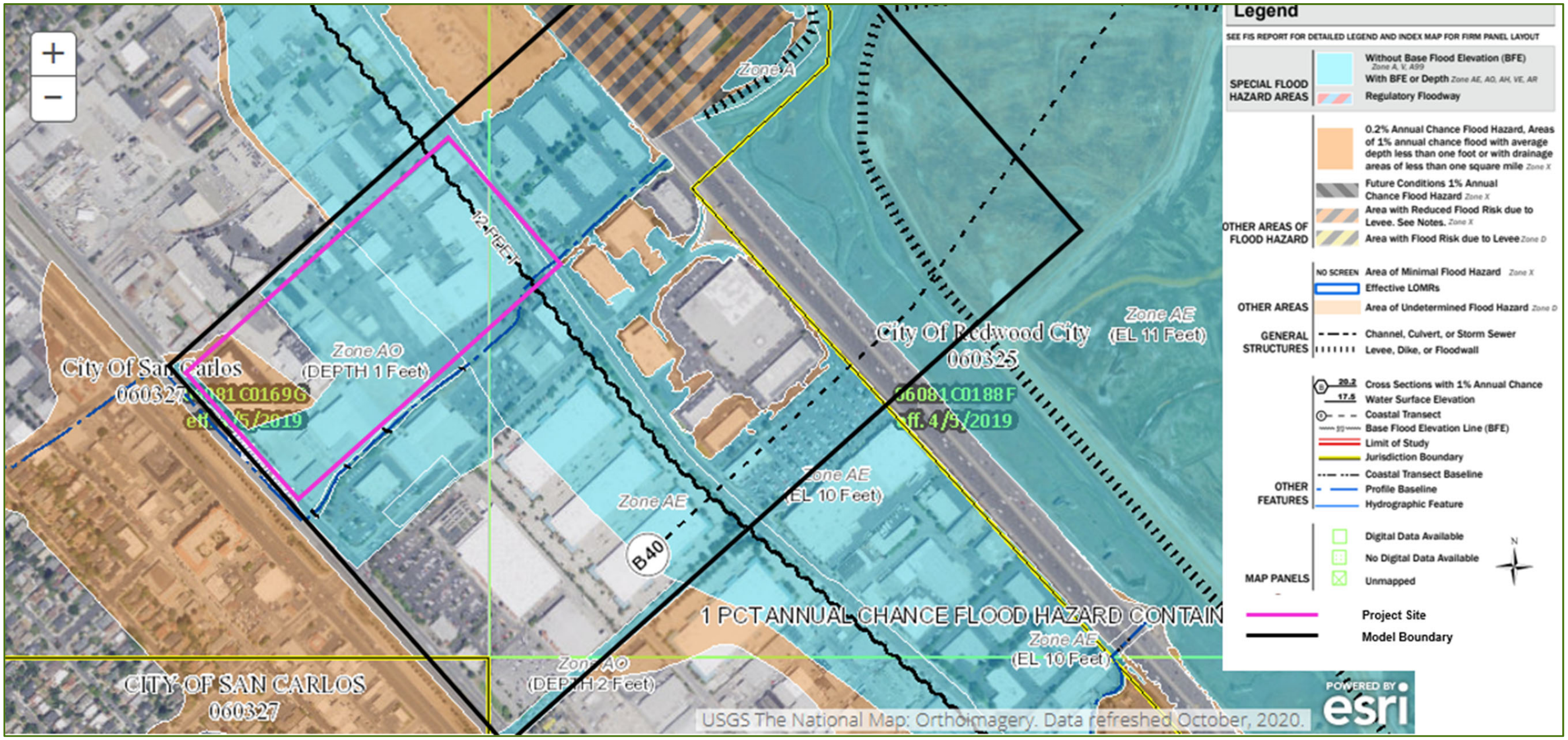
WRA, Inc. has conducted hydraulic studies for the Project to describe the existing flood conditions of the Project site and vicinity from watershed runoff, assess the potential for the Project to modify flooding off-site, and determine how the Project can be mitigated to minimize impacts. WRA produced a memo in October 2020 that reported the 100-year flooding analysis for the existing condition and the Project (without mitigation) (WRA, Inc., 2020). Based on the results of that analysis and requests from the City, WRA subsequently performed analysis of the 10-year flood and iterative modeling of potential design revisions to reduce the potential adverse impacts of the Project during both the 10-year flood and 100-year flood.

This memo focuses on presenting the additional information for the 10-year flood event and describing the mitigation strategy for the Project in response to the City's comments. The subsections and order are consistent with our October 2020 memo, which is also attached as Appendix A as reference regarding methods, model set-up, and the 100-year flood results for the existing and Project conditions (without mitigation).

3.0 Vicinity Flooding Context

The Project vicinity is the low-lying, nearly level bayshore portion of the City of San Carlos adjacent to the City of Redwood City which has Special Flood Hazard Areas designated by the Federal Emergency Management Agency (FEMA) (FEMA Flood Map Service Center, n.d.)(Figure 1) extending generally parallel to the bayshore. Much of the Project site (shown with magenta outline) is in the FEMA flood zone overlay (Figure 1). The model boundary (i.e., study area) for the Project specific flood analysis is shown with a black outline (Figure 1).

The City of San Carlos's (City) Storm Drain Master Plan (GHD, 2018) includes a hydrologic model of the watershed and urban system of open channels, pipe networks, and pump stations for a range of storm events including the 100-year and 10-year base conditions. Pulgas Creek is one of the four primary creeks in the GHD hydrologic model. The lower Pulgas Creek segment in our study is the low gradient (0.5 percent slope) portion downstream of underground culvert systems that daylight near Old County Road. The GHD model results for the Base Condition (i.e., existing conditions) of Project site and vicinity indicate overbank inundation on the Project site and across Pulgas Creek to the south within the Project reach between Old County and Industrial Roads under both of these storms (
Figure 2 and
Figure 3). The area and extent of inundation estimated by the GHD model is similar for 10-year and 100-year eve



Reference: FEMA Flood Map Service Center (https://msc.fema.gov/portal/home)

Figure 1: Effective FEMA Flood Information Rate Map (FIRM) for the Project Vicinity

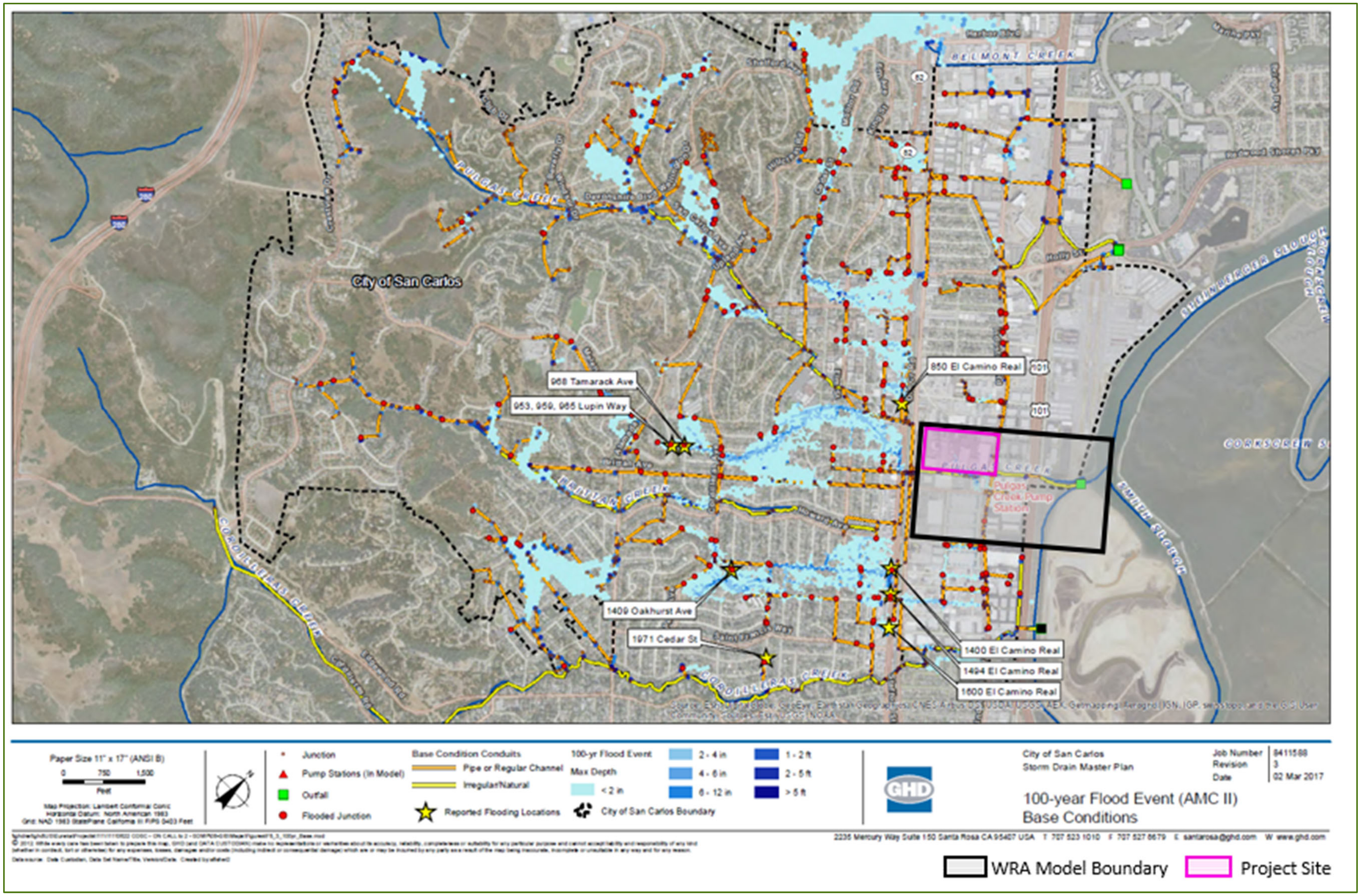


Figure 2: Storm Drain Master Plan 100-year Flood Event Base Conditions

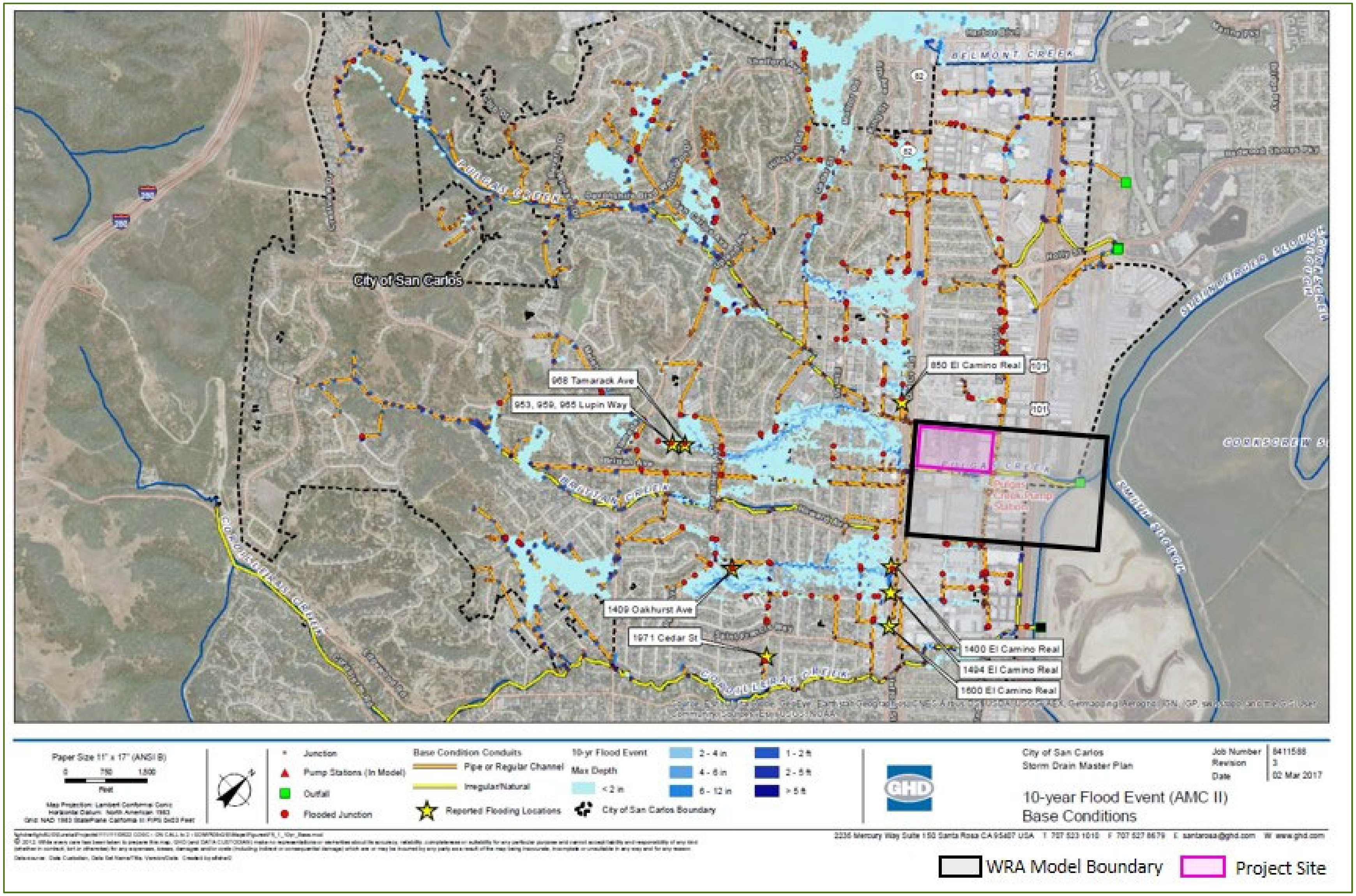


Figure 3: Storm Drain Master Plan 10-year Flood Event Base Conditions

4.0 Hydraulic Model Development

The hydraulic modeling for the 10-year event and the mitigation scenarios was performed using the same modeling software and version (HEC-RAS version 5.0.7) and combination of creek and study area model types one-dimensional [1D] model of the Pulgas Creek channel and two-dimensional [2D] model of surrounding areas) as the 100-year event modeling by WRA (October 2020). Please refer to the WRA memorandum dated October 2020 for additional discussion related to model development and calibration (Appendix A).

Similar to the original model calibration effort, the WRA of model 10-year flood modeling results were compared to the GHD 10-year model results and determined to be reasonably consistent with the GHD results in pattern and relative flood extent compared to the GHD 100-year model results. The GHD model was at a lower level of resolution than the Project-specific modeling herein, since the GHD model was addressing the entire City storm drain system and all contributing watersheds.

4.1 Model Extent

The 0.275 square mile (169 acre) model boundary (i.e., study area), 0.04 square mile (25 acre) Project site, and stream channel cross section locations used for the 100-year event modeling were also applied in the 10-year event and mitigation scenario modeling.

4.2 Topographic and Bathymetric Data

The topography of the site and bathymetry of the channel for the existing conditions modeling of the 10-year event are the same as for the 100-year event modeling, as described by WRA (October 2020).

4.3 Existing Buildings

The existing buildings for the existing conditions modeling of the 10-year flood event are the same as for the 100-year event modeling, as described by WRA (October 2020).

4.4 Channel Crossings

The channel crossings (i.e., bridges) for the existing conditions modeling of the 10-year flood event are represented in the same manner as for the 100-year event modeling, as described by WRA (October 2020).

4.5 Channel Profile

The existing channel bed and streambank elevation profiles for the existing conditions modeling of the 10-year flood event are the same as for the 100-year event modeling, as described by WRA (October 2020).

4.6 Downstream Boundary Conditions

The downstream boundary conditions for the 10-year flood analysis and mitigation scenario modeling are the same as for the 100-year event modeling, as described by WRA (October 2020).

4.7 Upstream and Project Reach Inflows

4.7.1 Upstream Inflow Hydrograph

The same 100-year peak flow magnitude and unsteady hydrograph applied in the existing conditions and Project modeling (WRA October, 2020) is used for the 100-year mitigation scenario modeling. The 10-year peak flow magnitude and unsteady hydrograph from the GHD study for the 10-year flood event and mitigation scenario modeling was also used to evaluate the project. The same data (GHD model node J24) is the source to represent the upstream watershed runoff inputs to the project reach for the 100-year and 10-year storms (Figure 4). Both hydrographs rise fairly steeply to a peak discharge around the six-hour mark of the storm, then decrease over the next couple of hours, but remain elevated (i.e., flows remain over 200 cfs for the 100-year event and over 100 cfs for the 10-year event) from hour 10 through 24.

4.7.2 Project Reach Inflows

The existing input flows in the Project reach and further downstream are simulated consistent with the City's storm drain master plan model base condition for each storm (Figure 5 and Figure 6). The pump station along Pulgas Creek downstream of Industrial Road is assumed to be operating at capacity (~75 cfs total) as a worst-case/conservative status, and is the largest of the lateral inputs. Other inflows to the Project reach are small, with peaks less than 30 cfs for the 100-year event (Figure 5) and less than 20 cfs for the 10-year event (Figure 6).

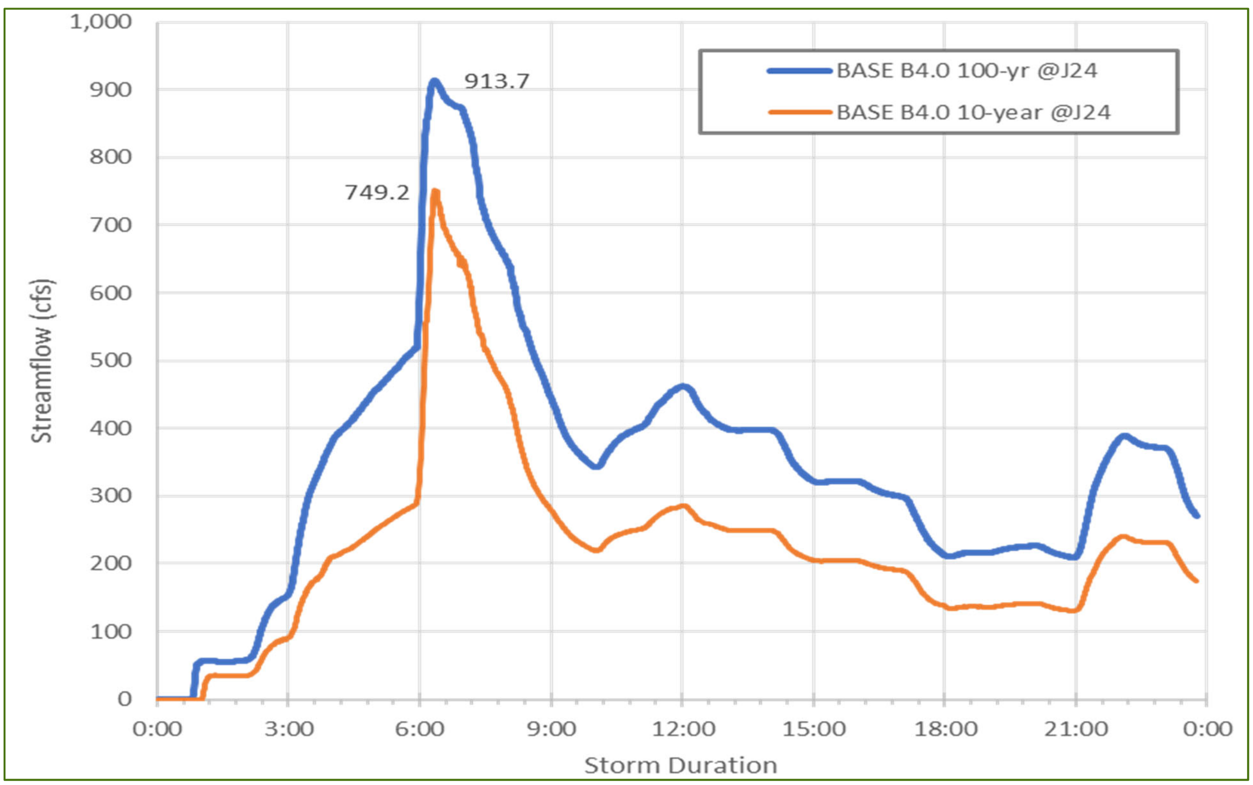


Figure 4: Upstream Input Hydrograph - 100-year and 10-year Base Conditions

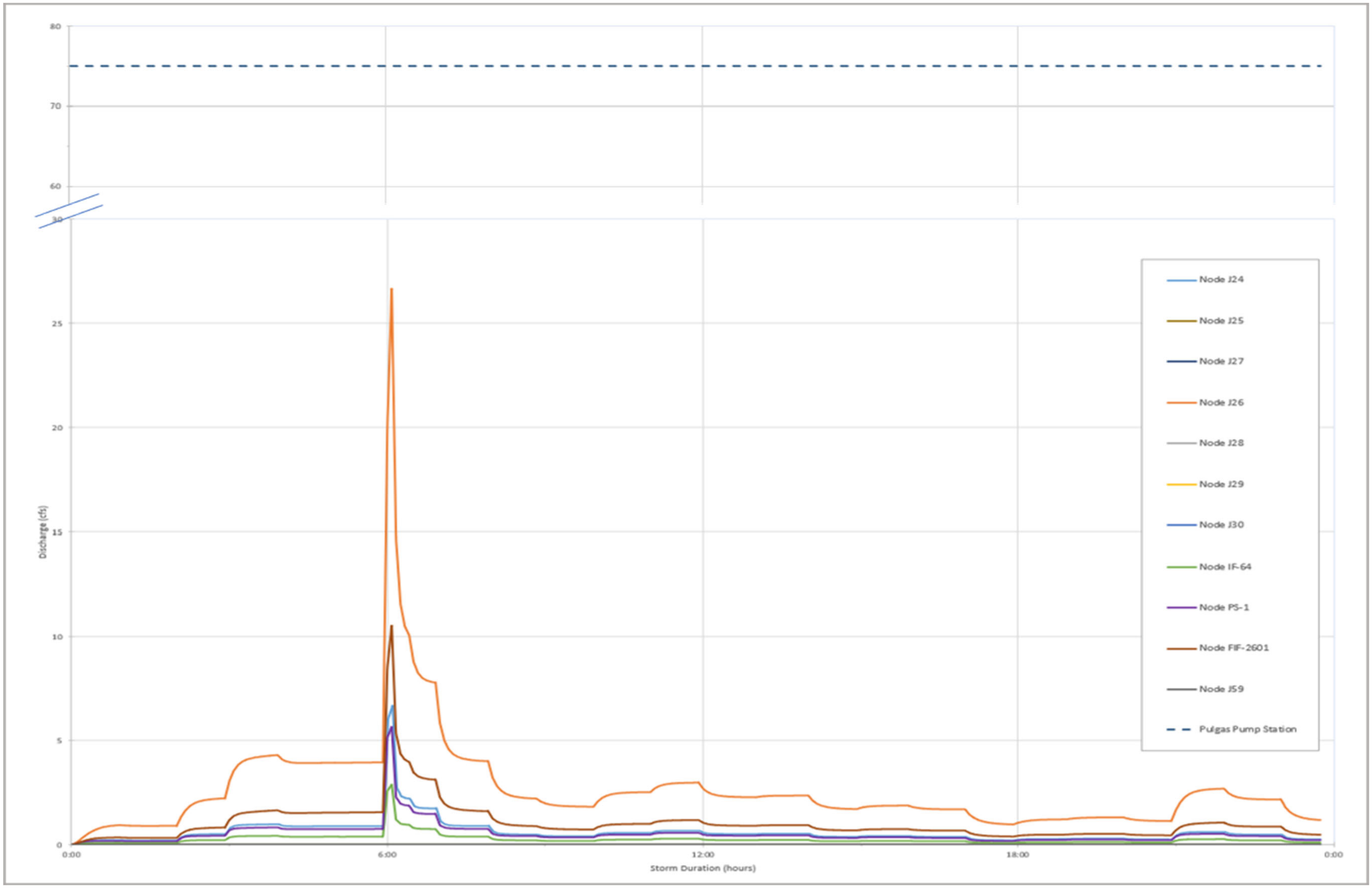


Figure 5: Lateral Inflow Hydrographs - 100-year Base Condition

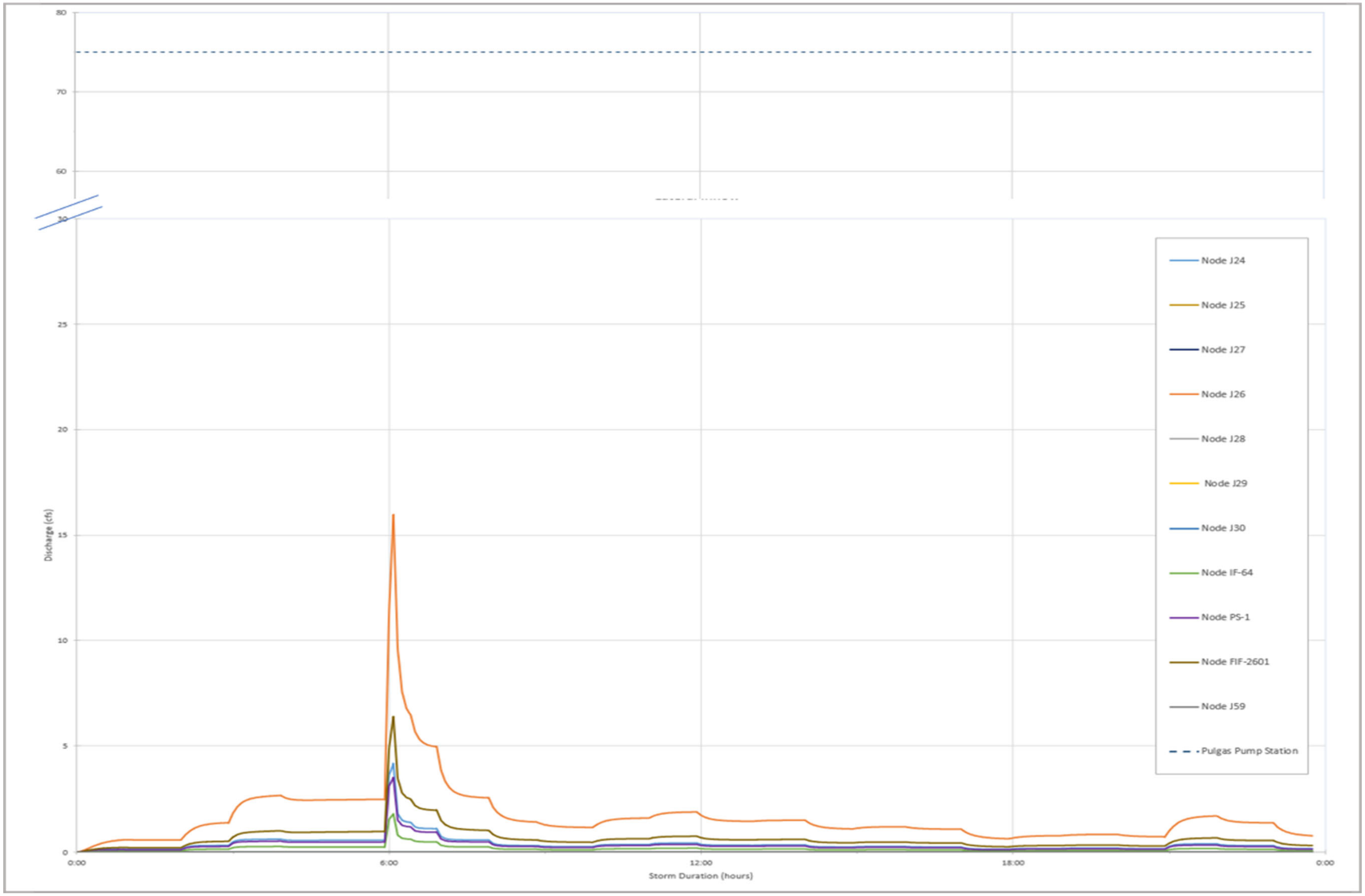


Figure 6: Lateral Inflow Hydrographs – 10-year Base Condition

4.8 Land Cover and Roughness

The hydraulic roughness parameters for the existing conditions modeling of the 10-year event are consistent with modeling of the 100-year event (WRA October 2020).

4.9 Model Sensitivity

See Appendix A with the WRA October 2020 memo for a description of model sensitivity testing.

5.0 Hydraulic Analysis of Existing Conditions

Below is a summary of the existing conditions modeling of the maximum water surface elevation (WSEL) and areal extent. Both the 100-year and 10-year results are included for ease of comparing the 10-year results with the previously presented 100-year results. The maximum WSEL and inundation area occurs after the peak flow, roughly six hours into the simulation.

5.1 Flood Water Surface Elevations and Depths

The existing 100-year flood extent covers 57.5 acres (roughly 34 percent) of the overall 169 acre model study area. The inundated areas include most of the Project site, the northeast side of Industrial Road, the Brittan Avenue corridor and along Industrial Road (Figure 7). The 100-year maximum WSEL at the downstream end of the model domain (east) of Highway 101 is around 7.7 feet . The 100-year maximum WSEL rises from 8.3 to 9.6 feet between Highway 101 and Industrial Road. The 100-year maximum WSEL upstream of Industrial Road is 11.4 feet and increases to about 12.1 feet at the parking lot bridge. The 100-year WSEL upstream of the parking lot bridge is 12.5 feet and rises to 12.8 feet downstream of the dual containers. The 100-year WSEL upstream of the dual container crossings is 14.1 feet, and increase to 16.0 feet near Old County Road. The existing maximum water depths for the 100-year event across the floodplains (outside of the channel) on both sides of the channel have areas between 0.5 and 1.0 feet deep, some areas between 1.0 and 2.0 feet deep, and a few deeper isolated areas. Onsite, the existing maximum flood depth for the 100-year event is just over 2.5 feet deep (Figure 7).

The existing 10-year flood extent is 44.6 acres (roughly 26 percent) of the overall 169 acre model study area. It is a subset of the 100-year flood extent, including much of the Project site, sections northeast of Industrial Road, and the vicinity of the Brittan Avenue and Industrial Road intersection (Figure 8). The 10-year maximum WSEL at the downstream end of the model domain (east) of Highway 101 is around 7.7 feet. The 10-year maximum WSEL rises from 8.3 to 9.5 feet between Highway 101 and Industrial Road. The 10-year maximum WSEL upstream of Industrial Road is 11.2 feet and increase about 11.9 feet at the parking lot bridge. The 10-year maximum WSEL upstream of the parking lot bridge is 12.3 feet and rises to 12.6 feet downstream of the dual containers. The 10-year maximum WSEL upstream of the dual container crossings is 13.7 feet, and increases to 15.6 feet near Old County Road. The water surface is generally similar on both sides of the creek as you move upstream from the bay, with slightly higher on the north (Project) side of the creek. The maximum water depths offsite for the 10-year event are generally shallower than for the 100-year and within a smaller footprint. Onsite, the maximum flood depth for the 10-year event is just under 2.5 feet, but much of the 10-year flood area has maximum depths close to that for the 100-year event (Figure 8).

Figure 7: Project Site and Vicinity 100-year Flood Maximum Extent and Depths – Existing Conditions

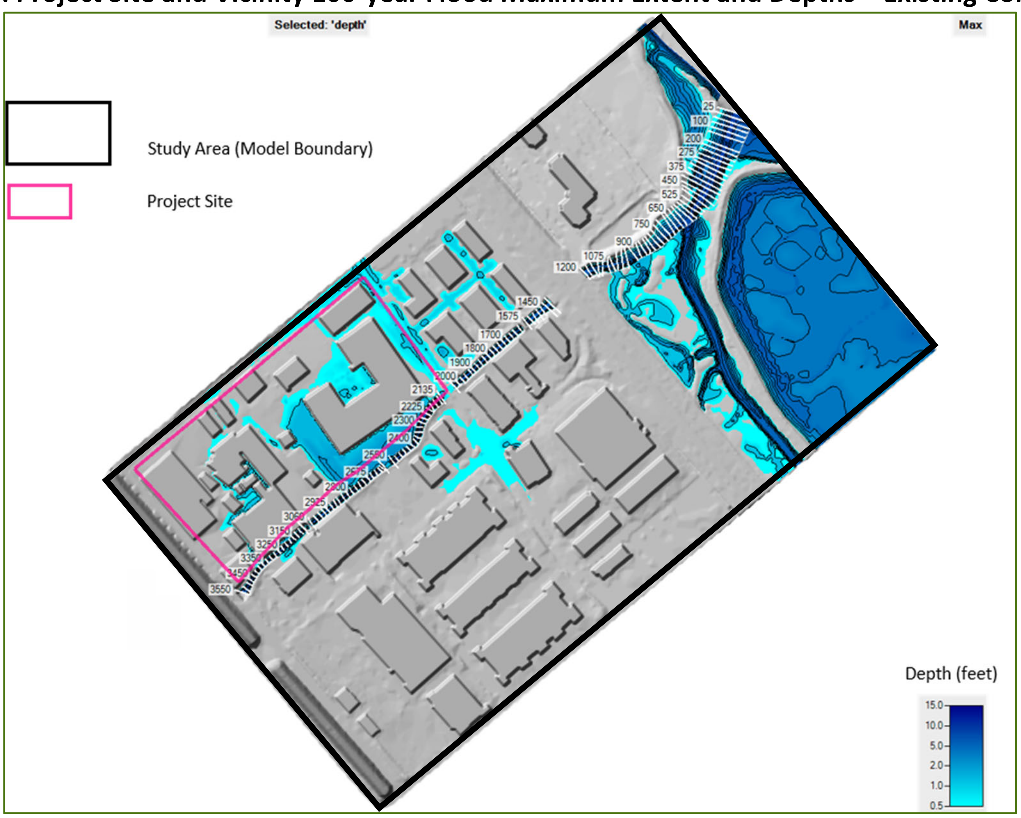


Figure 8: Project Site and Vicinity 10-year Flood Maximum Extent and Depth – Existing Conditions

5.2 Pulgas Creek Flood Profile and Cross Sections

The existing condition flood profiles of Pulgas Creek show how the modeled maximum WSELs for the 100-year and 10-year events relate to the channel bank heights and shapes (which are a mixture of irregular natural soils and human-constructed materials), as well as the effects of the bridge locations, cross-section areas, and underside elevations (i.e., bridge soffits) (Figure 9).

