January 2021
US 101/California SR 1 Junction and Manzanita Park-and-Ride

Manzanita Area Flood Reduction Study

Prepared for County of Marin, California, and California Department of Transportation

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ABBREVIATIONS

Caltrans	California Department of Transportation
CMP	corrugated metal pipe
CPE	corrugated polyethylene
EPA	U.S. Environmental Protection Agency
Flood Control District	Marin County Flood Control and Water Conservation District
Marin County	County of Marin Department of Public Works
MHHW	mean higher high water
MLLW	mean lower low water
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
Park-and-Ride	Manzanita Park-and-Ride
RCP	reinforced concrete pipe
SR 1	California State Route 1
SWMM	Stormwater Management Model
US 101	U.S. Highway 101

Executive Summary

This report summarizes the results of a flood reduction study completed by Marin County to characterize tidal flooding under sunny day conditions in the Manzanita area, and to identify potential flood reduction measures that can be implemented with relatively little complication in the near term to reduce tidal flooding in the area. The study area is located approximately 6 miles north of San Francisco, along Richardson Bay in Marin County. The study area extends along the shoreline of Richardson Bay from Gate 6 1/2 Road in Sausalito north to Coyote Creek. Within the study area, US 101 crosses Richardson Bay on an elevated bridge that extends over SR 1. Ramps in the study area provide access from SR 1 to US 101. The Manzanita Park-and-Ride is located under and adjacent to the US 101 bridge along the southwest side of SR 1.

The Park-and-Ride and the segment of SR 1 adjacent to the Park-and-Ride are within a relatively low-lying area prone to flooding during King Tide events. Flooding in the area will be further impacted by future sea level rise. On average, this location floods 20 to 30 times a year, between November and March (Marin County 2019). During King Tides, a California Department of Transportation (Caltrans) maintenance yard and adjacent commercial properties are also impacted by flooding. The adjacent Mill Valley-Sausalito Multi-Use Path (Bay Trail), an intensively used recreational path that runs along the west shoreline of Richardson Bay through the study area, also floods during King Tide conditions.

What was done as part of this study?

Marin County retained Anchor QEA to assist with this study. The work completed as part of this study included the following:

- An initial site visit and meeting with Marin County and Caltrans to document site conditions
- Topographic survey to supplement information available from the Marin County GIS database
- An assessment of site conditions, constraints, and data available for the study
- Coordination with Marin County, Caltrans, and other key stakeholders to gather data, complete the study, and process input on key pieces of the evaluation
- Preparation of a two-dimensional hydraulic model using PCSWMM and evaluation of potential flood reduction measures and alternatives
- Identification, engineering analysis and evaluation, and development of design concepts for potential flood reduction measures
- Development and evaluation of flood reduction alternatives, consisting of a combination of flood reduction measures
- Meetings and presentations to stakeholders
- Preparation of this report

Why was this work done?

Table ES-1 summarizes the key tide elevations used for this study, as measured at the National Oceanic and Atmospheric Administration (NOAA) Tide Station at San Francisco (NOAA Station 9414290). High tide events, often referred to as King Tides, exceed 7.00 feet in Richardson Bay multiple times each year, relative to the North American Vertical Datum of 1988 (NAVD 88). Recent tide events that exceeded 7.00 feet NAVD 88 include high tides in January and February 2019 and in November and December 2020.

Table ES-1
Key Tidal Elevations Relative to NAVD 88 and MLLW, San Francisco (Station 9414290)

Datum	Elevation, NAVD 88 (Feet)	Elevation, MLLW (Feet)
North American Vertical Datum of 1988 (NAVD 88)	0.00	-0.06
Mean Lower Low Water (MLLW)	0.06	0.00
Mean High Water (MHW)	5.29	5.23
Mean Higher High Water (MHHW)	5.90	5.84
Highest Astronomical Tide (HAT)	7.32	7.26
Maximum Tide Observed (01/27/1983)	8.72	8.66
Minimum Tide Observed (12/17/1933)	-2.82	-2.88

Elevations and mapped topography presented in the study are reported relative to NAVD 88, unless specified otherwise. Ground elevation of key facilities within the study area are as follows:

- Elevations along the segment of SR 1 adjacent to the Park-and-Ride and Caltrans maintenance yard range from just under 6 feet up to 8 feet.
- Elevations within the Caltrans maintenance yard range from approximately 7 feet, near the SR 1 frontage, to nearly 9 feet, along the north edge of the property.
- Elevations along the Bay Trail range from just under 7 feet to nearly 8 feet. The lowest elevations are just northwest of the US 101 bridge, just southeast of the US 101 bridge, and south of Pahono Street near the Seaplane Adventures commercial property.
- Elevations of the travel and parking surface within the Park-and-Ride vary from less than 6 feet, along the east edge of the Park-and-Ride, to nearly 10 feet, along the southwest edge of the Park-and-Ride.
- Elevations in the parking area around the Holiday Inn Express vary from approximately 6 feet to more than 9 feet.

Several key areas lie below an elevation of 7.00 feet NAVD 88. Whenever the tide exceeds the elevation of these low-lying areas, shallow flooding occurs. Shallow tidal flooding results in regular closures of a very busy portion of SR 1 adjacent to the Park-and-Ride at US 101. SR 1 is a major access route to and from the Manzanita, Mill Valley, and Tamalpais Valley areas in Marin County. Flooding can result in complete closure of access to US 101 at SR 1, causing extensive delays for those travelling to and from these areas. Periodic flooding also impacts the Park-and-Ride, adjacent commercial properties, and the Bay Trail.

What solutions were considered?

Several potential flood reduction measures were identified, with a focus on improvements that can be made in the near term to reduce tidal flooding in the area. Larger, more complicated and expensive projects, such as improvements to SR 1, resolution of settlement issues, reconstruction of the Manzanita Park-and-Ride, and installation of large pump stations, may be needed to provide a comprehensive long-term solution for both tidal flooding and storm-induced flooding. However, the focus of this study is relatively small-scale or lower cost solutions that can be implemented in the near term (5 to 10 years) to help reduce the impact of flooding during King Tide events.

The flood control measures included as part of this study are generally in the following categories:

1. Measures intended to prevent tidal waters from backing up through culverts and storm drains into areas that are currently flooding, such as Tideflex valves or tide gates.
2. Measures intended to create a barrier across a low spot to separate upland areas that are prone to tidal flooding from low-lying tidal areas, such as berms, walls, or other barriers.
3. Measures that would modify the Bay Trail to protect the trail from tidal flooding, such as raising the pathway or providing barriers along the edges of the trail.
4. A measure that would improve control of tidal inundation at the outlet of the major storm drain outfall in the study area by installing self-regulating tide gates at the outfall structure.
5. Measures that would upgrade the storm drain system to improve the conveyance of flood water to Richardson Bay, such as upgrades to storm drains and ditches, or incorporation of limited stormwater pumping.

The flood control measures were evaluated and compared against one another based on a common set of criteria. The criteria used for evaluation included flood reduction effectiveness, reliability/resilience (including consideration for future sea level rise), fluvial benefit (to characterize potential for relieving storm-induced flooding), permitting complexity, property impacts, public use impacts, relative cost, constructability, and operations and maintenance.

The flood control measures were then combined into alternatives for further consideration. The alternatives were developed with the following targets in mind:

- **Alternative 1**
  - Minimize flooding within the traveled SR 1 right-of-way and at the Caltrans maintenance yard.
- **Alternative 2**
  - Minimize flooding within the traveled SR 1 right-of-way and at the Caltrans maintenance yard.
  - Prevent the tide from overtopping the Bay Trail throughout the study area.
  - Reduce flooding within the storm drain systems that serve commercial properties to the northwest of the Caltrans maintenance yard.
  - Improve conveyance of flood water adjacent to and across SR 1.
- **Alternative 3**
  - Minimize flooding within the traveled SR 1 right-of-way and at the Caltrans maintenance yard.
  - Prevent the tide from overtopping the Bay Trail throughout the study area.
  - Reduce flooding within the storm drain systems that serve commercial properties to the northwest of the Caltrans maintenance yard.
  - Improve conveyance of flood water adjacent to and across SR 1.
  - Improve conveyance of flood water and stormwater runoff through the Park-and-Ride to limit impact on the use of that facility.

What was done to evaluate the potential solutions?

The alternatives were evaluated using a two-dimensional hydraulic model developed for the study area using PCSWMM software (a private version of the U.S. Environmental Protection Agency Stormwater Management Model [SWMM]). Key data including topography and existing storm drain infrastructure were incorporated into the model. The model was used to simulate flooding that occurs under existing conditions during the peak observed tide event, from January 1983, and a recent high tide cycle, from January and February 2019. The model results were reviewed with Marin County and Caltrans to confirm that the model was accurately simulating existing tidal flooding conditions. The model was then used to evaluate each alternative to demonstrate the impact of each alternative on tidal flooding.

What was learned?

The results indicate that all of the alternatives considered have potential to prevent flooding of SR 1 under sunny day conditions during all but the most extreme high tide events. Opinions of cost were developed to compare the potential flood reduction measures and alternatives. Additional work was done to evaluate the alternatives according to the criteria that were used to evaluate individual flood reduction measures. The alternatives were then scored for each criterion and ranked according to the overall average score given to each alternative. The results indicate the following:

- **Alternative 1** was scored the highest through this evaluation. Although it delivers the least benefit of the three alternatives, the difference in flood control benefit is only marginal and Alternative 1 delivers most of the flood control benefit at the lowest cost of the three alternatives. It successfully prevents flooding of SR 1 under all but the most extreme tide events under sunny day conditions. It does come with challenges, including impacts to tidally influenced areas, and does not substantially reduce tidal flooding over the Bay Trail.
- **Alternative 2** was scored only slightly lower than Alternative 1. In addition to the flood protection benefits provided by Alternative 1, Alternative 2 reduces flooding on the Bay Trail and provides some additional protection for adjacent commercial properties. It successfully prevents flooding of SR 1 under all but the most extreme tide events. It also comes with challenges, including additional work required within tidally influenced areas.
- **Alternative 3** was scored the lowest of the three alternatives, primarily due to the high cost and complication of operating and maintaining additional facilities. The cost and complication are primarily tied to the stormwater pump station included in this alternative. The pump station does not add a lot of value to flood reduction under King Tide, sunny day events, but could potentially add ability to reduce storm-induced flooding. Evaluation of storm events was beyond the scope of this study. Additional analysis should be completed to determine the extent to which the additional improvements recommended as part of Alternative 3 could potentially improve conveyance of storm flows under a full range of tide conditions.

Where do we go from here?

Based on the results of this study, it is recommended that Marin County and Caltrans continue to coordinate with one another to pursue near-term implementation of flood reduction measures that will reduce the impact of tidal flooding in the study area. The following is recommended:

1. Initiate a more comprehensive evaluation of flooding to look at not only tidal flooding, but also flooding caused by runoff from peak storm events during the full range of tide conditions.
2. Start planning for implementation of the improvements outlined in this study as Alternative 1 improvements, with the goal of minimizing the impact of tidal flooding on the traveled SR 1 right-of-way and Caltrans maintenance yard.
3. Add the benefits provided as Alternative 2 in this study by coordinating with the Marin County Parks Department and other key stakeholders on planned improvements to the Bay Trail that will reduce overtopping during King Tide events and improve public use.
4. Make any other improvements to the storm drain system warranted by the additional study of flooding caused by runoff from peak storm events during the full range of tide conditions.

1 Introduction

The County of Marin Department of Public Works (Marin County) is collaborating with the California Department of Transportation (Caltrans) to study opportunities to reduce the impact of tidal flooding in the area near the Manzanita Park-and-Ride (Park-and-Ride) at the junction of U.S. Highway 101 (US 101) and California State Route 1 (SR 1) in Marin County, California. The highest tide events, referred to as King Tides, cause shallow flooding in this area, resulting in regular closures of a very busy portion of SR 1 adjacent to the Park-and-Ride at US 101. SR 1 is a major access route to and from the Manzanita, Mill Valley, and Tamalpais Valley areas in Marin County. Flooding can result in complete closure of access to US 101 at SR 1, causing extensive delays for those travelling to and from these areas. Periodic flooding also impacts the Park-and-Ride, adjacent commercial properties, and the Mill Valley-Sausalito Multi-Use Path (Bay Trail).

This report summarizes the results of the study completed by Marin County to characterize tidal flooding under sunny day conditions and identify potential flood reduction measures that can be implemented with relatively little complication in the near term to reduce tidal flooding in the area.

1.1 Study Background

The study area for this project is located approximately 6 miles north of San Francisco, along Richardson Bay in Marin County, as shown in Figure 1-1. The study area extends along the shoreline of Richardson Bay from Gate 6 1/2 Road in Sausalito north to Coyote Creek. Within the study area, US 101 crosses Richardson Bay on an elevated bridge that extends over SR 1. Ramps in the study area provide access from SR 1 to US 101. The Park-and-Ride is located under and adjacent to the US 101 bridge along the southwest side of SR 1, as shown in Figure 1-2. The Park-and-Ride and the segment of SR 1 adjacent to the Park-and-Ride are within a relatively low-lying area prone to flooding from King Tides. Flooding in the area will be further impacted by future sea level rise. On average, this location floods 20 to 30 times a year, between November and March (Marin County 2019). During King Tides, a Caltrans maintenance yard and adjacent commercial properties are also impacted by flooding. The adjacent Bay Trail, an intensively used recreational path that runs along the west shoreline of Richardson Bay through the study area, also floods during King Tide conditions.

Key public facilities impacted by shallow tidal flooding include the following:

- SR 1 at the junction with US 101
- The Park-and-Ride, located at the intersection of SR 1 and US 101
- The Caltrans maintenance yard, north of the Park-and-Ride
- The Bay Trail

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Figure 1-1
Location Map
Flood Reduction Study Report
Manzanita Area Flood Reduction Study

LEGEND:

Study Area

Frequently Flooded SR 1 Section

SOURCES:
MarinMap, County of Marin, Golden Gate National Parks Conservancy.

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Feet

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Figure 1-2
Study Area Map
Flood Reduction Study Report
Manzanita Area Flood Reduction Study

Marin County retained Anchor QEA to evaluate shallow flooding impacts on these properties, with the intent of identifying potential measures that can be implemented in the near term to reduce the impact of flooding during King Tide events under sunny day conditions.

1.2 Prior Work

Flooding in the Manzanita area has long been a problem. Other documents that have been prepared to summarize and characterize flood conditions in the area include the following:

Draft Technical Memorandum No. 2, Richardson Bay Tidal Flood Study – Drainage Improvement Alternative Development (Winzler and Kelly 2007) and *Draft Technical Memorandum No. 3, Richardson Bay Tidal Flood Study – Final Alternatives Analysis* (Winzler and Kelly 2009). This study, completed in 2009 under direction of the Marin County Flood Control and Water Conservation District (Flood Control District), evaluated flooding over five locations adjacent to Richardson Bay that are prone to tidal flooding, including two areas (Manzanita West and Manzanita East) that are within the study area covered in this report. The study evaluated the capacity of local conveyance facilities to deliver stormwater to Richardson Bay for storms up to the 25-year storm event. The study suggested a tidal barrier wall and stormwater pumping as potential solutions to flooding in the Manzanita area. Drainage maps provided within the 2007 study were reviewed and compared with survey data and GIS data to help develop a complete understanding of drainage facilities.

Manzanita West Tidal Flooding Summary (Conatser 2013). This interoffice memorandum, prepared by Marin County Department of Public Works staff, summarized the County's existing knowledge of impacts from tidal flooding in the Manzanita area west of US 101 along SR 1. Key findings summarized in this memorandum include the following:

- In 2012, tides encroached on the SR 1 right-of-way on approximately 242 days, or 66% of the days in the calendar year. The memorandum indicated that the tides encroach onto the shoulder of SR 1 at a tide elevation of 3.0 feet relative to the National Geodetic Vertical Datum of 1929 (NGVD 29), which is roughly equal to 5.6 feet relative to the mean lower low water (MLLW) tidal datum.
- In 2012, tides encroached on the traffic lanes in SR 1 on approximately 63 days, or 17% of the days in the calendar year. The memorandum indicated that the tides encroach on the traffic lanes of SR 1 at a tide elevation of 3.8 feet NGVD 29, which is approximately equal to 6.5 feet MLLW.
- The mean higher high water (MHHW) tidal elevation in Richardson Bay is approximately 3.2 feet NGVD 29, which is roughly equal to 5.9 feet MLLW.
- The primary flow path for tidal flooding is from Coyote Creek, which rises with the tide and floods under an elevated connection to the Bay Trail north of the Holiday Inn Express hotel, and extends up a drainage channel to a culvert under SR 1 on the west side of the Caltrans maintenance yard.

Executive Summary, US 101/SR 1 Junction (Marin County 2019). This document was prepared to summarize flooding for the purpose of securing funding for this study. This document notes that there were six high tide events, from August 2018 to February 2019, that impacted the Park-and-Ride. This document also provides a short summary of the flooding problem and identifies potential strategies for addressing flooding that included installation of check valves in a drain west of US 101, use of active changeable message signs to warn about possible flood events, email or text communications to Park-and-Ride patrons, and the potential raising of SR 1 north of the Manzanita Park-and-Ride.

In response to flooding, Marin County installed a temporary sandbag barrier along the north edge of SR 1 at a low spot near the southwest corner of the Caltrans maintenance yard. This location was historically one of the first spots where tidal waters had encroached on SR 1 during King Tide events. Tidal water regularly inundates the tidal marsh located northeast of the Caltrans maintenance yard and adjacent commercial properties. If the tide rises high enough, tidal water also inundates a drainage channel that extends south from the tidal marsh to a culvert at SR 1 along the west side of the Caltrans maintenance yard. The tide then rises through a catch basin structure along the north curb line of SR 1 to cause shallow flooding in the roadway near the southwest corner of the Caltrans maintenance yard. King Tides have also historically overtopped the sidewalk and curb at this location, causing additional flooding. A sandbag barrier was installed across the back of the sidewalk between the Caltrans maintenance yard and the adjacent commercial property to provide a barrier between the low area to the north and SR 1. In addition, to prevent tide waters from backing up into the catch basin and flooding the roadway, Caltrans installed a tide valve in the culvert between the catch basin and the outlet to the drainage ditch. These improvements appear to have reduced the frequency and extent of flooding, but they have not completely eliminated tidal flooding in this area.

1.3 Related Work

The following key ongoing efforts could impact facilities within the study area. The solutions evaluated by and recommended in this memorandum would need to be carefully coordinated with the following work to ensure compatibility:

- **Planned Improvements to the Bay Trail**: The Marin County Parks Department is working with the Golden Gate National Parks Conservancy and other key stakeholders to evaluate potential improvements to the Bay Trail through the study area. These improvements are intended to improve public use of the trail and enhance the ecological functions of Bothin Marsh and Coyote Creek, where the trail intersects these areas. Conceptual solutions have been developed by Marin County Parks Department and their trail design team (WRT Design). They include alternatives that would reroute the Bay Trail between US 101 and Coyote Creek or elevate the trail through Bothin Marsh. The solutions presented in this report are focused on flood reduction and do not necessarily reflect the alignments or design characteristics of the alternatives being considered by the trail design team. Any improvements made to reduce flooding in the area will need to be well coordinated so that improvements to the Bay Trail are designed to help reduce tidal flooding while also meeting public use enhancement and ecological improvement objectives.

- **Settlement and Upgrades to the Park-and-Ride:** Much of the study area appears to be settling, including the most heavily impacted segment of SR 1, Park-and-Ride facilities, and the Bay Trail. Caltrans has noted that ground settlement has worsened the impact of tidal flooding on the area. Caltrans indicated that some high-level work has been done to identify costs associated with reducing settlement and refurbishing the Park-and-Ride. The early indication is that the cost would be very high. Evaluation of geotechnical conditions and settlement within the area was not part of the scope of this study. However, settlement should be carefully considered before making costly structural improvements, such as raising the Bay Trail or making improvements to the Park-and-Ride.

1.4 Scope of Study and Purpose

The following work was completed as part of this study, in accordance with the approved scope of work between Anchor QEA and Marin County, dated May 12, 2020:

- **Site Assessment and Identification of Constraints, Opportunities, and Data Gaps:** Anchor QEA visited the site with staff from Marin County Public Works and Caltrans to assess site conditions and discuss tide impacts. Anchor QEA also reviewed available background information and worked with Marin County and a local surveyor to collect topographic survey to supplement existing LiDAR data, GIS data, and other information, as needed to provide a more complete understanding of existing conditions and as input to the hydraulic model used to evaluate flooding at the site. A short memorandum was then prepared to summarize conditions at the existing site, identify constraints, summarize data to be used for the study, and identify data gaps. The content of the memorandum has been incorporated into Section 2 of this report.
- **Client Coordination and Stakeholder Collaboration:** Anchor QEA has coordinated work on this study with Marin County and has supported Marin County in collaborating with key stakeholders, including Caltrans, the Marin County Parks Department, and Golden Gate National Parks Conservancy.
- **Hydraulic Analyses:** Anchor QEA developed a two-dimensional hydraulic model to simulate tidal flooding under sunny day conditions at the site using PCSWMM, a stormwater model used to simulate hydraulic conditions in urban drainage basins. A summary of model development and the results of the hydraulic analysis are provided as Section 5 of this report.
- **Conceptual Design Evaluation:** Anchor QEA completed a conceptual design evaluation of potential flood reduction measures. Potential flood reduction measures were identified and evaluated based on a common set of evaluation criteria. The measures were then compared

against one another using an evaluation matrix, which is included in Section 3 of this report. Key measures were then combined into conceptual design alternatives and the alternatives were evaluated and compared against one another using the same evaluation criteria. The alternatives are summarized in Section 4 of this report. The evaluation and comparison of alternatives is summarized in Section 7 of this report. Conceptual drawings were also prepared to illustrate the potential flood reduction measures and alternatives. Those drawings are included in Appendix A to this report.

- **Flood Reduction Study Report:** As a final step, this report was prepared to summarize the flood reduction study. Key findings of the report will be summarized in a presentation to Marin County and key stakeholders after the draft report has been circulated. Comments on the draft report will then be incorporated into a final report.

The purpose of the flood reduction study is to identify and evaluate potential measures that can be implemented in the near term to reduce the impact of flooding on SR 1, the Park-and-Ride, the Bay Trail, and adjacent public facilities and commercial properties. The study will focus primarily on reducing the impacts of flooding that occurs during King Tide events under sunny day conditions. Larger scale solutions, such as major upgrades to SR 1, resolution of settlement issues, major upgrades to the Park-and-Ride, relocation of the Bay Trail, or other large infrastructure improvements, may be needed to provide a comprehensive long-term solution for both tidal flooding and storm-induced flooding, but the focus of this study is relatively small-scale or lower cost solutions that can be implemented in the near term (5 to 10 years) to help reduce the impact of flooding during King Tide events.

1.5 Overview of Report

This report is organized as follows:

- **Section 2 – Existing Study Area Characterization**: This section provides a detailed description of tide conditions, topography, existing infrastructure, and other characteristics of the existing study area. It also summarizes information from the site visit and meeting with Marin County and Caltrans staff, background information and data collected for use as a basis for the study, and site constraints and opportunities.
- **Section 3 – Comparison and Evaluation of Flood Reduction Measures:** This section summarizes the potential flood reduction measures that were identified, describes the criteria and methodology used to evaluate and compare the measures, and provides a comparison of the measures that were identified.
- **Section 4 – Summary of Flood Reduction Alternatives:** This section summarizes each of the flood reduction alternatives that were evaluated as part of this study. Three alternatives were evaluated, each consisting of a combination of the flood reduction measures summarized in Section 3 of this report.

- **Section 5 – Hydraulic Analysis:** This section summarizes the development of the hydraulic model in PCSWMM and summarizes the results of the hydraulic analysis of existing conditions and each flood reduction alternative summarized in Section 4 of this study.
- **Section 6 – Opinions of Probable Cost:** This section summarizes the probable costs of the flood reduction measures that were identified and the probable costs of implementing each of the improvement alternatives.
- **Section 7 – Evaluation and Comparison of Alternatives:** The alternatives summarized in Section 4 were evaluated and compared. This section summarizes this evaluation and provides a matrix comparing the alternatives.
- **Section 8 – Conclusions and Recommended Next Steps:** This section summarizes the key findings from this study and provides recommendations for additional work that can be done to further evaluate flooding in the Manzanita area and implement improvements.

Conceptual design drawings, photographs of the study area, hydraulic analysis results, and other key supporting documents are included as appendices to this study.

2 Existing Study Area Characterization

Anchor QEA visited the study area with staff from Marin County Public Works and Caltrans on June 8, 2020, to discuss the impacts of tidal flooding in the study area, assess site conditions, and review the scope of the flood reduction study. Anchor QEA also collected and reviewed available background information provided by Marin County and Caltrans. Anchor QEA then worked with Marin County and a local surveyor to identify where additional topographic data would be needed to support the study. The surveyor then collected the topographic survey data to supplement existing LiDAR data, GIS data, and other background information. The data were used to develop an understanding of existing site conditions and as input to the hydraulic model used to evaluate flooding at the site. A short memorandum was prepared to summarize existing conditions at the site, site constraints, information about the site, and data gaps for future study (Anchor QEA 2020a). The information provided in that memorandum has been incorporated into this section of the report.

2.1 Description of Study Area

The study area for this project is located approximately 6 miles north of San Francisco, along Richardson Bay in Marin County. The study area is generally bounded on the east by Richardson Bay, on the west by hills that rise west of US 101, on the north by Coyote Creek, and on the south by Gate 6 1/2 Road in Sausalito. US 101 extends through the study area from north to south, and SR 1 extends through the study area from east to west. Within the study area, US 101 crosses Richardson Bay on an elevated bridge that extends over SR 1. Ramps in the study area provide access from SR 1 to US 101. The Park-and-Ride is located under and adjacent to the US 101 bridge along the southwest side of SR 1, as shown in Figure 2-1. The study area also includes other public facilities, including the Bay Trail, private commercial properties, and tidal marsh. The Bay Trail is a heavily used path for cyclists, joggers, and pedestrians and provides a connection for cyclists from Marin County into San Francisco via connection to a trail that crosses the Golden Gate Bridge.

Figure 2-1 provides an overview of existing conditions at the site, including aerial photography, topography, and the locations of key drainage infrastructure. More detailed mapping of the existing conditions at the site is provided as Figures EC-1, EC-2, and EC-3 in Appendix A. These figures also show the extent of tidal flooding under the maximum observed tide condition at the site, as simulated by the hydraulic model that is summarized in more detail in Section 5. The Park-and-Ride, the segment of SR 1 adjacent to the Park-and-Ride, the Caltrans maintenance yard, and the Bay Trail are all within a relatively low-lying area prone to flooding during high tide events. Flooding in the area will be further impacted by future sea level rise.

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Figure 2-1
Detailed Study Area Map

2.1.1 Tide Conditions

The National Oceanic and Atmospheric Administration (NOAA) maintains several stations within San Francisco Bay that monitor tide conditions. Forecasted tide conditions and historical tidal information are available from the NOAA Tides and Currents site (NOAA 2020). The San Francisco Tide Station (ID 9414290) was selected as the reference station for this study based on relative proximity to the site and the extensive record of available data. Tides have been monitored by NOAA at the San Francisco station since June 1854. The station is located at the north end of the San Francisco Peninsula adjacent to the Golden Gate Bridge, approximately 7 miles south of the study area.

Table 2-1 provides a summary of tidal datums at the site and their relationship to the MLLW tidal datum. The LiDAR data and topographic survey used as a basis for this study are based on the North American Vertical Datum of 1988 (NAVD 88). Elevations presented in this study are reported relative to NAVD 88, unless specified otherwise. As indicated in Table 2-1, the NAVD 88 datum at San Francisco (NOAA Station 9414290) is only 0.06 foot below MLLW. Table 2-2 provides a summary of key tidal elevations at San Francisco (NOAA Station 9414290) relative to both MLLW and NAVD 88.

Table 2-1
Summary of Tidal Datums Relative to MLLW, San Francisco (Station 9414290)

Datum	Elevation, MLLW (Feet)
North American Vertical Datum of 1988 (NAVD 88)	-0.06
Mean Lower Low Water (MLLW)	0.00
Mean Low Water (MLW)	1.13
Mean Sea Level (MSL)	3.12
Mean High Water (MHW)	5.23
Mean Higher High Water (MHHW)	5.84

Table 2-2
Key Tidal Elevations Relative to NAVD 88 and MLLW, San Francisco (Station 9414290)

Datum	Elevation, NAVD 88 (Feet)	Elevation, MLLW (Feet)
North American Vertical Datum of 1988 (NAVD 88)	0.00	-0.06
Mean Lower Low Water (MLLW)	0.06	0.00
Mean High Water (MHW)	5.29	5.23
Mean Higher High Water (MHHW)	5.90	5.84
Highest Astronomical Tide (HAT)	7.32	7.26
Maximum Tide Observed (01/27/1983)	8.72	8.66
Minimum Tide Observed (12/17/1933)	-2.82	-2.88

Figures 2-2, 2-3, and 2-4 show observed tide cycles at San Francisco (NOAA Station 9414290) for periods of time where exceptionally high tides were recorded, as follows:

- Figure 2-2 charts tides observed from December 1, 1982, through January 31, 1983. This period includes the highest tide ever measured at San Francisco (NOAA Station 9414290) on January 27, 1983, at 8.72 NAVD 88 (8.66 feet MLLW).
- Figure 2-3 charts tides observed from February 1, 1998, through February 28, 1998. This period included a high tide of 8.49 NAVD 88 (8.43 feet MLLW).
- Figure 2-4 charts tides observed from January 1, 2019, to February 28, 2019. This recent period included several high tides that exceeded 7.50 feet NAVD 88.

These high tide events are often referred to as "King Tides," a non-scientific term used to describe the semi-annual astronomical perigean high tides. Within the study area, high tide events occur several times each year that cause shallow flooding. For example, Marin County found that from August 2018 to February 2019, there were six high tide events that impacted the Park-and-Ride. More frequent tide events result in shallow flooding along SR 1. Section 2.1.2 summarizes the topography of the study area. Several key areas lie below an elevation of 7.00 feet NAVD 88. Whenever the tide exceeds the elevation of these low-lying areas, shallow flooding occurs.

2.1.2 Topography

The detailed topographic survey of the study area is included as Appendix B. Elevations at the site vary from sea level, along the east side of the study area and at Coyote Creek, to more than 150 feet along the hillsides west of US 101 and south of SR 1. The Park-and-Ride, the segment of SR 1 adjacent to the Park-and-Ride, the Caltrans maintenance yard, and the Bay Trail are all within a relatively low-lying area prone to flooding during high tide events. The ground elevations of key facilities within the study area are as follows:

- Elevations along the segment of SR 1 adjacent to the Park-and-Ride and Caltrans maintenance yard range from just under 6 feet up to 8 feet.
- Elevations within the Caltrans maintenance yard range from approximately 7 feet, near the SR 1 frontage, to nearly 9 feet, along the north edge of the property.
- Elevations along the Bay Trail range from just under 7 feet to nearly 8 feet The lowest elevations are just northwest of the US 101 bridge, just southeast of the US 101 bridge, and south of Pahono Street near the Seaplane Adventures commercial property.
- Elevations of the travel and parking surface within the Park-and-Ride vary from less than 6 feet, along the east edge of the Park-and-Ride, to nearly 10 feet, along the southwest edge of the Park-and-Ride.
- Elevations in the parking area around the Holiday Inn Express vary from approximately 6 feet to more than 9 feet.

Figure 2-2
Observed Tides, NOAA Station 9414290, San Francisco (12/1/1982 to 1/31/1983)

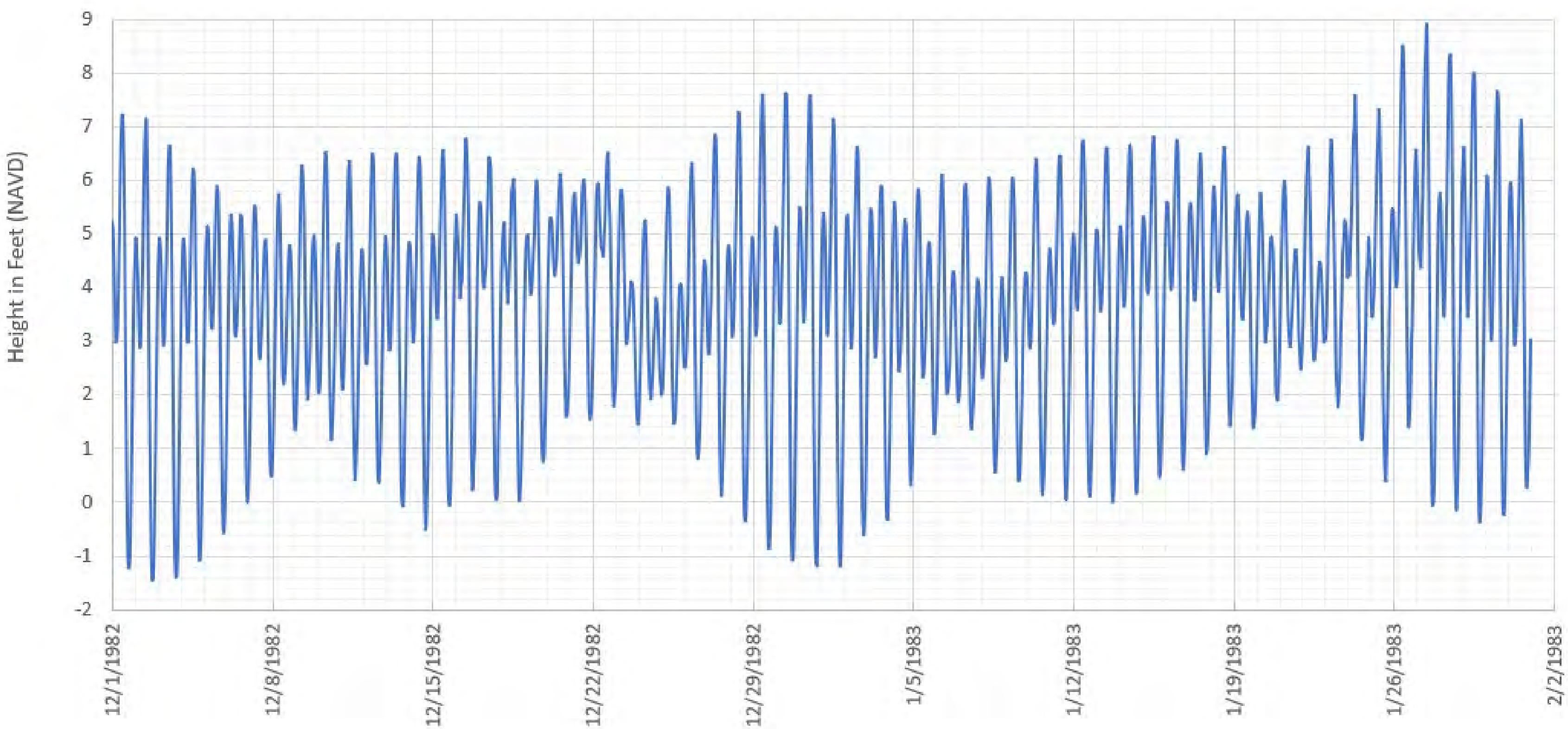


Figure 2-3
Observed Tides, NOAA Station 9414290, San Francisco (2/1/1998 to 2/28/1998)

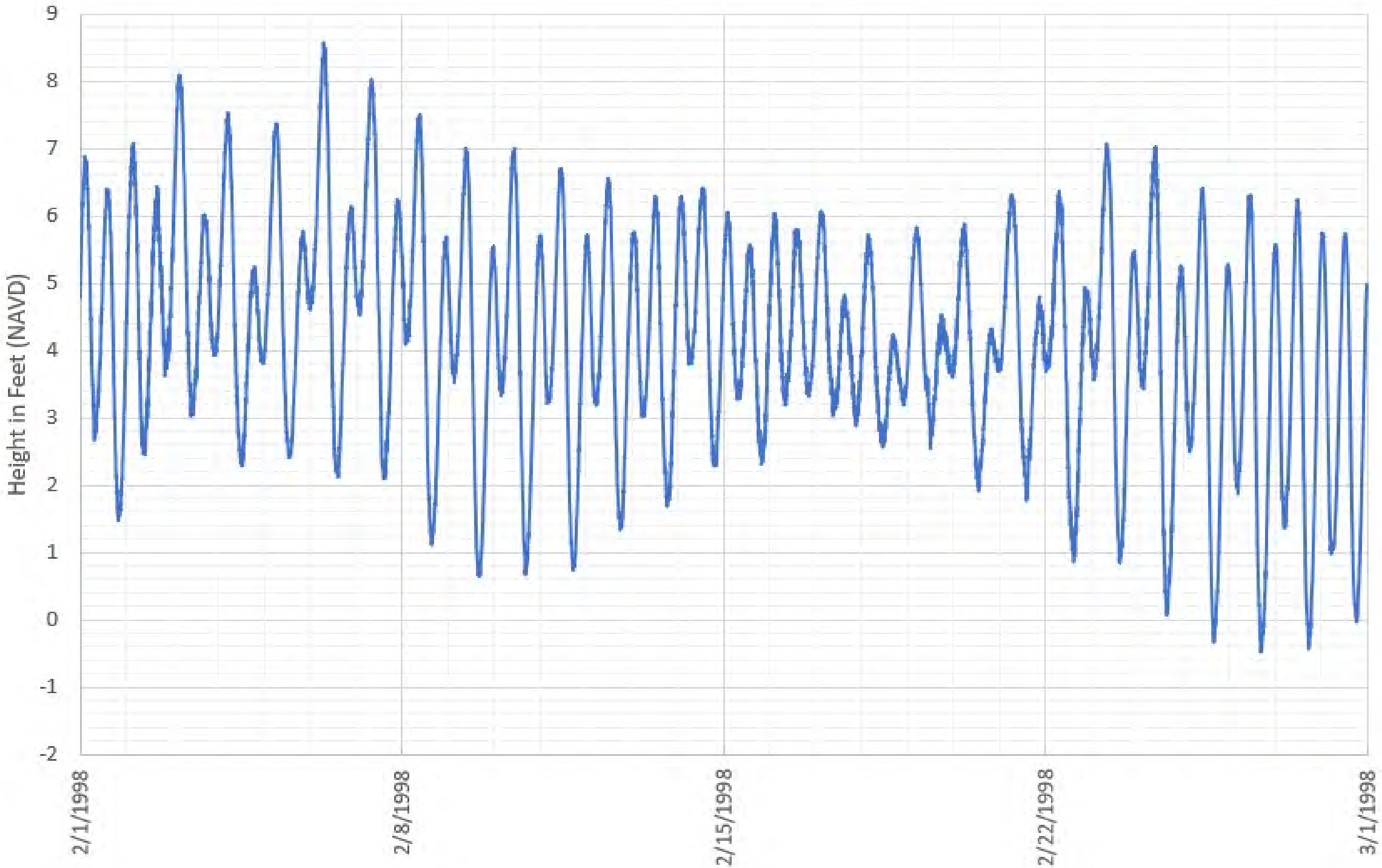
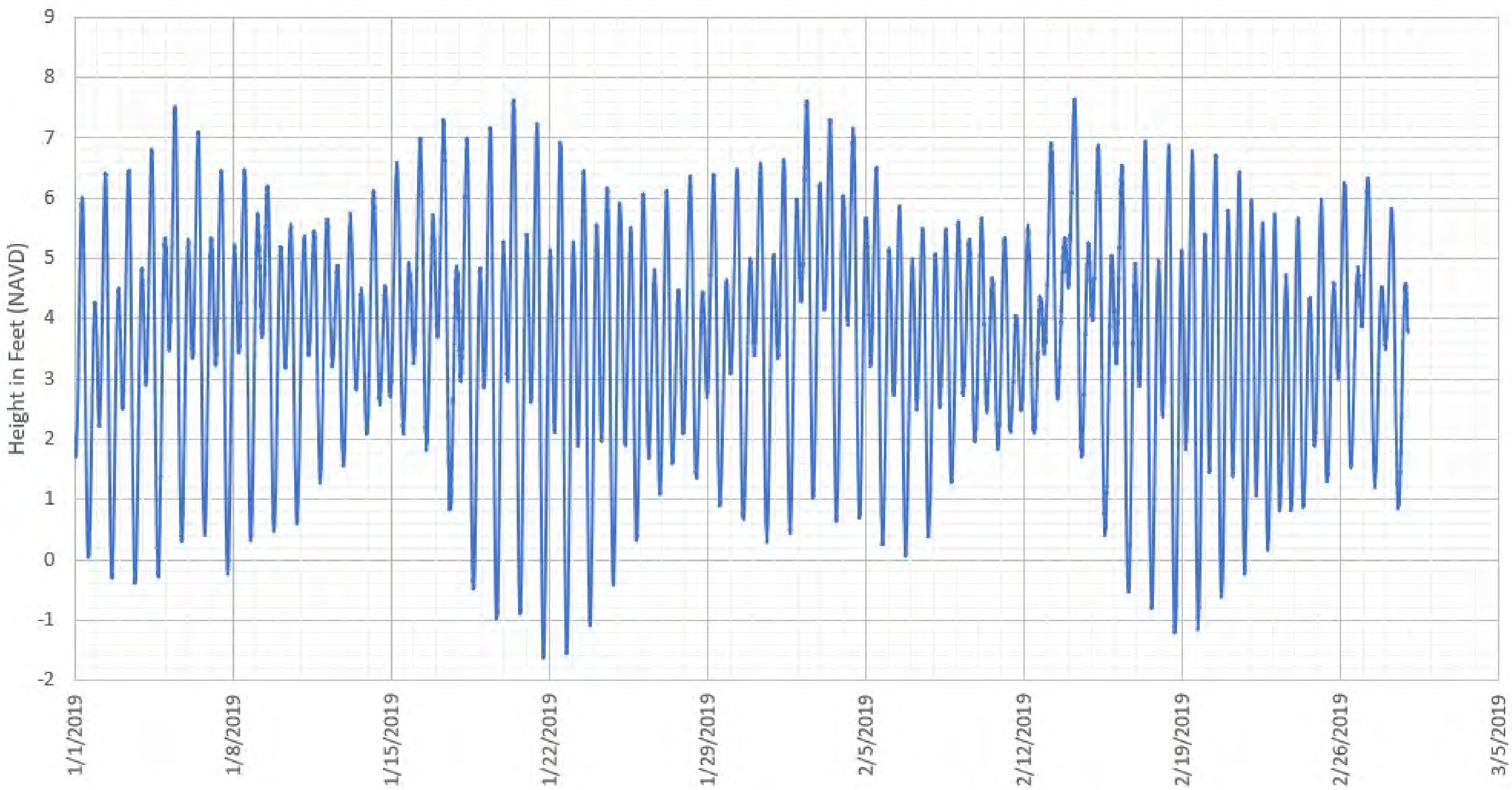


Figure 2-4
Observed Tides, NOAA Station 9414290, San Francisco (1/1/2019 to 2/28/2019)



2.1.3 Existing Drainage Infrastructure

A network of stormwater collection and conveyance facilities serve the study area. A series of catch basins, inlets, and manholes collect stormwater runoff from roadway and parking surfaces in the area. Stormwater is conveyed to tidal marshes, Coyote Creek, or Richardson Bay via a network of storm drain pipes, culverts, and ditches. These facilities are shown in Figure 2-1 and in more detail on Figures EC-1, EC-2, and EC-3. Key facilities include the following:

- A 24-inch corrugated metal pipe (CMP) culvert drains the tidal marsh between the Bay Trail and the commercial properties to the southwest. The culvert discharges to Coyote Creek and passes under a trail connection to the Bay Trail. The culvert also provides a hydraulic connection for tidal water to enter the marsh. When the tide is high enough, tidal water can also enter the marsh by passing under a portion of the connecting path that is a slightly elevated boardwalk.
- A small network of storm drains captures water at the northeast corner of the parking lot around the Holiday Inn Express hotel and discharges through an outfall located in the tidal marsh near the 24-inch CMP culvert. The tide often backs up through this outfall and floods the northeast corner of the parking lot at the hotel.
- A network of storm drains, ranging in size from 4-inch diameter to 18-inch diameter pipe, drains remaining parking areas around the Holiday Inn Express and the adjacent commercial buildings to an outfall located in the tidal marsh near Coyote Creek. The tide also regularly backs up through this system and can cause shallow flooding at low-lying storm drain inlets in the parking lot around these commercial buildings and in ditches connected to this storm drain system along the south side of SR 1.
- A network of storm drains, ranging in size from 12-inch diameter to 24-inch diameter pipe, drains the remaining commercial areas along SR 1 west of the US 101 bridge. These storm drain systems discharge to a channel that runs north to the tidal marsh between the Caltrans maintenance yard and the commercial property to the west. A 24-inch CMP culvert at the downstream end of this channel conveys water from the channel to the marsh. The tide backs up through this culvert into the channel and into the storm drain system at SR 1. As noted earlier, a sandbag barrier was installed along the north edge of SR 1 and a tide valve was installed on the pipe outlet from this storm drain system to reduce the impact of tidal flooding on SR 1.
- A network of storm drains, ranging in size from 8-inch diameter to 24-inch diameter pipe, drains the Park-and-Ride and areas upslope. These systems discharge to a ditch that runs along the east side of the Park-and-Ride, between the Park-and-Ride and SR 1. The tide often backs up into this ditch and floods the lower areas along the east edge of the Park-and-Ride adjacent to the ditch.

