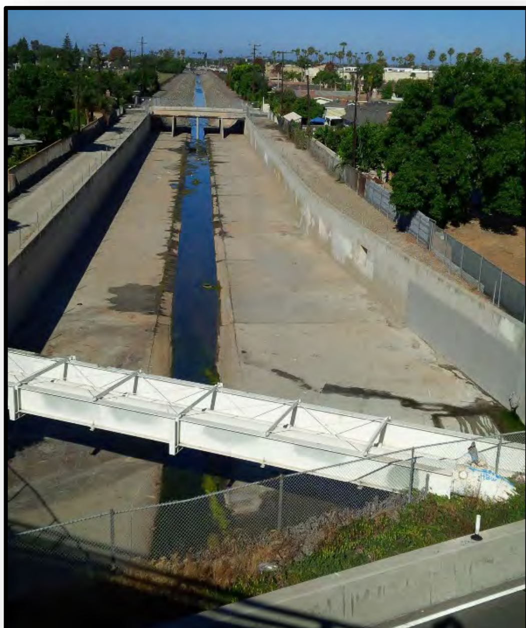
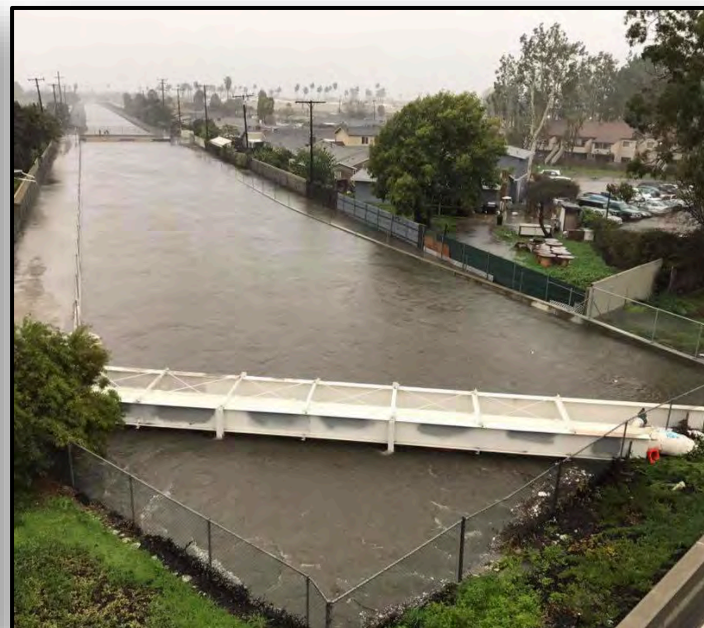
APPENDIX B - CIVIL ENGINEERING

For

WESTMINSTER, EAST GARDEN GROVE FLOOD RISK MANAGEMENT STUDY





April 2020

US Army Corps of Engineers
Chicago District

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Civil Appendix

For

WESTMINSTER, EAST GARDEN GROVE

FLOOD RISK MANAGEMENT STUDY

1.0 Objective

The purpose of this appendix is to provide results from the Civil Engineering Design effort. Design data and calculations were developed sufficiently to determine the technical and economic feasibility of the NED and LPP plans and in the event that project is authorized, to provide a design basis leading to the development of the construction plans and specifications.

2.0 Study Area/Existing Project Features

The study area is contained within the Westminster Watershed in western Orange County, California. The watershed is approximately 74 square miles and lies on a flat coastal plain that is almost entirely urbanized. Cities in the watershed include Anaheim, Stanton, Cypress, Garden Grove, Westminster, Fountain Valley, Los Alamitos, Seal Beach, and Huntington Beach.

The watershed is part of the former floodplain of the Santa Ana River (SAR) which historically meandered through out the existing watershed as far north as Anaheim Bay to as far south as Newport Bay. Channelization and large scale flood control Modifications have constrained the Santa Ana River to the main stem channel on the eastern border of the Westminster Watershed.

Figure 1 depicts the watershed boundary in orange, the Santa Ana River (SAR) in light blue, and the major drainage channels throughout the watershed in dark blue.

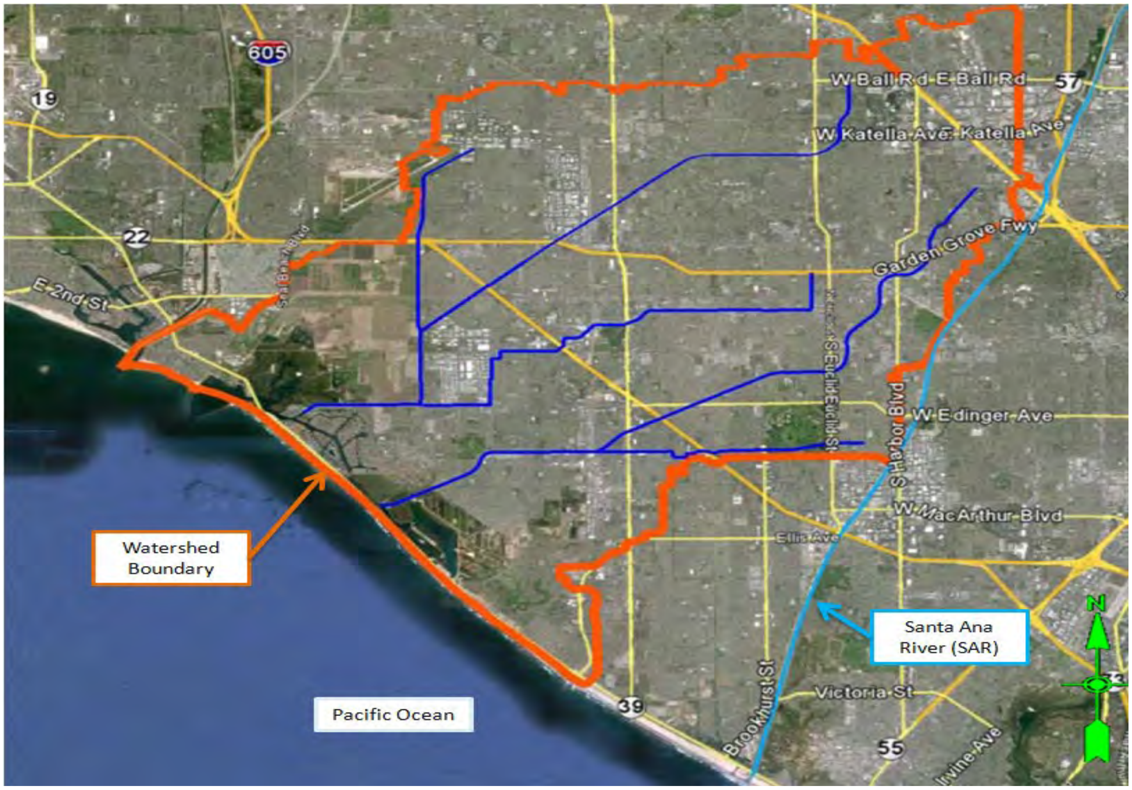

Figure 1: Westminster Watershed

The channels within the Westminster Watershed collect local storm water runoff and vary in size, geometry, and lining. Typical channel configurations include concrete rectangular (including invert); riprap- lined trapezoidal (soft-bottom), concrete-lined trapezoidal (including invert), and enclosed culverts. Configurations vary by reach and change throughout the channel systems.

This study will take a watershed approach to flood risk management by modifying the existing channel cross section configurations and armoring to convey the design flow. The study focus however will be on the channels illustrated in Figure 2, and will support the systems that warrant Federal consideration and that are shown to be incrementally justified.

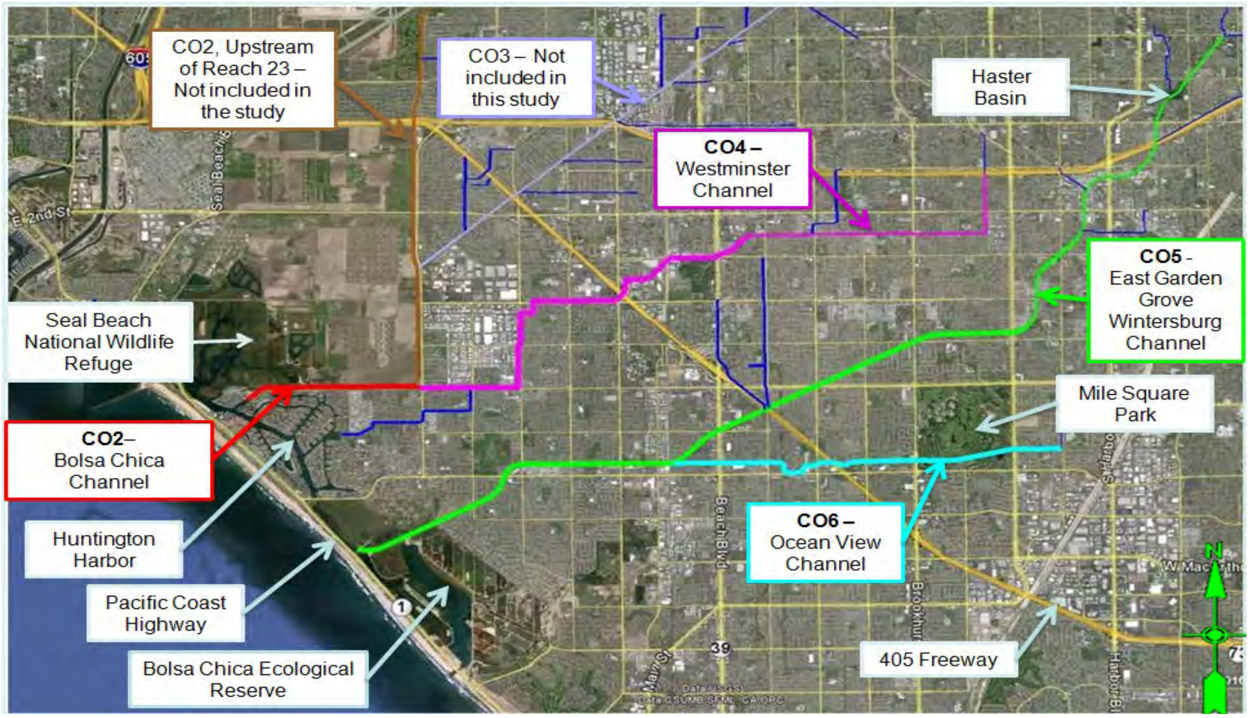

Figure 2: Drainage Channels within the Study Area

2.1 Bolsa Chica Channel (Channel C02)

The study will focus on the downstream-most segment that begins at the C02/C04 confluence at the Bolsa Chica Street/Edinger Avenue intersection. The segment extends to the west where it eventually discharges into Huntington Harbor.

2.2 Westminster Channel (Channel C04)

The C04 Channel begins approximately 0.25 miles west of the Highway 22 and Euclid Street overpass and extends approximately 8 miles southwest before joining the C02 channel near the Bolsa Chica Street/Edinger Avenue intersection.

2.3 East Garden Grove/Wintersburg Channel (Channel C05)

The C05 channel begins upstream of Haster Basin (a.k.a. Twin Lakes Park) and flows approximately eleven miles southwest where it discharges into Outer Bolsa Bay, located in the Bolsa Chica Ecological Reserve.

2.4 Ocean View Channel (Channel C06)

The C06 channel is a tributary to the C05 channel and begins east of Mile Square Park. The channel flows to the west, through the park, and continues an additional four miles where it ultimately discharges into the C05 channel at a point northeast of the intersection of Gothard Street and Warner Avenue.

2.5 Receiving Waters

This study will also focus on the receiving waters of the C02/C04 and C05/C06 channel systems. Figure 3 depicts the receiving waters of both the channel systems.

The C02/C04 channel system does not outlet directly to the Pacific Ocean. Waters from the C02/C04 system discharge into the north side of Huntington Harbour. The waters then pass through the northwestern end of the harbor into Seal Beach National Wildlife Refuge, under Pacific Coast Highway into Anaheim Bay and then flow from the Bay to the Pacific Ocean.

The C05/C06 channel system does not outlet directly to the Pacific Ocean. Waters from the C05/C06 system enter Outer Bolsa Bay, which is part of the Bolsa Chica Ecological Reserve, and flow under the Warner Avenue Bridge through the south end of Huntington Harbour. A tide gate where C05 enters Outer Bolsa Bay marks the downstream limit of the OCPW flood control easement and ownership interests. The flows continue through Huntington Harbour, draining through the northwestern end of the harbor into Seal Beach National Wildlife Refuge where they join with the waters from the C02/C04 channel system. Once the waters pass through the southern end of the refuge they travel under Pacific Coast Highway into Anaheim Bay and then to the Pacific Ocean.

Figure 3: C02/C04 and C05/C06 Receiving Waters

The receiving waters are comprised of the following four regions:

- **Huntington Harbour –** City of Huntington Beach residential community that includes five manmade islands and water ways used for boating. The layout of the harbor is illustrated in Figure 5.

- **Seal Beach National Wildlife Refuge -**A wildlife refuge that was developed through a collaboration of the U.S. Fish and Wildlife Service and the Department of the Navy. The reserve is part of the Seal Beach Naval Weapons Station located to the northeast adjacent to the right bank of the C02 channel.

- **Anaheim Bay –** The Bay serves as the outlet to the Pacific Ocean for the Wildlife Refuge, as well as the C02/C04 channel system.

- **Bolsa Chica Ecological Reserve –** This area is a nature reserve to protect a significant coastal wetland, home for many endemic plant and animal species, including endangered ones.

Figure 4: Bolsa Chica Ecological Reserve

The Bolsa Chica Ecological Reserve (BCER), completed in 2006, is owned by the State Lands Commission. The lower segment of the CO5 channel bisects the reserve. The reserve is divided into six sections as depicted in Figure 4. The BCER is comprised of the following areas:

- Full Tidal Basin - The Full Tidal Basin is located along the eastern edge of the CO5 channel and is considered an environmentally sensitive area. The Full Tidal basin is separated from the CO5 Channel, the Muted Tidal Basin, and Inner Bolsa Bay by levees. Water exchange between the Muted

Tidal Basin and the Full Tidal Basin is permitted by a series of culverts and is controlled by flap gates that respond to changes in tide. Water exchange between the Seasonal Pond Area and the basin is controlled by flap gates that respond to changes in tide. The basin is connected to the Pacific Ocean by an outlet that passes under Pacific Coast Highway.

- Muted Tidal Basin – The Muted Tidal Basins is located along the north eastern edge of the Full Tidal Basin. The basin is divided into three cells that are only allowing water to movie between them through overflow weirs during larger storm events. Each cell is separated from the Full Tidal Basin and the CO5 channel by a levee. Culverts permit water exchange between the Muted Tidal Basin and the Full Tidal Basin and flap gates allow regular but muted tidal influence.
- Inner Bolsa Bay - Inner Bolsa Bay is located between Pacific Coast Highway and the Full Tidal Basin. The bay is isolated from the Full Tidal Basin by a levee and is separated from Outer Bolsa Bay by a tide gate. The tide gate permits water from Outer Bolsa Bay to enter Inner Bolsa Bay to maintain a tidal influence within Inner Bolsa Bay. There is no water exchanged between the Full Tidal Basin and Inner Bolsa Bay.
- Muted Tidal Pocket - The Muted Tidal Pocket is located along the northern edge of the downstream end the CO5 channel. The Muted Tidal Pocket is isolated from the CO5 channel by a levee and is separated from Outer Bolsa Bay by a tide gate. The tide gate permits water from Outer Bolsa Bay into the Muted Tidal Pocket to maintain a muted tidal influence.
- Seasonal Ponds – The Seasonal Pond Area is located along the eastern edge of the Full Tidal Basin and is separated from the Full Tidal Basin by a levee. A single culvert controls discharge from the Seasonal Ponds Area into the Full Tidal Basin. This area is subject to runoff from surrounding developments. The seasonal pond has not yet been restored.
- Outer Bolsa Bay - Outer Bolsa Bay is located at the mouth of the CO5 channel. Water exchange between the CO5 channel and the bay is controlled by a tide gate. Outer Bolsa Bay is connected to Inner Bolsa Bay and the Muted Tidal Pocket by separate tide gates. These tide gates allow water to flow from Outer Bolsa Bay into either Inner Bolsa Bay or the Muter Tidal Pocket. Water is discharged from Outer Bolsa Bay through the Warner Ave Bridge into Huntington Harbor. Outer Bolsa Bay is separated from the Pacific Ocean by Pacific Coast Highway and Bolsa Chica State Beach.

2.6 Work Previously Completed

Due to immediate needs for flood risk reduction, OCPW has completed construction on channel Modifications in the lower segments of the CO5 channel near the Bolsa Chica Ecological Reserve. These Modifications include placing riprap along the banks of the CO5 channel near the downstream tide gate driving sheet pile into the existing levees along CO5. The sheet pile begins at the downstream end of the Muted Tidal Basin and extends upstream to Warner Avenue. Emergency sheet pile that was placed to prevent a levee breach was left in place along the right bank of CO5 and the new sheet pile extends from the upstream end of the emergency sheet pile to Warner Avenue, see figure 5.

Figure 5: C05 Modifications Near BCER

3.0 Design Assumptions

- Channels were developed to represent arrays of different types of possible channel Modifications. The entire channels were considered for modification to ensure flood risk was adequately addressed across the watershed and there was no increase in flood risk to downstream reaches as the capacity of the upstream reaches was increased.

- Existing utility surveys were requested from all local utilities and maps were provided to USACE. As expected, all of the received utilities ran parallel to the existing channels outside of the ROW. It is assumed that any remaining utilities (from agencies that were non-responsive or didn't have updated mapping) follow the same utility corridors and are not within the work areas with the exceptions of at the intersection crossings.

- The proposed structural thickness of the modified channels were based on design of similar structural channel walls and inverts in the region as constructed by Orange County.

- All proposed channel Modifications must be contained within the channel right of way due to dense commercial and residential development throughout the watershed.

- The proposed channel invert elevation cannot change significantly. High ground water and restricted change in elevation across the watershed limit the effectiveness of modifying the channel invert elevation.

- The proposed maximum flood wall height on the banks would be 3ft. This height is based on recommendations made by OCPW and would ensure maintenance equipment can travel over the flood wall and reach the invert of the channel.

- Maintain capacity for at least one access road along the top bank of the channel. A single access road would be required to ensure maintenance vehicles can access all reaches of the channel. The road could be on either side of the channel.

- The proposed design is based on existing channel design type of armoring and therefore less changes are expected during design refinements. Geotechnical testing would again be required as with all other channel designs. Additionally, and side drains have not been included in any of the proposed channel improvement designs but would need to be included when a final an alternative has been selected.

- Some channels are over 50 years old and may be considered historical structures. If so, additional cultural surveys, documentation and coordination will be required.

- The existing channels run through densely urban areas limiting site access. Noise and dust concerns can limit construction schedules. Bracing and shoring may be required for personal properties. Open flow channels convey surface runoff. Downstream areas would experience tidal influences. High groundwater could also be encountered. Local storm events, while seldom, also have a high intensity and may affect design protection.

4.0 Minimum Channel Modifications Alternative (NED)

The Minimum Channel Modifications Alternative (NED) is the plan with the highest Benefit-Cost ratios and the plan that USACE is recommending.

4.1 Channel Modifications

The channel Modifications in this alternative vary between no action on portions of the existing channel, to concrete lining of existing earthen channels and installation of sheet pile channel walls in leveed portions.

4.2 Downstream Modifications

Beyond the channel Modifications detailed above, this alternative will require some Modifications at the downstream end of the system. Based on the H&H modeling, the required Modifications include widening Warner Avenue Bridge and removing the tide gates at the downstream end of the C05 Channel. To widen Warner Avenue Bridge, Real Estate will need to be acquired from the State Lands Commission.

The Warner Ave Bridge currently acts as a downstream constriction and so will be widened to allow additional flow to pass into Huntington Harbor from Outer Bolsa Bay. The Hydraulic modeling for this alternative requires the removal of approximately 0.85 acres of land on the east edge of the Bolsa Chica Conservancy parking long just upstream of Warner Ave. Warner Avenue Bridge itself will need to be widened, and the pedestrian bridge just south of the automobile bridge will also need to be either widened or replaced. Refer to figure 7 and to the Structural Appendix for details on these modifications.

Figure 6: Warner Ave Bridge Modifications

The Tide Gates between Channel C05 and Outer Bolsa Bay will be removed. The current Tide Gates are ineffective and are leaking in many locations. Removing the structure is supported by the Local Sponsor and all of the local agencies as beneficial to the local ecosystem (see Environmental Appendix) as well as hydraulically beneficial to this project.

5.0 Maximum Channel Modifications Alternative (LPP)

The Maximum Channel Modifications Alternative (LPP) is the plan that will most likely end up being built, with the incremental cost difference paid by the local sponsor. Orange County would like to get all of its residents out of the 100 year floodplain to reduce insurance payments, and the LPP will reach that goal.

5.1 Channel Modifications

The channel Modifications in this alternative vary between no actions on portions of the existing channel, to a concrete lined rectangular channel with steel sheet pile floodwalls at the most extensive.

5.2 Diversion Channel at Westminster Mall

The NED plan includes a diversion channel on the C02/C04 channel at Westminster mall. On Channel C04 just downstream of the existing Hoover Street crossing, a diversion channel will be added to funnel a portion of the flow away from the existing channel. The proposed alignment follows an abandoned railway alignment which passes under the 405 Highway with an existing underpass. Two underground box culverts will be installed along this length. At Edwards St., the diversion will turn south and continue under the centerline of Edwards Street, replacing and overlapping with existing storm drains. The diversion will confluence with the existing open channel at the intersection of Edwards St. and Bolsa Ave. For a detailed description of the diversion channel, refer to Attachment 3, Diversion at Westminster Mall. Refer to Figure 8 for a plan view of the Diversion.

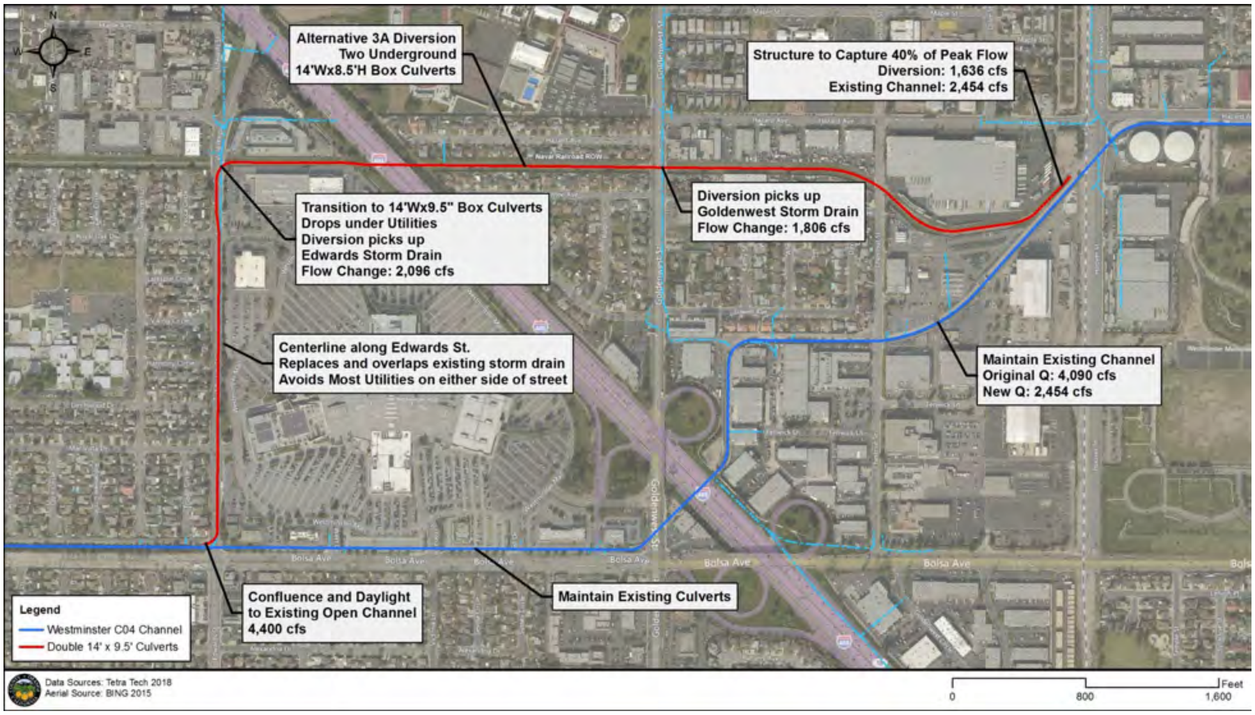

Figure 7: Westminster Mall Diversion

5.3 Crossings

The channel modifications will require replacing the channel crossings across 59 different roadways. These crossings were broken down into 5 different types which were representative of all of the different crossings. These were:

- No.1, Bolsa Avenue crossing (reinforced concrete box (RCB) culvert) on C05
- No.2, Beach Boulevard (Blvd) crossing (RCB culvert) on C06
- No.3, Beach Blvd/Heil Avenue intersection crossing (RCB culvert) on C05
- No.4, Edwards Street crossing (bridge) on C05
- No.5, Blake Street crossing (RCB culvert) on C04

These five types were further developed in design and costs, and representative one was used as the basis (then scaled accordingly) for each of the 59 crossings. For the detailed description and design of the representative crossings refer to Attachment 2, LPP Crossings.

5.4 Downstream Modifications

Beyond the channel Modifications detailed above, this alternative will require the same downstream Modifications at the downstream end of the system as the NED plan (Warner Ave Bridge widening and Tide Gates removal). Section 4.2 of this Appendix.

6.0 Operation and Maintenance

Operation and Maintenance costs were developed based on historic annualized costs from Orange County Public Works for existing channel segments. A summary of the costs for each alternative and reach is presented in the quantity calculation tables in Attachment 3. Operation and maintenance of the proposed project would be the responsibility of Orange County Flood Control District (OCFCD) and would include, but not limited to performing periodic inspections. Inspections would provide recommendations for maintenance including the following:

6.1 Vegetation Control

Active or passive establishment of vegetation on the earthen portions of the channels would attenuate erosion. However, vegetation maintenance may be required to ensure channel integrity. Structures to be maintained include the sides and bottom of channels, as well as access roads along the channels.

6.2 Rodent Control

Burrowing animals are capable of perforating channels with holes to the extent that the structural integrity of the channels may be jeopardized. To alleviate this problem, the rodent population should be kept under control by placing poison in the burrows. Rodent problems should be identified during the quarterly inspections.

6.3 Levee and Interior Drainage Structures Repair

In order to maintain the integrity of the levee and interior drainage structures, it is anticipated some repairs will be required after periods of significant flooding. This would include replacement of earth fill along eroded sections of the channel and interior drainage structures, repairs to gated outlets, and replacement of any damaged sections of soil cement, grouted/ungrouted riprap and gravel.

6.4 Sediment Removal

Removal of accumulated sediments in the vicinity of the channels will be required when it is determined there is a loss of channel capacity due to sediment build up.