The maximum WSEL profiles for both the 100-year and 10-year events have the same general shape. And, the potential for overbank flow is evident in some areas between Industrial Road and Old County Road where the maximum WSELs are higher than portions of the streambanks. The maximum WSEL for the 100-year and 10-year event is consistent at the downstream boundary in the bay, gently rising to about 8 feet at Highway 101 and up to 10 feet on the downstream side of Industrial Road. The WSELs are about one foot higher than the underside (soffit) of the Industrial Road bridge, indicating flow constriction (Figure 9). As a result, the maximum WSEL for both the 100-year and 10-year events steps up to around 11.5 feet on the upstream side of Industrial Road and slopes up over the parking lot bridge, with WSELs about 3.5 feet higher than its soffit (Figure 9). The maximum WSEL for both the 100-year and 10-year events also step up from constrictions at the dual container crossings . The maximum 10-year and 100-year WSELs are nearly identical downstream of Industrial Road, and the 10-year WSEL is slightly lower than the 100-year WSEL between Industrial Road and Old County Road (Figure 9).

5.3 FEMA Discussion

As presented in the October Memorandum, a qualitative comparison of the existing condition model results for the 100-year event profile and map views (Figure 9 and Figure 10) shows consistency with the FEMA Flood Insurance Study (FIS) (revised April 5, 2019) (FEMA, 2012) and effective Flood Insurance Rate Map (FIRM) (FEMA Flood Map Service Center, n.d.). The FEMA profile ((Figure 9) is slightly lower in portions of the creek where our modeling is more detailed and expectedly higher in the bay, since the FEMA analysis considers coastal flooding sources. The FEMA map shows a larger flood zone along the bayshore beyond the Project site and study area (Figure 10), since the FEMA mapping addresses the broader vicinity and the coastal flooding sources in addition to the local watershed-driven sources.

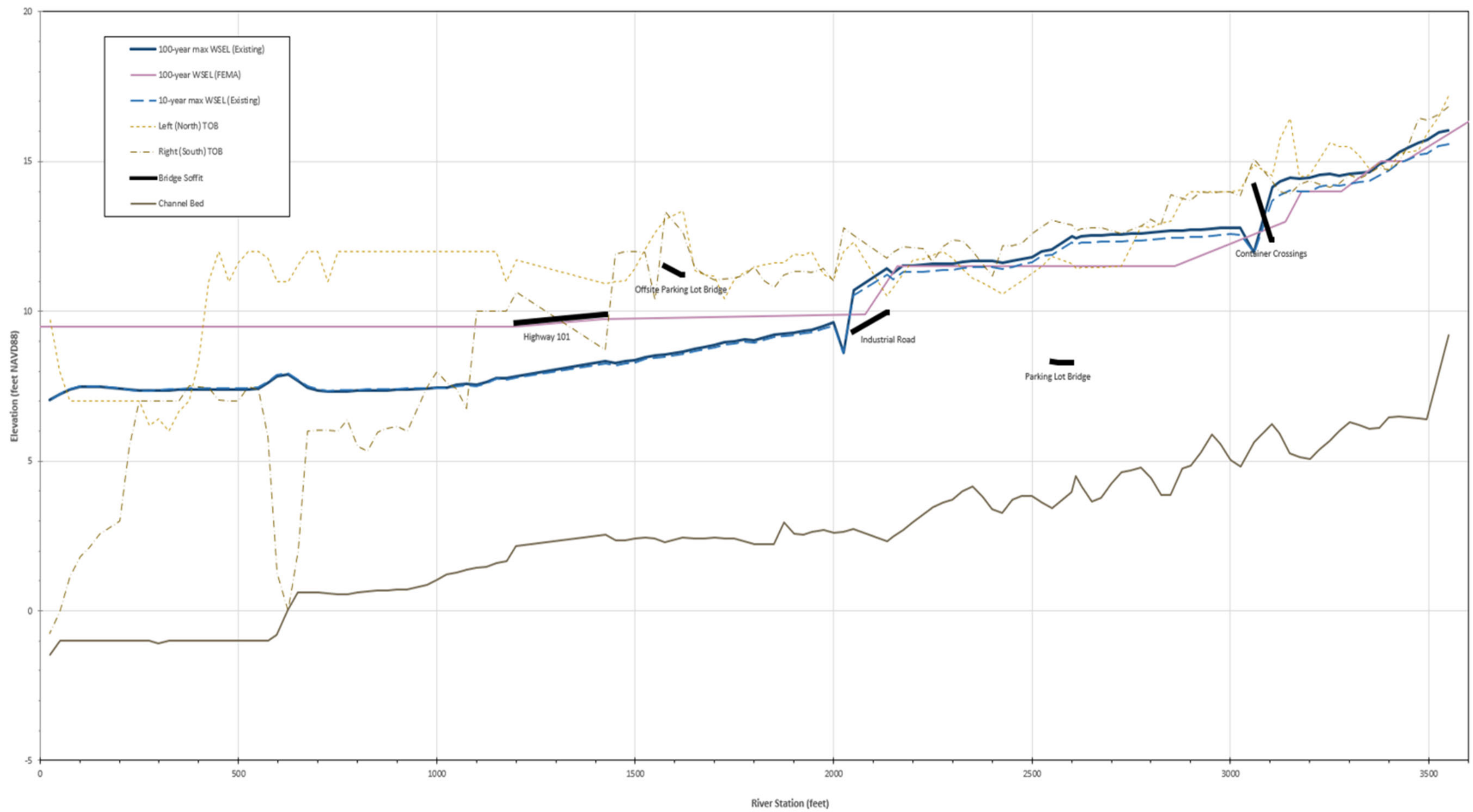


Figure 9: Pulgas Creek Channel Flood Profiles – Existing Conditions and FEMA

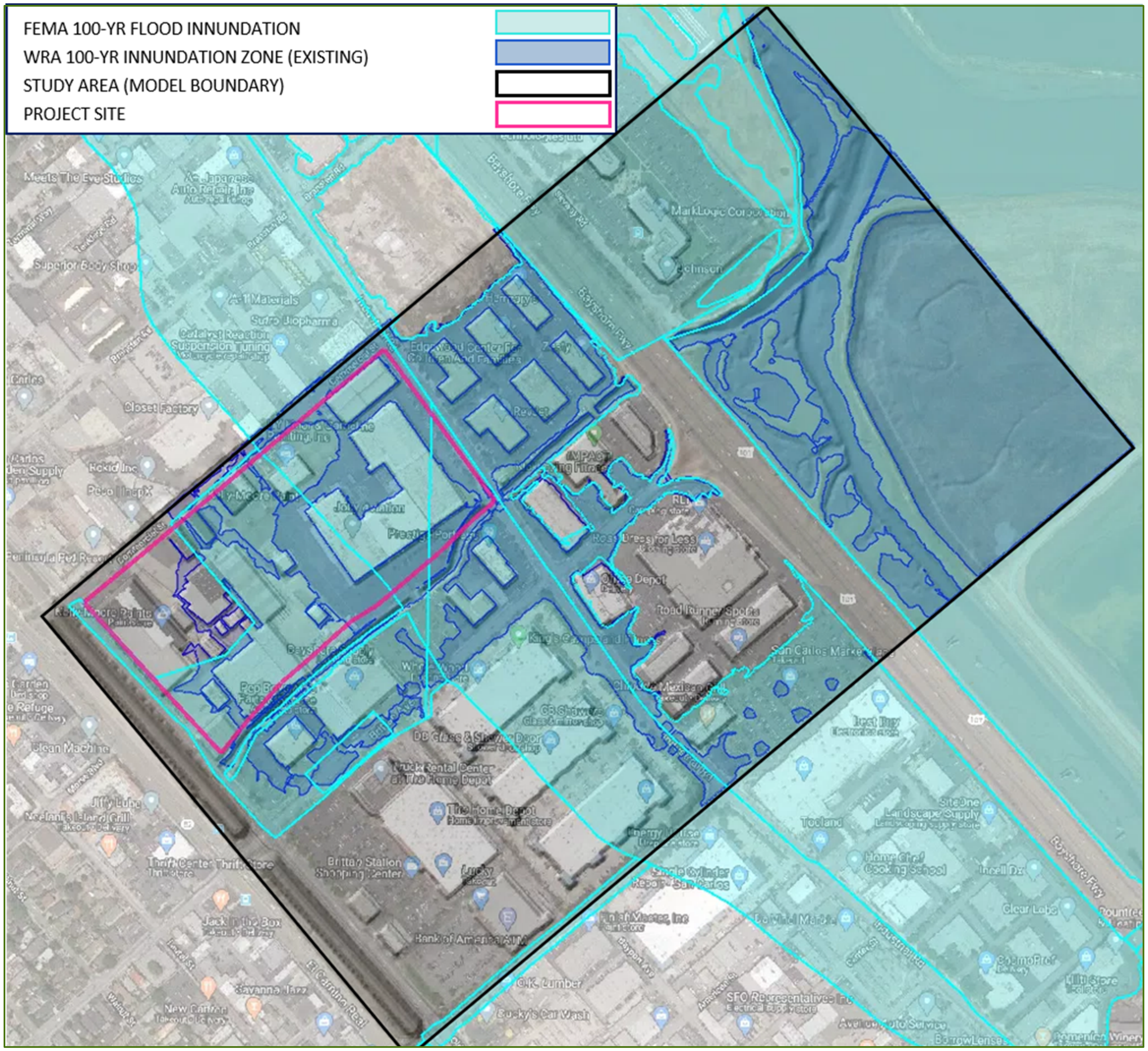


Figure 10: Project Site and Vicinity 100-year Flood Areas - Existing Conditions and FEMA

6.0 Hydraulic Analysis of the Project Without Mitigation

6.1 100-year Flooding for Project Without Mitigation

The hydraulic analysis of the 100-year flooding for the Project without mitigation was reported in the October 2020 WRA memo and is attached as Appendix A. The analysis indicated that the Project would reduce the 100-year flood conditions on the site and be protective of the proposed buildings and occupants. However, the Project could expand the area and increase the depth of 100-year flooding off site.

The summary of the 100-year flooding is included to facilitate comparison to the 10-year results (below). Under the Project without mitigation condition, the 100-year flooding is nearly eliminated from the Project site, aside from marginal areas along the northeast corner, along Industrial Road and small portions of the parking and landscape areas (Figure 11). However, the flood extent off site south of Pulgas Creek, is larger and more continuous within the flood boundary. Areas of Figure 11 that display using only bright blue tones have existing 100-year flooding that is reduced or eliminated under Project conditions. The fringe areas in gold are areas that have expansion of the 100-year flood extent. Areas of darker blue are areas of overlap that have 100-year flooding under both conditions.

6.2 10-year Flooding for Project Without Mitigation

Modeling of the 10-year event for the Project without mitigation was performed using the same model set-up and assumptions as for the 100-year event, with the exception of changing the upstream and lateral inflow hydrology to reflect the 10-year hydrology (as described in section 4.7, above).

Under the Project without mitigation condition, the 10-year flooding is nearly eliminated from the Project site, aside from marginal areas along the northeast corner, along Industrial Road and the bank of Pulgas Creek (Figure 12). However, the 10-year flood extent off site is larger than under existing conditions. Areas of Figure 12 that display using only bright blue tones have existing 10-year flooding that is reduced or eliminated under Project conditions. The fringe areas in gold are areas that have expansion of the 10-year flood extent. Areas of darker blue are areas of overlap that have 10-year flooding under both conditions.

The 10-year model outputs for key parameters (area, depth, volume, etc.) for the existing conditions, Project without mitigation, and mitigation features or scenarios have been considered during optimization and presented as appropriate in the following discussion of the mitigated Project scenario.

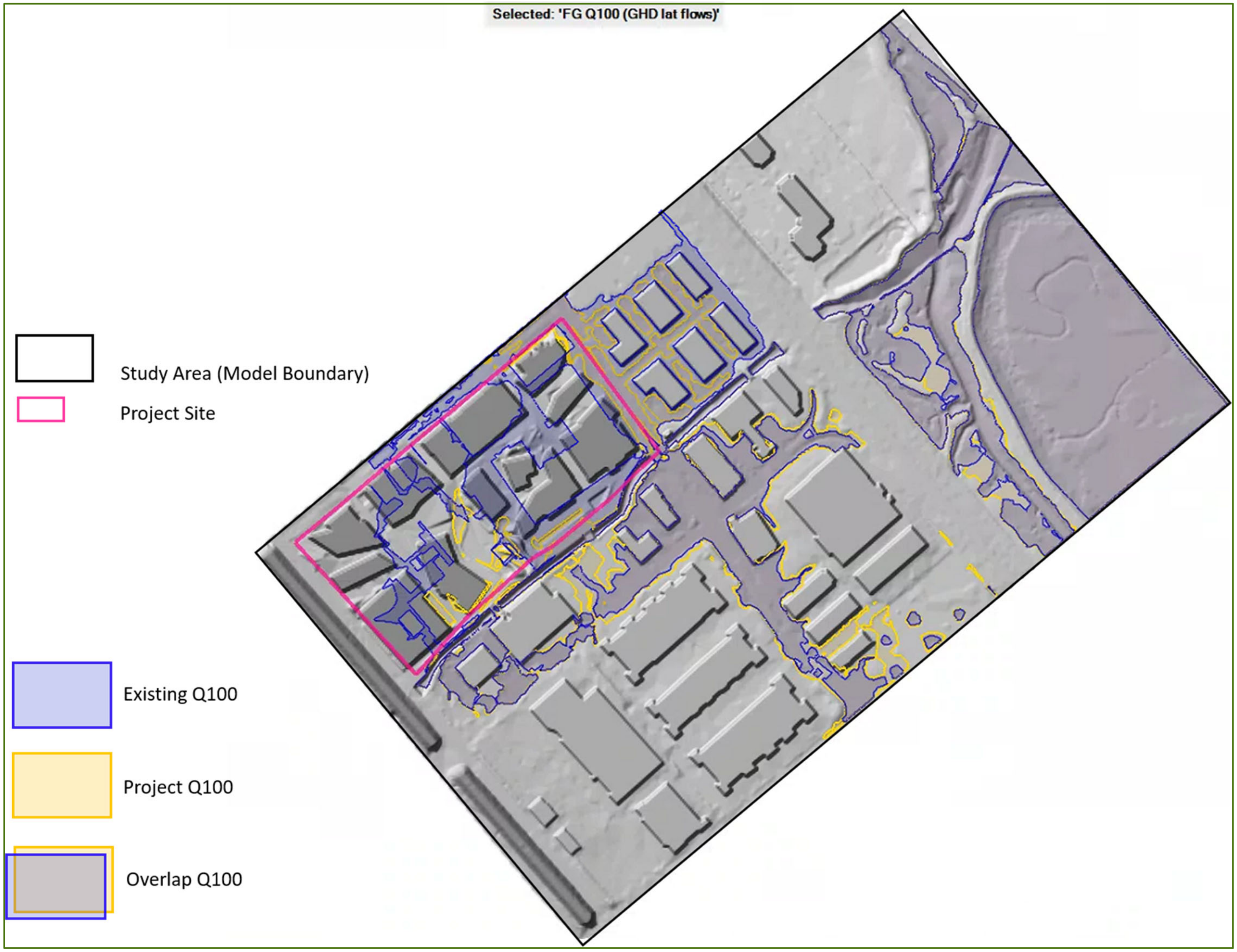


Figure 11: Overlay of Existing and Project Without Mitigation 100-year Flood Extents

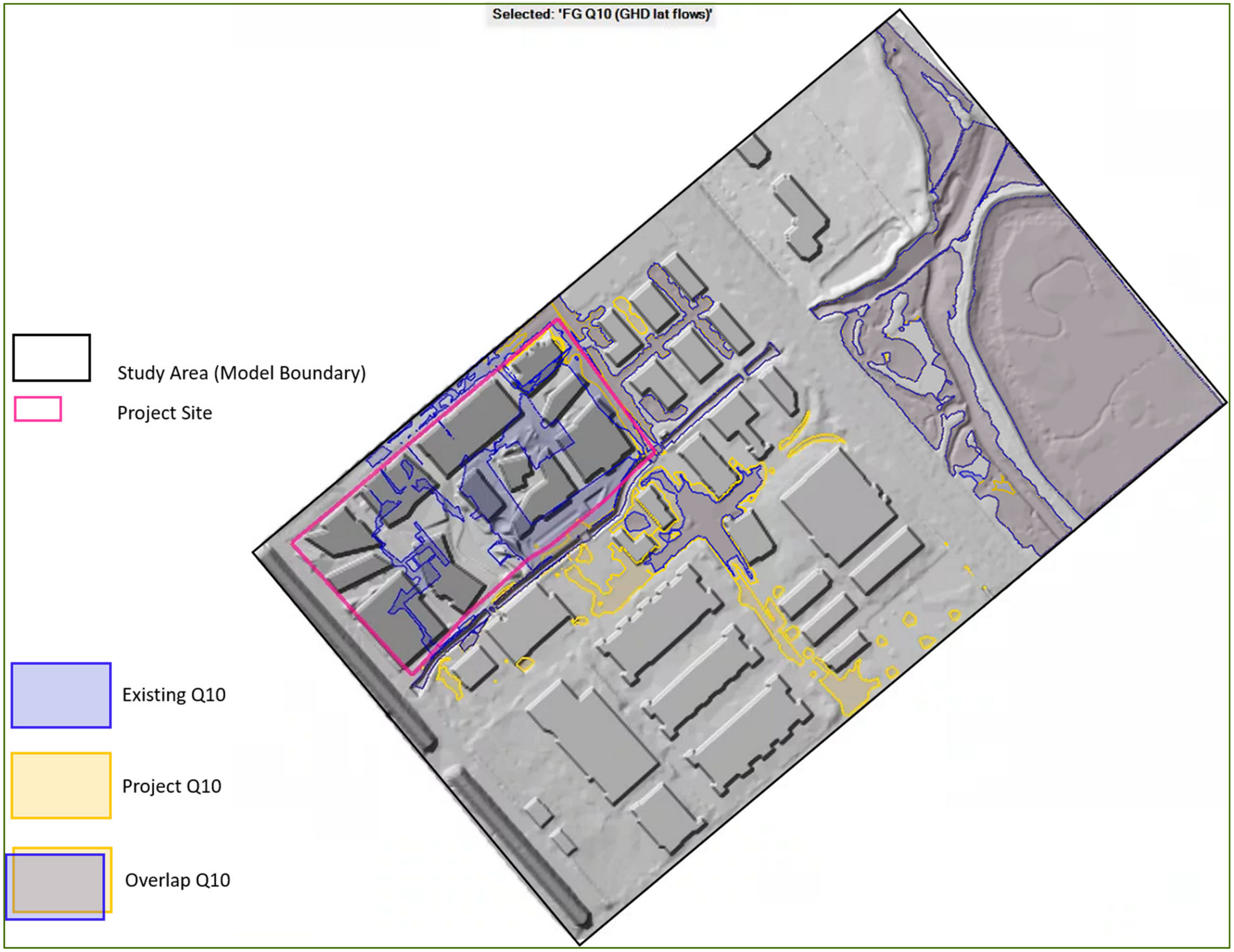


Figure 12: Overlay of Existing and Project Without Mitigation 10-year Flood Extents

7.0 Hydraulic Analysis of the Mitigated Project

7.1 Mitigated Project Conditions Modeling

The hydraulic analysis of Project mitigation features and scenarios was performed by modifying specific characteristics in the model such as the topographic surface, building layouts, bridge structures, surface swales or culverts, that would reflect the hydraulic effect of possible final design features for the Project.

No changes to any off-site areas were made in the model set-up (since the Project would not have the authority or responsibility to directly change off-site properties), and the model's boundary conditions and hydrologic inputs were held constant.

7.2 Mitigation Features and Scenarios

The potential mitigation features and combinations as mitigated Project scenarios were developed with the intent of successfully meeting key performance targets:

- Offsite flooding would be no worse than under existing conditions.
- The Project building layout would be preserved.
- Project operational impacts and flood cleanup needs within the Project site would be minimized.

Several potential mitigation features in varying combinations were evaluated by iterative hydraulic modeling to identify the preferred mitigation strategy. Potential Project mitigation features evaluated included:

- Removing the onsite parking lot bridge.
- Lowering finished grade of the southern parking lot through to Industrial Road.
- Allowing flow to enter the site upstream of the dual container crossing.
- Allowing flow to enter the site (and return to the creek) between the dual container crossing and the parking lot bridge.
- Deepening the proposed landscape depression in the middle of the site to increase temporary on-site storage.
- Conveying flood flow from the landscape depression to temporary storage in the parking garage and release on the existing flood flow path to Commercial Avenue.
- Smoothing the streambank crest elevation immediately upstream of Industrial Road on the Project (north) side.

The iterative hydraulic modeling demonstrated that a mitigated Project design to keep offsite flooding to no worse than present is feasible, even though the surrounding offsite areas are sensitive low elevation surfaces where minor topographic changes can result in large differences in how much, where, or how far flood waters flow. Hydraulic modeling of the various potential mitigation features and combinations indicates that the potential extent and depth of offsite flooding for a mitigated Project can match existing conditions with only minor local deviations in pattern and depth. Additional modeling during final design will be used to optimize Project features and validate that offsite flooding would be no worse than for existing conditions.

In summary the modeling to-date demonstrates the degree of usefulness, feasibility, and effectiveness of the various possible Project mitigation features and has informed a proposed Mitigated Project described below.

7.3 The Mitigated Project

7.3.1 Mitigated Project Terrain

The Mitigated Project incorporates several mitigation features that will be accommodated and optimized in final grading and operational plans for the Project (Figure 13).

The individual mitigation features are:

1. Allowing inflow of flood waters to the site in a predictable, controlled fashion via a surface swale or culvert off the north bank of Pulgas Creek upstream of the dual container crossing. The model represented this as a culvert with an invert elevation (at the creek bank) of 11 feet and an invert elevation (in the landscape depression) of 10.5 feet.
2. Allowing inflow of flood waters to the site in a predictable, controlled fashion via a surface swale or culvert off the north bank of Pulgas Creek upstream of the parking lot bridge. The model represented this as a culvert with an invert elevation (at the creek bank) of 10 feet and an invert elevation (in the landscape depression) of 10.5 feet.
3. Facilitating the outflow of water to return from the landscape depression to the creek via the downstream swale or culvert (bullet #2 above) as the flood hydrograph peak passes.
4. Directing flood water into an enlarged lowered landscape depression for temporary storage. The depression was modeled to have a low flow swale at 10.4 ft and the surrounding basin bottom elevation of 10.0 to 11 feet.
5. Maintaining a floodplain flow path through the south parking lot, modeled to have an upstream finished grade sloping from an elevation of 14 feet (west end) to an elevation of 12 feet at the east bioswale and then sloping down to meet existing grade of elevation 9.5 feet at Industrial Road. This would allow flood waters to mimic existing conditions by permitting flow to overbank, slow down, then flow across Industrial Road.

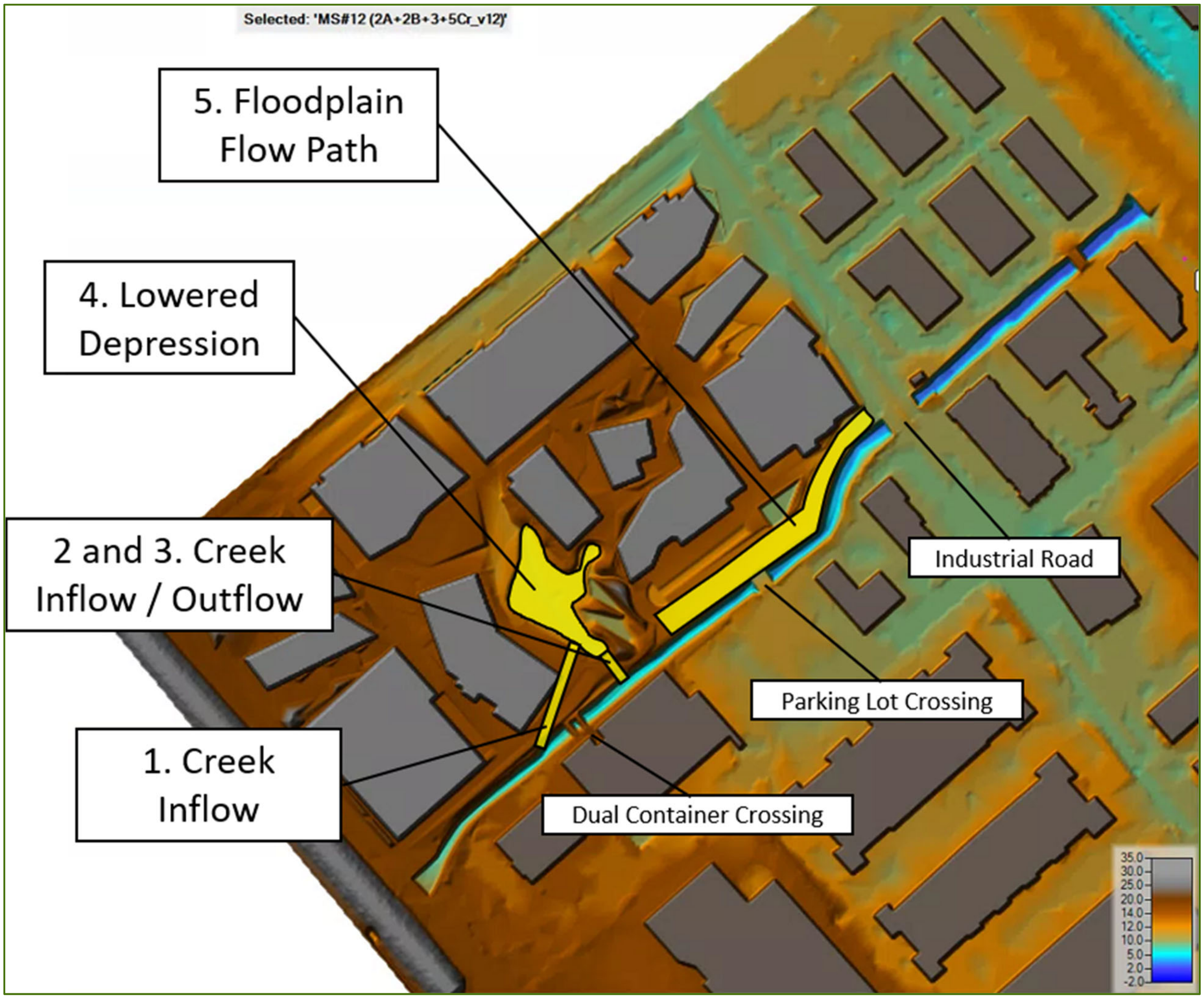


Figure 13: Optimized Project Mitigation Terrain

7.3.2 Mitigated Project Flood Extent and Depths

The Mitigated Project model results for the 100-year flood indicate the 100-year flooding is eliminated from the building footprint onsite while allowing the necessary mitigation flooding of the landscape depression and south parking lot (Figure 14).

The Mitigated Project model results for the 10-year flood indicate that the 10-year flooding is eliminated from the building footprint onsite, while allowing the necessary mitigation flooding of the landscape depression and south parking lot (Figure 15).

The 100-year flood extent off site for the Mitigated Project is modeled to be nearly identical to the existing condition (Figure 16). Areas of Figure 16 that display using only bright blue tones have existing 100-year flooding that is reduced or eliminated under Mitigated Project conditions. The fringe areas in lime green are the minor areas with modeled extent beyond the existing conditions (primarily the onsite Project mitigation feature flooding). The areas of darker green are areas with overlap that have 100-year flooding under both conditions (i.e., no change).

The 10-year flood extent off site for the Mitigated Project is modeled to nearly eliminate flooding south along Brittan Avenue or Industrial Road (Figure 17). Areas of Figure 17Figure 16 that display using only bright blue tones have existing 10-year flooding that is reduced or eliminated under Mitigated Project conditions. The fringe areas in lime green are areas with modeled extent beyond the existing conditions (the onsite Project mitigation feature area and some areas northeast of Industrial Road. Areas of darker green are areas with overlap that have 10-year flooding under both conditions (i.e., no change).

Figure 14: Mitigated Project 100-year Flood Extent and Depth

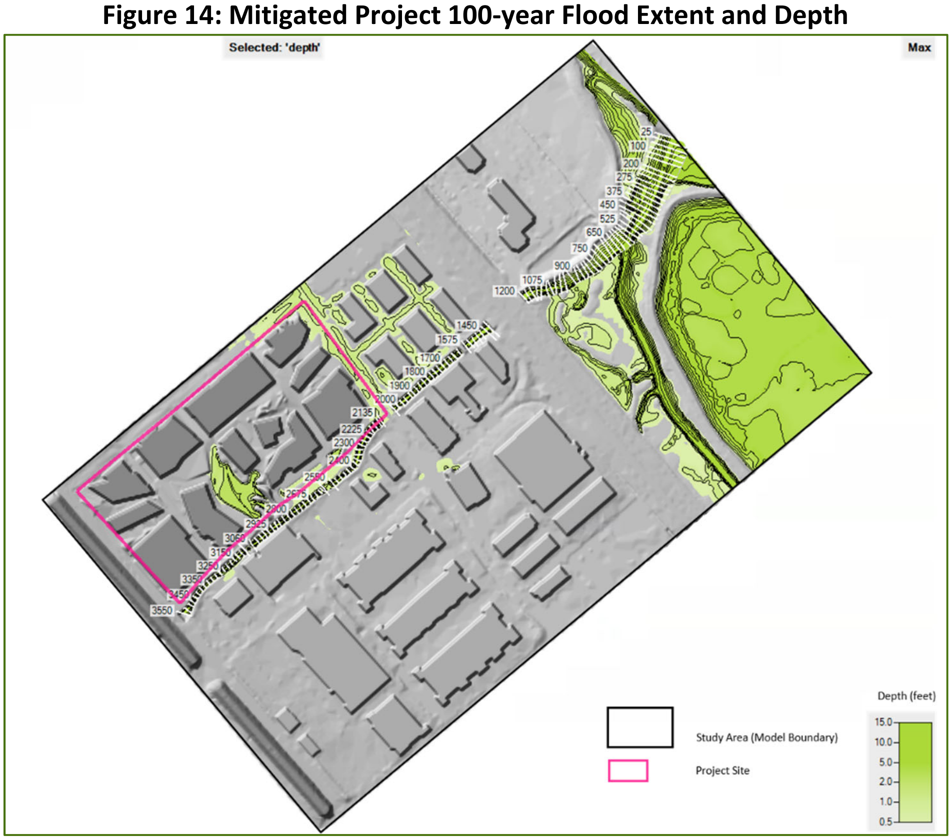


Figure 15: Mitigated Project 10-year Flood Extent and Depth

Figure 16: Existing Conditions and Mitigated Project 100-year Flood Extents

Figure 17: Existing Conditions and Mitigated Project 10-year Flood Extents

7.3.3 Mitigated Project Flood Profiles

The mitigated Project 100-year maximum WSEL along Pulgas Creek would not be higher than existing conditions downstream between Industrial Road and the Bay and it would be lower than existing conditions upstream of the dual container crossing (Figure 18). The mitigated Project 100-year maximum WSEL would be similar or slightly lower than existing between Industrial Road and the Parking Lot Bridge. The mitigated Project would have Maximum WSEL higher than existing between the Parking Lot Bridge and the dual container crossings, which is necessary and consistent with the mitigation feature functions that allow flood water to enter the site and return from the landscape depression.

7.3.4 Mitigated Project Channel Shear Stress

The mitigated Project will decrease channel bed shear stress under the 100-year event relative to the existing conditions through the project reach (Figure 19). The mitigation features allow overbank flow to commence slightly earlier in the hydrograph, which reduces shear and is supportive of channel bed and bank stability.

The changes can be compared to known resistance/stability of channel materials (Fischenich, 2001) as context to assess whether an appreciable change in the channel condition or stability would occur. Materials along the existing channel bed and banks of Pulgas Creek are quite varied and include sections with concrete bed or banks, sakrete banks, rooted woody and herbaceous vegetation, unvegetated soils, as well as fine sediment, sand, gravel, small cobble, and occasional larger rock or concrete slabs.