- A 12-inch reinforced concrete pipe (RCP) culvert conveys drainage collected in the ditches along the east and north sides of the Park-and-Ride under SR 1 to a ditch that collects water along the northeast side of SR 1. Only the north end of this culvert was located by the topographic survey, likely because the culvert is typically submerged or buried in sediment. Additional work may be needed to verify the size and condition of this culvert.
- The ditch that collects water along the northeast edge of SR 1 east of US 101 also collects drainage discharge from a series of storm drain systems that serve parking and roadway surfaces adjacent to some of the commercial properties east of SR 1. The ditch and a series of culverts convey water along the northeast edge of SR 1 to a gated structure between SR 1 and the Bay Trail right under the east edge of the US 101 bridge. The structure includes two 48-inch slide gates with hand-wheel operators. The slide gates are manually raised and lowered to help manage drainage and to prevent tidal water from backing up into the ditch from culverts that outfall to Richardson Bay. The bottom of the gates are buried in sediment, which makes fully opening and closing the gates a challenge.
- Parallel 36-inch and 48-inch RCP culverts convey water to an outfall location on Richardson Bay just east of the US 101 bridge. Storm drain systems from adjacent parking surfaces also discharge water into the structures along the outfall pipe. The outfall provides the primary connection for drainage to Richardson Bay from the Park-and-Ride, roadway surfaces, the surface of US 101, and commercial properties east of US 101. If the gates on the outfall are not fully closed, the tide can back up through the outfall pipes into the ditch system.

2.2 Observations from Site Visit and Meeting with Caltrans

As an initial step toward assessing existing site conditions, Anchor QEA's project manager, project engineer, and hydraulic engineer visited the site and met with Roger Leventhal (Marin County), Will Hauke (Caltrans), Chad Klein (Caltrans), and the project surveyor, Jim Dickey (Cinquini and Passarino). The Caltrans representatives work at the Caltrans maintenance yard adjacent to SR 1 and the Park-and-Ride and are very familiar with the study area, where and when flooding occurs, and what impacts result from flooding.

The following are key observations gathered during the site visit and discussion with Marin County and Caltrans:

- SR 1 has settled under the US 101 bridge adjacent to the Park-and-Ride, which has exacerbated the effects of flooding on SR 1.
- Caltrans installed a tide valve on the downstream side of the culvert adjacent to (just west of) their maintenance yard to reduce the potential for the tide to back up through the culvert to the south side of SR 1.
- Marin County installed the sandbag barrier along the top of the culvert crossing, adjacent to the Caltrans maintenance yard on the north side of SR 1, as an additional control.

- Caltrans believes that the Bay Trail has also settled. Historically, flooding over the path would not occur until tides were at approximately 6.6 feet MLLW (6.5 feet NAVD 88) or higher. Their recent observations indicate that flooding over the path occurs when tides reach approximately 6.4 feet MLLW (6.3 feet NAVD 88).
- The tides back up into ditches, culverts, and storm drains until they flood SR 1. The lowest point on SR 1 is directly under US 101 and at the entrance to the Park-and-Ride.
- During mild flood conditions, Caltrans can reroute traffic onto a higher frontage road to the ramp that accesses southbound US 101 from SR 1. During more intense flooding, SR 1 must be completely closed through this area.
- When SR 1 is completely closed, some residents of Manzanita and the south end of Mill Valley and Talmapais Valley must detour up to 20 minutes to access US 101.
- Traffic control during flood events is labor intensive and expensive.
- Saltwater flooding damages the pavement along SR 1 and in the Park-and-Ride.
- Maintenance of these facilities has been very challenging due to the impacts of flooding.
- Flood reduction efforts will likely need to include adjustments to the Bay Trail to prevent or reduce flooding over the path. Once the path is overtopped, flooding extends inland to SR 1 and the Park-and-Ride.

Photographs of key site features are included in Appendix C.

2.3 Background Information

2.3.1 Sources of Data Used for this Study

Background data for this study were provided by Marin County. Key sources of data used to support this study included the following:

- **LiDAR Data:** High-resolution aerial LiDAR elevation data were provided by Marin County. The data were collected in 2019 and extend throughout the study area but do not include ground elevations under the US 101 bridge.
- **Other GIS Data:** GIS data for key features within the study area were downloaded from the Marin Map, a public online GIS database hosted by Marin County. The data downloaded for this study included the following:
  - Parcel data
  - Storm drains, culverts, and stormwater channels
  - Stormwater structures (manholes and catch basins)
  - Stormwater ponds
  - Other pertinent utility data available from the Marin Map
- **Prior Studies:** The studies outlined in Section 1.2 were reviewed and used to provide additional context for the work.

- **Tide Data:** Data on tides provided by the NOAA Tides and Currents web site were used. The nearest station is Station 9414806 at Sausalito, just south of the project area. The station with the longest period of record is Station 9414290 at San Francisco, near the Golden Gate Bridge, 6 miles south of the project site. As noted previously, Station 9414290 was selected for reference because of proximity and the longer period of record of available data.

2.3.2 Topographic Survey

A detailed topographic survey was also completed by Cinquini and Passarino to supplement elevation data provided by Marin County and to identify elevations and sizes of key storm drainage facilities that were not clearly mapped or identified in the County GIS mapping.

The topographic survey included collection of the following data:

- Surface topography for the area under the US 101 bridge and the northbound off-ramp at SR 1, including the Park-and-Ride area and the portion of SR 1 that extends under US 101
- The clearance under the US 101 bridge at the edge of asphalt on both the north and south sides of SR 1
- Surface topography of approximately 250 feet of the Bay Trail, including points along the edges of the path west of the US 101 bridge
- Surface topography of approximately 250 feet of the Bay Trail, including points along the edges of the path in front of the Commodore Marina
- Rim elevations, structure type, and lid or grate type for various drainage structures

The topographic survey data have been provided on California Coordinate System of 1983, Zone 3 and NAVD 88. A PDF copy of the completed survey is included as Appendix B. The data were combined with LiDAR topography and GIS data on the storm drainage system from the Marin County GIS database to provide a more complete dataset and surface that represent the existing conditions within the study area.

2.3.3 Additional Data Needs for Future Study

The background data and topographic survey listed in this section were used for the needs of the Manzanita Flood Reduction Study. However, additional data may be needed to support detailed design and implementation of the solutions that will be identified in the study. Additional data needs may include, but are not limited to, the following:

- Additional survey data in areas where infrastructure may be modified by a proposed solution
- Verification of some storm drain sizes and invert elevations
- Record drawings for infrastructure that may be modified by a proposed solution
- Groundwater data
- Stormwater flow data

- Regulatory requirements for solutions proposed by the study
- Detail on existing utilities that may be affected by a proposed solution

2.4 Key Site Constraints

The primary site constraints identified through the site visit, collection and review of background information, and topographic survey include the following:

- **Tides and Future Sea Level Rise –** Implementation of flood reduction measures will need to consider the full range of current tide conditions and future sea level rise. This study is focused on near-term improvements, so tide scenarios used for the hydraulic analysis of potential flood control measures do not include future sea-level rise scenarios. However, resilience and ability to accommodate future sea level rise was a key criterion used to evaluate flood reduction measures and alternatives.
- **Public Facilities and Right-of-Way –** US 101 and SR 1 are key transportation corridors in Marin County. Flood reduction measures will need to be designed and implemented in a way that will not reduce or negatively impact the capacity and service level of these facilities in the near term.
- **Commercial Properties –** The study area includes private commercial properties that are affected by shallow flooding and that discharge stormwater to Richardson Bay, adjacent tidal marshes, or Coyote Creek. The impact of potential flood reduction on commercial properties will need to be considered. Flood reduction measures will need to be designed and implemented in a way that preserves existing access constraints and does not increase impacts to these properties.
- **Tidal Marshes –** The impact of the potential flood reduction measures on tidal marsh areas will need to be considered. Permitting of improvements within areas currently inundated by tides may be challenging.
- **Settlement –** Caltrans indicated that there are significant settlement issues associated with the Park-and-Ride, SR 1, the Bay Trail, and adjacent surfaces. The settlement has worsened the impact of shallow tidal flooding. Evaluating the settlement issues and recommending potential solutions is beyond the scope of this study. However, any flood reduction measures will need to consider future settlement as a constraint.

3 Comparison and Evaluation of Flood Reduction Measures

This study identified and evaluated a series of potential flood reduction measures. These were initial summarized in a short memorandum submitted to Marin County (Anchor QEA 2020b). The content of that memorandum and the evaluation of flood reduction measures was then refined, based on feedback from Marin County, and has been incorporated into this section. The measures identified are intended to represent relatively small-scale or lower cost improvements that can be implemented in the near term (5 to 10 years) to reduce the impact of tidal flooding on SR 1, the Park-and-Ride, the Bay Trail, and adjacent public facilities and commercial properties. This section summarizes the criteria and methodology used to evaluate flood reduction measures and summarizes the potential flood reduction measures that were identified, evaluated, and compared as part of this study.

3.1 Criteria for Evaluating Flood Reduction Measures

Table 3-1 summarizes criteria that were used to evaluate flood reduction measures as part of the flood reduction study. The criteria are not listed by priority or in any particular order of significance.

Table 3-1
Summary of Criteria for Evaluating Flood Reduction Measures

Criteria	Description
Flood Reduction Effectiveness	This criterion is intended to measure how effective a particular flood reduction measure would be in reducing the impact of flooding in the study area during King Tide conditions on a sunny day. Flood reduction measures that have potential to reduce flooding over a larger area and under a wider range of conditions were given the most favorable scoring.
Reliability/Resilience (Future Sea Level Rise)	This criterion is intended to measure how reliably a flood reduction measure would reduce sunny day flooding impacts under the full range of existing and future tide conditions at the site. This includes how resilient a flood reduction measure would be to predicted sea level rise conditions. Flood reduction measures that are more reliable and resilient to a wider range of conditions were given a more favorable scoring than those that are less adaptable to changing conditions.
Impacts to Stormwater Flooding	This criterion is intended to measure the potential impact of a flood control measure on storm-related flood protection. Because this study is focused on reducing sunny day tidal flooding, flooding that results from storm events has not been analyzed in detail. However, evaluation of this criterion will attempt to characterize whether a flood reduction measure has potential to also reduce or amplify flood impacts that result from runoff during storm events. Flood reduction measures that have potential to reduce storm-related flood impacts were given a more favorable scoring than those that do not.
Permitting Complexity	This criterion is intended to measure the complexity of permitting a flood reduction measure. Those that would have more impact on environmental and other critical resources would take more time and effort to plan and permit. Those measures that would require less effort to plan and permit were given a more favorable scoring.

Criteria	Description
Property Impacts	This criterion is intended to measure challenges or complications that would result from impacts to private property needed to implement a flood reduction measure. Those measures that would require extensive coordination with property owners and impact existing and future uses of private property were given less favorable scoring than those that would have little or no impact on private property.
Public Use Impacts	This criterion is intended to measure impacts to the use of public facilities, including the Bay Trail, public roadways, and other facilities. Those measures that would enhance or facilitate improved use of public facilities were given a more favorable scoring than measures that would constrain or impact the use of public facilities.
Relative Cost	This criterion is intended to measure the order-of-magnitude difference in cost to implement various flood reduction measures. The overall cost and the magnitude of the cost relative to the flood reduction benefit were both considered.
Constructability	This criterion is intended to measure the complexity of constructing or installing a flood reduction measure. Those measures that would require more effort to construct or install were give a less favorable score than those that can be easily implemented.
Operations and Maintenance	This criterion is intended to measure the effort that would be required to operate and maintain a flood reduction measure over the long term. Those measures that would have few operation and maintenance requirements were given a more favorable score than those that would require regular inspection, maintenance, and repair.

3.2 Methodology for Evaluating Flood Reduction Measures

The following methodology summarizes the steps that were used to evaluate flood reduction measures for this study and includes additional steps that were used to evaluate alternatives and select a preferred flood reduction alternative to be implemented at the site:

1. A brainstorming exercise was completed to identify a wide range of potential flood reduction measures that could be applied to reduce flooding at the site. These flood reduction measures are summarized in Section 3.3.
2. A table or matrix was prepared (see Table 3-4) that identifies, characterizes, and compares different flood reduction measures according to the criteria summarized in Table 3-1.
3. A favorability score from 1 to 5 was given to each measure for each criterion, as summarized in Table 3-2. Scoring was based on the description of the criteria outlined in Table 3-1, with higher scores given if a measure was determined to perform more favorably for a given criterion.
4. Scores were totaled as a way to compare the performance of flood reduction measures. The criteria were not weighted to develop a total score.
5. Anchor QEA made adjustments to the evaluation and scoring of flood reduction measures with input from Marin County.
6. Anchor QEA developed three conceptual design alternatives, as summarized in Section 4. Each alternative includes a combination of flood reduction measures intended to reduce tidal flooding under sunny day conditions within the study area.

7. Analyses were completed to model the effectiveness of each alternative in reducing flooding, and an opinion of the probable costs was developed for implementing each alternative.
8. After identifying alternatives, Anchor QEA applied the same criteria and scoring methodology outlined in Steps 1 through 4 to each alternative to evaluate the favorability of each alternative.
9. A matrix (see Table 7-1) was prepared to compare the alternatives.

The evaluation results are presented in this report, with recommendations for further study so that Marin County and Caltrans can consider the alternatives and select a preferred alternative for further evaluation and design.

Table 3-2
Summary of Criteria Scoring

Rating	Scoring Symbol/Number
Low (Least Favorable)	1
Medium Low	2
Medium	3
Medium High	4
High (Most Favorable)	5

3.3 Identification of Potential Flood Reduction Measures

Potential flood reduction measures were identified through engineering experience, research, and brainstorming. The flood reduction measures that were identified generally fall into the following categories:

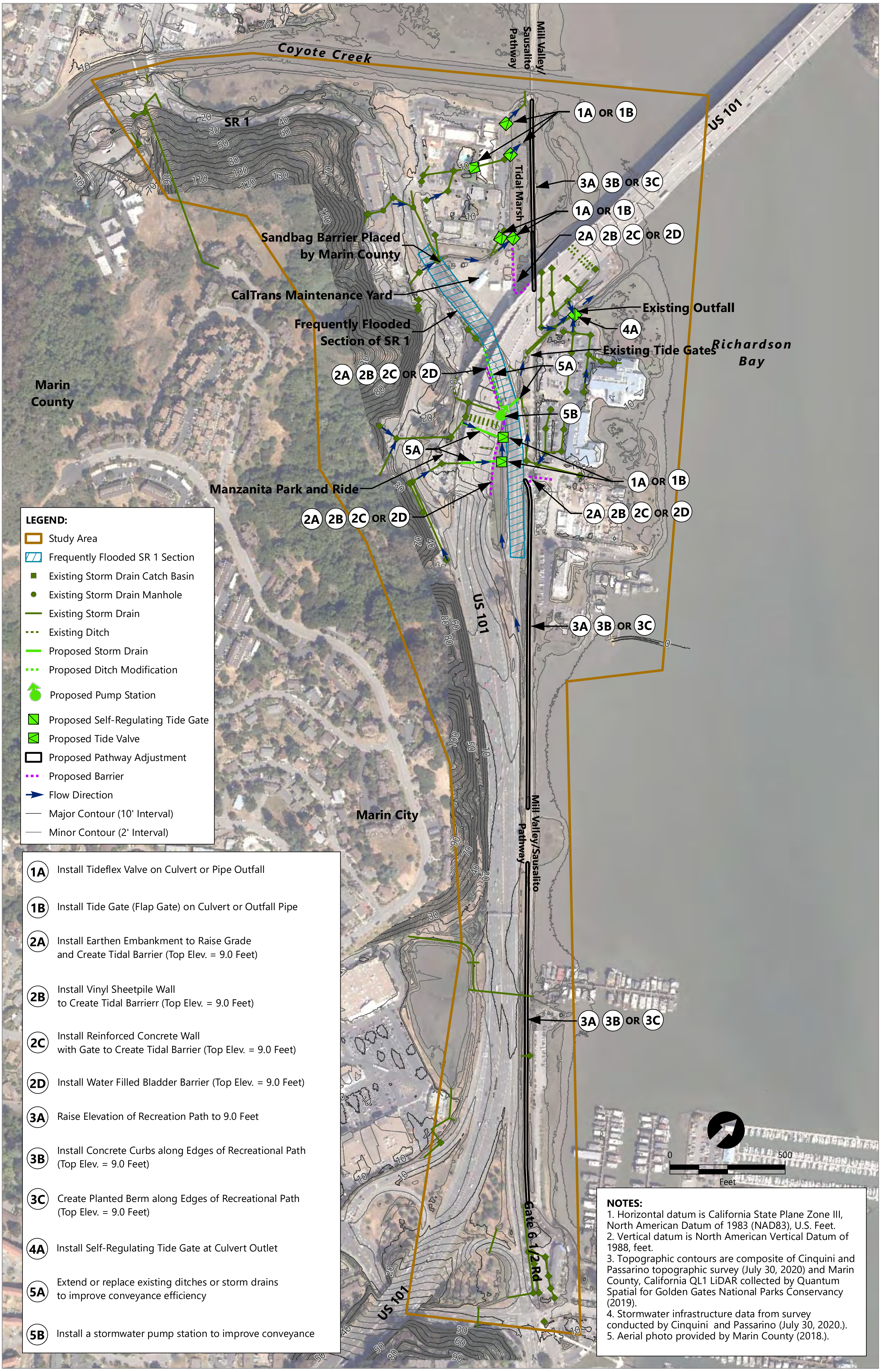
1. Measures that would prevent tidal waters from backing up through culverts and storm drains into areas that are currently flooding.
2. Measures that would create a barrier across a low spot to separate upland areas that are prone to tidal flooding from low-lying tidal areas.
3. Measures that would modify the Bay Trail to protect the Bay Trail from tidal flooding. Raising the Bay Trail alone will not prevent flooding of upland areas because the tide can reach those areas without overtopping the trail.
4. A measure that would improve control of tidal inundation at the outlet of the major storm drain outfall in the study area.
5. Measures that would improve the conveyance efficiency through the storm drain system to improve the conveyance of flood water to Richardson Bay.

Table 3-3 provides a brief description of each potential flood reduction measure. Figure 3-1 illustrates where these potential flood reduction measures could be applied within the study area to reduce shallow tidal flooding. A conceptual section or detail showing what each of these flood control measures might look like is included in Figures C-1 through C-5 in Appendix A. Examples of manufactured flood reduction measures (1A, 1B, 2D, and 4A) are included in Appendix D.

Table 3-3
Potential Flood Reduction Measures

Measure	Description
1A	**Tideflex Valve, or Equal:** Install a flexible, duck-bill style rubber check valve inside or at the end of a culvert or storm drain outfall pipe to prevent the tide from backing up through the culvert or outfall pipe and flooding upland areas.
1B	**Tide (Flap) Gate, or Equal:** Install a metal flap gate at the end of a culvert or outfall pipe to prevent the tide from backing up through the culvert or outfall pipe and flooding upland areas.
2A	**Earthen Embankment:** Grade and vegetate a small berm or embankment to create a tidal barrier. This would be applied to relatively narrow, low areas that currently provide a path for the tide to enter and flood upland areas, such as the low area between the Caltrans maintenance yard and the adjacent commercial property.
2B	**Vinyl Sheet Pile Wall:** Install a vinyl sheet pile wall with a reinforced concrete cap to create a tidal barrier. This would also be applied to relatively narrow, low areas that currently provide a path for the tide to enter and flood upland areas, such as the low area between the Caltrans maintenance yard and the adjacent commercial property.
2C	**Reinforced Concrete Wall:** Install a reinforced concrete wall to create a tidal barrier. The wall could be constructed with a gate or stop log controls to allow tidal exchange, if desired, but also provide protection against high tides. This would also be applied to relatively narrow, low areas that currently provide a path for the tide to enter and flood upland areas, such as the low area between the Caltrans maintenance yard and the adjacent commercial property.
2D	**Water-Filled Bladder Barrier:** Install a water-filled bladder to create a tidal barrier. Bladders could be constructed across relatively narrow, low areas that currently provide a path for the tide to enter and flood upland areas, such as the low area between the Caltrans maintenance yard and the adjacent commercial property. The bladder could be filled in anticipation of high tide events and then emptied when not needed as a tidal barrier.
3A	**Raise Elevation of the Bay Trail:** Raise the elevation of the Bay Trail to at least 9.0 feet NAVD 88 through the study area to prevent high tides from overtopping the path.
3B	**Concrete Curbs Along the Bay Trail:** Install concrete curbs along both sides of the Bay Trail to provide a barrier between the trail and the tide to an elevation of at least 9.0 feet NAVD 88 through the study area.
3C	**Planted Berms Along the Bay Trail:** Install earthen berms along both sides of the Bay Trail to provide a barrier between the trail and the tide to an elevation of at least 9.0 feet NAVD 88 through the study area. Berms would be planted with tide-resistant plants.
4A	**Self-Regulating Tide Gates:** Install self-regulating or automatic tide gates on the primary stormwater outfall east of US 101. The existing outfall has slide gates at the upstream end that can be lowered and raised manually to control tides, but Caltrans has indicated that sediment and debris collect at the bottom of the gates, which makes it hard to completely close them. This measure would add another more automatic way of controlling the influence of the tides on that outfall.

Measure	Description
5A	**Storm Drain Improvements:** Install new storm drains, extend existing storm drains, or replace existing storm drains to improve the flow of water from flooded areas to Richardson Bay. When flooding occurs in response to King Tides, the shallow flooding typically recedes well after tide levels have dropped. The lag in the shallow flood response to tides dropping is especially pronounced where limited storm drain capacity exists. The additional capacity would also help reduce flooding that results from storm events.
5B	**Stormwater Pumping:** Install a stormwater pump station to alleviate shallow flooding in an area that is low and prone to flooding.



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ANCHOR QEA

Figure 3-1
Map of Potential Flood Reduction Measures

3.4 Comparison of Flood Reduction Measures

Table 3-4 summarizes the evaluation of the flood reduction measures listed in Table 3-3. The measures were evaluated, compared, and contrasted based on the criteria and methodology established in this memorandum. It is likely that a combination of measures will be required as part of an effective solution that maximizes flood reduction benefits. The following are general conclusions drawn from the comparison of the flood reduction measures that were identified:

- The most favorable overall solutions include the following:
  - Installing Tideflex valves or tide gates on outfalls and culverts to prevent tide water from backing up into culverts and the storm drain system
  - Installing vinyl sheet pile walls or concrete walls to provide a barrier against the tide across low spots adjacent to the marsh and ditch areas that experience tidal flooding
  - Raising the grade of the Bay Trail, initially in targeted areas needed to provide an effective barrier to tidal flood paths that reach SR 1 and then, further in the future, raising all segments of the Bay Trail to an elevation of 9.0 feet to prevent the tide from overtopping the trail and impacting its use
  - Installing some targeted storm drainage upgrades to improve conveyance efficiency
- None of the solutions alone would prevent tidal flooding. For example, if Tideflex valves are installed on key culverts and storm drain outfalls, areas upstream would still flood when the tides breached the ground elevations or the Bay Trail at points of low elevation. A combination of measures will be required to significantly reduce flooding in the area. No solution will be able to create a complete barrier to tide intrusion without a combination of valves or gates on outfalls and culverts, barriers at key locations, and at least some targeted raising of the Bay Trail.
- Although this study is intended to be focused on solutions that would be relatively easy to implement and have potential to reduce tidal flooding in the near term, the measures identified vary in complexity, expense, and the time required for implementation. The measures that are more complex and expensive include longer walls or berms, raising the elevation or modifying the Bay Trail, and installing a stormwater pump station. In most cases, the complexity, potential permitting difficulties, and cost of these solutions drove down the overall score.

Table 3-4
Evaluation and Comparison of Potential Flood Reduction Measures

Information or Criteria	Measure 1A	Measure 1B	Measure 2A	Measure 2B	Measure 2C	Measure 2D	Measure 3A	Measure 3B	Measure 3C	Measure 4A	Measure 5A	Measure 5B
Description	Tideflex Valve, or Equal	Tide (Flap) Gate, or Equal	Earthen Embankment	Vinyl Sheet Pile Wall	Reinforced Concrete Wall	Water-Filled Bladder Barrier	Raise Elevation of the Bay Trail	Concrete Curbs Along the Bay Trail	Planted Berms Along the Bay Trail	Self-Regulating or Automatic Tide Gate	Storm Drain Improvements	Stormwater Pump Station
Where would it be applied?	Culvert North of Holiday Inn; Storm Drains Near Holiday Inn, Storm Drain NW of Caltrans Maintenance Yard Culvert NW of Caltrans Maintenance Yard	Culvert North of Holiday Inn, Storm Drains Near Holiday Inn, Storm Drain NW of Caltrans Maintenance Yard Culvert NW of Caltrans Maintenance Yard	Low Spot North of Caltrans Maintenance Yard; Low Spots East of Caltrans Maintenance Yard; Along East Side of Park-and-Ride Under US 101; Low Spots Near Seaplane Adventures	Low Spot North of Caltrans Maintenance Yard; Low Spots East of Caltrans Maintenance Yard; Along East Side of Park-and-Ride Under US 101; Low Spots Near Seaplane Adventures	Low Spot North of Caltrans Maintenance Yard; Low Spots East of Caltrans Maintenance Yard; Along East Side of Park-and-Ride Under US 101; Low Spots Near Seaplane Adventures	Low Spot North of Caltrans Maintenance Yard; Low Spots East of Caltrans Maintenance Yard; Along East Side of Park-and-Ride Under US 101; Low Spots Near Seaplane Adventures	Segments of Trail Where Surface Elevation is Less than 9.0 Feet NAVD 88	Segments of Trail Where Surface Elevation is Less than 9.0 Feet NAVD 88	Segments of Trail Where Surface Elevation is Less than 9.0 Feet NAVD 88	Outfall on East Side of US 101 Bridge, West of Glass Door	Improve Ditch, South Side of SR 1 near Park-and-Ride; Culvert Under SR 1 from Low Spot Near Park-and-Ride; Storm Drains in Park-and-Ride	Near Low Spot in Park-and-Ride
Flood Reduction Effectiveness	Effective at preventing tide from entering pipe or culvert. Would need to be combined with other measures to prevent flooding upstream of pipe or culvert. 4	Effective at preventing tide from entering pipe or culvert, but flap gates are more prone to catching debris. Would need to be combined with other measures to prevent flooding upstream of pipe or culvert. 3	Provides a barrier to prevent tide from overtopping and flooding low-lying areas upland of the embankment, but would need to be combined with other measures. Effectiveness could be affected by erosion. 3	Provides a fixed barrier to prevent tide from overtopping and flooding low-lying areas upland of wall, but would need to be combined with other measures. 4	Provides a fixed barrier to prevent tide from overtopping and flooding low-lying areas upland of wall, but would need to be combined with other measures. 4	Provides a fixed barrier to prevent tide from overtopping and flooding low-lying areas upland of barrier, but would need to be combined with other measures. Effectiveness could be affected by durability. 3	Effective at eliminating trail flooding within study area. 4	Effective at eliminating trail flooding within study area. 4	Effective at eliminating trail flooding within study area. Effectiveness could be affected by erosion. 3	Likely more effective at preventing tide from entering the outfall system than the current gate configuration. Effectiveness could be affected by debris blocking gate operation. 3	Would help dissipate flooding more quickly after high tide events. Would also provide more capacity for storm flooding. 3	Would help dissipate flooding more quickly after high tide events. Would also provide more capacity for storm flooding. 3
Reliability/ Resilience	Valve would be durable and relatively easy to replace. Would reliably prevent tide from entering pipe under existing and future sea level rise conditions. 4	Valve would be durable and relatively easy to replace. Would reliably prevent tide from entering pipe under existing and future sea level rise conditions. Reliability could be affected by debris blocking gate operation. 3	Depending on construction and final elevation, should reliably reduce flooding under existing and future sea level rise conditions. Reliability could be affected by settlement and erosion. 3	Depending on construction and final elevation, should reliably reduce flooding under existing and future sea level rise conditions. 5	Depending on construction and final elevation, should reliably reduce flooding under existing and future sea level rise conditions. 5	If configured and maintained, would reliably reduce flooding under existing and future sea level rise conditions. Would require regular inspection and maintenance. 2	Depending on construction, should reliably reduce flooding under existing conditions, but could be overtopped under future sea level rise conditions if only raised to an elevation of 8.0 feet NAVD 88. 4	Depending on construction, should reliably reduce flooding under existing conditions, but may need to be a very tall curb to accommodate potential future sea level rise conditions. 4	Depending on construction, should reliably reduce flooding under existing conditions, but may need to be a taller berm to accommodate potential future sea level rise conditions. Could be prone to erosion and settlement. 3	Gate would be durable but could be expensive to replace. Would reliably prevent tide from entering pipe under future sea level rise conditions. Reliability could be affected by debris blocking gate operation, and by operations and maintenance of gate. 3	Could be sized to handle existing and future tide and stormwater runoff conditions. Would help address impacts to future flooding from seal level rise and would make existing storm drain system more reliable and resilient. 4	Could be sized to handle existing and future tide and stormwater runoff conditions. Would help address impacts to future flooding from sea level rise. Pump system would require regular inspection and maintenance. 2

Information or Criteria	Measure 1A	Measure 1B	Measure 2A	Measure 2B	Measure 2C	Measure 2D	Measure 3A	Measure 3B	Measure 3C	Measure 4A	Measure 5A	Measure 5B
Impacts to Stormwater Flooding	Would add a small amount of hydraulic loss in the pipe or culvert, which would increase upstream flood levels only slightly. 1	Would add a small amount of hydraulic loss in the pipe or culvert, which would increase upstream flood levels only slightly. 1	Depending on location, could be a barrier to runoff from adjacent properties, but would likely have little impact on storm-induced flooding. 2	Depending on location, could be a barrier to runoff from adjacent properties, but would likely have little impact on storm-induced flooding. 2	Depending on location, could be a barrier to runoff from adjacent properties, but would likely have little impact on storm-induced flooding. 2	Depending on location, could be a barrier to runoff from adjacent properties, but would likely have little impact on storm-induced flooding. 2	Would improve ability to prevent flooding under all conditions. 4	Could create a barrier to trail drainage, which could cause ponding on the trail during storms, but this could be addressed during design. 2	Could create a barrier to trail drainage, which could cause ponding on the trail during storms, but this could be addressed during design. 2	Would add a small amount of hydraulic loss in the pipe or culvert, which would increase upstream flood levels only slightly. 1	Would improve ability to convey flood flows to Richardson Bay under all conditions. 4	Would improve ability to convey flood flows to Richardson Bay under all conditions. 4
Permitting Complexity	Very little impact, low permitting complexity. 4	Very little impact, low permitting complexity. 4	Relatively complex, depending on location and whether it would be considered filling below the ordinary high water mark. 2	Could be relatively complex, depending on location and whether it would be considered filling below the ordinary high water mark. 2	Could be relatively complex, depending on location and amount of fill within tidal area. Could be more adaptable than other barrier measures if gate included. 2	Could be relatively complex depending on operation, but would be more adaptable than other barrier solutions. 3	Relatively complex, depending on how additional elevation was created, and it could be considered filling in the marsh below the ordinary high water mark. 2	Relatively complex, depending on how the curs or barriers were constructed, and it could be considered filling in the marsh below the ordinary high water mark. 3	Relatively complex, due to the extent and configuration of the berms that would have to be constructed, and it would be considered filling in the marsh below the ordinary high water mark. 2	Somewhat complex because it would likely require work below the ordinary high water mark, but the work would be less extensive than other measures. 3	Relatively complex due to impacts on hydrology in marsh area east of Park-and-Ride. 2	Relatively complex due to impacts on hydrology in marsh area east of Park-and-Ride. 2
Property Impacts	Very little impact to private properties. 4	Very little impact to private properties. 4	Could impact properties, depending on location. 3	Could impact properties, depending on location. 3	Could impact properties, depending on location. 3	Could impact properties, depending on location. 3	Would primarily impact the Bay Trail, not private property. 4	Would primarily impact bike path, not private property. 4	Would primarily impact bike path, not private property. 4	Very little impact to private properties. 4	Very little impact to private properties. 4	Very little impact to private properties. 4
Public Use Impacts	Would reduce flooding on public roadways and in Park-and-Ride. 5	Would reduce flooding on public roadways and in Park-and-Ride. 5	Would reduce flooding on public roadways and in Park-and-Ride. 4	Would reduce flooding on public roadways and in Park-and-Ride. 4	Would reduce flooding on public roadways and in Park-and-Ride. 4	Would reduce flooding on public roadways and in Park-and-Ride. Would still require activation to work. 3	Would improve use of bike path, particularly during high tide events. 5	Curb would limit width of the trail shoulder, but impact would be small. 4	Berm would limit width of the trail shoulder, but impact would be softer than a curb. 4	Would reduce flooding on public roadways and in Park-and-Ride. 4	Would reduce flooding on public roadways and in Park-and-Ride. 5	Would reduce flooding on public roadways and in Park-and-Ride. 5
Relative Cost	Low Cost $ High Cost-Benefit 5	Low Cost $ High Cost-Benefit 5	Medium Cost $$ Medium-High Cost-Benefit 4	Medium-High Cost $$$ Medium Cost-Benefit 3	Medium-High Cost $$$ Medium Cost-Benefit 3	Medium Cost $$ Medium Cost-Benefit 4	High Cost $$$$ Medium-High Cost-Benefit 3	High Cost $$$ Medium Cost-Benefit 2	High Cost $$$ Medium Cost-Benefit 2	Medium-High Cost $$$ Medium Cost-Benefit 3	Medium-High Cost $$$ Medium Cost-Benefit 3	High Cost $$$$ Medium Cost-Benefit 2

Information or Criteria	Measure 1A	Measure 1B	Measure 2A	Measure 2B	Measure 2C	Measure 2D	Measure 3A	Measure 3B	Measure 3C	Measure 4A	Measure 5A	Measure 5B
Constructability	Relatively easy to implement. Could be done by maintenance staff without a construction contract. 5	Relatively easy to implement. Could be done by maintenance staff without a construction contract. 5	More complicated, depending on location. Could require a construction contract. 3	More complicated, depending on location. Would require a construction contract. 3	More complicated, depending on location. Would require a construction contract. 3	More complicated, depending on location. Would require a construction contract. 3	Would require a construction contract but would be straightforward construction. 3	Would require a construction contract but would be straightforward construction. 3	Would require a construction contract but would be straightforward construction. 3	More complicated, but relatively short timeline. Would require a construction contract. 4	Would require a construction contract but would be straightforward construction. 3	More complicated, longer timeline, more pieces involved. Would require a construction contract. 2
Operations and Maintenance	Would require regular inspection, cleaning after a storm event. Would be familiar to operations staff. 4	Would require regular inspection, cleaning after a storm event. Would be familiar to operations staff. 3	Would require monitoring, occasional erosion repair, or maintenance of vegetation. Would be familiar to operations staff. 3	Would require monitoring, but would be fixed, solid infrastructure with little maintenance required. 5	Would require monitoring, but would be fixed, solid infrastructure with little maintenance required. A gate would require regular inspection and operation. 4	Maintenance would be unfamiliar and would require regular inspection and testing to ensure that barrier works before tide events. Caltrans suggested that bladders should not be considered as an effective permanent or long-term solution. 1	Would not change operation and maintenance, other than pavement would be new and would not need to be replaced for segments of trail that are raised. 5	Would not change operation and maintenance on the trail. 4	Would require monitoring and maintenance of berms and vegetation on berms. 3	Would require regular inspection, cleaning after a storm event. Would reduce operation and maintenance of existing tide gates that have to be operated manually to reduce tidal inundation. Would be somewhat familiar to operations staff. 3	Would require regular inspection, cleaning after a storm event. Would be familiar to operations staff. 4	Would require regular inspection, maintenance of pumps, and other mechanical equipment. Would be somewhat familiar to operations staff. 2
Average Score	**4.00**	**3.67**	**3.00**	**3.44**	**3.33**	**2.67**	**3.78**	**3.33**	**2.89**	**3.11**	**3.56**	**2.89**

4 Summary of Flood Reduction Alternatives

The flood reduction measures identified in Section 3 were reviewed and combined to create three alternatives that are each intended to provide an improved level of tidal flood protection in the study area. Based on stakeholder discussions during completion of the study, the following general objectives were identified for the alternatives:

- **Alternative 1**
  - Minimize tidal flooding within the traveled SR 1 right-of-way and at the Caltrans maintenance yard under sunny day conditions.
- **Alternative 2**
  - Minimize tidal flooding within the traveled SR 1 right-of-way and at the Caltrans maintenance yard under sunny day conditions.
  - Prevent the tide from overtopping the Bay Trail throughout the study area.
  - Reduce flooding within the storm drain systems that serve commercial properties to the northwest of the Caltrans maintenance yard.
  - Improve conveyance of flood water adjacent to and across SR 1.
- **Alternative 3**
  - Minimize tidal flooding within the traveled SR 1 right-of-way and at the Caltrans maintenance yard under sunny day conditions.
  - Prevent the tide from overtopping the Bay Trail throughout the study area.
  - Reduce flooding within the storm drain systems that serve commercial properties to the northwest of the Caltrans maintenance yard.
  - Improve conveyance of flood water adjacent to and across SR 1.
  - Improve conveyance of flood water and stormwater runoff through the Park-and-Ride to limit impact on the use of that facility.

Table 4-1 provides a summary of the alternatives. The paragraphs that follow summarize the alternatives in more detail.