Appendix B - Civil Engineering

Attachment 1: Proposed Typical Sections

Appendix B - Civil Engineering

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CHICAGO DISTRICT
231 S. LASALLE ST, SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

PROJECT LAYOUT PLAN

PLAN NORTH

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A1 PROJECT LAYOUT PLAN
SCALE: 1" = 2000'

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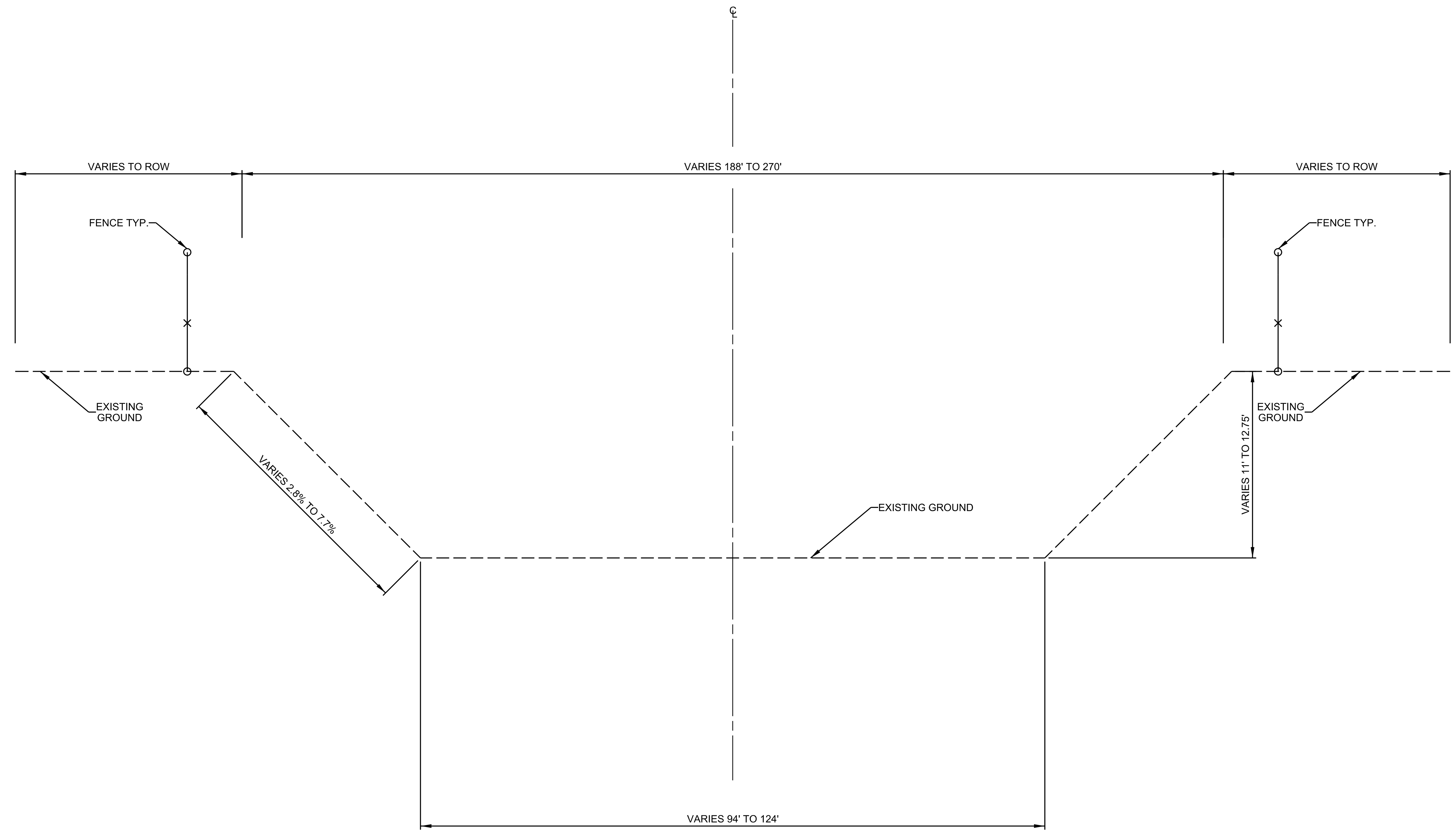

EXISTING TYPICAL SECTION - TRAPEZOIDAL EARTHEN CHANNEL

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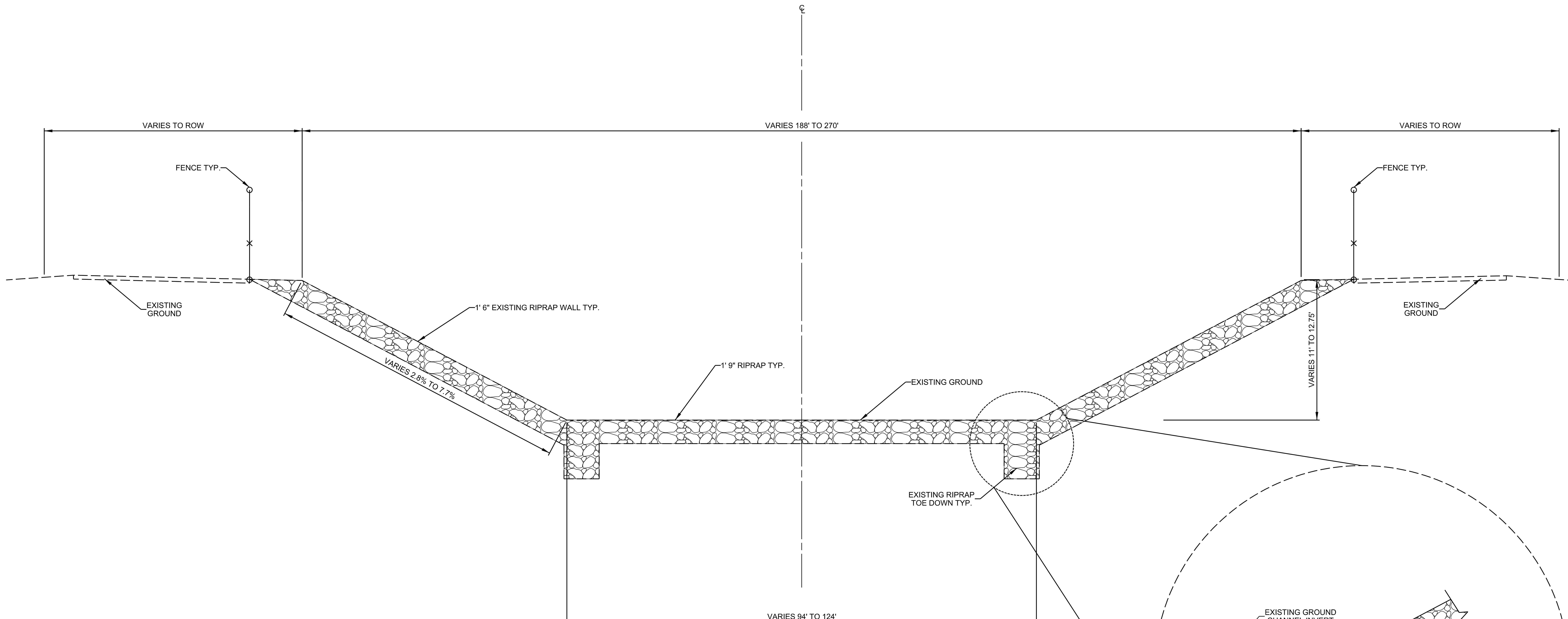

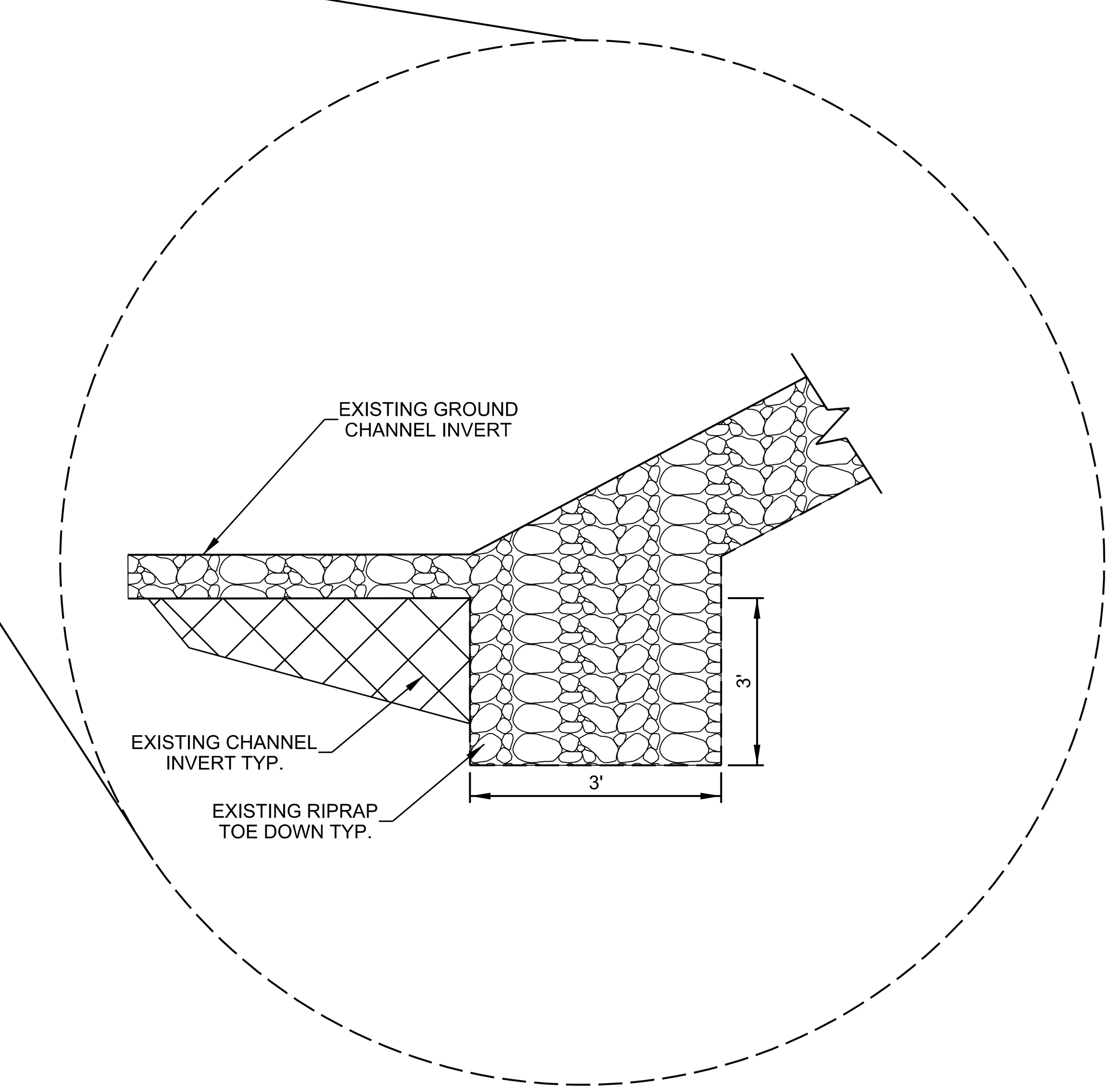

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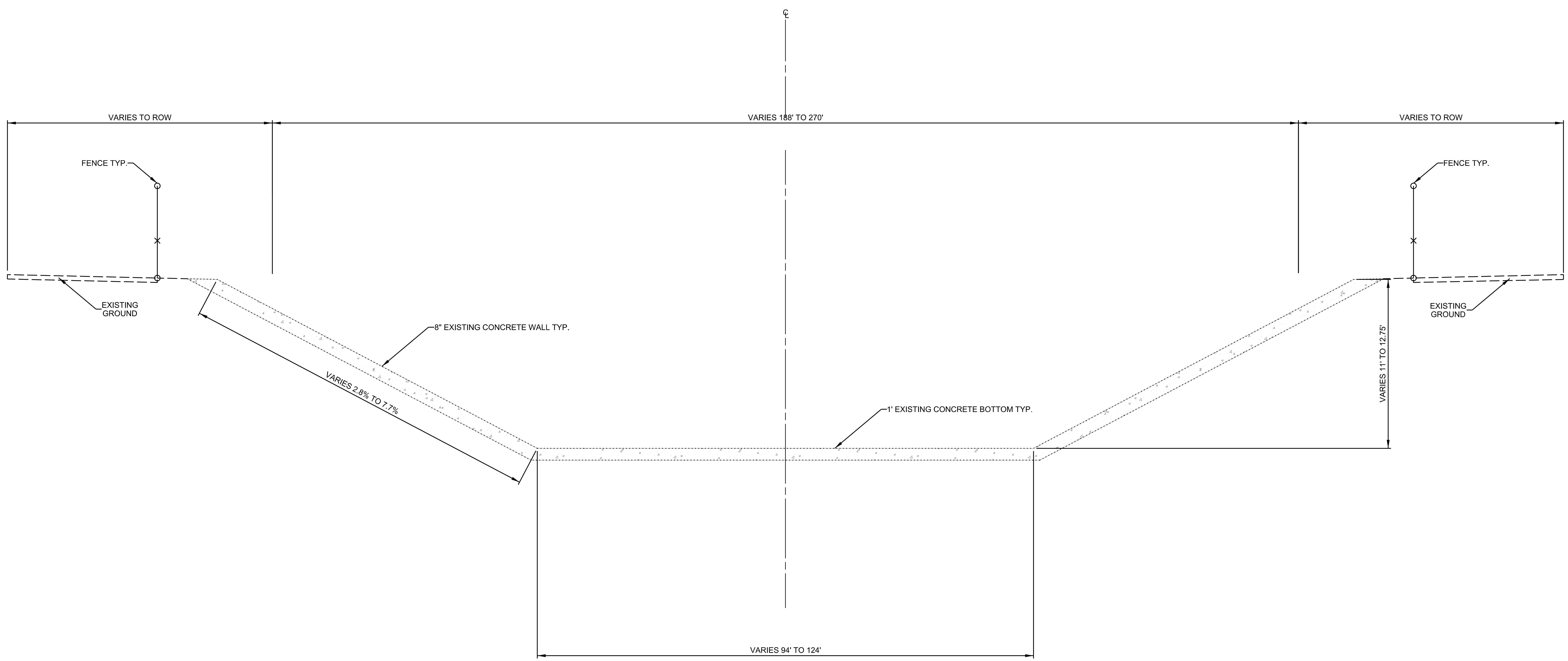

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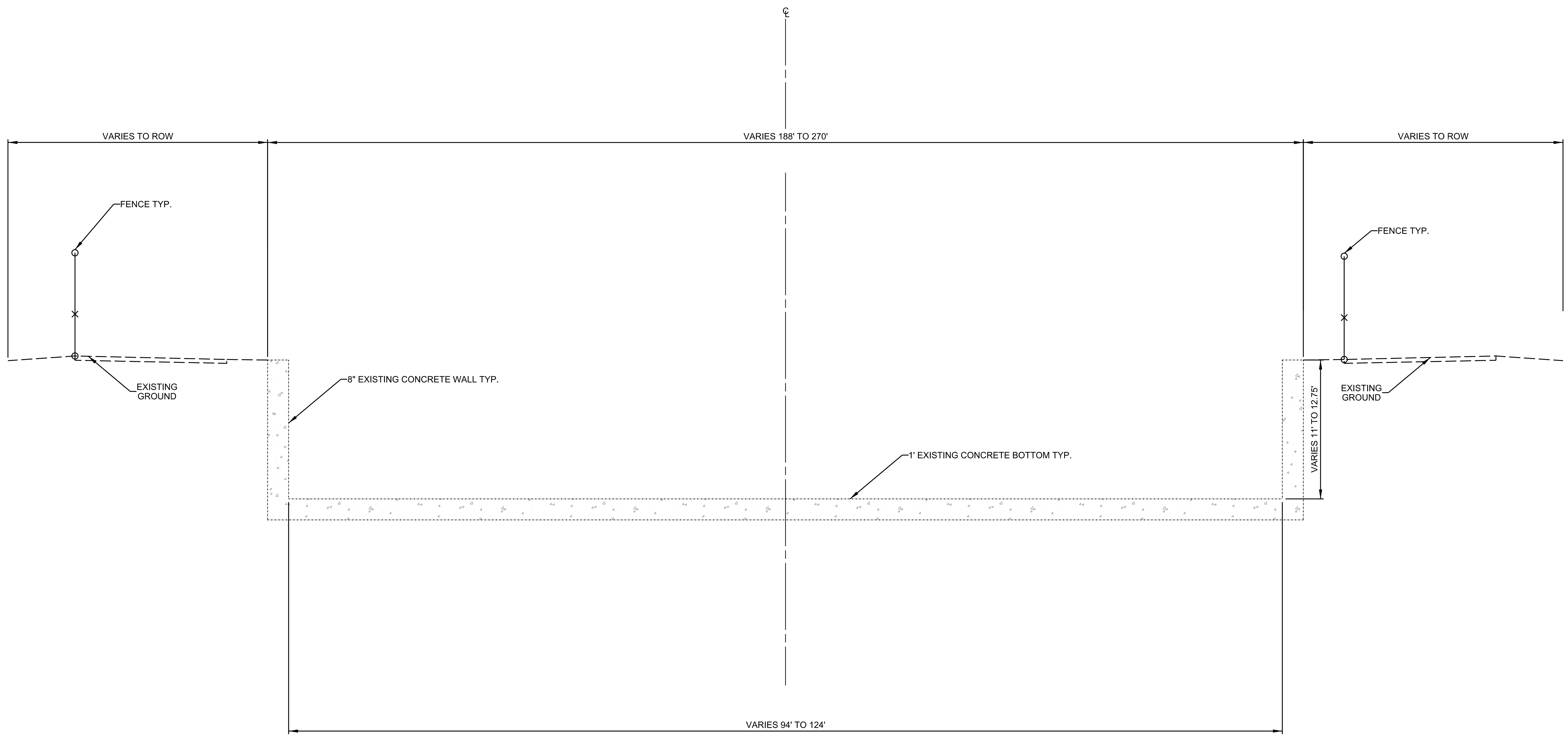

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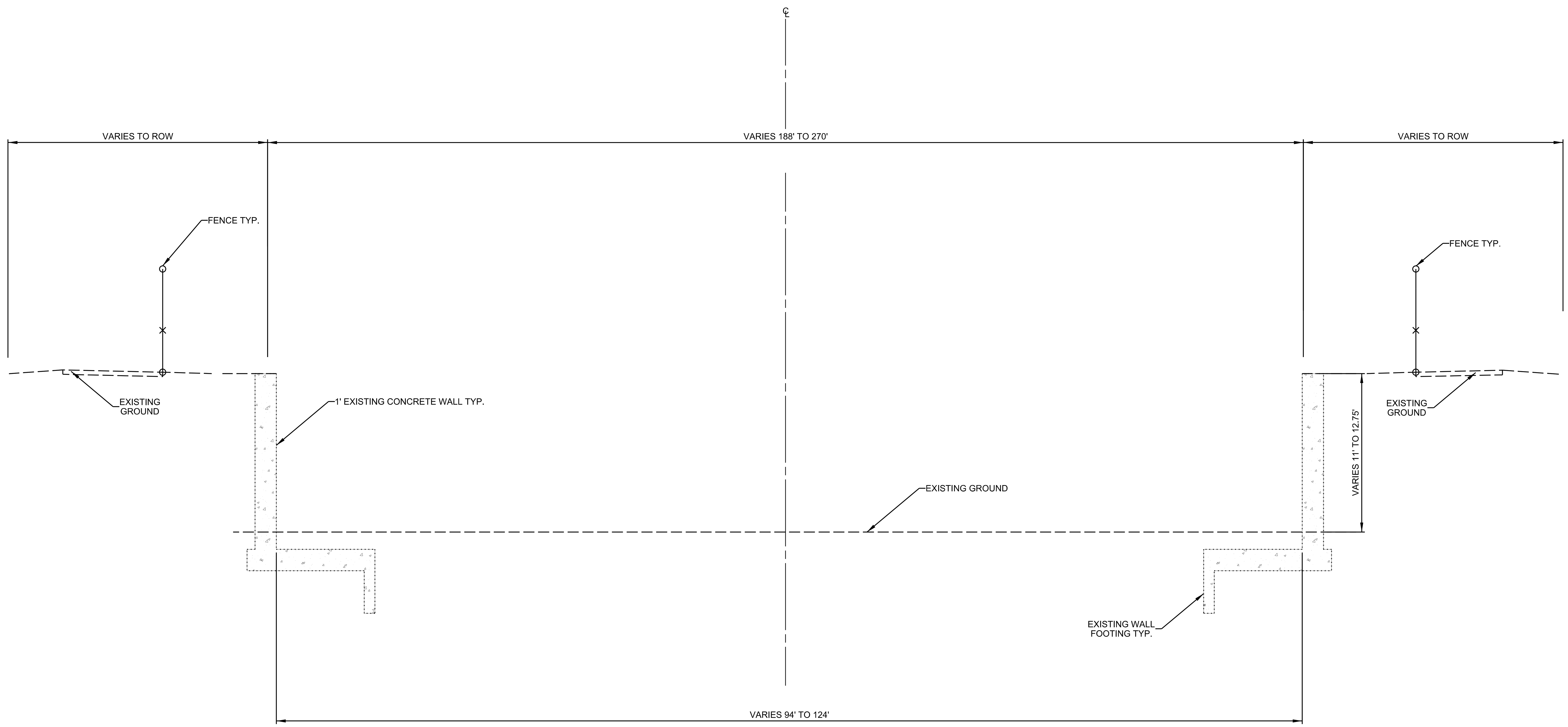

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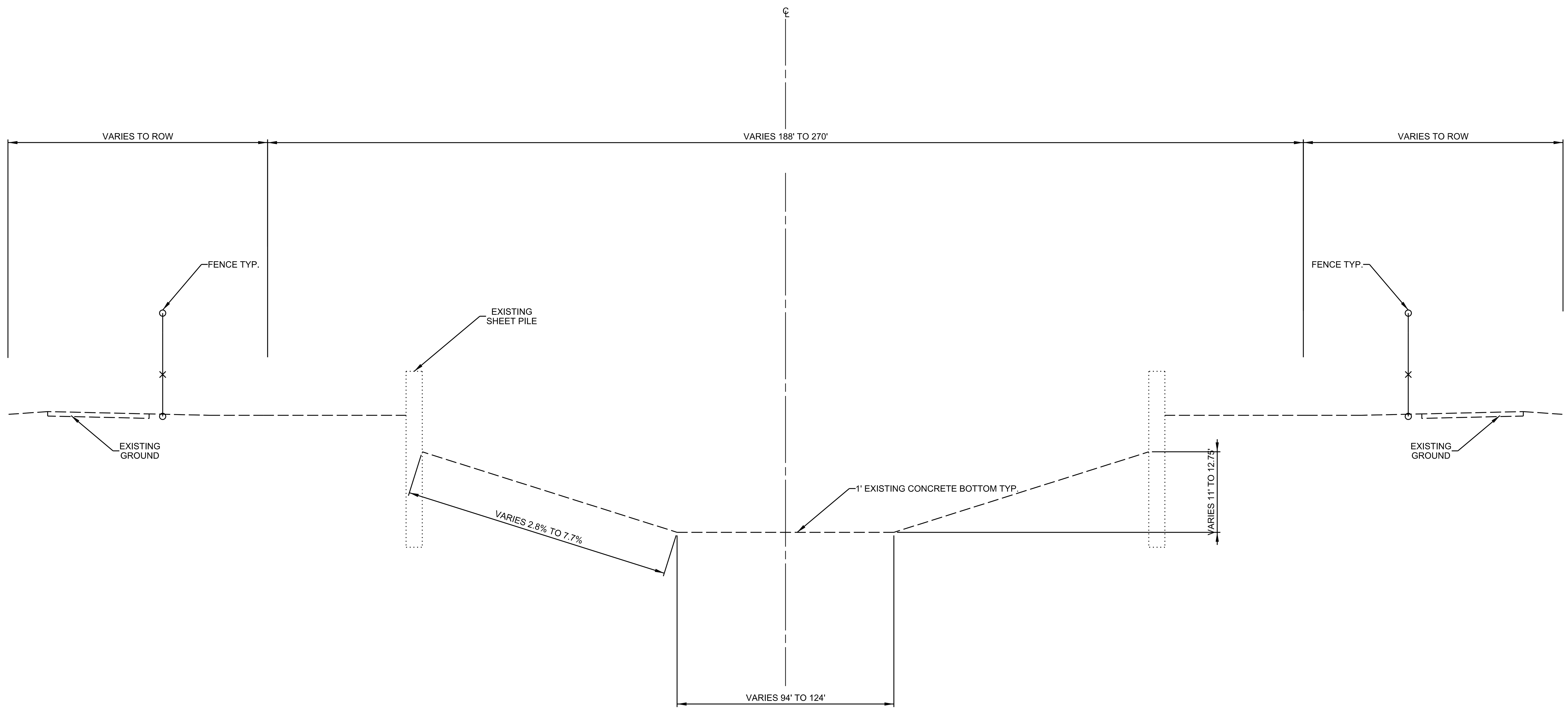

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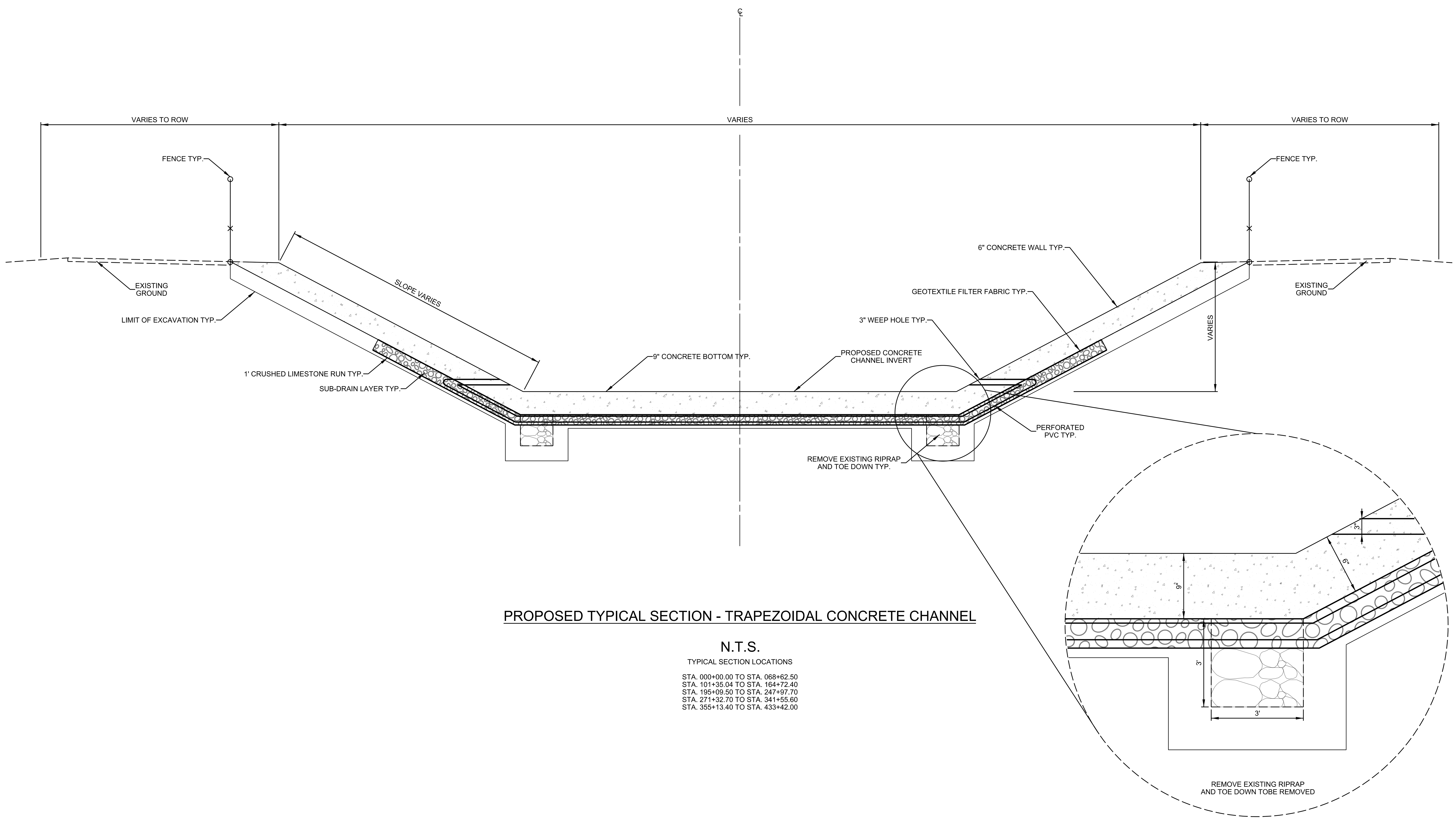

PROPOSED TYPICAL SECTION - TRAPEZOIDAL CONCRETE CHANNEL

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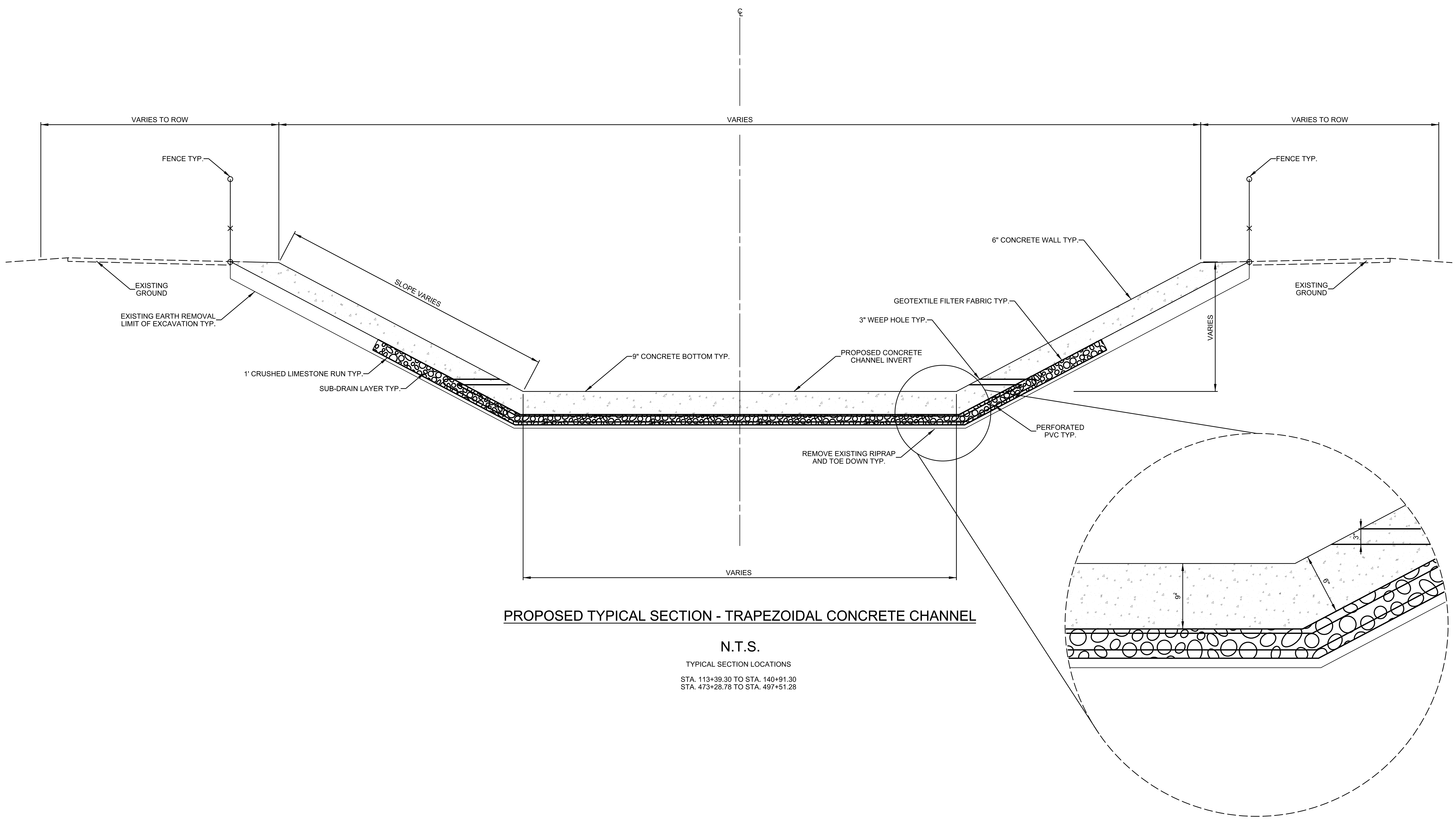
U.S. ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
231 S. LASALLE ST. SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

SHEET ID
C-206



PROPOSED TYPICAL SECTION - TRAPEZOIDAL CONCRETE CHANNEL

N.T.S.