The 100-year channel bed shear stress with the mitigated Project would provide more consistent shear stress throughout the study reach, generally under or around 0.3 to 0.4 pounds per square foot (lb/sq ft) aside from local areas downstream of the Industrial Road crossing of up to 2.0 lb/sq ft (Figure 19). The bed material expected to remain stable would be more consistently in gravel to small cobble size classes.

7.3.5 Mitigated Project Flood Water Surface Elevations

Comparison of water surface elevations along key profiles in the study area supplement the map views to indicate the ability of the Mitigated Project to match existing conditions for the 100-year (Figure 20) and 10-year (Figure 21) floods. They demonstrate the ability of the proposed mitigations to not only limit the areal extent of flooding (as shown in the above maps), but also manage water elevations. The existing conditions are shown in blue lines, and the Mitigated Project in green. Full size versions of these graphs are provided as Appendix B for closer inspection.

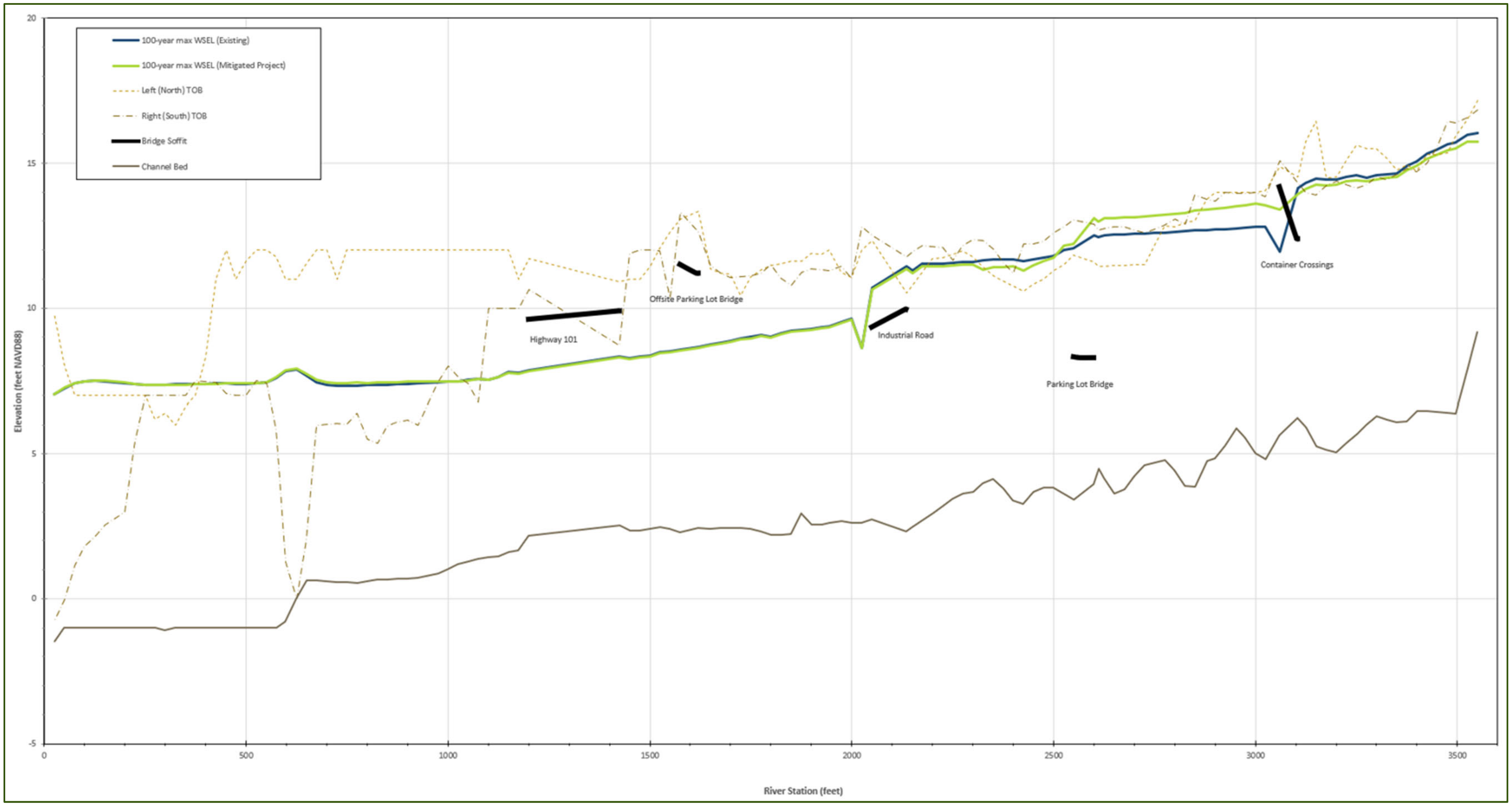


Figure 18: Pulgas Creek Maximum Water Surface Elevation Profiles for the 100-year Flood

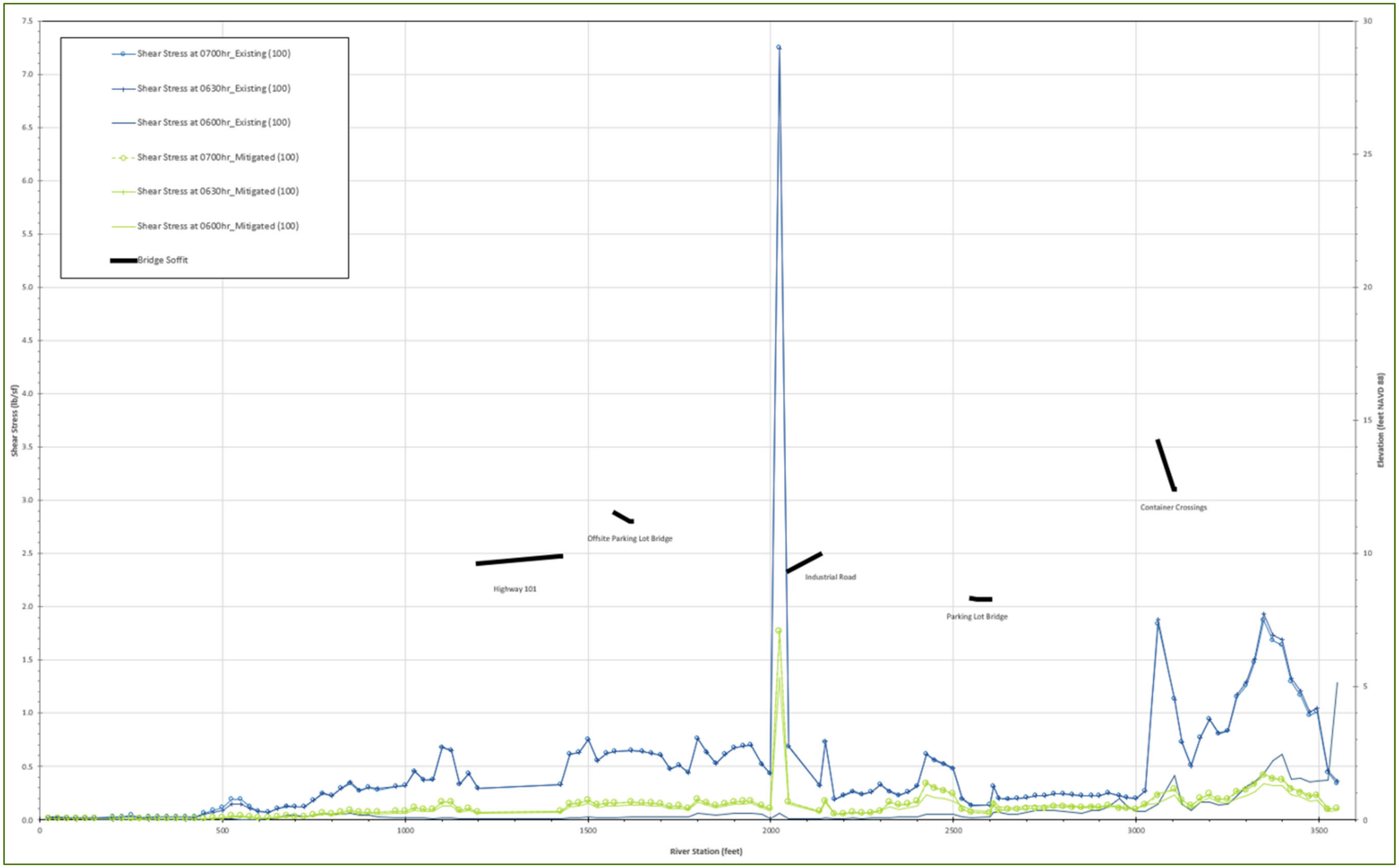


Figure 19: Pulgas Creek Shear Stress Profiles for the 100-year Flood

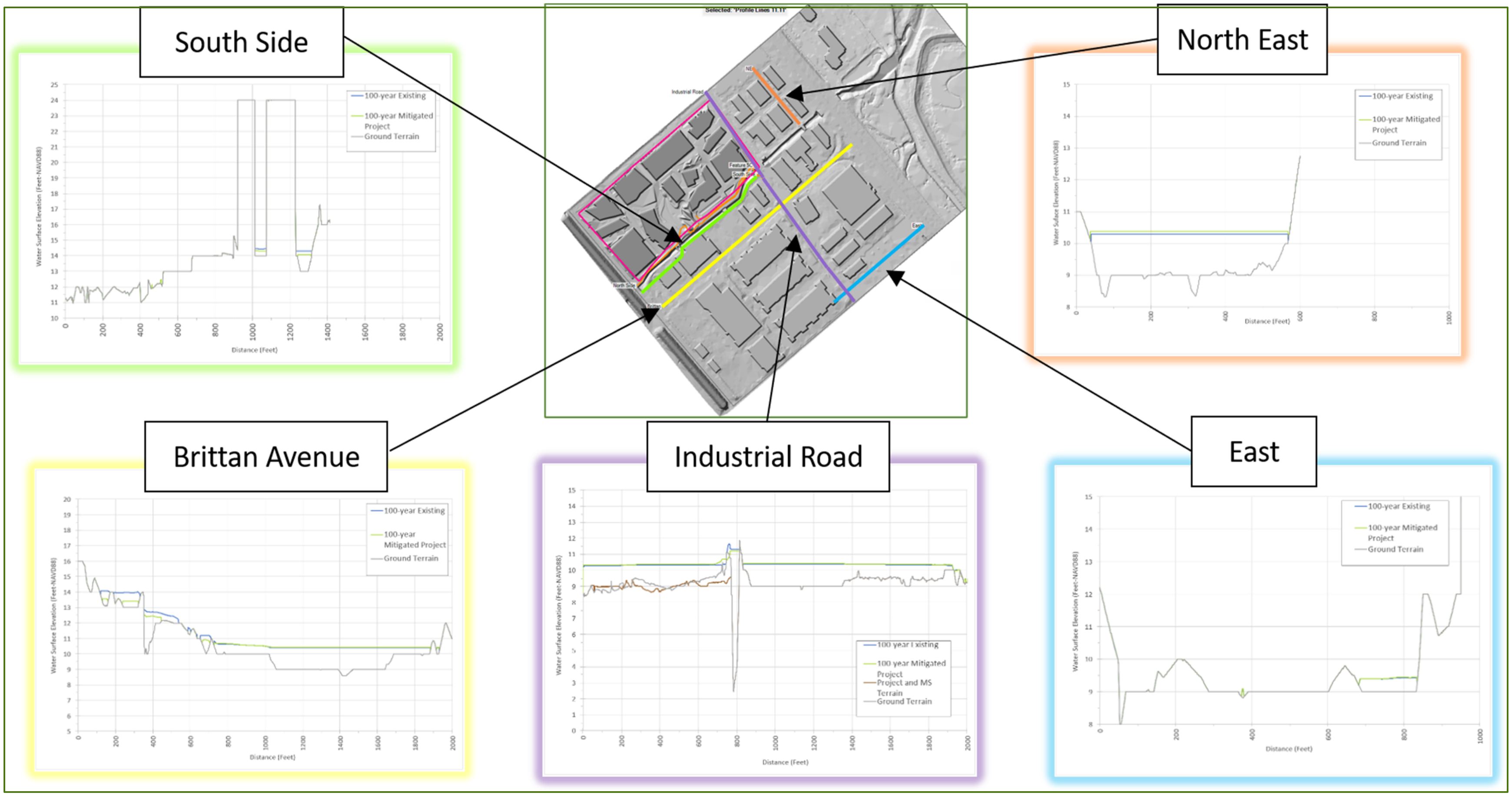


Figure 20: Maximum Water Surface Elevations and Ground Surfaces: 100-year Flood

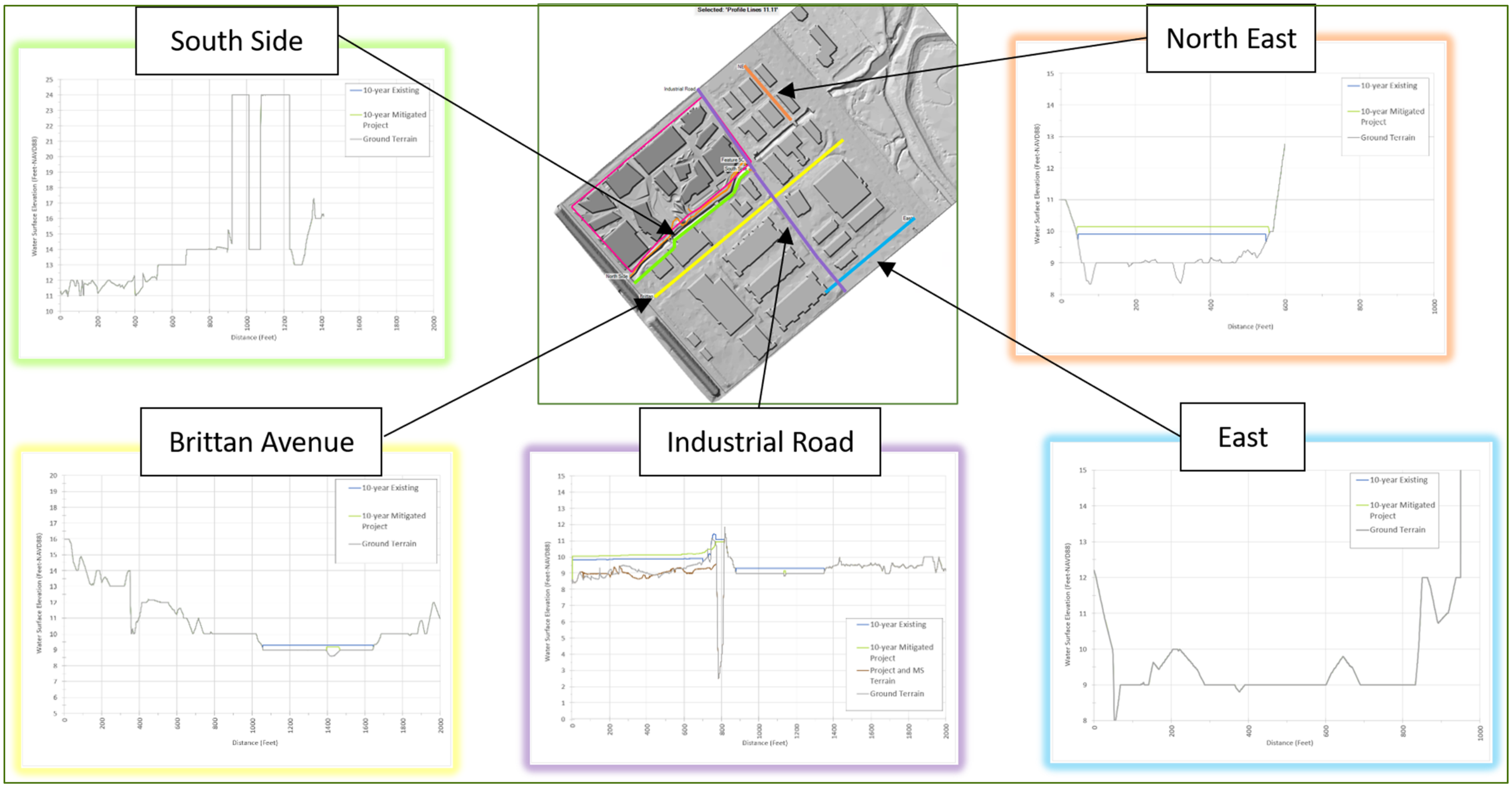


Figure 21: Maximum Water Surface Elevations and Ground Surfaces: 10-year Flood

8.0 Conclusion

WRA performed iterative hydraulic modeling of potential project mitigation features to eliminate or minimize increases to off-site flooding extent and depth and local shear stresses in the creek. *Based on our understanding of the site hydraulics from modeling several possible mitigation features and combinations, this memo presents results for a Mitigated Project whose final design would reduce the potential adverse offsite impacts for the 100-year and 10-year floods to a less-than-significant impact.* Modeling indicates that the Mitigated Project will reduce the 100-year flood conditions on site and be protective of the proposed buildings.

The Mitigated Project could successfully address the potential flood issues of the Project without mitigation that were assessed in our October memo (Appendix A).

As previously presented the individual key design features within the identified Mitigated Project are:

6. Allowing inflow of flood waters to the site in a predictable, controlled fashion via a surface swale or culvert off the north bank of Pulgas Creek upstream of the dual container crossing.
7. Allowing inflow of flood waters to the site in a predictable, controlled fashion via a surface swale or culvert off the north bank of Pulgas Creek upstream of the parking lot bridge.
8. Facilitating the outflow of water to return from the landscape depression to the creek via the downstream swale or culvert as the flood hydrograph peak passes.
9. Directing flood water into the enlarged lowered landscape depression for temporary storage.
10. Maintaining a floodplain flow path on the creek side portion of the south parking lot at a finished grade elevation that allows water to flow overbank, be slowed down and detained, but follow their existing route across Industrial Road.

Each of these design features will be further optimized for the Mitigated Project during final design and fully realize their functionality and verify their performance relative to the flood impact requirements of the City and the project layout and project operations targets.

Project modeling assumes that preservation of channel conveyance capacity will be maintained by the City for long-term flood management to address potential in-channel sedimentation associated with sea level rise or from upstream sources, or vegetation and debris restrictions.

9.0 Limitations

The models developed for this study have focused particular recurrence interval events (i.e. 100 -year and 10-year) rather than a full range of recurrence interval peak flows or hydrographs. The scope and emphasis of model optimization was on comparing and evaluating the relationship between the existing conditions and the proposed and/or mitigated Project within the study area.

It is important to acknowledge that as for any numerical model, is there is uncertainty or a margin of error in the hydraulic model. The model sensitivity analysis shows the water surface elevation may be within +/- 0.3 ft of the model results. The volume of water quantified may be within 10 acre-ft of the model results. These are reasonable and typical for the resolution of modeling herein.

Additionally, we note that the scope of this flood analysis is limited to the physical hydraulics and does not address options for flood safety hazard measures such as signage, trash management, monitoring or maintenance.

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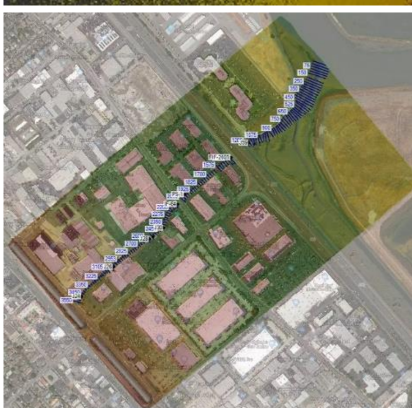
Appendix A

ALEXANDRIA PHASE 2 PROJECT PULGAS CREEK 100-YEAR FLOODING ANALYSIS

ALEXANDRIA PHASE 2 PROJECT

PULGAS CREEK 100-YEAR FLOODING ANALYSIS

SAN CARLOS, CALIFORNIA



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WRA #30042-1
OCTOBER 2020

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APPENDIX A – ANIMATIONS OF MODEL RESULTS (separate PowerPoint file)

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Andrew Smith, PE – Lead Engineer
Audriana Ossenberg, PE –Engineer

LIST OF ACRONYMS

Acronym	Full Name
1D	One-dimensional
2D	Two -Dimensional
AF	acre-feet
Cfs	Cubic Feet per Second
CLOMR	Conditional Letter of Map Revision
F&L	Freyer & Laureta, Inc.
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
ft	Feet
HEC-RAS	Hydrologic Engineering Center – River Analysis System
LiDAR	Light Detection and Ranging
MHHW	Mean Higher High Water
n	Manning’s roughness coefficient
NOAA	National Oceanic and Atmospheric Administration
PLS	Professional Land Surveyor
RS	River Station
TOB	Top of Bank
WSEL	Water Surface Elevation

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1.0 Introduction

1.1 Project Understanding and Site Overview

The proposed Alexandria Phase 2 project (Project) is adjacent to Pulgas Creek in the City of San Carlos, San Mateo County, between Old County Road and Industrial Road, south of Commercial Street.

1.2 Purpose, Scope and Limitation

The focus of this study is to describe the existing 100-year flood conditions of the Project site and vicinity and assess the potential for the Project to modify the 100-year flooding and create adverse changes within the site or potential off-site impacts.

2.0 Vicinity Flooding Context

The Project vicinity is the low-lying, nearly level bayshore portion of San Carlos. Special Flood Hazard Areas designated by the Federal Emergency Management Agency (FEMA) (FEMA Flood Map Service Center, n.d.) overlie much of the site as well as broad areas of the urban corridor downstream to the bay (Figure 1). The Base Flood Elevation for the 1% annual chance (100-year recurrence) flood is identified as 12 feet on the west side of Industrial Road. The Flood Insurance Study (FIS) (FEMA, 2012) flood profile along Pulgas Creek (Figure 2) indicates that the water surface elevation (WSEL) gradually increases from just under 10 feet at the bay upstream to Industrial Road, increases to 12 feet with steeper, stepped increases to 15 feet further upstream and to around 17 feet at the culverts under Old County Road.

The City of San Carlos's (City) Storm Drain Master Plan (GHD, 2018) includes a hydrologic model of the watershed and urban system of open channels, pipe networks, and pump stations for a range of storm events including the 100-year base condition. Pulgas Creek is one of the four primary creeks in the hydrologic model. The lower Pulgas Creek segment in our study is the low gradient (0.5 percent slope) portion downstream of underground culvert systems that daylight near Old County Road. The model results for the Base Condition (e.g., existing) of the storm drain study indicate overbank inundation on the Project site and across Pulgas Creek to the south within the Project reach (Figure 3).

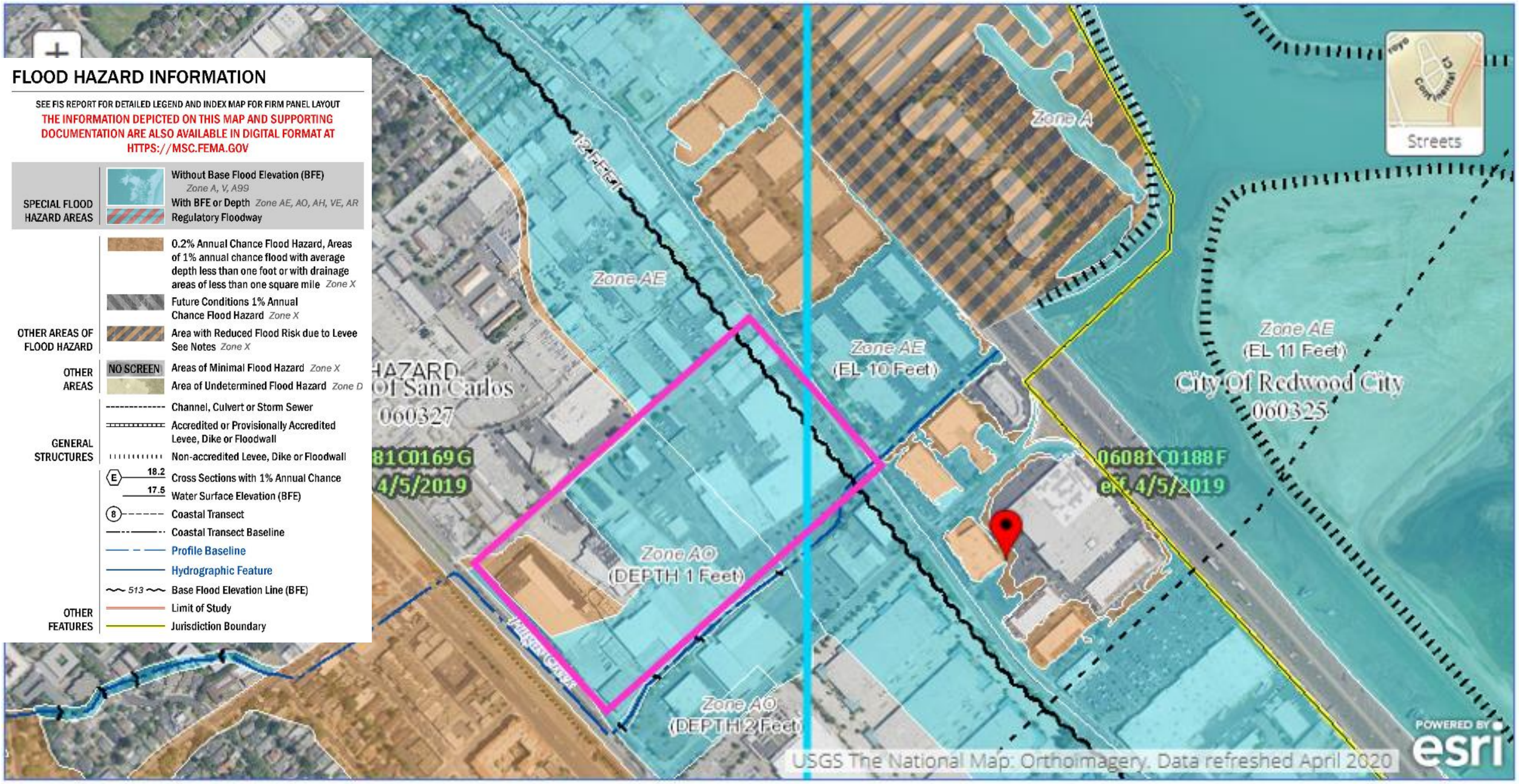


Figure 1: Effective FEMA Flood Information Rate Map (FIRM) for the Project Site and Vicinity

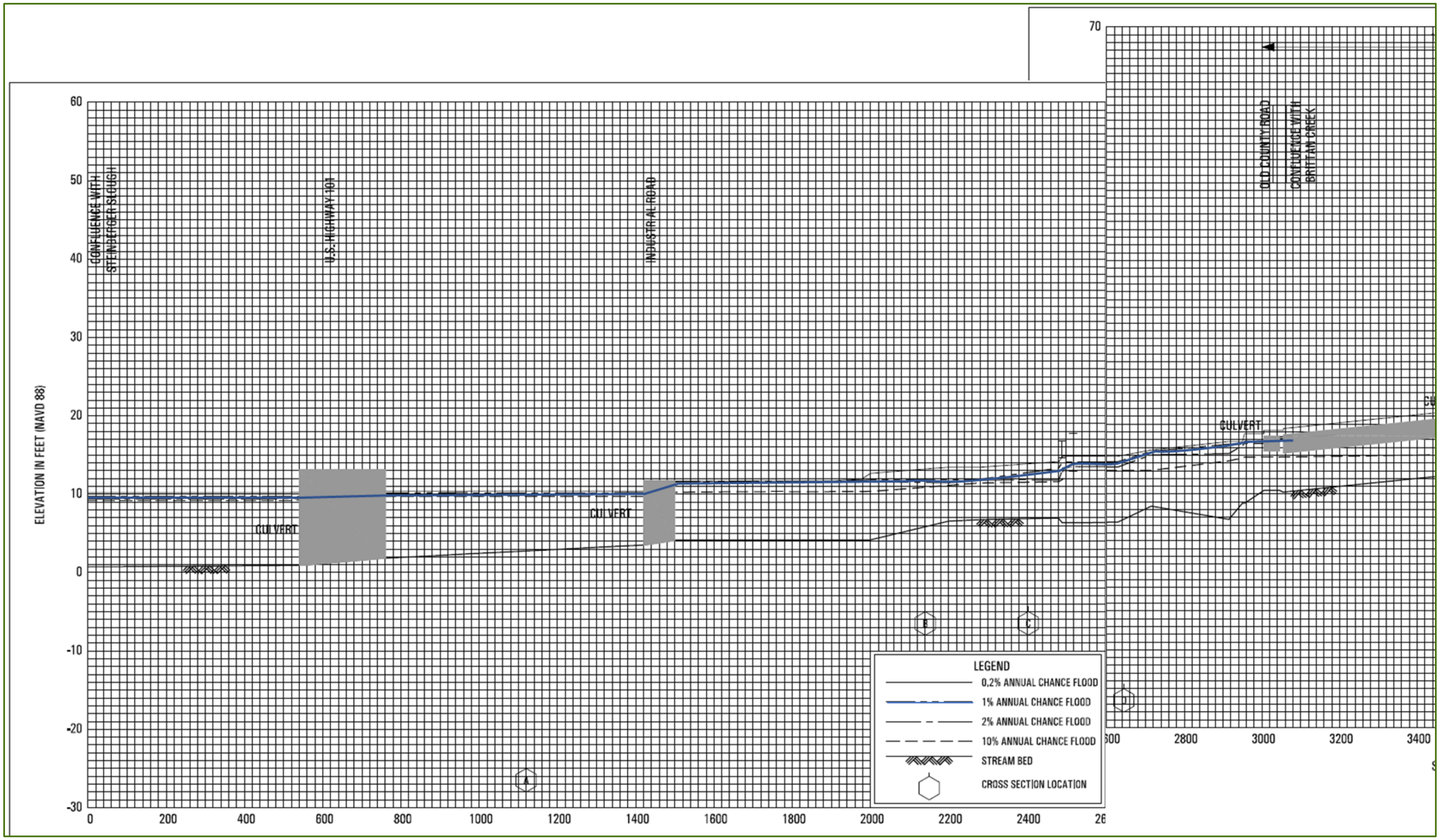


Figure 2: Effective FEMA Flood Insurance Study Pulgas Creek Profiles

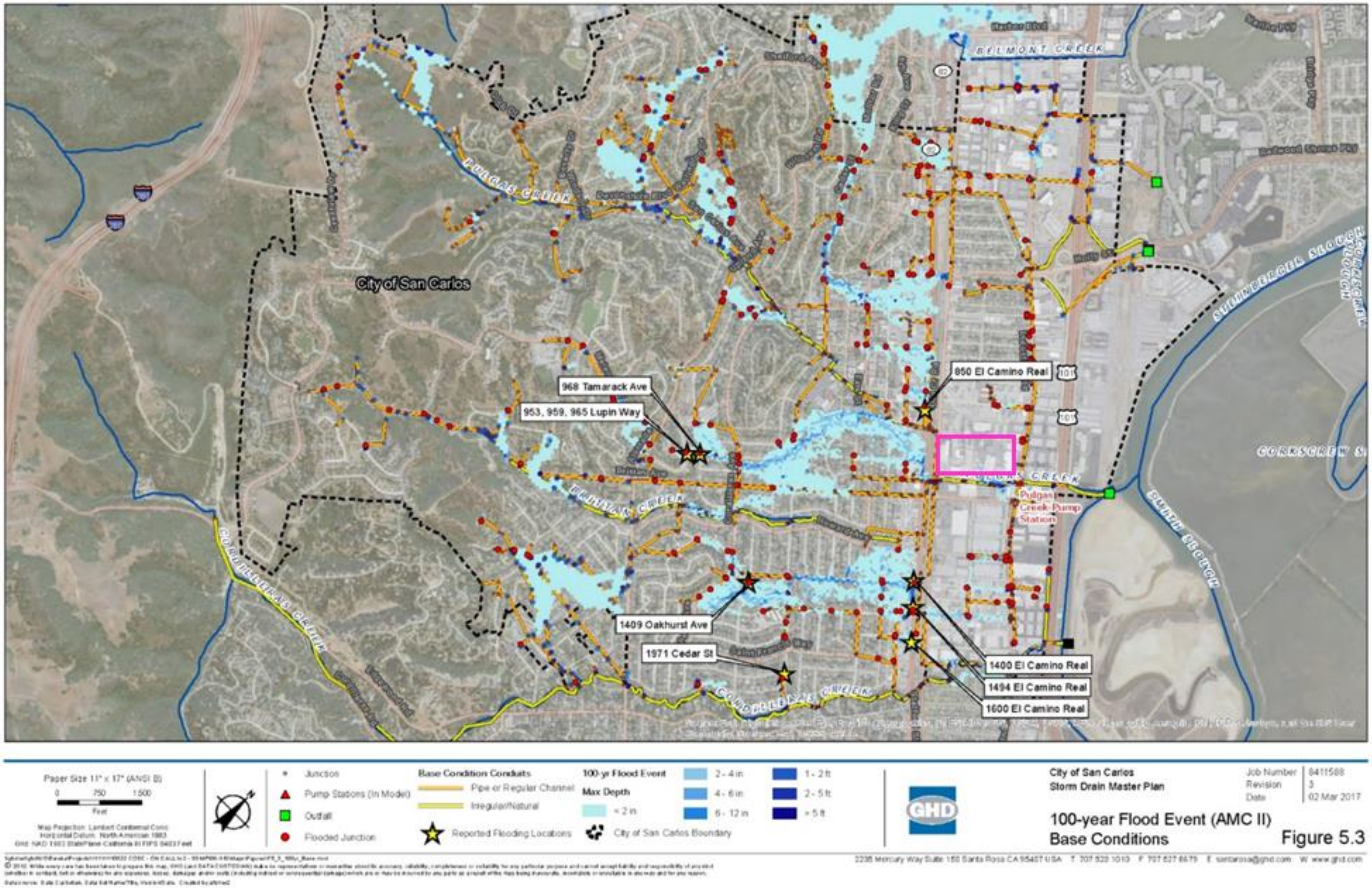


Figure 3: Storm Drain Master Plan 100-year Flood Event Base Conditions

3.0 Hydraulic Model Development

The hydraulic modeling is performed using HEC-RAS version 5.0.7 to build a one-dimensional (1D) model of the Pulgas Creek channel, in combination with a two-dimensional (2D) model of the flow areas surrounding Pulgas Creek (including the Project site).