Table 4-1
Summary of Flood Reduction Alternatives

Improvement Option	Alternative 1	Alternative 2	Alternative 3
Install a Tideflex valve (1A) or a tide gate (1B) to prevent the tide from backing up through a storm drain			
• Storm drain outfall from NE corner of Holiday Inn parking lot		✓	✓
• Storm drain outfall near SE corner of Holiday Inn parking lot		✓	✓
• Storm drain at structure SW of Holiday Inn Express	✓	✓	✓
• Storm drain from commercial property NW of Caltrans yard	✓	✓	✓
• Culvert near the north corner of the Caltrans yard	✓	✓	✓
• On storm drain through central portion of Park-and-Ride			✓
• On storm drain that drains the south end of Park-and-Ride			✓
Install an embankment (2A), vinyl sheet pile wall (2B), or concrete wall (2C)			
• Between the Caltrans yard and commercial property NOW of the Caltrans yard	✓	✓	✓
• Along the east side of the Caltrans yard to the Bay Trail	✓	✓	✓
• Along the east side of the Park-and-Ride; seal up existing wall		✓	✓
• Along the east side of the Park-and-Ride, extend to the south end of the Park-and-Ride at the bridge abutment			✓
• Along the south side of Pohono Street	✓	✓	✓
Raise the Bay Trail (3A), install curbs along the trail (3B), or install vegetated berms along the trail (3C)			
• From the west side of the US 101 bridge, extending 200 feet to the northwest	✓		
• From the west side of US 101 to the Bay Trail bridge over Coyote Creek		✓	✓
• From Pohono Street south to a high point 1,350 feet southwest of Pohono Street	✓	✓	✓
• From the high point southwest of Pohono Street to a high point near the Gate 6 1/2 Road		✓	✓
Install self-regulating tide gates (4A)			
• At the main storm drain outfall east of the US 101 bridge	✓	✓	✓
Improve existing storm drains or ditches (5A), or install a stormwater pump station (5B)			
• Improve the ditch connection along the south side of SR 1 under the US 101 bridge		✓	✓
• Replace the existing 12-inch RCP culvert that crosses under SR 1 just east of the US 101 bridge with a 24-inch culvert		✓	✓
• Replace or extend storm drains that drain the central portion of the Park-and-Ride			✓
• Replace or extend storm drains that drain the south portion of the Park-and-Ride			✓
• Install a stormwater pump station at the low point on the south side of SR 1 near the Park-and-Ride			✓

4.1 Alternative 1

An overview of Alternative 1 is provided in Figure 4-1. A more detailed illustration of the proposed improvements associated with Alternative 1 is provided in Figures A1-1 through A1-3 in Appendix A. Alternative 1 is designed primarily to keep tide water from encroaching on the traveled SR 1 right-of-way and flooding the entrance to the Caltrans maintenance yard. Alternative 1 includes the following combination of improvements:

- Installation of a Tideflex valve or a tide gate to prevent water from backwatering storm drains or culverts at the following locations:
  - In the storm drain system in the parking lot southwest of the Holiday Inn Express to prevent tidal connection through the storm drain system to ditches along SR 1
  - On a 12-inch storm drain that originates in the parking area adjacent to the commercial property northwest of the Caltrans property and daylights in the ditch along the northwest side of the Caltrans maintenance yard.
  - On the 24-inch CMP culvert that conveys water from the channel along the northwest side of the Caltrans maintenance yard to the marsh north of the Caltrans property
- Installation of an embankment, vinyl sheet pile wall, or concrete wall to create a barrier and prevent tidal intrusion across points of low elevation at the following locations:
  - Between the Caltrans maintenance yard and the commercial property to the west
  - Along the east side of the Caltrans maintenance yard, extending to a high point that would need to be established along the Bay Trail by modifying a portion of the trail under the west edge of the US 101 bridge
  - Adjacent to the southeast corner of the intersection of Pahono Street with the Bay Trail
- Installation of a water-filled bladder was also considered as an option, but it was scored as the least feasible barrier option in Section 3. Caltrans has indicated that a bladder would only be acceptable as an emergency measure and would not be adequate for installation as a permanent barrier.
- Installation of 36-inch and 48-inch self-regulating tide gates at the outlet of the main stormwater outfall within the study area, just east of the US 101 bridge. This would prevent the tide from backwatering the outfall without the need to lift or lower a gate, as is currently done, and would require retrofitting of the existing outfall structure at that location.

- Raising the Bay Trail or installing raised curbs or berms along the edges of the trail to prevent overtopping at the following targeted locations, which is needed to keep the tide from encroaching on SR 1:
  - From under the west edge of the US 101 bridge extending northwest approximately 200 feet, or as needed to prevent tide waters from inundating the pathway and areas adjacent to the pathway under the bridge
  - From Pohono Street to a high point approximately 1,350 feet southwest of Pohono Street

4.2 Alternative 2

An overview of Alternative 2 is provided in Figure 4-2. A more detailed illustration of the proposed improvements associated with Alternative 2 is provided in Figures A2-1 through A2-3. Alternative 2 is designed to keep tide water from encroaching on the traveled SR 1 right-of-way and prevent flooding at the entrance to the Caltrans maintenance yard, as well as prevent overtopping of the Bay Trail through the study area, reduce flooding on adjacent commercial properties, and improve conveyance in the stormwater system along the south edge and across SR 1. Alternative 2 includes the following combination of improvements:

- Installation of a Tideflex valve or a tide gate to prevent water from backwatering storm drains or culverts at the following locations:
  - On the storm drain that captures water from the catch basin structure in the northeast corner of the parking lot at the Holiday Inn Express and discharges to the north end of the tidal marsh
  - On the storm drain that captures water from the storm drain system that serves the other parking areas adjacent to the Holiday Inn Express and neighboring commercial buildings and discharges to the tidal marsh east of the Holiday Inn Express
  - In the storm drain system in the parking lot southwest of the Holiday Inn Express to prevent tidal connection through the storm drain system to ditches along SR 1
  - On a 12-inch storm drain that originates in the parking area adjacent to the commercial property northwest of the Caltrans property and daylights in the ditch along the northwest side of the Caltrans maintenance yard.
  - On the 24-inch CMP culvert that conveys water from the channel along the northwest side of the Caltrans maintenance yard to the marsh north of the Caltrans property
- Sealing of the wall along the northeast side of the Park-and-Ride under the US 101 bridge to provide a barrier between the ditch east of the Park-and-Ride and the Park-and-Ride. This solution would need to be coupled with storm drain improvements in the Park-and-Ride to reduce flooding in the Park-and-Ride, especially during storm events.

- Installation of an embankment, vinyl sheet pile wall, or concrete wall to create a barrier and prevent tidal intrusion across points of low elevation at the following locations:
  - Between the Caltrans maintenance yard and the commercial property to the west
  - Along the east side of the Caltrans maintenance yard, extending to a high point that would need to be established along the Bay Trail under the west edge of the US 101 bridge
  - Adjacent to the southeast corner of the intersection of Pahono Street with the Bay Trail.
- Installation of 36-inch and 48-inch self-regulating tide gates at the outlet of the main stormwater outfall within the study area, just east of the US 101 bridge. This would prevent the tide from backwatering the outfall without the need to lift or lower a gate, as is currently done and would require some retrofitting of the existing outfall structure at that location.
- Raising the Bay Trail or installing raised curbs or berms along the edge of the trail to prevent overtopping at the following locations:
  - From the west side of the US 101 bridge to the bridge crossing at Coyote Creek
  - From Pohono Street to a high point approximately 1,350 southwest of Pohono Street
  - From the high point southwest of Pohono Street to a high point near Gate 6 1/2 Road
- Improvement of storm drain system conveyance efficiency along and across SR 1 to prevent flood waters collected in the ditches, the tidal marsh, or other areas from backwatering the storm drain systems that discharge water through these drains to tidal areas. This would include the following improvements:
  - Improve the ditch connection along the south edge of SR 1 under the US 101 bridge to improve the conveyance of water from the Park-and-Ride entrance to the culvert that crosses SR 1 east of the US 101 bridge
  - Replace the existing 12-inch RCP culvert that crosses SR 1 at the low point under the east edge of the US 101 bridge with a 24-inch corrugated polyethylene (CPE) culvert

4.3 Alternative 3

An overview of Alternative 3 is provided in Figure 4-3. A more detailed illustration of the proposed improvements associated with Alternative 3 is provided in Figures A3-1 through A3-3. Alternative 3 is designed to keep tide water from encroaching on the traveled SR 1 right-of-way, prevent flooding at the entrance to the Caltrans maintenance yard, prevent overtopping of the Bay Trail through the study area, reduce flooding on adjacent commercial properties, and improve the conveyance of flood water from the Park-and-Ride to Richards Bay. Alternative 3 includes the following combination of improvements:

- Installation of a Tideflex valve or a tide gate to prevent water from backwatering storm drains or culverts at the following locations:

- On the storm drain that captures water from the catch basin structure in the northeast corner of the parking lot at the Holiday Inn Express and discharges to the north end of the tidal marsh
    - On the storm drain that captures water from the storm drain system that serves the other parking areas adjacent to the Holiday Inn Express and neighboring commercial buildings and discharges to the tidal marsh east of the Holiday Inn Express
    - In the storm drain system in the parking lot southwest of the Holiday Inn Express to prevent tidal connection through the storm drain system to ditches along SR 1
    - On a 12-inch storm drain that originates in the parking area adjacent to the commercial property northwest of the Caltrans property and daylights in the ditch along the northwest side of the Caltrans maintenance yard.
    - On the 24-inch CMP culvert that conveys water from the channel along the northwest side of the Caltrans maintenance yard to the marsh north of the Caltrans property
    - On storm drains that would be improved or extended to convey stormwater collected within the Park-and-Ride to the ditch that runs along the east side of the Park-and-Ride adjacent to SR 1
- Sealing of the wall along the northeast side of the Park-and-Ride under the US 101 bridge to provide a barrier between the ditch east of the Park-and-Ride and the Park-and-Ride.
- Installation of an embankment, vinyl sheet pile wall, or concrete wall to create a barrier and prevent tidal intrusion across points of low elevation at the following locations:
    - Between the Caltrans maintenance yard and the commercial property to the west
    - Along the east side of the Caltrans maintenance yard, extending to a high point that would need to be established along the Bay Trail under the west edge of the US 101 bridge
    - Adjacent to the southeast corner of the intersection of Pahono Street with the Bay Trail
    - Along the east side of the Park-and-Ride, to complete the barrier between the ditch and the Park-and-Ride
- Installation of a 36-inch and 48-inch self-regulating tide gates at the outlet of the main stormwater outfall within the study area, just east of the US 101 bridge. This would prevent the tide from backwatering the outfall without the need to lift or lower a gate, as is currently done and would require some retrofitting of the existing outfall structure at that location.
- Raising the Bay Trail or installation of raised curbs or berms along the edge of the trail to prevent overtopping at the following locations:
    - From the west side of the US 101 bridge to the bridge crossing at Coyote Creek
    - From Pohono Street to a high point approximately 1,350 southwest of Pohono Street
    - From the high point southwest of Pohono Street to a high point near Gate 6 1/2 Road
- Improvement of storm drain system conveyance efficiency to prevent flood waters collected in the ditches, the tidal marsh, or other areas from backwatering the storm drain systems that

discharge water through these drains to tidal areas. This would include the following improvements:

- Improve the ditch connection along the south edge of SR 1 under the US 101 bridge to improve the conveyance of water from the Park-and-Ride entrance to the culvert that crosses SR 1 at the east side of the Park-and-Ride
- Replace the existing 12-inch RCP culvert that crosses SR 1 at the low point under the east edge of the US 101 bridge with a 24-inch CPE culvert
- Replace or extend storm drains that convey stormwater collected in storm drain systems within the Park-and-Ride to the ditch that runs along the east side of the Park-and-Ride adjacent to SR 1
- Install a stormwater pump station at the low point on the south side of SR 1 under the US 101 bridge

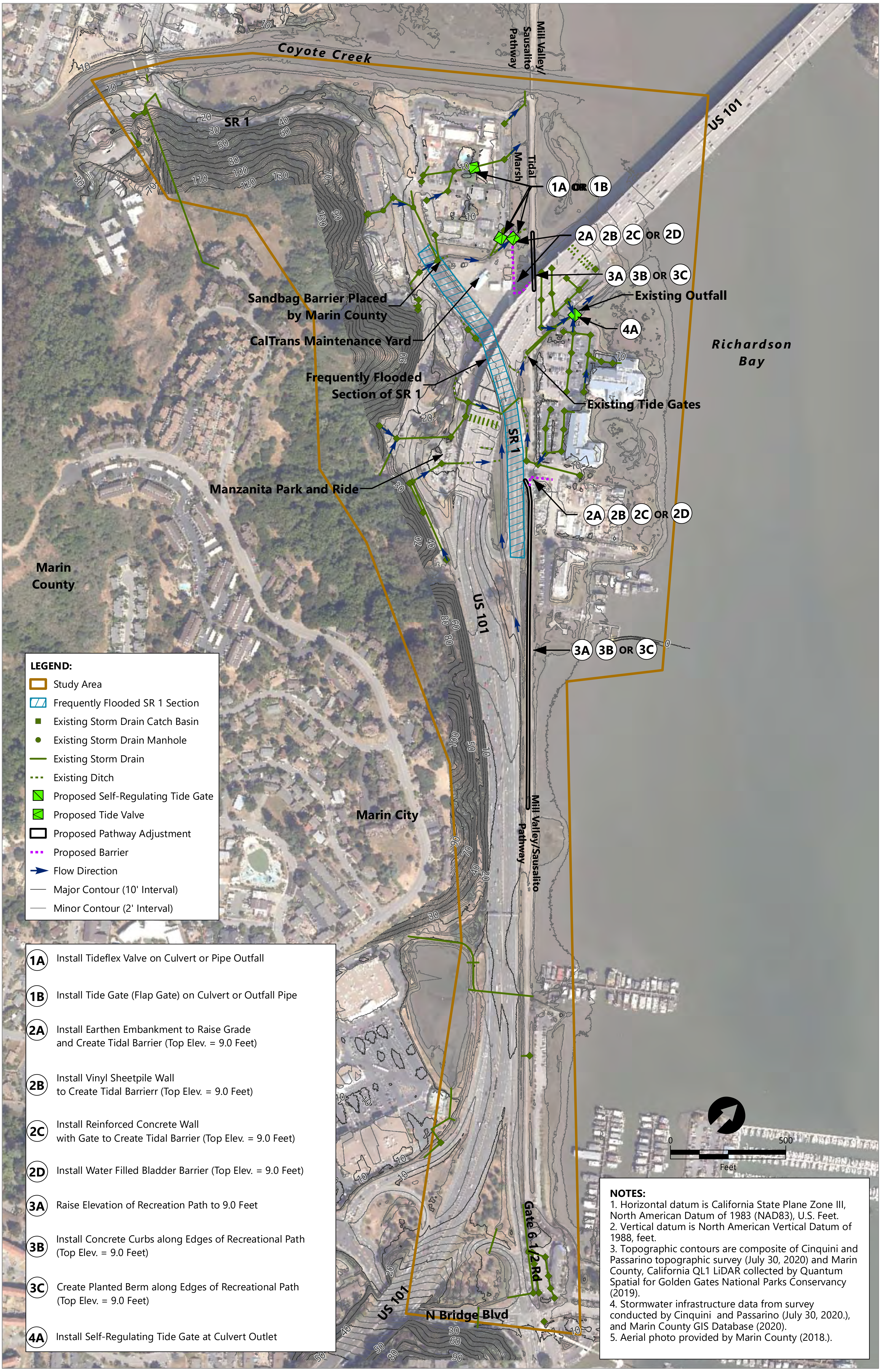

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Figure 4-1
Overview – Improvement Alternative 1

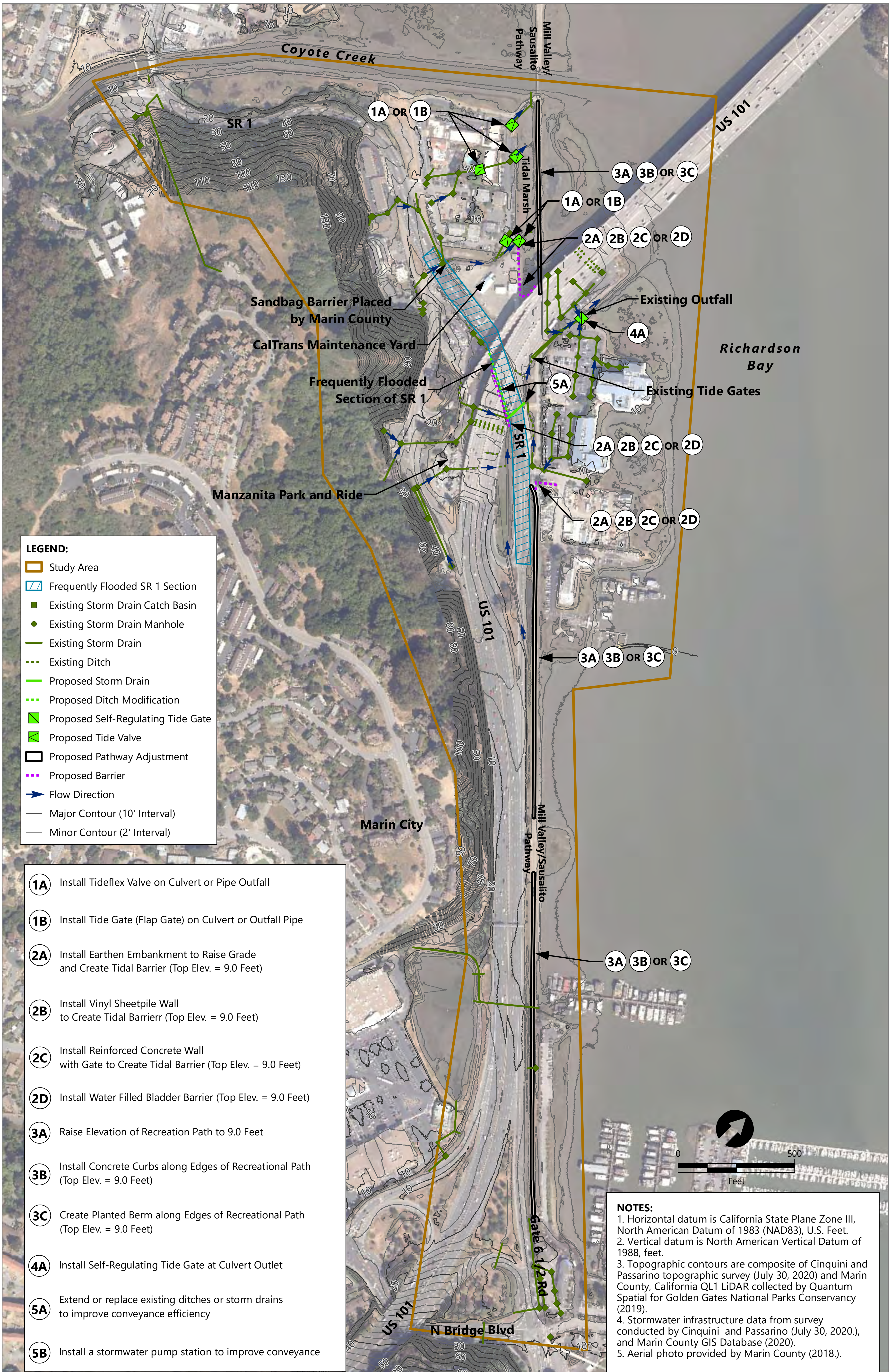

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Figure 4-2
Overview – Improvement Alternative 2

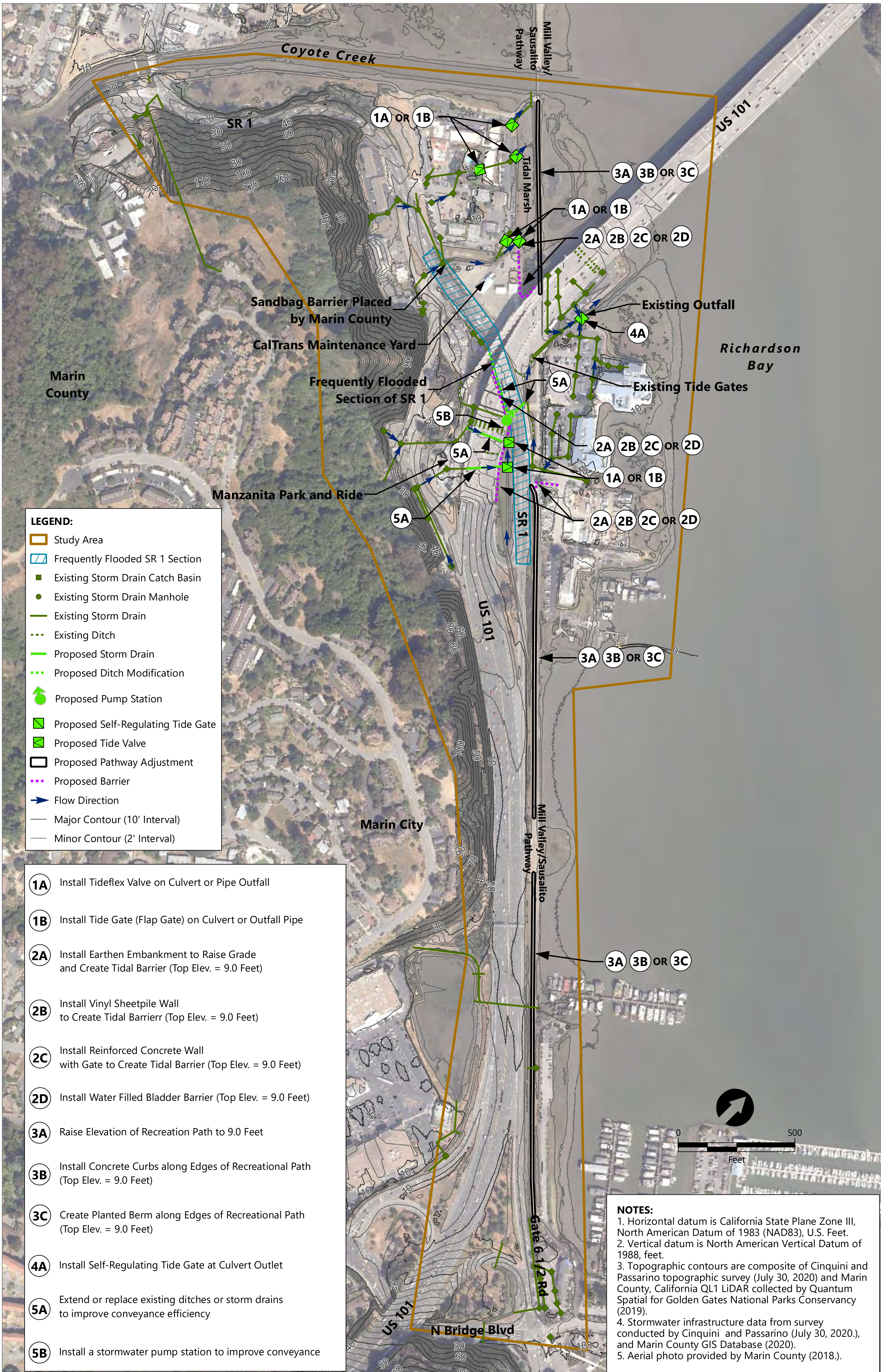

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Figure 4-3
Overview – Improvement Alternative 3

5 Hydraulic Analysis

A hydraulic analysis was completed to analyze the impacts of the alternatives proposed in the previous section on flooding due to King Tide events during sunny day (non-rainstorm) conditions. This section summarizes the development of the hydraulic model, scenarios evaluated by the hydraulic model, and analysis results of the scenarios evaluated.

5.1 Hydraulic Model Development

Analysis of the project area was developed using CHI's PCSWMM (Professional 2D 2019 Version 7.2.2785), a modeling software for stormwater, wastewater, watershed, and water distribution systems. PCSWMM utilizes the U.S. Environmental Protection Agency (EPA) Stormwater Management Model (SWMM) Version 5.1.013, a dynamic rainfall-runoff simulation model used for single-event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas.

For this project, PCSWMM was used to model overland topographic features and connecting underground storm drains and other conveyance structures. Information used as input to the model were obtained from data described in Section 2.3. Catch basins, culverts, and stormwater pipes were modeled as one-dimensional features; they were connected to the two-dimensionally modeled overland topographic features via bottom orifices. Manning's roughness values for the culverts and stormwater pipes were assumed to range from 0.010 to 0.024 depending on type.

Two-dimensional areas were based on digital elevation model surfaces generated using a combination of the LiDAR data and survey data summarized in Section 2. Modeled cell sizes were dependent on the importance of features and elevation changes; cell sizes ranged from 6 feet to 25 feet. Manning's roughness values ranged from 0.016 to 0.060 and are based on professional judgment and roughness values stated in the Caltrans Highway Design Manual (Caltrans 2020). The two-dimensional area assumptions are summarized in Table 5-1.

Table 5-1
Summary of Modeled Two-Dimensional Areas

Description of Areas	Cell Resolution Size (feet)	Manning's Roughness	Basis for Roughness
Drainage Ditches/Creeks	6	0.060	Fallow with grass
Bike Path/Boardwalk	6	0.016	Asphalt
Caltrans Yard, Park-and-Ride, SR 1/US 101 Intersection	12	0.020	Asphalt with cement rubble
All other areas	25	0.030	Concrete with fallow and grass

Source: Caltrans 2020

Elevations at critical locations (berms, bike path, etc.) were reviewed (and adjusted, where necessary) within the model to confirm that two-dimensional cells appropriately represented those critical areas that would most impact analysis results.

Boundary conditions were set to tidal conditions. There were assumed to be no baseflows or drainage from subbasins tributary to the area that was modeled. Evaporation was assumed to be negligible. To calibrate and verify the accuracy of the model, the February 2019 event was simulated with existing infrastructure and topographic conditions and the simulation results were reviewed with Marin County and Caltrans to determine if the flooded areas appeared to generally be consistent with observations made during high tide events. This review confirmed that the results were generally consistent with observed tidal flooding conditions. Scenarios were then set up to evaluate each improvement alternative identified in Section 4 to determine the potential for each alternative to reduce flooding under King Tide, sunny day conditions.

5.2 Scenarios Evaluated

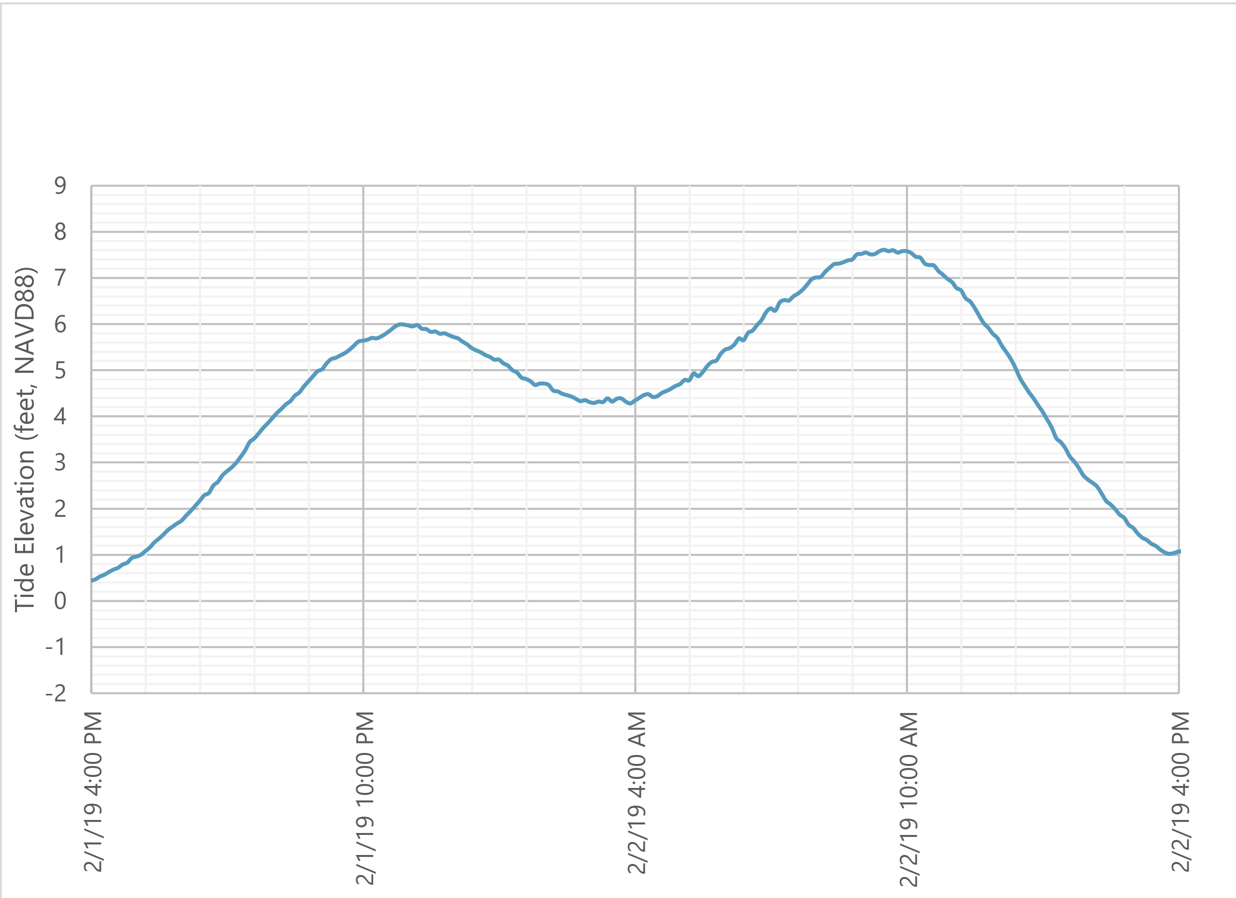
A total of eight scenarios were evaluated for flood impacts using the model. Four infrastructure conditions were modeled, each with two different tide scenarios. Table 5-2 lists the scenarios that were modeled.

Table 5-2
Summary of Model Scenarios

Scenario	Peak Tide Condition Modeled in Scenario	Existing or Improved Infrastructure Condition Modeled
Existing – 2019 High Tide	February 2019 Peak Tide	Existing Conditions
Existing – Peak Observed Tide	Peak Observed Tide	Existing Conditions
Alternative 1 – 2019 High Tide	February 2019 Peak Tide	Improved Alternative 1
Alternative 1 – Peak Observed Tide	Peak Observed Tide	Improved Alternative 1
Alternative 2 – 2019 High Tide	February 2019 Peak Tide	Improved Alternative 2
Alternative 2 – Peak Observed Tide	Peak Observed Tide	Improved Alternative 2
Alternative 3 – 2019 High Tide	February 2019 Peak Tide	Improved Alternative 3
Alternative 3 – Peak Observed Tide	Peak Observed Tide	Improved Alternative 3

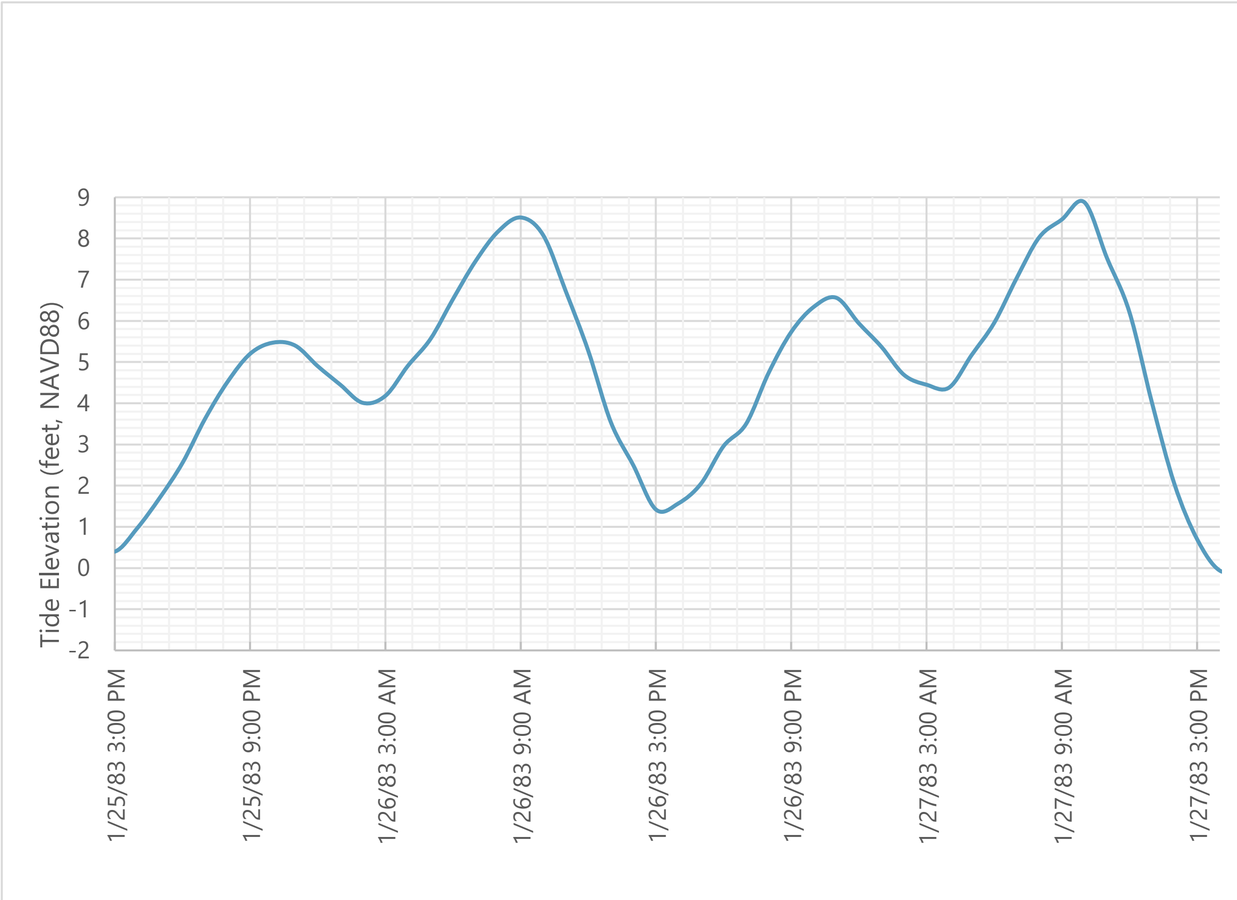
The tide events simulated were based on a recent high tide cycle recorded February 1 to 2, 2019, and the peak observed tide cycle, recorded January 25 to 27, 1983. The February 2019 peak tide model ran for 24 hours from 4 p.m. February 1, to 4 p.m. February 2, 2019. The peak tide reached 7.61 feet (NAVD 88) at 9:30 a.m. This scenario represents tides typically reached during King Tide events. Out of 123 calendar years for which the San Francisco tide gage has data (1898 to 2020), 29 years had peak tides higher than the February 2019 peak tide. Figure 5-1 shows the tide modeled in the February 2019 scenario.

Figure 5-1
Tide Conditions Used in the February 2019 Scenarios



The peak observed tide model ran for 49 hours from 3 p.m. January 25, 1983, to 4 p.m. January 27, 1983. Two tide cycles were captured for more model stability; the single tide cycle from January 26 to 27 caused model issues that were resolved by adding the previous cycle. The peak tide reached 8.88 feet (NAVD 88) at 10:00 a.m. on January 27. Figure 5-2 shows the tide modeled in the peak observed tide scenario.

Figure 5-2
Tide Conditions Used in the Peak Observed Scenarios



5.3 Analysis of Existing King Tide, Sunny Day Flood Conditions

The following analysis is based on modeling results; actual flood pathways and locations may vary slightly due to minor elevation differences not captured in modeling resolution. Model results for existing conditions of King Tide events during sunny day floods are depicted in Figure E-0A for the February 2019 peak tide scenario and in Figure E-0B for the peak observed tide scenario (see Appendix E). Tide results for the peak observed tide scenario are also mapped on the conceptual design Figures EC-1 to EC-3 (see Appendix A).

For existing conditions, tide water starts to flood the Bay Trail when the tide reaches approximately 6.9 feet (NAVD 88) between Coyote Creek and the SR 1/US 101 interchange. The Bay Trail starts to flood between the SR 1/US 101 interchange and Gate 6 1/2 Road when the tide reaches approximately 7.0 feet (NAVD 88). At this point, the northwestern corner of the Holiday Inn also begins to flood. When the tide reaches approximately 7.2 feet (NAVD 88), water begins to enter the

SR 1 traveled right-of-way near the Caltrans maintenance yard and in front of the helipad parking lot. Tides from both east and west of the SR 1/US 101 interchange are connected through drainage ditches and flood the bike path under the US 1010 bridge when the tide reaches approximately 7.45 feet (NAVD 88). When the tide reaches approximately 7.5 feet (NAVD 88), flooding occurs in the Park-and-Ride underneath US 101, extends across SR 1, and fully submerges the bike path between Coyote Creek and Gate 6 1/2 Road (except for some high elevation areas). At this tide level, extensive flooding also occurs in the helipad property, in the northern portion of the Holiday Inn parking lot, and in much of the Caltrans maintenance yard. Flooding increases in nearby areas up to the modeled tide level of 8.88 feet (NAVD 88).

The model results indicate that shallow flooding remains well beyond the time of tides receding. In the peak observed tide scenario, the first high tide cycle reached an elevation of 8.50 feet (NAVD 88). The model indicated that shallow flooding remained in the Park-and-Ride and some spots in the Caltrans maintenance yard and Seaplane Adventures parking lot for the entire time between the high tides (25 hours). This is likely due to limited storm drain conveyance capacity and closure of the existing tide gates on the main outfall under the east edge of the US 101 bridge. The model assumes that these tide gates are manually closed prior to the tide event and remain closed until they are manually opened after the tide recedes, based on input provided by Caltrans about how the existing gates are operated.

5.4 Analysis of Improvement Alternative 1

Model results for scenarios that simulated Alternative 1 improvements during King Tide events under sunny day conditions are depicted in Figure E-1A for the February 2019 peak tide scenario and in Figure E-1B for the peak observed tide scenario (see Appendix E). The model results for the peak observed tide scenario are also mapped on the conceptual design Figures A1-1 to A1-3 (see Appendix A).

Under Alternative 1, the model results indicate that flooding under the February 2019 peak tide scenario would mostly be eliminated within the travelled SR 1 right-of-way and the Park-and-Ride. The model indicates that some shallow flooding would persist in the northern portion of the Holiday Inn parking lot, on the Bay Trail between Coyote Creek and the SR 1/US 101 interchange, in the Seaplane Adventures parking lot, and on the Bay Trail near Gate 6. The model results indicate that during the peak observed tide scenario, some shallow flooding would occur across SR 1 near the Caltrans maintenance yard and in low-lying areas of the Park-and-Ride, in addition to the flooding noted previously. The flooding would result from inundation of the parking area around the Holiday Inn and adjacent commercial properties, which would migrate to the southeast and eventually overtop the ditch bank northwest of the Caltrans maintenance yard and fill the ditch until shallow flooding occurs at SR 1. Flood waters would then migrate across SR 1 to cause flooding in the low-lying areas of the Park-and-Ride. When tides recede from the peak observed tide, remaining flooding would recede at a faster pace than for existing conditions.

5.5 Analysis of Improvement Alternative 2

Model results for scenarios that simulated Alternative 2 improvements during King Tide events under sunny day conditions are depicted in Figure E-2A for the February 2019 peak tide scenario and in Figure E-2B for the peak observed tide scenario (see Appendix E). The model results for the peak observed tide scenario are also mapped on the conceptual design Figures A2-1 to A2-3 (see Appendix A).

Under Alternative 2, the model results indicate that flooding would be very similar to the flooding seen in Alternative 1. The primary difference is that the Bay Trail would be completely elevated or modified as part of Alternative 2, so the model results show that the trail would remain above tide levels along all improved segments of the trail for both tide conditions that were modeled. Under the February 2019 peak tide scenario, flooding would mostly be eliminated within the travelled SR 1 right-of-way and the Park-and-Ride. Similar to Alternative 1, under the peak observed tide scenario, flood waters would cause shallow flooding in the Holiday Inn parking lot, across SR 1, and in the low-lying areas of the Park-and-Ride. The flooding occurring during the peak observed tide scenario would recede at a similar pace to Alternative 1.

5.6 Analysis of Improvement Alternative 3

Model results for scenarios that simulated Alternative 3 improvements during King Tide events under during sunny day conditions are depicted in Figure E-3A for the February 2019 peak tide scenario and in Figure E-3B for the peak observed tide scenario. The model results for the peak observed tide scenario are also mapped on the conceptual design Figures A3-1 to A3-3 (see Appendix A).

Under Alternative 3, the model results indicate that conditions would be very similar to Alternatives 1 and 2. During the February 2019 peak tide scenario, flooding would be mostly be eliminated within the travelled SR 1 right-of-way and the Park-and-Ride. Similar to Alternatives 1 and 2, under the peak observed tide scenario, flood waters would cause shallow flooding in the Holiday Inn parking lot, across SR 1, and in the low-lying areas of the Park-and-Ride. Shallow flooding would be slightly increased in the Park-and-Ride compared to Alternative 2 under the peak observed tide condition. The model results indicate that the barrier walls included along the east side of the Park-and-Ride would prevent flood water from draining to the adjacent ditch very quickly. However, more detailed, refined modeling of storm drain improvements and pumping in the Park-and-Ride would likely demonstrate that these improvements could increase conveyance of flood waters through the Park-and-Ride to Richardson Bay. If this alternative moves forward, more detailed modeling and analysis of pumping and conveyance should be completed to better reflect storm drainage improvements that would alleviate shallow flooding in the Park-and-Ride after high tide events.

6 Opinions of Probable Cost

6.1 Overview

Planning level unit costs were developed for each flood reduction measure that include both materials costs and contractor labor, overhead, and profit costs. These unit costs were then applied to each alternative to develop an overall planning level opinion of probable cost for each alternative outlined in Section 4. Non-construction costs, including engineering, permitting, administration, an allowance for environmental mitigation, and a contingency, were added to estimate a total project cost for each alternative. The detailed opinions of probable cost are included in Appendix F.