TYPICAL SECTION LOCATIONS

STA. 113+39.30 TO STA. 140+91.30
STA. 473+28.78 TO STA. 497+51.28

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MARK	DESCRIPTION	DATE

ISSUE DATE: 11/2018
SOLICITATION NO.: W912P6-19-B-00XX
CONTRACT NO.: W912P6-19-C-00XX
PROJECT ID: 465002

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SUBMITTED BY:
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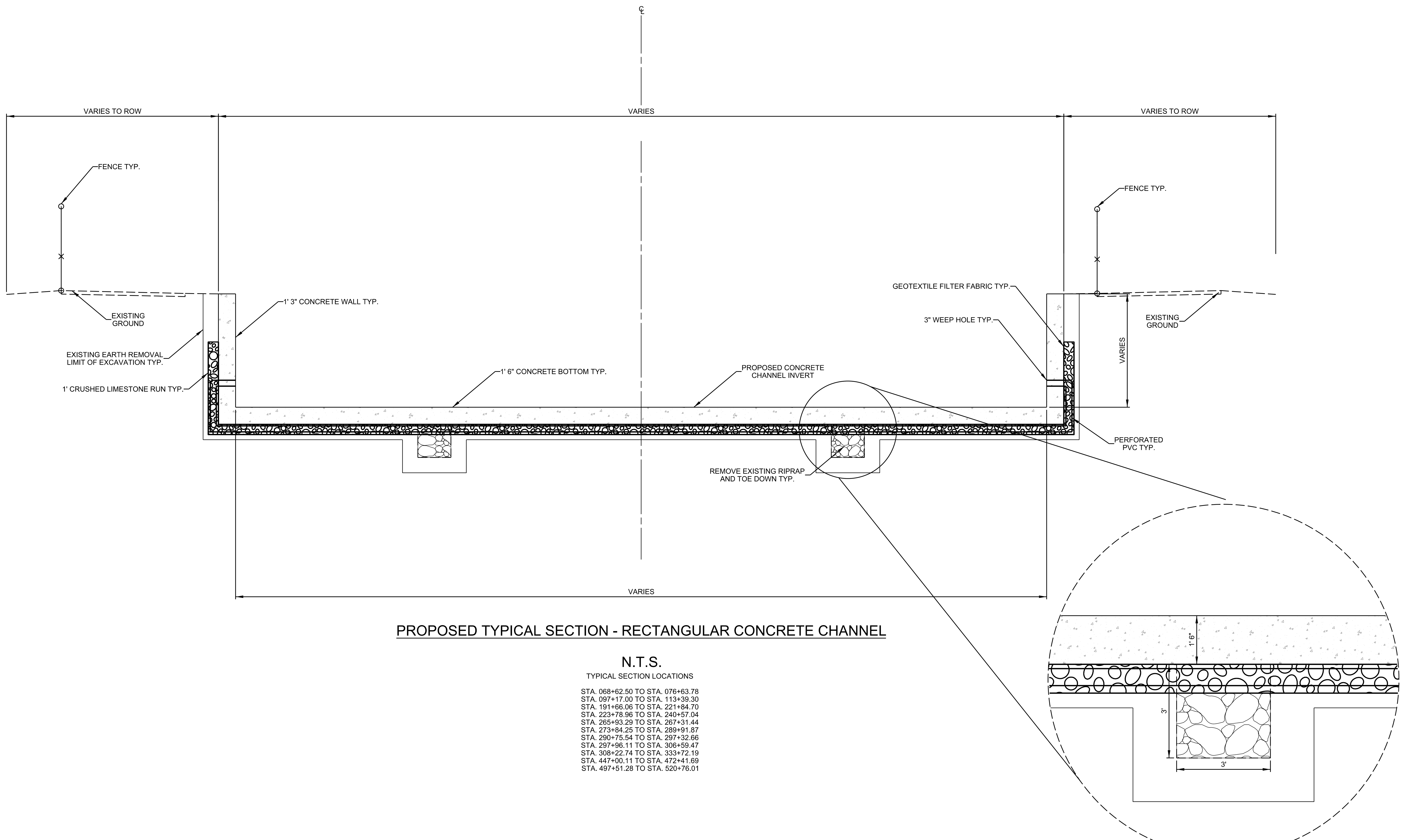
CHICAGO DISTRICT
231 S. LASALLE ST. SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

SHEET ID

C-207



PROPOSED TYPICAL SECTION - RECTANGULAR CONCRETE CHANNEL

N.T.S.

TYPICAL SECTION LOCATIONS

STA. 068+62.50 TO STA. 076+63.78
STA. 097+17.00 TO STA. 113+39.30
STA. 191+66.06 TO STA. 221+84.70
STA. 223+78.96 TO STA. 240+57.04
STA. 265+93.29 TO STA. 267+31.44
STA. 273+84.25 TO STA. 289+91.87
STA. 290+75.54 TO STA. 297+32.66
STA. 297+96.11 TO STA. 306+59.47
STA. 308+22.74 TO STA. 333+72.19
STA. 447+00.11 TO STA. 472+41.69
STA. 497+51.28 TO STA. 520+76.01

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CHICAGO, ILLINOIS 60604

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SIZE:
FILE NAME: C-208TYP.dgn
ISSUE DATE: 11/2018
SOLICITATION NO.: W912P6-19-B-00XX
CONTRACT NO.: W912P6-19-C-00XX
PROJECT ID: 465002

WESTMINSTER
EAST GARDEN GROVE

SHEET ID
C-208

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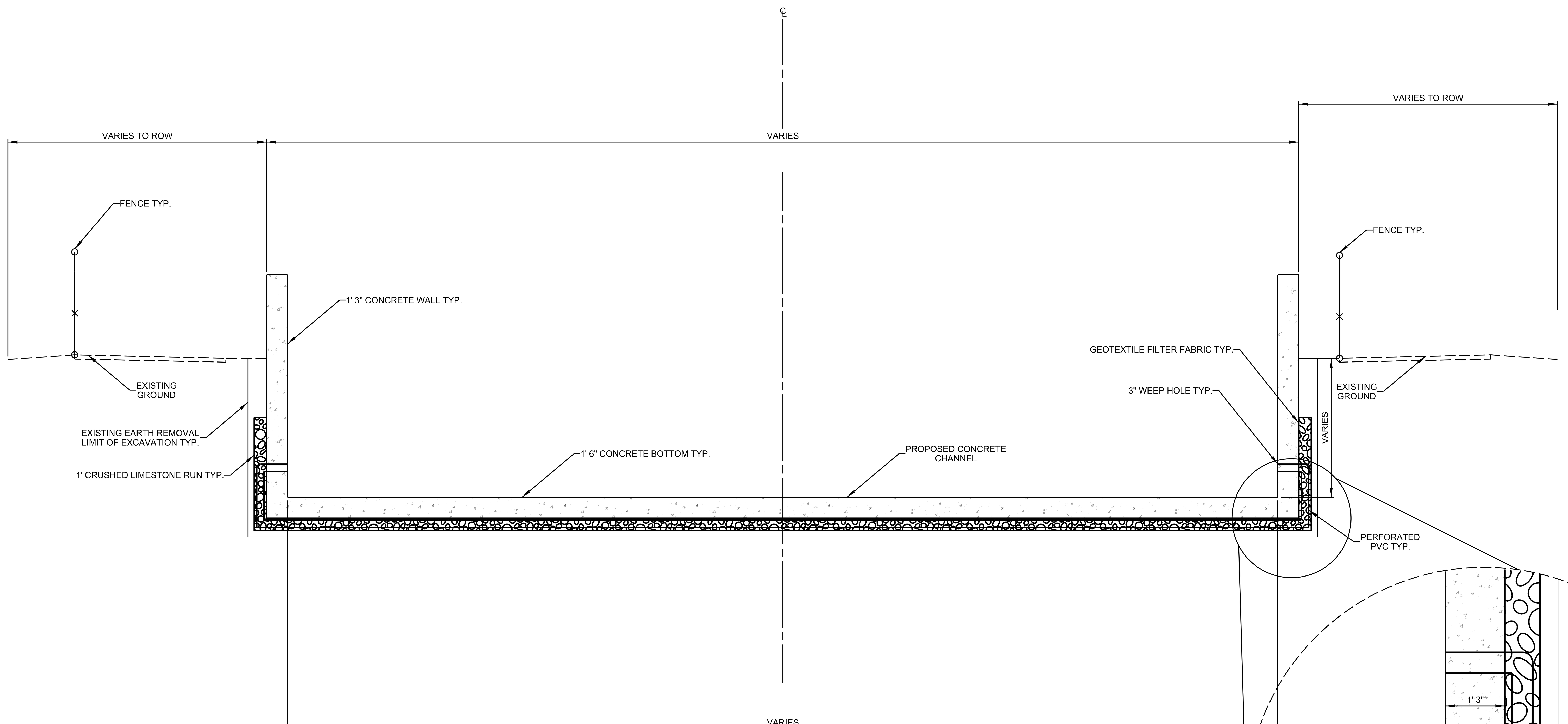

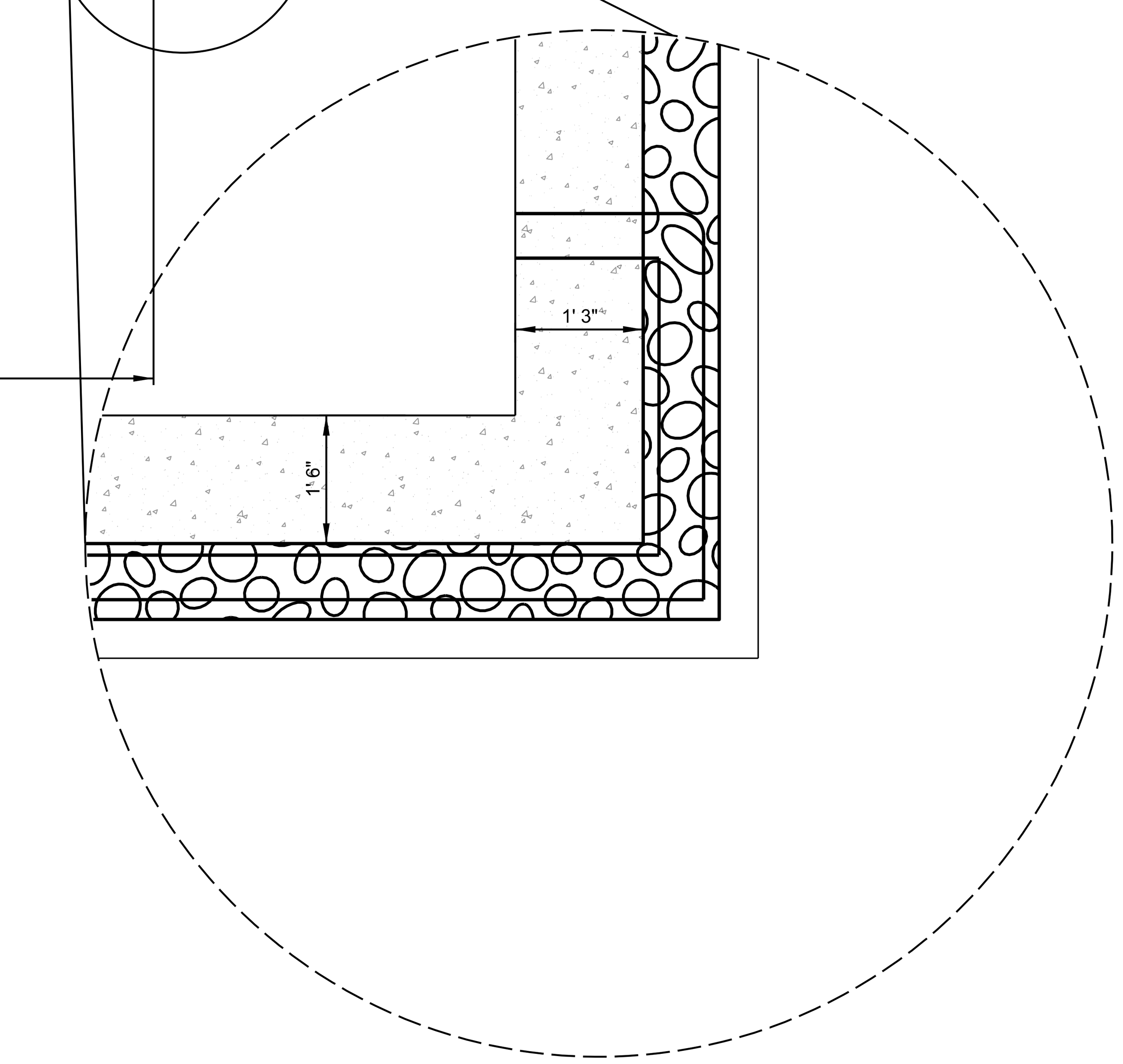

PROPOSED TYPICAL SECTION - RECTANGULAR CONCRETE WITH EXTEND WALL CHANNEL

N.T.S.

TYPICAL SECTION LOCATIONS

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STA. 191+66.06 TO STA. 221+84.70
STA. 223+78.96 TO STA. 240+57.04
STA. 265+93.29 TO STA. 267+31.44
STA. 273+84.25 TO STA. 289+91.87
STA. 290+75.54 TO STA. 297+32.66
STA. 297+96.11 TO STA. 306+59.47
STA. 308+22.74 TO STA. 333+72.19
STA. 336+62.66 TO STA. 365+94.21
STA. 366+59.84 TO STA. 392+30.61
STA. 447+00.11 TO STA. 472+41.69
STA. 497+51.28 TO STA. 520+76.01

US Army Corps of Engineers®

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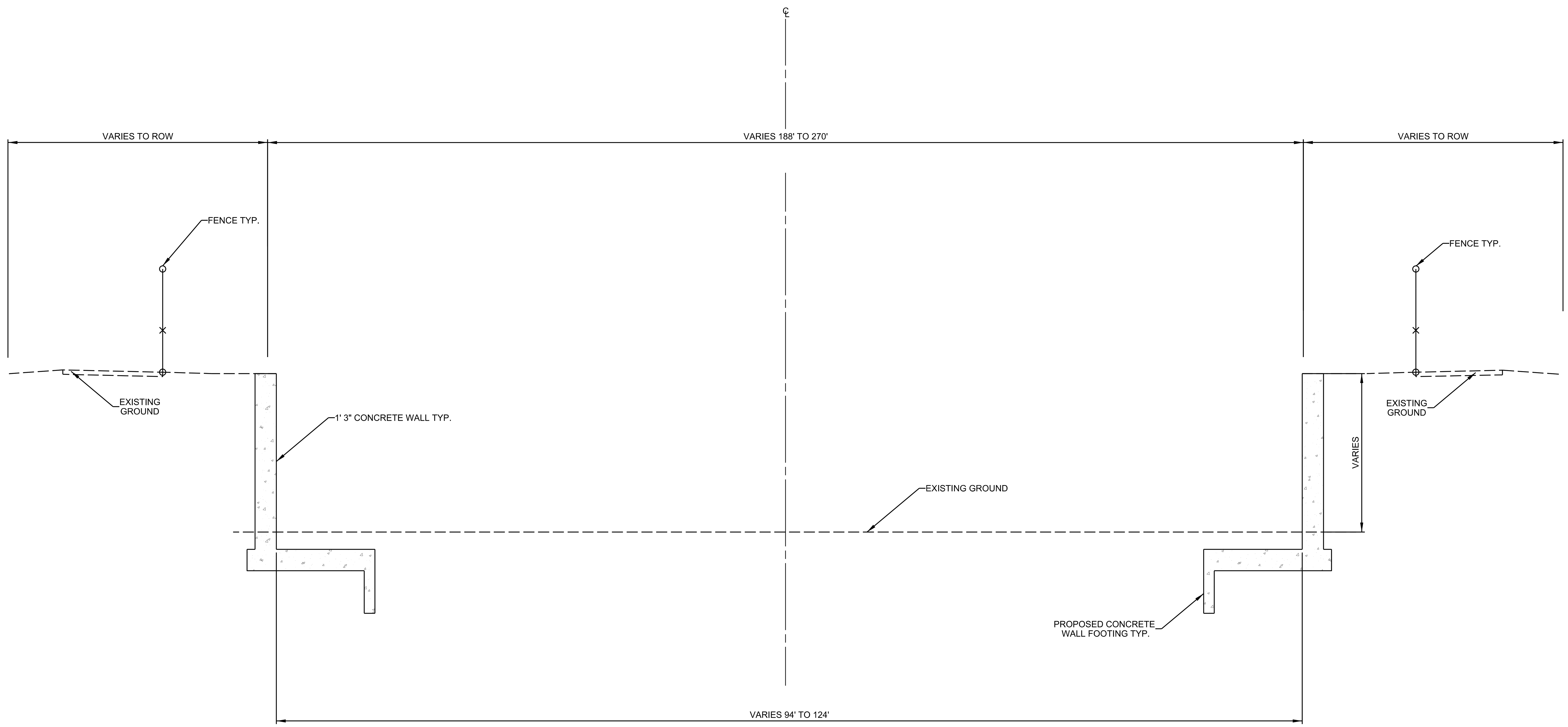
ISSUE DATE: 11/2018
SOLICITATION NO.: W912P6-19-B-00XX
CONTRACT NO.: W912P6-19-C-00XX
PROJECT ID: 465002
FILE NAME: C-209TYP.dgn

U.S. ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
231 S. LASALLE ST, SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

SHEET ID

C-209



PROPOSED TYPICAL SECTION - RECTANGULAR CONCRETE WALL WITH EARTHEN BOTTOM CHANNEL

N.T.S.

TYPICAL SECTION LOCATIONS

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STA. 140+47.08 TO STA. 189+17.70
STA. 393+28.75 TO STA. 397+11.00
STA. 440+18.83 TO STA. 444+96.08

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CONTRACT NO.: W912P6-19-C-00XX
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CHICAGO DISTRICT
231 S. LASALLE ST. SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

SHEET ID

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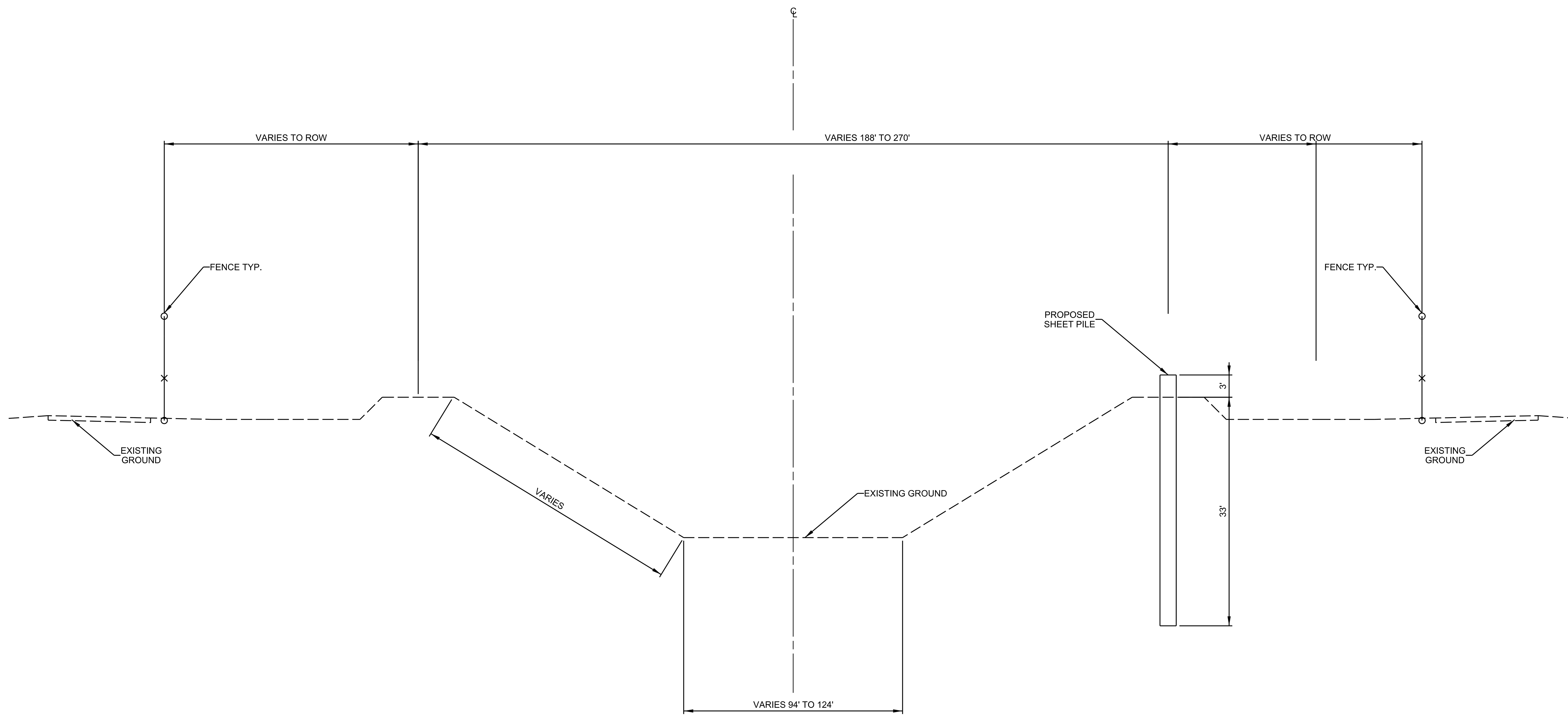

PROPOSED TYPICAL SECTION - TRAPEZOIDAL EARTHEN WITH SHEET PILES CHANNEL

N.T.S.

TYPICAL SECTION LOCATIONS

STA. 006+05.87 TO STA. 090+50.00

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

DESIGNED BY:
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SUBMITTED BY:
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FILE NAME: C-211TYP.dgn

ISSUE DATE: 11/2018
SOLICITATION NO.: W912P6-19-B-00XX
CONTRACT NO.: W912P6-19-C-00XX
PROJECT ID: 465002

U.S. ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
231 S. LASALLE ST, SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

SHEET ID

C-211

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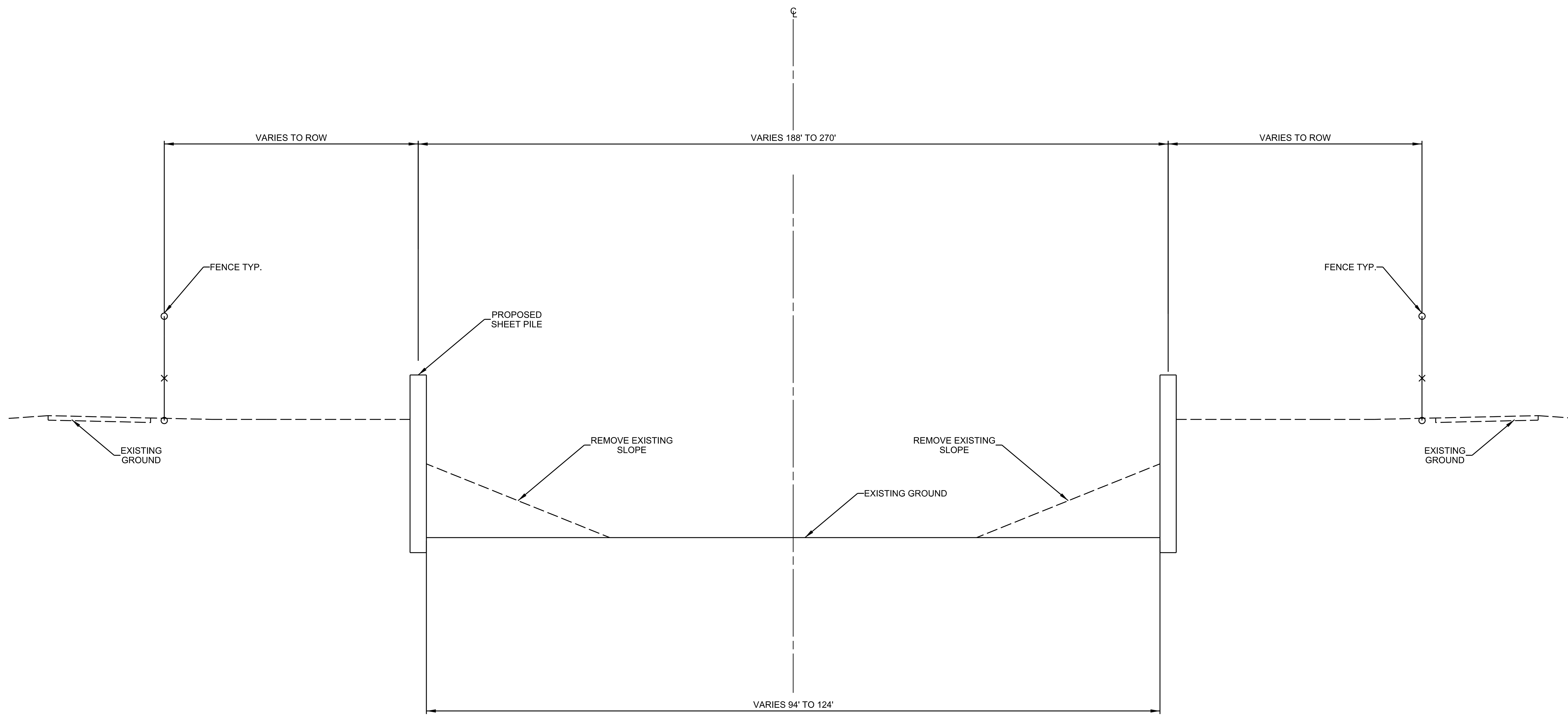

PROPOSED TYPICAL SECTION - RECTANGULAR EARTHEN WITH SHEET PILES CHANNEL

N.T.S.