3.1 Model Extent

The model extent (i.e., study area) is limited to that required to represent the upstream floodwater sources and downstream boundary conditions, the Project site and potential off-site impact areas. It extends upstream from the San Francisco Bay near Pulgas Creek's confluence with Steinberger Slough (MHHW) to Old County Road and from northwest of Commercial Street to Howard Avenue (Figure 4). The Project site is approximately 25 acres (0.04 square miles) in the northwest corner of the overall 0.275 square mile study area, which extents about 3,560 feet inland from the bay and about 2,150 feet wide to include areas on either side of Pulgas Creek.

Figure 4: Hydraulic Surface and Channel Cross Sections – Existing Conditions

3.2 Topographic and Bathymetric Data

The site and Pulgas Creek (including the onsite parking lot bridge) were surveyed in July 2020 by a professional land surveyor (PLS) under contract to Freyer & Laureta, Inc. (F&L). The survey effort included a 3D scan of the container crossing (Figure 5) and the downstream side of Industrial Road. The 3D scan was stored in ReCap point cloud form. A field survey of the remaining bridges (the upstream side of Industrial Road, the off-site parking lot bridge and Highway 101) was performed by F&L. Topographic data from a National Oceanic Atmospheric Administration (NOAA) Light Detection and Ranging (LiDAR) scan from 2010 was used to complete the topographic information for the entire model boundary area. F&L compiled the topographic and bathymetric information from all the different sources to create a continuous ground surface.

3.3 Existing Buildings

The topographic surface surrounding the creek was modified to incorporate the existing buildings as potential obstacles to flow for the 2D modeling by digitizing the building footprints using a combination of recent georeferenced aerial imagery and topographic survey taken of the site. Existing building footprint areas were confirmed by F&L. A standard elevation of 24 feet was applied to the building footprints to ensure a full flow blockage.

3.4 Channel Crossings

Representation of Pulgas Creek in the 1D model requires incorporating geometry of the channel, changes to the geometry (constrictions), roughness of surfaces within the channel related to Manning's n, features within the channel or crossings over the channel. The features that primarily affect hydraulics in Pulgas Creek are channel crossings (bridges). Bridges in HEC-RAS use a series of equations to calculate significant hydraulic functions (including water surface elevation, velocity and conservation of energy) both upstream and downstream of each bridge. Each crossing is represented as a bridge in HEC-RAS (Figure 6) with specific data to indicate their conveyance configuration, dimensions and any ineffective flow areas.

The model extent along Pulgas Creek includes downstream bridges at Hwy 101, an off-site parking lot, and Industrial Road, as well as a parking lot bridge and two closely space container crossings within the Project reach downstream of Old County Road (Table 1). The vertical clearance from the channel bed to the bridge soffit (underside of the bridge) and the total cross section area are both lowest at the parking lot bridge in the Project reach. The container crossing(s) and Industrial Road also have relatively small cross-sectional areas compared to the upstream and downstream bridges.

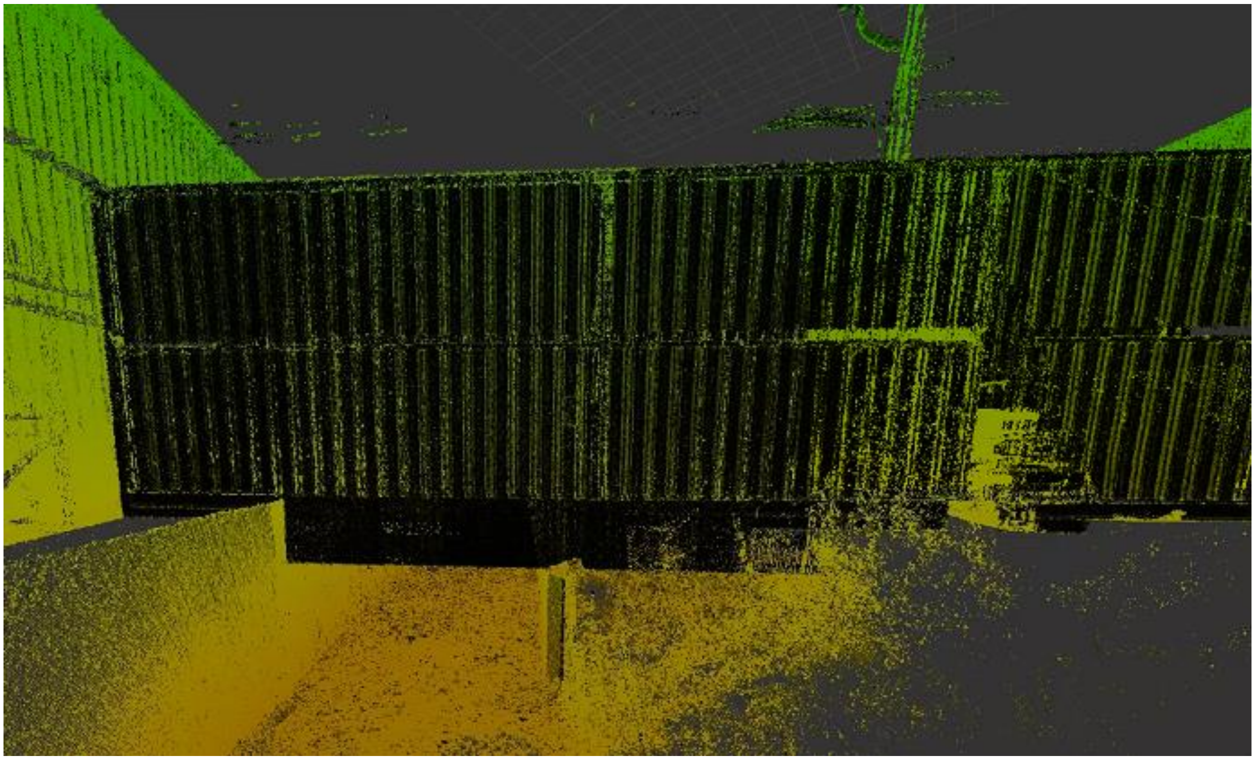


Figure 5: Point Cloud Data Example: Upstream Side of Container Crossing (RS 3103)

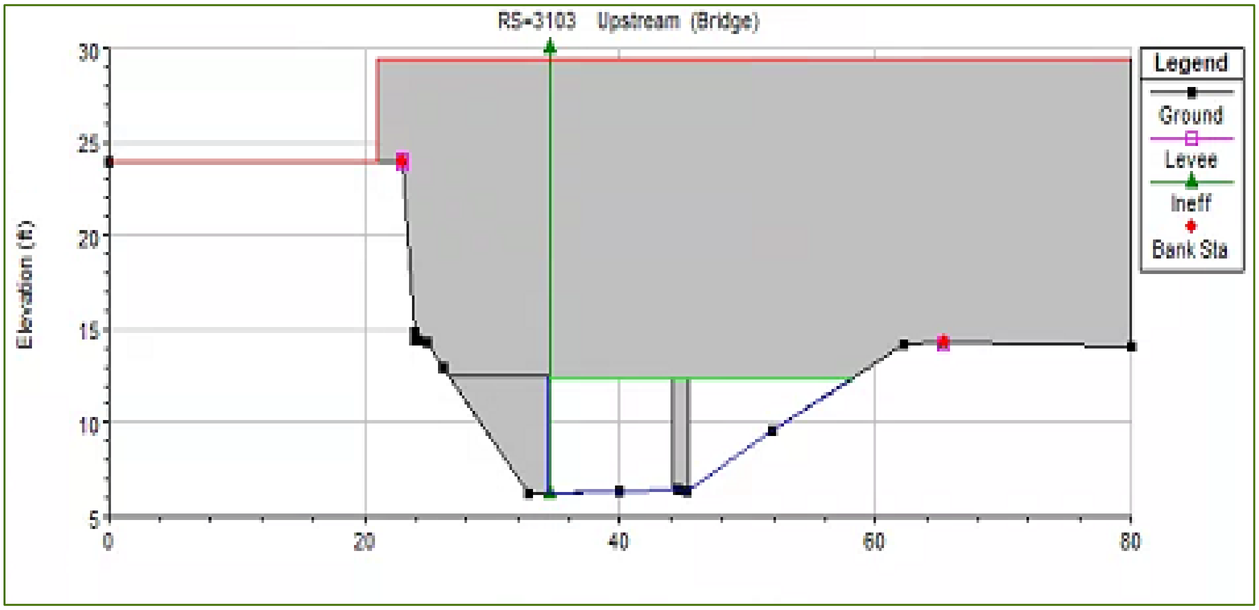


Figure 6: HEC-RAS Bridge Cross Section Example: Upstream Side of Container Crossing (RS 3103)

Table 1: Lower Pulgas Creek Bridge Parameters

Bridge Name	Model RS (Upstream Side)	Average Bed Elevation	Soffit Elevation	Cross Section Area
	feet	Feet NAVD 88	Feet NAVD 88	square feet
Hwy 101	1425	2.75	9.0	265
Off-Site Parking Lot	1615	2.45	11.0	255
Industrial Road	2135	3.0	10.0	140
Parking Lot Bridge	2600	4.0	8.5	100
Container Crossing	3105	6.0	13.0	125
Old County Road	3550	9.5	*	355

* Model extends to downstream side but does not cross under Old County Road

3.5 Channel Profile

The topography, bathymetry and crossings data along the existing channel of lower Pulgas Creek indicate key features of the channel bed and bank profiles that influence flooding (Figure 7). The channel bed is nearly level and smooth in the marsh/bay, including a step at the slough confluence downstream of Highway 101. The channel bed remains relatively smooth, with small grade breaks, upstream to Industrial Road, then exhibits increasing irregularity in the Project reach, with a stepped rise to meet culverts under Old County Road at the upstream end. The channel bed is below the Mean Higher High Water (MHHW) tidal elevation throughout the study reach. The channel banks are irregular with minor (and similar magnitude) variations on the left (north) and right (south) banks upstream of Highway 101. Downstream of Highway 101, the left bank is an elevated/constructed levee, while the right bank drops to natural tidal marsh elevations. The crossing structures are quite varied in profile, displaying an array of vertical clearances between channel bed and soffit, having different thicknesses between soffit and deck surfaces, and a range of resulting maximum elevations.

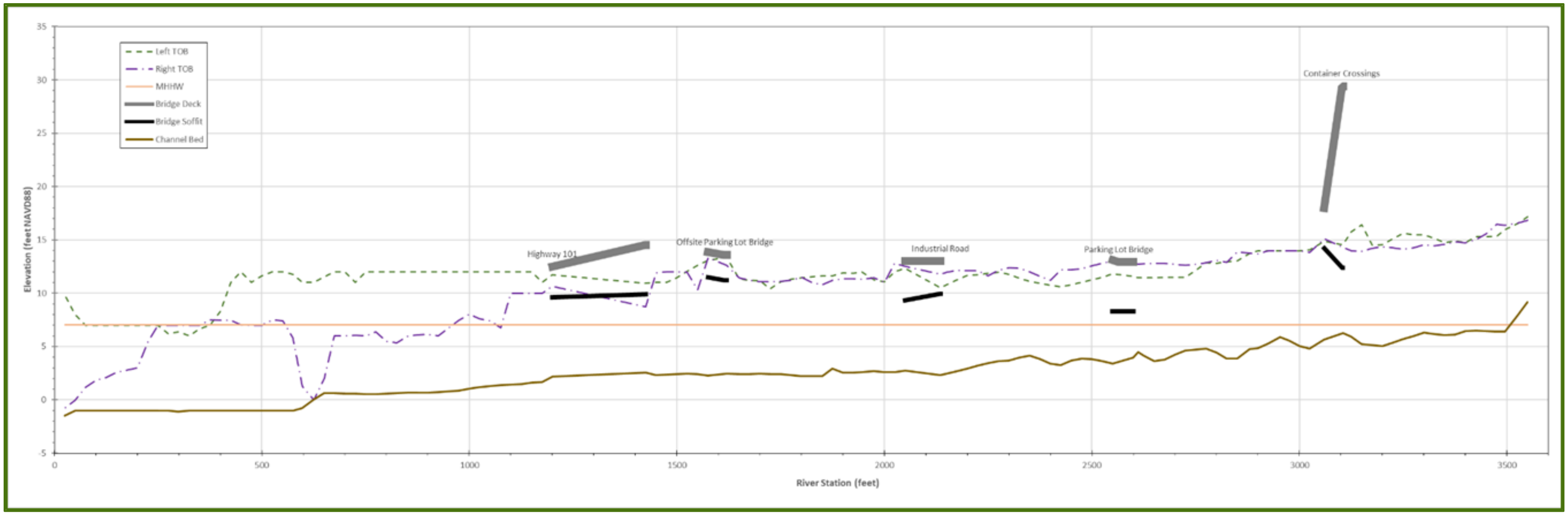


Figure 7: Existing Channel Bed and Top of Bank Profiles, Channel Crossings, and MHHW Elevation

3.6 Downstream Boundary Conditions

The primary modeling assumption at the downstream boundary is a steady-state mean higher high water (MHHW) of 7.04 ft NAVD 88 reported for Point 765 in the AECOM tidal datums report for SF Bay locations (AECOM, 2017). For additional sensitivity testing, the unsteady downstream hydrograph from the storm drain master plan model (GHD, 2018) is applied. The unsteady tidal cycle includes a high tide of 9.15 ft NAVD88 occurring six hours into the simulation and a low tide of -1.1 ft NAVD88 occurring thirteen hours into the simulation.

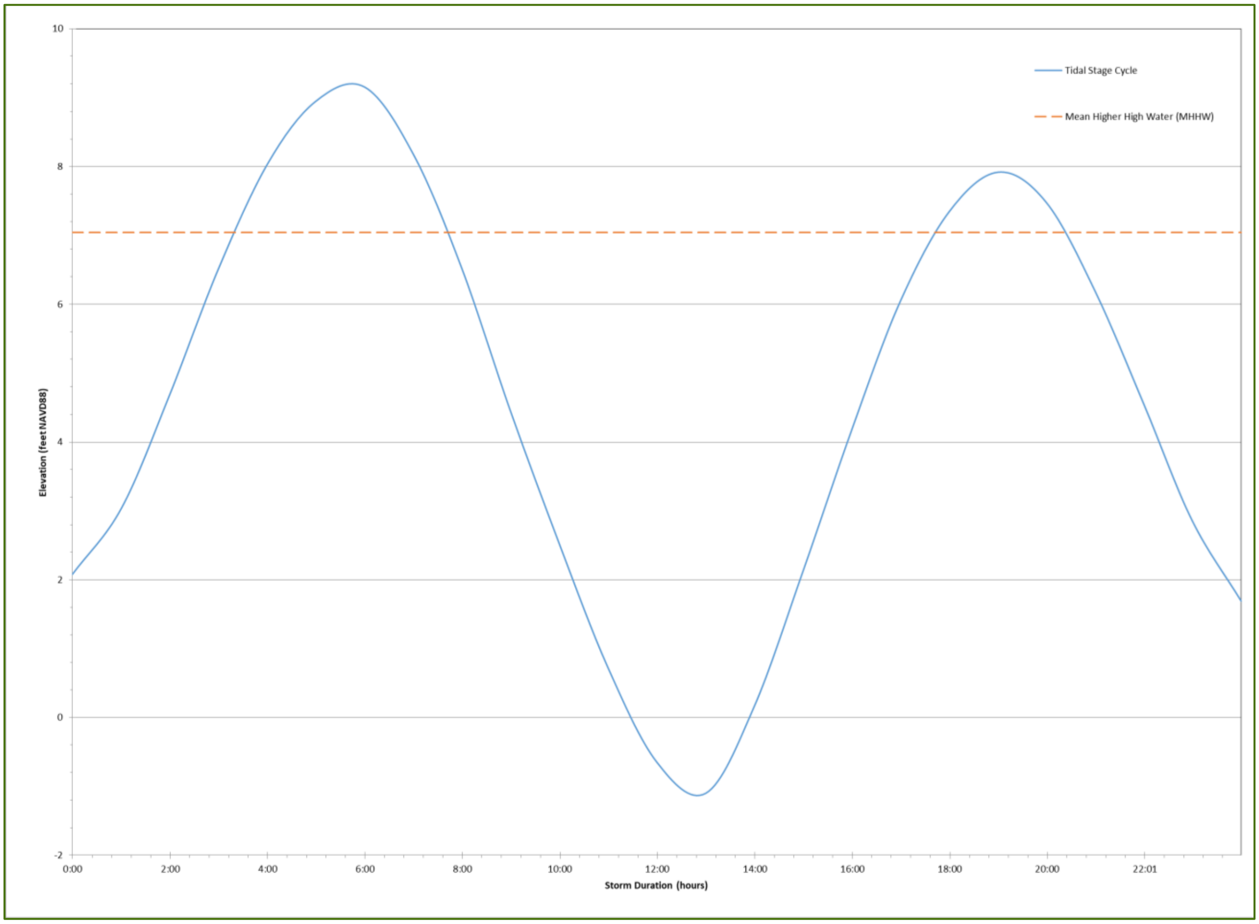


Figure 8: Downstream Tidal Boundary Conditions

3.7 Upstream and Project Reach Inflows

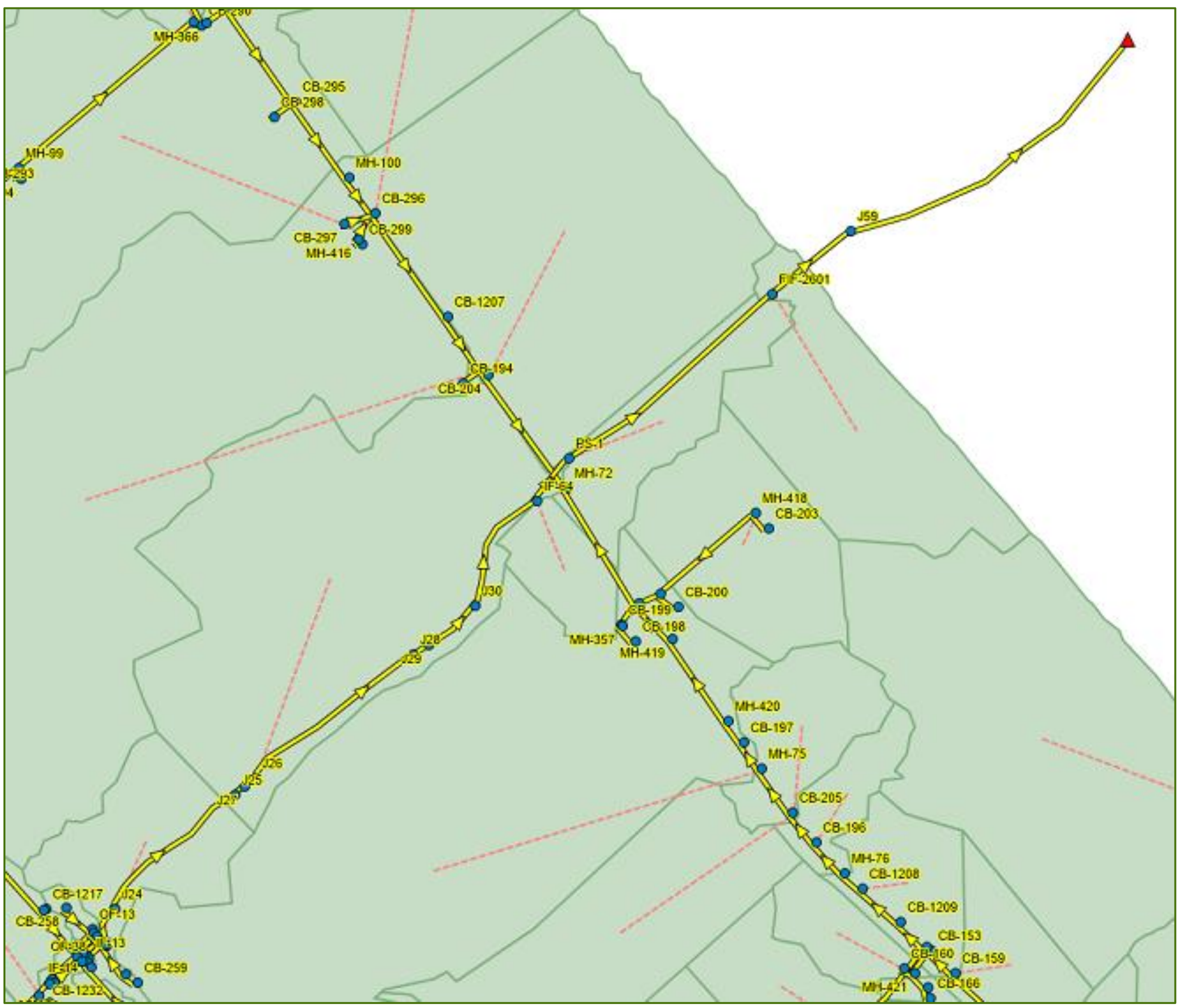
3.7.1 Upstream Inflow Hydrograph

The 100-year (1-percent annual chance) peak flow magnitudes are not listed in the FEMA FIS, although the 100-year peak flows at certain points along Pulgas Creek are listed in the City storm drain master plan (Table 2). These provide context for the inflow hydrograph selection.

Table 2: 100-year Peak Flows

Location (in downstream order)	100-year Peak Flow (cfs)
Pulgas Creek at Elm	678
Brittan Creek at Laurel St	149
Pulgas Creek at Hwy 101	698

To represent 100-year flow delivered from the watershed above Old County Road, node J24 in the hydrologic network from the storm drain master plan model (Figure 9) is used to reflect the combined sources upstream. The unsteady hydrograph of the existing (Base Condition) 24 hour 100-year event (Figure 10) provides the upstream inflow to the model. This hydrograph rises fairly steeply to a peak discharge of 911 cfs just after the six-hour mark of the storm, then decreases over the next couple of hours to remain elevated between 200 and 400 cfs for the duration.



Source: GHD 2018 SWMM model files

Figure 9: Storm Master Plan Hydrologic Network 100-year Base Conditions

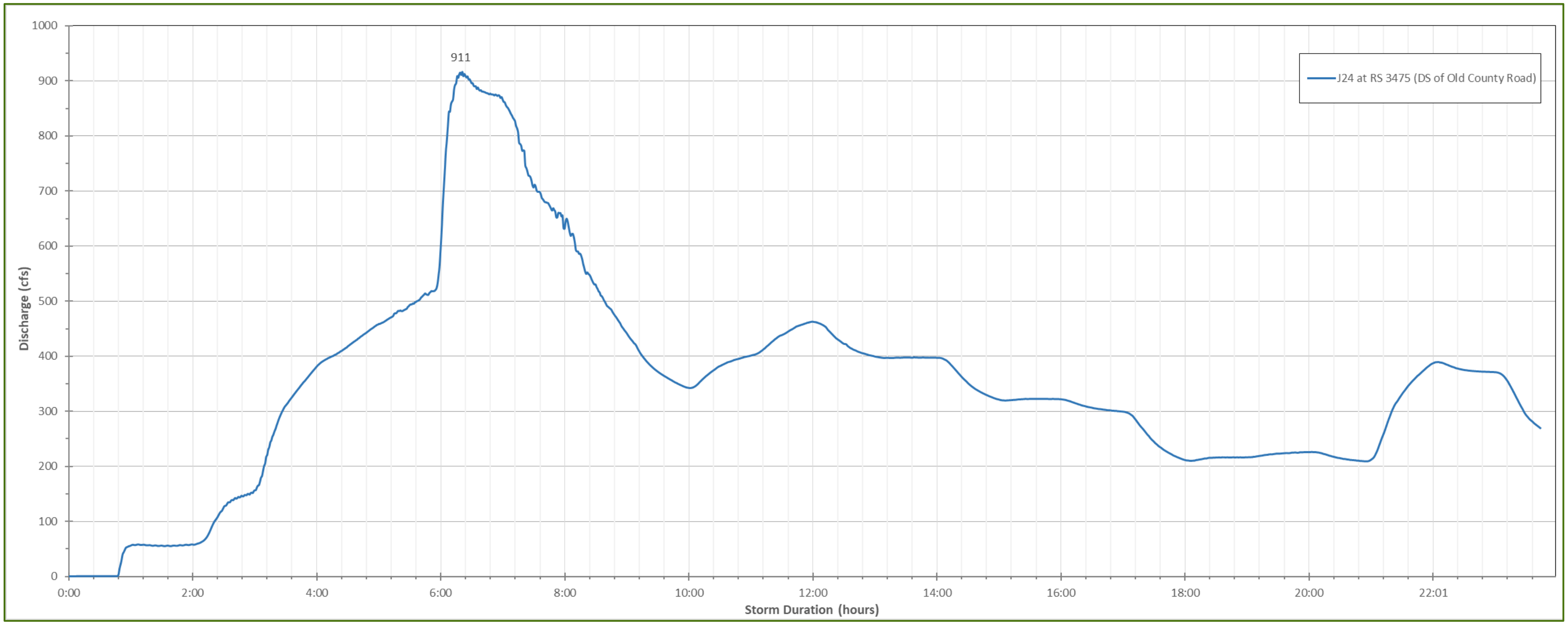


Figure 10: Upstream Input Hydrograph - 100-year Base Condition

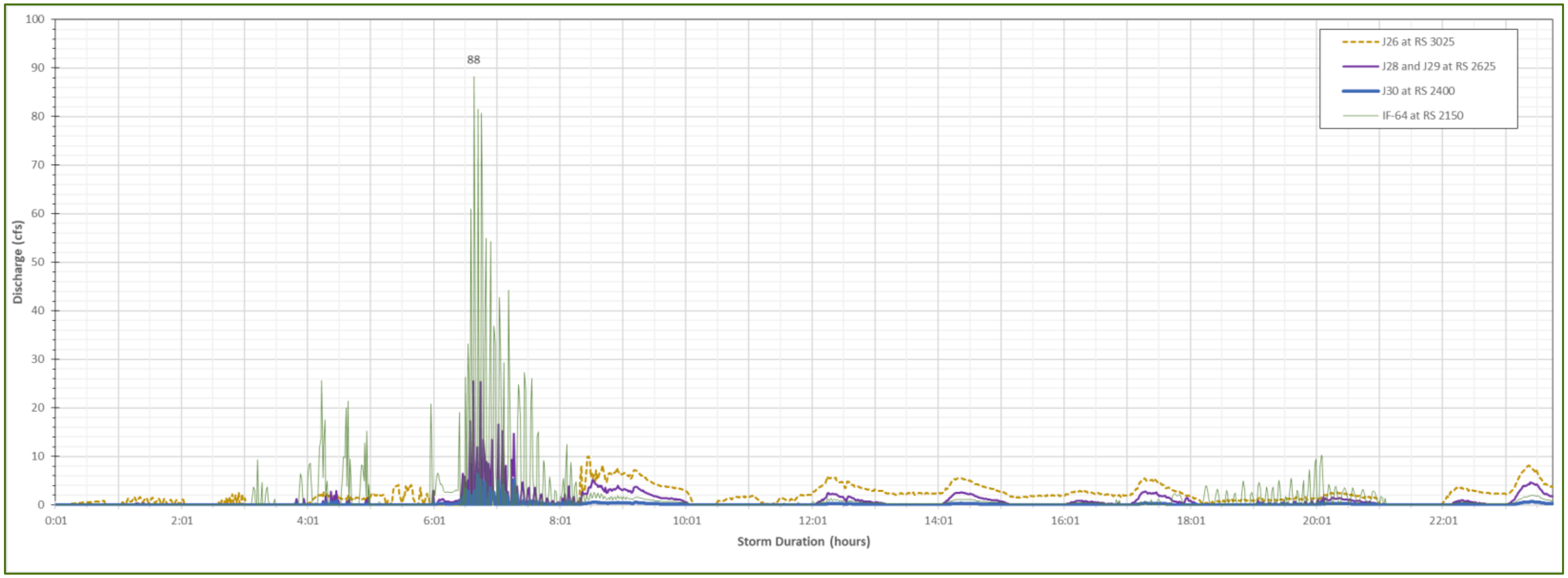


Figure 11: Project Reach Lateral Inflow Hydrographs - 100-year Base Condition

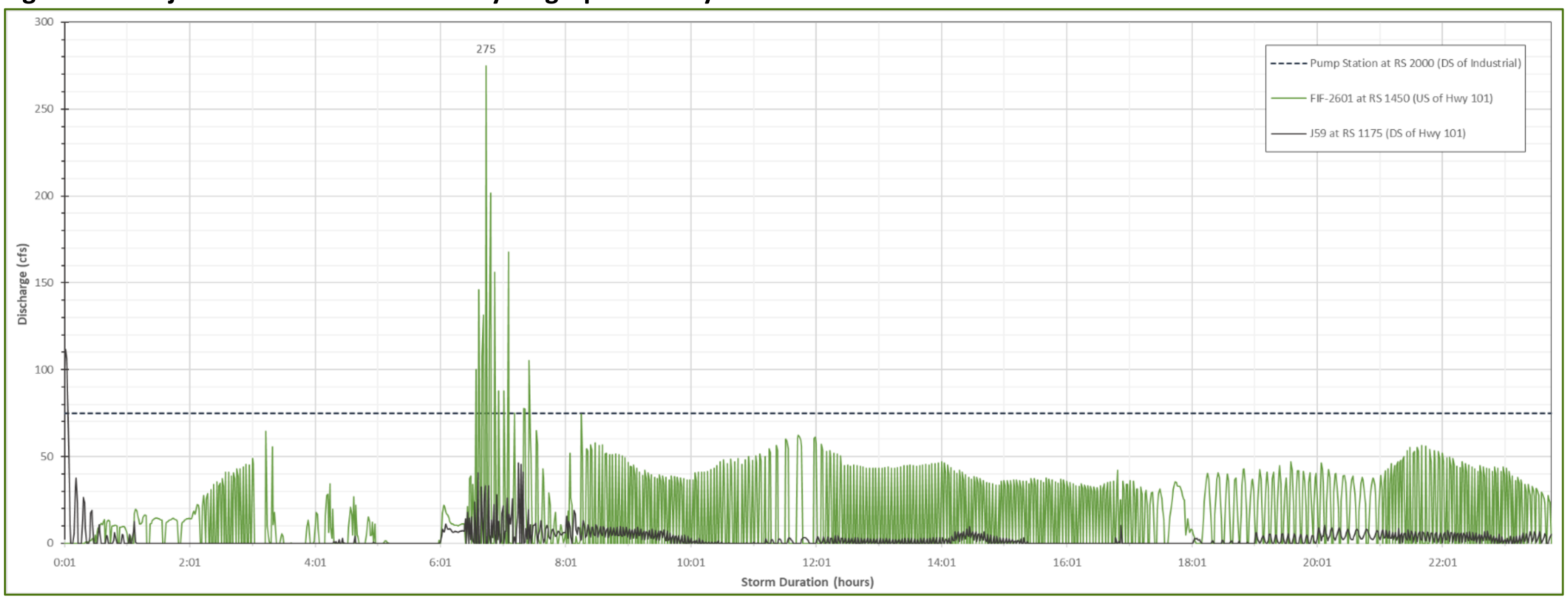


Figure 12: Downstream Lateral Inflow Hydrographs – 100-year Base Condition

3.7.2 Project Reach Inflows

There are several storm drain outfalls within the Project reach:

- There are four culverts on the downstream side of Old County Road
- The container crossings have 2 culverts each on the north and south banks
- The parking lot bridge has 2 culverts each on the north and south banks
- The upstream side of Industrial Road has 2 culverts

The existing input flows in the Project reach and downstream throughout the model extent are simulated consistent with the City's storm drain master plan model 100-year base condition (Figure 11 and Figure 12). The pump station along Pulgas Creek downstream of Industrial Road is assumed to be operating at capacity (~75 cfs total) during the 100-year event. Inflows with the Project reach are small, generally below 10 cfs throughout most of the storm. The largest local inflow reaches 88 cfs in the downstream half of the Project reach. The pump station discharge and other inputs downstream of Industrial Road are larger.