6.2 Assumptions

The overall project costs include the following:

- An allowance of 25% of the construction subtotal was included for engineering, permitting, and administration. Actual engineering, permitting, and administration costs will need to be estimated at the time of design based on the scope of work for design and the time and effort required to develop designs, permit the project, and administer implementation.
- An allowance of 20% to 25% of the total cost of each alternative was included for environmental mitigation. Actual mitigation costs will vary based on the impact of the project that is implemented and the regulatory requirements for mitigation.
- A contingency of 30% was included in the total opinion of the probable project cost.

The opinions of cost developed are intended to be "order-of-magnitude" costs and were developed primarily for comparing the relative cost of each alternative. More refined opinions of cost will need to be developed as the measures to be implemented are more clearly defined.

6.3 Summary of Opinions of Probable Cost

6.3.1 By Individual Flood Reduction Measure

Table 6-1 provides a summary of the unit costs developed for each flood reduction measure that was identified. The unit costs for each flood reduction measure were developed using cost information from RS Means (RS Means 2020), available bid tabs from similar projects, typical manufacturer costs (where available), and engineering experience. Additional notes regarding how each of the unit costs were developed are provided in the detailed opinion of cost tables in Appendix F. Because the proposed improvements are not well defined, assumptions were made about the quantity and type of materials and work that would be required. Due to the conceptual nature of this study, assumptions regarding the cost and quantity of materials, labor, profit, and overhead costs are intended to be conservative. The unit costs developed for each flood reduction measures are intended to include all taxes and fees associated with implementing the measure.

Table 6-1
Summary of Flood Reduction Measure Unit Costs

Measure	Description	Unit	Materials Unit Cost[1]	Contractor Labor/Profit Unit Cost[1]	Total Unit Cost[1]
1A	24” Tideflex Valve, or Equal	EA	$7,800	$2,000	$9,800
	18” Tideflex Valve, or Equal	EA	$5,800	$1,500	$7,300
	12” Tideflex Valve, or Equal	EA	$3,500	$900	$4,400
1B	24” Tide (Flap) Gate, or Equal	EA	$3,600	$900	$4,500
	18” Tide (Flap) Gate, or Equal	EA	$3,000	$800	$3,800
2A	Earthen Embankment	LF	$50	$20	$70
2B	Vinyl Sheet Pile Wall	LF	$240	$110	$350
2C	Reinforced Concrete Wall	LF	$180	$210	$390
2D	Water-Filled Bladder Barrier	LF	$70	$40	$110
3A	Raise Elevation of the Bay Trail	LF	$100	$30	$130
3B	Concrete Curbs Along the Bay Trail	LF	$40	$50	$90
3C	Planted Berms Along the Bay Trail	LF	$50	$20	$70
4A	48” Self-Regulating Tide Gate	EA	$48,000	$15,000	$63,000
	36” Self-Regulating Tide Gate	EA	$30,000	$9,000	$39,000
5A	18” Storm Drain or Culvert	LF	$30	$30	$60
	12” Storm Drain or Culvert	LF	$20	$20	$40
	Improve Ditch Connection	LF	$6	$4	$10
5B	Stormwater Pumping	MGD	$540,000	$220,000	$760,000

Notes:
1. Unit costs were developed using cost information from RS Means (RS Means 2020), available bid tabs from similar projects, typical manufacturer costs (where available), and past engineering experience. Additional notes regarding how each of the unit costs were developed are provided in the detailed opinion of cost tables in Appendix F.
2. Unit costs are intended to include all taxes and fees associated with the implementing the flood reduction measure.

6.3.2 *By Alternative*

Table 6-2 includes a summary of costs for each alternative that was developed. Additional detail is provided in the detailed opinion of cost tables in Appendix F. To develop the costs for each alternative, the unit cost for a specific flood reduction measure was assumed to be applied for each location or improvement. The detailed table in Appendix F indicates which flood reduction measure’s unit cost was used. These were selected as follows:

- For the first group of measures, which include those that would prevent tidal waters from backing up through culverts and storm drains into areas that are currently flooding, the unit cost for a Tideflex valve (1A) was used and unit costs for two different sizes were developed.

- For the second group of measures, which include those that would create a barrier across a low spot to separate upland areas that are prone to tidal flooding from low-lying tidal areas, the unit cost for a vinyl sheet pile (2B) was used, with one exception. For the improvement that describes sealing up an existing wall along the east side of the Park-and-Ride, the unit cost of a berm or embankment was used.
- For the third group of measures, which include those that would modify the Bay Trail to protect the trail from tidal flooding, the unit cost for raising the trail (3A) was used.
- The fourth group of measures includes unit costs for furnishing and installing both a 36-inch and a 48-inch self-regulating tide gate.
- For the fifth group of measures, unit costs were assigned based on assumed pipe size and type of improvement.

Table 6-2
Summary of Opinions of Probable Cost for Each Alternative

Improvement Option	Alternative 1	Alternative 2	Alternative 3
Install a Tideflex valve (1A) or a tide gate (1B) to prevent the tide from backing up through a storm drain			
• Storm drain outfall from NE corner of Holiday Inn parking lot		$4,400	$4,400
• Storm drain outfall near SE corner of Holiday Inn parking lot		$7,300	$7,300
• Storm drain system near SW corner of Holiday Inn parking lot	$3,500	$3,500	$3,500
• Culvert near the north corner of the Caltrans yard	$9,800	$9,800	$9,800
• Storm drain from commercial property NW of Caltrans yard	$4,400	$4,400	$4,400
• On storm drain through central portion of Park-and-Ride			$4,400
• On storm drain that drains the south end of Park-and-Ride			$4,400
Install an embankment (2A), vinyl sheet pile wall (2B), concrete wall (2C), or water-filled bladder barrier (2D)			
• Between the Caltrans maintenance yard and commercial property north of the Caltrans maintenance yard	$21,000	$21,000	$21,000
• Along the east side of the Caltrans maintenance yard to the Bay Trail	$105,000	$105,000	$105,000
• Along the east side of the Park-and-Ride; seal up existing wall		$16,100	$16,100
• Along the east side of the Park-and-Ride, extend to the south end of the Park-and-Ride at the bridge abutment			$101,500
• Along the south side of Pohono Street	$56,000	$56,000	$56,000

Improvement Option	Alternative 1	Alternative 2	Alternative 3
Raise the Bay Trail (3A), install curbs along the trail (3B), or install vegetated berms along the trail (3C)			
• From the west side of the US 101 bridge, extending 200 feet to the northwest	$26,000		
• From the west side of US 101 to the Bay Trail bridge over Coyote Creek		$111,800	$111,800
• From Pohono Street south to a high point 1,350 feet southwest of Pohono Street	$175,500	$175,500	$175,500
• From the high point southwest of Pohono Street to a high point near the Gate 6 1/2 Road		$179,400	$179,400
Install self-regulating tide gates (4A)			
• Install at 48-inch tide gate the main storm drain outfall east of the US 101 bridge	$63,000	$63,000	$63,000
• Install at 36-inch tide gate the main storm drain outfall east of the US 101 bridge	$39,000	$39,000	$39,000
Improve existing storm drains or ditches (5A), or install a stormwater pump station (5B)			
• Improve the ditch connection along the south side of SR 1 under the US 101 bridge		$3,000	$3,000
• Replace the existing 12-inch RCP culvert that crosses under SR 1 just east of the US 101 bridge with a 24-inch culvert		$5,700	$5,700
• Replace or extend storm drains that drain the central portion of the Park-and-Ride			$7,200
• Replace or extend storm drains that drain the south portion of the Park-and-Ride			$9,200
• Install a stormwater pump station at the low point on the south side of SR 1 near the Park-and-Ride			$1,094,400
Construction Subtotal[1,2,3]	**$503,000**	**$805,000**	**$2,026,000**
Engineering, Permitting, and Administration (25%)[4]	$125,750	$201,250	$506,500
Environmental Mitigation Allowance[5]	$100,000	$160,000	$420,000
Project Cost Subtotal[1,2,3]	**$729,000**	**$1,166,000**	**$2,953,000**
Planning Contingency (30%)	$218,700	$349,800	$885,900
Total Project Cost - With Contingency[1,2,3]	**$948,000**	**$1,516,000**	**$3,839,000**

Notes:
1. Costs are in 2020 dollars.
2. Subtotals and totals are rounded to the nearest $1,000.
3. Costs are based on conceptual designs and are intended to be "order-of-magnitude" costs for the primary purpose of comparing alternatives, actual costs will vary based on the elements that are implemented, Caltrans requirements for the proposed project, and permitting requirements.
4. Engineering, permitting, and administration costs should be considered an allowance and were estimated based on the percentage shown. Actual costs will need to be estimated at the time of design based on the scope of work for design and the time and effort required to develop designs, permit the project, and administer implementation.
5. Environmental mitigation costs should be considered an allowance. Actual costs will vary based on the impact of the project to be implemented and regulatory requirements for mitigation.
6. All taxes and fees not listed as separate items are assumed to be included in the unit costs for each item.

As indicated in Table 6-2, the total opinions of probable project costs with a 30% contingency included range from $948,000 for Alternative 1 to approximately $3.8 million for Alternative 3. The proposed improvements that will likely cost the most include stormwater pumping, raising long segments of the Bay Trail, constructing a wall or barrier along the east side of the Caltrans maintenance yard, and constructing a wall or barrier along the east side of the Park-and-Ride. The lowest cost items, which will also likely be the easiest to implement, include installing Tideflex valves or flap gates and improving ditches and storm drains.

7 Evaluation and Comparison of Alternatives

Individual flood reduction measures were identified and evaluated, as summarized in Section 3, by evaluating each measure based on key criteria and comparing the flood reduction measures in a matrix provided as Table 3-4. Those measures were then combined into overall improvement alternatives, as described in Section 4. Flood control measures were chosen for inclusion in each alternative based on the following objectives:

- **Alternative 1** was developed to be the lowest cost and least complicated alternative, with the primary focus on reducing tidal flooding within the SR 1 traveled right-of-way and at the entrance to the Caltrans maintenance yard.
- **Alternative 2** was developed to include the flood reduction measures included in Alternative 1, but with the added objectives of preventing overtopping of the Bay Trail during King Tide events, reducing flooding at adjacent commercial properties, and improving stormwater conveyance along and across SR 1.
- **Alternative 3** was developed as the most comprehensive and costly alternative, with the intent of meeting the objectives for Alternative 2, but also adding further improvements to storm drainage facilities within the Park-and-Ride to further improve conveyance of stormwater and flood waters from the Park-and-Ride and from the ditch on the east side of the Park-and-Ride to Richardson Bay.

The following methodology was used to develop and evaluate each of these alternatives:

1. Anchor QEA developed three conceptual design alternatives, as summarized in Section 4. Each alternative includes a combination of flood reduction measures intended to reduce tidal flooding under sunny day conditions within the study area.
2. Analyses were completed to model the effectiveness of each alternative in reducing flooding, as summarized in Section 5, and an opinion of the probable costs was developed for implementing each alternative, as summarized in Section 6.
3. After identifying alternatives, Anchor QEA applied the same criteria and scoring methodology outlined in Section 3 for evaluating individual flood control measures to each alternative to evaluate the favorability of each alternative.
4. A matrix (Table 7-1) was prepared to compare the alternatives.
5. The evaluation results are presented in this report, with recommendations for further study so that Marin County and Caltrans can consider the alternatives and select a preferred alternative for further evaluation and design.

7.1 Evaluation and Scoring of Alternatives

The alternatives were each evaluated according to the criteria summarized in Table 3-1. A favorability score from 1 to 5 was given to each measure for each criterion, as summarized in Table 3-2. Scoring was based on the description of the criteria outlined in Table 3-1, with higher scores given if a measure was determined to perform more favorably for a given criterion.

7.2 Ranking of Alternatives

An overall score for each alternative was developed by averaging the scores of all the criteria and then ranking the alternatives according to their overall average scores. Alternative 1 was the highest ranked of the alternatives, with an average score of 3.78, followed by Alternative 2, with an average score of 3.67, and then by Alternative 3, with an average score of 3.44.

7.3 Comparison of Alternatives

Table 7-1 provides a summary and comparison of the evaluation of the alternatives. Notes are provided summarizing the key findings of the evaluation of each criterion for each alternative. The following provides a summary of the overall findings of this evaluation:

- **Alternative 1** was scored the highest through this evaluation. Although it delivers the least benefit of the three alternatives, the difference in flood control benefit relative to the other alternatives is only marginal, and Alternative 1 delivers most of the flood control benefit at the lowest cost of the three alternatives. It successfully prevents flooding of SR 1 under all but the most extreme tide events. It does come with challenges, including impacts to tidally influenced areas, and does not substantially reduce tidal flooding over the Bay Trail.
- **Alternative 2** was scored only slightly lower than Alternative 1. In addition to the flood protection benefits provided by Alternative 1, Alternative 2 reduces flooding on the Bay Trail and provides some additional protection for adjacent commercial properties. It successfully prevents flooding of SR 1 under all but the most extreme tide events. It also comes with challenges, including additional work required within tidally influenced areas.
- **Alternative 3** was scored the lowest of the three alternatives, primarily due to the high cost and complication of operating and maintaining additional facilities. The cost and complication are primarily tied to the stormwater pump station that was included in this alternative. The pump station does not add a lot of value to flood reduction under King Tide, sunny day events, but could potentially add ability to reduce storm-induced flooding. Evaluation of storm events was beyond the scope of this study. Additional analysis should be completed to determine whether the additional improvements recommended as part of Alternative 3 would actually help better convey storm flows under a full range of tide conditions.

Table 7-1
Evaluation and Comparison of Flood Reduction Alternatives

Information or Criteria	Alternative 1	Alternative 2	Alternative 3
Description	Tideflex valves, barriers, and targeted trail modifications focused on reducing tidal flooding on SR 1 and at entrance to Caltrans maintenance yard.	Same as Alternative 1, but with additional Tideflex valves and barriers to reduce flooding on adjacent commercial properties, complete modifications to prevent the trail from flooding, and improved drainage facilities adjacent to and across SR 1.	Same as Alternative 3, but with additional Tideflex valves, barriers, and storm drain improvements intended to improve the flows from the Park-and-Ride and south side of SR 1 to Richardson Bay. This is the most comprehensive alternative evaluated.
Flood Reduction Effectiveness	Effectively prevents tidal flooding of SR 1 under all but the most extreme high tide conditions. Flooding still occurs in and around commercial properties northwest of the Caltrans maintenance yard. Under peak observed tide conditions, flooding near the commercial properties fills the storm drain system and then causes limited flooding from the storm drain system in SR 1 near the Caltrans maintenance yard and Park-and-Ride. 4	Effectively prevents tidal flooding of SR 1 under all but the most extreme high tide conditions. Flooding still occurs in and around commercial properties northwest of the Caltrans maintenance yard. Under peak observed tide conditions, flooding near the commercial properties fills the storm drain system and then causes limited flooding from the storm drain system in SR 1 near the Caltrans maintenance yard and Park-and-Ride. 4	Effectively prevents tidal flooding of SR 1 under all but the most extreme high tide conditions. Flooding still occurs in and around commercial properties northwest of the Caltrans maintenance yard. Under peak observed tide conditions, flooding near the commercial properties fills the storm drain system and then causes limited flooding from the storm drain system in SR 1 near the Caltrans maintenance yard and Park-and-Ride. 4
Reliability/ Resilience	Primarily relies on Tideflex valves, self-regulating tide gates, and barriers to reduce flooding. Each of these facilities will require some level of maintenance to be reliable. The barriers are not as extensive as for other alternatives. The top elevations of the barriers may need to be higher to more effectively address resiliency to sea level rise. 3	Primarily relies on Tideflex valves, self-regulating tide gates, and barriers to reduce flooding. Each of these facilities will require some level of maintenance to be reliable. The addition of the trail modifications adds to the reliability of this alternative. The top elevations of the barriers and trail may need to be higher to more effectively address resiliency to sea level rise. 4	Primarily relies on Tideflex valves, self-regulating tide gates, and barriers to reduce flooding. Each of these facilities will require some level of maintenance to be reliable. The addition of the trail modifications adds to the reliability of this alternative. The addition of storm drain improvements and pumping does not make a big difference under sunny day King Tide conditions. The top elevations of the barriers and trail may need to be higher to more effectively address resiliency to sea level rise. 4

Information or Criteria	Alternative 1	Alternative 2	Alternative 3
Fluvial Benefit	Would add a small amount of hydraulic loss at outfalls with Tideflex valves. Would also create barriers to tidal intrusion into ditches and the storm drain system, reserving more capacity for storm flows. Overall, offers the least benefit to storm-induced flooding of the alternatives evaluated, but probably offers an overall net gain by reducing tidal intrusion into ditches and storm drains. 3	Would add a small amount of hydraulic loss at outfalls with Tideflex valves. Would also create barriers to tidal intrusion into ditches and the storm drain system, reserving more capacity for storm flows. Would improve storm drain capacity by improving the ditch between the Park-and-Ride and SR 1 and replacing a culvert under SR 1. This all represents moderate improvement to capacity available to convey storm flows. 3	Would add a small amount of hydraulic loss at outfalls with Tideflex valves. Would also create barriers to tidal intrusion into ditches and the storm drain system, reserving more capacity for storm flows. Would improve storm drain capacity by improving the ditch between the Park-and-Ride and SR 1 and replacing a culvert under SR 1. Storm drain improvements in the Park-and-Ride and pumping could further improve storm flows through the system. Overall, this alternative offers the most potential benefit to control of storm-induced flooding. 4
Permitting Complexity	Would be the least complex of the alternatives considered. However, complex permitting and resource impact issues would be triggered by construction of barriers, self-regulating tide gates, and targeted raising of the Bay Trail within the tidal marsh area. 3	Would be more complex than Alternative 1, primarily due to extensive modification to the Bay Trail within the tidal marsh area. Complex permitting and resource impact issues would also be triggered by construction of barriers and self-regulating tide gates in the tidally influenced area. 2	Similar to Alternative 2, Alternative 3 would be more complex than Alternative 1, primarily due to extensive modification to the Bay Trail within the tidal marsh area. Complex permitting and resource impact issues would also be triggered by construction of barriers and self-regulating tide gates in the tidally influenced area. 2
Property Impacts	Construction of barriers could impact private properties, but impacts would be relatively minor overall. 4	Construction of barriers could impact private properties, but impacts would be relatively minor overall. 4	Construction of barriers could impact private properties, but impacts would be relatively minor overall. 4
Public Use Impacts	Would reduce flooding on public roadways and in the Park-and-Ride. 4	Would reduce flooding on public roadways and in the Park-and-Ride and would reduce flooding across the Bay Trail. 5	Would reduce flooding on public roadways and in the Park-and-Ride and would reduce flooding across the Bay Trail. 5

Information or Criteria	Alternative 1	Alternative 2	Alternative 3
Cost	$948,000 High benefit to cost ratio; represents most of benefit targeted for a relatively low cost. 5	$1,516,000 High benefit to cost ratio; represents most of benefit targeted for a relatively low cost. Additional cost results in substantially reduced flooding of the Bay Trail. 4	$3,839,000 Medium benefit to cost ratio; additional improvements do not result in a lot of additional benefit under sunny day, King Tide conditions, but may add benefit to storm conditions that have not yet been evaluated. 3
Constructability	Least complicated construction effort with shortest timeline for implementation. Would require a construction contract. 4	Moderately complicated construction effort with longer timeline for implementation. Would require a construction contract. 3	Most complicated construction effort with longest timeline for implementation. Would require a construction contract. 2
Operations and Maintenance	Would require regular inspection, cleaning of valves, and inspection of barriers after King Tide and storm events. Most of the new facilities would be familiar to operations staff and easy to maintain. 4	Would require regular inspection, cleaning of valves, and inspection of barriers after King Tide and storm events. Most of the new facilities would be familiar to operations staff and easy to maintain. 4	Would require regular inspection, cleaning of valves, and inspection of barriers after King Tide and storm events. Would also require maintenance of a pump station, which would complicate operations and maintenance. 3
Average Score	**3.78**	**3.67**	**3.44**
Rank	**1**	**2**	**3**

8 Conclusions and Recommended Next Steps

The purpose of the flood reduction study was to identify and evaluate potential measures that can be implemented in the near term to reduce the impact of flooding on SR 1, the Park-and-Ride, the Bay Trail, and adjacent public facilities and commercial properties. The evaluation and recommendations provided in this study are specifically focused on relatively small-scale or lower cost solutions that can be implemented in the near term (5 to 10 years) to help reduce the impact of flooding during King Tide events under sunny day conditions.

The evaluation identified several flood reduction measures that could be implemented to better protect the area from tidal flooding under sunny day conditions. The flood reduction measures identified some relatively simple, low-cost, straightforward improvements, such as adding Tideflex valves or tide gates at key locations where stormwater is backing up through the storm drain system to cause flooding. Other flood reduction measures that were identified would be more complicated, due to potential impacts to tidal marsh areas and other resources, and would likely require a more detailed planning, design, and implementation effort. It is feasible that all of the flood reduction measures identified could be implemented within the next 5 to 10 years and could substantially reduce the cost and effort currently required to deal with flooding during King Tide events.

8.1 Flood Control Measures

Based on our evaluation of flood control measures summarized in Section 3, we recommend consideration of the following measures for implementation as part of a strategy for reducing tidal flooding in the Manzanita area:

1. **Measures that would prevent tidal waters from backing up through culverts and storm drains into areas that are currently flooding.** Installation of either Tideflex valves or flap gates would work at these locations. However, primary consideration should be given to Tideflex valves because they are less prone to being obstructed with debris that could prevent full closure and can be somewhat more flexible in how they are installed. The conditions at each location should be considered and the most appropriate valve or gate should be selected to prevent tidal inundation of the storm drain or culvert at the specific location.
2. **Measures that would create a barrier across a low spot to separate upland areas that are prone to tidal flooding from low-lying tidal areas.** Four different barriers were considered. Based on the evaluation and discussion with key stakeholders, further consideration of a water-filled bladder as a permanent, long-term flood control measure is not recommended. Concerns about long-term operation, maintenance, and durability are reflected in the scoring represented in Table 3-4. One of the other measures (earthen berm, vinyl sheetpile wall, or a reinforced concrete wall) should be considered for implementation at these locations based on the

topographic and access constraints, space available, and conditions at each location where a barrier is to be installed.

3. **Measures that would modify the Bay Trail to protect it from tidal flooding.** Based on our evaluation and development of conceptual designs for potential measures that could be taken to modify the Bay Trail to prevent overtopping, it is recommended that raising the trail be given further consideration. Adding concrete curbs or barriers alongside the trail would create safety and drainage concerns. Adding earthen berms alongside the trail would also result in larger volumes of fill being placed in tidal areas and would likely be very difficult to permit. Caltrans should consider further coordination with Marin County Parks Department and the Golden Gate Parks Conservancy to identify trail improvements that accomplish flood reduction goals, are most compatible with long-term plans for the trail system, and will address concerns about placing fill within tidally influenced areas.
4. **A measure that would improve control of tidal inundation at the outlet of the major storm drain outfall in the study area.** Installation of barn-door style self-regulating tide gates at the primary outfall along the east side of US 101 should be considered as part of any flood reduction measure moving forward. This measure would allow for more automatic control of tidal flooding through the outfall. It will also allow for the existing tide gates to remain open and for flood waters to recede more quickly following peak tide events.
5. **Measures that would improve the conveyance efficiency through the storm drain system to improve the conveyance of flood water to Richardson Bay.** Storm drain improvements should be considered to improve conveyance of flood waters from the SR 1 right-of-way and the Park-and-Ride to Richardson Bay. These improvements have potential to improve conveyance of flood waters to allow tidal flooding to recede more quickly following peak tide events and should be considered in relation to the benefit they could provide during storm-induced flooding. Pumping should be considered as a last priority due to the expense and complication associated with installation of a stormwater pump station.

8.2 Other Considerations

Although not specifically part of the focus of this study, the following variables should be carefully considered as planning for flood reduction improvements moves forward:

- **Storm-induced Flooding:** The scope of this study was specifically limited to evaluating flooding that results from King Tide events during sunny day conditions. Flooding also occurs in the area as a result of runoff from large storm events. That flooding is particularly critical when storms coincide with high tides, which does often occur during the winter. The model and information provided in this report should be used as a starting point for additional evaluation of flooding that occurs under the full range of storm and tide conditions to provide a more comprehensive understanding of how the improvements recommended in this study will affect the ability of stormwater infrastructure to convey storm flows to Richardson Bay.

- **Future Sea Level Rise (SLR):** SLR has been noted as a condition that could exacerbate future tidal flooding conditions. The flood reduction measures evaluated by this study were sized to reduce tidal flooding under all historical tide conditions, including the maximum observed tide. However, SLR projections would result in tides that could exceed the maximum observed tide condition. The duration and frequency of high tide events is also projected to increase under future SLR conditions. Additional analysis should be completed to more clearly define projected SLR conditions at the site and determine what tide level should be used as a constraint for implementation of flood reduction measures.
- **Planned Improvements to the Bay Trail**: The Marin County Parks Department is working with the Golden Gate National Parks Conservancy and other key stakeholders to evaluate potential improvements to the Bay Trail through the study area. Potential improvement options include rerouting the Bay Trail between US 101 and Coyote Creek or elevating the trail through Bothin Marsh. Any improvements made to reduce flooding in the area will need to be well coordinated so that improvements to the trail are designed to help reduce tidal flooding while also meeting public use enhancement and ecological improvement objectives.
- **Settlement:** Caltrans noted that one of the key factors that has worsened the impact of tidal flooding on the area is settlement. Much of the area appears to be settling, including the most heavily impacted segment of SR 1, Park-and-Ride facilities, and the Bay Trail. Evaluation of geotechnical conditions and settlement within the area was not part of the scope of this study. However, settlement should be carefully considered before making costly structural improvements, such as raising the Bay Trail or making improvements to the Park-and-Ride.
- **Limited Clearance Under US 101.** Caltrans has noted that there is limited clearance between the bottom of the US 101 bridge and SR 1. That clearance may limit any improvements that could be made to SR 1 as part of a longer term strategy for flood reduction in the area. Although those types of long-term improvements to SR 1 were explicitly not included in the scope of this study, the topographic survey completed as part of this study did measure elevations on the roadway and along the bottom edges of the US 101 bridge crossing SR 1. Table 8-1 summarizes the data points collected and the approximate clearance values. These should be considered relative to any long-term improvements to SR 1.
- **Barrier at Northwest End of Tidal Marsh Near Holiday Inn Express.** The alternatives that were evaluated in this report all resulted in shallow flooding under high tide conditions in the parking area near the Holiday Inn Express hotel. The tide overtops the trail connection along Coyote Creek adjacent to the hotel and inundates the parking lot when the tide reaches an elevation of approximately 7.0 feet. Caltrans suggested evaluating a barrier adjacent to Coyote Creek that would run along the trail from the northwest corner of the Holiday Inn Express property across the northwest end of the tidal marsh to the Bay Trail. This barrier

could potentially replace the need for barriers further south along the Caltrans maintenance yard by blocking the primary path of tidal inundation, which is from Coyote Creek under the boardwalk portion of the trail to the tidal marsh. A barrier at this location had been considered as part of the initial identification of potential flood control measures but was not fully evaluated as part of this study due to the anticipated permitting complications that would result from cutting off free tidal exchange between Coyote Creek and the tidal marsh. However, future consideration could be given to a barrier at this location if it includes an automated gate system that would allow for tidal exchange during normal tide conditions (below the MHHW) and prevent tidal exchange when the tide exceeds MHHW.

Table 8-1
Summary of Clearance Under US 101 Bridge

Location	Elevation on Underside of Bridge	Elevation of Nearest Point on Ground	Approximate Clearance	Elevation of Nearest Point on Roadway	Approximate Clearance
US 101 SB Off Ramp Bridge, North side of SR 1, West Edge of Bridge	44.32	7.60	36.72	7.10	37.22
US 101 SB Off Ramp Bridge, South side of SR 1, West Edge of Bridge	39.58	5.42	34.16	6.00	33.58
US 101 SB Off Ramp Bridge, North side of SR 1, East Edge of Bridge	42.81	7.90	34.91	7.33	35.48
US 101 SB Off Ramp Bridge, South side of SR 1, East Edge of Bridge	38.67	5.13	33.54	6.00	32.67
US 101 Main Bridge, North side of SR 1, West Edge of Bridge	42.18	8.23	33.95	7.68	34.50
US 101 Main Bridge, South side of SR 1, West Edge of Bridge	39.80	6.22	33.58	6.28	33.52
US 101 Main Bridge, North side of SR 1, East Edge of Bridge	27.98	8.26	19.72	8.04	19.94
US 101 Main Bridge, South side of SR 1, East Edge of Bridge	23.91	7.26	16.65	7.31	16.60

8.3 Recommended Priorities and Next Steps

Based on the information provided in this study, it is recommended that Caltrans continue to pursue near-term implementation of flood reduction measures that will reduce the impact of tidal flooding on SR 1, the Park-and-Ride, and the Caltrans maintenance yard. These improvements should be coordinated with efforts to reduce flooding on the Bay Trail and adjacent commercial properties. The following is a possible list of recommended next steps for consideration:

1. Initiate a more comprehensive evaluation of flooding to look at not only tidal flooding, but also flooding caused by runoff from peak storm events during the full range of tide conditions.
2. As all funding and permits are obtained and staff resources are available, start planning for implementation of the improvements outlined in this study as Alternative 1 improvements, with the goal of minimizing the impact of tidal flooding on the traveled SR 1 right-of-way and Caltrans maintenance yard. Final design will likely involve detailed civil, geotechnical, and structural engineering as well as a comprehensive biological assessment of impacts to wetlands and mitigation costs to complete design and permitting. The improvements could start with those that are easiest to plan for and implement and progress toward those that will require more coordination, permitting, and design effort, as follows:
    a. Purchase and install a Tideflex valve or a tide gate in the culvert near the north corner of the Caltrans maintenance yard to prevent water in the tide marsh from backwatering the culvert and ditch along the west side of the Caltrans maintenance yard.
    b. Purchase and install Tideflex valves or a tide gates at key locations on the storm drain systems near the Holiday Inn Express and adjacent commercial properties to prevent shallow flooding in the Holiday Inn Express parking lot from backwatering the storm drain system and flooding the ditches adjacent to the northeast side of SR 1.
    c. Prepare plans for, permit, and install a barrier across the low spot between the Caltrans maintenance yard and the commercial property to the north and west to provide a barrier to tidal intrusion at that location.
    d. Prepare plans for, permit, and install a barrier along the east side of the Caltrans maintenance yard and tie that barrier into the Bay Trail to prevent tidal flooding along the back of the Caltrans maintenance yard and along the trail under US 101.
    e. Incorporate into the plans the ability to raise the Bay Trail to prevent tidal overtopping northwest of the US 101 bridge and south of Pahono Street. Tidal flooding cannot be fully resolved with reconstruction of the trail, but substantially minimizing flooding on SR 1 will require that bike path elevations be modified just west of US 101 and south of Pohono Street. If the trail continues to be overtopped in these areas during King Tide events, flooding of SR 1 will continue.
3. Caltrans should then consider coordinating with others to add the benefits provided as Alternative 2 in this study by completing the following:
    a. Coordinate efforts to reduce flooding at Caltrans facilities with plans to implement improvements to the Bay Trail that will reduce overtopping during King Tide events, improve the ecologic functions of Bothin Marsh, and improve public use of trail facilities.
    b. If warranted by additional study of flooding caused by runoff from peak storm events during the full range of tide conditions, plan for and evaluate the cost-effectiveness and

feasibility of near-term improvements to the ditch and storm drainage system along SR 1, including the following:

- Complete ditch maintenance activities including excavation and improvement of the ditch connection between the entrance to the Park-and-Ride and the low spot in the ditch along the south side of SR 1 under the US 101 bridge, between SR 1 and the Park-and-Ride.
- Plan for and develop designs to replace the culvert under SR 1 with a larger culvert at a slightly higher elevation. The size and condition of the culvert should be verified as part of the design process. The south end of the culvert was mostly buried and was not located as part of the survey effort completed for this study.

c. Evaluate and obtain funding and permits as staff resources allow for other improvements to the storm drain system warranted by the additional study of flooding caused by runoff from peak storm events during the full range of tide conditions.

9 References

Anchor QEA, 2020a. Draft Manzanita Flood Reduction Study, Summary of Existing Conditions, Site Constraints, Data Gaps, and Opportunities Memorandum. Prepared for Roger Leventhal, Marin County Department of Public Works, September 28, 2020.

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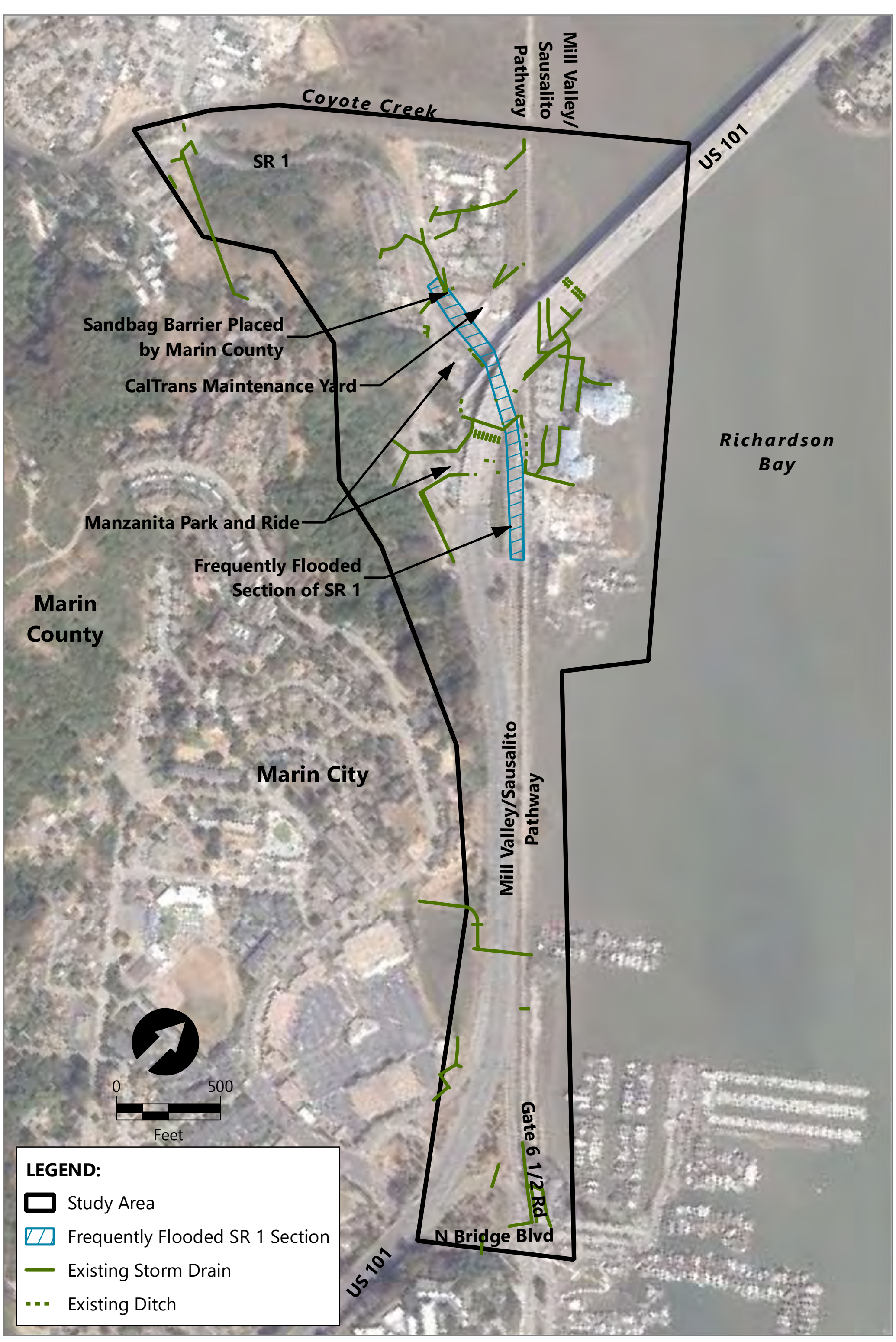
Appendix A
Conceptual Design Figures

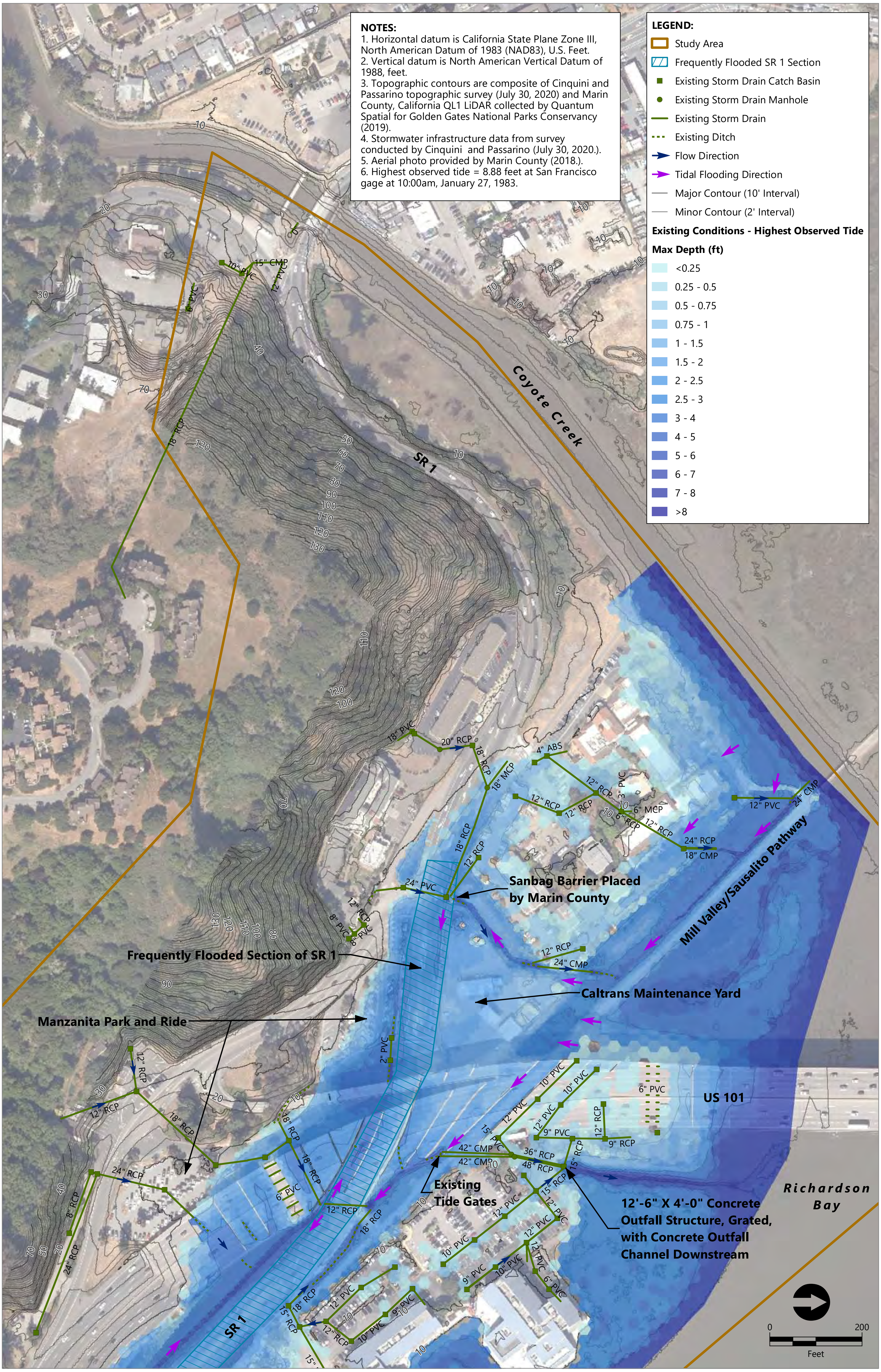
List of Exhibits

Vicinity Map



Site Map

NOTES:
1. Horizontal datum is California State Plane Zone III, North American Datum of 1983 (NAD83), U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Topographic contours are composite of Cinquini and Passarino topographic survey (July 30, 2020) and Marin County, California QL1 LiDAR collected by Quantum Spatial for Golden Gates National Parks Conservancy (2019).
4. Stormwater infrastructure data from survey conducted by Cinquini and Passarino (July 30, 2020.), and Marin County GIS Database (2020).
5. Aerial photos provided by Marin County (2018.) and Esri ArcGIS Online.