TYPICAL SECTION LOCATIONS

STA. 006+05.87 TO STA. 090+50.00

US Army Corps of Engineers®

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SOLICITATION NO.: W912P6-19-B-00XX
CONTRACT NO.: W912P6-19-C-00XX
PROJECT ID: 465002
FILE NAME: C-212TYP.dgn

U.S. ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
231 S. LASALLE ST. SUITE 1500
CHICAGO, ILLINOIS 60604

WESTMINSTER
EAST GARDEN GROVE

SHEET ID

C-212

Appendix B - Civil Engineering

Attachment 2: LPP Roadway Crossings

Appendix B - Civil Engineering

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For Double-sided Printing

Feasibility Level AE Design of Channel Crossing Structures for Westminster East Garden Grove Flood Management Study Orange County, California

Summary Report

Prepared for

U.S. Army Corps of Engineers
Chicago District

Prepared by:

TETRA TECH

17885 Von Karman Ave, Suite 500
Irvine, California 92614

Final Submittal

May 2019

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1. INTRODUCTION

1.1 OVERVIEW

1.1 The study area is located within the Westminster watershed in western Orange County, California. The 87 square mile watershed is almost entirely urbanized and includes cities such as Anaheim, Stanton, Cypress, Garden Grove, Westminster, Fountain Valley, Los Alamitos, Seal Beach, and Huntington Beach.

1.2 The project area includes 4 drainage channel systems within the watershed that are operated and maintained by County of Orange (County) as shown on Figure 1.1. The channel systems are as follows:

- Orange County (OC) Facility No. C02 – Bolsa Chica Channel
- OC Facility No. C04 – Westminster Channel
- OC Facility No. C05 – East Garden Grove/Wintersburg Channel
- OC Facility No. C06 – Ocean View Channel

1.2 PURPOSE AND SCOPE OF WORK

1.3 The purpose of the overall study, that the U.S. Army Corps of Engineers (USACE) Chicago District, is currently conducting, is to evaluate the flood risk within the Westminster watershed area that experiences channel overtopping during 5 to 10-year level floods (USACE 2018b). This study includes evaluation of multiple design alternatives to increase the channel capacity of the existing channel systems to accommodate a greater flood event. The design alternatives involve conversion of various segments of existing trapezoidal earthen or riprap channels into concrete trapezoidal or concrete rectangular channels. Strategic use of floodwalls to increase channel capacity is also considered in the alternatives (USACE 2018a).

1.4 These 4 drainage channel systems have a significant number of channel crossings in forms of culverts and bridges that need to be improved to meet increased channel capacity upstream and downstream of the crossings. The purpose of this AE design study is to prepare a feasibility level design of 5 representative channel crossings in order to develop feasibility level cost estimates to be incorporated into the USACE's overall study. It is Tetra Tech's understanding that USACE would scale and adjust the design layout and construction cost from the 5 representative channel crossings as necessary to be applied to the rest of the channel crossings in the watershed in evaluation of the design alternatives.

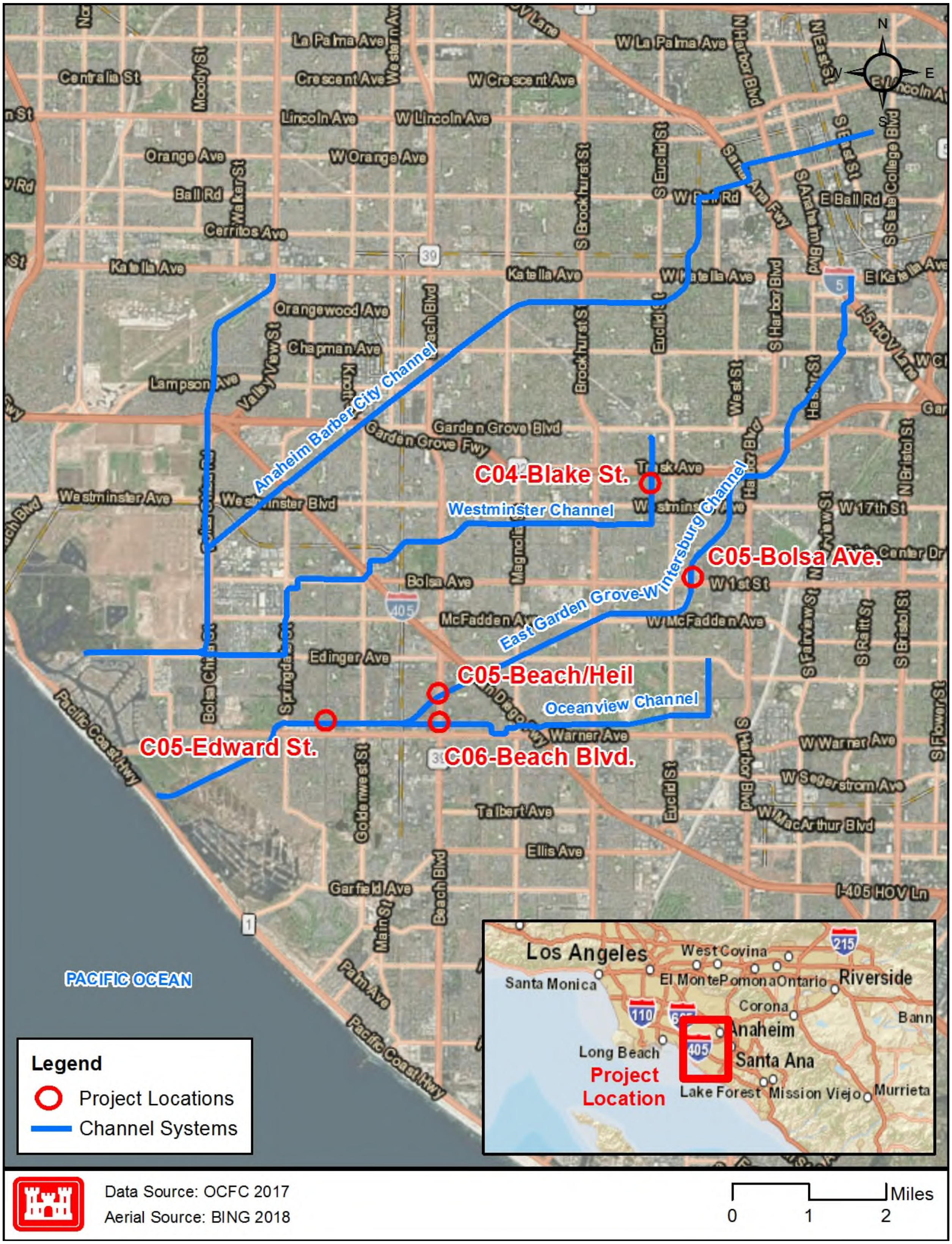

Figure 1.1 – Location Map

1.5 USACE selected the following 5 representative channel crossings for AE's design study (Figure 1.1).

- No.1, Bolsa Avenue crossing (reinforced concrete box (RCB) culvert) on C05
- No.2, Beach Boulevard (Blvd) crossing (RCB culvert) on C06
- No.3, Beach Blvd/Heil Avenue intersection crossing (RCB culvert) on C05
- No.4, Edwards Street crossing (bridge) on C05
- No.5, Blake Street crossing (RCB culvert) on C04

1.6 For each of the 5 crossings, a design drawing showing a plan view layout of the improvement and typical section, quantity calculation, and cost estimate were prepared.

1.7 Abbreviate Risk Analysis (ARA) was performed to analyze primary risks specific to the 5 representative channel crossings for this study and global risks that may be incurred over the USACE's overall channel improvement study.

1.3 GENERAL DESIGN ASSUMPTIONS AND LIMITATIONS

1.3.1 RCB and Bridge Sizing

1.8 Hydraulic sizing of RCB culvert was provided by USACE. It is assumed that the sizing of RCB would provide the required channel culvert capacity. It is also assumed that the resulting transition structure between the USACE-provided RCB sizing and USACE's future channel improvement geometry would create an adequate transition of flow and desired flow conditions. USACE also verified that the current bridge deck elevation at Site No.4, Edwards Street crossing, would provide an adequate bridge opening size.

1.9 No additional hydraulic analysis was performed by Tetra Tech.

1.3.2 Geotechnical Analysis

1.10 USACE provided the geotechnical appendix report which contained geotechnical information to be used for the design (USACE 2018a). The appendix report is to be part of the USACE's overall study. No subsurface investigation was conducted in the field specifically for this appendix report. This feasibility level report was based on numerous previously completed geotechnical reports and plan sets.

1.11 Due to a significant size of study area and level of design required for this appendix report, the geotechnical recommendations were provided as ranges. Therefore, the recommendations should not be considered as absolute to the 5 crossing sites, but they should be verified during the construction design phase with a site-specific subsurface exploration and analysis.

1.12 The appendix report recommends overexcavation at all 5 crossing sites (Figure 12c, USACE 2018a) due to poor soil conditions. However, the report does not specify a recommended overexcavation depth. Based on recent channel design project Tetra Tech performed for USACE in the same drainage system (Ocean View Channel, C06), overexcavation of 2 feet, which was recommended by the geotechnical report for that specific project, was also assumed for this study at each crossing site (USACE 2017).

1.3.3 Structural Analysis

1.13 No structural analysis was performed. Wall and slab thicknesses were determined based on recent and similar USACE projects that Tetra Tech performed in the area and verified against California Transportation Department (CalTrans) Standard Plans.

1.3.4 Utilities

1.14 USACE in coordination with Orange County Public Works (OCPW) provided available information on existing utilities in the area (See Section 1.4.2, *Utilities*). At this time, USACE is still waiting for the utility information from several other utility companies. The current design and cost estimates were based on only the available information, and the additional utility information in the future is likely to increase the construction costs.

1.15 The available information on existing utilities only showed horizontal layout of the utilities. The vertical elevations were assumed unless profiles or other vertical information of the utilities were shown on the as-built plans of RCB culverts.

1.3.5 Temporary Shoring

1.16 Because of limited Right-of-Way (R/W) available along the channel alignment and proximity to existing structures beyond R/W, and to minimize disturbance to street traffic during construction, temporary shoring is assumed around excavation areas. Use of temporary shoring allows vertical excavation face along an open trench to construct a culvert crossing at roadways. Without shoring, an open slope cut would likely extend beyond the R/W limit and create a much larger construction footprint and bigger disturbance to vehicular traffic in a busy street crossing. Additionally, use of shoring would reduce the need for relocation of interfering underground utility by reducing a construction footprint.

1.17 Temporary shoring is assumed to be used along the RCB alignment to reduce the construction footprint. In the areas where multiple phases of construction is required, additional shoring would be required and installed perpendicular to the RCB alignment (along the street alignment). This would allow only a selected portion of the entire RCB to be built within the limits of particular construction phase.

1.18 Temporary shoring using beams and lagging is assumed to be used for construction. This type of temporary shoring is a preferred shoring method by OCPW and is being widely used in this area.

1.3.6 Limits of Design

1.19 It is assumed that the upstream and downstream limits of culvert replacement design would include an existing culvert footprint and transition structures between the culvert and uniform channel section. The transitions vary from 20 to 30 feet in length along the channel alignment. The existing transition structure between a RCB and channel would be replaced with a new transition structure.

1.20 The design also includes removal, modification, and/or reconstruction of any hard structures and relocation of any existing utility that would be affected by the culvert replacement design.

1.4 DATA COLLECTION

1.4.1 As-built Plans

1.21 As-built plans (PDF format) for the 5 crossings were obtained from Tetra Tech's previous project with OCPW.

1.4.2 Utilities

1.22 Information for existing utilities within the 5 crossing areas was provided by USACE. Prior to the award of this AE design contract, OCPW, in support of the USACE's study, reached out to potentially affected utility owners and agencies by sending out utility information request letters. The request covered the entire reaches of the 4 drainage channels in the watershed, not just the 5 crossing sites.

1.23 Tetra received and reviewed the first package of existing utility information documents from USACE on February 6, 2019, which encompassed the entire channel reaches. The results are summarized in Table 1.1. The information from these utility companies were digitized into a Microstation format to create a utility base map for the civil design.

Table 1.1 – Summary of Affected Utility Companies

Utility Company	Conflict	System	Crossing Location	Type of Affected Utility
Andeavor	N	N.A.		
ATT - Distribution	**Yes**	C04	5	Aerial telecommunication, poles, and conduits
ATT - Distribution	**Yes**	C05	1	Aerial telecommunication
ATT - TCA	**Yes**	C05	1	Aerial telecommunication
California Resources Corporation	N	N.A.		
CenturyLink	**Yes**	C05	1	Underground & Level 3
Charter	**Yes**	C05	4	Aerial telecommunication
Charter	**Yes**	C05	1	Aerial and underground telecommunication
Charter	**Yes**	C06	2	Aerial telecommunication
Chevron Pipeline & Power	N	N.A.		
City of Fountain Valley	N	N.A.		
City of Garden Grove	**Yes**	C04	5	Water
City of Garden Grove	**Yes**	C04	5	Sewer
City of Huntington Beach	**Yes**	C05	4	Storm Drain, Water, & Sewer

Utility Company	Conflict	System	Crossing Location	Type of Affected Utility
City of Huntington Beach	**Yes**	C06	2	Storm Drain, Water, & Sewer
City of Huntington Beach	**Yes**	C05	3	Storm Drain & Water
City of Santa Ana	**Yes**	C05	1	Abandoned Sewer & Water
City of Santa Ana	**Yes**	C05	3	Strom Drain, Water, Gas, &Traffic Light
City of Seal Beach	N	N.A.		
City of Westminster	N	N.A.		
Crimson Pipeline	N	N.A.		
Crown Castle Inc	N	N.A.		
Long Beach Gas & Oil	N	N.A.		
Orange County Water District	N	N.A.		
Orange County Water District	**Yes**	C05	1	Sewer & Gas
Plains All American Pipeline LP	N	N.A.		
SCE Telecom	**Yes**	C05	1	Telecommunication
SCE Telecom	**Yes**	C06	2	Telecommunication
SCE Telecom	**Yes**	C05	3	Telecommunication
SoCal Gas - Distribution	**Yes**	C05	3	Gas
SoCal Gas - Distribution	**Yes**	C06	2	Gas
SoCal Gas - Distribution	**Yes**	C04	5	Gas
SoCal Gas - Transmission	N	N.A.		
Verizon - MCI_XO	N	N.A.		
Wilcon	N	N.A.		

1.24 The 2nd package containing additional utility information has not been provided by USACE at this time. Based on the conference call with USACE on February 25, 2019, this AE study would be based only on the utility information contained in the 1st package to meet the submittal deadline stated in the project scope of work.

1.4.3 Field Investigation

1.25 Tetra Tech performed a field investigation of the 5 crossing sites on February 21, 2019. The investigation included visual assessment of the site conditions and photo documentation.

1.5 MAPPING

1.26 A topographic survey of the project site was not performed for this study. An aerial photo map from the ESRI website was used as background information. Then, the existing culvert and channel were overlaid on the aerial mapping based on the information provided in the channel as-built plans. The existing above-ground features on the aerial mapping were verified against Google Street Map and during the field investigation.

1.27 The project horizontal datum for the project mapping is the California Coordinate System, Zone VI, North American Datum of 1983 (NAD83). The vertical datum is the North American Vertical Datum of 1988 (NAVD88). All units are in Survey Feet.

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2. HYDRAULIC DESIGN

2.1 RCB SIZING

2.1. For the 4 RCB culvert crossing sites, USACE provided the RCB sizing information to be incorporated into the design. For the bridge crossing site, USACE verified that the current bridge deck elevation and pier locations in conjunction with the future improved channel section would provide the required channel capacity.

2.2. The existing and proposed RCB dimensions for each culvert crossing are summarized in Table 2.1.

Table 2.1 – Existing and Proposed RCB Dimensions

No.	Crossing Location	Drainage System	Existing Dimension	Proposed Dimension
1	Bolsa Avenue	C05	(2) 10'(W) x 8.5'(H)	(3) 13.5'(W) x 8.5'(H)
2	Beach Boulevard	C06	(2) 9'(W) x 10'(H)	(2) 12'(W) x 12'(H)
3	Beach Blvd/Heil Avenue Intersection	C05	(3) 10'(W) x 10'(H)	(3) 20'(W) x 10'(H)
4	Edwards Street	C05	133’ Span Bridge	133’ Span Bridge
5	Blake Street	C04	(1) 9.5'(W) x 7'(H)	(1) 9.5'(W) x 7'(H) & (1) 8'(W) x 7'(H)

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3. CIVIL DESIGN

3.1 SITE NO.1 – BOLSA AVENUE CROSSING ON C05

3.1.1 Description

3.1. Site No.1, Bolsa Avenue Crossing, is located along East Garden Grove/Wintersburg Channel (OC Facility No. C05), approximately 0.25 miles east of Euclid Street and 1.5 miles south of 22 Freeway (Figure 1.1). The existing double 10-foot-wide by 8.5-ft-high RCB culvert connects a riprap trapezoidal channel, located upstream and downstream of 122-foot-long Bolsa Avenue crossing.

3.2. The culvert design included replacement of the existing RCB with a new triple 13.5-foot wide by 8.5-foot high RCB culvert. Existing transition structures between the existing RCB and a trapezoidal channel at both upstream and downstream of the RCB would be with new transition structures between the new RCB and a future reinforced concrete rectangular channel to be designed by USACE.

3.3. A typical section of the RCB design is shown on Figure 3.1. An overall layout of the design is shown on Exhibit 1.

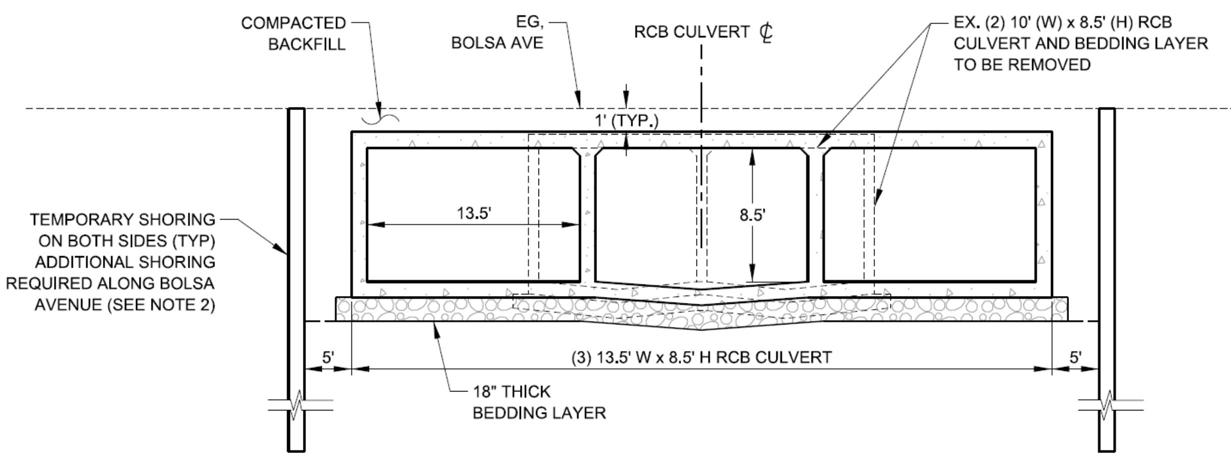


Figure 3.1 – Typical Culvert Section (Site No.1)

3.1.2 Utilities

3.4. A number of utilities including water, sewer, gas, and underground telecommunication cables were found within the RCB footprint. Existing utilities would need to be relocated during construction as a new RCB requires a wider and deeper footprint. The utilities would need to be adequately relocated either over or under the new RCB. The exposed ends of the utilities at excavation faces would likely require temporary support during construction of RCB.

3.5. An existing storm drain that used to feed the existing RCB structure would need to be modified based on its pipe diameter. Per USACE's requirement on the side drain connection into flood control channels, a side drain with a pipe size up to 24 inches is allowed to connect to the structure at 90 degrees, while a pipe with a greater diameter needs to meet the maximum permissible angles of entry that varies from 30 to 60 degrees, depending on its diameter (USACE, 1998). Therefore, the existing 48-inch and 60-inch diameter storm drain pipes would need to be redirected to meet the required angles of entry. The existing pipes with a diameter of 24 inches or less were cut short to meet the new RCB wall with a junction structure.

3.1.3 Constructability

3.6. During construction, Bolsa Avenue would likely be affected in both directions. To avoid complete shutdown of the entire street during construction, this site would require multiple construction phases along the street. In each phase, construction of RCB would need to be segmented in a way to provide continuous traffic in both directions but with a reduce number of traffic lanes.

3.7. For construction of the RCB headwall and transition structure, while the east side of the RCB includes a 20-foot wide existing access road, providing sufficient clearance from other structures, the west side is very close to both commercial and residential hard structures and utilities. Private block walls at the upstream (on the west side) would need to be removed and replaced for installation of temporary shoring. A review of aerial image showed that houses were located just beyond these private walls, and construction would need to ensure installation process of shoring would not adversely affect the structural integrity of the residential properties.

3.8. At the downstream (on the west side), a significant amount of above-ground private utilities were found just beyond the R/W. Additional research of these private utilities and pre-construction potholing of the area may be required to ensure there is no conflict with construction activities.

3.2 SITE NO.2 – BEACH BLVD CROSSING ON C06

3.2.1 Description

3.9. Site No.2, Beach Boulevard Crossing, is located along Ocean View Channel (OC Facility No. C06), approximately 0.14 miles north of Warner Avenue and 1.0 mile south of 405 Freeway (Figure 1.1). The existing double 9-foot wide by 10-foot high RCB culvert connects a riprap trapezoidal channel, located upstream and downstream of 122-foot-long Beach Boulervard crossing.

3.10. The culvert design included replacement of the existing RCB with a new double 12-foot wide by 12-foot high RCB culvert. The new RCB has a taller barrel opening and appears to be possible due to a sufficient earth cover available for this site (about 5 feet). Existing transition structures between the existing RCB and a trapezoidal channel at both upstream and downstream of the RCB would be replaced with new transition structures between the new RCB and a future reinforced concrete rectangular channel to be designed by USACE.

3.11. Currently, a portion of channel downstream of the existing RCB is being repaired by USACE-Los Angeles District under Flood Control and Coastal Emergencies Act (PL 84-99). The purpose of this channel repair, designed by Tetra Tech under contract with USACE-LA District, was to restore the original channel capacity and functions (USAE, 2017). It is recommended that USACE evaluate whether this portion of the channel, once repaired, provides the capacity and functionality that the overall study requires.

3.12. A typical section of the RCB design is shown on Figure 3.2. An overall layout of the design is shown on Exhibit 2.

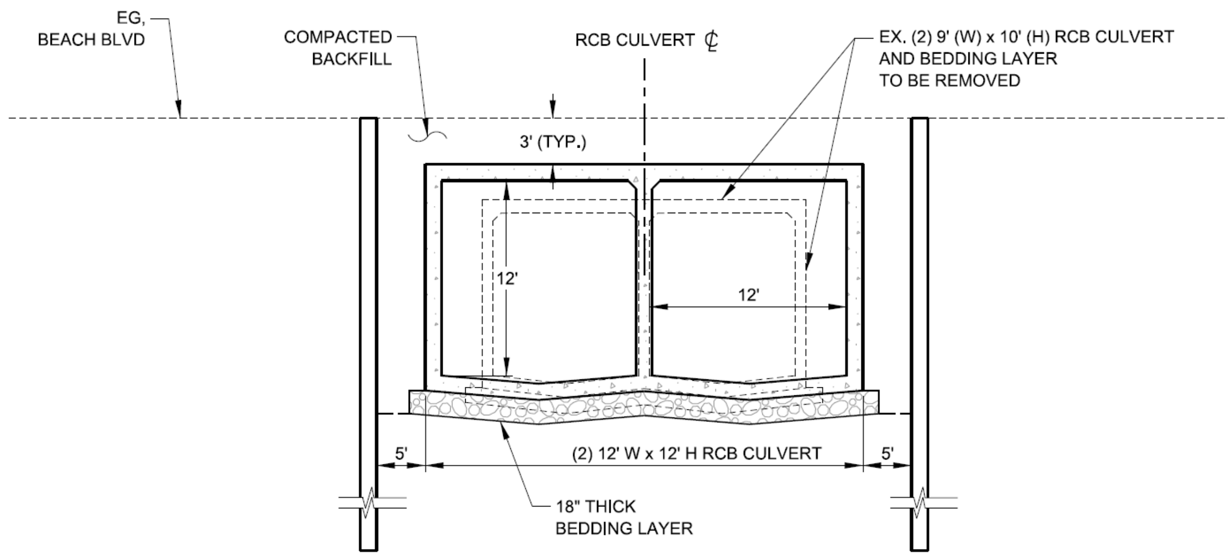


Figure 3.2 – Typical Culvert Section (Site No.2)

3.2.2 Utilities

3.13. A number of utilities including water, sewer, and gas were found within the RCB footprint. Relocated water and gas lines would be attached to a downstream headwall of the new RCB. The existing sewer siphon in steel casing would need to be relocated to a new deeper elevation as the new wider RCB has a thicker concrete slab and thicker bedding layer underneath.

3.14. An existing water line would need to be relocated during construction as a new RCB requires a wider footprint.

3.2.3 Constructability

3.15. During construction, Beach Boulevard would likely be affected in both directions. To avoid complete shutdown of the entire street during construction, this site would require multiple construction phases along the street. In each phase, construction of RCB would need to be segmented in a way to provide continuous traffic in both directions but with a reduce number of traffic lanes.

3.3 SITE NO.3 – BEACH BLVD/HEIL AVENUE INTERSECTION CROSSING ON C05

3.3.1 Description

3.16. Site No.3, Beach Boulevard/Heil Avenue Crossing, is located along East Garden Grove/Wintersburg Channel (OC Facility No. C05), at the intersection of the two street and approximately 0.7 miles south of 405 Freeway (Figure 1.1). The existing triple 10-foot wide by 10-foot high RCB culvert connects a riprap trapezoidal channel, located upstream and downstream of a 240-foot long street crossing.

3.17. The culvert design included replacement of the existing RCB with a new triple 20-foot wide by 10-foot high RCB culvert. Existing transition structures between the existing RCB and a trapezoidal channel at both upstream and downstream of the RCB would be replaced with new transition structures between the new RCB and a future reinforced concrete rectangular channel to be designed by USACE.

3.18. A car dealership is located on a southwest corner of the intersection. Currently, based on a review of the aerial mapping, the dealership property encroaches into the R/W and construction footprint and would need to be relocated during construction.

3.19. A typical section of the RCB design is shown on Figure 3.3. An overall layout of the design is shown on Exhibit 3.

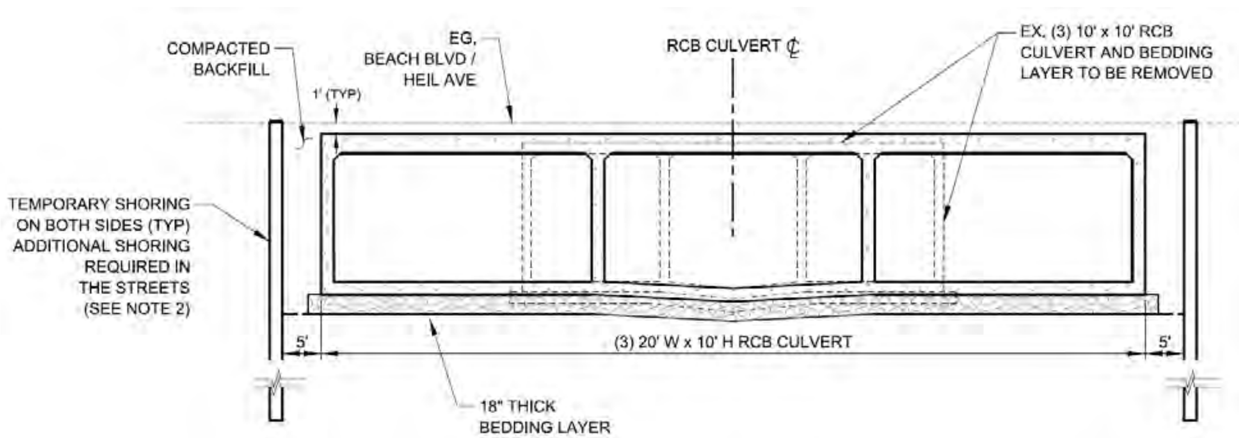


Figure 3.3 – Typical Culvert Section (Site No.3)

3.3.2 Utilities

3.20. A number of utilities including water, and gas were found within the RCB footprint. Existing utilities would need to be relocated during construction as a new RCB requires a wider and deeper footprint. Most of the utilities would need to be adequately relocated under the new RCB, while others on the north side of the RCB could be relocated horizontally to the outside of the footprint to avoid interference with the new RCB, where feasible. The exposed ends of the utilities at excavation faces would likely require temporary support during construction of RCB.