3.8 Land Cover and Roughness

The existing building layouts and tree survey in the topography drawing, along with visual inspection of recent aerial imagery inform the basic spatial pattern for roughness coefficients in the hydraulic model. According to the available survey data and site descriptions, the land cover of the entire site is concrete, asphalt or building surfaces, aside from the narrow creek corridor. Based on this information, the floodplain is represented with a Manning's roughness (n) value of 0.013 and the channel is assigned a composite value of 0.05 (Chow, 1959). These roughness values are appropriate for the land cover/surface types in the drawings and aerials and for the average channel conditions under high flows. They are within the roughness value ranges in the FIS (FEMA, 2012).

To provide a detailed existing versus Project comparison of floodplain capacity and water conveyance, the modeling surface represents the building footprints as 'solid' obstacles that do not provide floodwater storage.

3.9 Model Sensitivity

Key model parameters were evaluated through sensitivity testing to assess the direction and magnitude of their influence on model results. These steps help clarify how well the hydraulic model represents the physical system and give context for interpreting the results.

3.9.1 Hydrologic Inputs

One sensitivity test was to modify the streamflow entering the model domain from upstream. Using the same Storm Drain Master Plan model hydrology (GHD, 2018), the 10-year storm hydrograph was modeled showing similar but slightly smaller areas of flooding for the 10-year event output. Our model results show a slightly lower water surface profile in the channel as expected, since the 10-year event peak flow is roughly 20 percent lower than the 100-year event. The water surface profile along the channel is roughly the same from RS 2100 to RS 3050 due to flow overtopping the channel banks.

3.9.2 Lateral Model Boundaries

The sensitivity of the model to flow leaving the model domain laterally (i.e., to the north of Commercial St and south of Howard Ave) was evaluated using three scenarios. The boundary condition analysis method to approximate flow leaving the system was held constant in each case: normal depth at a fixed energy gradient. Three scenarios tested different energy gradients of 0.1%, 0.01% and 0.001%. Model results show that all three scenarios have the same water surface profile along the channel. This validates that the water surface along Pulgas Creek is not sensitive to the model boundary conditions along Commercial St and Howard Ave. However, slight changes in flood WSEL were simulated along the boundaries of the model domain (a difference of approximately 0.5 feet between each gradient scenario).

3.9.3 Downstream Boundary

The Storm Drain Master Plan model's unsteady tidal stage hydrograph (Figure 8) (GHD, 2018) provides an opportunity to assess model sensitivity to downstream boundary conditions. In contrast to the steady stage tidal hydrograph of 7.04 ft NAVD88 as our base assumption, the unsteady hydrograph increases the maximum water surface profile along the channel. This is expected since the streamflow peak occurs at the same time as high tide, six hours into the simulation. But the unsteady model reduces maximum inundation across the floodplain because the low tide periods allow the water to drain back into Pulgas Creek.

3.9.4 Roughness Estimates

The model's sensitivity to the Manning's roughness parameter was evaluated using two scenarios. One scenario increased the Manning's roughness values by 20 percent. The other scenario decreased the Manning's roughness values by 20 percent. Under both scenarios, the water surface is unchanged within the Project reach between RS 2150 and RS 3075 due to overtopping the channel banks. At the upstream end of the model domain the water surface elevation responds as expected to the roughness changes: increasing 0.3 feet with the higher roughness and a decrease of 0.3 feet with the lower roughness. The roughness scenarios also affect results 25 feet downstream of Industrial Road to a similar magnitude of 0.3 feet, but they converge at the downstream boundary. Although the water surfaces are relatively insensitive to roughness, the volume accumulation varies by plus or minus 10 acre-ft over the roughness sensitivity ranges. The variation in volume accumulation suggests that at this level of design and modeling, the best use of results is comparing trends and relative change between existing and proposed conditions, rather than specific magnitudes.

3.9.5 Time Step

The effect of changing model calculation time step modes on resulting water surface elevation and volume accumulation estimates was also tested. Two fixed-time step scenarios (1 second and 3 seconds) were run. The third scenario used an adaptive time step based on the Courant Condition (Brunner, 2016). All time step modes result in water surface elevations within 0.05 feet of each other. However, the volume accumulation is sensitive to the time step scenarios, with results varying by plus or minus 10 acre-ft. The variation in volume accumulation suggests that at this level of design and modeling, the best use of results is comparing trends and relative change between existing and proposed conditions, rather than specific magnitudes.

4.0 Hydraulic Analysis of Existing Conditions

Below is a summary of the model results for the 100-year existing conditions, emphasizing the maximum water surface elevation (WSEL). Because the model applies an unsteady flow hydrograph with flows ranging from 0 to 911 cfs over the 24-hour storm duration, the water surface in the model simulation changes depending on the simulation hour. The peak flow occurs roughly six hours into the simulation, and the maximum WSEL and inundation extent follow.

An animation of the model results (Appendix A) shows initial overbank inundation around hour 04:00, along the left (north) bank upstream of the onsite parking lot bridge (RS 2600-2700 area). The flow around hour 04:00 in the simulation is approximately 400 cfs. As the simulation continues from 04:00, the overbank inundation spreads from the initial breach location. Around hour 06:00, overbank inundation occurs at RS 3350 spilling on both side of Pulgas Creek. Off-site flooding south of Pulgas Creek occurs near RS 2550. As the simulation continues, the overbank flow primarily enters the Project site along RS 2600-2700 and exits the Project site along Commercial Street and Industrial Road. Overbank flow entering the off-site property south of Pulgas Creek primarily occurs along from RS 3350 and exits onto Brittan Avenue and Industrial Road.

4.1 Flood Water Surface Elevations and Depths

The existing 100-year flood extent covers much of the study area, excluding areas on the far western corner (of the site) and south western corner off-site (Figure 13). The maximum WSEL at the downstream end of the model domain (east) of Highway 101 is around 7.2 feet. The WSEL ranges from 8.8 to 10.0 feet between Highway 101 and Industrial Road. The WSEL at the upstream edge of Industrial Road is 11.6 feet. Upstream of Industrial Road, the WSEL increases to about 12.2 feet at the parking lot bridge connecting to the Project site. The WSEL increases at the upstream edge of the parking lot bridge to 12.5 feet. The WSEL increases to 12.8 feet downstream of the dual crossing. The WSEL on the upstream edge of the dual crossing is 14.1 feet. Maximum WSEL are generally similar on both sides of the creek as you move upstream from the bay, with slightly higher WSEL on the Project site.

The existing maximum water depths across the floodplains (outside of the channel) on both sides of the channel have similar ranges, with areas between 0.5 and 1.0 feet deep, some areas between 1.0 and 2.0 feet deep, and smaller deeper areas. Onsite, the maximum flooding depth around or just over 2.5 feet (Figure 14).

4.2 Pulgas Creek Flood Profile and Cross Sections

The existing conditions model WSEL profile illustrates the influence of existing structures within Pulgas Creek on the inundation pattern (Figure 15). The WSEL is around 7.04 feet downstream of Highway 101, and sloping up to about 8 feet at Highway 101. From Highway 101 to Industrial Road it rises to 10 feet. The upstream side of Industrial Road is around 11.5 feet, and WSEL steps up to 14 feet at RS 3180 due to constrictions.

To illustrate the water levels and channel capacity at the maximum 100-year flood condition, see representative cross sections from Figure 16 to Figure 19.

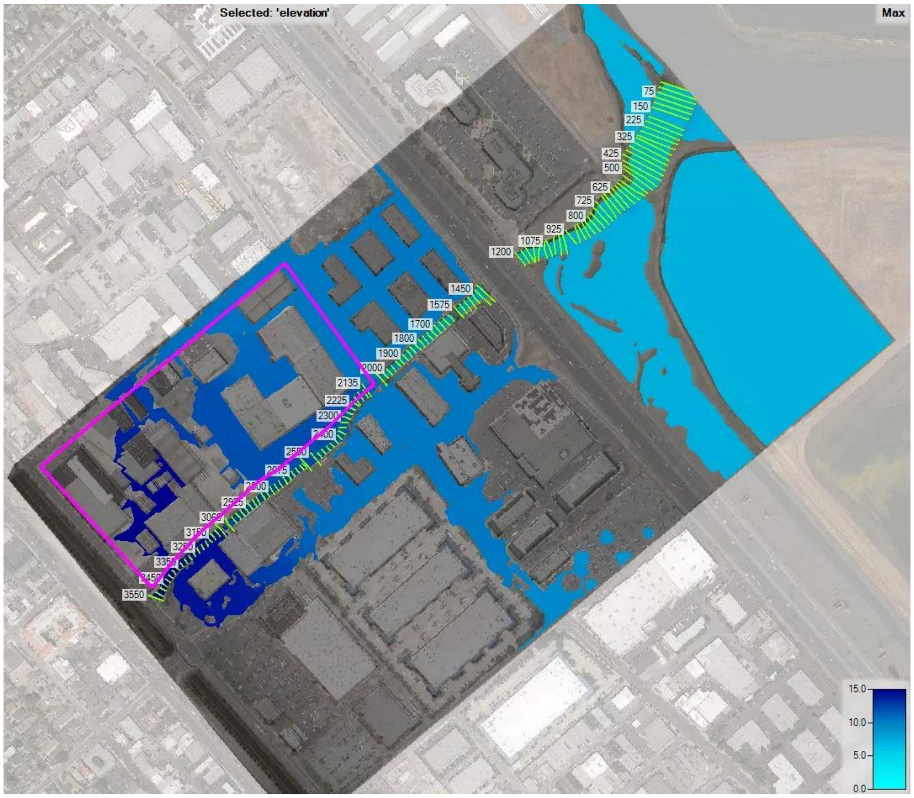


Figure 13: Project Site and Vicinity 100-year Flood Max Water Surface Elevations – Existing Conditions

Figure 14: Project Site and Vicinity 100-year Flood Maximum Depth – Existing Conditions

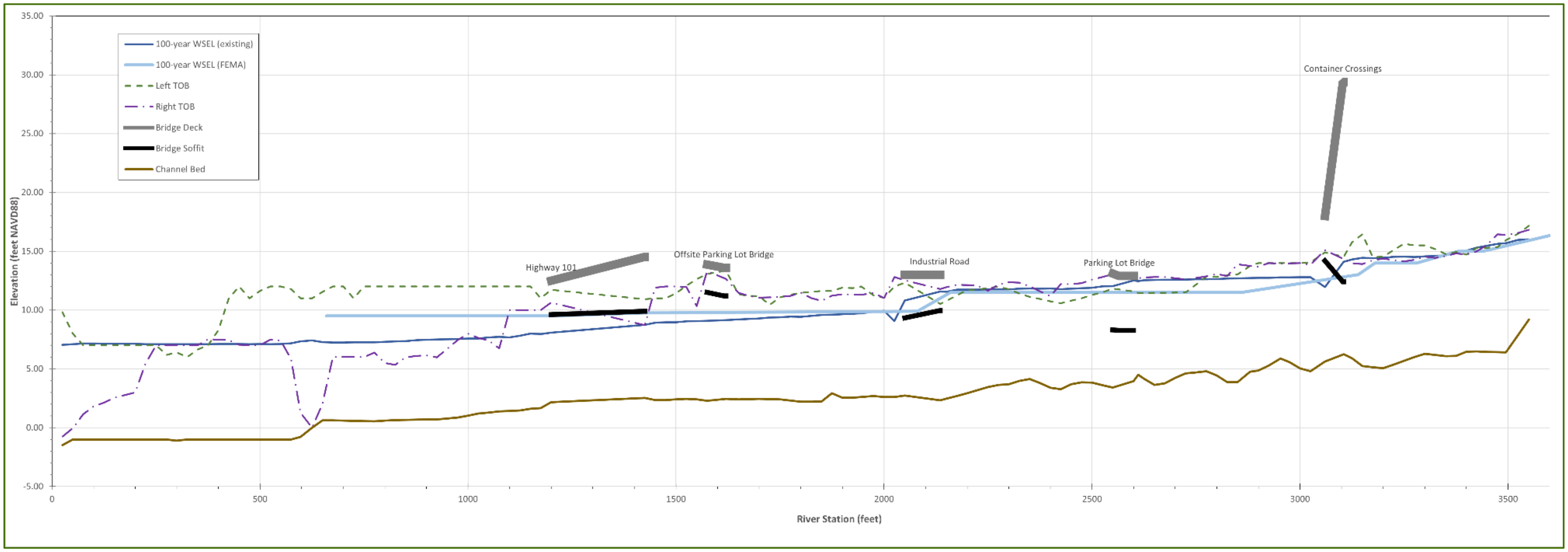


Figure 15: Pulgas Creek Channel and 100-year Flood Profiles – Existing Conditions and FEMA

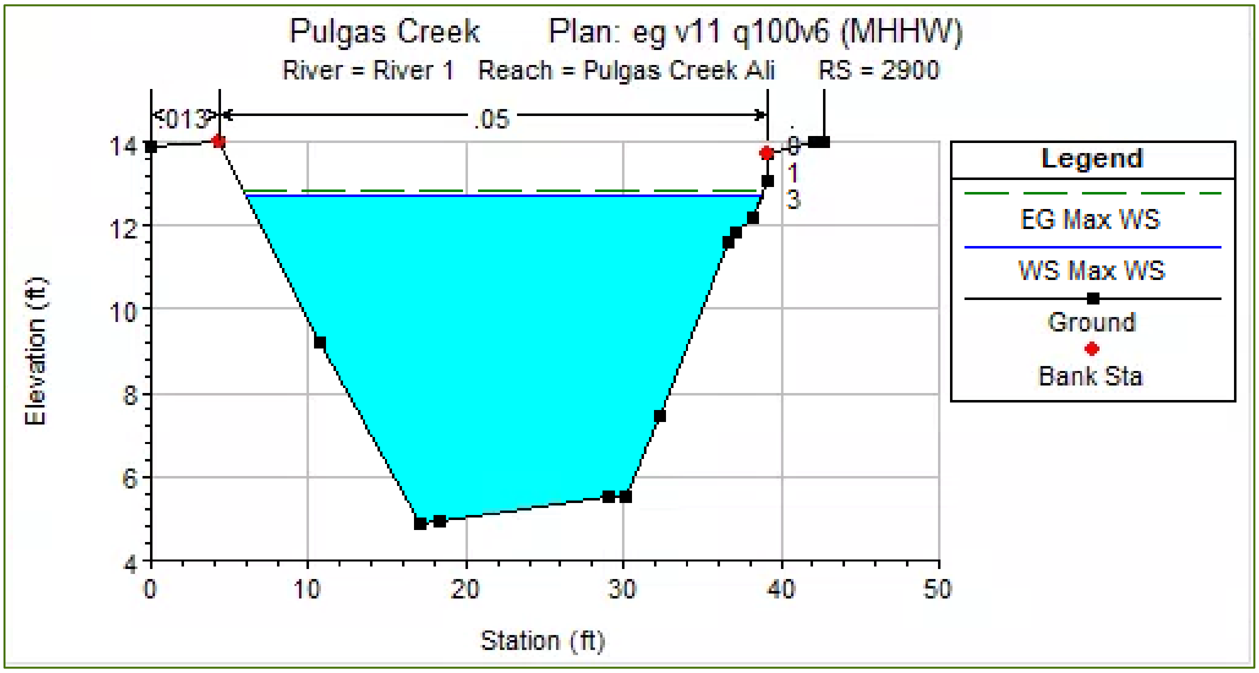


Figure 16: Pulgas 100-year Water Surface Elevation - Existing Conditions RS 2900

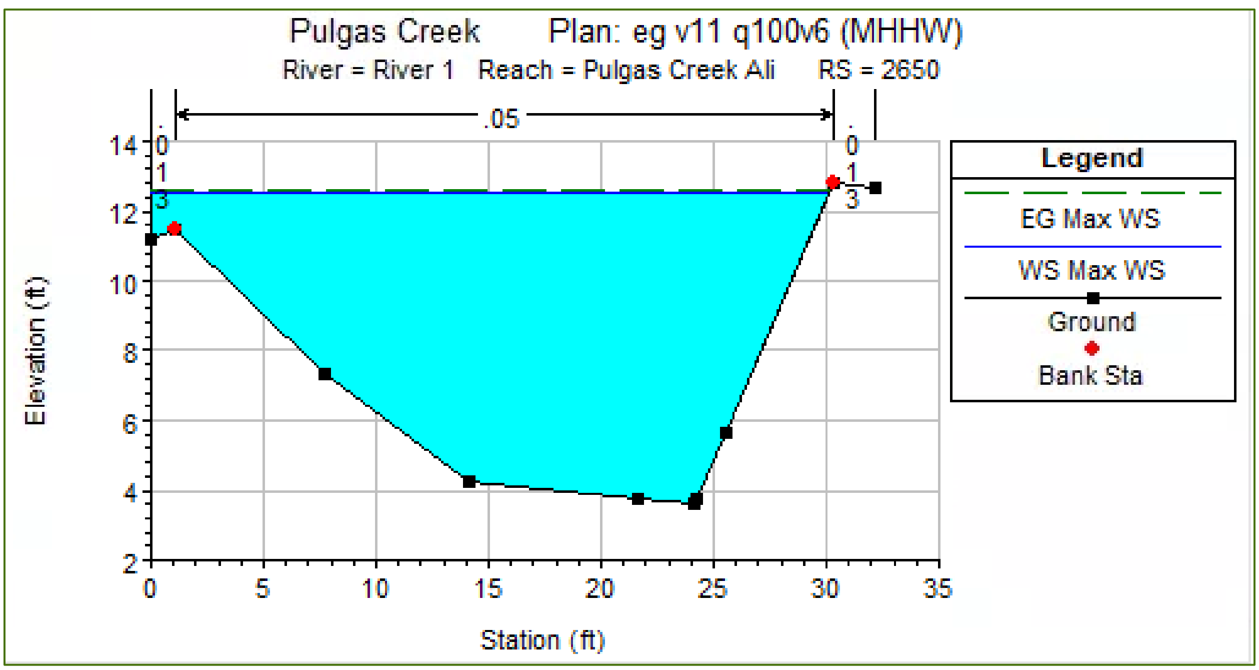


Figure 17: Pulgas 100-year Water Surface Elevation - Existing Conditions RS 2650

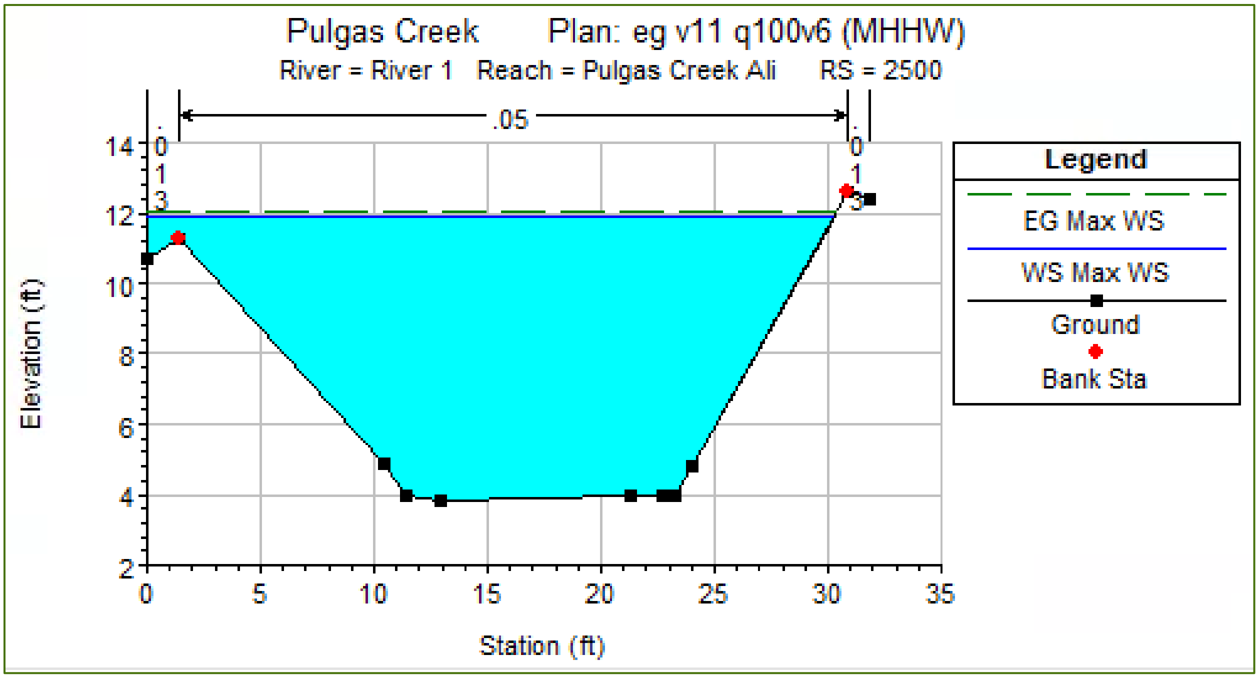


Figure 18: Pulgas 100-year Water Surface Elevation - Existing Conditions RS 2500

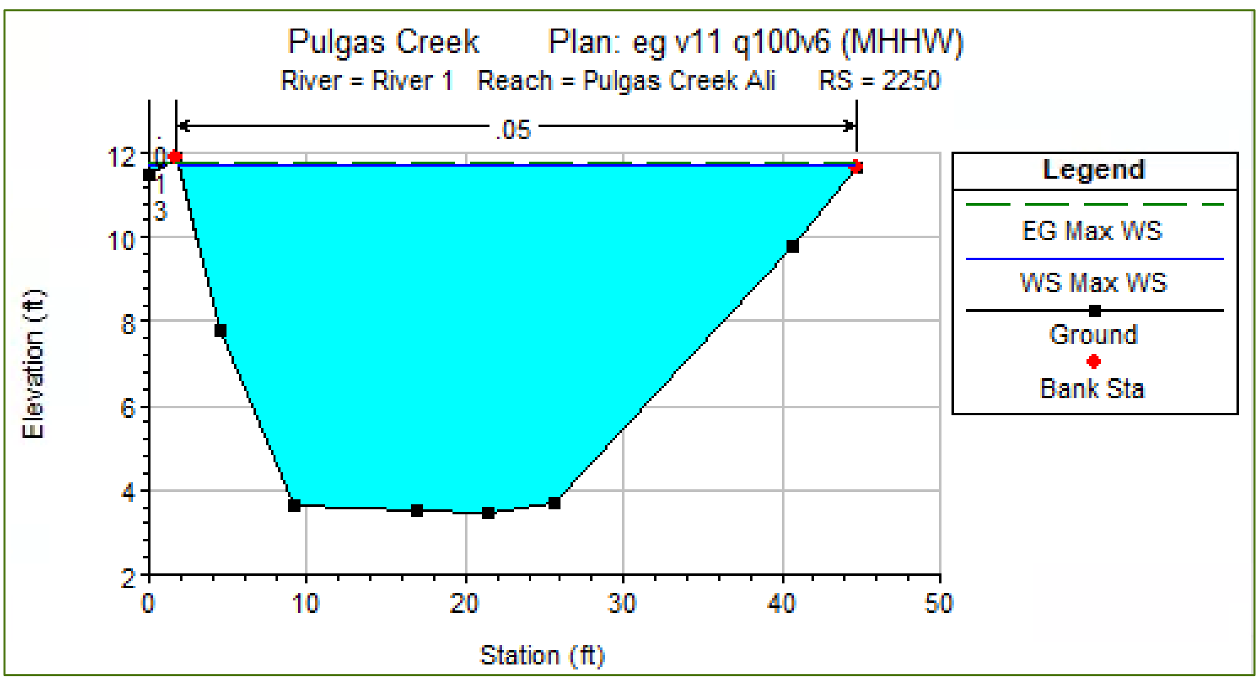


Figure 19: Pulgas 100-year Water Surface Elevation - Existing Conditions RS 2250

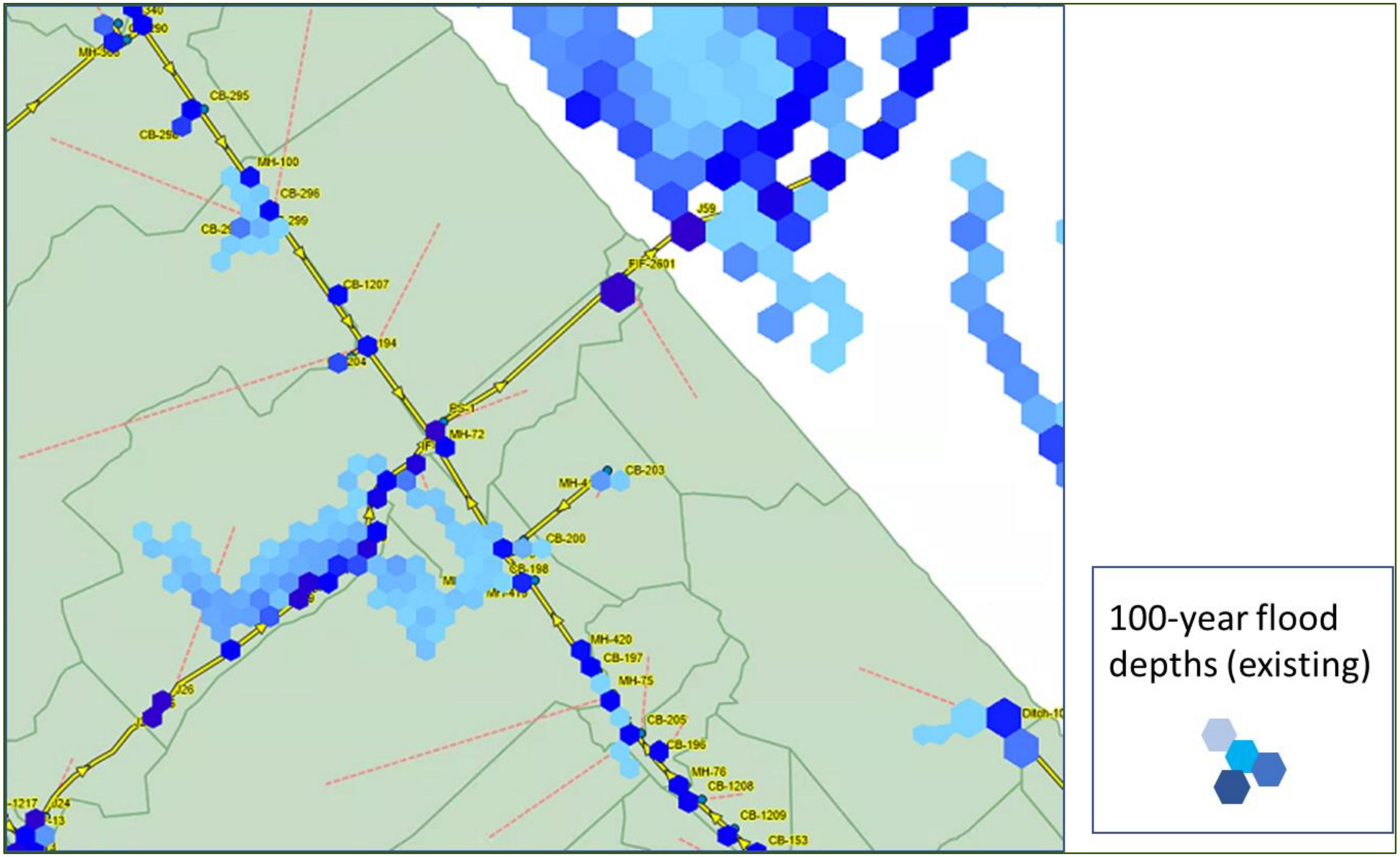
4.3 Discussion

A qualitative comparison of the existing condition modeling shows consistency with the FEMA Flood Insurance Study (FIS) (revised April 5, 2019) (FEMA, 2012) and effective Flood Insurance Rate Map (FIRM) (FEMA Flood Map Service Center, n.d.) and the storm drain master plan (GHD, 2018).

This modeling effort is not calibrated to physical observations or other models because it is only being used to evaluate any potential changes to flooding as a result of the Project improvements relative to the existing conditions rather than process a map revision. This model is compared to the FEMA flood inundation boundaries (Figure 20) and water surface profile (Figure 2) for qualitative validation. The extent is similar, with minor differences related to the high-resolution detail of our 2D representation of existing building obstacles on the floodplain. The profile is similar along most of Pulgas Creek (Figure 29). The exception is from RS 2550 to RS 3000 where the model predicts WSEL approximately 1 foot higher than the FEMA profile. There are various reasons why the model results would differ. The existing conditions model has a detailed representation of the channel and bridges based on survey and includes the parking lot bridge. Additionally, the existing conditions model includes buildings as obstructions to 2D flow. These are key differences between the existing conditions model and the FEMA model hydraulic representations.

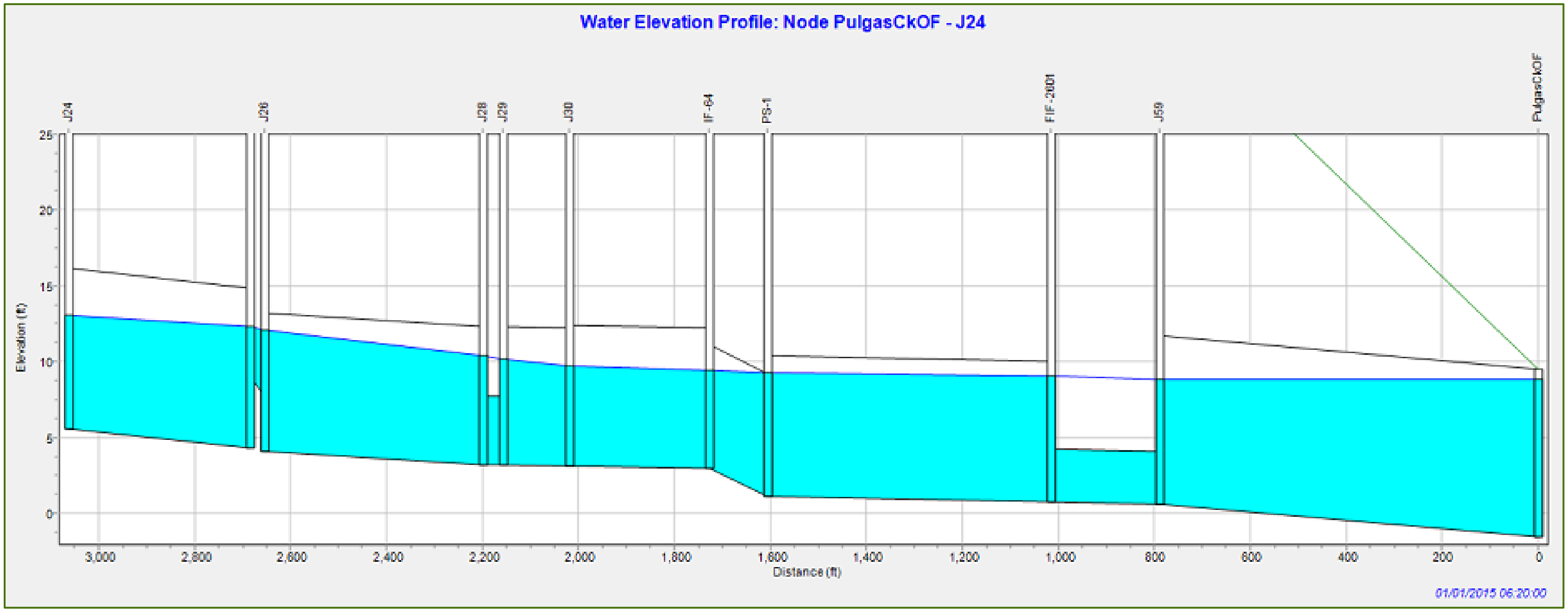
Comparison to the storm drain master plan (Figure 21 and Figure 22) indicates that the general extents of flooding are similar, although the existing conditions model has more extensive inundation. A consistency is that our sensitivity with the 10-year event produced similar relative inundation extent as found in the GHD (2018) modeling. Results of existing HEC-RAS modeling have been generated using significantly more detailed input parameters for our smaller study area and focused channel reach. In contrast, the master plan storm drain modeling addresses a much larger spatial area, at lower detail and with simplifying assumptions for the open channel and crossings, and used a lower Manning's n of 0.03 (instead of 0.05) for the Pulgas Creek bed.

Figure 20: Project Site and Vicinity 100-year Flood Areas - Existing Conditions and FEMA



Source: GHD 2018 SWMM model files

Figure 21: Lower Pulgas Creek Storm Drain Master Plan 100-year Flooding



Source: GHD 2018 SWMM model files

Figure 22: Lower Pulgas Creek Storm Drain Master Plan 100-year Profile

5.0 Hydraulic Analysis of Project Conditions

5.1 Project Conditions Model Set-Up

5.1.1 Conditions held constant

The Project condition model uses a very similar set up as the existing condition. The model domain 'study area' is identical. The off-site topography and off-site site buildings remain unchanged (Figure 23 and Figure 24). All the channel crossings (bridges) remain the same. The upstream, lateral, and downstream boundary conditions remain the same. All inflows are the same. Stormwater inflows estimated from the Project site are not substantially different from the existing 100-year stormwater inflows and very small relative to the 911 cfs peak flow from upstream. Lastly, the Manning's roughness coefficients are held constant.