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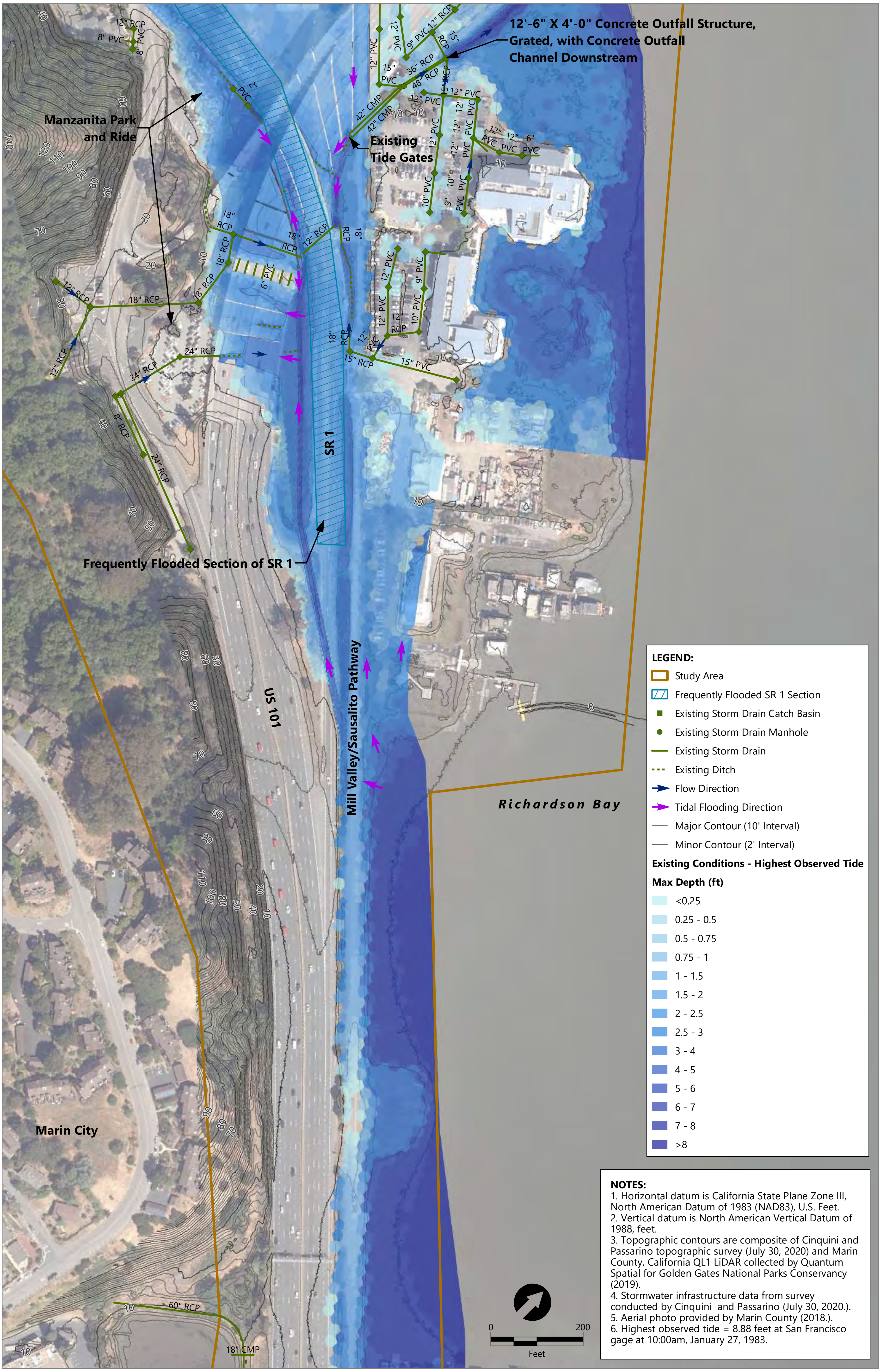
ANCHOR QEA

Figure EC-1
Existing Conditions – West Study Area
Flood Reduction Study Report
Manzanita Area Flood Reduction Study



NOTES:
1. Horizontal datum is California State Plane Zone III, North American Datum of 1983 (NAD83), U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Topographic contours are composite of Cinquini and Passarino topographic survey (July 30, 2020) and Marin County, California QL1 LiDAR collected by Quantum Spatial for Golden Gates National Parks Conservancy (2019).
4. Stormwater infrastructure data from survey conducted by Cinquini and Passarino (July 30, 2020.).
5. Aerial photo provided by Marin County (2018.).
6. Highest observed tide = 8.88 feet at San Francisco gage at 10:00am, January 27, 1983.

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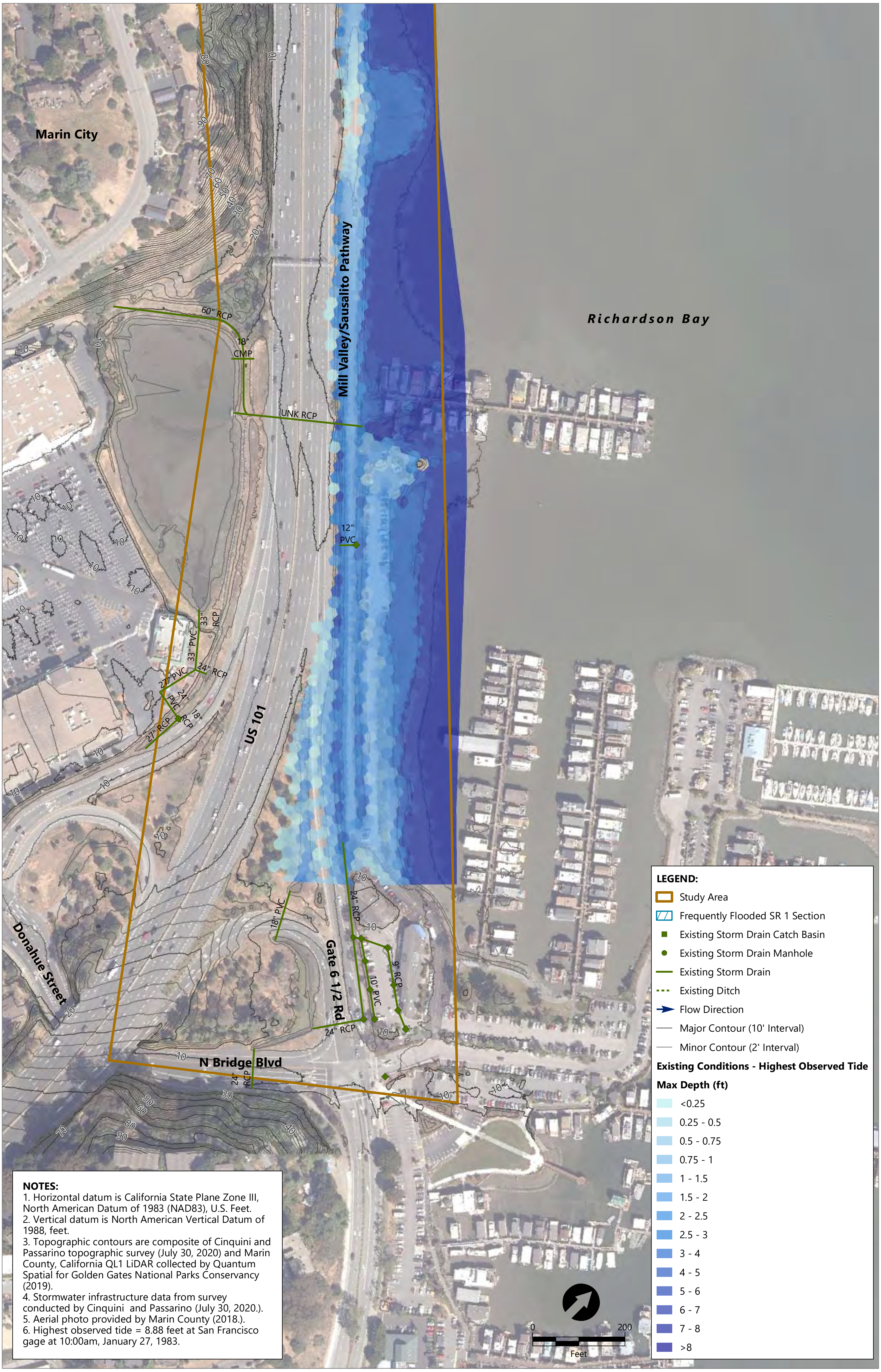
ANCHOR QEA

Figure EC-2
Existing Conditions – East Study Area



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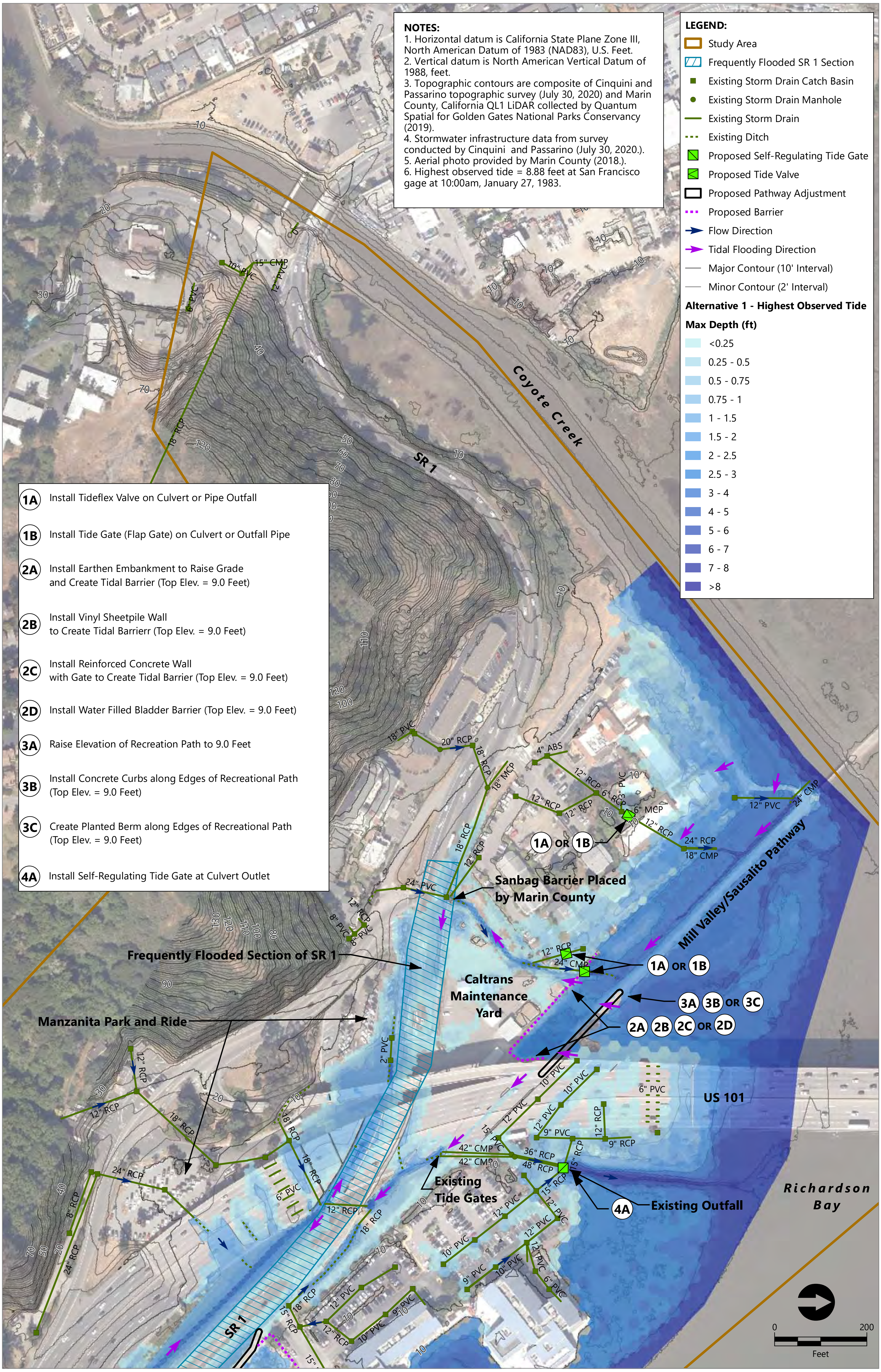
ANCHOR QEA

Figure EC-3
Existing Conditions – South Study Area



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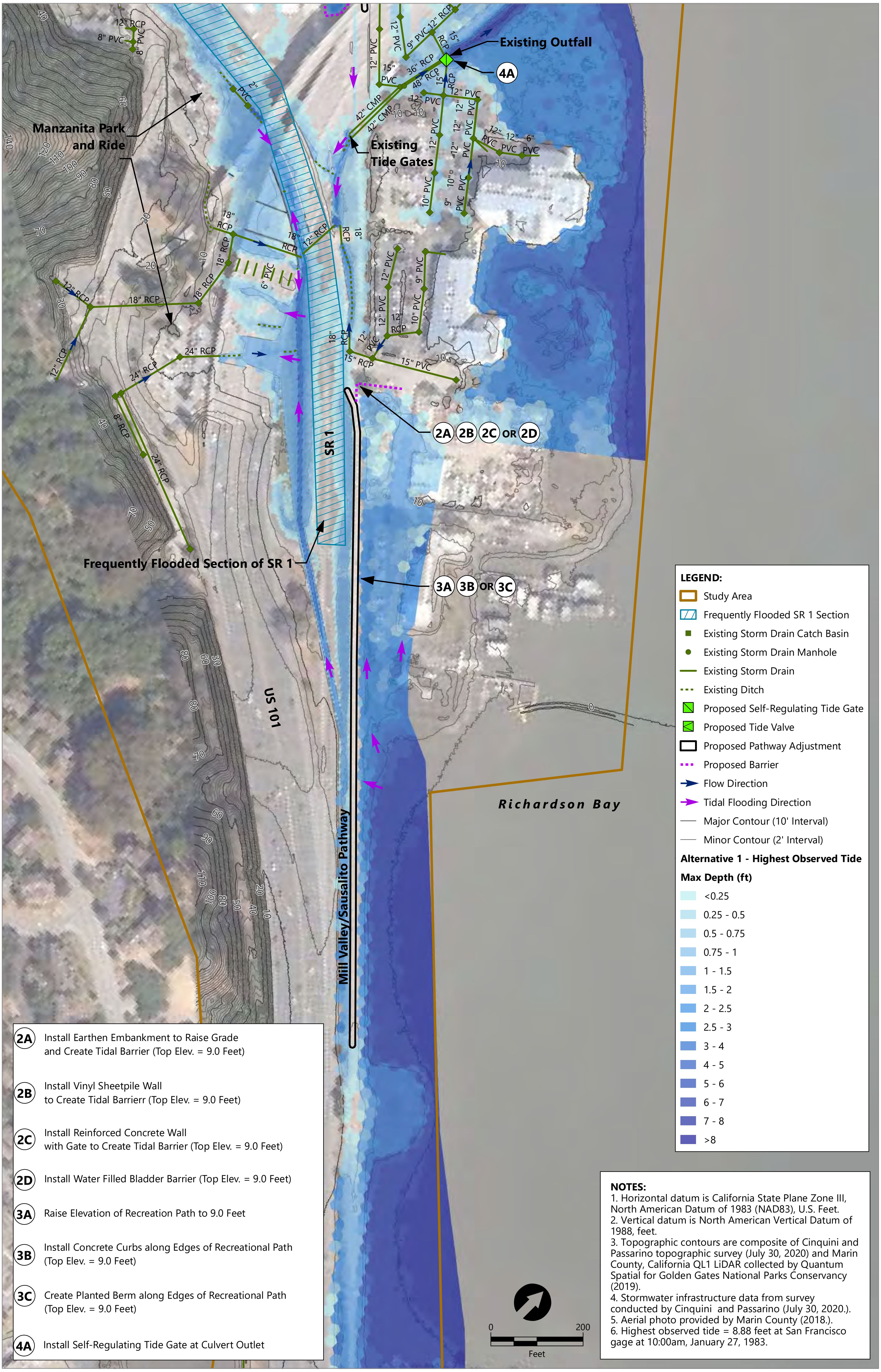
ANCHOR QEA

Figure A1-1
Improvement Alternative 1 – West Study Area
Flood Reduction Study Report
Manzanita Area Flood Reduction Study



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ANCHOR QEA

Figure A1-2
Improvement Alternative 1 – East Study Area

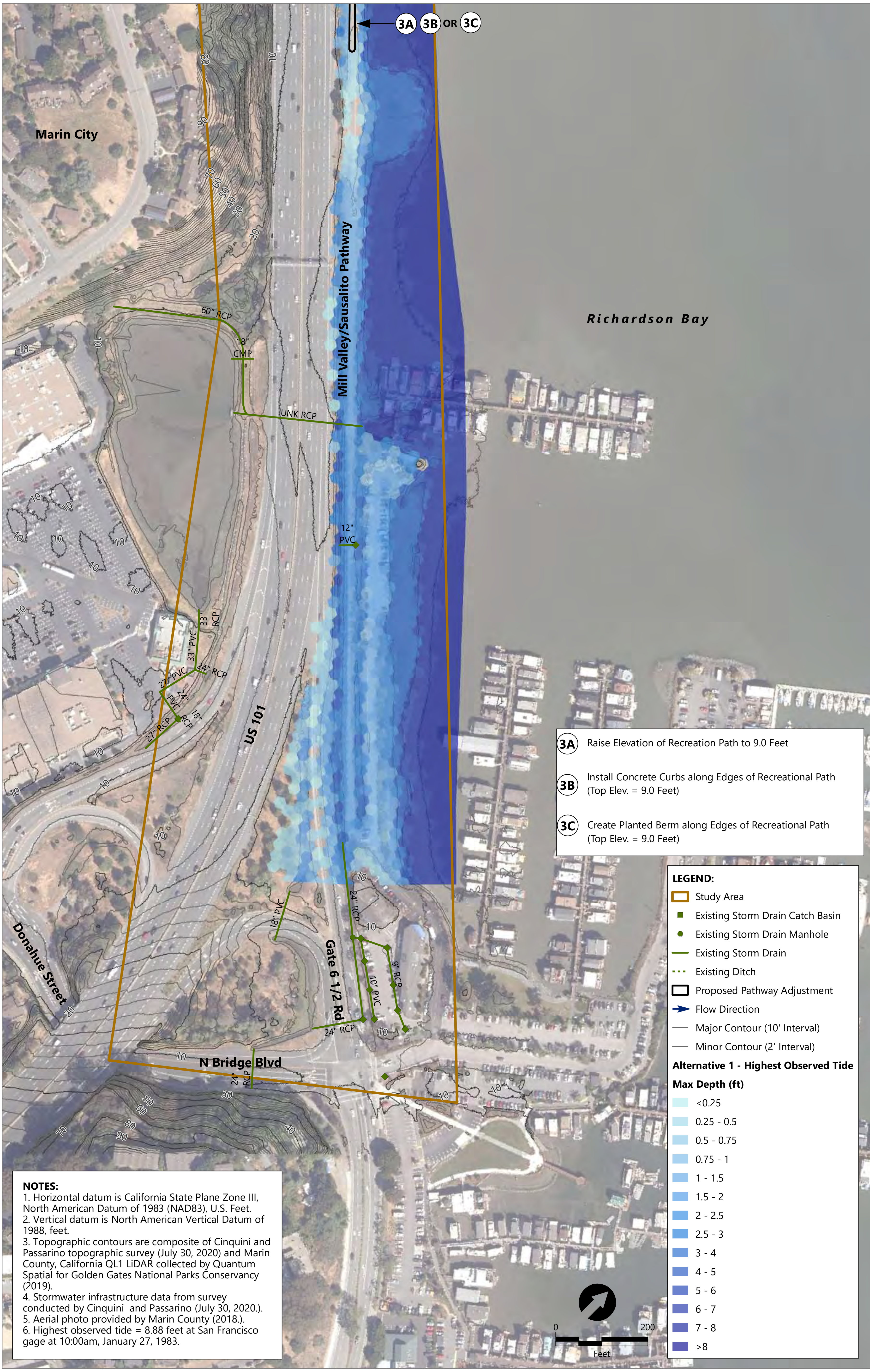

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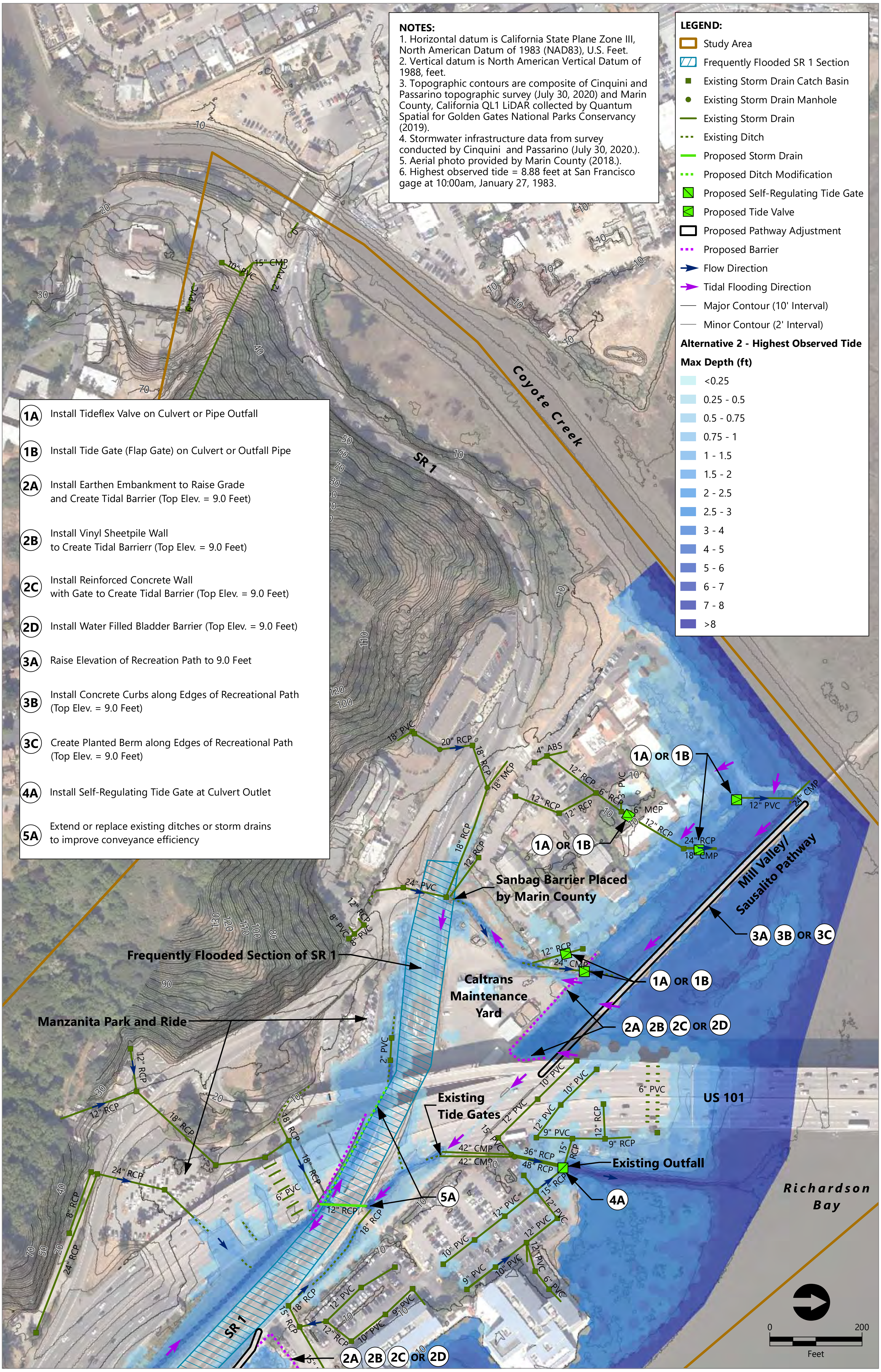
Figure A1-3
Improvement Alternative 1 – South Study Area



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ANCHOR QEA

Figure A2-1
Improvement Alternative 2 – West Study Area
Flood Reduction Study Report
Manzanita Area Flood Reduction Study

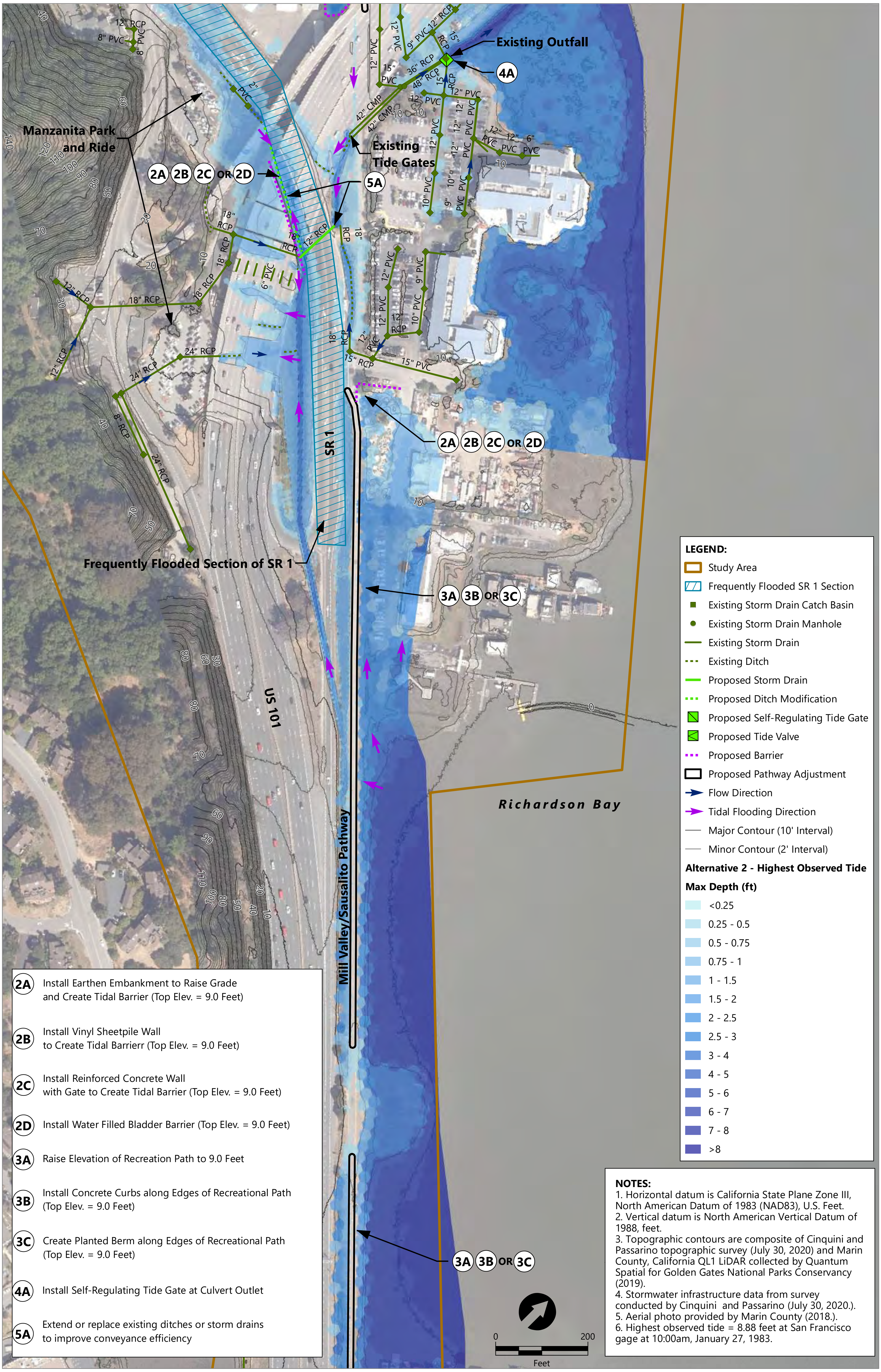

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Figure A2-2
Improvement Alternative 2 – East Study Area

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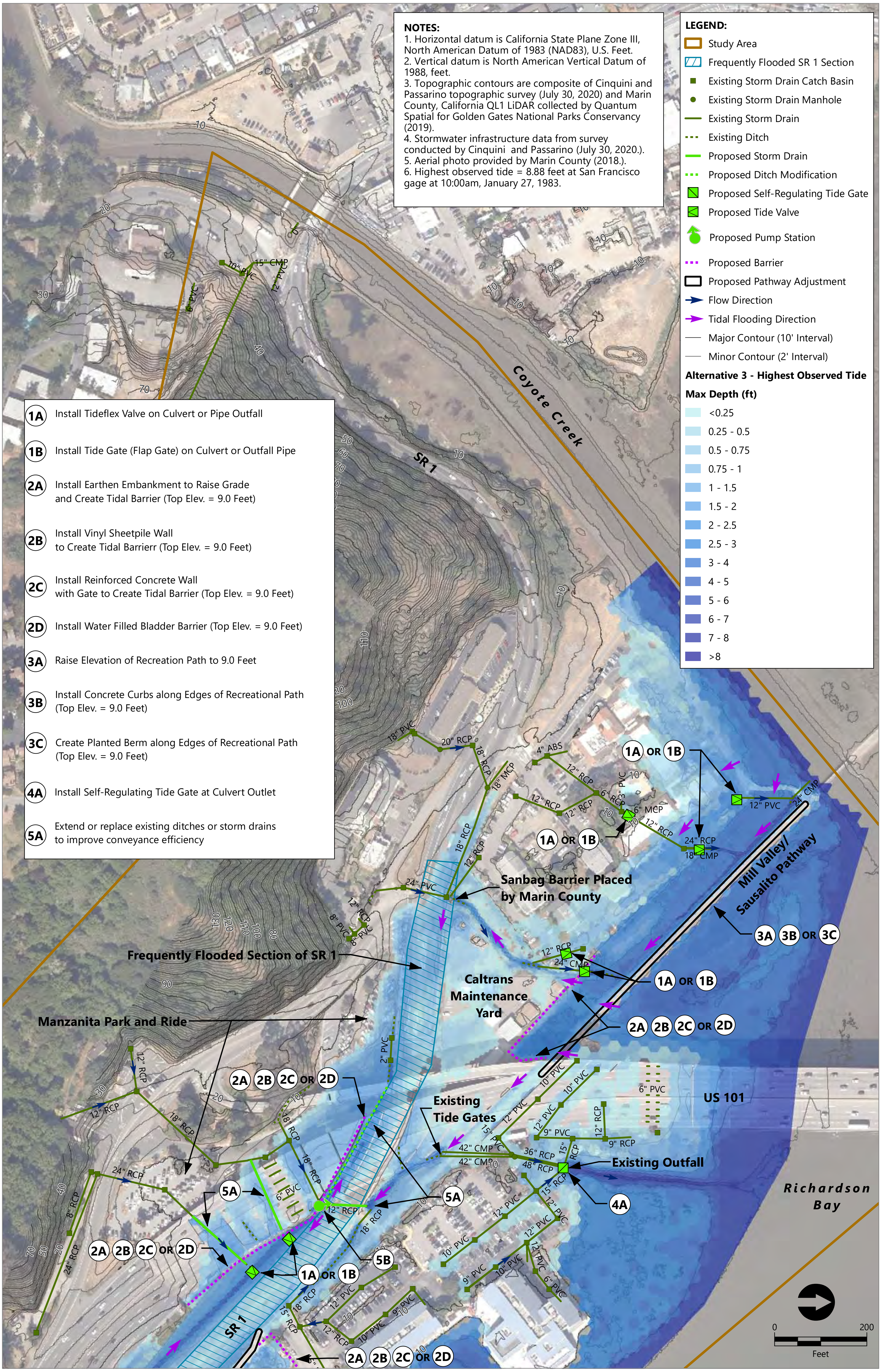
ANCHOR QEA

Figure A2-3
Improvement Alternative 2 – South Study Area



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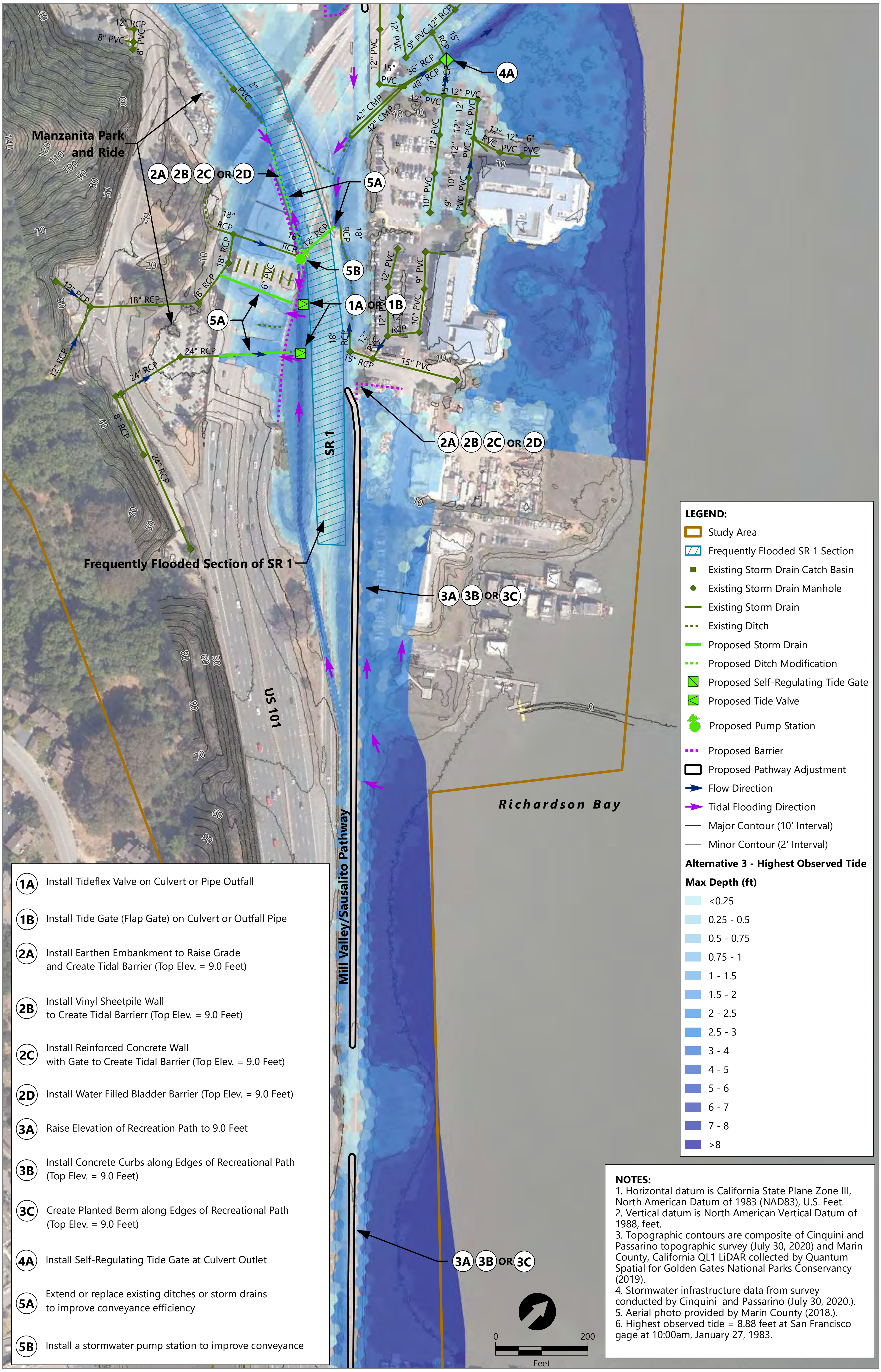
ANCHOR QEA

Figure A3-1
Improvement Alternative 3 – West Study Area
Flood Reduction Study Report
Manzanita Area Flood Reduction Study



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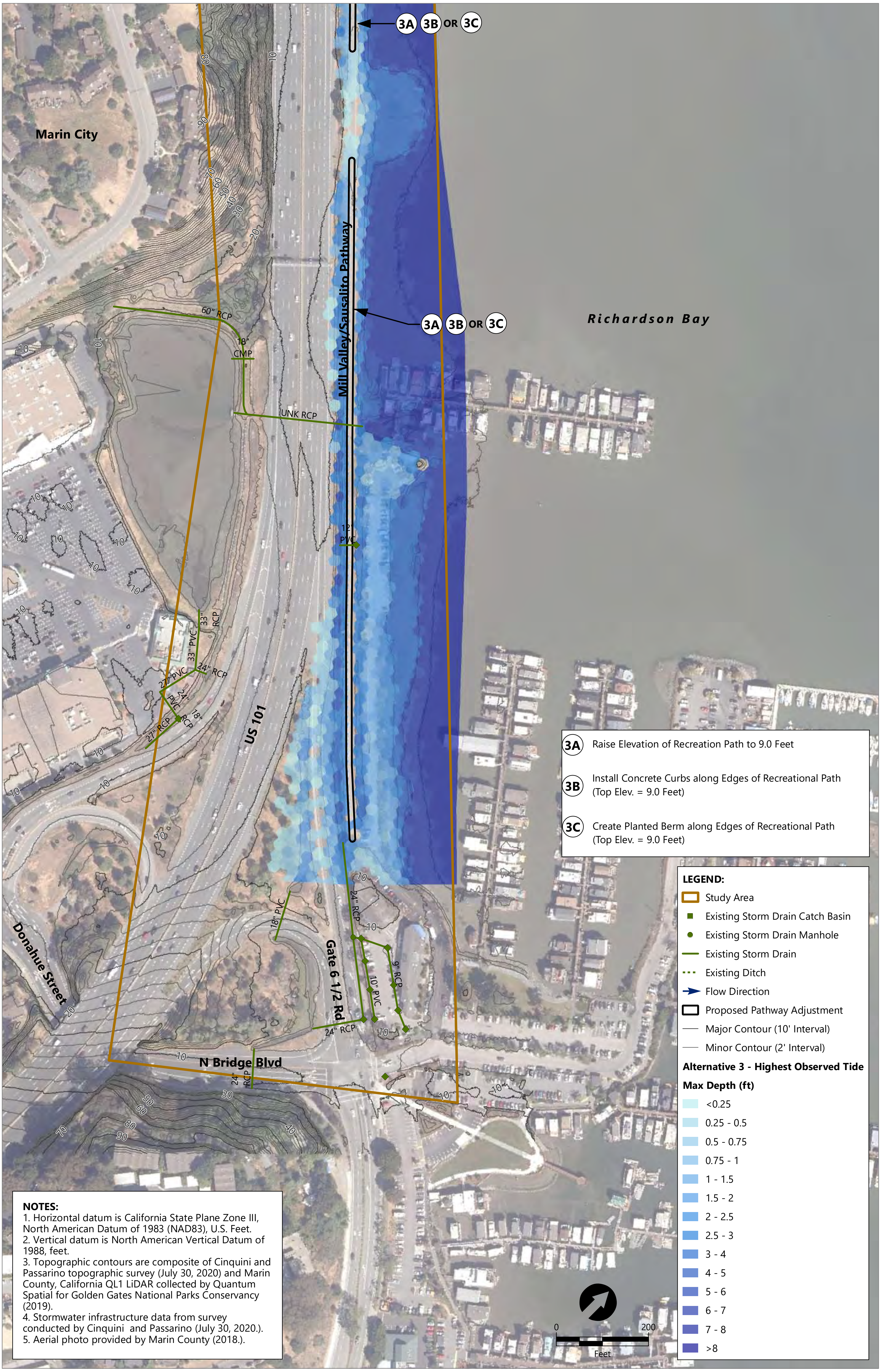
ANCHOR QEA

Figure A3-2
Improvement Alternative 3 – East Study Area



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ANCHOR QEA

Figure A3-3
Improvement Alternative 3– South Study Area
Manzanita Area Flood Reduction Study
US 101/California SR1 Junction and Manzanita Park and Ride

Appendix B
Topographic Survey

LOCATION MAP (N.T.S)

BENCHMARK

CINQUINI & PASSARINO CONTROL POINT NO. 1, BEING A SET MAG NAIL AND WASHER TAGGED PLS7935 AS SHOWN HEREON.
ELEVATION = 5.93' ASSUMED)

BASIS OF BEARINGS

BEING NORTH 21°47'21" WEST BETWEEN TIDAL MONUMENT 941 4819 TIDAL 32 (HT1067) AND N501. A COORDINATE SHIFT WAS PERFORMED AFTER REVIEWING THE PREVIOUS 2014 SURVEY BY MERIDIAN. THE COORDINATE VALUES OF THE SURVEY WERE SHIFTED SOUTH 31°49'42" EAST 1.985 FEET FROM THE USACE PUBLISHED COORDINATES.

SURVEYOR'S STATEMENT

THIS MAP REPRESENTS A FIELD SURVEY MADE BY ME OR UNDER MY DIRECTION ON JULY 30, 2020 AND REPRESENTS THE VISUAL SURFACE CONDITIONS AS OF AFORESAID DATE.