3.21. An interfering portion of the abandoned existing storm drain (double 4-foot by 2-foot RCB) on the south side of the RCB would need to be removed and disposed of. The opening of the remaining portion should be plugged.

3.22. Relocation would include several traffic signals.

3.3.3 Constructability

3.23. During construction, Beach Boulevard and Heil Avenue would likely be affected in both directions. However, this is a busy intersection between two large streets. To avoid complete shutdown of the entire street during construction, this site would require multiple construction phases along the streets. It is likely to be very difficult to open the both streets in both traffic directions at each phase. Considering Beach Boulevard is a major arterial street, each phase should be planned to provide continuous traffic along Beach Boulevard in both directions but with a reduce number of traffic lanes, while traffic along Heil Avenue is only allowed to turn left or right at the intersection at some phases. A detour plan would be necessary to redirect the east to west traffic along Heil Avenue who wishes to go to the other side of the intersection to other adjacent east to west streets (Warner Avenue or Edinger Avenue).

3.4 SITE NO.4 – EDWARDS STREET CROSSING ON C05

3.4.1 Descriptions

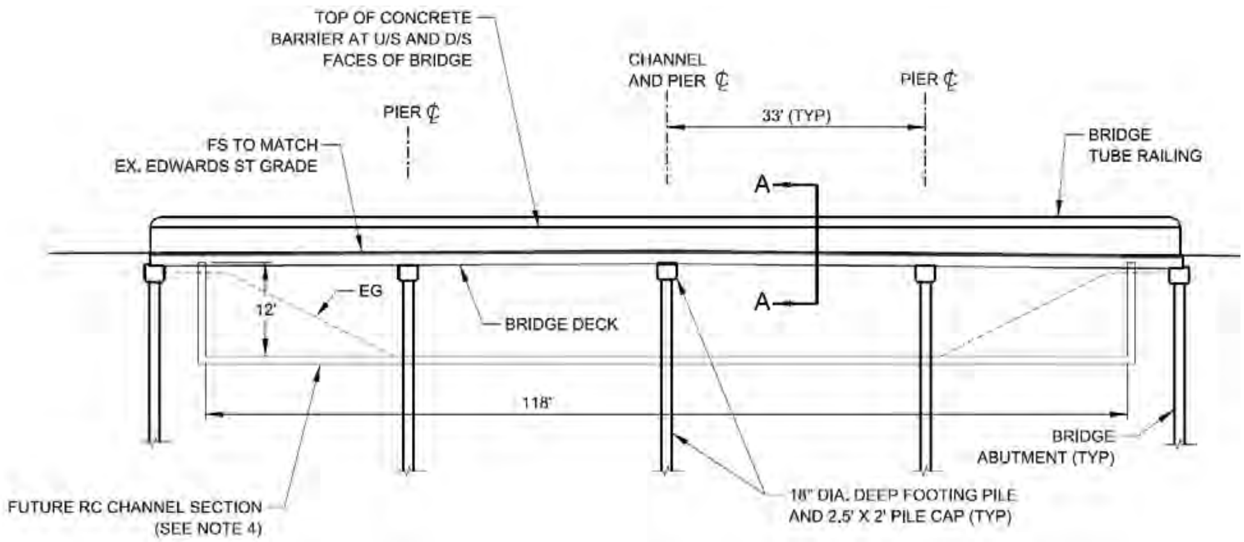
3.24. Site No.4, Edwards Street Crossing, is located along East Garden Grove/Wintersburg Channel (OC Facility No. C05), approximately 0.14 miles north of Warner Avenue (Figure 1.1). The existing 133-foot span bridge is located over an earthen trapezoidal. This reach is affected by a tidal influence and consists of large water pools along the channel bottom.

3.25. The bridge design included replacement of the existing bridge with a 133-foot span and 80-foot wide bridge. The USACE-provided sizing confirmed that the deck elevation of the existing bridge would not need to be raised. Three piers and bridge abutments with deep piles would be included. USACE's geotech appendix report indicated that due to poor soil condition, a bridge would require deep foundation and deep piles on the order of 40 to 60 feet below ground surface (bgs) (USACE 2018a).

3.26. A debris wall would be installed at the upstream of each pier. For cost purposes, a debris wall was used per OCPW's Standard Plans Detail No.1324 (OCPW, 2018).

3.27. An existing sidewalk and 5-foot high chain link fence along the upstream and downstream faces of the bridge would be demolished and removed. They would be replaced with 3-foot high concrete barrier and 1.3-foot high tube railing on top of the barrier along the both faces of the bridge.

3.28. A typical section of the bridge design is shown on Figure 3.4. An overall layout of the design is shown on Exhibit 4.



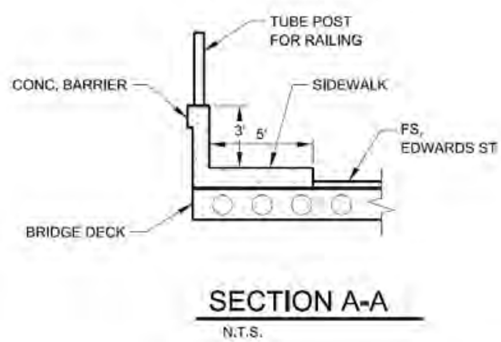


Figure 3.4 – Typical Bridge Section (Site No.4)

3.4.2 Utilities

3.29. In addition to overhead power and telephone lines, a sewer line was found within the bridge footprint. The existing sewer line was built under the channel bottom using a siphon system. Whether the sewer siphon needs to be relocated would be determined during the channel improvement design by USACE. For the bridge design, deep piles from the piers near the upstream face need to be spaced so that they would avoid the sewer pipe.

3.30. Currently, two existing storm drains, 84-inch diameter reinforced concrete pipe (RCP) and 68-inch by 106-inch RCP, are located within the footprint of the north bridge abutment. With the deep footing required for the abutment, portions of these storm drains would be modified to be cleared of the footing location. However, the new storm drains would need to enter the channel at the required angle of entry. Per USACE's requirement on the side drain connection into flood control channels, a side drain with a pipe diameter greater than 60 inches needs to meet the maximum permissible angles of entry of 30 degrees (USACE, 1998).

3.4.3 Constructability

3.31. During construction, Edwards Street would likely be affected in both directions. To avoid complete shutdown of the entire street during construction, this site would require multiple construction phases along the street. In each phase, construction of a bridge would need to be segmented in a way to provide continuous traffic in both directions but with a reduce number of traffic lanes.

3.32. Due to the proximity to the ocean, it is likely that this site would be under tidal influence of the ocean. The downstream barrier for diversion of water during construction would need to be designed to account for tidal effect from the ocean.

3.5 SITE NO.5 – BLAKE STREET CROSSING ON C04

3.5.1 Description

3.33. Site No.5, Blake Street Crossing, is located along Westminster Channel (OC Facility No. C04), just west of Taft Street and approximately 0.2 miles south of 22 Freeway (Figure 1.1). The existing single barrel, 9.5-foot wide by 7-foot high RCB culvert connects a concrete trapezoidal channel, located upstream and downstream of 62-foot long Blake Street crossing.

3.34. The culvert design included replacement of the existing RCB with a combination of new 9.5-foot wide by 7-foot high barrel and 8-foot wide by 7-foot high barrel RCB culvert. Existing transition structures between the existing RCB and a trapezoidal channel at both upstream and downstream of the RCB would be replaced with new transition structures between the new RCB and a future reinforced concrete rectangular channel to be designed by USACE.

3.35. A typical section of the RCB design is shown on Figure 3.5. An overall layout of the design is shown on Exhibit 5.

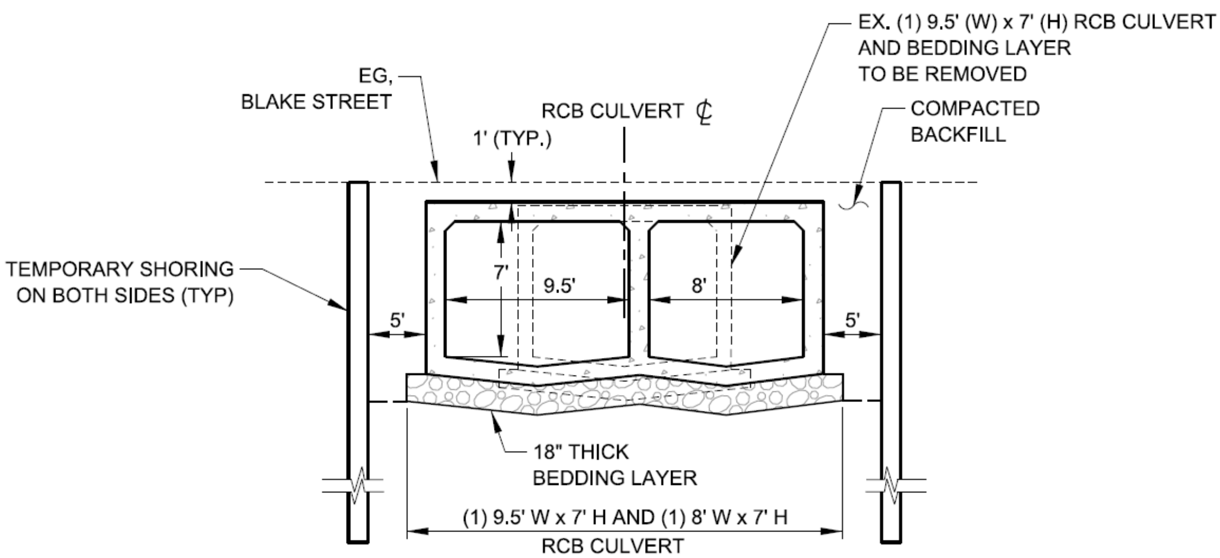


Figure 3.5 – Typical Culvert Section (Site No.5)

3.5.2 Utilities

3.36. A number of utilities including water and sewer were found within the RCB footprint. Existing utilities would need to be relocated during construction as a new RCB requires a wider and deeper footprint. Per the RCB as-built plans, both water and sewer lines were built under the existing RCB. These utilities would need to be relocated to a new deeper elevation as the new RCB has a thicker concrete slab and thicker bedding layer underneath.

3.5.3 Constructability

3.37. During construction, Blake Street would likely be affected in both directions. Considering that Blake Street at this location is a small residential street and that phasing would likely to provide only a single lane width, complete shutdown of the entire street should take place during construction. A detour plan would be necessary to redirect the east to west traffic along Blake Street to other adjacent east to west streets (Woodbury Road or Ranny Avenue).

4. COST ESTIMATE SUMMARY

4.1 INTRODUCTION

4.1 This section discusses the development of detailed MCACES construction cost estimates consistent with the feasibility level design of five channel crossings. The estimates have been developed based on the information and assumptions referenced in this report.

4.2 BASIS OF ESTIMATE

4.2 The estimate is based on detailed quantity take-offs that have been calculated from the information presented in this report. A quantity summary for each crossing along with detailed calculations is presented in Appendix A. The estimate includes several waste/loss factors for materials that include:

Loose Soils	15%
Aggregates	15%
Concrete	10%

4.3 COST ESTIMATE ASSUMPTIONS

4.3 The following assumptions and information were used in development of the MCACES cost estimate. A summary print out of the MCACES is presented in Appendix B.

- Mobilization / Demobilization – Estimate assumes mobilizing and demobilizing all crews and equipment to perform the crossing work. Each phase of construction, at each site, would require mobilization and demobilization of required equipment to complete the temporary shoring.
- Traffic Control – Estimate assumes that traffic control would be required at each site, and that flaggers would be on-site for duration of mobilization/demobilization and phase change durations.
- Diversion and Control of Water – All five crossing would require diversion and control of water during construction. For the crossings with concrete bottoms (all sites, except Edwards), the estimate assumes placing a small temporary cofferdam in channel. The water would be pumped and diverted downstream of the limits of construction at each crossing.

  For the Edwards St. crossing, diversion and control of water would be significantly different in that tidally-influenced flows are encountered at this site. Therefore, the estimate assumes driving a sheetpile cofferdam downstream of the bridge to block the tide from transporting water upstream to the crossing. A small diversion cofferdam, similar to the other four sites, would be constructed upstream to block and divert the surface flows.
- Utilities – Estimate assumes all utilities would be demolished, and all demolished materials would be hauled off-site for disposal. All potential earthwork is currently

assumed to be accounted for in earthwork items elsewhere in the estimate. The reinstallation of the utilities is assumed to be completed with all new materials.

- Demolition – Estimate assumes all demolished materials would be removed off-site for disposal, including appropriate tipping fees for Orange County landfills.
- Earthwork – Estimate assumes all excavated material would need to be transported to a general staging and stockpiling area that is assumed to be already in use for the main channel work of the larger project. From there, any excess material not required for backfill, would be hauled off-site for disposal. Earthen backfill material is assumed to come from the excavated material, and all bedding and base materials would be imported.
- Culverts – Estimate assumes all culverts would be constructed of reinforced cast-in-place concrete.
- Edwards St. Bridge – Estimate assumes removing existing bridge and piles and replacing with entire new structures. Piles are assumed to be steel pipe piles filled with concrete.

4.4 PROJECT MARKUPS AND FUNCTIONAL COSTS

4.4 The following assumptions and information were used in the development of the project markups and functional costs used in the development of the construction cost estimates.

- Contracting – Estimate assumes that the primary contractor would be an earthwork contractor capable of completing the necessary demolition and roadwork as well. It is assumed that subcontractors would be used for the utility relocations, fencing, concrete and shoring items.
- Job Office Overhead – Typically JOOH is based on a calculated percentage, but for this effort a running 20 percent was used.
- Labor Rates – All labor rates were updated with current Davis-Bacon wage rates for Orange County.
- Planning, Engineering and Design (PED) – No costs for PED are included in the MCACES estimate.
- Construction Management (CM) – No costs for CM are included in the MCACES estimate.
- Escalation – No escalation has been included for this cost estimate.
- Real Estate – No costs for real estate have been included in the estimate.
- Contingency – No contingencies are included in the MCACES estimate. An abbreviated risk analysis is discussed in subsequent sections of this report.

4.5 MCACES COST SUMMARY

4.5 Table 4.1 presents the total construction costs for each of the five crossings estimated in MCACES. The costs are separated by the two features used in formatting the estimate.

Table 4.1 – MCACES Construction Cost Summary by Crossing

Crossing / Feature Account	Construction Cost (Rounded)
Crossing No. 1 – Bolsa Avenue on C05	
02 – Relocations	$143,000
08 – Roads, Railroads & Bridges	$2,550,000
Crossing No. 1 - Construction Cost	$2,693,000
Crossing No. 2 – Beach Blvd. on C06	
02 – Relocations	$85,000
08 – Roads, Railroads & Bridges	$2,052,000
Crossing No. 2 - Construction Cost	$2,137,000
Crossing No. 3 – Beach Blvd. / Heil Avenue on C05	
02 – Relocations	$325,000
08 – Roads, Railroads & Bridges	$5,784,000
Crossing No. 3 - Construction Cost	$6,109,000
Crossing No. 4 – Edwards St. on C05	
02 – Relocations	$196,000
08 – Roads, Railroads & Bridges	$3,329,000
Crossing No. 4 - Construction Cost	$3,525,000
Crossing No. 5 – Blake St. on C04	
02 – Relocations	$18,000
08 – Roads, Railroads & Bridges	$1,077,000
Crossing No. 5 - Construction Cost	$1,095,000

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5. RISK ANALYSIS

5.1 INTRODUCTION

5.1 This section discusses potential risks regarding the construction and implementation of the channel crossing work documented in this report. The scope of this risk analysis is to (1) develop abbreviated risk analysis documents for each of the five crossings estimated in MCACES; (2) provide a discussion of the primary risks for the 5 representative crossings; and (3) generally review all the crossings inside the limits of the USACE's overall study to provide more global risks that may be incurred , as well as provide some insight into how representative the five crossings analyzed are over the entire project.

5.2 ABBREVIATED RISK ANALYSIS

5.2 An abbreviated risk analysis (ARA) spreadsheet has been developed for each of the five channel crossings estimated in MCACES. The ARA documents are presented in Appendix C, and a summary of the resulting crossing specific contingencies is presented in Table 5.1.

Table 5.1 – Five Representative Channel Crossing Costs with ARA Contingency

Crossing No.	Crossing Name	Construction Cost	Contingency	Total Cost
01	Bolsa Avenue on C05	$2,693,000	46.2%	$3,938,000
02	Beach Blvd. on C06	$2,137,000	45.4%	$3,107,000
03	Beach Blvd. / Heil Avenue on C05	$6,109,000	45.8%	$8,910,000
04	Edwards St. on C05	$3,525,000	48.6%	$5,238,000
05	Blake St. on C04	$1,095,000	44.4%	$1,581,000

5.3 KEY RISKS FROM ARA

5.3 A discussion of the risks that are discussed in the ARA files across all 5 representative crossings is provided below. These risks are considered applicable to most of the other crossings that would be included in the full project cost estimate.

- Utilities - An attempt has already been made to estimate the cost to relocate all potential utilities at each crossing location. However, not all utility information has been provided by local utility companies. There is still a risk of underestimating the costs of the utility relocations. Also, as is the case with most projects, there is still a risk of unknown utilities being encountered even if all utility information is provided. This risk is anticipated to occur, but due to the relative cost of the utility relocations, this risk is not anticipated to cause significant increases to the total cost.
- Geotechnical Risks - The current feasibility-level designs have been developed with general engineering assumptions regarding the geotechnical parameters. However, the geotechnical report does state that the project locations do have poor soil, bridges require deep footings, and have shallow ground water. As the project progresses these risks are

likely to be analyzed in more detail, and future estimates will incorporate any changes. But currently, there is risk of design changes due to further geotechnical investigations.

- HTRWs - Encountering hazardous and toxic materials at these crossings is a real possibility. These channels are located in heavily urbanized locations, and many of them abutting large commercial/industrial facilities.
- Dewatering – The current assumptions for water control at the four culvert sites (not including Edwards Street Bridge) are based on water control efforts that contractors have used in other channel construction projects in the area. The water control features are relatively minor typically since these channels do not see significant flows outside of the rainy season. However, depending on climate at time of construction, more robust diversion and dewatering efforts could be required.
- Staging and Site Access – Each of the channel crossings analyzed have very limited ancillary space for access roads and/or staging areas. The estimates assume that all materials taken out or brought to the site would need to be almost immediately hauled off-site or placed, such that there is limited stockpiling at the crossing location. This could be a productivity issue.
- Vibration – All of the channels are located in heavily urbanized environments. There are buildings and other structures located very close to the crossings. There may be a requirement to significantly limit vibration and construction noise, which could potentially add additional cost to the project.
- Real Estate / Rights-of-way / Encroachments – No real estate costs are included in the costs developed in this study. However, costs for removing significant encroachments and other items have attempted to be quantified and included in the estimate. But there are still other items that may have been missed or could be constructed at some point between now and the start of construction.
- Traffic Control – Four of the five project sites (excluding Blake St.) are located on significantly trafficked roadways. Traffic control will be a significant effort on the part of the contractor to ensure these roads are still accessible to two-way traffic during construction. Phases were developed to account for this. Flaggers have been included for a subset of the construction duration but are not assumed to be needed full time. Therefore, if this assumption is changed, there could be significant changes to the estimate.
- Contract Acquisition – The current estimates have been developed such that the bridges are being constructed as a stand-alone contract. However, when the bridges are incorporated into the full project estimate, then there could be a potential to include the bridge work as being performed by subcontractors to the prime, and or by a small business. These changes could increase markups and thus costs.

5.4 GLOBAL RISKS

5.4 Figure 2 from the geotechnical appendix was reviewed to locate all channel crossings within the limits of the USACE's overall study. Along with this figure, other mapping and imagery programs were used to view these crossings to compile a list of other risks that are not apparent at the five sites estimated above. The potential risk to other crossing locations may include the followings:

- Railroads Impacts – Any site in which the project footprint encroaches upon railroad property would likely have additional cost risk associated with it. Upon review, there appears to be at least one crossing on the C04 channel, near the intersection of Hazard Ave. and Hoover St, that requires crossing under a railroad track.
- Freeway Culverts – There appear to be five locations where the project channels flow under either the 405 or 22 Freeways. These sites are likely to incur significant costs risk due to dealing with Caltrans requirements and potential for significant traffic control costs if the freeways themselves require modifications. Another potential risk at the 405 Freeway crossing along C05, is that there is a road overcrossing above the freeway at this location as well. Therefore, if there needs to be modifications to the freeway, other potential risks could arise due to a second overcrossing located above (Newland St.).
- Pedestrian Crossings – Several pedestrian crossings were observed within the project channels. Some of these are likely constructed above and beyond the existing channel, and likely do not need modifications. But in terms of counting all crossings, it was not apparent whether these pedestrian bridges need to be included in future analysis.
- Tidal Influence – For crossings located closer to the ocean (on C04 and C05) tidal water is an issue. Most of these crossings appear to be bridges, and therefore may not require significant water control efforts for the bridge work, but there still is greater risk than other locations where the channels will be mostly dry during work windows. These sites with tidal influenced water may also require greater insurance and safety requirements due to working over water. These tidally influenced areas might also have environmental windows that limit in-channel construction windows. Thus, this may be another risk to productivities and scheduling based on potential environmental conditions.

6. REPRESENTATIVENESS OF SAMPLED CROSSINGS

6.1 INTRODUCTION

6.1 This section discusses how representative the five sampled channel crossings are for use in estimating the remaining channel crossings in the full project study area.

6.2 SAMPLED CROSSINGS

6.2 A desktop survey of all channel crossings for the C04, C05 and C06 channels was completed. This survey started at the downstream end of each channel system and moved upstream to count and document basic characteristics of each crossing found in available aerial imagery. A total of 71 crossings were found during this survey. Table 6.1 lists the number of crossings in each channel, as well as the number of sampled crossings for each channel.

Table 6.1 – Total Number of Crossings by Channel

Channel	Total No. of Crossings	Sampled Crossings
C04	22	1
C05	39	3
C06	10	1
Total	71	5

6.3 CROSSINGS CHARACTERISTICS

6.3 In locating all potential channel crossings, visual characteristics were noted as each crossing was documented. The characteristics documented are considered key characteristics that could impact the replacement costs for a given crossing. The characteristics found include the following:

- Intersections – If a crossing spanned an intersection, mostly via traversing diagonally across, then this was noted. Figure 6.1 provides a sample of an intersection traversing crossing.

- Number of Lanes – The number of traffic lanes located on the crossing directly over the channel was noted. This could be helpful in differentiating between arterial roads, and minor, more local, neighborhood roads, which would have differing construction assumptions as well as traffic control efforts.

- Tidal Influence – An attempt was made to determine whether tidal flows would impact a crossing. The tidal influences would create additional dewatering requirements for construction, especially for crossings that are box culverts.

- Freeway – Freeway crossings are a major risk item, as referenced in previous sections. Therefore, all freeway crossings were noted in the survey.

- Crossing/Culvert Type – An attempt was made to document the crossing type at each location. The crossings were sorted into clear span bridge, bridge with piers, or box culvert.

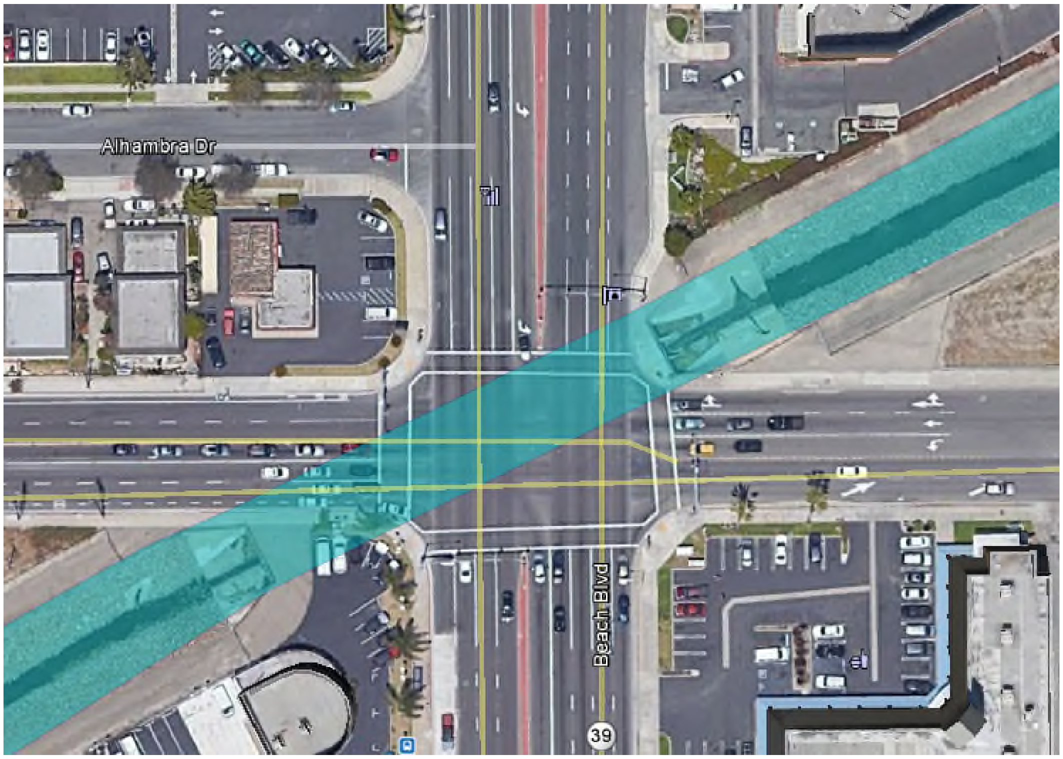

Figure 6.1 – Sample Intersection Crossing

6.4 A summary of the noted characteristics is provided in Table 6.2. The table provides the overall number of crossings found with the given characteristic, plus the number of sampled crossings that match that characteristic for comparison.

6.5 As the table shows, there are seven crossings that would require work within an intersection, and one sampled crossing that could help estimate at those locations. A wide number of traffic lanes are found throughout the project reach. The largest of which are freeways. But overall the five representative crossings encompass a good array of those sizes. The representative crossings account for small 2-lane roads within neighborhoods, to major arterial roadways with upwards of 9-lanes (not including intersections).

6.6 In regards to tidal influences, it has been estimated that at least 17 of the crossings could be impacted by tidal waters. The representative crossings are located at approximately two of these locations. Lastly, the crossing type shows that the representative crossings cover the major designated crossing types quite well. There is one representative crossing for each type. The only major feature not covered is the freeway crossings. But, as previously referenced in the report, the crossings that have freeway impacts will result in significantly different costs, and significantly higher traffic control needs in order to complete.

Table 6.2 – Channel Crossing Characteristics

Crossing Characteristic	Total No. of Crossings	Sampled Crossings
Intersection	7	1
2-Lane	16	1
3-Lane	1	0
4-Lane	3	0
5-Lane	13	1
6-Lane	1	0
7-Lane	13	1
8-Lane	2	0
9-Lane	3	2
10-Lane	0	0
11-Lane	2	0
12-Lane	1	0
Freeway	3	0
Tidal Influenced	17	2
Bridge w/ Piers	16	1
Box Culvert	48	3
Bridge, Clear Span	7	1

6.4 CROSSING SIZE

6.7 Approximate dimensions of the channel crossings were also documented during the desktop survey. The approximate channel width and length under the crossing were measured from aerial imagery to estimate the total square footage of the crossing. Summary statistics for the estimated areas is provided in Table 6.3.

Table 6.3 – Channel Crossing Average Areas

Crossing Data	All Crossings (sf)	Sampled Crossings (sf)
Minimum	320	1,800
Mean	7,632	8,830
Median	5,000	8,750
Maximum	70,200	14,400

6.8 Table 6.4 provides a summary by crossing size. The table demonstrates that many of the crossings have representative crossings estimated by the five crossings sampled in this study. Crossings under 3,000 feet are predominantly local neighborhood roads, and are well represented by Crossing No. 5 (Blake St.) The other crossing sizes are well represented as well based on the findings for the areas between 4,000 and 15,000 square feet.

Table 6.4 – Channel Crossing Areas by Size

Crossing Area (sf)	Total No. of Crossings*	Sampled Crossings
< 500	2	0
500 - 1000	2	0
1000 - 2000	6	1
2000 - 3000	3	0
3000 - 4000	11	0
4000 - 5000	8	0
5000 - 7500	9	1
7500 - 10000	6	1
10000 - 12500	4	1
12500 - 15000	6	1
>15000	5	0
* The total number of crossings listed here does not reflect the full total of crossings (71) as lengths and widths were not readily measurable through available imagery.		

6.9 This survey also found that there are several large culverts, some that go under schools and other facilities, that are not represented in the five estimated crossings (see Figure 6.2 for sample location). These locations would require further analysis to provide better representative samples, as these sites would have significantly higher demolition, earthwork, concrete, and other construction costs than the sampled crossings.