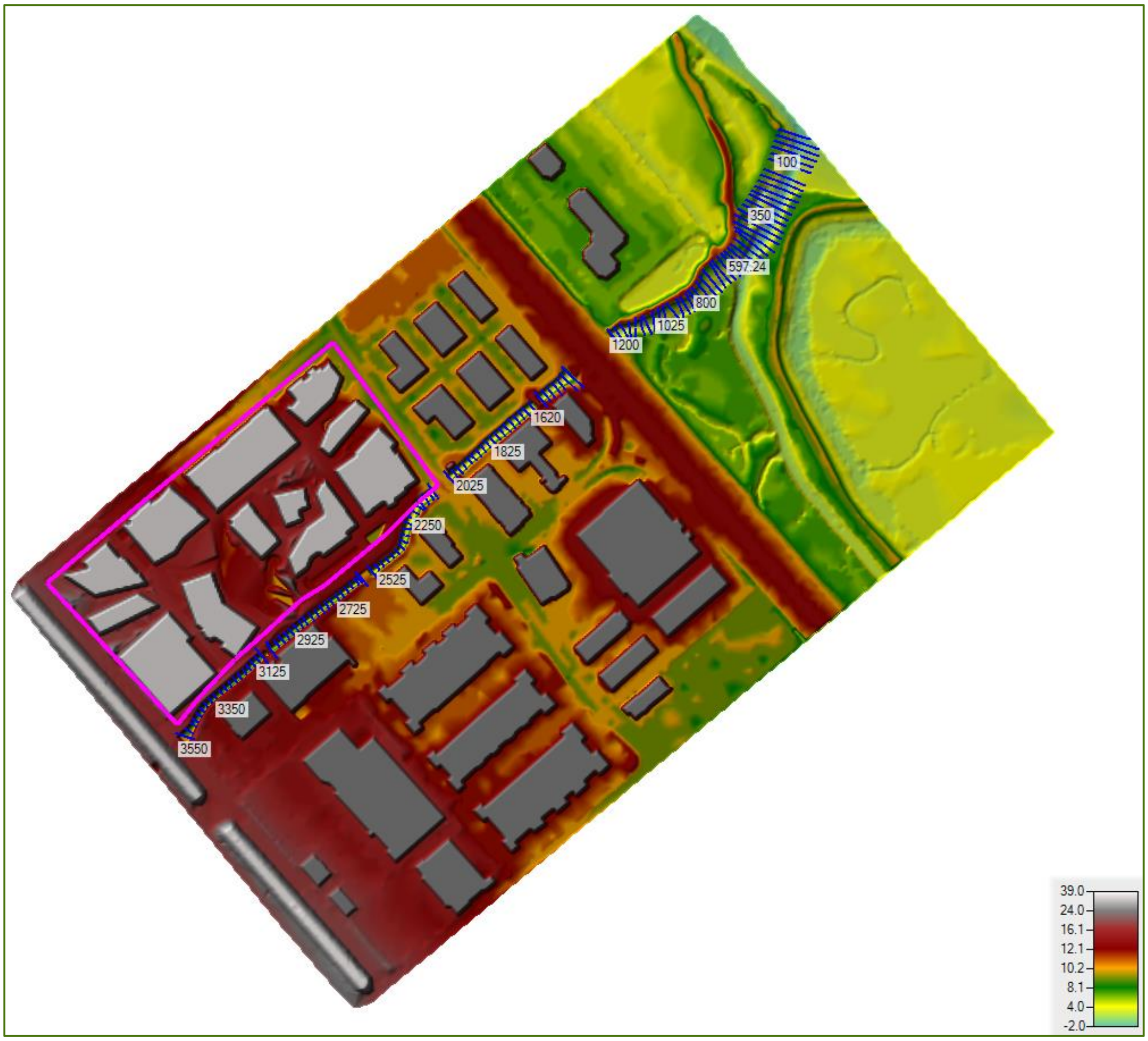


Figure 23: Topography and Channel Cross Sections – with Project

5.1.2 Project Terrain

The primary difference between existing and Project conditions in the modeling is the topography and buildings (together comprising the terrain). The Project ground surface is roughly 1 to 3 feet higher than existing ground across the site. There is a proposed road or path along the north bank of Pulgas Creek that is roughly 3 feet higher than the existing conditions upstream of RS 2975. The Project terrain also includes landscape mounds that range in height from 8 to 14 feet relative to finished grade. The proposed buildings are modeled in the same manner used as existing buildings. The Project buildings layout and dimensions of the building footprints were provided and confirmed by F&L. A standard elevation of 24 feet was applied to the proposed buildings to ensure a full flow blockage, consistent with the existing conditions simulation.

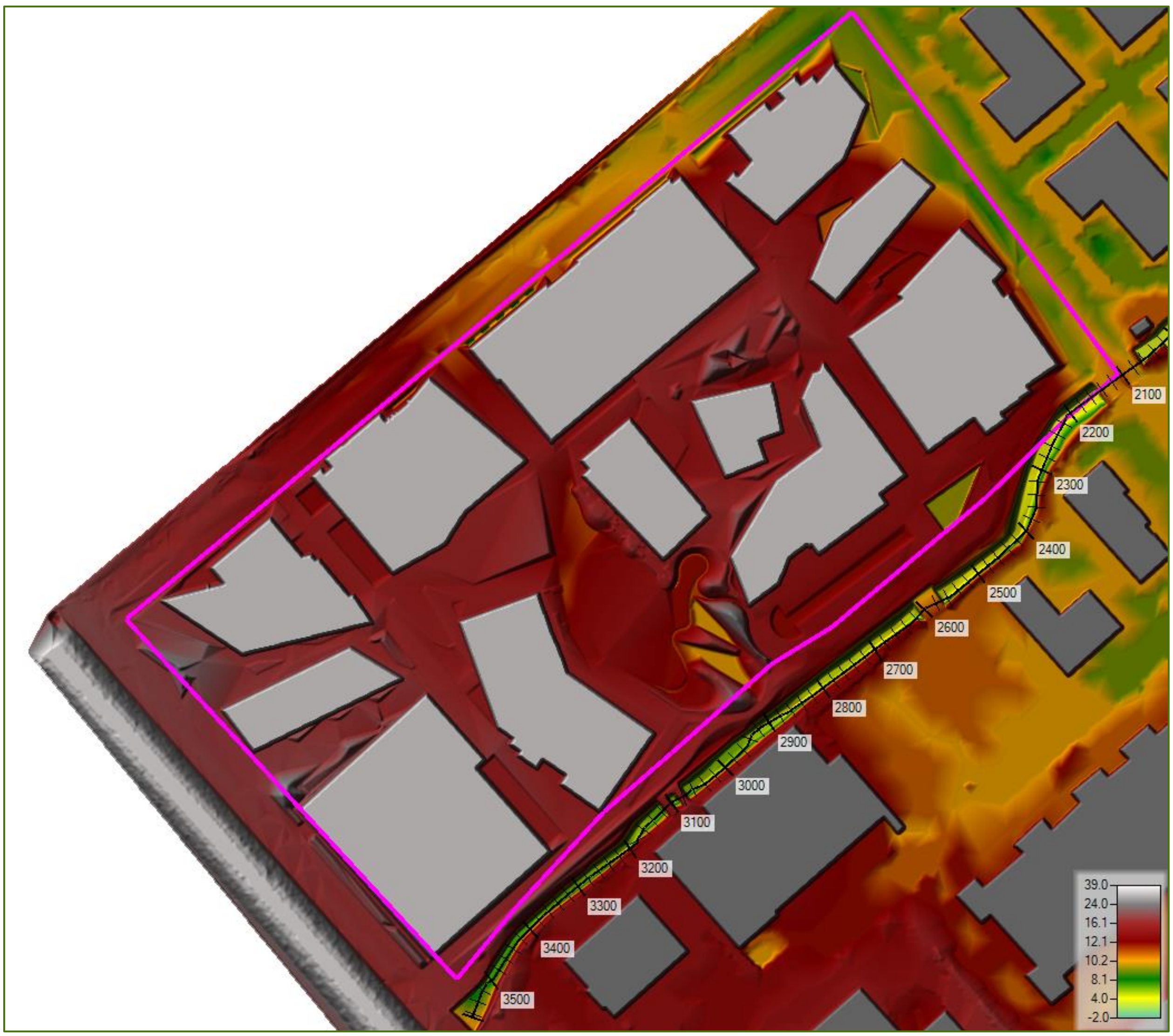


Figure 24: Hydraulic Surface and-Project Terrain – With Project

5.2 Project Results and Comparison

An animation of the model results for the Project condition (Appendix A) shows initial overbank inundation around hour 05:00, along the north bank near Industrial Avenue. The flow around hour 05:00 in the simulation is approximately 450 cfs. As the simulation continues, overbanking begins about 06:00 along the south bank at multiple locations, as well as in a small portion of the project site by the Parking Lot bridge. The flows cross Industrial to the south about 06:10, and flows north along Industrial towards Commercial Street.

5.2.1 Comparison of Flood Water Surface Elevations and Depths

Under the Project condition, the 100-year flooding is nearly eliminated from the Project site, aside from marginal areas along the northeast corner, Industrial Road and Pulgas Creek itself. However, the flood extent off site, south of Pulgas Creek, is larger and more continuous within the flood boundary.

The maximum Project WSEL for inundation areas south of Pulgas Creek and upstream of Industrial Road is generally around 11 feet but increases to over 14 feet near Old County Road (Figure 25). Downstream between Industrial Road and Highway 101 has maximum Project WSELs around 10 feet on the north floodplain and around 11 feet on the south floodplain.

The maximum water depths across the floodplains (outside of the channel) under the Project condition differs on each side of the channel. The Project site has minor fringe areas with shallow water only. The off-site (south) inundation areas would experience increase in the maximum depth of 0.1 to 0.5 feet (Figure 26).

An overlay of the existing and Project condition flood extents and WSELs using shades of blue and yellow, respectively, facilitates comparison (Figure 27 and Figure 28). Areas that display using only blue tones have existing 100-year flooding that is reduced or eliminated under Project conditions. The fringe areas that are yellow or orange tones are areas that have expansion of the 100-year flood extent. Areas of greenish or darkened tints indicate areas that have 100-year flooding under both scenarios, but the WSEL is higher with the Project.

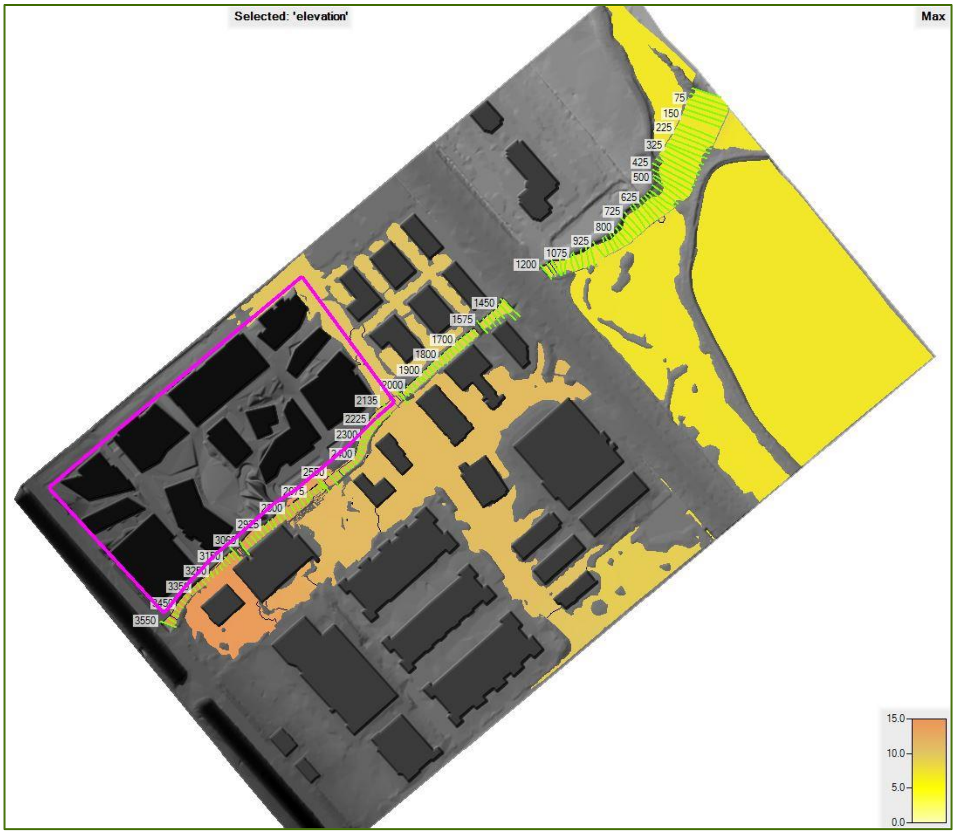


Figure 25: Project Site and Vicinity 100-year Flood Maximum Water Surface Elevations – With Project

Figure 26: Project Site and Vicinity 100-year Flood Maximum Depth – With Project

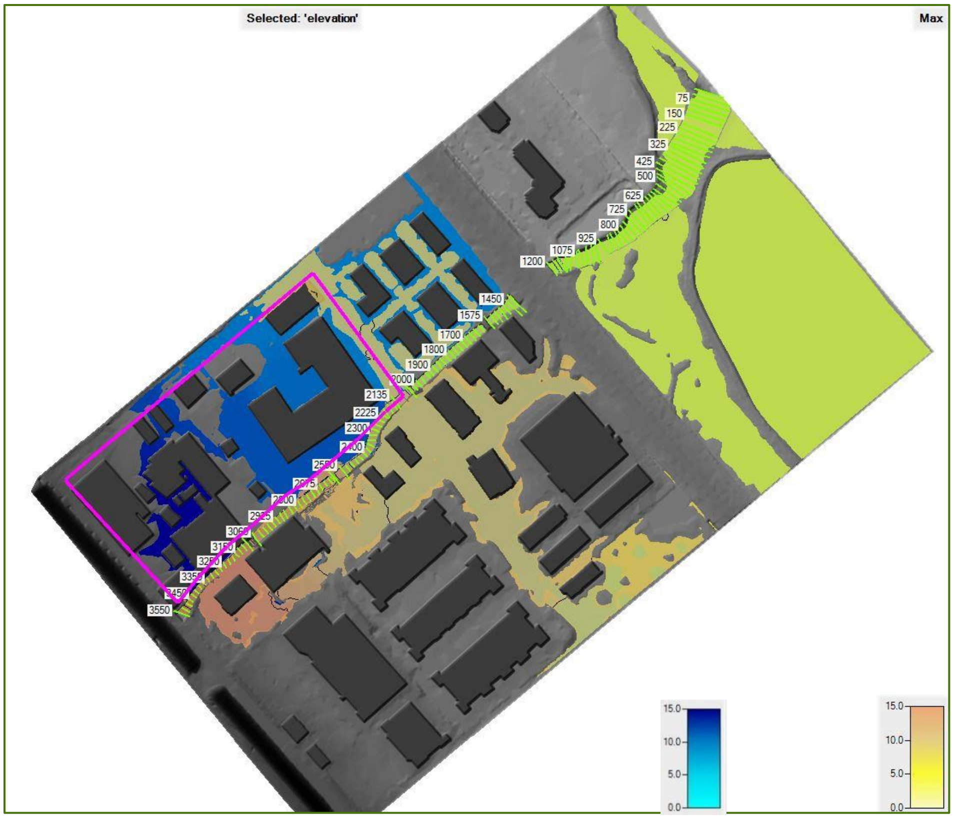


Figure 27: Overlay of Existing and With Project 100-year Flood Extents and Water Surface Elevations

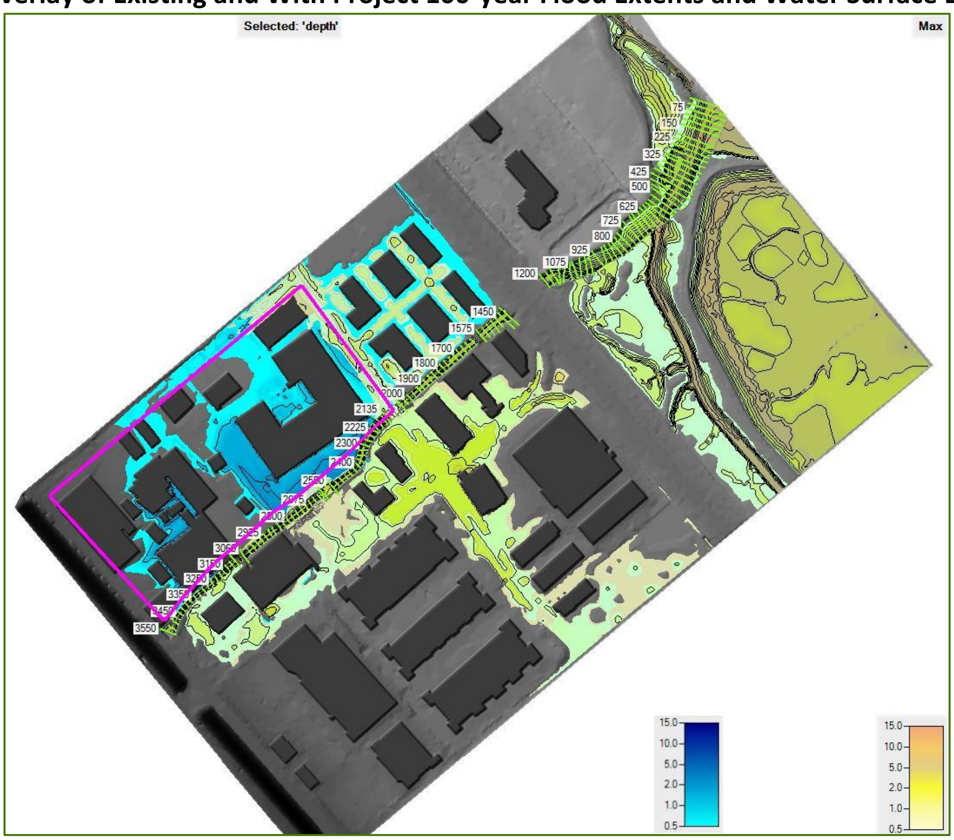


Figure 28: Overlay of Existing and With Project 100-year Flood Extents and Depth

5.2.2 Comparison of Pulgas Creek Flood Profiles

The profile graph (Figure 29) also indicates how the WSELs compare between existing and Project conditions. The Project WSEL ranges from 9 to 9.5 feet between Highway 101 and the downstream side of Industrial Road (RS 1825), similar to the existing condition. The Project WSEL at the upstream edge of Industrial Road is 11.6 feet (RS 2150), also the same as for existing conditions. Upstream of Industrial Road, the WSEL increases to about 12.15 feet at the parking lot bridge connecting to the Project site (RS 2550), same as existing condition. The Project WSEL increases 0.75 feet higher than existing conditions at the upstream edge of the parking lot bridge (RS 2625) to 13.25 feet. The Project WSEL of 13.8 feet downstream of the dual crossing is 1.8 feet higher than existing condition. On the upstream edge of the dual crossing (RS 3100) the existing and Project WSELs are both 14.1 feet (Figure 29).

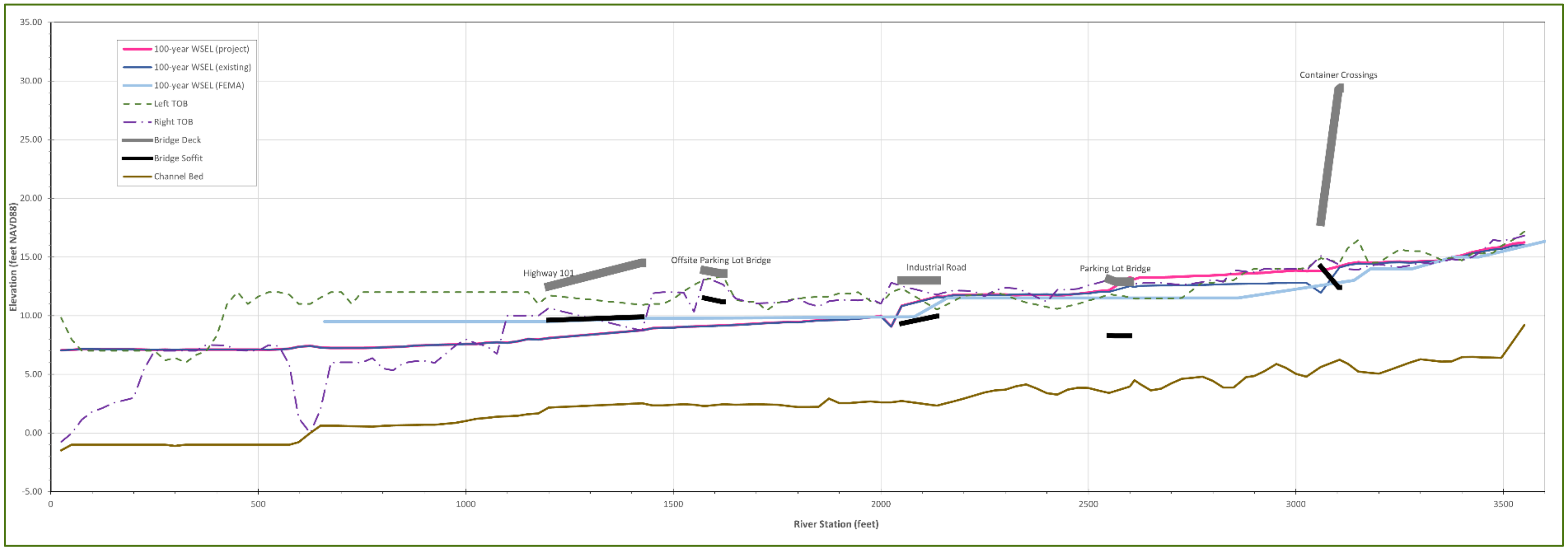


Figure 29: Pulgas Creek Channel and 100-year Flood Profiles – Existing Conditions and With Project

5.2.3 Comparison of Pulgas Creek Cross Sections

The maximum WSEL for both the existing (eg) and Project (fg) model simulations at representative cross sections (Figure 30 to Figure 33) indicate how the relationship of the water to the top of bank elevation, and the resulting potential overbank flooding, varies within the Project reach.

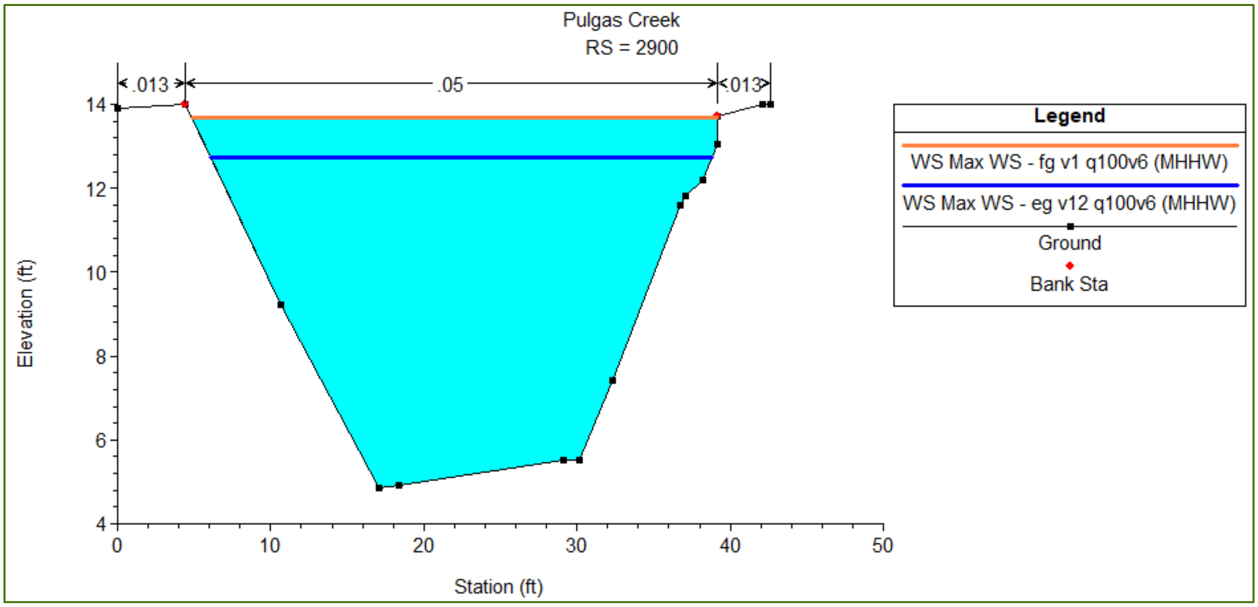


Figure 30: Pulgas 100-year Water Surface Elevation – Existing Conditions and With Project RS 2900

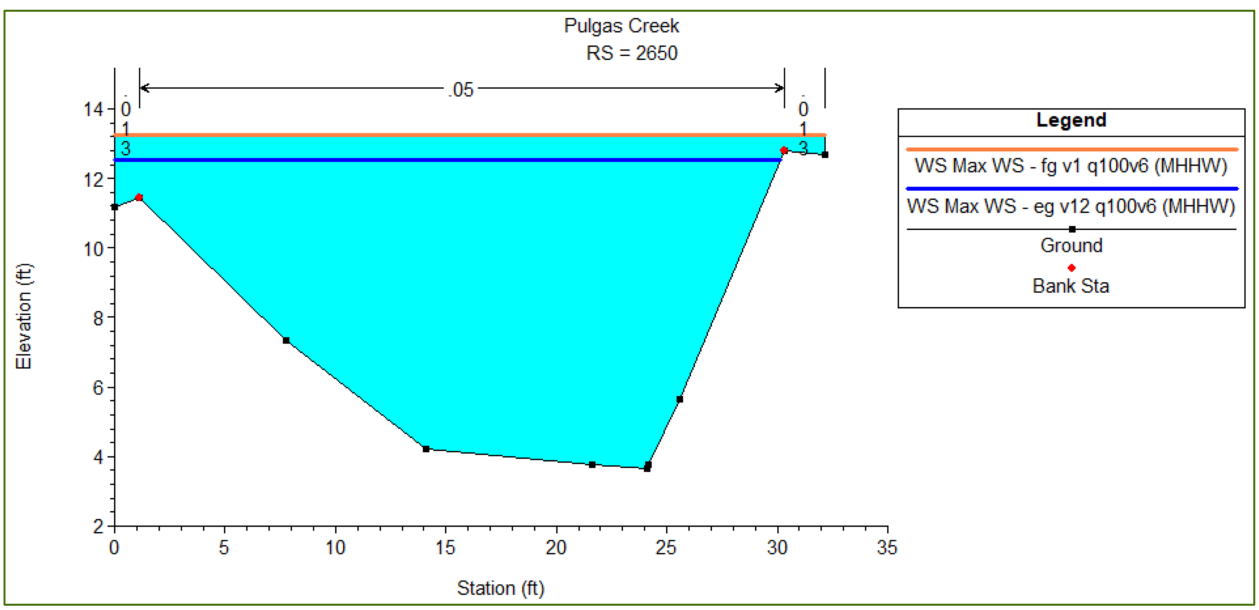


Figure 31: Pulgas 100-year Water Surface Elevation – Existing Conditions and With Project RS 2650

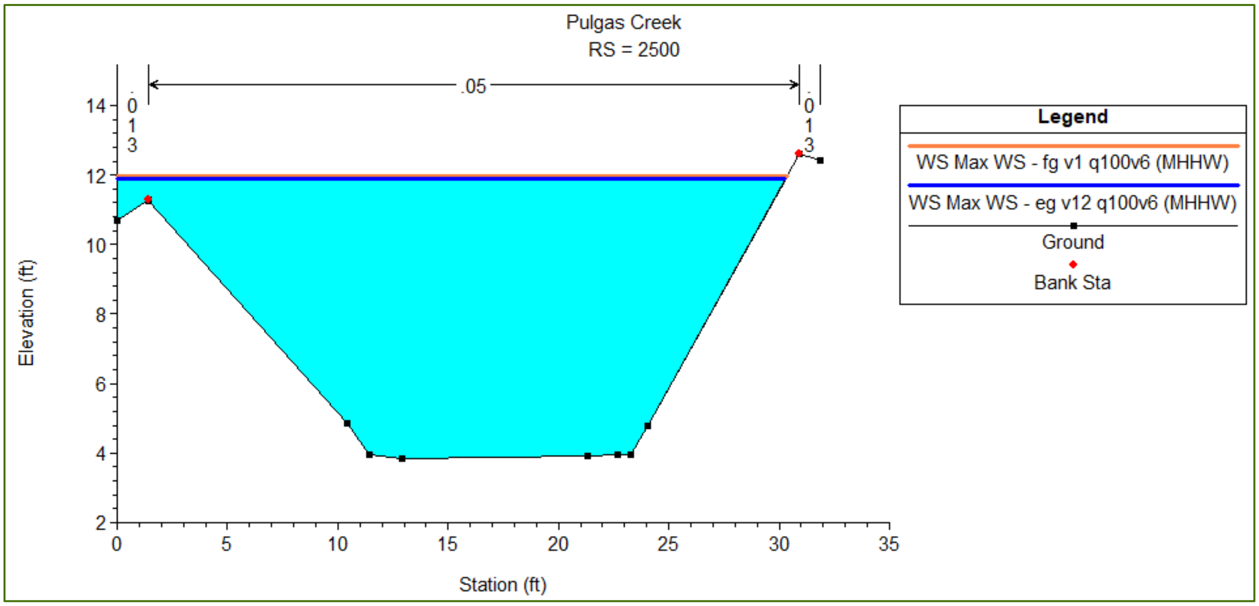


Figure 32: Pulgas 100-year Water Surface Elevation – Existing Conditions and with Project RS 2500

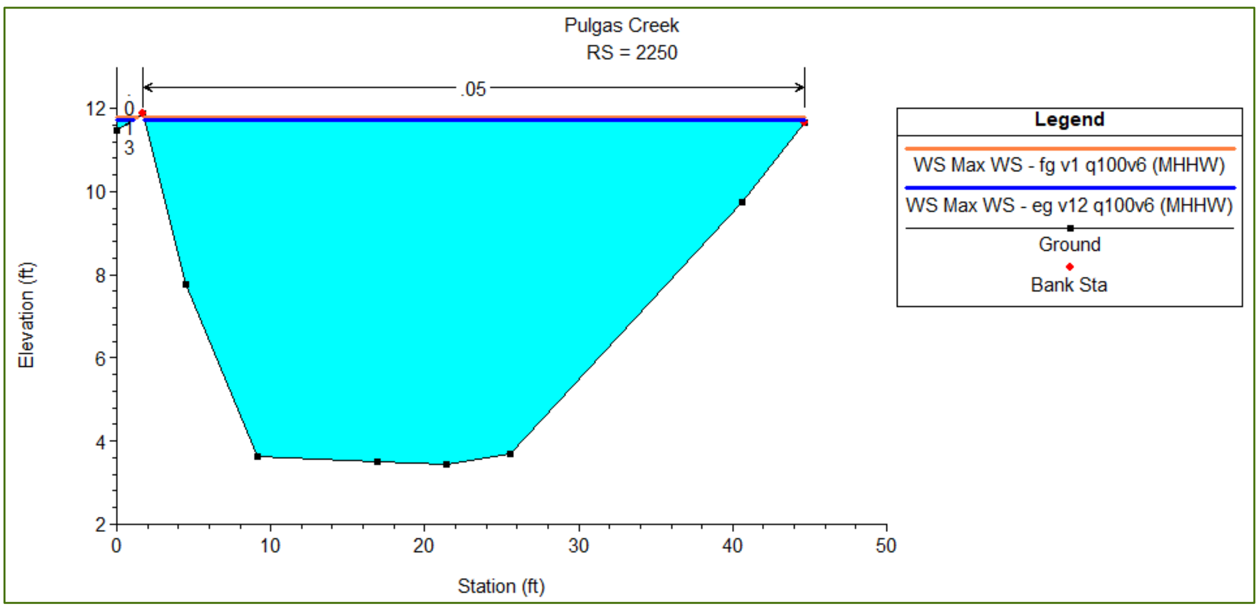


Figure 33: Pulgas 100-year Water Surface Elevation – Existing Conditions and with Project RS 2250

5.2.4 Study Area Cross Section WSEL and Flow Patterns

Comparison of the 100-year flood conditions under existing and with Project conditions across the study area is also shown using representative cross sections through RS 2750, 2825 and 3400 (Figure 34 through Figure 36). In all cross sections, the changes in finished grade associated with the Project conditions reduce the 100-year flood WSEL on site and raise the 100-year flood WSEL off site.