James M. Dickey, P.L.S. 7935

LICENSED LAND SURVEYOR
JAMES M. DICKEY
No. 7935
STATE OF CALIFORNIA

12/22/2020
DATE

LEGEND (ALL SYMBOLS MAY NOT APPLY)

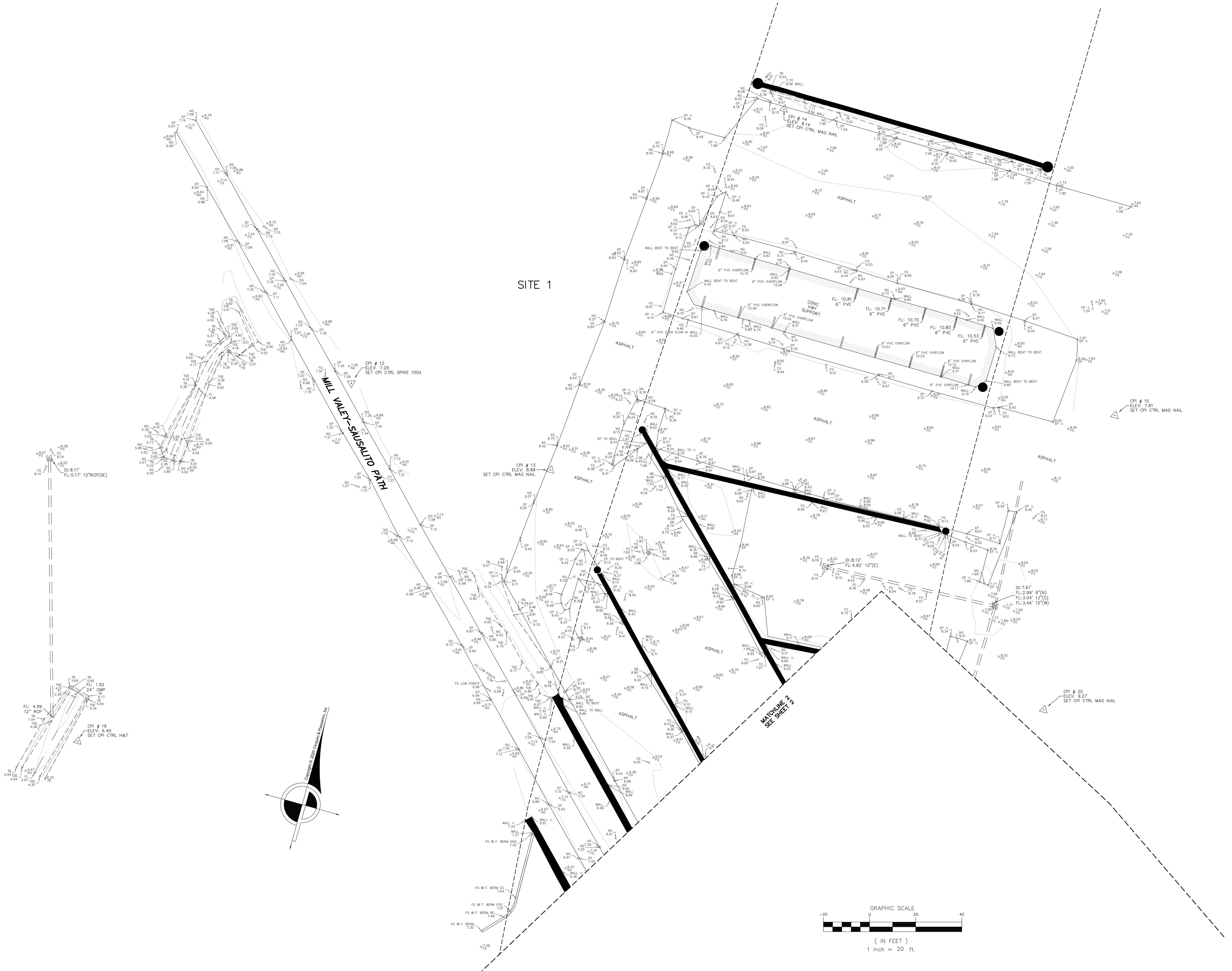
SUBJECT PROPERTY BOUNDARY
OHE — OVERHEAD ELECTRIC LINE
OHT — OVERHEAD TELEPHONE LINE
OHU — OVERHEAD UTILITY LINES (MULTIPLE)
OHE-HV — OVERHEAD ELECTRIC (HIGH VOLTAGE)
OHU-HV — OVERHEAD UTILITY LINES (HIGH VOLTAGE)
G — GAS LINE
SD — STORM DRAIN LINE
SS — SANITARY SEWER LINE
W — WATER LINE
UGTS — UNDERGROUND TRAFFIC SIGNAL WIRE
CHAINLINK FENCE
WOOD FENCE
WIRE FENCE
CONCRETE
PERIMETER OF BUILDING
SURVEY CONTROL POINT
+ 100.00 SPOT ELEVATION
CO SANITARY SEWER CLEANOUT
SS SANITARY SEWER MANHOLE
SD STORM DRAIN MANHOLE
STORM DRAIN CATCH BASIN
DRAINAGE INLET
DRAINAGE INLET
DS DRAINAGE DOWNSPOUT
I IRRIGATION CONTROL VALVE
MW MONITORING WELL
W WELL
FIRE HYDRANT
WATER VALVE
W WATER METER
HOSE BIB
E ELECTRIC BOX
PG&E PG&E VAULT
E ELECTRIC LID
PP POWER POLE
JP JOINT UTILITY POLE
JP JOINT POLE W/STREET LIGHT
S TRAFFIC SIGNAL
S TRAFFIC SIGNAL POLE W/STREET LIGHT
T TELEPHONE POLE
STREET LIGHT
LANDSCAPE LIGHT
LB STREET LIGHT BOX
S TRAFFIC SIGNAL LIGHT BOX
D TRAFFIC DETECTOR LID
T TELEPHONE BOX
T TELEPHONE MANHOLE
C CABLE TV BOX
TEL TELEPHONE VAULT
GAS VALVE
G GAS METER
BOLLARD
SIGN
M MAILBOX
FOUND IRON PIPE, SIZE AND TAGGED AS NOTED
FOUND MONUMENT, SIZED AND STAMPED, AS NOTED
TREE SYMBOL AND DRIP LINE
BIR. BIRCH

B.O.	BLACK OAK	BLDG	BUILDING	FL	FLOWLINE	RWB	RETAINING WALL BOTTOM
EUC	EUCALYPTUS	BSW	BACK OF SIDEWALK	FG	FINISH GRADE	RWT	RETAINING WALL TOP
L.A.	LIQUID AMBER	CMP	CORRUGATED METAL PIPE	GB	GRADE BREAK	SD	STORM DRAIN
L.O.	LIVE OAK	DI	DRAINAGE INLET	HC	HANDICAPPED PARKING SPACE	SLB	STREET LIGHT BOX
MAD	MADRONE	DN	DOCUMENT NUMBER	HDPE	HIGH DENSITY POLYETHYLENE	SWBUT	SINGLE WHITE BUTTON
ORN	ORNAMENTAL	DW	DRIVEWAY	(ITEM NO.)	TITLE REPORT ITEM NUMBER	SYBUT	SINGLE YELLOW BUTTON
RWD	REDWOOD	DYBUT	DOUBLE YELLOW BUTTON	JB	JUNCTION BOX	TB	TOP OF BANK
W.O.	WHITE OAK	EP	EDGE PAVING	LIP	LIP OF GUTTER	TOE	TOE OF BANK
SYC	SYCAMORE	ER	EDGE OF ROAD	NG	NATURAL GROUND	TC	TOP OF CURB
WIL	WILLOW	ETW	EDGE TRAVELED WAY	O.R.	OFFICIAL RECORDS	BRC	BACK OF ROLLED CURB
AC	ASPHALT	EXIST	EXISTING	PL	PROPERTY LINE	TSB	TRAFFIC SIGNAL BOX
B.F.P.C.V.	BACK FLOW PREVENTION CHECK VALVE			RCP	REINFORCED CONCRETE PIPE	TW	TOP OF WALL
						OH	OVERHEAD

Job Name: MANZANITA PARK & RIDE LOT	DRAWN BY: TJN / CHECKED BY: JMD
	SCALE: 1" = 20'
	SHEET: 1 OF 5 / JOB NUMBER: 9052-20
Description: TOPOGRAPHIC MAP	DWG. PATH: Y:\9052\Cad\
	DWG. FILE: 9052_TOPO_AdditionalPoints_20200901.dwg
	DATE/TIME: Dec 21, 2020 – 9:34am

CINQUINI & PASSARINO, INC.
LAND SURVEYING
1360 N. Dutton Ave. #150
Santa Rosa, Ca. 95401
Phone: (707) 542-6268
Fax: (707) 542-2106
WWW.CINQUINIPASSARINO.COM
BOUNDARY
TOPOGRAPHIC
CONSTRUCTION
SUBDIVISIONS

MATCHLINE 2 SEE SHEET 3
MATCHLINE 10 SEE SHEET 6
SITE 3
MILL VALEY-SAUSALITO PATH
MATCHLINE 8 SEE SHEET 6
MATCHLINE 12 SEE SHEET 4
MATCHLINE 7 SEE SHEET 6
MATCHLINE 11 SEE SHEET 6
HIGHWAY 1 (SHORELINE HIGHWAY)
SITE 1
MATCHLINE 1 SEE SHEET 1
BUILDING
CPI # 22 ELEV: 8.17 SET CPI CTRL MAG NAIL
CPI # 4187 ELEV: 12.98 FND BRASS TAG NO TAG
CPI # 29 ELEV: 7.61 SET CPI CTRL MAG NAIL
CPI # 21 ELEV: 6.55 SET CPI CTRL SPIKE 100d
CPI # 28 ELEV: 7.26 SET CPI CTRL MAG NAIL
CPI # 24 ELEV: 10.23 SET CPI CTRL SPIKE 100d
CPI # 85 ELEV: 6.61 SET CPI CTRL MAG NAIL
FND MON NO TAGACE CPI# 13595 ELEV: 6.98
GRAPHIC SCALE
-20 0 20 40
(IN FEET)
1 inch = 20 ft.
Job Name:
MANZANITA PARK & RIDE LOT
DRAWN BY: TJN
CHECKED BY: JMD
SCALE: 1" = 20'
SHEET: 2 OF 5
JOB NUMBER: 9052-20
Description:
TOPOGRAPHIC MAP
DWG. PATH: C:\Users\jdickey\appdata\local\temp\AcPublish_19840\
DWG. FILE: 9052_TOPO_AdditionalPoints_20200901.dwg
DATE/TIME: Dec 22, 2020 - 9:04am
CINQUINI & PASSARINO, INC.
LAND SURVEYING
1360 N. Dutton Ave. #150
Santa Rosa, Ca. 95401
Phone: (707) 542-6268
Fax: (707) 542-2106
BOUNDARY
TOPOGRAPHIC
CONSTRUCTION
SUBDIVISIONS
WWW.CINQUINIPASSARINO.COM



Job Name:	DRAWN BY: TJN	CHECKED BY: JMD
MANZANITA PARK & RIDE LOT	SCALE: 1" = 20'	
	SHEET: 3 OF 5	JOB NUMBER: 9052-20
Description: TOPOGRAPHIC MAP	DWG. PATH: C:\Users\jdickey\appdata\local\temp\AcPublish_19840\	
	DWG. FILE: 9052_TOPO_AdditionalPoints_20200901.dwg	
	DATE/TIME: Dec 22, 2020 - 9:04am	

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Job Name:	DRAWN BY: TJN	CHECKED BY: JMD
MANZANITA PARK & RIDE LOT	SCALE: 1" = 20'	
	SHEET: 4 OF 5	JOB NUMBER: 9052-20
Description:	DWG. PATH: C:\Users\jdickey\appdata\local\temp\AcPublish_19840\	
TOPOGRAPHIC MAP	DWG. FILE: 9052_TOPO_AdditionalPoints_20200901.dwg	
	DATE/TIME: Dec 22, 2020 - 9:04am	

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- TOPOGRAPHIC
- CONSTRUCTION
- SUBDIVISIONS

MATCHLINE 9
SEE SHEET 6

DI:11.51'
FL:9.00' 24"RCP(W)

GRAPHIC SCALE

-20 0 20 40

(IN FEET)
1 inch = 20 ft.

Job Name: MANZANITA PARK & RIDE LOT	DRAWN BY: TJN / CHECKED BY: JMD
	SCALE: 1" = 20'
	SHEET: 5 OF 5 / JOB NUMBER: 9052-20
Description: TOPOGRAPHIC MAP	DWG. PATH: C:\Users\jdickey\appdata\local\temp\AcPublish_19840\
	DWG. FILE: 9052_TOPO_AdditionalPoints_20200901.dwg
	DATE/TIME: Dec 22, 2020 - 9:04am

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Job Name: MANZANITA PARK & RIDE LOT	DRAWN BY: TJN	CHECKED BY: JMD
	SCALE: 1" = 20'	
	SHEET: 5 OF 5	JOB NUMBER: 9052-20
Description: TOPOGRAPHIC MAP	DWG. PATH: C:\Users\jdickey\appdata\local\temp\AcPublish_9840\	
	DWG. FILE: 9052_TOPO_AdditionalPoints_20200901.dwg	
	DATE/TIME: Dec 22, 2020 - 9:05am	

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Appendix C
Photographs

Note:

Photographs included in this appendix were taken at the following times:

- January 13, 2020. The high tide reached 6.33 feet MLLW on that day and the photographs were taken within an hour of the high tide.
- June 8, 2020. The high tide reached 6.05 feet MLLW on that day but occurred at 12:12 AM and the photographs were taken during a site visit between 9:00 AM and 11:00 AM when the tide had already dropped a few feet from the high.
- November 15, 2020. The high tide reached 6.91 feet MLLW on that day and the photographs were taken within an hour of the high tide.
- December 13, 2020. The high tide reached 7.22 feet MLLW on that day during a rainstorm. The photographs were taken within an hour of the high tide.

Photograph 1

Evidence of SR 1 Settlement under US 101 (June 8, 2020)

Photograph 2

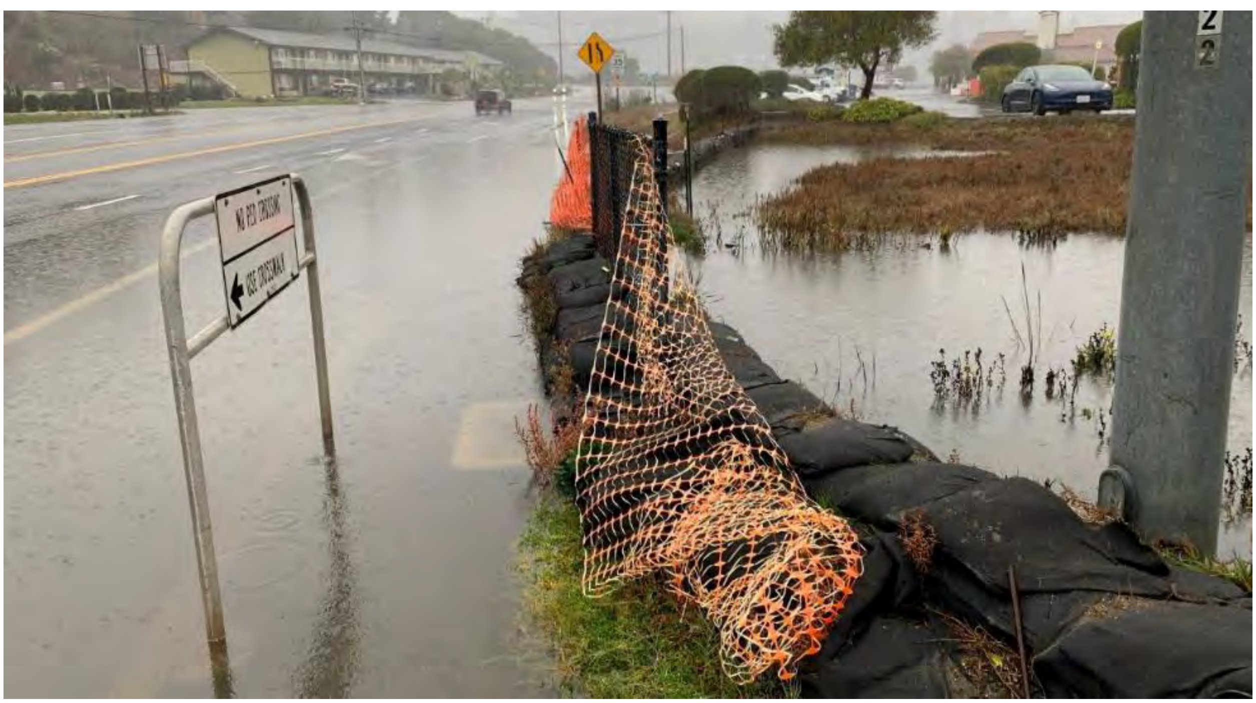
Sandbag Barrier, Northeast Side of SR 1 (June 8, 2020)

Photograph 3

Sandbag Barrier, Northeast Side of SR 1 (January 13, 2020)

Photograph 4

Sandbag Barrier, Northeast Side of SR 1 (December 13, 2020)



Photograph 5

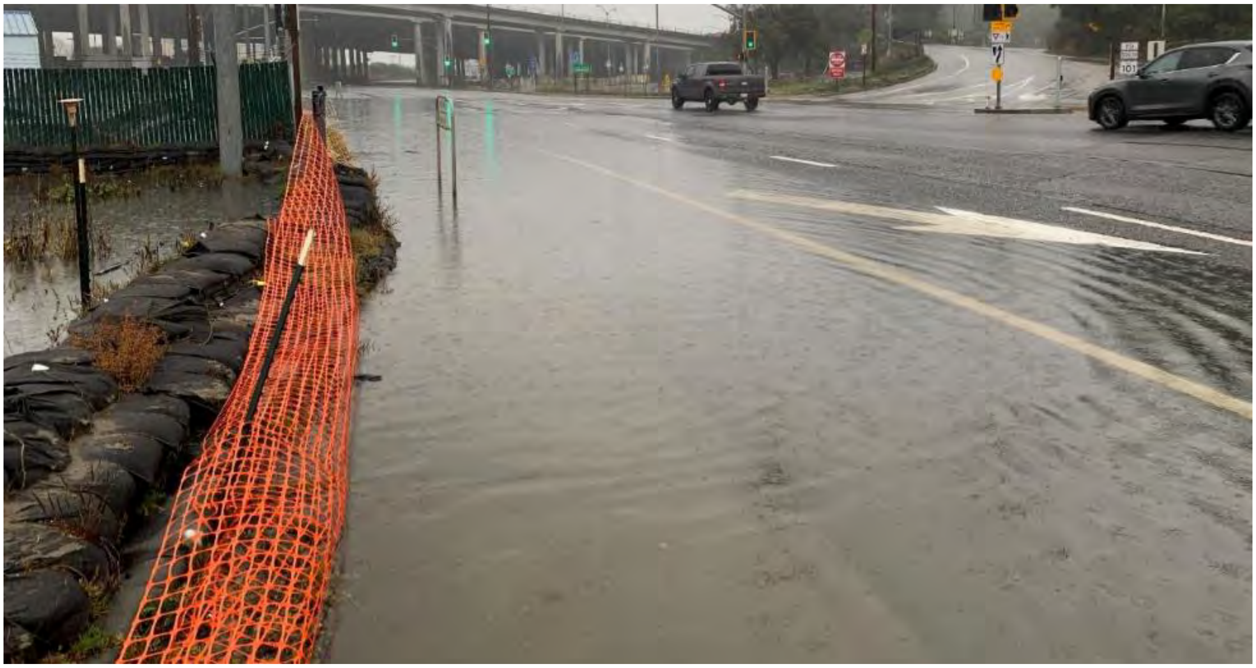
SR 1, Looking West from Under US 101 (June 8, 2020)

Photograph 6

SR 1, Looking East Toward US 101 (November 15, 2020)

Photograph 7

SR 1, Looking East Toward US 101 (December 13, 2020)



Photograph 8

Ditch Along West Side of Caltrans Maintenance Yard (June 8, 2020)

Photograph 9

Ditch Along West Side of Caltrans Maintenance Yard (January 13, 2020)

Photograph 10

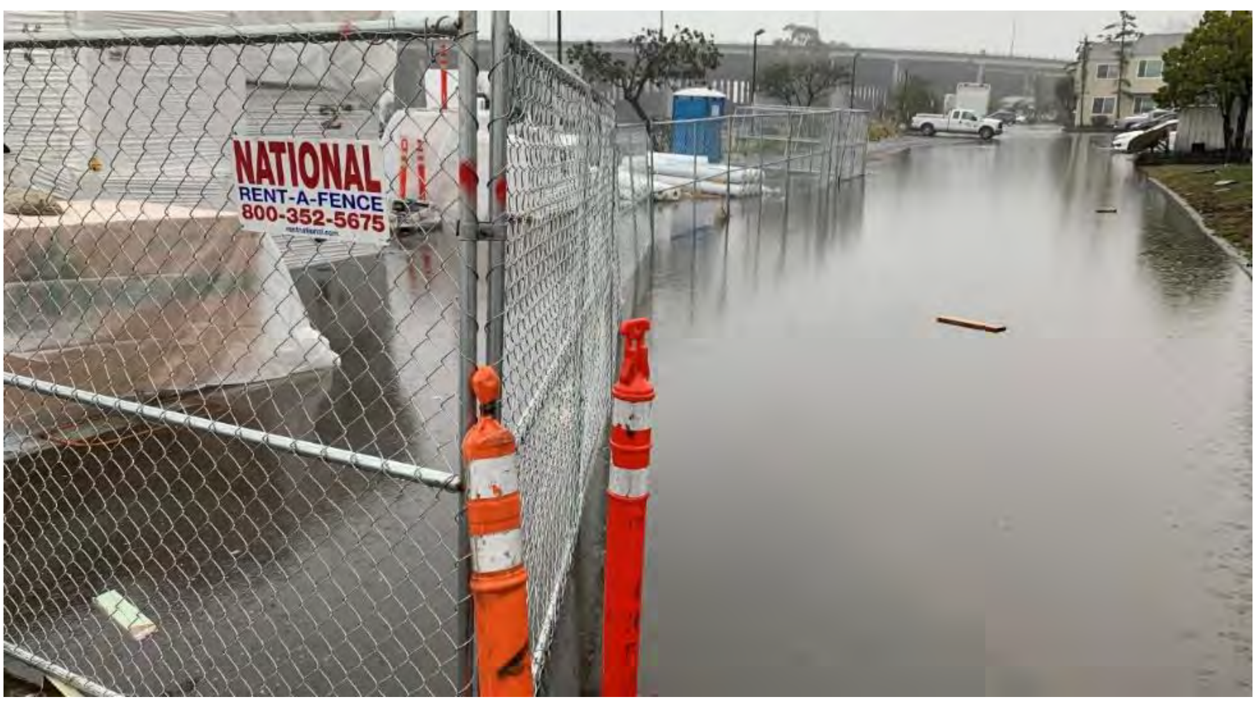
Ditch Along West Side of Caltrans Maintenance Yard (December 13, 2020)

Photograph 11

Parking Lot North of Holiday Inn Express (January 13, 2020)

Photograph 12

Parking Lot North of Holiday Inn Express (December 13, 2020)



Photograph 13

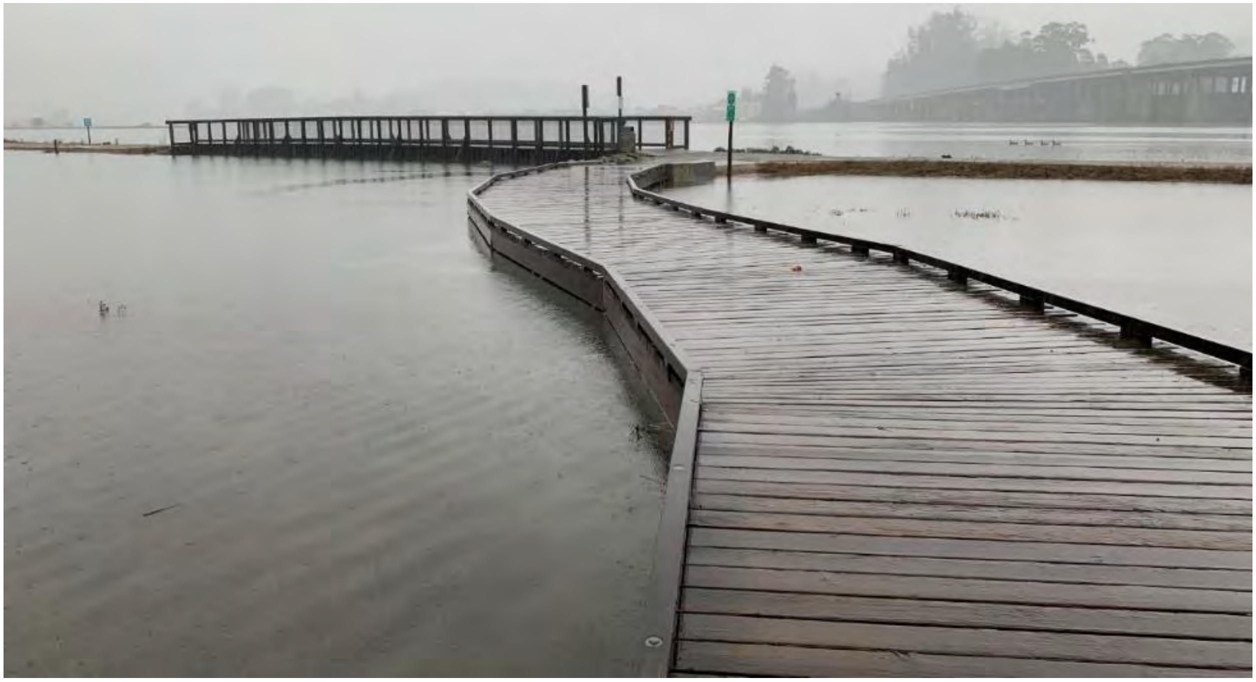
Connecting Trail and Bay Trail at Northwest End of Tidal Marsh (June 8, 2020)

Photograph 14

Connecting Trail and Bay Trail at Northwest End of Tidal Marsh (November 15, 2020)

Photograph 15

Connecting Trail and Bay Trail at Northwest End of Tidal Marsh (December 13, 2020)



Photograph 16

Bay Trail Looking Southeast Toward US 101 (January 13, 2020)

Photograph 17

Bay Trail Looking Southeast Toward US 101 (December 13, 2020)

Photograph 18

Bay Trail Near West Edge of US 101 (June 8, 2020)

Photograph 19

Bay Trail Near West Edge of US 101 (November 15, 2020)

Photograph 20

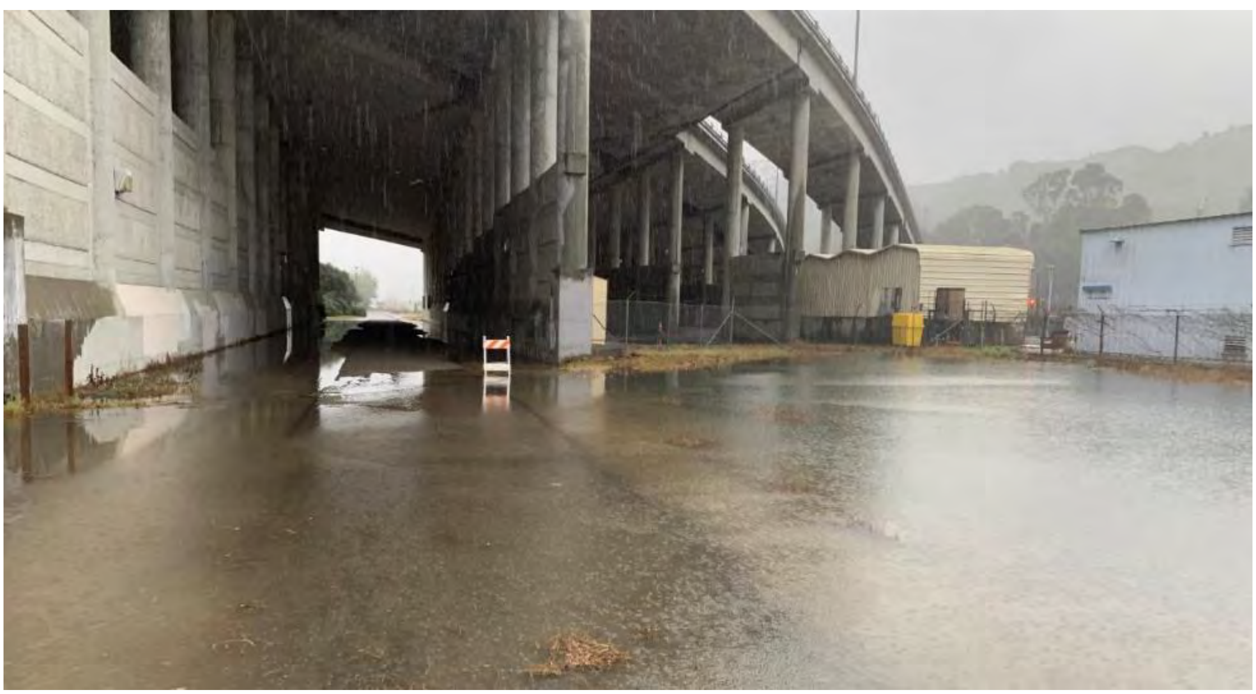
Bay Trail Near West Edge of US 101 (December 13, 2020)

Photograph 21

Bay Trail at West Edge of US 101 (November 15, 2020)

Photograph 22

Bay Trail at West Edge of US 101 (December 13, 2020)



Photograph 23

Bay Trail at East Edge of US 101 and Tide Gates on Outfall (June 8, 2020)

Photograph 24

Bay Trail at East Edge of US 101 and Tide Gates on Outfall (January 13, 2020)

Photograph 25

Bay Trail at East Edge of US 101 and Tide Gates on Outfall (December 13, 2020)

Photograph 26

Outfall Channel on East Side of US 101 (June 8, 2020)

Photograph 27

Bay Trail South of US 101 (June 8, 2020)

Photograph 28

Bay Trail South of US 101 (June 8, 2020)

Photograph 29

Looking Across to Park-and-Ride from SR 1 (January 13, 2020)

Photograph 30

Looking Across to Park-and-Ride from SR 1 (December 13, 2020)

Photograph 31

Entrance to Park-and-Ride (December 13, 2020)

Photograph 32

Park-and-Ride Under US 101 (June 8, 2020)

Photograph 33

Park-and-Ride Under US 101 (January 13, 2020)

Photograph 34

Park-and-Ride Under US 101 (December 13, 2020)

Appendix D
Examples of Tide Control Devices

Technical Data

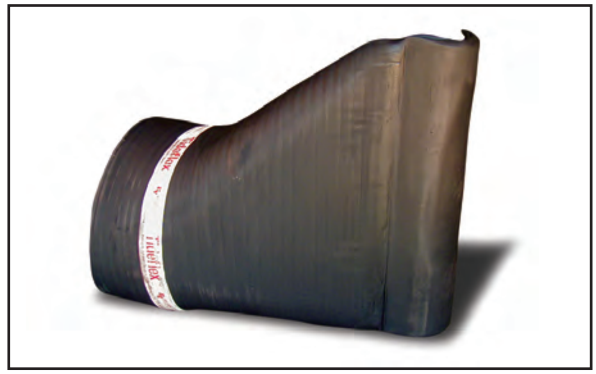
Series TF-1—Tideflex® Check Valve

Features & Benefits

- Ideal for manhole installations
- Lightweight, all-elastomer design
- Seals around entrapped solids
- Cost-effective, maintenance-free design

Materials of Construction

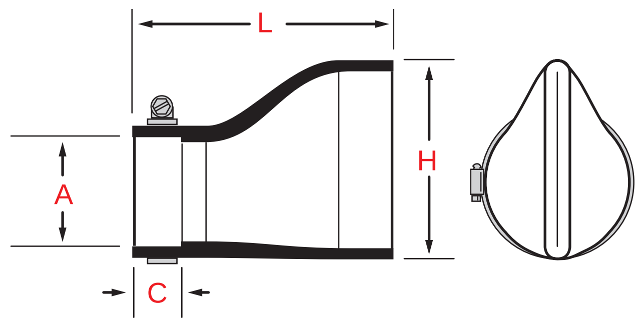
- Elastomers available in Pure Gum Rubber, Neoprene, Hypalon®, Chlorobutyl, Buna-N, EPDM, and Viton®



We are pleased to announce the introduction of the revolutionary TF-1 Check Valve. It functions and operates under the same simple principle of operation as the original TF-2 Tideflex®.

This design is ideal for existing manhole installations where the invert of the pipe is close to the floor of the vault. There are many check valves in interceptors, manholes, and vaults. These vaults are designed so that there would be a maximum gravity head; thus, the invert pipe is as close to the base as possible. The TF-1 allows installations in such applications.

The Tideflex® Technologies Series TF-1 Tideflex® Check Valve is designed for applications in manholes, where the bottom of the manhole is close to the invert of the pipe. The TF-1 configuration allows the valve to be properly installed without manhole modification, ensuring positive backflow prevention and a lifetime of maintenance-free performance.



Pipe O.D. (A)	Length (L)	Bill Height (H)	Cuff Length (C)
4	10	8	1 1/2
5	10	8	1 1/2
6	16	12	2
8	18	16	2
10	23	19	3
12	27	23	4
14	27	23	4
16	35	30	5
18	36	34	6
20	44	37	8
22	44	37	8
24	48	43	8
26	48	43	8
28	48	43	8
30	56	55	9
32	56	55	9
36	67	69	10
38	67	69	10
40	67	69	10
42	61	71	10
44	61	71	10
48	66	78	10
50	66	78	10
54	66	78	10
58	66	78	10
60	73	91	14
68	73	91	14
72	96	115	16

Numbers indicate maximum dimensions in inches.

Series TF-2

- ▶ 100% elastomer construction
- ▶ Will not rust or corrode
- ▶ Will not warp or freeze open or shut
- ▶ Custom-built to customer specifications
- ▶ Low cracking pressure, low headloss
- ▶ Eliminates backflow

Materials of Construction

Neoprene, Hypalon®, Buna-N, EPDM, Viton®.

Mounting Bands

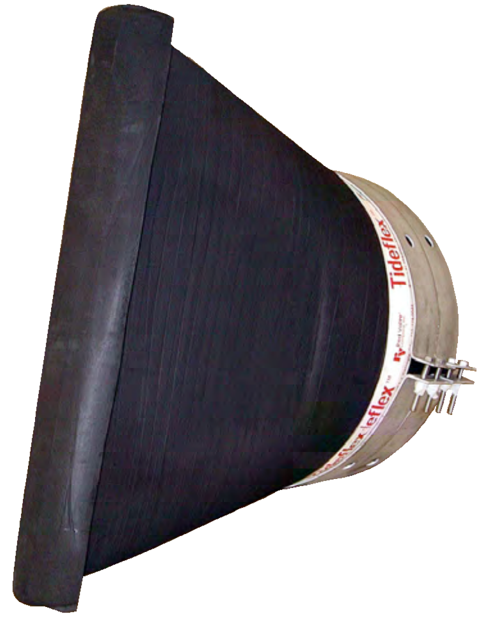
304 or 316 Stainless steel.

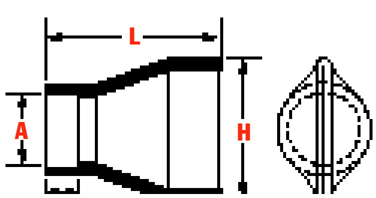
The Tideflex® Check Valve is a revolutionary design for backflow prevention. It offers low cracking pressure to eliminate standing water and very low headloss that is not affected by rust, corrosion or lack of lubrication. Tideflex® Check Valves are cost-effective because they require no maintenance or repairs and have a long operational life span. Tideflex® operate using line pressure and backpressure to open and close so no outside energy source is required.

Tideflex® valves are excellent replacements for ineffective metal flapgate valves because they will not warp or freeze and are virtually maintenance free.

The inside diameter of the TF-2's cuff is constructed to exactly match the outside diameter of the pipe.

The valve is slid onto the pipe and held in place with steel or stainless steel band clamps, eliminating flanging costs. Tideflex® TF-2 valves are constructed with a curved bill as standard.





Pipe O.D. (A)	Length (L)	Bill Height (H)	Cuff Length (C)
1/2	3	1 1/2	1/2
3/4	3	2	1
1	4	2	1
1 1/2	7	4	1
2	6	4	1
2 1/2	8	5	1
3	9	6	1 1/2
4	12	7	1 1/2
5	16	9	2
6	16	11	2
8	17	13	2
10	23	17	3
12	27	21	4
14	26	22	4
16	28	27	5
18	30	27	6
20	34	33	8 1/2
22	38	33	8
24	42	39	8
26	42	39	8
28	42	39	8
30	45	50	9
32	46	53	10
36	50	61	10
38	50	61	10
40	50	61	10
42	55	71	10
44	55	71	10
48	60	78	12
50	60	78	12
54	72	97	12
58	72	97	12
60	75	97	15
68	75	97	15
72	95	115	17
84	92	111	18
90	102	119	17
92	102	119	17
96	102	119	17

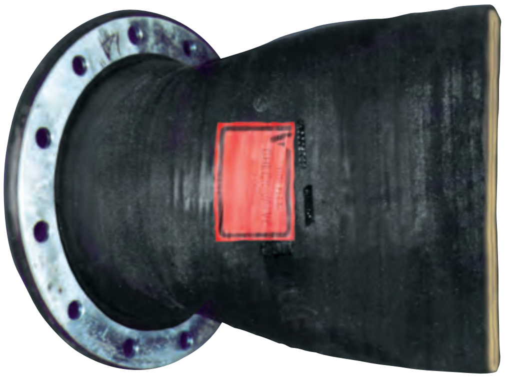
Tideflex® Technologies

Technical Data

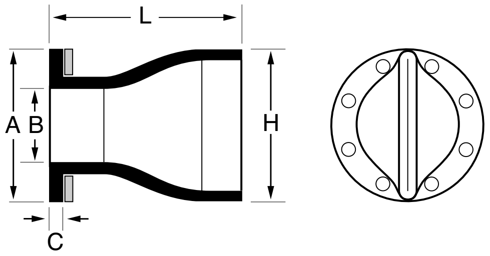
Series 35 - Flanged Check Valve

Materials of Construction

- Pure Gum Rubber, Neoprene, Chlorobutyl, Buna-N, Hypalon, Viton, EPDM, Food Grade
- NSF61 Certified for Potable Water
- Galvanized Steel, Stainless Steel



The Tideflex® Technologies Series 35 Check Valve is manufactured identically to the Tideflex® Check Valve, with the addition of an integral elastomer flange as part of the valve. The standard flange size drilling conforms to ANSI B16.5 and ANSI B16.47, Class 150 standards. All other domestic and international standards, as well as customer specified flange dimensions, are available. The Series 35 Check Valve is furnished complete with 3/8" thick steel back-up rings for installation.



In some applications and installations, a slip-over pipe Check Valve is not feasible because of an existing flange in the piping system or an existing flange cemented in the outfall piping system vault. In these cases, the Series 35 Check Valve is the solution.

The Tideflex® Technologies Series 35 Check Valve is simple in design, with only one part - the all-rubber duck bill check sleeve. There are no seats or interference fits to corrode or freeze valve operation, making the Series 35 virtually maintenance free. The Series 35 seals completely around solids, making it ideal for fly ash, raw sewage, sludge, lime, mining slurries, and many other abrasive and corrosive slurries.

DIMENSIONS SERIES 35

ANSI FLANGE SIZE	FLANGE O.D. A	INSIDE DIAMETER B	FLANGE THICKNESS C	MAXIMUM LENGTH L	MAXIMUM HEIGHT H
1/2"	3-1/2"	1/2"	1/2"	2-1/2"	1-1/4"
3/4"	3-7/8"	3/4"	1/2"	3"	1-1/2"
1"	4-1/4"	1"	1/2"	3"	1-1/2"
1-1/4"	4-5/8"	1-1/4"	1/2"	5-3/4"	2-3/4"
1-1/2"	5"	1-1/2"	1/2"	5-3/4"	3-5/8"
2"	6"	2"	1/2"	5-3/4"	3-5/8"
2-1/2"	7"	2-1/2"	1/2"	7-1/2"	4-5/8"
3"	7-1/2"	3"	3/4"	9"	5-3/8"
4"	9"	4"	3/4"	12"	7"
5"	10"	5"	3/4"	15-1/4"	8-7/8"
6"	11"	6"	1"	15-5/8"	10-3/8"
8"	13-1/2"	8"	1"	16-1/2"	13"
10"	16"	10"	1"	21-1/2"	16-7/8"
12"	19"	12"	1"	26-1/2"	20-1/8"
14"	21"	14"	1"	25-3/8"	21-1/2"
16"	23-1/2"	15-1/4"	1"	27-1/2"	22-1/4"
18"	25"	17-1/2"	1-1/2"	30"	26-3/4"
20"	27-1/2"	19-1/4"	1-1/2"	32-3/8"	32-1/2"
22"	29-1/2"	21-1/4"	1-1/2"	35-1/2"	32-1/2"
24"	32"	24"	1-1/2"	40-1/2"	37"
30"	38-3/4"	29-1/2"	1-1/2"	43"	49-1/2"
32"	41-3/4"	32"	1-1/2"	51-3/8"	46"
36"	46"	35-1/4"	1-1/2"	54"	58"
42"	53"	42"	2"	60-1/4"	72-1/2"
48"	59-1/2"	48"	2"	59"	77-1/2"
60"	73"	60"	2"	72"	96-3/4"
72"	86-1/2"	72"	2"	95"	102"
84"	99-3/4"	84"	2"	92"	110-1/2"

AF-41 ALUMINUM DRAINAGE (FLAP) GATES

- **LIGHTER WEIGHT REDUCES INSTALLATION COSTS**
- **SIZES 12" - 84" (CUSTOM SPIGOT SIZES AVAILABLE)**
- **SEATING HEADS TO 40 FEET.**

A CORROSION-RESISTANT RUST-PROOF AUTOMATIC DRAINAGE GATE DESIGNED FOR USE WITH ALUMINUM CORRUGATED PIPE, OR FOR FLANGE MOUNTING OR USE WITH HDPE

PREVENTS ELECTROLYSIS ASSOCIATED WITH CAST IRON GATES TO ALUMINUM PIPE CONNECTIONS.

J-BULB NEOPRENE ADJUSTABLE SEATS PROVIDE EXCELLENT SEALING AGAINST RETURN FLOW.

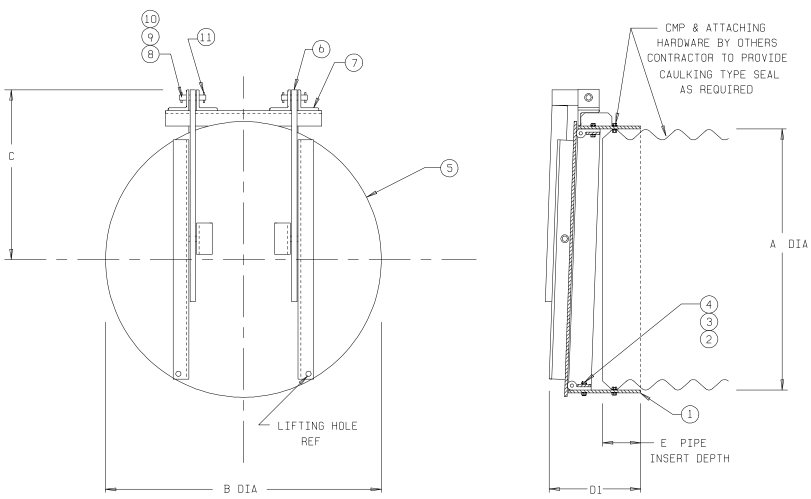
FRAME, COVER, RETAINER RING, HINGE ARM, AND PIVOT LUG ARE OF ALUMINUM ALLOY 6061-T6. GATE HARDWARE IS STAINLESS STEEL.