Figure 6.2 – Sample Culvert Under Major Structure

6.5 OVERALL REPRESENTATIVENESS

6.10 The five sampled crossings estimated in this study do provide a good representation of all crossings in the full project area. A comparison of key crossing characteristics, and size of the crossings, show that the five sampled crossings cover a wide array of the crossing characteristics found in the full project area. There are several limitations though, which primarily relate to freeway crossings and relatively long culverts. These crossings could require further analysis to better develop assumptions and construction elements for estimating purposes. But, based on the tables and information compiled from the desktop survey, the five sampled crossings provide valuable information that is directly applicable to a majority of the other crossings in the full project extent.

7. REFERENCES

1. EM 1110-2-1302, "*Civil Works Cost Engineering,*" U.S. Army Corps of Engineers, 31 March 1994.

2. U.S. Army Corps of Engineers (USACE), 1998. *Memorandum for Record, H&H Policy Memorandum Number 1, Side Drain Connections into Flood Control Channels.* December 29, 1998.

3. USACE, 2017. *Ocean View Channel, Huntington Beach, California, Design Documentation Report*, prepared by Tetra Tech, June 30, 2017.

4. USACE, 2018a. *Appendix G: Geotechnical for Westminster, East Garden Grove Flood Risk Management Study,* October 2018.

5. USACE, 2018b. *Scope of Work for Feasibility Level AE Design of Channel Crossing Structures, Orange County Flood Control District (OCFD) – Westminster East Garden Grove Flood Risk Management Study*, December 2018.

6. Orange County, Public Works Department (OCPW), 2018. *Standard Plans.* September edition, 2018.

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Exhibits
(Design Sheets)

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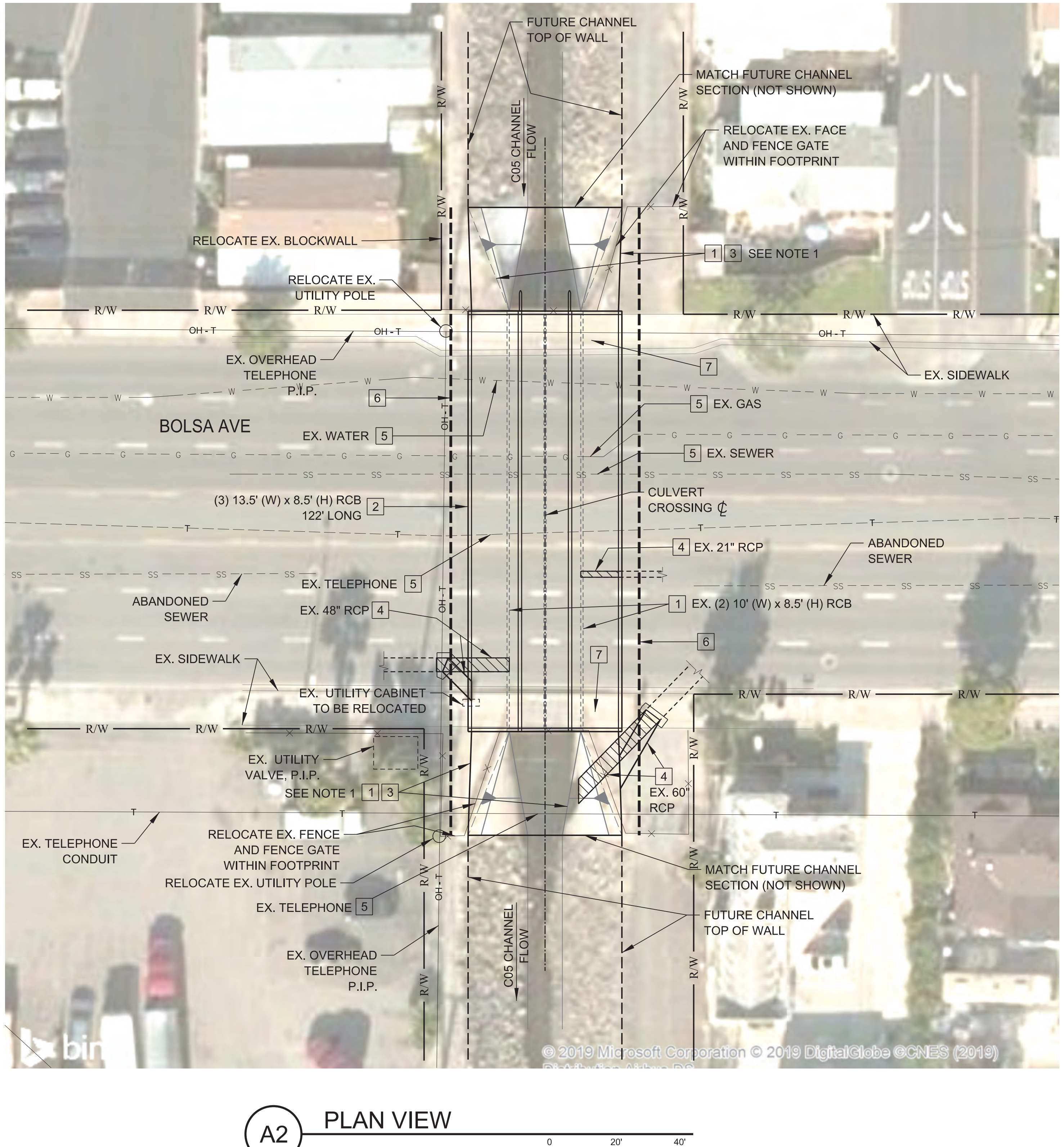


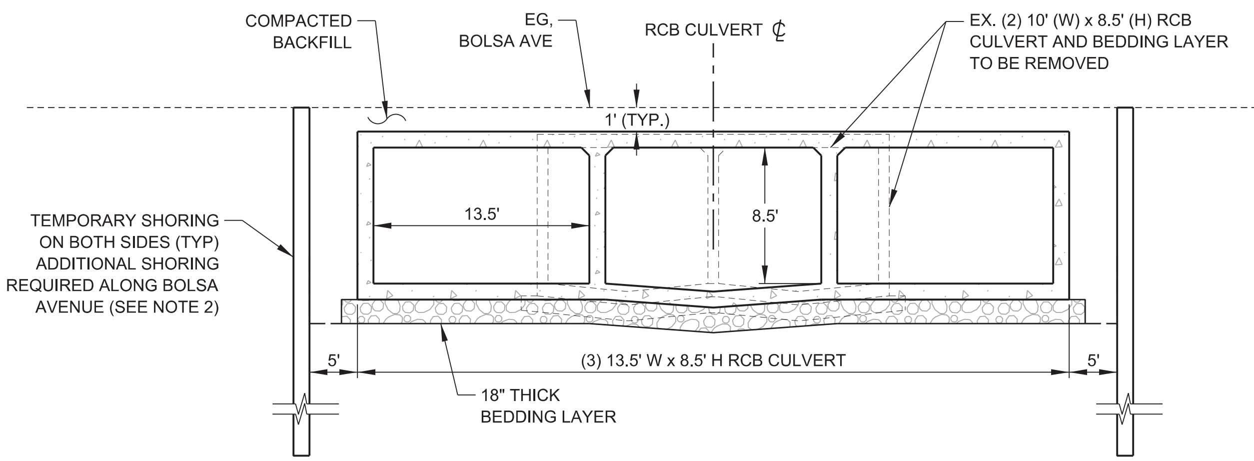
A2 PLAN VIEW

CONSTRUCTION NOTES

1. REMOVE EXISTING CULVERT AND TRANSITION STRUCTURE PER PLAN AND TYPICAL SECTION HEREON.
2. CONSTRUCT RCB CULVERT PER PLAN AND TYPICAL SECTION HEREON.
3. CONSTRUCT TRANSITION STRUCTURE BETWEEN NEW CULVERT AND CHANNEL SECTION PER PLAN.
4. REMOVE INTERFERING PORTION OF EXISTING STORM DRAIN AND PROVIDE A JUNCTION STRUCTURE TO CONNECT WITH NEW STRUCTURE PER PLAN.
5. PROVIDE UTILITY CROSSING FOR EXISTING UTILITY PER PLAN.
6. CONSTRUCT TEMPORARY SHORING PER PLAN AND TYPICAL SECTION HEREON.
7. REMOVE AND RECONSTRUCT INTERFERING PORTIONS OF EX. SIDEWALK, CURB, AND GUTTER PER PLAN.

NOTES

1. AN EXISTING TRANSITION STRUCTURE BETWEEN RCB AND RIPRAP TRAPEZOIDAL CHANNEL IS REPLACED WITH A NEW RC TRANSITION STRUCTURE BETWEEN RCB AND RC RECTANGULAR CHANNEL (USACE FUTURE IMPROVEMENT).
2. CONSTRUCTION IS PERFORMED IN MULTIPLE PHASES IN ORDER TO PARTIALLY OPEN BOLSA AVENUE TO PUBLIC TRAFFIC DURING CONSTRUCTION. ADDITIONAL TEMPORARY SHORING (NOT SHOWN ON THIS SHEET) SHALL BE INSTALLED AS REQUIRED ALONG THE STREET DURING DIFFERENT PHASES.
3. ALL EXISTING UTILITIES, NOT LABELED FOR REMOVAL OR RELOCATION, SHALL BE PROTECTED IN PLACE.



A - TYPICAL CULVERT SECTION
N.T.S.

N

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

U.S. ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
231 SOUTH LA SALLE ST, SUITE 1500
CHICAGO, IL 60604

TETRA TECH, INC.
17885 Von Karman Avenue, Suite 500
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CHECKED BY: A. TORREYSON	CONTRACT NO.: W912PL-15-D-0007
SUBMITTED BY: J. SUH	SCALE: AS SHOWN
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WESTMINSTER EAST GARDEN GROVE
ORANGE COUNTY, CALIFORNIA
FLOOD RISK MANAGEMENT STUDY
BRIDGE CROSSING FEASIBILITY DESIGN

PLAN AND TYPICAL SECTION (1)
C05 AT BOLSA AVE CROSSING

SHEET ID
CF101

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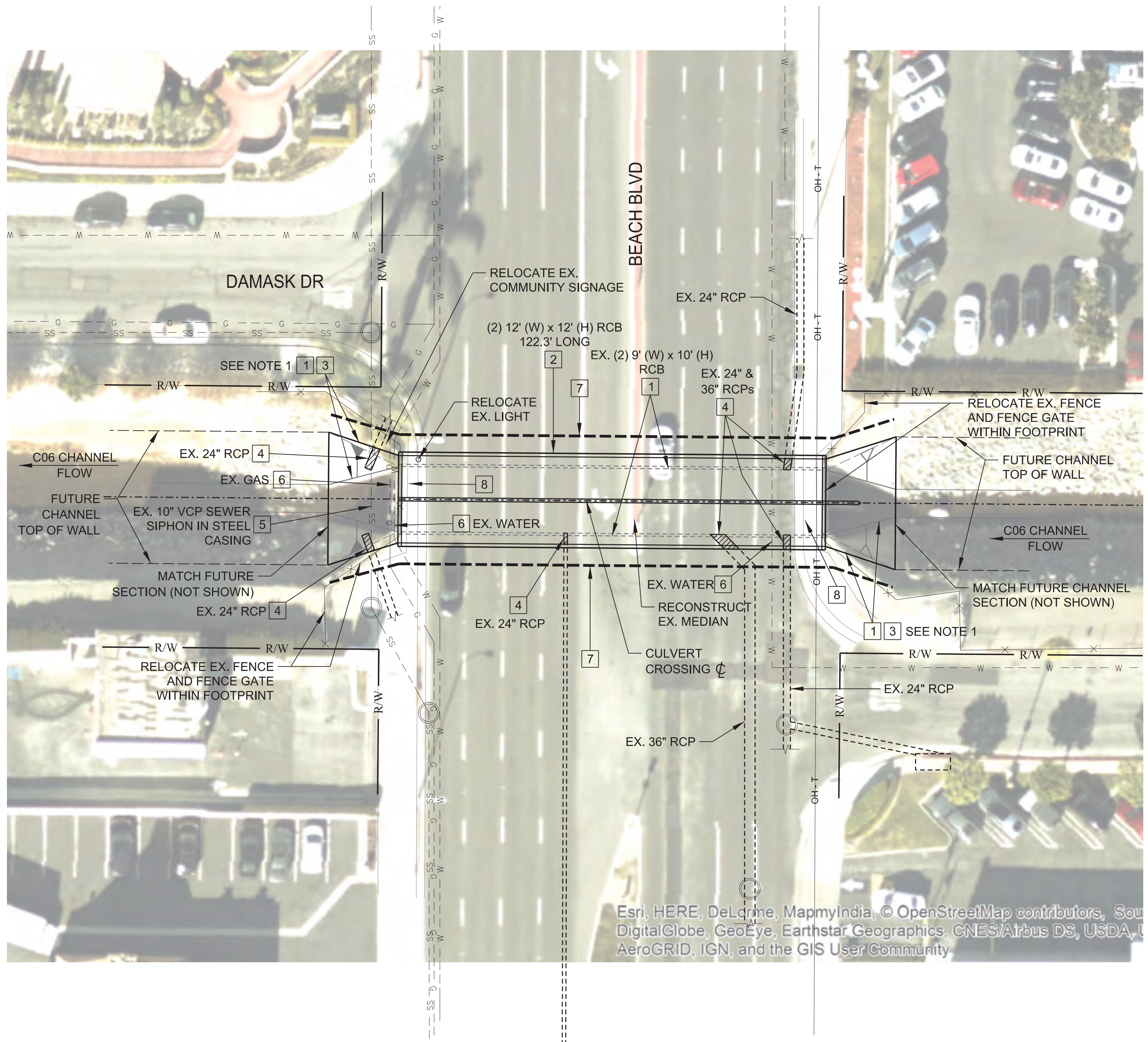
CONSTRUCTION NOTES

1. REMOVE EXISTING CULVERT AND TRANSITION STRUCTURE PER PLAN AND TYPICAL SECTION HEREON.
2. CONSTRUCT RCB CULVERT PER PLAN AND TYPICAL SECTION HEREON.
3. CONSTRUCT TRANSITION STRUCTURE BETWEEN NEW CULVERT AND CHANNEL SECTION PER PLAN.
4. REMOVE INTERFERING PORTION OF EXISTING STORM DRAIN AND PROVIDE A JUNCTION STRUCTURE TO CONNECT WITH NEW STRUCTURE PER PLAN.
5. RELOCATE EXISTING UTILITY SIPHON LINE TO BELOW NEW RCB STRUCTURE AND BEDDING LAYER.
6. PROVIDE UTILITY CROSSING FOR EXISTING UTILITY PER PLAN.
7. CONSTRUCT TEMPORARY SHORING PER PLAN AND TYPICAL SECTION HEREON.
8. REMOVE AND RECONSTRUCT INTERFERING PORTIONS OF EX. SIDEWALK, CURB, AND GUTTER PER PLAN.

NOTES

1. AN EXISTING TRANSITION STRUCTURE BETWEEN RCB AND RIPRAP TRAPEZOIDAL CHANNEL IS REPLACED WITH A NEW RC TRANSITION STRUCTURE BETWEEN RCB AND RC RECTANGULAR CHANNEL (USACE FUTURE IMPROVEMENT).
2. CONSTRUCTION IS PERFORMED IN MULTIPLE PHASES IN ORDER TO PARTIALLY OPEN BEACH BLVD TO PUBLIC TRAFFIC DURING CONSTRUCTION. ADDITIONAL TEMPORARY SHORING (NOT SHOWN ON THIS SHEET) SHALL BE INSTALLED AS REQUIRED ALONG THE STREET DURING DIFFERENT PHASES.
3. ALL EXISTING UTILITIES, NOT LABELED FOR REMOVAL OR RELOCATION, SHALL BE PROTECTED IN PLACE.



A2 PLAN VIEW

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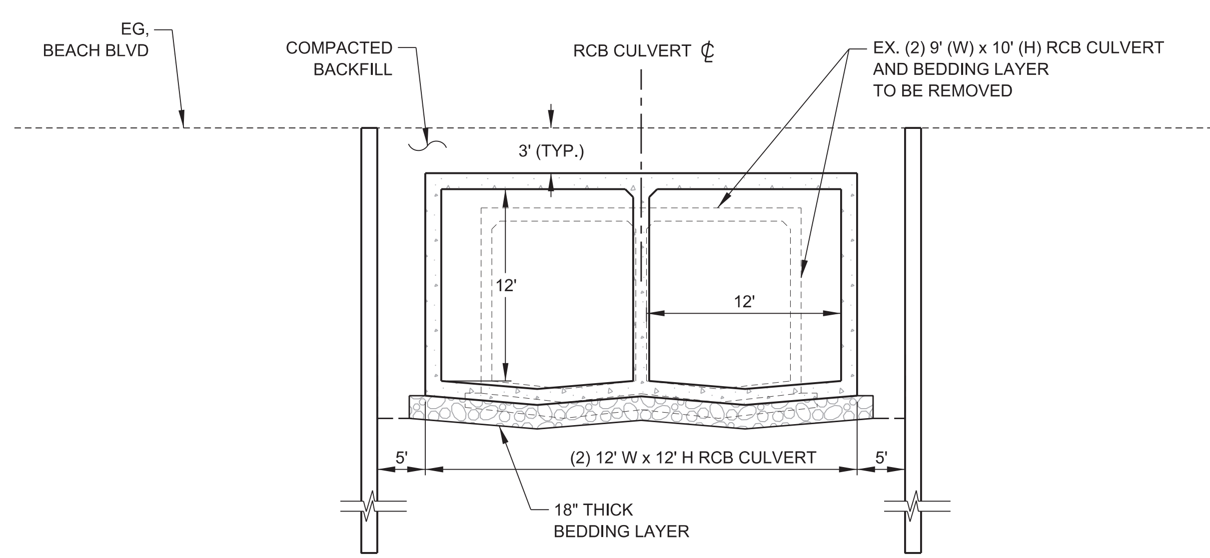

A - TYPICAL CULVERT SECTION

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ORANGE COUNTY, CALIFORNIA
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BRIDGE CROSSING FEASIBILITY DESIGN

PLAN AND TYPICAL SECTION (2)
C06 AT BEACH BLVD CROSSING

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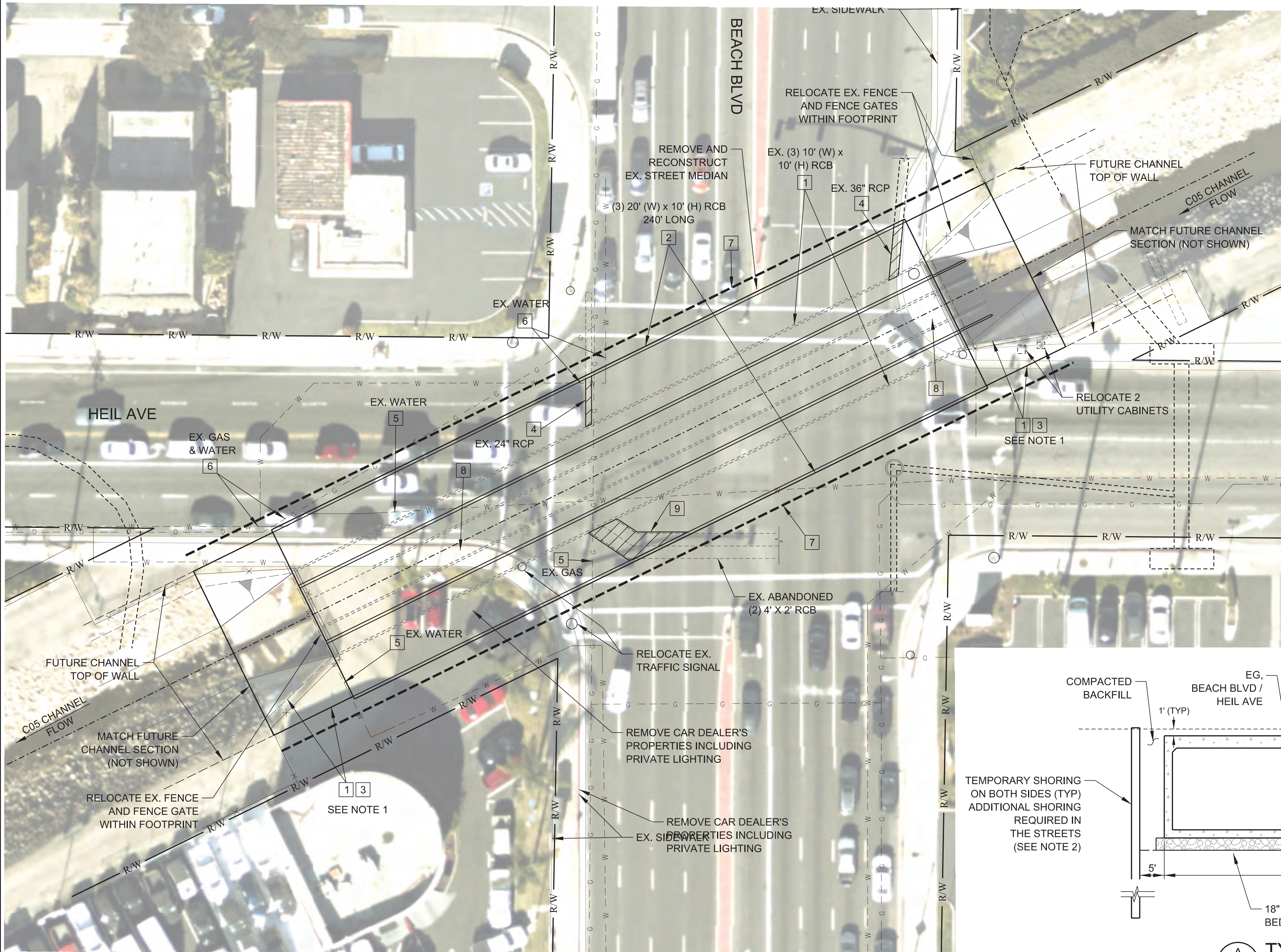

A2 PLAN VIEW

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CONSTRUCTION NOTES

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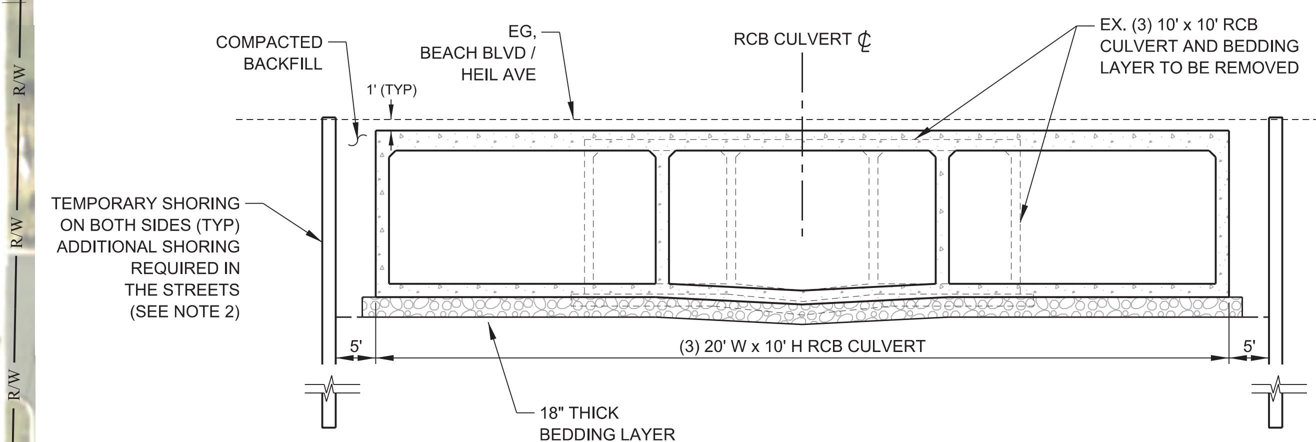
2. CONSTRUCT RCB CULVERT PER PLAN AND TYPICAL SECTION HEREON.
3. CONSTRUCT TRANSITION STRUCTURE BETWEEN NEW CULVERT AND CHANNEL SECTION PER PLAN.
4. REMOVE INTERFERING PORTION OF EXISTING STORM DRAIN AND PROVIDE A JUNCTION STRUCTURE TO CONNECT WITH NEW STRUCTURE PER PLAN.
5. PROVIDE UTILITY CROSSING FOR EXISTING UTILITY PER PLAN.
6. RELOCATE EXISTING UTILITY TO OUTSIDE OF NEW RCB CULVERT FOOTPRINT PER PLAN.
7. CONSTRUCT TEMPORARY SHORING PER PLAN AND TYPICAL SECTION HEREON.
8. REMOVE AND RECONSTRUCT INTERFERING PORTIONS OF EX. SIDEWALK, CURB, AND GUTTER PER PLAN.
9. REMOVE INTERFERING PORTION OF EXISTING ABANDONED STORM DRAIN AND PLUG THE OPENING OF REMAINING STORM DRAIN.

NOTES

1. AN EXISTING TRANSITION STRUCTURE BETWEEN RCB AND RIPRAP TRAPEZOIDAL CHANNEL IS REPLACED WITH A NEW RC TRANSITION STRUCTURE BETWEEN RCB AND RC RECTANGULAR CHANNEL (USACE FUTURE IMPROVEMENT).
2. CONSTRUCTION IS PERFORMED IN MULTIPLE PHASES IN ORDER TO PARTIALLY OPEN BOLSA AVENUE AND HEIL AVE TO PUBLIC TRAFFIC DURING CONSTRUCTION. ADDITIONAL TEMPORARY SHORING (NOT SHOWN ON THIS SHEET) SHALL BE INSTALLED AS REQUIRED ALONG THE STREET DURING DIFFERENT PHASES.
3. ALL EXISTING UTILITIES, NOT LABELED FOR REMOVAL OR RELOCATION, SHALL BE PROTECTED IN PLACE.