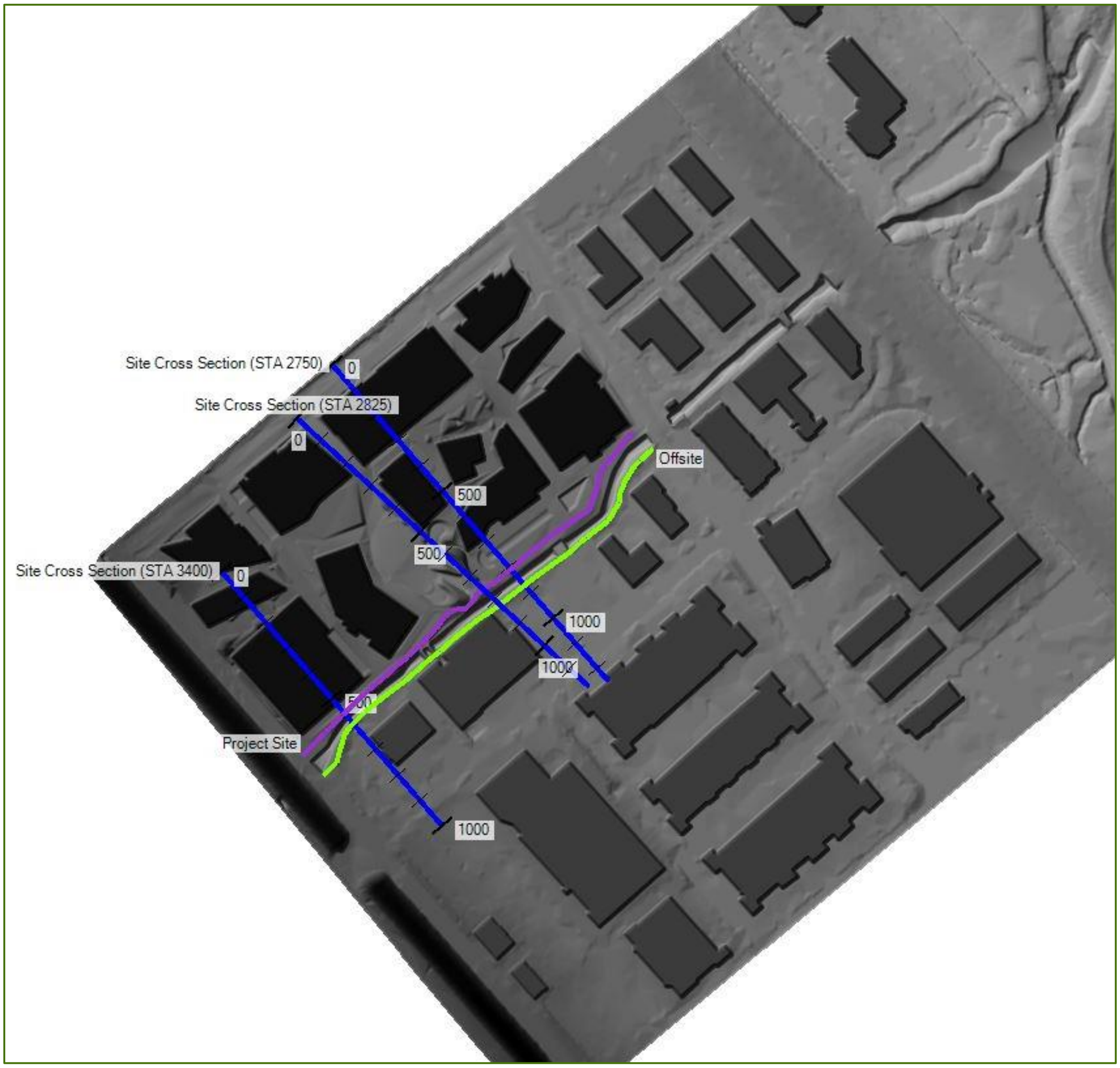


Figure 34: Representative Cross Sections and Project and Off-Site Alignments

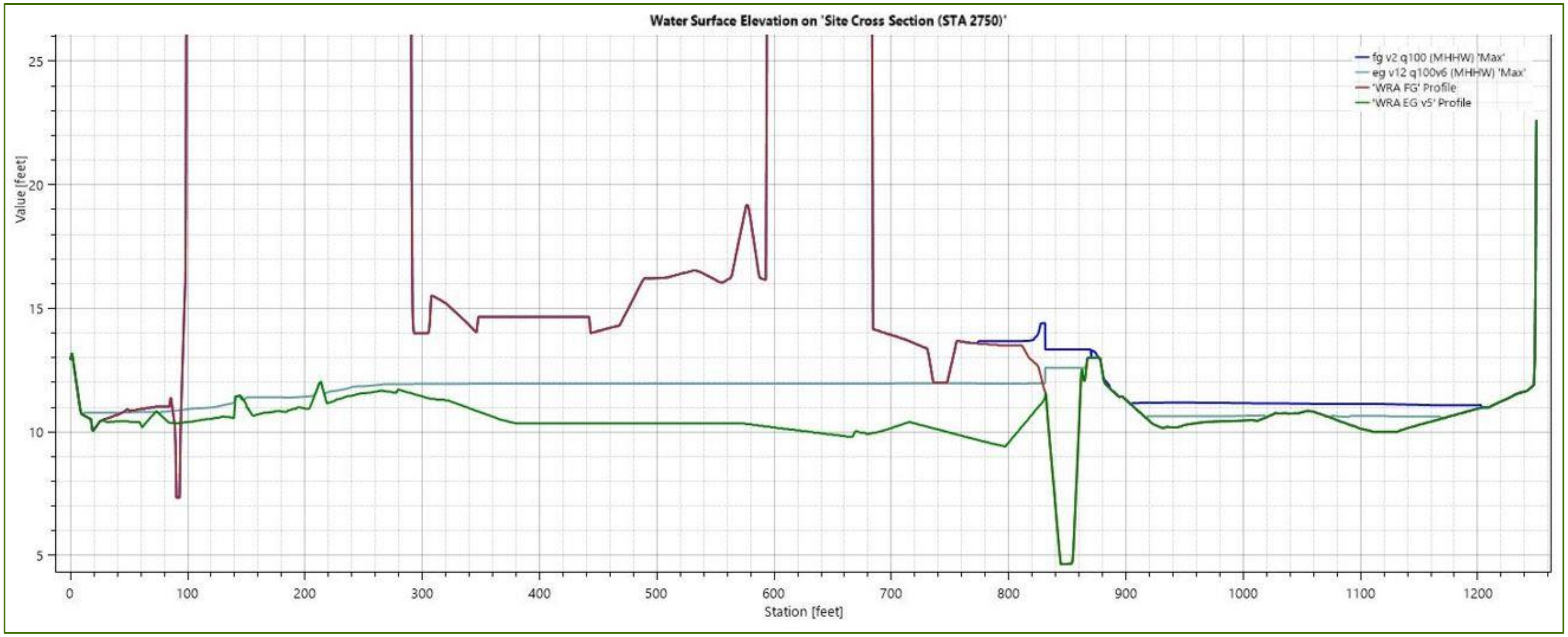


Figure 35: Topography and WSEL along Cross Section at RS 2750 under Existing Conditions and With Project

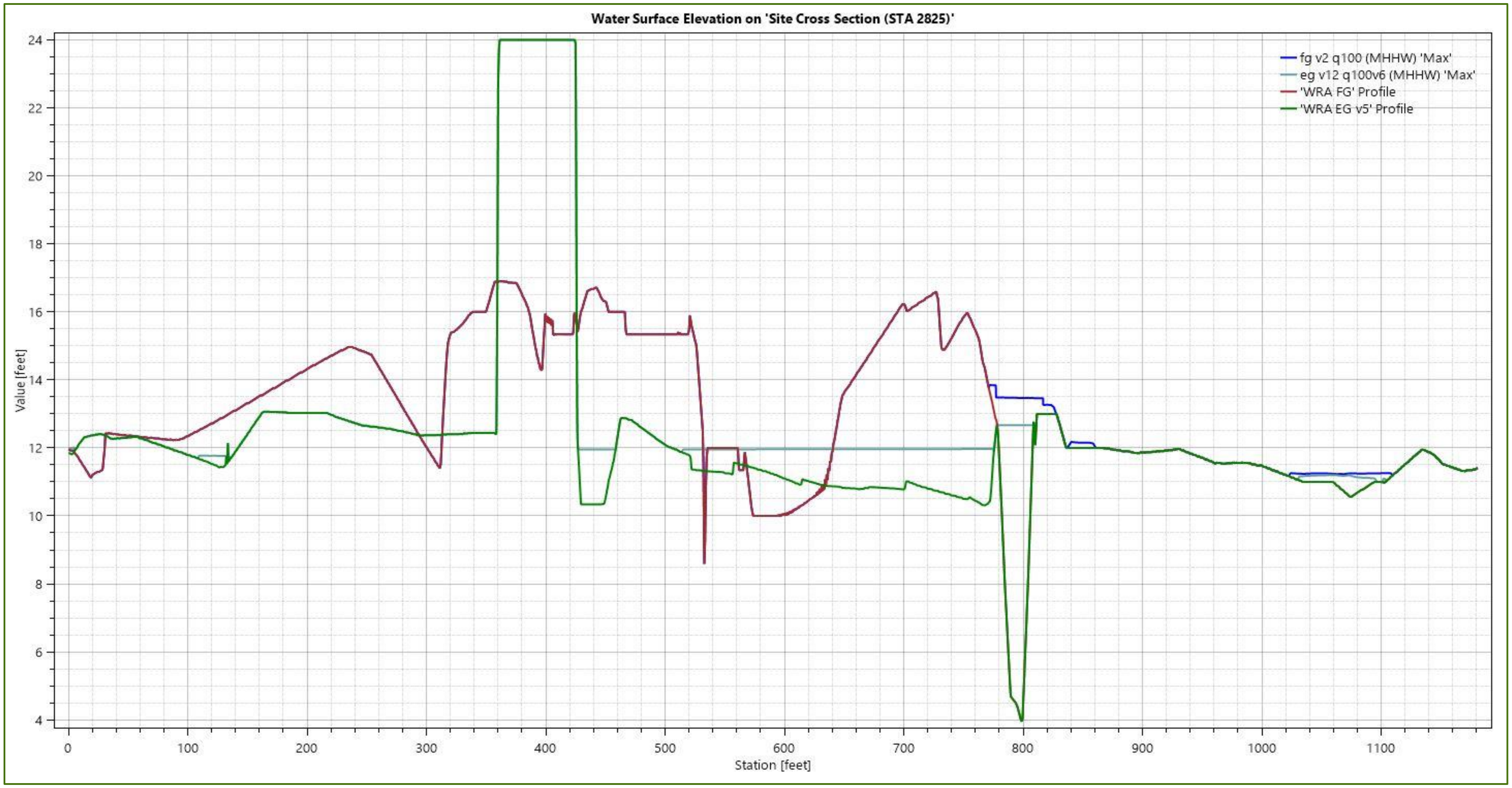


Figure 36: Topography and WSEL along Cross Section at RS 2825 under Existing Conditions and With Project

Figure 37: Topography and WSEL along Cross Section at RS 3400 under Existing Conditions and With Project

The flow patterns at similar points in the simulation (Figure 38 and Figure 39) illustrate how the existing pathways of flow relate to the proposed building layout versus how flow paths off site would be expected under the Project condition.

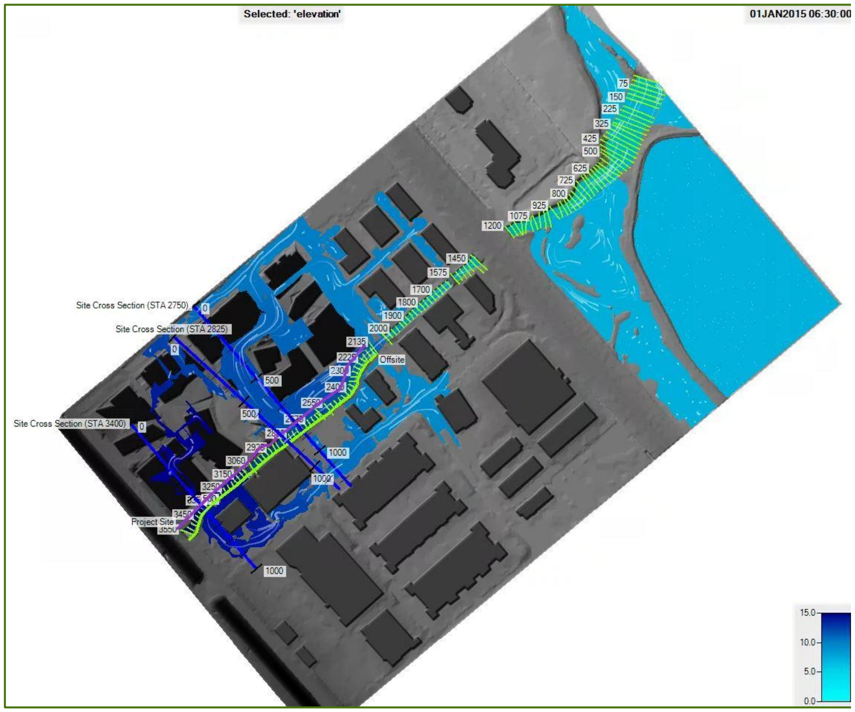


Figure 38: Flow Patterns – Existing Conditions with Project Terrain

Figure 39: Flow Patterns – with Project

5.2.5 Project and Off-Site Area Flood Water Volume Accumulation

Another comparison that can be made is reviewing the differences in flood water volumes accumulating over time across key alignments of both sides of Pulgas Creek. The alignments (Figure 34) represent waters coming on to the Project site (Figure 40) versus the off-site areas (Figure 41), respectively. There is a large difference between existing and with Project conditions. The existing conditions is shown as the blue line, and Project conditions is shown as the green line. There is a near complete reversals in volume accumulation patterns with the Project. The site has a significant decrease in accumulated volume (Figure 40), while the off-site area accumulates more (Figure 41).

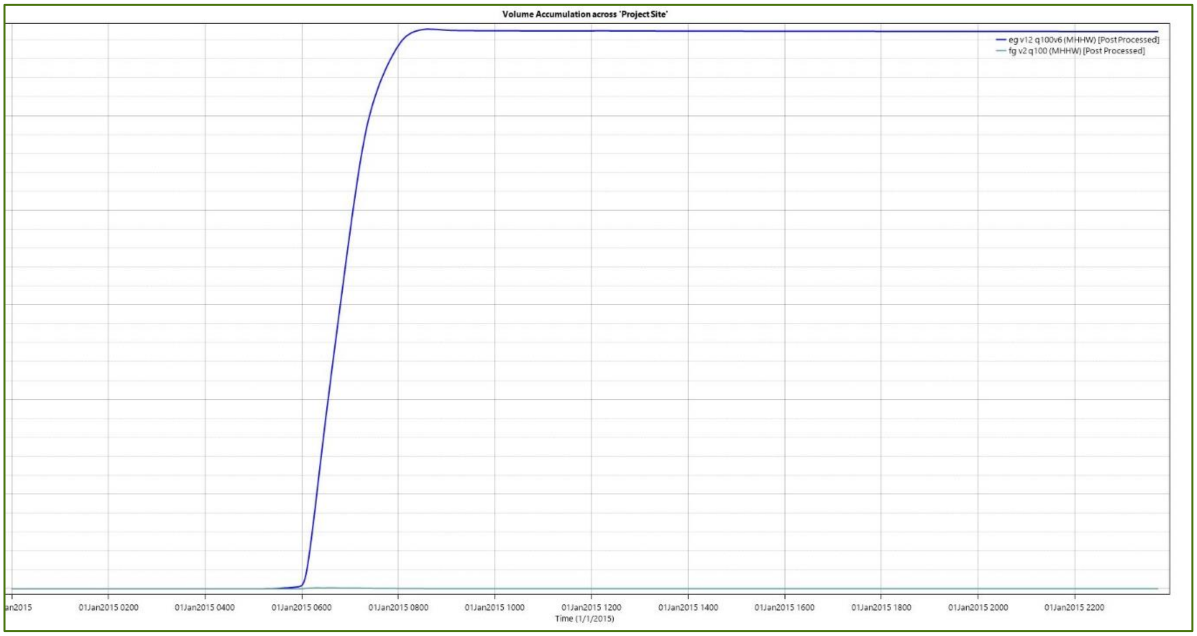


Figure 40: Flow Volume Accumulation along the Project Area Pulgas Creek Margin

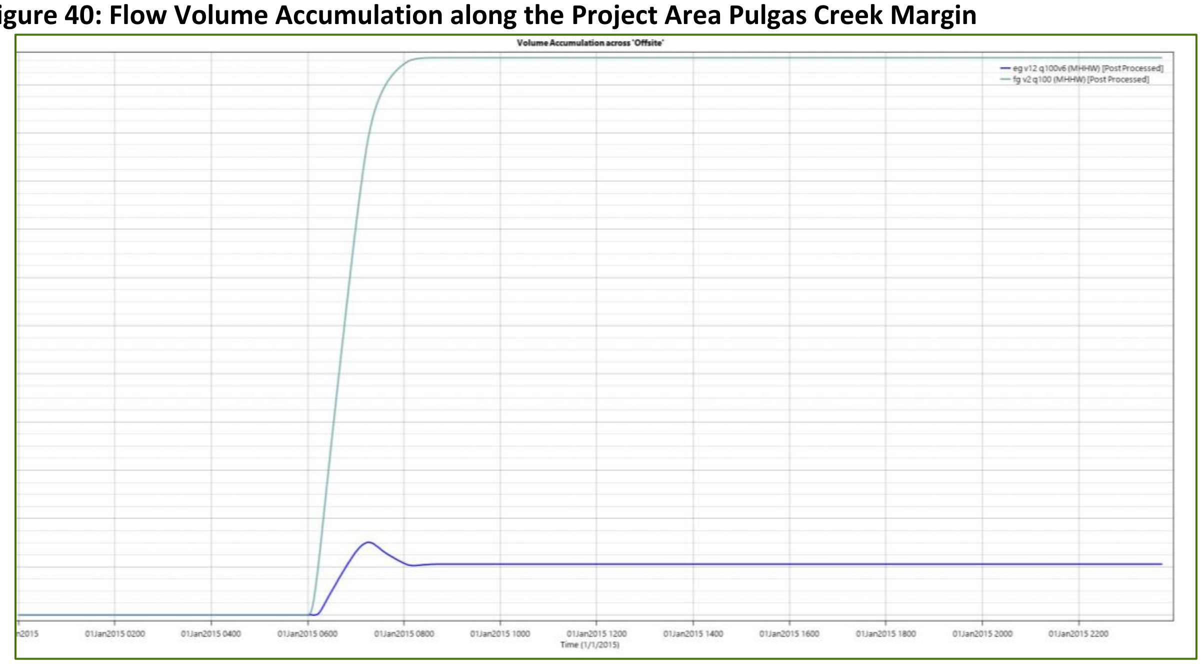


Figure 41: Flow Volume Accumulation along the Off-site Area Pulgas Creek Margin

5.2.6 Channel Shear Stress

Since the Project is simulated to produce higher 100-year WSELs along portions of the Project reach of Pulgas Creek (see maps and profiles above), the potential change in shear stress is evaluated to assess the stability of channel substrate. Comparison of modeled shear stress at consistent time steps in the simulation on the peak flow hydrograph (at 600, 630, and 700 hours) along the creek profile is shown for existing and with Project conditions in Figure 42. In the Project reach, shear stress under existing conditions is generally lower than with the Project. In the downstream reaches, shear stress would remain the same or decrease slightly with the Project.

The changes are not large in magnitude, and can be compared to known resistance/stability of channel materials (Fischenich, 2001) as context to assess whether an appreciable change in the channel condition or stability would occur. Materials along the existing channel bed and banks of Pulgas Creek are quite varied and include sections with concrete bed or banks, sakrete banks, rooted woody and herbaceous vegetation, unvegetated soils, as well as fine sediment, sand, gravel, small cobble, and occasional larger rock or concrete slabs.

In some locations, the change in shear stress with the Project might induce a coarsening of the bed material or (if adequate size material is not present) increase channel instability. For example, at RS 2400, the model results for existing conditions suggest gravel approximately 1 inch in diameter would mobilize during the 100-year event. Model results with the Project suggest that larger gravel (approximately 2.5 inch in diameter) could mobilize during the 100-year event. However, long native grasses and willows with substantial roots would likely be stable under either the existing or Project conditions.

In other locations, the change in shear stress would still fall within the same range of material resistance. For example, at RS 3350, the model results for both existing and proposed conditions suggest cobble approximately 6 inch in diameter would mobilize during the 100-year event. Long native grasses would be mobilized, but willows with substantial roots would likely be stable in both scenarios at this location.

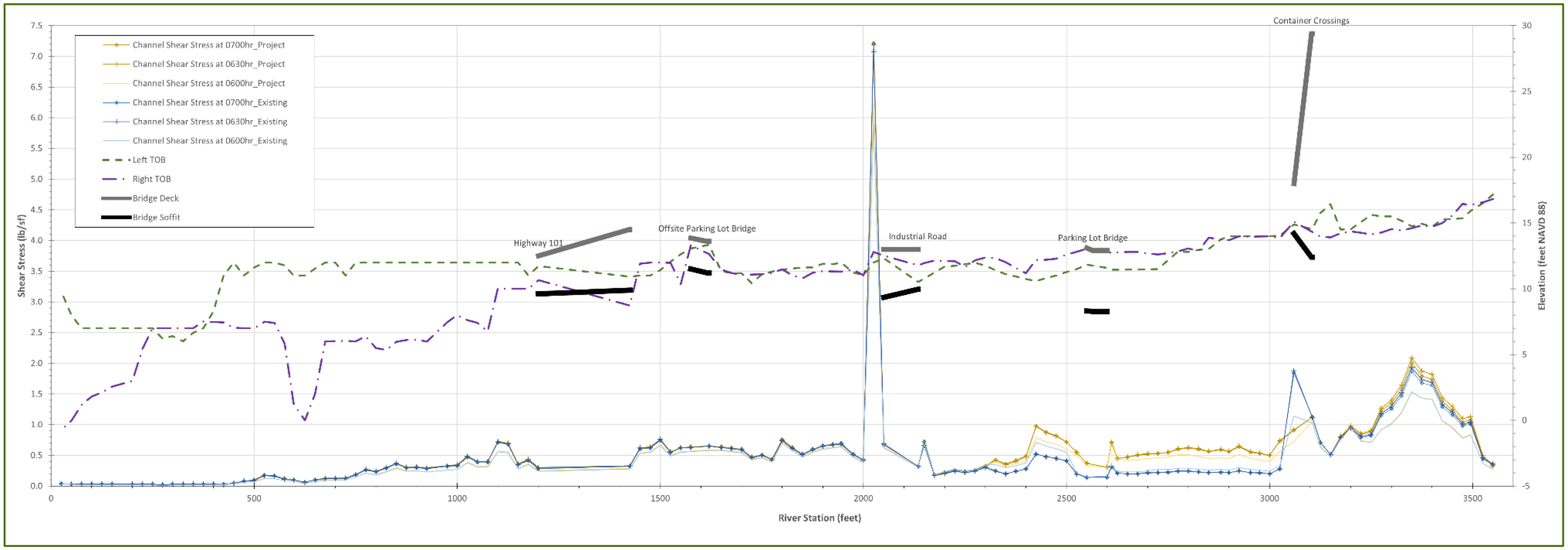


Figure 42: Shear Stress Profiles under the Existing and Project 100-year Flood Conditions

6.0 Conclusion and Recommendations

Modeling indicates that the Project will reduce the 100-year flood conditions on the site and be protective of the proposed buildings and occupants. However, the Project would expand the area and increase the depth of 100-year flooding off site and increase local shear stress in some areas of the degraded creek.

These adverse changes would likely be considered potential significant impacts to flooding and creek stability under CEQA unless the Project is modified. The design team is collaborating to perform iterative hydraulic modeling to adjust the proposed Project to minimize changes to off-site 100-year flooding extent and depth and to factors driving creek stability.

Based on our understanding of the site hydraulics from modeling to-date, we anticipate that some combination of the following design revisions could reduce the potential adverse impacts for the 100-year flood to a level that is less-than-significant under CEQA. The modifications being explored include:

- Modifying the north creek bank to mimic existing location(s), timing and amount of overbanking.
- Changes to existing crossings within the site reach (e.g., parking lot bridge) to improve channel hydraulics.
- Providing flood water storage areas and flow paths that mimic existing volumes and routes.

The City has requested additional analysis of flooding associated with smaller magnitude, more frequent events (i.e., the 10-year storm), which will proceed concurrently with the Project iteration modeling.

Regardless of the outcome of these iterations to improve the proposed Project site design, preservation of channel conveyance capacity will be important for long-term adequate flood management. Monitoring of potential future sedimentation (i.e., associated with sea level rise or from upstream sources) or vegetation and debris restrictions should occur, and maintenance actions may be required on a regular or periodic basis. Such activities in the public drainage system easement would typically be a City responsibility.

7.0 Limitations

The models developed herein were focused only on addressing 100 -year event rather than a full range of recurrence interval peak flows or hydrographs. The scope and emphasis of model optimization was on comparing and evaluating the relative change between the existing conditions and with the proposed Project within the study area. While the existing conditions model is shown to be reasonable comparable to and consistent with the effective FEMA, FIRM and FIS, additional model development and calibration would be necessary to process a possible flood map revision.

It is important to acknowledge that is there is uncertainty or a margin of error in the hydraulic model. The model sensitivity analysis shows the water surface elevation could be within +/- 0.3ft of the model results. The volume of water quantified could be within 10 acre-ft of the model results. Based on the sensitivity analysis, model results within 0.3 ft in elevation and 10 acre-ft in volume accumulation should be considered within the margin of error for model results.

Additionally, note that the scope of this flooding analysis is limited to the physical hydraulics and does not address potential safety hazards to property or persons.

8.0 References

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APPENDIX A – ANIMATIONS OF MODEL RESULTS

(Provided in a separate PowerPoint presentation file)