- **SPECIFY:**
  - **AF-41sb... for corrugated pipe**
  - **AF-41f... for wall mounting**
  - **AF-41ff... for flange mounting**
  - **AF-41-4... for plastic pipe**
  - **AF-41-6... for HDPE**

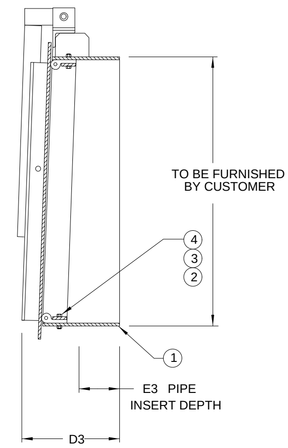
AF-41 FLATBACK

AF-41 SPIGOTBACK

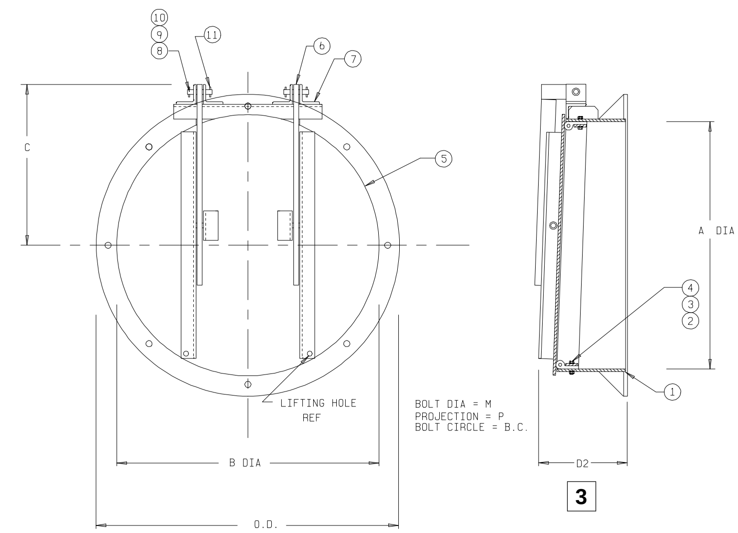
AF-41 SPIGOTBACK



AF-41 TYPE 6 SPIGOT FOR HDPE PIPE

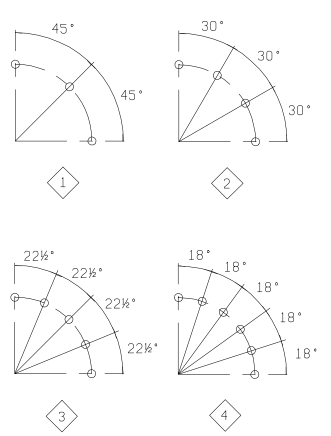


AF-41 FLATBACK (FLANGEBACK SIMILAR BUT WITH ASA STANDARD FLANGE DIMENSIONS)



PARTS LIST	
No.	**Name**
1	Frame
2	Seat
3	Retainer Ring
4	Hex Hd. Bolt/Nut
5	Cover
6	Hinge Arm
7	Pivot Lug
8	Hex Hd. Bolt/Nut
9	Hinge Pin
10	Bushing
11	Washer
12	Spring Pin

1. Add grout pad thickness to anchor bolt projection.
2. Also available with flange and drilling to attach to a 125# standard pipe flange.
3. If grout pad mounting is used add grout thickness to dimension.



DIMENSIONS IN INCHES

GATE SIZE	A	B	C	D1	D2	D3	E	E3	O.D.	B.C.	M	P 1	◊
12	13⅛	13½	10¼	8¾	8⅞	11½	4	7	17½	15¾	½	1	1
15	16⅛	17	12¼	8¾	8⅞	11½	4	7	20½	18¾	½	1	2
18	19⅛	20	14¼	8¾	8⅞	11½	4	7	23½	21¾	½	1	2
24	25⅛	26½	16¾	8¾	8⅞	11½	4	7	30⅝	28¼	½	1½	2
30	31⅛	32½	19¾	10½	10⅝	12	4½	7	36⅝	34¼	½	1½	3
36	37⅛	38½	24	10¼	10⅜	12	4½	7½	42⅝	40¼	½	1½	3
42	43⅛	46	28	13	13⅛	-	5½	-	48⅝	46¼	½	1½	3
48	49⅛	52	31	13⅝	13¾	-	5½	-	54⅝	52¼	½	1½	4
54	55⅛	58	35	13¼	13⅜	-	6½	-	60⅝	58¼	⅝	2	4
60	61⅛	64	38	15¼	15⅜	-	6½	-	66⅝	64¼	⅝	2	4
72	73⅛	76	44½	17⅛	17¼	-	7¼	-	78⅝	76¼	⅝	2	4
84					DIMENSIONS ON APPLICATION								

Waterman Industries

F-25 MEDIUM DUTY DRAINAGE GATE

- **CAST IRON CONSTRUCTION**
- **AUTOMATIC OPERATION**
- **FULLY ADJUSTABLE HINGE LINKS**
- **25 FOOT SEATING HEAD MAXIMUM**

The Waterman Model F-25 Drainage Gate features a high strength, fully adjustable linkage, providing for sensitive adjustment of the flap cover after installation. The design of this gate prevents jamming and assures proper seating through the use of built-in safety stops and a $2\frac{1}{2}^\circ$ to 5° seating angle.

Flatback and Spigotback models are available.

A choice of seat facings is available and includes machined or ground iron, bronze or neoprene cover gasket which is available with either iron or bronze mating frame seats.

The use of the Waterman neoprene cover seal provides a long life tight seal, which can be easily renewed. The heavy seal also provides a moderate cushioning of shock loads where some slamming may occur.

This model is **not** recommended for pump discharges where violent slamming can occur.

- Cast Iron Frame and Cover
- High Strength Ductile Iron or Steel Links
- Stainless Steel Studs, Bolts and Pins, Standard. Brass or Monel, Optional.
- Bronze Bushings, Standard. Permanently Lubricated Bronze or Teflon, Optional.
- Minimum $2\frac{1}{2}^\circ$ Seating Angle. 24" Diameter and over.
- Minimum 5° Seating Angle. 21" Diameter and smaller.
- Optional 25 lb. and 125 lb. ANSI Flange Drilling.

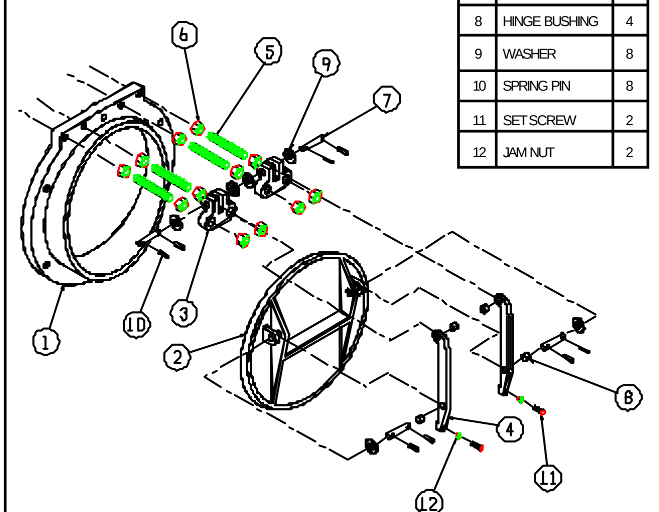
CAST IRON SEAT - Standard. Used for moderate conditions where costs must be minimized.

BRASS SEAT - Optional. Used for corrosive conditions where long service is important.

NEOPRENE SEAT (with iron or bronze) - Optional. Replaceable in flap cover. Cushions "slam" on closing and provides tighter seal.

Model F-25f - Flatback
Model F-25sb - Spigotback

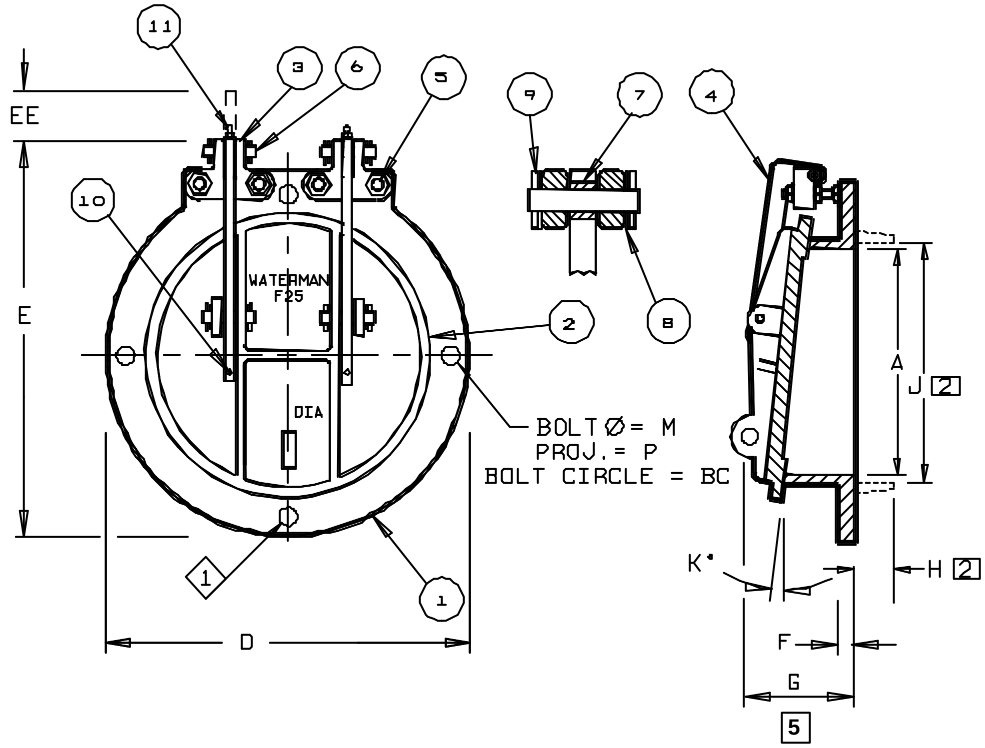
PARTS LIST		
No.	Name	Qty.
1	FRAME	1
2	COVER	1
3	PIVOT LUG	2
4	HINGE LINK	2
5	HINGE STUD	4
6	HINGE NUT	12
7	HINGE PIN	4
8	HINGE BUSHING	4
9	WASHER	8
10	SPRING PIN	8
11	SET SCREW	2
12	JAM NUT	2



Waterman Industries

F-25 DRAINAGE GATE

PARTS LIST	
No.	Name
1	FRAME
2	COVER
3	PIVOT LUG
4	HINGE LINK
5	HINGE STUDS & NUTS
6	HINGE PIN
7	HINGE BUSHING
8	WASHERS
9	SPRING PIN
10	SET SCREW 4
11	LUBE FITTING (optional) 6



1. 12 Bolt pattern per ◊6 available on 42" & 48" only on request.

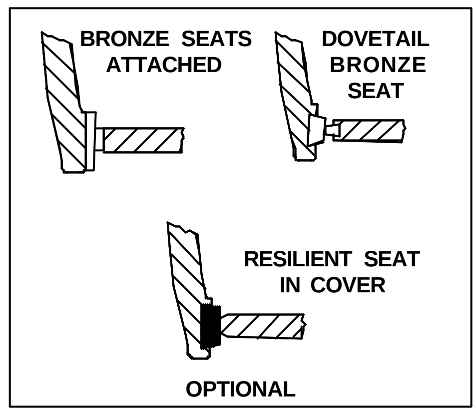
2. Applies to spigotback gate only. Optional spigot shown in phantom.

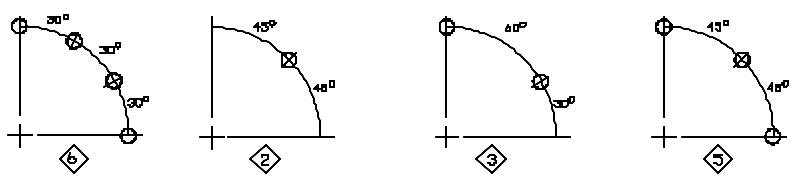
3. 25 Lb. & 125 Lb. Standard drilling available on request for all gates except 15" & 21".

4. Except 4" & 6" gates

5. If grout pad mounting is used add grout thickness to dimension.

6. Not available on 4" and 6" gates - use permalube bushings.





GATE DIMENSIONS IN INCHES

GATE SIZE A	4	6	8	10	12	14	15	16	18	20	21	24	30	36	42	48	54	60
BC	7½	9½	11¾	14¼	17	18¾	20	21¼	22¾	25	25	29½	36	42¾	49½	56	62¾	69¼
D	9	11	13½	16	19	22½	22½	23½	25	27½	27½	32	38¾	46	53	59¾	66½	73
E	9¾	12	14½	16	19	22	25	24	28½	28	30	35	40½	46½	54¾	66	72	75
EE	1⅞	2	2⅛	2⅝	3	3⅛	3⅛	3	3⅛	3⅜	2⅞	3	3½	3½	4⅛	4⅞	6	6⅛
F	½	⅝	⅝	¾	⅝	1	1	⅞	⅞	⅞	⅞	⅞	1⅛	1⅛	1½	1½	1½	1½
G	3 9/16	5	5	6	5½	6	6½	6½	7	7	7½	8	8	9	8½	10	10	10 1/16
H 2	2	2	2⅛	2¼	2⅛	2⅛	2⅛	2¼	2⅛	2⅛	2⅛	2⅛	2⅜	2⅛	2⅜	2½	3	3¼
J 2	5	7	9	11	13	15	16	17	19	21	22	25	31	37	43 9/16	49⅛	55⅛	61⅛
K*	5	5	5	5	5	5	5	5	5	5	5	2½	2½	2½	2½	2½	2½	2½
M	½	½	½	½	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾	¾	⅞	⅞	1	1⅛
P	1½	1½	1½	1½	1½	1½	1½	1½	1½	1¾	1¾	1¾	2¼	2¼	2¼	2⅜	2¾	3
No. of Bolts	4	4	4	6	6	6	6	6	6	8	8	6	8	8	6 1	6 1	12	12
◊	2	1	1	3	3	3	3	3	3	5	5	3	5	5	3	3	6	6

* Degrees

NOTE: FOR PRELIMINARY DESIGN PURPOSES ONLY
DO NOT USE FOR INSTALLATION
UNLESS PART OF CERTIFIED & APPROVED SUBMITTAL

Waterman Industries

TYPICAL SPECIFICATIONS
F-25 MEDIUM DUTY AUTOMATIC DRAINAGE (FLAP) (TIDE) GATES

General
The drainage gate shall be designed to allow free outflow and prevent backflow for maximum seating heads up to 25 feet. Gates shall be Waterman Model F-25 or equal.

Construction
The frame shall be cast iron of flatback or spigotback design, with machined seating surface inclined from vertical at minimum of $2\frac{1}{2}^{\circ}$, to assure positive closure. For flatback gates mounted to thimbles or flanges, the gate flange shall be machined and drilled to match.

The cover shall be cast iron, cast in one piece, with reinforcing ribs, designed to withstand the seating head specified. An integral cast on lifting eye shall be provided for manual operation.

Seating surfaces for frame and cover shall be:
(bronze on seat and cover) (machined iron on frame, neoprene on cover) (bronze on frame, neoprene on cover)

All machined seats shall have a minimum 63 microinch finish.

The gate shall be provided with adjustable, double pivoted hinge links so designed to permit complete seating, full opening, and with stops or other arrangement to prevent cover from rotating sufficiently to become wedged in the open position. Pivot lugs mounted to frame shall be adjustable to allow adjustment of hinge links without having to remove cover from gate. The hinge links shall be bronze-bushed, structural steel (or high strength ductile iron, cast manganese bronze, or wrought stainless steel). All assembly hardware shall be type 18-8 stainless steel.

Finish
All cast iron shall be painted with manufacturer's standard shopcoat paint (or special paint). Structural steel hinge links shall be galvanized. All bronze and stainless steel parts do not require further finish.

Materials
Frame and Cover - Cast Iron per ASTM A-126, Class B.
Pivot Lug - Ductile Iron per ASTM A-536, Gr. 65-45-12.
Hinge Link - Structural Steel per ASTM A-36, galvanized per ASTM A-123.
Bronze Bushings and Washers - Commercial Bronze.
Assembly Hardware and Pins - 18-8 Stainless Steel (Type 304).

{TIDE GATES}

GH-850-R Restrained Side Hinge Tide Gate
GH-35 Self-Regulating Tide Gate
GH-37 Tide-Regulated Tide Gate*

*Manufactured exclusively by Golden Harvest, Inc.
Under GHI patent #US 6,779,947

GOLDEN HARVEST, INC.

TIDE GATES

FOR TIDAL WETLANDS PRESERVATION AND RESTORATION

- **RESTORES TIDAL FLUSHING OF MARSHES WITHOUT FLOODING OF UPLAND** PROPERTY BEHIND DIKES AND LEVEES
- **RESTORATION OF ESTUARINE PLANTS,** FISH, SHELLFISH, WATERFOWL AND WILDLIFE
- **NATURAL CONTROL OF MARSHES AND ESTUARIES**
- **HELPS REDUCE MOSQUITO BREEDING**
- **MINIMIZES SHEET FLOODING OF THE MARSH**

Phone: 360-757-4334
Fax: 360-757-1135

PO Box 287 • Burlington, WA 98233

e-mail: sales@goldenharvestinc.com
www.goldenharvestinc.com

The Tide Gate is usually mounted to an end wall or cross culvert on the tidal side of a headwall or dike. The floats are fully-adjustable to meet the required gate closure water levels on a site-specific basis. In the event of a storm surge the Tide Gate will close and latch automatically and will resume normal water control when the tide returns to normal cycles and levels. The functions of operation are solely dependent upon the goals of the water management agency.

Similar to a conventional flap gate, at low tide the Tide Gate will allow complete discharge of upland storm water runoff and creek water. Conventional flap gates, however, are forced closed by the incoming tide preventing saltwater from returning to the wetland. In contrast, the Tide Gate can be adjusted to allow flow into the culvert thereby feeding essential tide waters to the channel or marsh behind the dike. Because the Tide Gate is located on the outfall or tidal side of the headwall, its float system responds to any tidal change allowing the predetermined amount of water in and closing to incoming water when the tide reaches the design high water level. With the storm tide water elevation, the Tide Gate closes “early” thereby preserving a relatively large volume of potential water storage capacity behind the dike should it be needed for detention of upland runoff associated with the coastal storm. In this way the Tide Gate simultaneously maintains flood protection to the upland area while allowing tidal flushing of the low-lying wetlands.

MODEL GH-850-R
MODEL GH-35
MODEL GH-37

{TIDE GATES}

MODEL GH-850-R

MODEL GH-37

MODEL GH-35

GH-850-R

MODEL GH-850-R
SIDE HINGE TIDE GATE

General Design

All metal parts shall be stainless steel and shall provide adequate corrosion resistance for the environment. Gate shall be sized for the clear opening. Frame width and height shall be no larger than the outside dimensions of the Box Culvert. Gate shall include neoprene compression seals between the gate and gate frame. Provide all components shown on the Contract Drawings and those needed for proper gate actuation All 316 stainless steel mounting hardware shall be included.

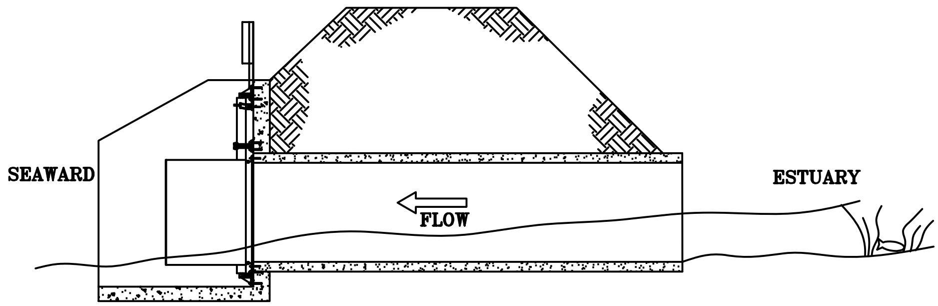
Side-hinged Tidal Actuated Control Gate shall be initially opened using a hydraulic cylinder, crank arm, hydraulic lines, and hydraulic control box as shown on the Contract Drawings. Normal operation is to be controlled by differential water level. Hydraulic controls shall be housed in a locking, NEMA 4X stainless steel tamper-proof box. Upper and lower gate hinge bearings shall be Gar-Max or equal.

Side-hinged Tidal Actuated Control Gate shall include a float tube and float assembly with connection to the hydraulic control box as shown on the Contract Drawings. Gate float closure setting shall result in release of hydraulic system pressure to components such that gate closure will occur on a rising (flood) tide at the pre-set elevation. Gate hinge tube mounting shall be orientated in an offset position as shown on the Contract Drawings to facilitate gate closure when the gate hydraulic system pressure is released. Gate opening swing shall provide for a maximum gate opening angle of 70 degrees prior to hydraulic cylinder actuation.

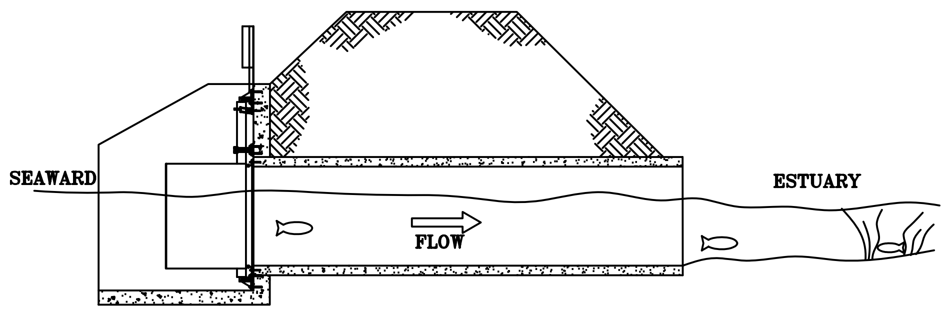
Operating Principles

- Gate start position is fully closed (gate seated against the frame) with the float below the actuation point. In this condition the gate prevents the intrusion of salt water upstream of the closed gate.
- As water flows downstream a determined amount of differential head will initiate gate opening. The unseating head differential opens the gate regardless of tide elevation; this allows drainage during high run-off periods of a storm event even at high tide.
- The hydraulic system is designed in such manner as to prevent gate closure. This feature is independent of the degree of open position and continuously locks-out gate closure for every increment of increased opening. The mechanics of the system limits the degree of opening to a maximum of seventy degrees. This angle can be reduced by use of the adjustment system provided.
- As the tide elevation increases there is an exchange through the gate of tidal and creek (stream, river, slough etc.) water. This allows free passage of fish as well as water. This exchange continues until the tide elevation achieves the float set point.
  At the float set point a valve is triggered which allows back flow of hydraulic fluid. This unlocks the hydraulic cylinder and allows free movement of the gate in the closing direction. As the tide continues to rise, the head differential and flow will push the gate closed and prevent the intrusion of salt water upstream of the closed gate.

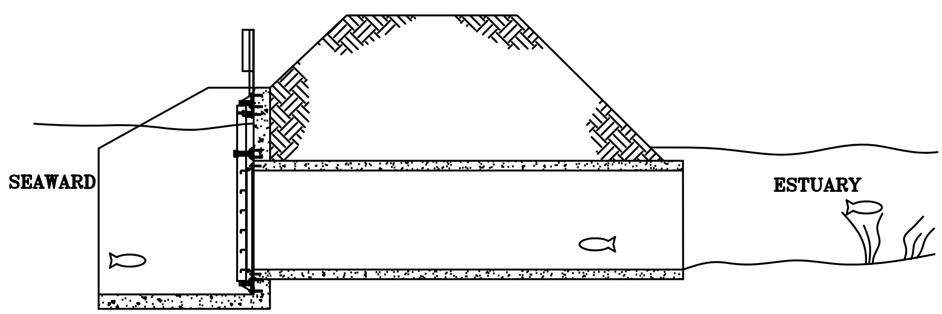
MODEL GH-850 RESTRAINED SIDE-HINGE TIDE GATE
TIDE SEQUENCE DIAGRAM



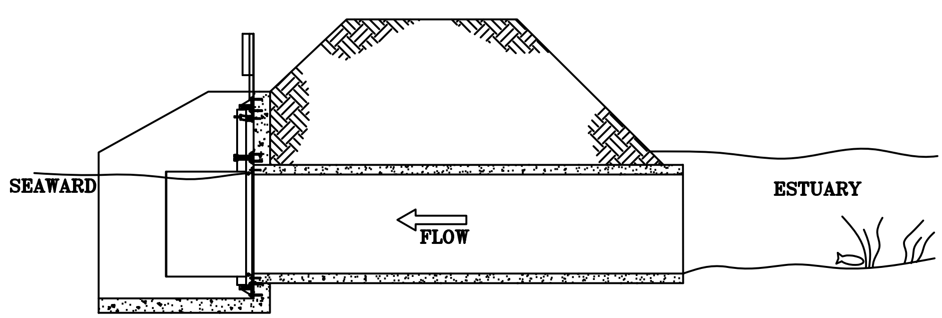
GH-850-R ACTING AS NORMAL
FLAP GATE ALLOWING ESTUARY
DRAINAGE



RISING TIDE ALLOWING INCOMING
TIDE TO FLOOD ESTUARY BASIN



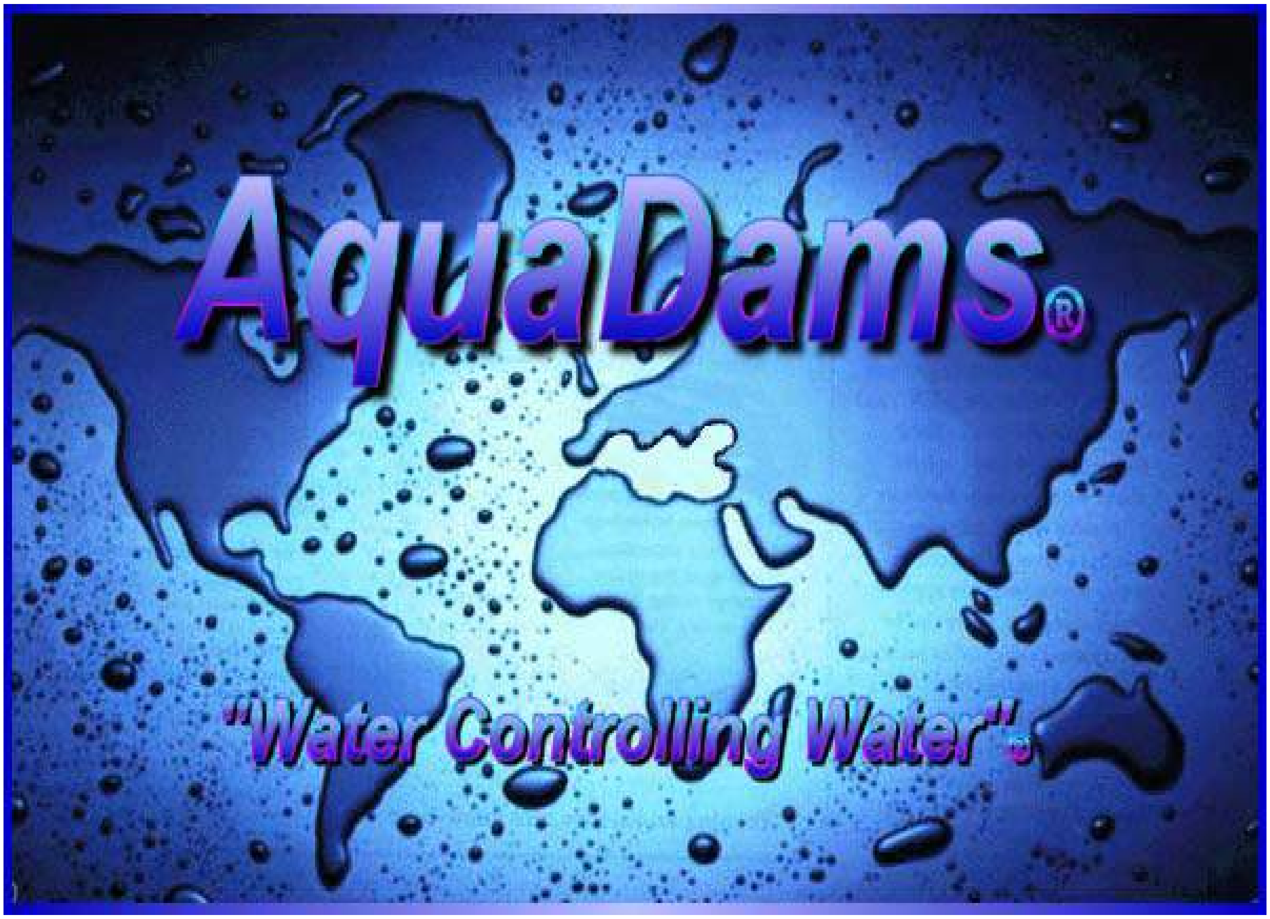
GH-850-R CLOSES AT SET LEVEL
LIMITING ESTUARY FLOOD LEVEL



GH-850-R OPENS WHEN TIDE LEVEL
IS LOWER THAN ESTUARY LEVEL

AquaDam Applications

(Includes Material Specifications)



Water Filled Cofferdams

LOW-IMPACT, ENVIRONMENTALLY FRIENDLY WATER FILLED COFFERDAMS FOR WATER DIVERSIONS, DEWATERING, FLOOD CONTROL, REMEDIATION, HAZ-MAT CONTAINMENT, AND WATER STORAGE

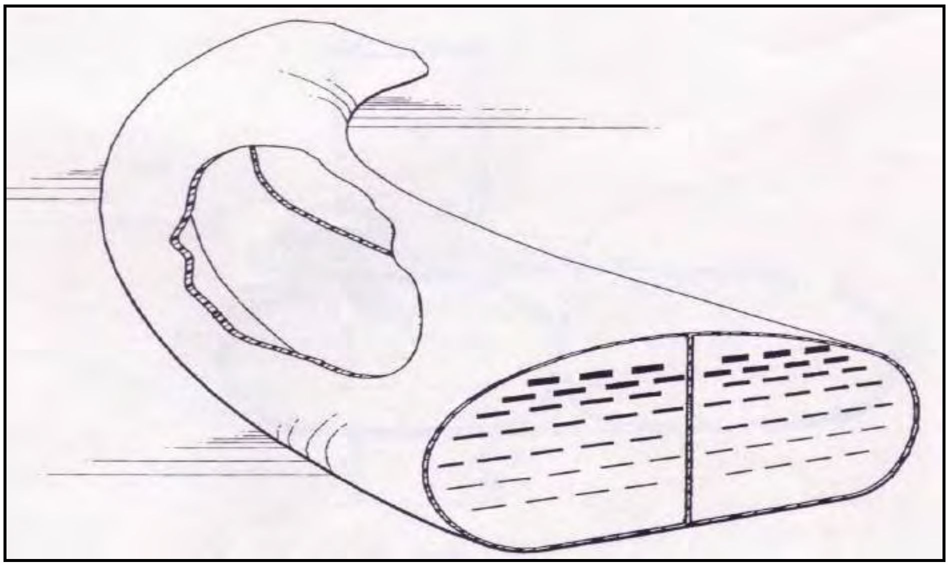
Aqua Dam, Inc.® AquaDams® are water filled barriers that can be used as dams or cofferdams for stream diversions and dewatering boat ramps, boat docks, and pond liners for repairs. Also excellent for flood protection, they are more effective than sandbags and other water control devices.

Aqua Dam, Inc. ®
P.O. Box 144 / 121 Main Street
Scotia, CA 95565 USA
800-682-9283 (International: 707-764-1999)
www.aquadam.net
email: kelly@aquadam.net

Table of Contents:

THE CONCEPT:

AquaDams® are portable dams filled with onsite water that can be installed wherever needed to control, contain, or divert the flow of water. AquaDams® consist of two basic components: two watertight inner polyethylene tubes which contain the water, and an outer or "master tube" made of a heavy duty geotextile woven polypropylene which holds the two inner tubes in contact when filled. The outer and inner tubes combine to form an AquaDam. This picture shows a cut away section illustrating the relationship between the inner and outer tubes of a typical filled AquaDam®.



To inflate an AquaDam®, water is pumped into the two inner tubes. The durable woven outer tube confines the water-inflated inner tubes and prevents them from moving away from each other. The counter friction / hydraulic pressure between the inner tube and the outer tube, along with the mass and weight of the water, creates pressure and stabilizes the AquaDam®, even when lateral water pressure is exerted against it. Due to the inherent flexibility of the materials used in their construction, AquaDams® will conform to most surfaces, providing an excellent seal and keeping water seepage to a minimum.

AquaDams® come in a variety of sizes, ranging from 1 to 16 feet in height when inflated. AquaDams® come in standard lengths of 50 or 100 feet, and these are available for immediate shipment. However, any length can be fabricated, and shorter, longer, or irregular lengths are available with notice. Using attachment collars, two or more AquaDams® can be joined together to form a continuous dam of any necessary length. AquaDams® are joined together by a patented coupling collar connection (standard with each AquaDam®). Large and small AquaDams® can be used in conjunction with each other, making the possible configurations almost endless. They can be used in a straight line, to form an arc, or to encircle an area. AquaDams® can also be connected at angles to each other, as necessitated by the job requirements. AquaDams® are usually assembled at the factory and shipped rolled and ready for use at the job site. However, it is not unusual to assemble larger AquaDams® on site. A typical AquaDam® consists of the "master tube" and a pair of inner tubes rolled up on a wooden or metal core. In many instances, the core also plays an important part in the installation, rerolling, and transportation of AquaDams®.

COMMON APPLICATIONS:

• Cofferdams for dewatering construction sites • Water diversion in rivers and wetlands • Water containment • Flood control • Erosion control through diversion or containment of flowing water • Water storage • Boat ramp dewatering • Pond liner repair dewatering • Bridge pier repair • Pipeline crossings	• Water intake structures for municipalities • Water discharge structures • Fish habitat improvement • Silt containment, sediment collection, or settling ponds • Levees, levee toppings • Hazardous material or chemical spills (containment) • Temporary foot causeway through environmentally sensitive areas • Wetlands management

The old ways of earthen fill discharges and expensive sheet piling have been the historic ways of working in waterways. These methods are environmentally detrimental, time consuming, and expensive because of their reliance on heavy equipment.

Water filled cofferdams make the ideal water control structure for construction sites. Onsite water is pumped into an AquaDam®, which unrolls due to the water pressure inside it and can be installed in hours in most applications, without causing damage to the aquatic environment. Complete dewatering of the work site can be achieved to form and pour concrete, remove sediments, and install geotextiles.

When used for flood control and augmenting levees, for example, AquaDams® are much more effective than sandbags. They can be installed far quicker, at a fraction of the cost, without all the foot traffic associated with labor-intensive sandbagging, and best of all AquaDams® are reusable.

The amount of water that can be stored in a standard 4 foot AquaDam®, with a width of 10 feet and a length of 100 feet (filled to capacity), is about 25,000 gallons. AquaDams® are durable, long lasting, and with proper installation and removal can be stored and used again and again. Should an inner tube develop a leak, patching tape is available. If necessary, replacement tubes are available from Aqua Dam Inc.®. AquaDams® are relatively easy to install, requiring only a couple of portable pumps, an onsite water supply, and two or more laborers depending on the size of the AquaDam®.

FLOOD CONTROL:

3’ high AquaDams® being used for homeowner flood protection in Clear Lake, CA.

3’ high AquaDams® used to protect a home from floodwaters in Sun Valley, ID.

FLOOD CONTROL (CONT.):

4’ high AquaDams® used for flood protection of the Skylark Hotel in Clear Lake, CA.

More 3’ and 4’ high AquaDams® used for flood protection in Sun Valley, ID.

AquaDam® Material Specifications

Inflated Dimensions	Specifications of Inner & Outer Tubes	Capacity in Gallons (per 100 ft.)	Empty Weight (per 100 ft.)
1' H x 2' W	10 mil polyethylene inside tubes LP300* woven outer tube	1,200	75 lbs.
1.5' H x 3' W	10 mil polyethylene inside tubes LP300* woven outer tube	2,500	95 lbs.
2' H x 4' W	10 mil polyethylene inside tubes LP300* woven outer tube	5,500	120 lbs.
3' H x 7' W	12 mil polyethylene inside tubes LP300* woven outer tube	12,000	250 lbs.
4' H x 10' W	12 mil polyethylene inside tubes LP300* woven outer tube	24,000	425 lbs.
5' H x 13' W	12 mil polyethylene inside tubes LP300* woven outer tube	30,000	500 lbs.
6' H x 15' W	12 mil polyethylene inside tubes LP300* woven outer tube	40,000	850 lbs.
8' H x 19' W	14 mil polyethylene inside tubes Doubled LP300* woven outer tube	50,000	1,300 lbs.
10' H 24' W**	Doubled 8 mil polyethylene inside tubes 2-ply LP300* woven outer tube	80,000	4,000 lbs.
12' H 20' W**	Doubled 8 mil polyethylene inside tubes LP300* woven inner tube Doubled 2-ply LP300* woven outer tube	90,000	5,000 lbs.
16' H x 28' W**	30 mil vinyl inside tubes LP300* woven inner tube Doubled 2-ply LP300* woven outer tube	125,000	8,000 lbs

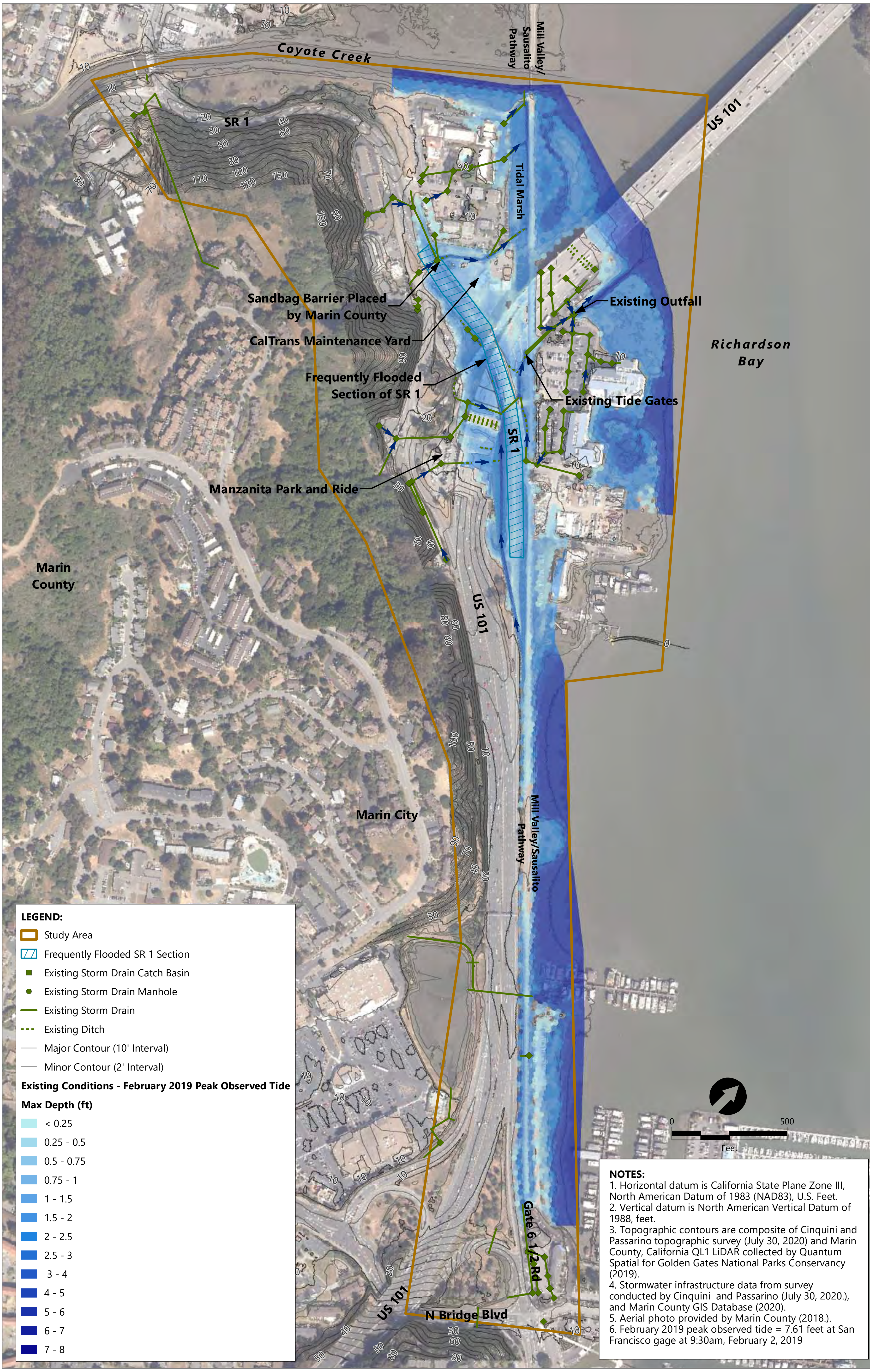
Many different materials could have been used in the construction of the Aquadam but extruded film tubing was chosen for its superior strength, light weight, ease of manufacturing, and most importantly it contained NO WELDED SEAMS! This alone makes it the ideal tubing chosen to contain water. The inside tubing can be completely replaced to make your Aquadam new again. Replacement tubes cost 20% of the AquaDam's retail purchase price. This includes our services to do it for you. Freight charges may apply. You can also repair small holes by using butyl tape.