A - TYPICAL CULVERT SECTION
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FLOOD RISK MANAGEMENT STUDY
BRIDGE CROSSING FEASIBILITY DESIGN

PLAN AND TYPICAL SECTION (3)
C05 AT BEACH BLVD/ HEIL AVE CROSSING

SHEET ID
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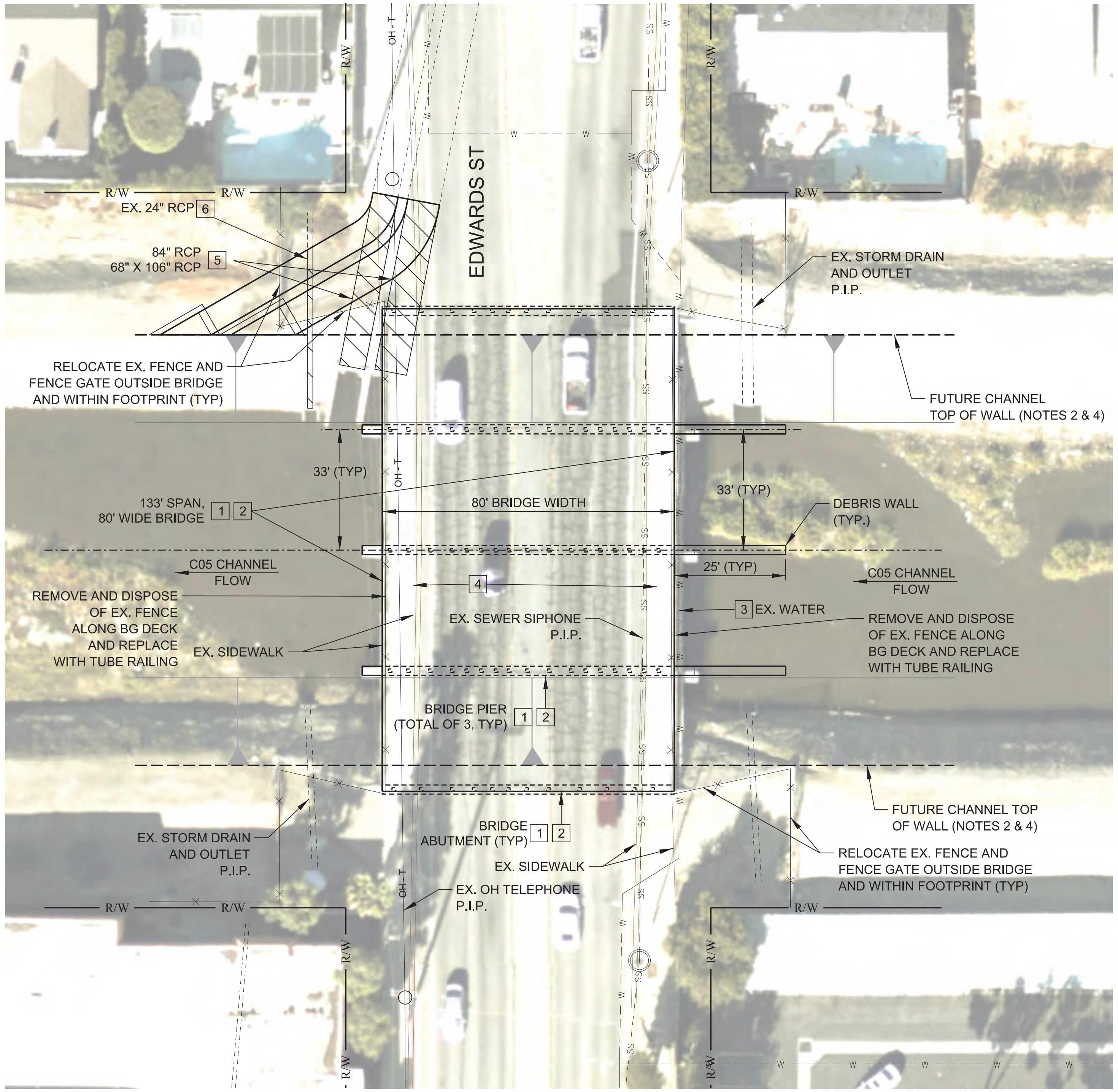


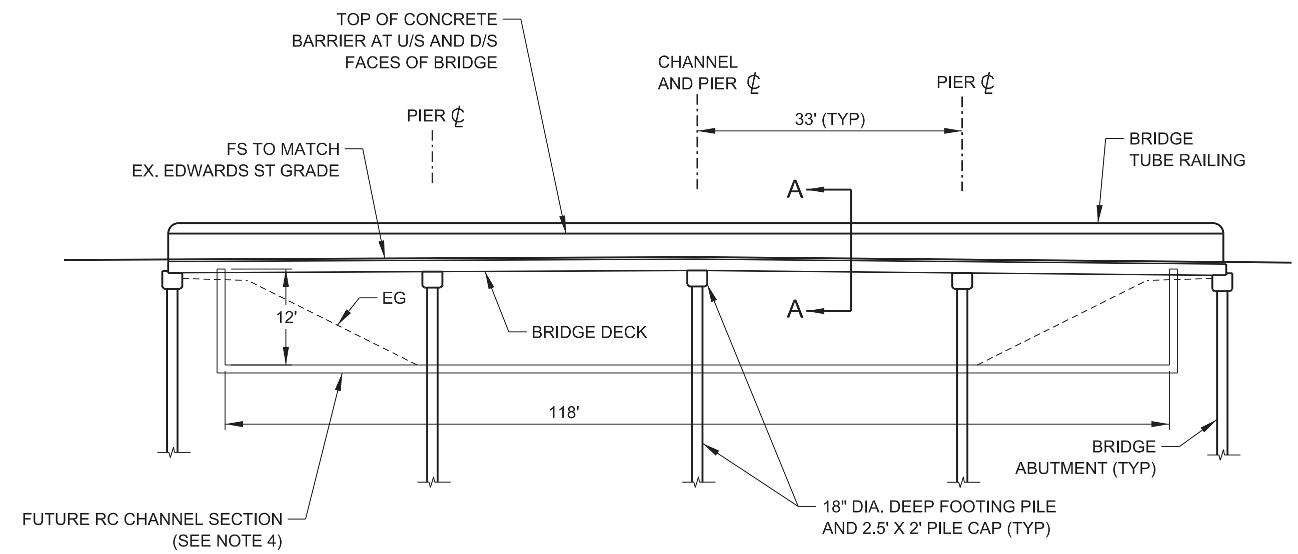
A2 PLAN VIEW

NOTES

1. CONSTRUCTION IS PERFORMED IN MULTIPLE PHASES IN ORDER TO PARTIALLY OPEN EDWARDS STREET TO PUBLIC TRAFFIC DURING CONSTRUCTION.
2. CONSTRUCTION DETAILS FOR RC CHANNEL UNDER NEW BRIDGE SHALL BE BASED ON USACE'S FUTURE CHANNEL IMPROVEMENT PLANS.
3. ALL EXISTING UTILITIES, NOT LABELED FOR REMOVAL OR RELOCATION, SHALL BE PROTECTED IN PLACE.
4. CONSTRUCTION COST FOR CHANNEL IMPROVEMENT UNDERNEATH IS NOT PART OF THE BRIDGE CROSSING COST.

CONSTRUCTION NOTES

1. REMOVE EXISTING BRIDGE AND PER PLAN AND TYPICAL SECTION HEREON.
2. CONSTRUCT BRIDGE PER PLAN AND TYPICAL SECTION HEREON.
3. PROVIDE UTILITY CROSSING FOR EXISTING UTILITY PER PLAN.
4. REMOVE AND DISPOSE OF INTERFERING PORTIONS OF EXISTING SIDEWALK, CURB, AND GUTTER PER PLAN.
5. REMOVE INTERFERING PORTIONS OF EXISTING STORM DRAIN AND CONSTRUCT NEW STORM DRAIN PIPES AND OUTLET STRUCTURES AT CHANNEL WALL TO MEET THE REQUIRED ANGLE OF ENTRY.
6. REMOVE INTERFERING PORTION OF EXISTING SOTRM DRAIN AND PROVIDE A JUNCTION STRUCTURE TO CONNECT WITH NEW STRUCTURE PER PLAN.



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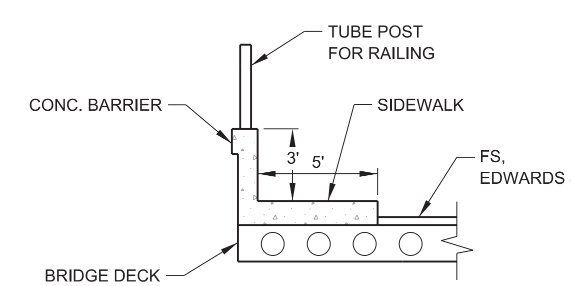

SECTION A-A

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WESTMINSTER EAST GARDEN GROVE
ORANGE COUNTY, CALIFORNIA
FLOOD RISK MANAGEMENT STUDY
BRIDGE CROSSING FEASIBILITY DESIGN

PLAN AND TYPICAL SECTION (4)
C05 AT EDWARDS STREET CROSSING

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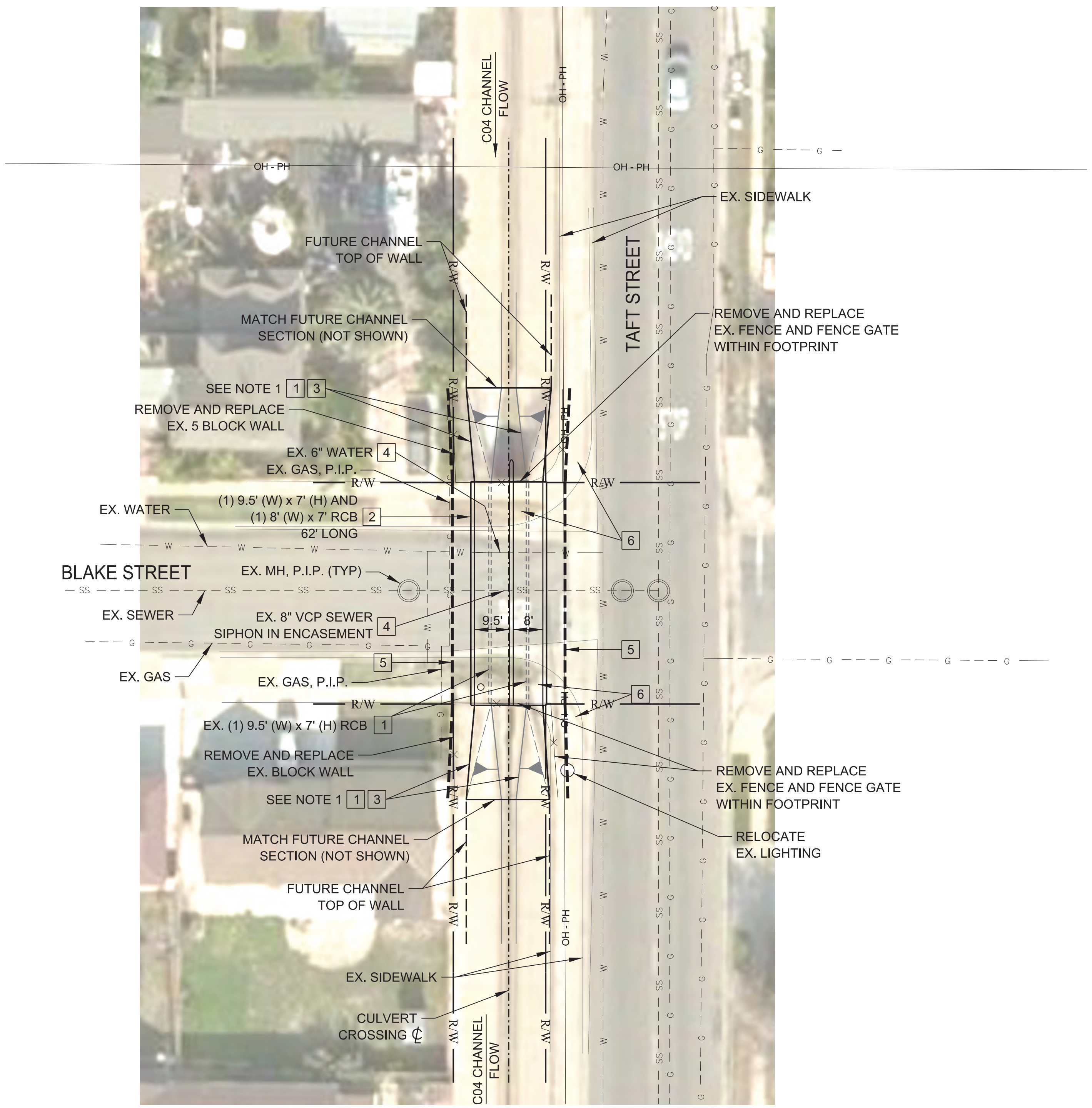

A2 PLAN VIEW

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CONSTRUCTION NOTES

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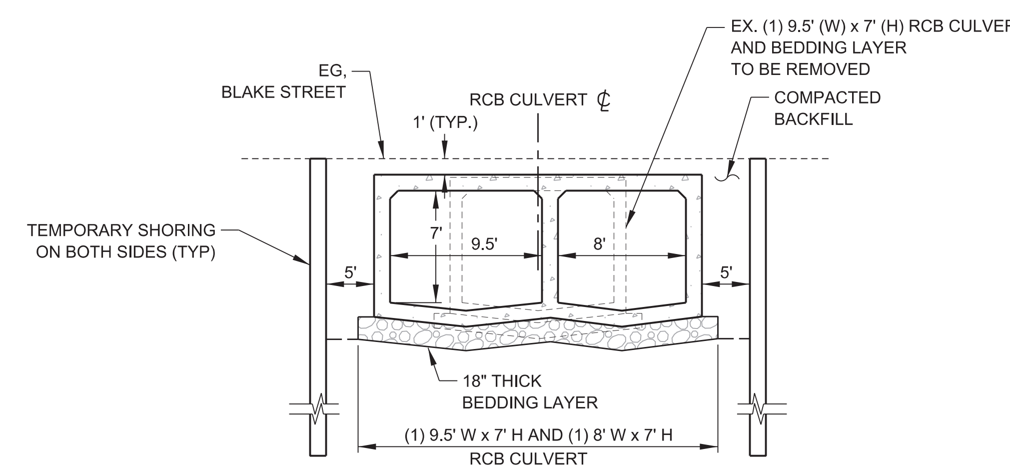
2. CONSTRUCTION IS PERFORMED WITH COMPLETE CLOSURE (SINGLE PHASE) OF BLAKE STREET TO PUBLIC TRAFFIC DURING CONSTRUCTION.
3. ALL EXISTING UTILITIES, NOT LABELED FOR REMOVAL OR RELOCATION, SHALL BE PROTECTED IN PLACE.



A TYPICAL CULVERT SECTION
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BRIDGE CROSSING FEASIBILITY DESIGN

PLAN AND TYPICAL SECTION (5)
C04 AT BLAKE STREET CROSSING

SHEET ID
CF105

Appendix B - Civil Engineering

Attachment 3: Westminster Mall Diversion

Alternative 3 Design (C02/04 Channel) for Westminster East Garden Grove Flood Risk Management for the USACE Feasibility Study

Orange County, California

May 2018

Prepared for:
Orange County Public Works
300 N Flower Street
Santa Ana, California 92703

Prepared by:

TETRA TECH

17885 Von Karman Ave, Suite 500
Irvine, California 92614

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Alternative 3 Design (C02/04 Channel) for Westminster East Garden Grove Flood Risk Management for the USACE Feasibility Study

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May 2018

Prepared for:

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300 N Flower Street
Santa Ana, California 92703

Prepared by:

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1. Introduction

1.1. Study Overview

The Westminster East Garden Grove Flood Risk Management Study is a cost share feasibility study in which Orange County Public Works (OCPW) is the non-Federal sponsor with the Army Corps of Engineers (Corps).

The study area includes the Westminster watershed within western Orange County, California. Cities in the watershed include Anaheim, Stanton, Cypress, Garden Grove, Westminster, Fountain Valley, Los Alamitos, Seal Beach, and Huntington Beach (see **Figure 1**). The purpose of the study is to evaluate residual flood risk within the Westminster Watershed after the completion of channelization improvements of the Santa Ana River and the subsequent removal of the Westminster Watershed from the Santa Ana River floodplain. The region within the floodplain is the most significant region within Orange County still within the FEMA 1% Floodplain, and analysis shows that approximately 20,000 structures are at risk of flooding.

Alternative 3 is the locally preferred plan being evaluated as part of the feasibility study currently underway with the Corps and includes modifications recommended by OCPW. Through hydraulic modeling it was determined that there is not sufficient capacity in the C04 channel near Westminster Mall to convey floodwaters when there is a 1% (100-year flood) or greater discharge. The purpose of this effort is to evaluate alternative alignments that reduce the flooding and improve conveyance within the areas between Hoover and Edwards Streets and incorporate those modifications into Alternative 3 in the feasibility study.

Two alternative alignments and methods to improve the flood conveyance are investigated. One alternative alignment will be recommended based on these results and will consider costs, right-of-way, and existing structures.

2. Hydraulic Design

2.1. Overview

The existing Westminster Channel from Hoover Street down to Edwards Street consists of the following facility elements. At the immediate upstream face of Hoover Street there is a confluence of an existing open box channel (Hazard Channel), as well as a parallel box culvert (Hazard Culvert). These merge to combine with each other as well as storm drains for both Hoover Street and Hazard Street. This combined flow passes through a quadruple box culvert under Hoover Street. Upstream of the Interstate 405 freeway (I-405) to Hoover Street, the channel is an open box 40-feet wide by 10-feet deep near I-405 and 38-feet wide by 12-feet deep near Hoover Street. There are three crossings along this reach; two with triple box culverts, and a third with a single span bridge. The I-405 crossing consists of two 12’ x 9.25’ reinforced concrete box (RCB) and two 121” x 77” reinforced concrete pipes (RCPs). Under Goldenwest Street these become two 12’ x 9.25’ RCBs and two 108” RCPs. These facilities briefly daylight and merge into a 40-foot wide by 13-foot deep RCB that then goes underground again into triple 14-foot x 9.5-foot RCBs. These daylight at Edwards street into an open trapezoidal rip-rap lined channel. A fourth box daylights at Edwards Street as well where an existing 66-inch storm drain enters the channel.

2.2. Assumptions

In choosing the design alternatives, the route choice was a primary driver for the design in terms of cost, feasibility, and simplicity. Assumptions made regarding these factors included the avoidance of the acquisition of private property, particularly residences. This effectively drives a preference for public rights of way, including existing streets, utility or infrastructure easements, but also vacant lots and other property with minimal buildings. Another assumption was to avoid or minimize the relocation of utilities, particularly gravity flow lines such as sewer. This also included an assumption to protect in place where possible. Also, an assumption on impacts to the Interstate 405 freeway required consideration. Any alterations that require excavating the freeway would have a disproportionate impact on cost and traffic. Lastly, with much of the area urbanized, it was assumed the system improvements would be underground due to overlapping existing roadways or infrastructure, and with plans for parcels. With these assumptions in mind, hydraulic design to meet those needs followed. Hydraulically, the existing model flow amounts and change locations were assumed to be correct and correspond with local storm drain networks entering the existing and/or proposed systems.

2.3. Previous Studies

The Westminster East Garden Grove Watershed Management Feasibility Study has been ongoing for a number of years. The Alternatives Milestone was completed in February 2014 and the next major milestone is the Tentatively Selected Plan Milestone. At this point in time there is an array of 5 alternatives (including No Action) under consideration.

Hydraulic models of the system were previously developed using HEC-RAS and FLO-2D. It was decided modeling would be revised using the current version of HEC-RAS which includes 2D modeling. Tetra Tech was contracted by OCPW to complete revisions to the 1-D channel modeling, with the Corps- Chicago District performing the 2D modeling.

Through hydraulic modeling conducted by Tetra Tech and concluded in April 2018, it was determined that there is not sufficient capacity in the C04 channel near Westminster Mall to convey floodwaters when there is a 1% (100-year flood) or greater discharge.

An off-channel retention/detention basin option was considered to provide additional flood flow storage basin(s) without modifications of the existing channel system from Edwards Street to Hoover Street. It was estimated that forty percent (40%) of the 100-year peak flow needed to be diverted at upstream of Hoover Street to remove the 100-year floodplain from Edwards Street to Hoover Street. The estimated 100-year runoff volume was 1,160 acre-feet. For a basin with flow depths of 8-10 feet, the minimum required surface area would be 116 acre-feet without considering freeboard and other flood control apparatus. The estimated cost for acquisition of the land required to construct this basin was $250-300 million. Based on that cost estimate, this option was abandoned due to the cost of land acquisition alone. Without a detention basin alternative to consider, all the alternatives to address conveyance near Westminster Mall focused on channel configurations and alignments.

2.4. Alternative Alignments

Two main alignments were considered to provide 100-year capacity along the C02/04 channel. The first is the northern alignment along the existing railroad tracks. This alignment was developed to minimize changes to the existing system, specifically the culverts at the I-405 crossing. The second alternative follows the existing channel alignment and was developed to maximize use of the existing facilities and right-of-way.

2.4.1. Alternative 3A - Railroad Alignment to Edwards

A cursory review of the landscape in the project area identifies a potential alignment quickly, via an abandoned railway alignment and along local major roads. The first alignment would take advantage of this open route, which has an overpass from the 405 freeway and thus potentially no impact on the highway, and then down a public road. The features of this path would potentially minimize right of way and infrastructure impacts and costs when looked at together. The alignment of the route for Alternative 3A begins immediately downstream of Hoover Street crossing (see **Figure 2**). To prevent overtopping flows in the existing system that begin at Hoover Street and extend downstream through the C04 channel system, discharge is diverted here. The diversion would funnel 40% of the combined flow passing under Hoover Street, with the remaining 60% utilizing the existing channel system. The diversion relieves pressure on the downstream system, allowing the existing four box/pipe structure under Hoover Street to pass the existing 100-yr peak flow of 4,090 cfs through the combined system. The diverted flow would progress down the new alignment along the abandoned Naval Railway right of way. Right of way requirements are discussed further in **Section** Error! Reference source not found.. The diversion route would f low under Goldenwest Street and then turn south upon reaching Edwards Street. It would then progress south along Edwards Street, where it would replace and pick up the discharge from an existing storm drain before re-joining the C04 channel in a confluence where the current storm drain daylights. Two variations of this alignment along Edwards Street were considered.

2.4.1.1. Centerline of Edwards Alignment

The first alignment along Edwards Street that was considered was a route that would follow and replace an existing storm drain line down Edwards Street. The benefit of this route would be to avoid acquiring an easement along the edge of the Westminster Mall street side landscaping and parking lot, as well as utilizing and occupying an existing storm drain facility's footprint. The downside to using this alignment however is that the proposed boxes, with a combined width of 31-feet, are much wider than the existing 66-inch storm drain and will require additional right of way within the street that would not only require replacing the existing storm drain, but relocate or protect in place some utilities for both the cities of Huntington Beach and Westminster. Most of the utilities in the street (see Figure 9 and Figure 10) however can likely be avoided except for those crossing at the bend from the railroad right of way, as well as an existing gas line that runs down the center of much of Edwards Street.

2.4.1.2. East of Edwards Alignment

The second alignment considered along Edwards Street would be immediately next to the street within the landscaping and parking lot beside the road. The benefit of this route is that there would be no need to replace the existing 66-inch storm drain, and the route avoids many utilities on the Huntington Beach (west) side of Edwards Street. The utilities for Westminster mostly serve the mall and are less extensive. These lines do not extend along the entire reach of Edwards Street. The downside to utilizing this alignment is the utilities affected include sewer and water lines servicing businesses of the Westminster Mall. Due to the gravity flow of sewer lines, these are more difficult to design around as changes in their grade lines may not be feasible during possible relocation. The need to acquire a right of way easement through the landscaping and parking lot of the mall may also be prohibitively expensive compared to right of way in the street.

2.4.1.3. Alignment Selection

The centerline of Edwards Street alignment was chosen due to the location of utilities and their type, and to the likely cost of purchasing private property right of way. The east of Edwards alignment encompassed water and sewer lines that may need to be protected in place due to gravity drainage, and may interfere with the placement of the designed diversion system. Additionally, the costs of purchasing privately owned land for right of way would add significantly more cost than using public right of way in Edwards Street. The Edwards Street alignment will fit the proposed design while primarily only impacting gas lines that can be moved.

2.4.2. Alternative 3B - Edwards to Hoover Additional Capacity

The route along the Alternative 3B alignment corresponds mainly with the existing C04 system from just downstream of Hoover Street, extending all the way to just downstream of Edwards Street (see **Figure 3**). Although this alignment does not change from the existing system, changes and modifications required for expanding the system capacity will require additional right of way. From I-405 to Goldenwest Street, underground right of way is required to add capacity. Similarly, capacity increases from Goldenwest Street to Edwards Street will require right of way along Bolsa Avenue. Right of way requirements are discussed further in **Section** Error! Reference source not f ound..

2.5. Proposed Alternative Descriptions

2.5.1. Alternative 3A Description

Alternative 3A includes constructing two underground 14-ft wide by 8.5-ft high reinforced concrete box culverts along the diversion route from Hoover Street to Edwards Street, transitioning to 14-ft wide by 9.5-ft along Edwards Street, as well as the diversion structure itself. It begins at the downstream end of Hoover Street and ends at the downstream end of the Edwards Street crossing of the C04 existing channel as seen in **Figure 2**. The alternate route assumes a diversion of forty percent (40%) of the peak flow existing under Hoover Street. A summary of the flow rates in the Alternative A system are found in **Table 1**. The box culverts maintain a slope of 0.1%, matching the energy grade of the hydraulics, down to Edwards Street. The boxes then drop under utilities crossing at Edwards and continue to follow the slope of 0.1% under the street until the confluence. Additional flow enters the diversion at Goldenwest Street where it is assumed that the storm drain running along that street is captured by the new culverts. Similarly, additional flow enters the diversion at Edwards Street where the storm drain running along that street is captured by the new culverts. The two culverts will daylight at the same location downstream of Edwards Street as the culverts that run underground along Bolsa Ave adjacent to Westminster Mall.

Table 1: Alternative 3A Flow Rates

	Model Station	Location Description	Flow Rate (cfs)
Existing Channel	288+68.42	Hoover Crossing	4,090
	288+38.4	D/S of Hoover	2,454
	249+66.54	U/S of 405 (Storm Drain Inflows)	2,474
Diversion Culverts	76+18.00	D/S of Hoover	1,636
	49+18.00	Goldenwest Street	1,806
	79+18.00	Edwards Street	2,096

Consideration was given for utilizing three boxes rather than two, but the system was oversized upstream, with the additional box reducing velocities and creating backwater effects in the boxes at the downstream end. Consideration was also given for three boxes along Edwards Street, with only two boxes upstream, but the results were similar in that with three boxes for the entire length, even if additional flow from the Edwards Street 66-inch storm drain was included.

2.5.2. *Alternative 3A Hydraulic Results*

The results for the Alternative 3A diversion show no overtopping of the existing C04 system while the diversion itself flows near capacity with approximately 0.5-ft of freeboard from the WSEL to soffit in the Edwards Street reach. Along the railroad right of way, there is approximately 0.5 to 1.0 feet of freeboard. Throughout the system the water surface elevation (WSEL) is controlled by the downstream confluence with the existing channel. **Figure 5** shows the water surface elevation (WSEL) profile for the existing system model from Hoover Street to the downstream end of the C04 system at Edwards Street. **Figure 5** shows the same profile but for the diversion from Hoover Street to the downstream end of the C04 system at Edwards Street. The matching of the invert and energy grade slope from Edwards to Hoover allows the upstream WSEL of the existing channel and the diversion channel to align. The existing system WSEL is at 30.07-ft, with the diversion WSEL at 29.74-ft. The diversion culverts provide sufficient capacity to the existing system, passing the remaining flow with no overtopping through the existing system reaches covered by the scope of this project. The estimated average RCB flow velocity is between 7.5-9 feet per second (fps). The underground closed conduit does not become pressurized with depths ranging between 7.5-8 feet in the 14x8.5" boxes, and approximately 9" in the 14x9.5" boxes. The estimated existing facilities average velocity and flow depth from Hoover Street to Edwards Street vary between 6-8 fps, with some spikes around culverts and bridges, and 8-9.5 feet deep. A tabulated summary of the results can be found in the hydraulic results in **Appendix A**.

2.5.3. Alternative 3B Description

Many channel and culvert configurations had been investigated in developing a final Alternative 3B. The three most feasible configurations are presented in the order of recommendation.

2.5.3.1. Replacements of I-405 Crossings and Chestnut Street and Naval Railway Culverts

The proposed Alternative 3B (see **Figure 3**) includes replacing existing Naval Railway and Chestnut Street culverts by free span bridges, replacing existing I-405 crossing with five 14' x 9.5' RCBs. Three of the proposed RCBs on the northside will be connecting to the existing three 14' x 9.5' RCBs that are through Westminster Mall Parking lot and the other two proposed RCBs will be transiting into two 14' x 6' RCBs along the Bolsa Avenue and joining the open channel at downstream of Edwards Street. Vertical walls are needed to meet the OCPW channel freeboard requirements and its height varies from approximate 1.5 feet at the upstream of I-405 to 0.5 feet at downstream of Chestnut Street.

2.5.3.2. Replacements of I-405 Crossings and Adding RCB between Chestnut Street and Hoover Street

One of the considerations analyzed was to add a 15' x 9.5' RCB from upstream of Chestnut Street to downstream of Hoover Street and leaving the existing Chestnut Street and Naval Railway culverts in-place. Instead of widening the existing open channel, the proposed underground RCB is to preserve the ground surface for existing usage per instructions from OCPW. This option required an additional 1-foot of vertical walls from Chestnut Street to Hoover Street along the top of existing channel to meet the channel freeboard requirements

2.5.3.3. Retaining Part of the Existing I-405 Crossing and Widening the Channel between I-405 and Hoover Street

Another consideration also analyzed was to utilize as many of the existing I-405 crossing facilities as possible due to the complexity of making changes at the I-405 crossing (e.g., removing existing facilities and/or connecting to proposed facilities, etc.). This resulted in a much wider channel from Hoover Street to I-405 crossing (i.e., widening existing 38 feet wide channel to 65 feet wide channel), in addition to changes to culverts immediately downstream of the freeway that would have required additional transition structures, or a separate set of diversion pipes may have been needed to cross the I-405. Both considerations analyzed were discarded as being impractical due to the constructability at I-405 and additional right-of-way cost from I-405 to Hoover Street.

2.5.4. Alternative 3B Hydraulic Results

The hydraulic results for the Alternative 3B show no overtopping from downstream of Hoover Street to Edwards Street. **Figure 6** shows the water surface elevation (WSEL) profile for the entire C02-C04 proposed system. The estimated average channel flow velocity is approximately 7.6 feet per second (fps) from upstream of Edwards Street to downstream of Goldenwest Street and the underground closed conduit is pressurized. The estimated channel flow velocities vary from 5.8 to 12.5 fps and the estimated channel flow depths vary for 8.5 to 10.0 feet within the reach from upstream of I-405 to downstream of Chestnut Street. The estimated channel flow velocities vary from 7.3 to 11.6 fps and the estimated channel flow depths vary for 9.7 to 10.9 feet within the reach from upstream of Chestnut Street to downstream of Hoover Street. A tabulated summary of the results can be found in the hydraulic results in **Appendix A**.