Appendix B

MITIGATED PROJECT WATER SURFACE ELEVATION PROFILES

Appendix B

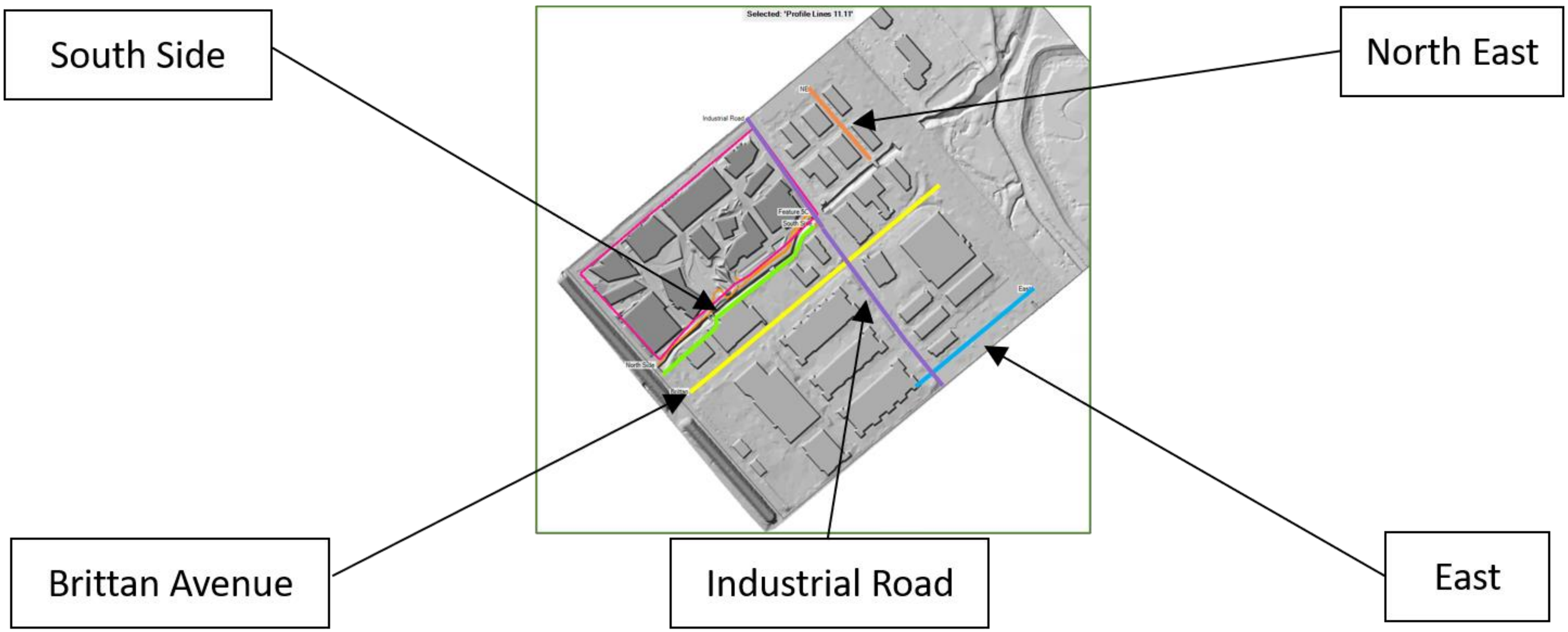

Figure B-1: Water Surface Elevation (WSEL) Comparison Q100 Key

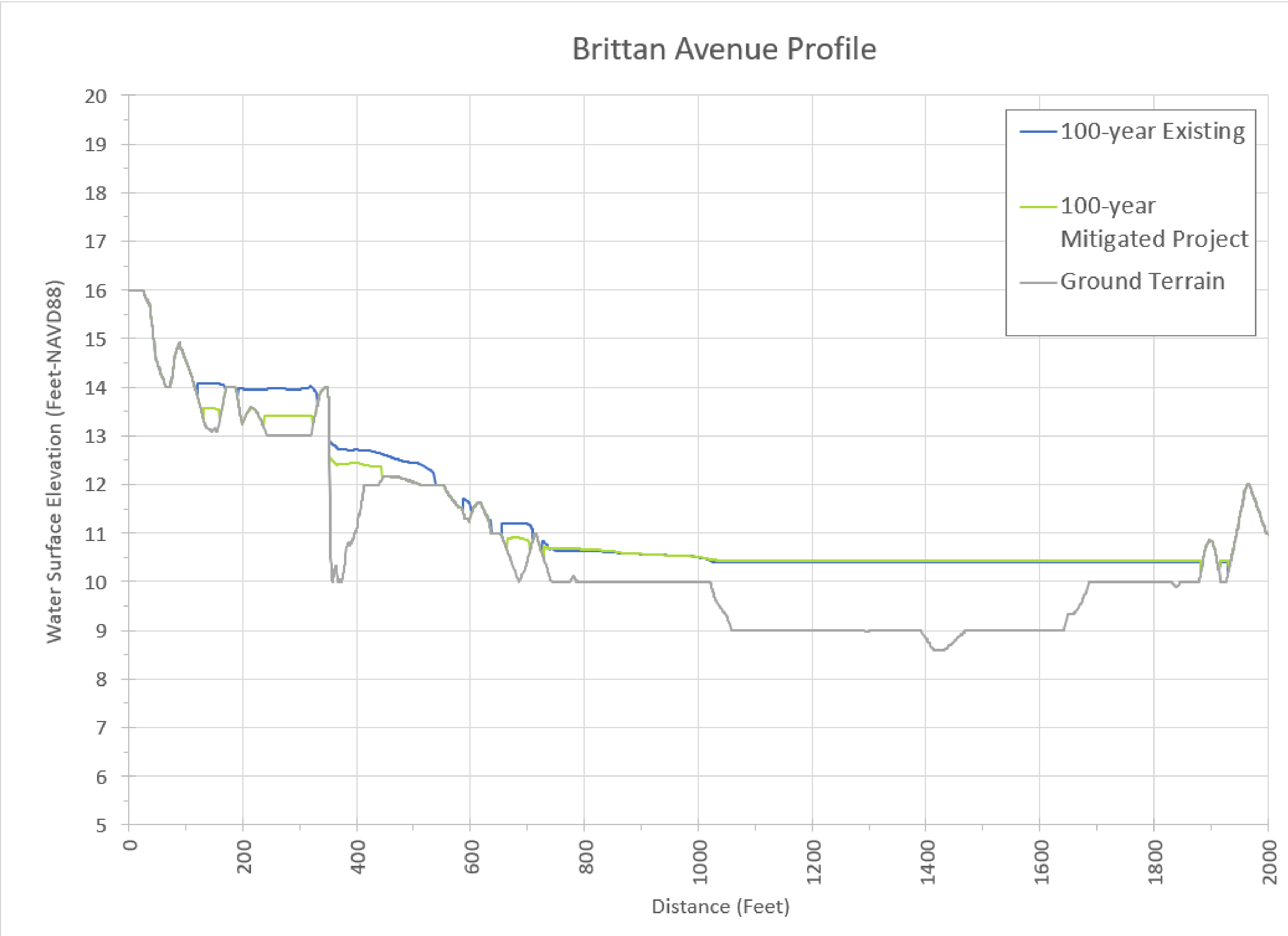

Figure B-2: Brittan Avenue WSEL Profile Q100

Figure B-3: East WSEL Profile Q100

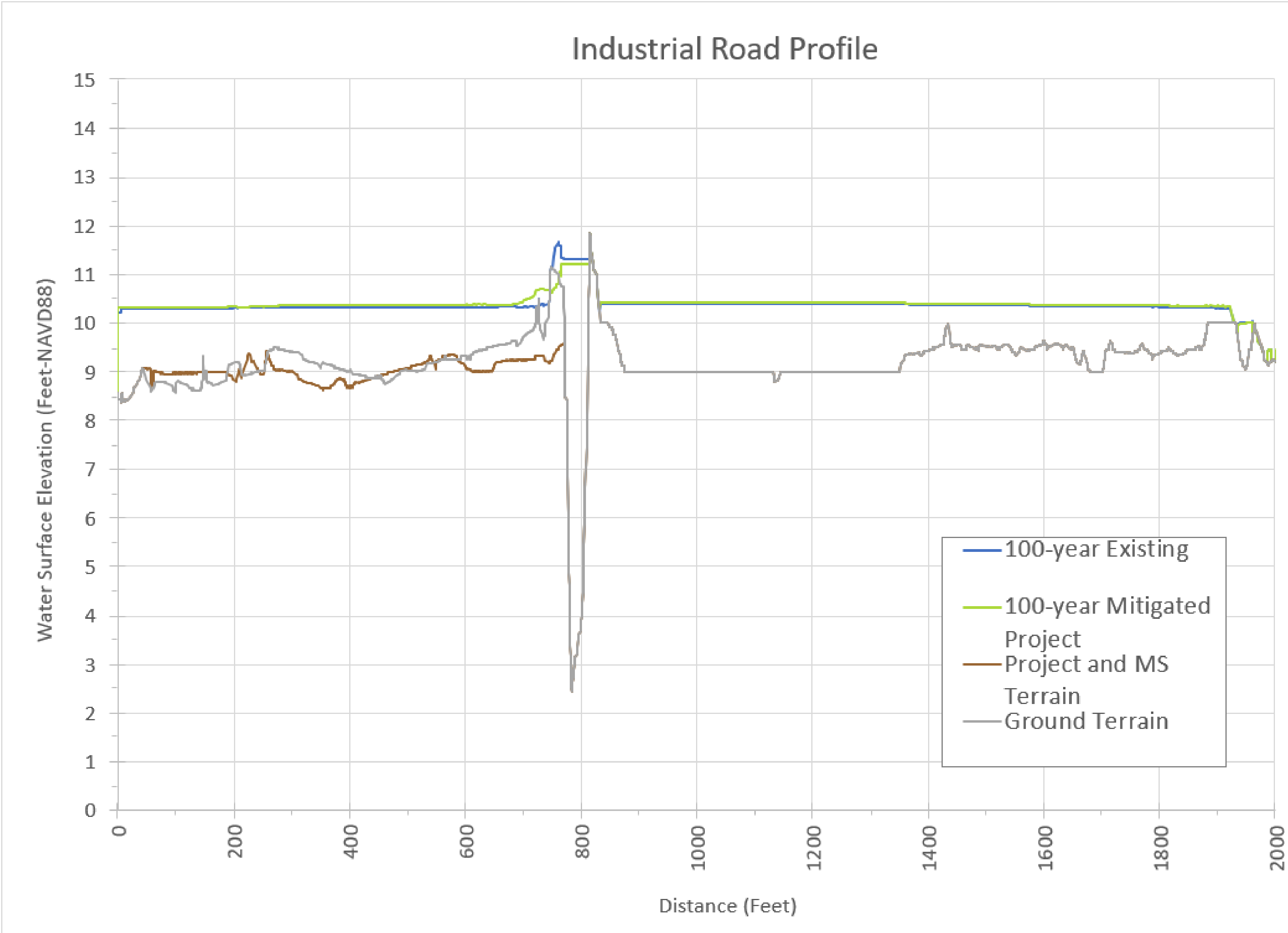

Figure B-4: Industrial Road WSEL Profile Q100

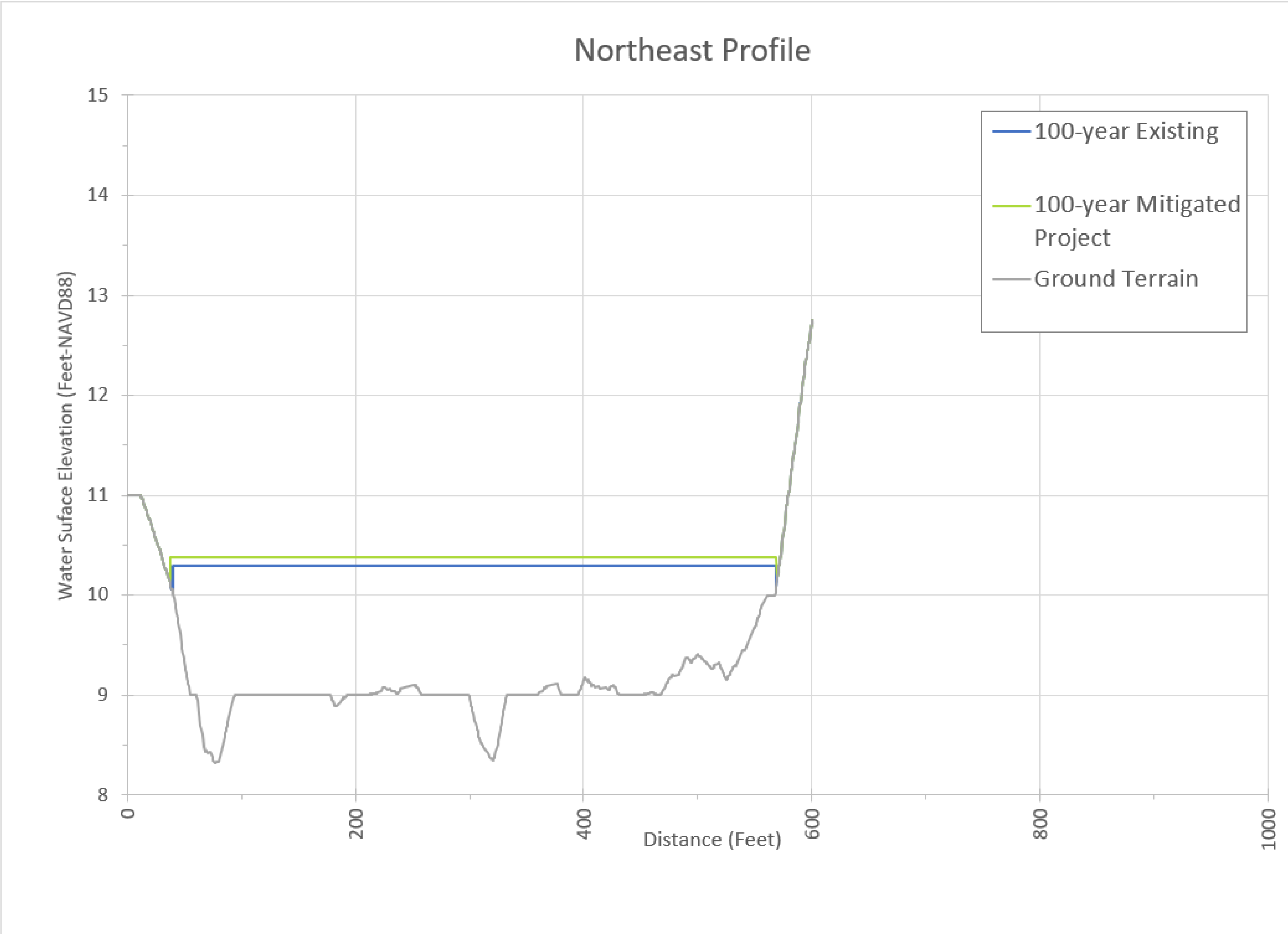

Figure B-5: Northeast WSEL Profile Q100

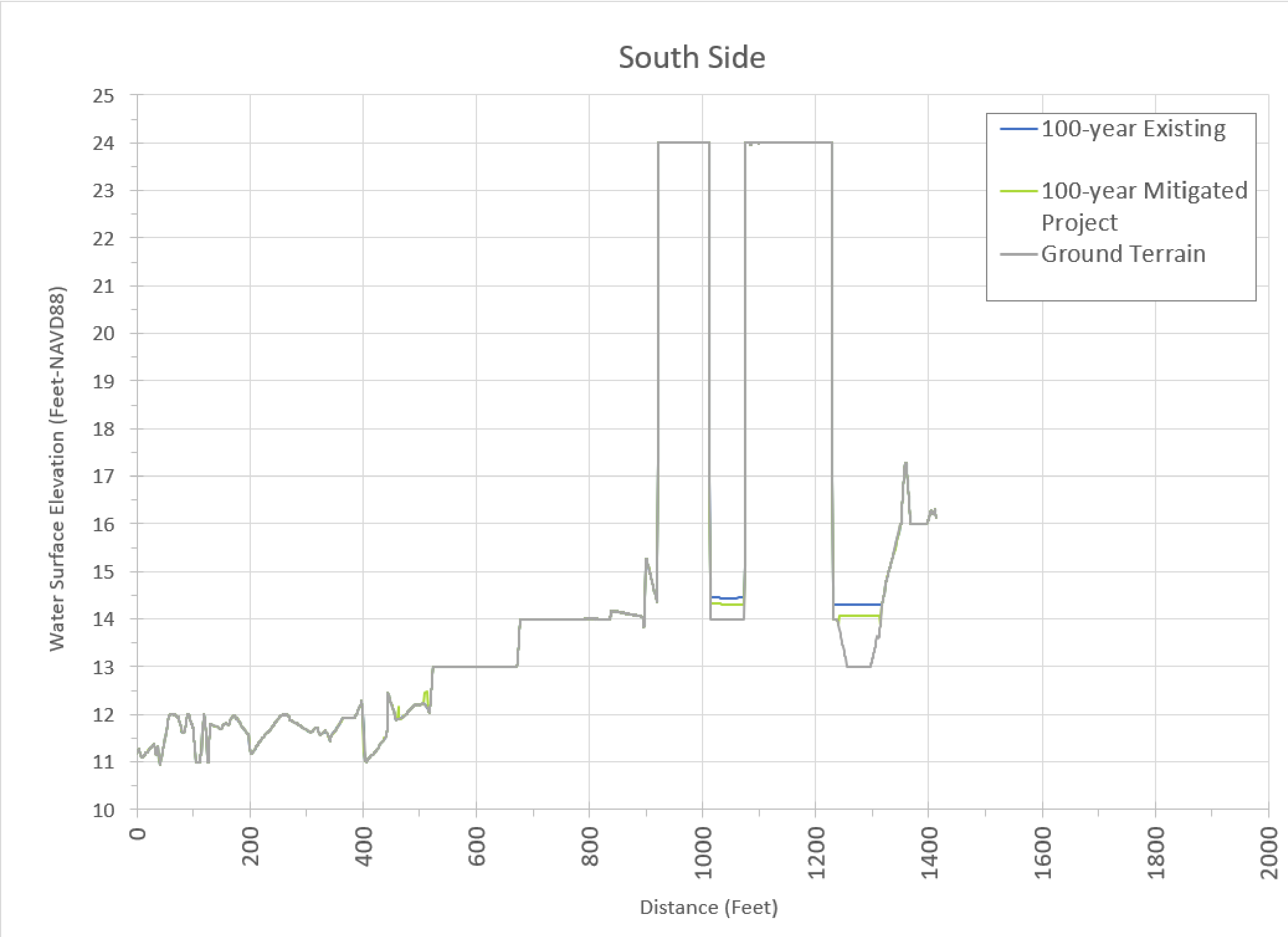

Figure B-6: South Side WSEL Profile Q100

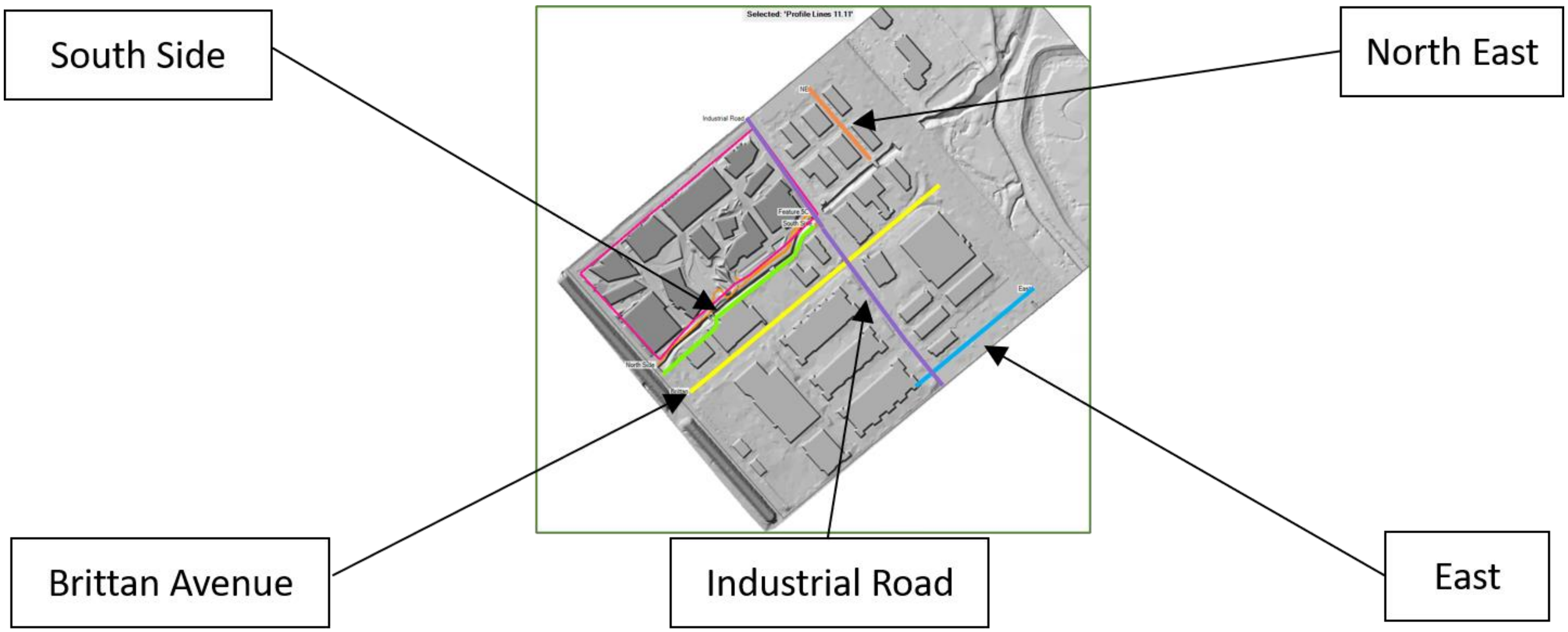

Figure B-7: Water Surface Elevation (WSEL) Comparison Q10 Key

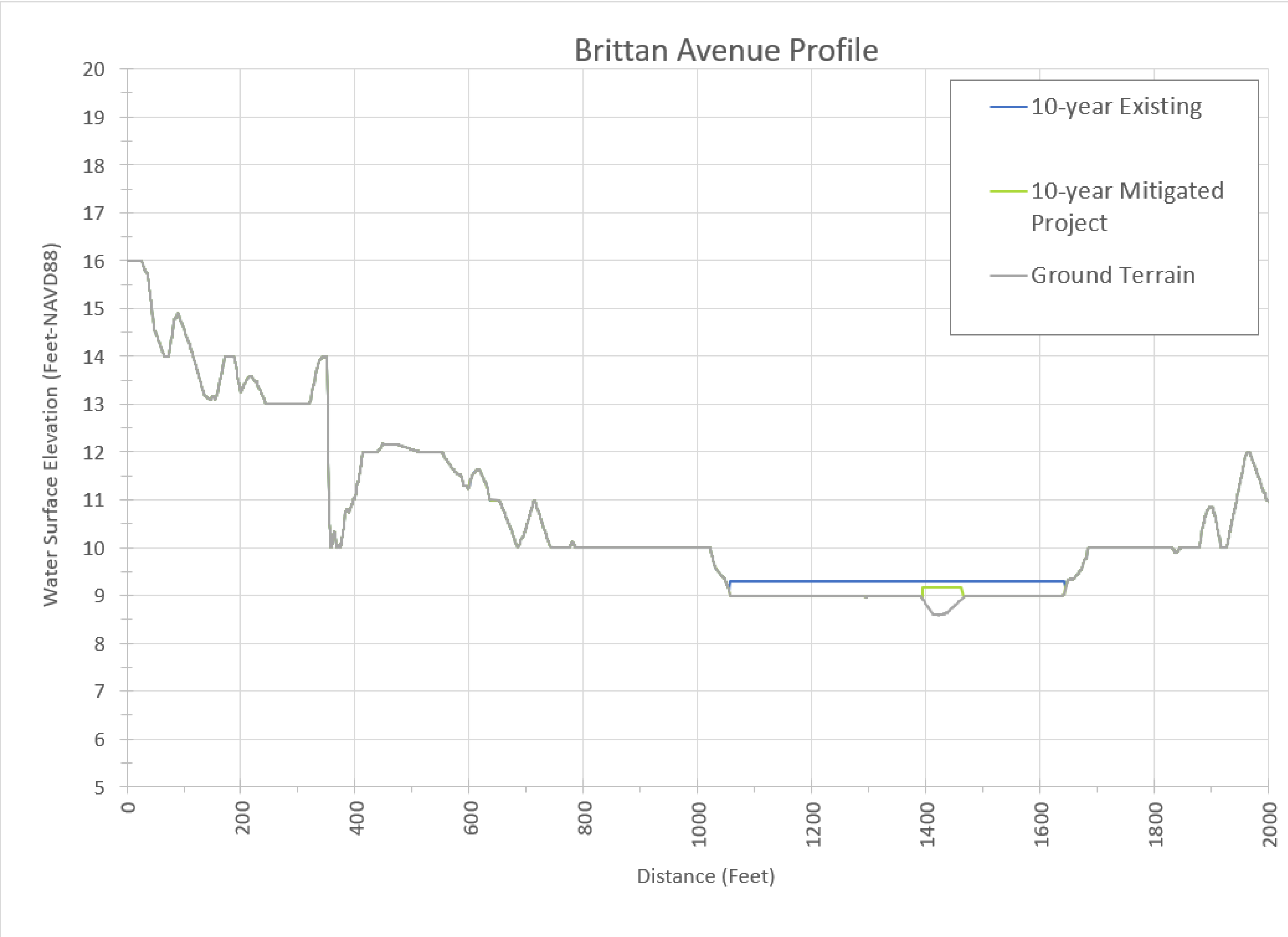

Figure B-8: Brittan Avenue WSEL Profile Q10

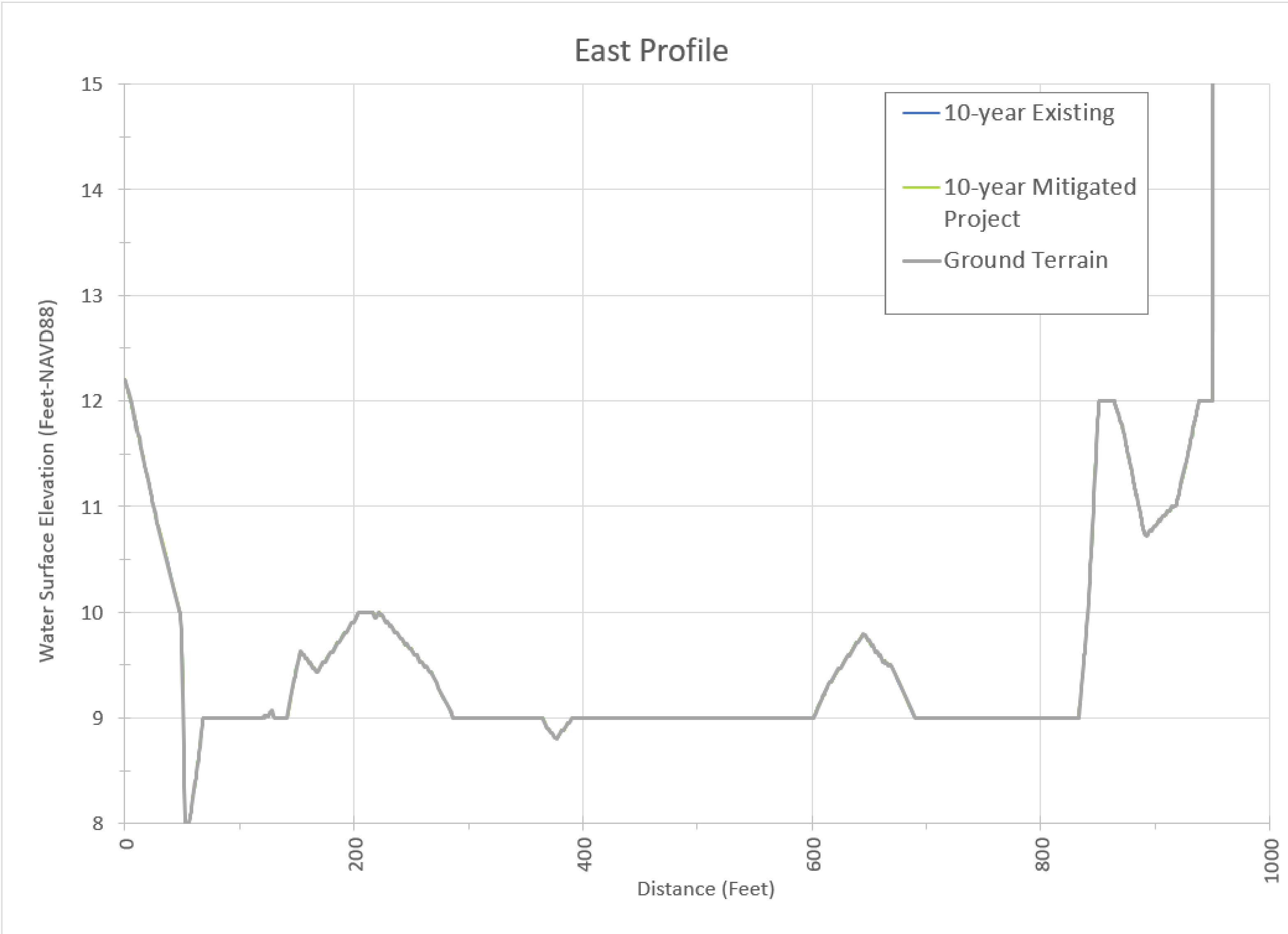

Figure B-9: East WSEL Profile Q10

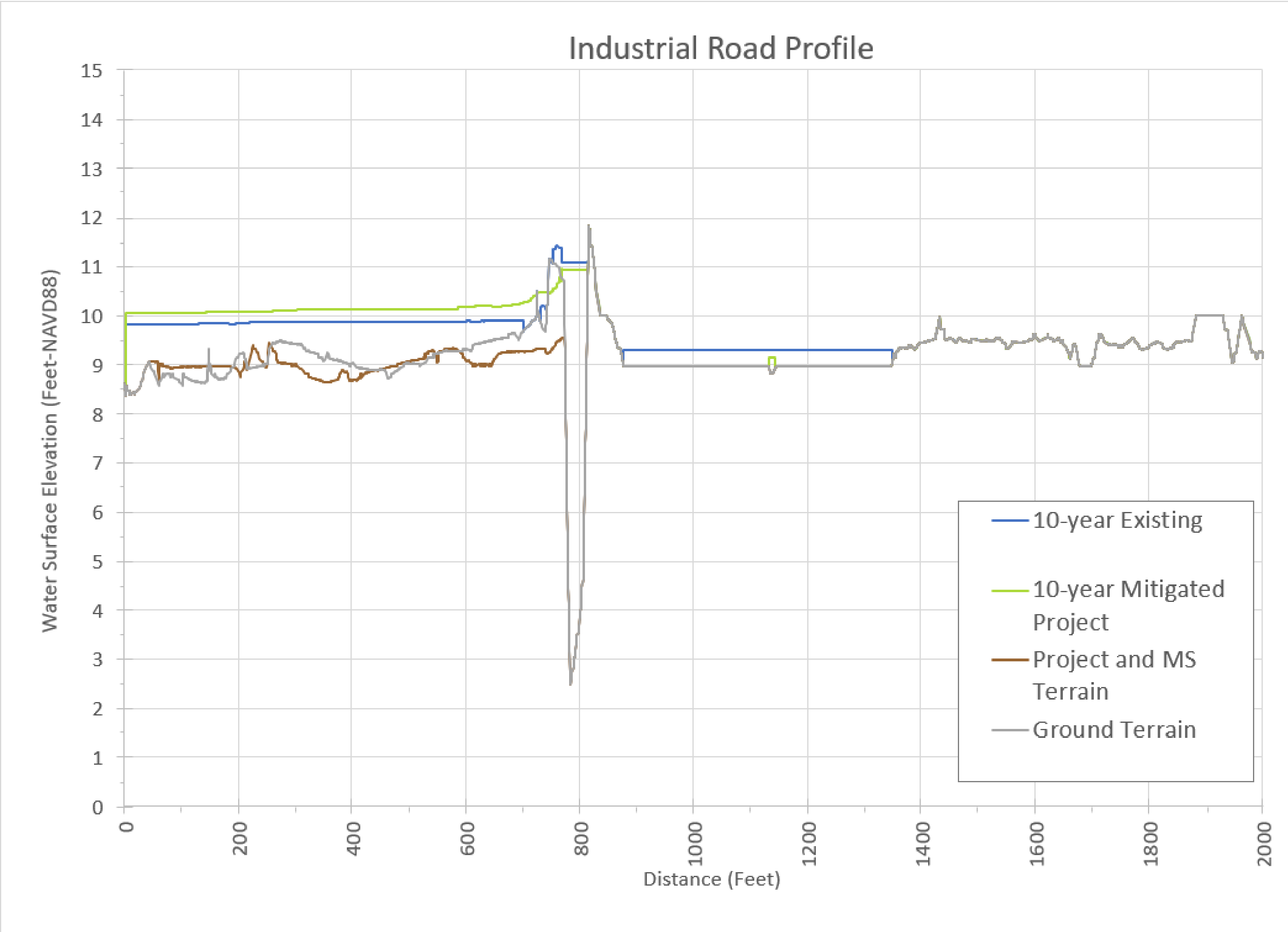

Figure B-10: Industrial Road WSEL Profile Q10

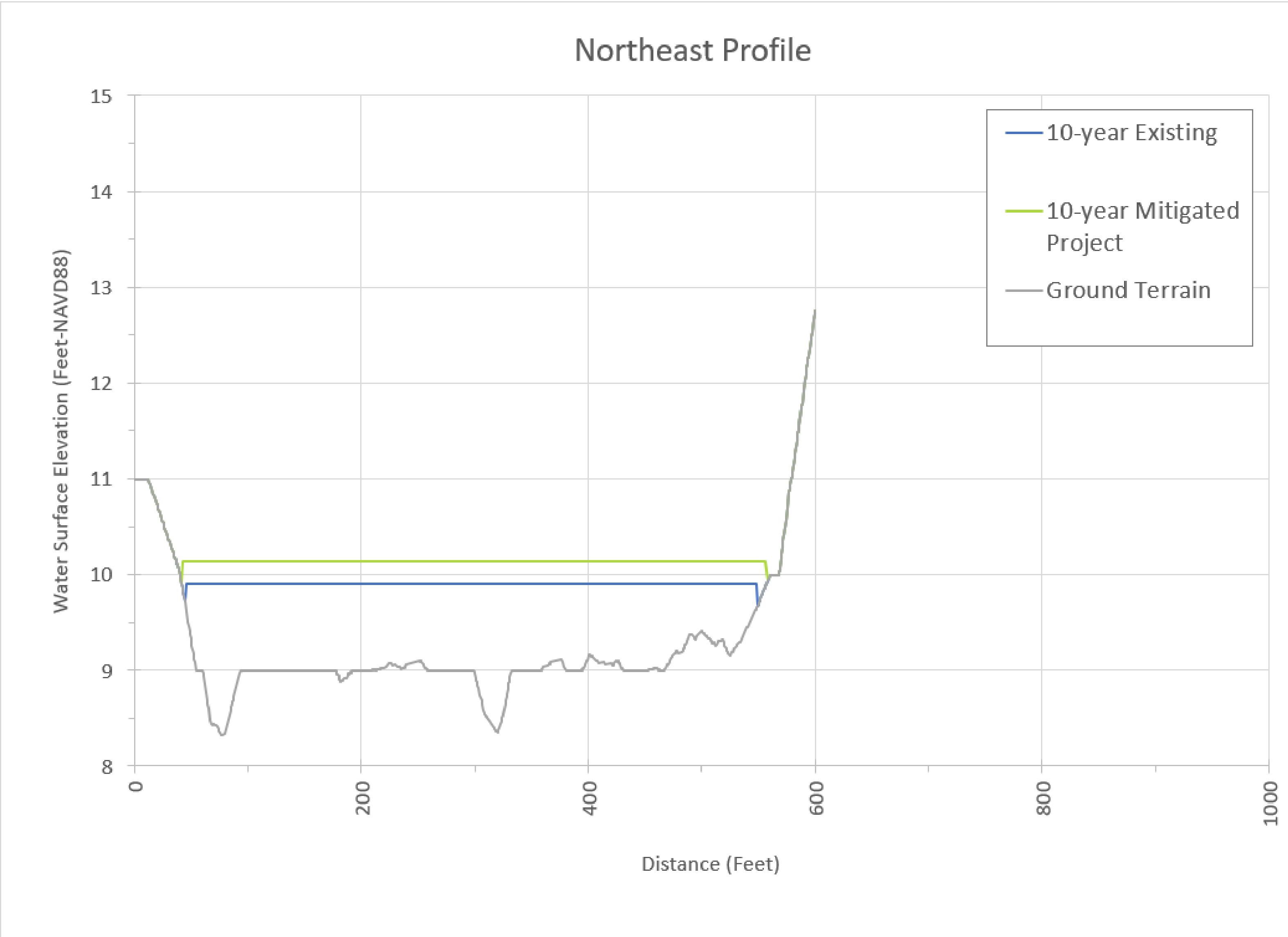

Figure B-11: Northeast WSEL Profile Q10

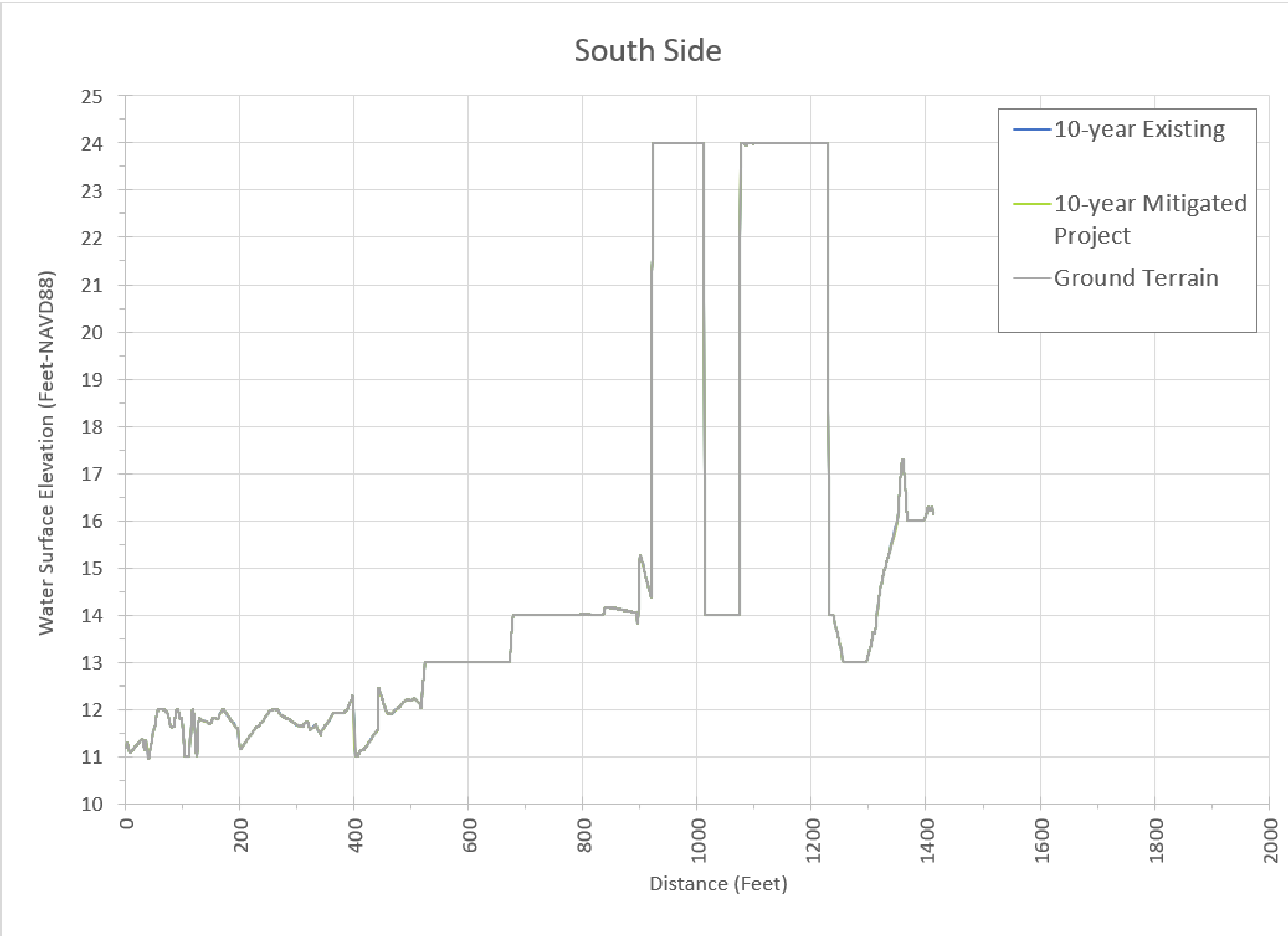

Figure B-12: South Side WSEL Profile Q10