*LP 300 is a woven polypropylene fabric used in high survivability separation applications, supplied by Layfield Plastic, Inc. Equivalent products are also made by Linq Industrial Fabrics, Inc. (GTF-300) and by T C Marafi (Marafi 600-X). **NOTE: 1 gallon of water weighs 8.33 lbs!**

**The 8' and higher AquaDams are made from 70" plus laid flat width panels of 6.5 oz. circular woven material. Panel edges are overlapped and then triple-stitched together using an overlapping seam for maximum strength. This provides for a 4-ply seam running around the tube (these are called ribs). The material is folded over and then seamed laterally to form a tube. This lateral seam is reinforced by sewing in 3" wide heavy-duty seat belt strapping material on each side of the seam to give it added strength and durability. There are a total of 6 seams, three in one direction and three in the opposite direction. One of the triple-stitch seams uses high-tensile strength Kevlar thread. This makes an excellent 2-ply tube for the added pressures of these large water-filled cofferdams. For AquaDams 12' high and larger we use two 2-ply tubes, giving them a total of 4-ply thickness.

Appendix E

Hydraulic Analysis Results



LEGEND:

- Study Area
- Frequently Flooded SR 1 Section
- Existing Storm Drain Catch Basin
- Existing Storm Drain Manhole
- Existing Storm Drain
- Existing Ditch
- Major Contour (10' Interval)
- Minor Contour (2' Interval)

Existing Conditions - February 2019 Peak Observed Tide

Max Depth (ft)

- < 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8

NOTES:

1. Horizontal datum is California State Plane Zone III, North American Datum of 1983 (NAD83), U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Topographic contours are composite of Cinquini and Passarino topographic survey (July 30, 2020) and Marin County, California QL1 LiDAR collected by Quantum Spatial for Golden Gates National Parks Conservancy (2019).
4. Stormwater infrastructure data from survey conducted by Cinquini and Passarino (July 30, 2020.), and Marin County GIS Database (2020).
5. Aerial photo provided by Marin County (2018.).
6. February 2019 peak observed tide = 7.61 feet at San Francisco gage at 9:30am, February 2, 2019

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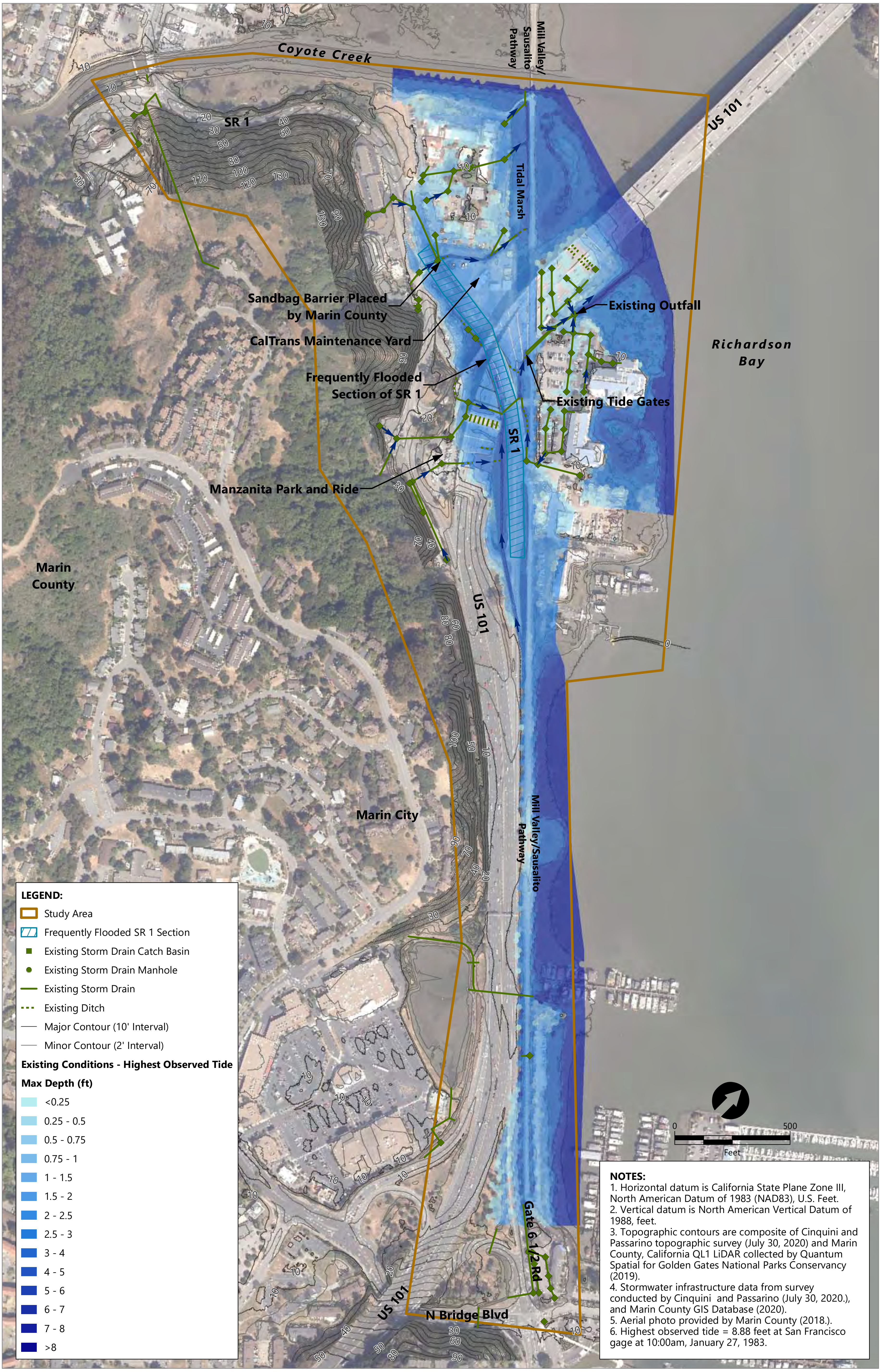
ANCHOR QEA

Figure E-0A
Hydraulic Model Results - Existing Conditions, Peak 2019 Tide



NOTES:
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2. Vertical datum is North American Vertical Datum of 1988, feet.
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4. Stormwater infrastructure data from survey conducted by Cinquini and Passarino (July 30, 2020.), and Marin County GIS Database (2020).
5. Aerial photo provided by Marin County (2018.).
6. Highest observed tide = 8.88 feet at San Francisco gage at 10:00am, January 27, 1983.

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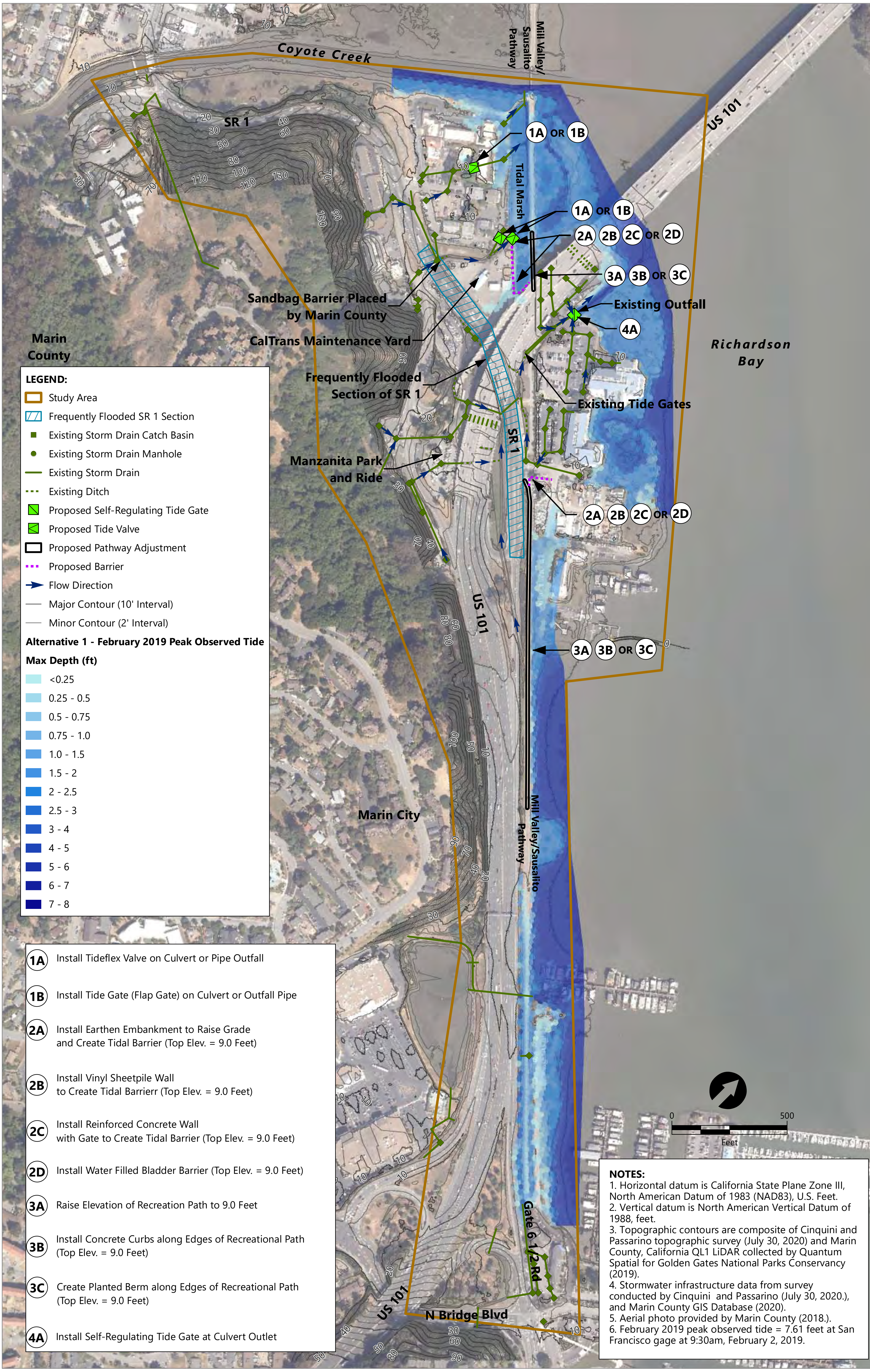
Figure E-0B
Hydraulic Model Results - Existing Conditions, Highest Observed Tide



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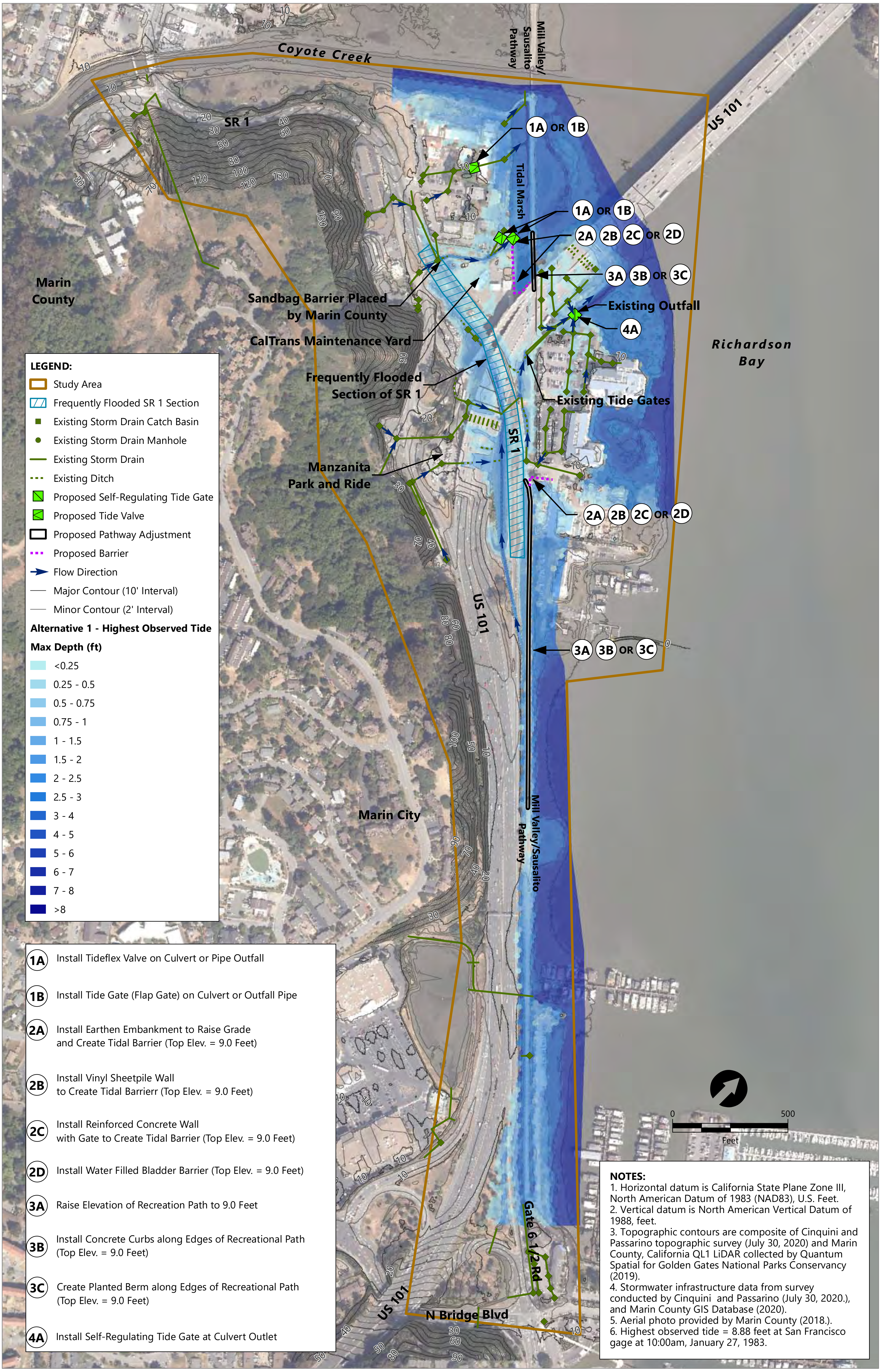
ANCHOR QEA

Figure E-1A
Hydraulic Model Results – Alternative 1, Peak 2019 Tide



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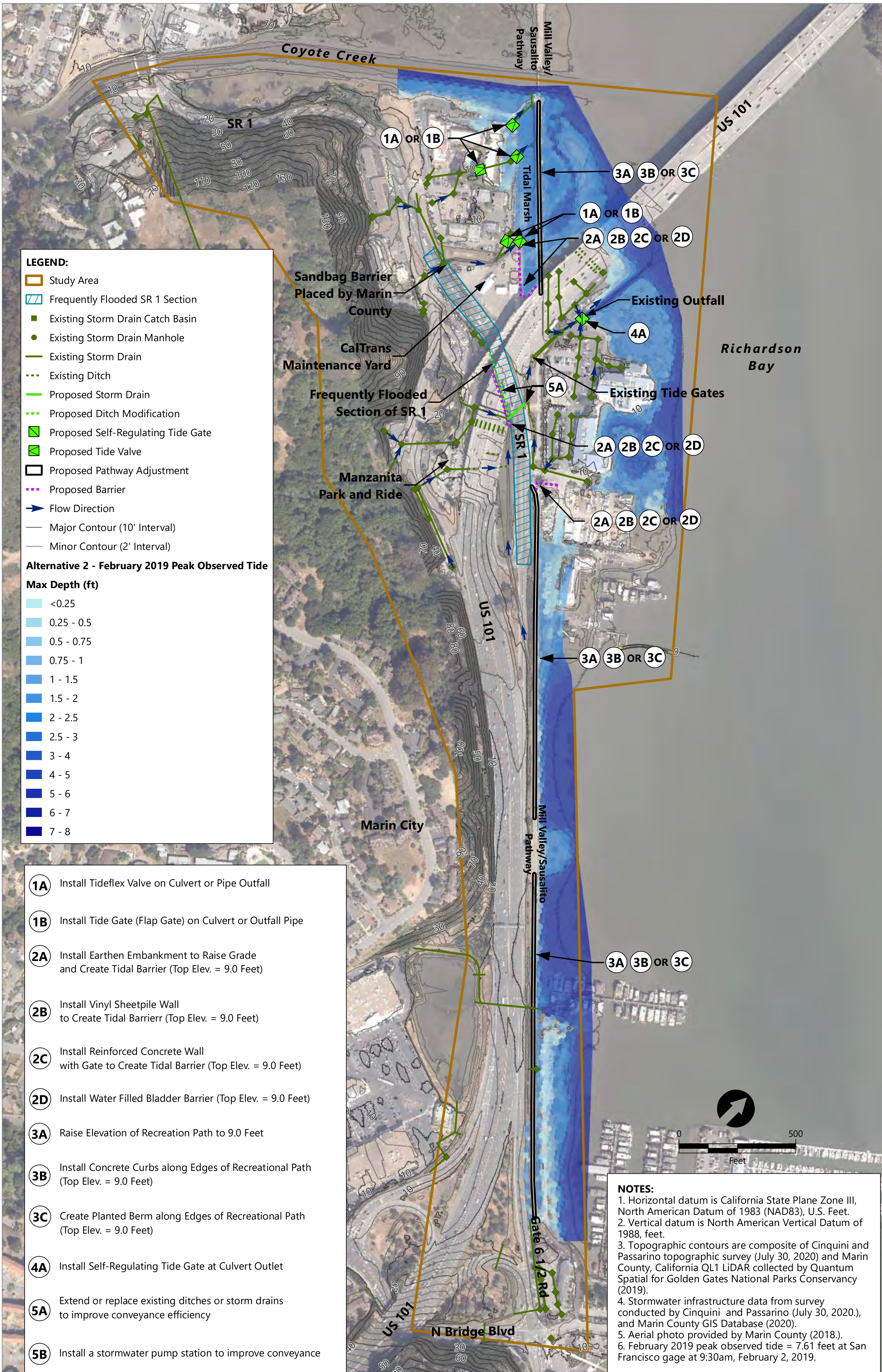
ANCHOR QEA

Figure E-1B
Hydraulic Model Results – Alternative 1, Highest Observed Tide



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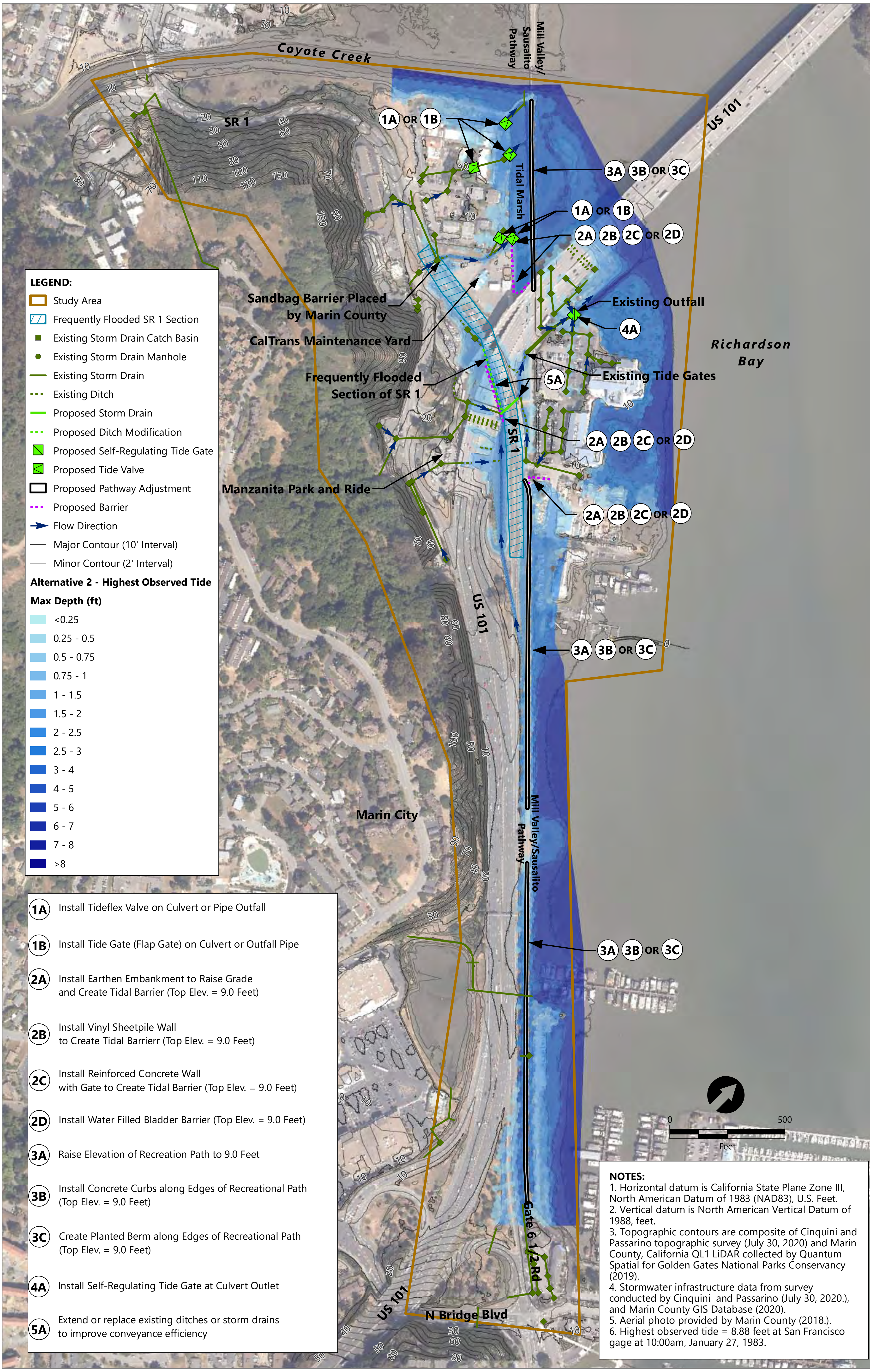
ANCHOR QEA

Figure E-2A
Hydraulic Model Results – Alternative 2, Peak 2019 Tide



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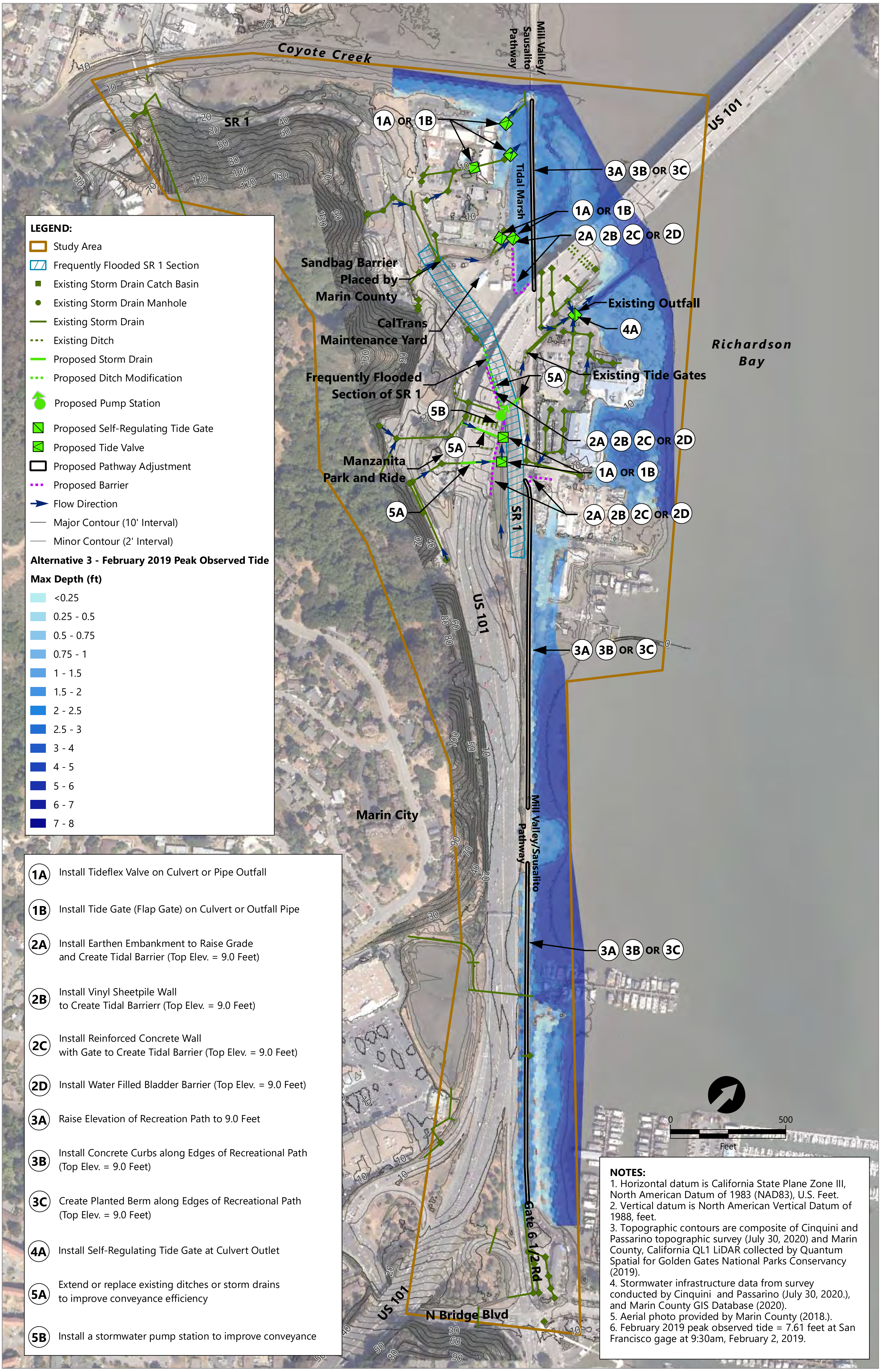
ANCHOR QEA

Figure E-2B
Hydraulic Model Results – Alternative 2, Highest Observed Tide



Publish Date: 2021/01/19, 9:19 PM | User: epipkin
Filepath: Q:\Jobs\MarinCounty_1031\Maps\Manzanita Park and Ride Flood Study\Flood Reduction Study Report\AQ_FigureE3A_Model2019Tide_Alt3.mxd

ANCHOR QEA

Figure E-3A
Hydraulic Model Results – Alternative 3, Peak 2019 Tide

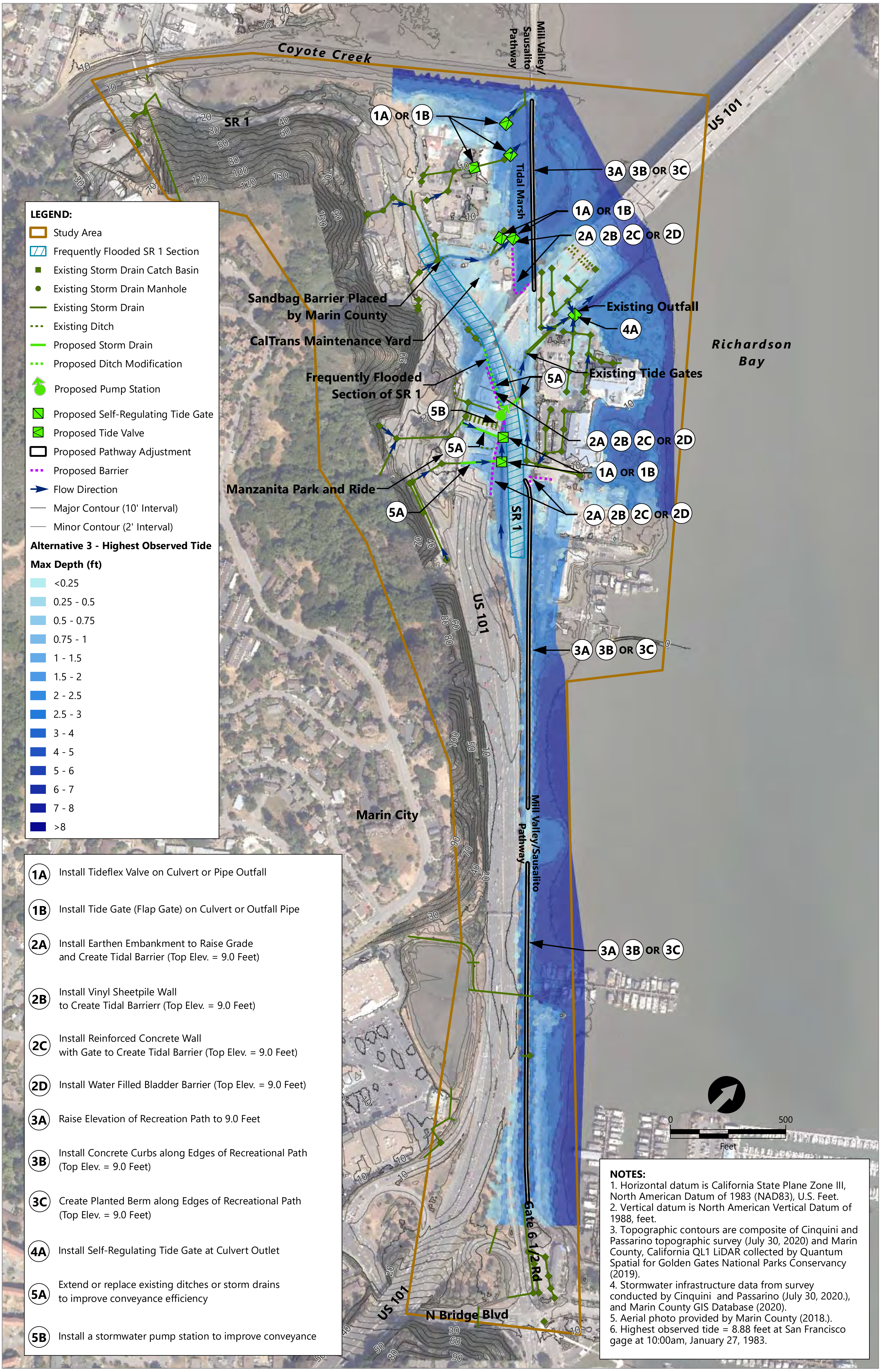


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Figure E-3B
Hydraulic Model Results – Alternative 3, Highest Observed Tide
Flood Reduction Study Report
Manzanita Area Flood Reduction Study

Appendix F
Opinions of Probable Cost

Manzanita Flood Reducton Study
Marin County

Flood Reduction Measure Unit Cost Development

Flood Reduction Measure	Description	Size	Unit	Unit Cost			Notes
				Materials	Labor and Profit	Total	
1A	Tideflex Valve, or Equal	24"	EA	$7,800	$2,000	$9,800	-Materials price from USA Blue Book, based on $5,000 for 18" flanged TF-35 valve ($280 per inch diameter). Add 15% to be conservative and roundup to nearest $100. -Add 25% for labor and profit -Round up to $100.
		18"	EA	$5,800	$1,500	$7,300	-Materials price from USA Blue Book, based on $5,000 for 18" flanged TF-35 valve ($280 per inch diameter). Add 15% to be conservative and roundup to nearest $100. -Add 25% for labor and profit -Round up to $100.
		12"	EA	$3,500	$900	$4,400	-Materials price from USA Blue Book, based on $5,000 for 18" flanged TF-35 valve ($280 per inch diameter). Add 15% to be conservative and roundup to nearest $100. -Add 25% for labor and profit -Round up to $100.
1B	Tide (Flap) Gate, or Equal	24"	EA	$3,600	$900	$4,500	-Materials price from RS Means. Add 15% to be conservative and roundup to nearest $100. -Add 25% for labor and profit -Round up to $100.
		18"	EA	$3,000	$800	$3,800	-Materials price from RS Means. Add 15% to be conservative and roundup to nearest $100. -Add 25% for labor and profit -Round up to $100.
2A	Earthen, Vegetated Berm	N/A	LF	$50	$20	$70	-Assume 0.8 CY of fill per LF of earthen berm. -Use $60/CY for imported select fill. -Add $20/CY for labor, profit, and planting. -Round up to $10.
2B	Vinyl Sheet Pile Wall	N/A	LF	$240	$110	$350	-$200/LF (materials+labor) was used for 6-foot vinyl sheetpile on a recent project. Add 5% for inflation. Add another 20% for adjustment to Marin County and other miscellaneous costs (Use~$250/LF for materials+labor). -Assume ave. 6-foot high. -Use $195 for vinyl sheetpile materials. -Add 30% for labor and profit, round up to $10. -Use $500/CY for concrete at 0.083 CY/LF. -Use $600/CY for concrete forming, placement, labor. -Round up to $10.

Manzanita Flood Reducton Study
Marin County

Flood Reduction Measure Unit Cost Development

Flood Reduction Measure	Description	Size	Unit	Unit Cost: Materials	Unit Cost: Labor and Profit	Unit Cost: Total	Notes
2C	Reinforced Concrete Wall	N/A	LF	$180	$210	$390	-We typically use ~$800 to $900/CY for reinforced structural concrete (materials+forming/placement/labor/profit). Add another 15% for adjustment to Marin County and other miscellaneous costs (Use~$1,100/CY total). -Assume ave 6-foot high. -Use $500/CY for concrete at 0.35 CY/LF for materials. -Use $600/CY for concrete forming, placement, labor. -Round up to $10.
2D	Water-Filled Bladder Barrier	36"	LF	$70	$40	$110	-Materials from Internet search. -Use $60/LF for bladder barrier. -Use $10/LF for ground preparation. -Add 15% for hoses to fill bladder. -Add 30% for placement, labor, and profit. -Round up to $10.
3A	Raise Elevation of Pathway	N/A	LF	$100	$30	$130	-Assume average 2-foot trail raise -Assume 0.8 CY of compacted fill per LF. -Assume 0.12 CY of asphalt per LF @ $120/TN material cost. -Assume 0.25 CY of crushed base per LF @ $50/TN material cost. -Use $60/CY for imported select fill material cost -Add 30% for labor, profit, and planting.
3B	Concrete Curbs Along Pathway	N/A	LF	$40	$50	$90	-Use $500/CY for cast-in-place concrete at 0.073 CY/LF. -Use $600/CY for concrete forming, placement, labor. -Round up to $10. -Unit price would be doubled for curbs on each side of path.
3C	Planted Berms Along Pathway	N/A	LF	$50	$20	$70	-Assume 0.7 CY per LF of earthen berm. -Use $60/CY for imported select fill. -Add $20/CY for labor, profit, and planting. -Round up to $10. -Unit price would be doubled for berms on each side of berm.
4A	Self-Regulating or Automatic Tide Gate	48"	EA	$48,000	$15,000	$63,000	-Materials from Internet search. -Add 30% for placement, labor, and profit. -Round up to $10.
	Self-Regulating or Automatic Tide Gate	36"	EA	$30,000	$9,000	$39,000	-Materials from Internet search. -Add 30% for placement, labor, and profit. -Round up to $10.

Manzanita Flood Reducton Study
Marin County

Flood Reduction Measure Unit Cost Development

Flood Reduction Measure	Description	Size	Unit	Unit Cost: Materials	Unit Cost: Labor and Profit	Unit Cost: Total	Notes
5A	Storm Drain/Culvert	18"	LF	$30	$30	$60	-Pipe materials price from RS Means. -Add $15/LF to materials for backfill and asphalt. -Add 40% for pipe installationl labor and profit. -Add 50% for trenching, backfilling, and compaction.
	Storm Drain/Culvert	12"	LF	$20	$20	$40	-Pipe materials price from RS Means. -Add $12/LF to materials for backfill and asphalt. -Add 40% for pipe installationl labor and profit. -Add 50% for trenching, backfilling, and compaction.
	Improve Ditch Connection	N/A	LF	$6	$4	$10	-Assume 0.3 CY of excavation per LF. -Use $20/CY of excavation. -Add $12/CY for haul, labor, profit, and planting.
5B	Stormwater Pumping	N/A	MGD	$540,000	$220,000	$760,000	-0.8 MGD Lift Station from RS Means, cost scaled and inflated 20% to account for miscellaneous associated materials. -Add 40% for labor and profit. -Assume capacity ~1,000 gpm (1.44 MGD). -Assume packaged station in manhole.

Notes:
1) Unit costs are in 2020 dollars.

Manzanita Flood Reducton Study
Marin County

Opinion of Probable Costs for Improvement Alternatives

Measure Used for Cost	Improvement Description	Unit	Unit Cost	Alternative 1		Alternative 2		Alternative 3	
				Quantity	Cost[1]	Quantity	Cost[1]	Quantity	Cost[1]
Install a Tideflex valve (1A) or a tide gate (1B) to prevent the tide from backing up through a storm drain:									
1A	Storm drain outfall from NE corner of Holiday Inn parking lot	EA	$4,400		$0	1	$4,400	1	$4,400
1A	Storm drain outfall near SE corner of Holiday Inn parking lot	EA	$7,300		$0	1	$7,300	1	$7,300
1A	Storm drain system near SW corner of Holiday Inn parking lot	EA	$3,500	1	$3,500	1	$3,500	1	$3,500
1A	Culvert near the north corner of the Caltrans Yard	EA	$9,800	1	$9,800	1	$9,800	1	$9,800
1A	Storm drain from commercial property NW of the Caltrans Yard	EA	$4,400	1	$4,400	1	$4,400	1	$4,400
1A	On storm drain through central portion of Park and Ride	EA	$4,400		$0		$0	1	$4,400
1A	On storm drain or extended storm drain that drains south end of Park and Ride	EA	$4,400		$0		$0	1	$4,400
Install an embankment (2A), vinyl sheet pile wall (2B), concrete wall (2C), or water-filled bladder barrier (2D):									
2B	Between Caltrans Maintenance Yard and commercial property NW of Caltrans Yard	LF	$350	60	$21,000	60	$21,000	60	$21,000
2B	Along east side of Caltrans Maintenance Yard to recreational pathway	LF	$350	300	$105,000	300	$105,000	300	$105,000
2A	Along east side of Park and Ride, seal up existing wall	LF	$70		$0	230	$16,100	230	$16,100
2B	Along east side of Park and Ride, extend to south end of Park and Ride at bridge abutment	LF	$350		$0		$0	290	$101,500
2B	Along south side of Pohono Street	LF	$350	160	$56,000	160	$56,000	160	$56,000
Raise recreation pathway (3A), install curbs along path (3B), or install vegetated berms along path (3C):									
3A	From west side of US 101 Bridge, extending 200 feet to northwest	LF	$130	200	$26,000		$0		$0
3A	From west side of US 101 to the recreational pathway bridge over Coyote Creek	LF	$130		$0	860	$111,800	860	$111,800
3A	From Pohono Street south to high point 1,350 Street southwest of Pohono Street	LF	$130	1,350	$175,500	1,350	$175,500	1,350	$175,500
3A	From high point southwest of Pohono Street to high point just north of Gate 6 1/2 Road	LF	$130		$0	1,380	$179,400	1,380	$179,400
Install self-regulating tide gate (4A):									
4A	48" Tide gate at main storm drain outfall on East Side of US 101 Bridge	EA	$63,000	1	$63,000	1	$63,000	1	$63,000
4A	36" Tide gate at main storm drain outfall on East Side of US 101 Bridge	EA	$39,000	1	$39,000	1	$39,000	1	$39,000
Improve existing storm drains or ditches (5A), or install a stormwater pump station (5B):									
5A	Improve ditch connection along south side of SR 1 under the US 101 Bridge	LF	$10		$0	300	$3,000	300	$3,000
5A	Replace existing 12” culvert under SR 1 just east of the US 101 bridge with an 18” CPE culvert	LF	$60		$0	95	$5,700	95	$5,700
5A	Replace or extend storm drains that drain the central portion of the Park and Ride	LF	$40		$0		$0	180	$7,200
5A	Replace or extend storm drains that drain the south portion of the Park and Ride	LF	$40		$0		$0	230	$9,200
5B	Install a stormwater pump station at the low point, south side of SR 1 near the Park and Ride	MGD	$760,000		$0		$0	1.4	$1,094,400
Construction Subtotal[2,3]					**$503,000**		**$805,000**		**$2,026,000**
Engineering, Permitting, and Administration (25%)[4]					$125,750		$201,250		$506,500
Environmental Mitigation Allowance[5]					$100,000		$160,000		$420,000
Project Cost Subtotal[2,3]					**$729,000**		**$1,166,000**		**$2,953,000**
Planning Contingency (30%)					$218,700		$349,800		$885,900
Total Project Cost - With Contingency[2,3]					**$948,000**		**$1,516,000**		**$3,839,000**

Notes:
1) Costs are in 2020 dollars.
2) Subtotals and Toals are rounded to the nearest $1,000.
3) Costs are based on conceptual designs and are intended to be "order-of-magnitude" costs for the primary purpose of comparing alternatives. Actual costs will vary based on the elements that are implemented, Caltrans requirements for the proposed project, and permitting requirements.
4) Engineering, permitting, and admistration costs should be considered an allowance and were estimated based on the percentage shown. Actual costs will need to be estimated at the time of design based on the scope of work for design and the time and effort required to develop designs, permit the project, and administer implementation.
5) Environmental mitigation costs should be considered an allowance. Actual costs will vary based on the impact of the project to be implemented and regulatory requirements for mitigation.
6) All taxes and fees not listed as separate items are assumed to be included in the unit costs for each item.