It should be noted there is still channel overtopping from Hoover Street to Beach Boulevard with the current proposed improvements. The overtopping flow depths vary from 0.5 feet at 500 feet upstream of Hoover Street to 1.0 foot at the upstream end of Hoover Street crossing. By replacing the existing 10’ x 9.5’ RCB with 15’ x 9.5’ RCB will eliminate the flow overtopping the Hoover Street but will only decrease the maximum overtopping of 1 foot to approximately 0.5 feet within the reach. Detailed and in-depth analysis is recommended during the final design due to the complexities of confluence with open channel and various sizes of underground conduits at the upstream of Hoover Street crossing which could not be properly modeled by the HEC-RAS 1D approach.

3. Civil Design and Cost Estimating

3.1. Alternative 3A - Railroad Alignment to Edwards

3.1.1. Utilities

A review of utilities identified clusters of existing utilities along the Alternative 3A route in two distinct locations. The first is at Goldenwest Street at the Naval Railway right of way crossing where a full range of utility and oil industry lines crosses the railroad right of way (see **Figure 8**). The second are the utilities that run within Edwards Street for both the Cities of Huntington Beach and Westminster (see **Figure 9** and **Figure 10**). The west side and center of Edwards Street hosts water, sewer, gas, and electrical lines for the city of Huntington Beach. Edwards Street has an existing 63-inch/66-inch storm drain on the Westminster side of the Street, and to a lesser extent sewer and water lines servicing businesses of Westminster Mall. The proposed alignment for Alternative 3A occupies the footprint of the existing storm drain line and avoids most except for where the culverts turn off the Naval Railroad right of way and onto Edwards Street, and a gas line that runs near to the center of Edwards Street. The existing 63-inch/66-inch storm drain which is affected by the project footprint would be removed.

3.1.2. Design Limitations and Assumptions

For utility crossings over the proposed alignment, it was assumed that these pressurized gas and water lines and electrical lines would be adequately relocated either over or under the proposed system.

No geotechnical or structural analysis was performed for the project. Therefore, wall and slab thicknesses of a proposed RCB structure were assumed based on recent and similar projects by Tetra Tech. Also, temporary excavation slope was assumed based on available subsurface information from adjacent facilities.

I-405 crosses the proposed alignment as an overpass bridge with piers. The gap between the piers was wide enough to accommodate the project RCB structure. It was assumed that excavation and construction of the proposed structure between the piers would not affect the structural integrity of the freeway overpass.

3.1.3. Description

The selection process of the horizontal alignment for this alternative is described in Section 2.4, *Alternative Alignments*. The alignment was further adjusted along Edwards Street to either avoid or minimize the impacts by the proposed system to the existing utilities that run along the street.

At OCPW's request, the footprint of the proposed structure was at least 5 feet away from the existing curb and gutter along the street.

A potential alignment that extends through the mall parking lot, along the private access roads, was also considered to avoid the closure of Edwards street and reduce the need for temporary shoring. However, at this time, it is assumed that the alignment along public right of way was preferred. Thus, construction of an alignment through the mall property was not incorporated into the alternative. Should this alternative 3A be selected, a more detailed analysis of this potential alignment revision may be investigated further in detailed design

According to the hydraulic analysis in Section 2.5, *Proposed Alternative Description*, the proposed system would include double 14.5-ft wide by 9.5-ft high RCB culvert along Edwards Street (**Figure 11)** and double 14.5-ft wide by 8.5-ft high RCB culvert along the railroad right-of-way (**Figure 12**). The proposed system would also include a junction structure for a 63-inch/66-inch storm drain along Edwards Street at the bend near the railroad right-of-way.

3.1.4. Temporary Shoring

Without any subsurface investigation for this study or existing boring information available along the project alignment, the boring logs from the as-built plans of existing Westminster Channel were used to determine allowable temporary excavation geometry. Based on the information available and Tetra Tech's experiences from similar projects, a temporary excavation should include 4-foot high vertical cut at the bottom and 1.5 horizontal to 1 vertical slope cut above to the daylight as shown in **Figure 12**. This geometry should be verified in the construction-level study when a subsurface investigation is performed for the project site.

Along Edwards Street, open slope cut for excavation would likely encroach into existing sidewalks on both sides of the street, limiting a contractor's access to the site and requiring removal and replacement of the existing features such as curb and gutter, sidewalk, and trees. This type of excavation would also expose more existing utilities during construction, requiring extensive utility protection measures. Due to limited space available for construction and to avoid adverse impacts to existing facilities, temporary shoring using sheet piles would be used along Edwards Street.

Along the railroad right-of-way which is wider than the street width, open slope cut would be allowed without temporary shoring.

3.1.5. Constructability

During construction, Edwards Street would likely be closed in both traffic directions. To avoid complete shutdown of the entire street during construction, this alternative would require multiple phases or segmentation of construction along the street.

3.2. Alternative 3B - Edwards to Hoover Additional Capacity

3.2.1. Utilities

Utilities located along the Alternative 3B existing route are mostly utility crossings for the existing channel and culverts. The expansion of the existing route facilities will require re-routing or protecting in place these existing utilities. **Figure 13** highlights these utilities at Goldenwest, but also highlights the lack of utilities that extend down Bolsa Avenue where expansion of the culverts along Westminster Mall would be required.

3.2.2. Design Limitations and Assumptions

For utility crossings over the proposed alignment, it was assumed that these utility lines would be adequately relocated either over or under the proposed system.

No geotechnical or structural analysis was performed for the project. Therefore, wall and slab thicknesses of a proposed RCB structure were assumed based on recent and similar projects by Tetra Tech.

Construction of RCB under I-405 would require creating an open trench through the freeway embankment. It is likely that a RCB would be constructed in multiple segments along the alignment and with one or two barrels at a time to reduce the open trench footprint at any time during construction. It is also likely that the open trench would be covered with temporary bridges to allow construction underneath. It is possible that Caltrans would require construction at night time only to ensure construction safety. Based on the discussion with OCPW, tunneling of culverts at the freeway was assumed not to be feasible considering lack of cover below the freeway embankment. This method of open trench would be perceived by the public as very difficult, due to required complete or partial shutdown of I-405, one of the busiest freeways in the region.

For raising of channel walls, the existing channel walls were assumed to be structurally sound to receive wall extension.

3.2.3. Description

The selection process of the horizontal alignment for this alternative is described in Section 2.4, *Alternative Alignments*, and generally follows the alignment of the existing C04 channel.

According to the hydraulic analysis in Section 2.5, *Proposed Alternative Description*, the proposed system would include construction of following features:

- Along Bolsa Ave between Edwards Street (downstream limit) and Goldenwest Street - double 14-ft wide by 6-ft high RCB culverts along Bolsa Avenue (**Figure 14**), running parallel to existing C04 channel which would remain in place
- I-405 area between Goldenwest Street and upstream face of freeway – five 14-ft wide by 6-ft high RCB culverts (**Figure 15**) to replace existing two RCBs and two RCPs.
- From upstream of I-405 to Chestnut Street – raising channel walls by 0.5 or 1.0 foot on both sides of the channel by adding reinforced concrete wall sections with dowels on the top of existing walls (**Figure 16**)
- Replacement of 2 existing culverts at Chestnut Street and Naval railway with free span bridges

3.2.4. Temporary Shoring

Along Bolsa Avenue, shoring on the south edge of RCB would be required to limit the impacts of construction to a westbound direction roadway. On the north edge of RCB, the existing RCB would provide support for excavation, making temporary shoring unnecessary (**Figure 14**).

3.2.5. Constructability

During construction, Bolsa Avenue would likely be closed in a westbound direction, limiting the mall access from south. To avoid complete shutdown of the westbound street during construction, this alternative would require multiple phases or segmentation of construction along the street.

Complete or partial shutdown of I-405 during construction would require extensive planning and implementation in freeway traffic detour plan, construction schedule, and safety plan to work on freeway. If permitted, it is likely that construction would occur during nighttime hours.

3.3. Cost Estimates

Conceptual level cost estimates have been developed for the two options discussed above. Detailed quantity take-offs were developed for the primary construction components (i.e. earthwork, concrete and shoring) and other assumptions were made to follow with the conceptual level design.

The cost estimates were developed to be consistent with USACE Feasibility Study requirements. The cost estimate back-up information, which includes detailed cost estimates, unit prices, quantity calculations, and abbreviated risk analysis for contingency development, can be found in Attachment C.

3.3.1. Unit Prices

Unit prices for most of the cost items were taken from the RS Means construction costbook. The unit prices were adjusted with local multipliers that modified the base costs to reflect localized labor, equipment and material prices.

3.3.2. Non-Construction Costs

Project costs for non-construction elements have been included in the estimates. These costs include planning, engineering and design (PED) and construction management (CM) costs. These items are based on percentages of the overall construction costs, and currently the estimate assumes 10.0% for PED and 6.0% for CM, which are consistent with typical percentages used by the USACE.

3.3.3. Real Estate Costs

Estimated areas have been developed that can be used to determine the costs to acquire necessary lands for construction of both alternatives. These include temporary construction easements, and permanent easements for underground structures as indicated in Table 2 and displayed in **Figure 17**. The estimated cost for the new easement associated with Alternative 3A is $6 million.

Table 2: Alternative Right of Way Estimates

Alternative	Ownership	Detail	Acres
	Private	Permanent Private Purchased Easement (Underground)	3.83
	Private	Temporary Construction Easement	3.74
	Public	Permanent Expanded Public Easement (Underground)	1.70
3A	Public	Temporary Construction Easement	0.32
	Private	Existing Private Easement (Underground)	0.12
	Private	Permanent Private Purchased Easement (Underground)	0.06
3B	Private	Temporary Construction Easement	0.03

	Public	Existing Public Easement	1.61
	Public	Existing Public Easement (Underground)	0.77
	Public	Permanent Expanded Public Easement (Underground)	2.21
	Public	Temporary Construction Easement	1.02

3.3.4. Contingencies

Contingencies represent allowances to cover unknowns, uncertainties and/or unanticipated conditions that are not possible to adequately evaluate from the data on hand at the time the cost estimate is prepared, but must be represented by a sufficient cost to cover the identified risks. An abbreviated risk analysis (ARA) has been prepared for this project to determine alternative specific contingencies.

3.3.5. Alternative Cost Summaries

The following tables reflect summaries of the construction cost estimates (see Appendix C for detailed cost estimates).

Table 3: Alternative 3A Summary Cost Estimate

Item Description	Quantity	UOM	First Cost	Contingency	Total Cost
Mob/Demob and Site Prep	1	LS	$3,332,000	32.9%	$4,428,000
Earthwork	1	LS	$5,582,000	40.4%	$7,838,000
Culverts and Channels	1	LS	$32,197,000	40.4%	$45,208,000
Demolition and Relocations	1	LS	$1,317,000	36.8%	$1,801,000
Traffic Control	1	LS	$100,000	38.7%	$139,000
Planning, Engineering and Design	1	LS	$4,253,000	34.8%	$5,733,000
Construction Management	1	LS	$2,552,000	34.8%	$3,440,000
Real Estate	1	LS	TBD	-	TBD-
Alternative 3A Total Cost:			**$49,333,000**	**39.0%**	**$68,587,000**

Table 4: Alternative 3B Summary Cost Estimate

Item Description	Quantity	UOM	First Cost	Contingency	Total Cost
Mob/Demob and Site Prep	1	LS	$3,034,000	32.9%	$4,032,000
Earthwork	1	LS	$2,416,000	40.4%	$3,392,000
Culverts	1	LS	$19,310,000	40.4%	$27,113,000
Demolition and Relocations	1	LS	$4,350,000	36.8%	$5,949,000
Traffic Control	1	LS	$9,600,000	72.1%	$16,524,000
Planning, Engineering and Design	1	LS	$3,871,000	34.8%	$5,218,000
Construction Management	1	LS	$2,323,000	34.8%	$3,131,000
Real Estate	1	LS	$TBD	-	TBD
Option A Total Cost:			**$44,904,000**	**46.2%**	**$65,359,000**

4. Alternative Comparisons and Recommendation

Two separate options for Alternative 3 were evaluated in this effort. Since there is not sufficient capacity within the C04 channel near Westminster Mall these options considered means to reduce flooding and improve conveyance though the reach between Hoover and Edwards Streets.

Alternative 3A includes a diversion structure along the abandoned Navy Railway alignment and continues down Edwards Street to the same location of the existing culverts on Bolsa Avenue. A diversion structure diverts approximately 40% of the flow downstream of Hoover into two underground 14-ft wide by 8.5-ft high RCB's. These transition to 14-ft wide by 9.5-ft RCB's along Edwards Street and include flows from the existing 63" RCP that conveys flow from areas to the north.

Alternative 3B includes modifications to the existing C04 channel. This includes replacing two existing culverts (Naval Railway and Chestnut Street) with free span bridges and replacing the existing I-405 crossing with five 14' x 9.5' RCBs. Three of the proposed RCBs on the northside will be connecting to the existing three 14' x 9.5' RCBs that are located in the Westminster Mall Parking lot. The other two proposed RCBs will be transiting into two 14' x 6' RCBs along Bolsa Avenue and joining the open channel downstream of Edwards Street. Between Chestnut Street and the I-405 the channel walls will be raised from between 0.5 to 1.5 feet to meet OCPW freeboard requirements.

Both alternatives meet the objective of reducing overbank flooding and improving conveyance. Differences in the alternatives are compared below.

4.1. Costs

Cost estimates for the two alternatives are described in Section 3.3 above and detailed in Appendix C. Not including land costs, Alternative 3A is approximately $69 million and Alternative 3 is approximately $65 million.

Most of the costs for 3A are attributed to the length of the diversion route and associated excavation and culverts to be installed. Since Alternative 3B follows the existing alignment and modifies culverts the costs associated with the culverts are much less but still make up a substantial portion of the overall cost. Traffic control associated with modifications to the I-405 are also a substantial portion of the cost ($16.5 million) of Alternative 3B.

4.1. Right of Way

The right of way required to implement Alternative 3A includes approximately 10 acres. Most of this is along the Navy Railway alignment and the rest within public right of way along Edwards. The estimated cost to acquire right of way along this route is $6 million.

Right of way requirements to construct Alternative 3B is less because it is largely within existing project right of way. Approximately 4.25 acres of additional right of way including temporary construction easements and easements within both public and private property are required for this alternative. This includes a temporary construction easement associated with construction under the I-405.

4.2. Construction

Construction of Alternative 3B will be more complicated than that of Alternative 3A due to the crossing at the I-405. There is minimal cover where the existing culverts pass under the freeway and therefore removal of existing structures and placement of new ones will require open cut. If this can be approved by CALTRANS it will require significant traffic controls and likely nighttime construction.

Other options at this crossing may include construction of a slab bridge for construction, or an inverted siphon design. It is assumed that slab bridge for construction would have a similar cost to what is estimated. An inverted siphon at this location would allow lowering the invert to allow for enough cover for jack and bore construction but would still likely cost more than the selected alternative.

4.2.1. Traffic delays

Both alternatives would have similar impacts to traffic on surface streets. Alternative 3A construction would impact traffic on Edwards Street and Alternative 3B traffic on Bolsa Avenue. The impacts of these would likely be similar.

Traffic delays on the I-405 associated with Alternative 3B could be significant. According to CALTRANS 2016 Traffic Volumes[1] the average annual daily traffic on this part of the I-405 is approximately 264,000. This is a large volume of traffic and one of the busiest freeways in the

[1] http://www.dot.ca.gov/trafficops/census/volumes2016/Route280-405.html

region. Therefore, delays to traffic during construction could have a significant impact that should be considered.

4.3. Draft Recommendation

Based on hydraulic modeling the existing system of culverts passing under the I-405 and continuing along Bolsa Avenue are a bottleneck that restrict the ability of the C02-C04 system to pass flood flows. This report recommends removal of the existing culvers and replacement with a more efficient configuration that meets the objective of passing the 1% discharge and reducing overtopping of the upstream channel.

There is minimal cover over the culverts where they pass the I-405. That combined with the fact that this is a very busy section of freeway with an AADT of approximately 264,000 at this location complicates construction. Construction would either need to be accomplished through open cut or construction of a temporary bridge type structure. This would require coordination and approval by CALTRANS, and if approved would likely require construction during night time hours to reduce traffic impacts.

Alternative 3A avoids construction on the I-405 by implementing a diversion along the abandoned Navy Railway alignment. This alternative is slightly costlier than 3B largely due to its length and amount of excavation and concrete required. In addition, the right of way has an estimated cost of $6 million for acquisition. Including the cost of the Navy Railway alignment it is approximately $9 million more than modifying the I-405.

Although Alternative 3A costs more than Alternative 3B it is recommended that alignment be considered for Alternative 3. It is not certain that CALTRANS will allow the removal and replacement of the existing culvert systems through the I-405. If the freeway had to be closed or traffic were to be delayed the economic costs of delays to that much traffic would be significant, likely millions of dollars in lost time. Therefore, it seems prudent to avoid the challenges of modifications to this location and seek an alternate route.

FIGURES

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Figure 1: Project Location Map

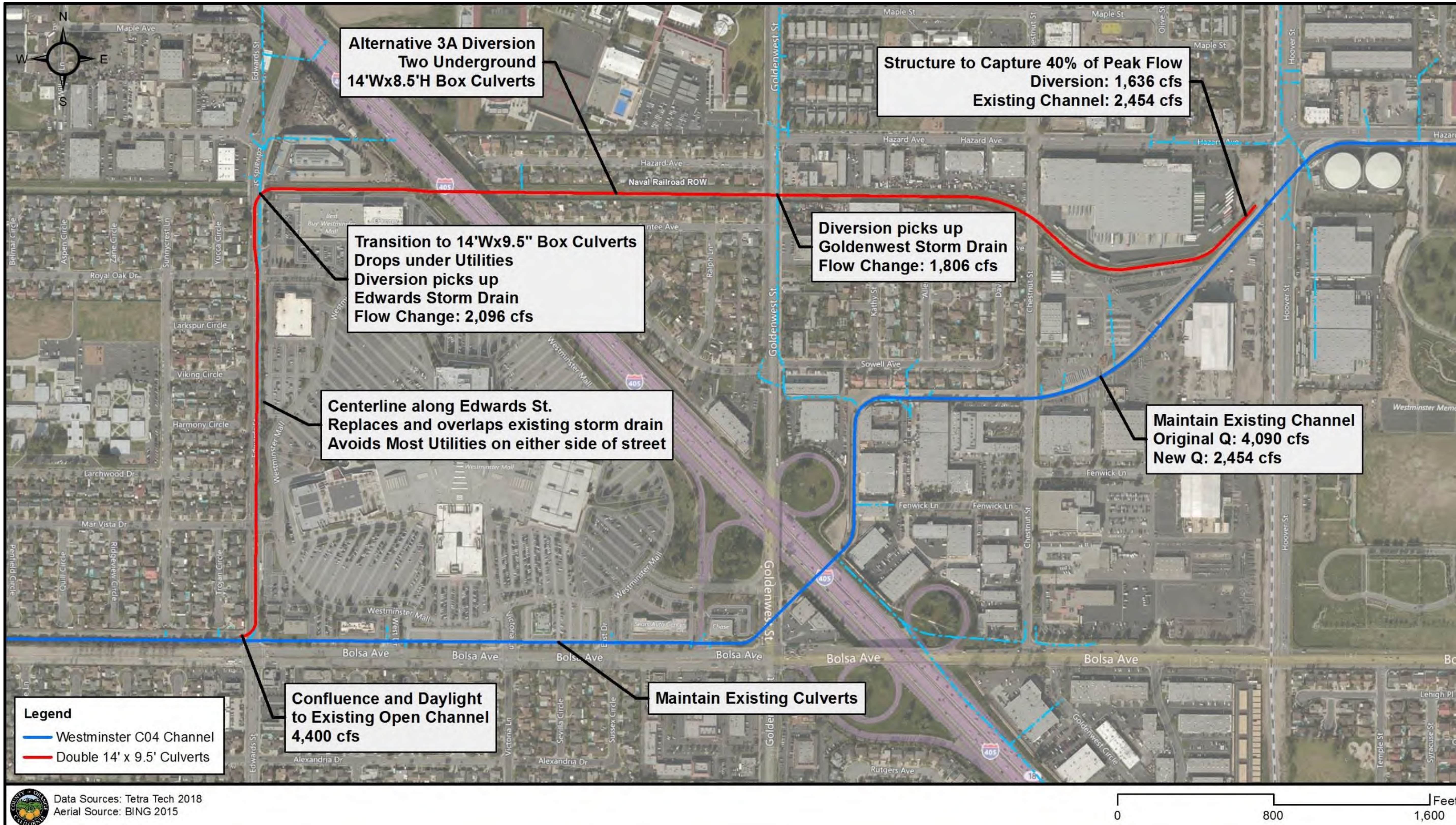


Figure 2: Alternative 3A Overview Map

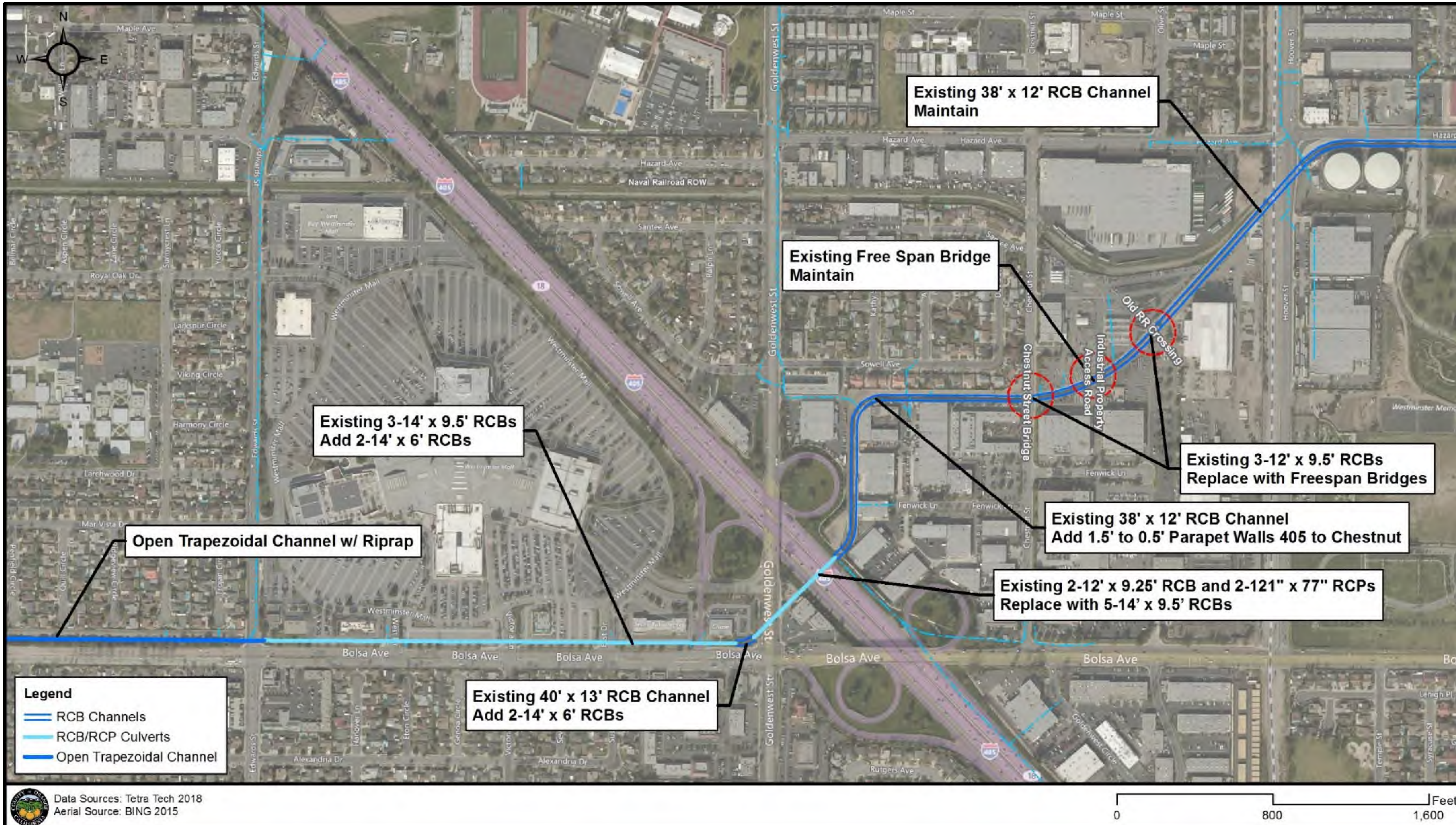


Figure 3: Alternative 3B Overview Map

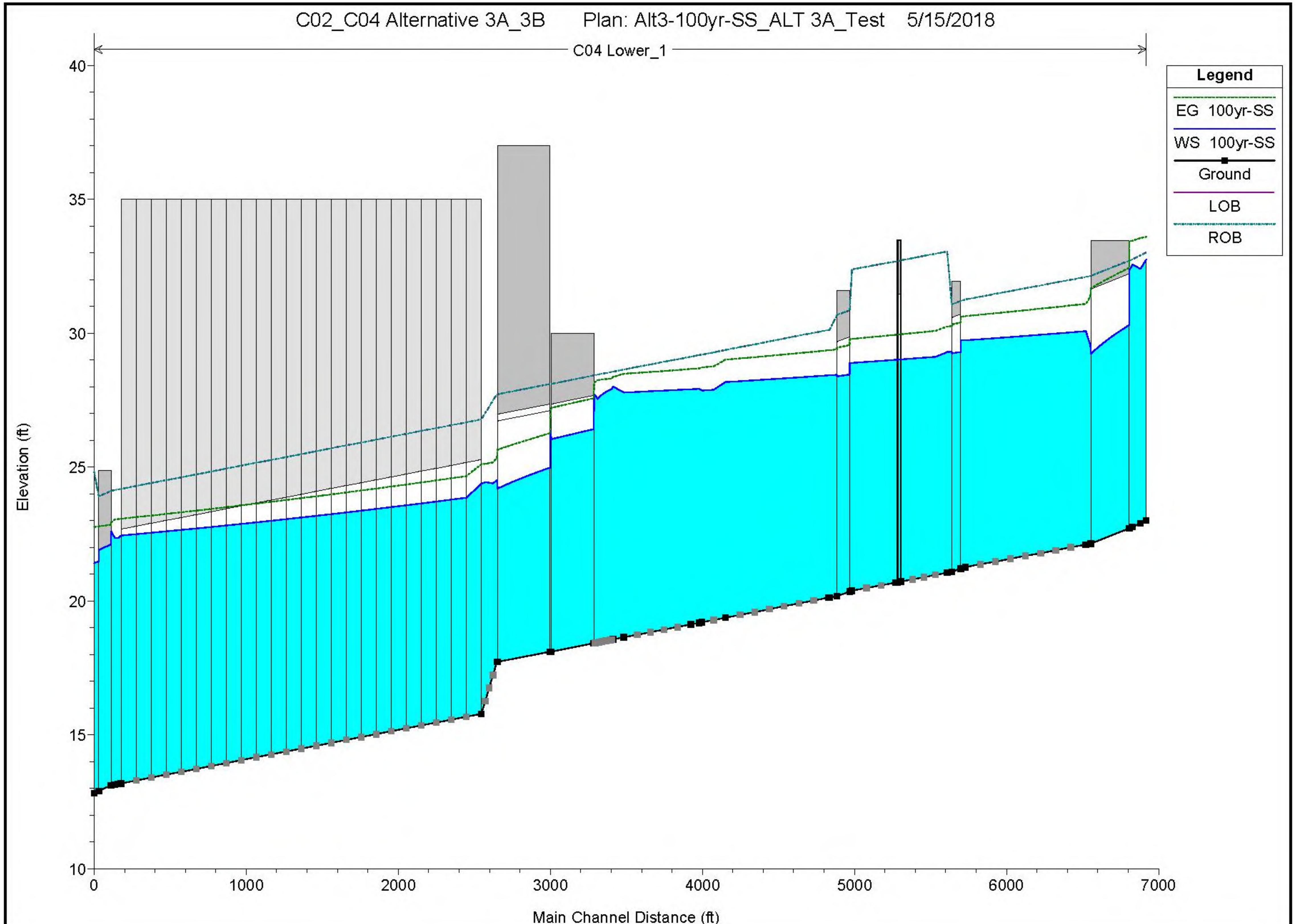


Figure 4: Alternative 3A Profile Results – Main Channel (Hoover to Edwards)

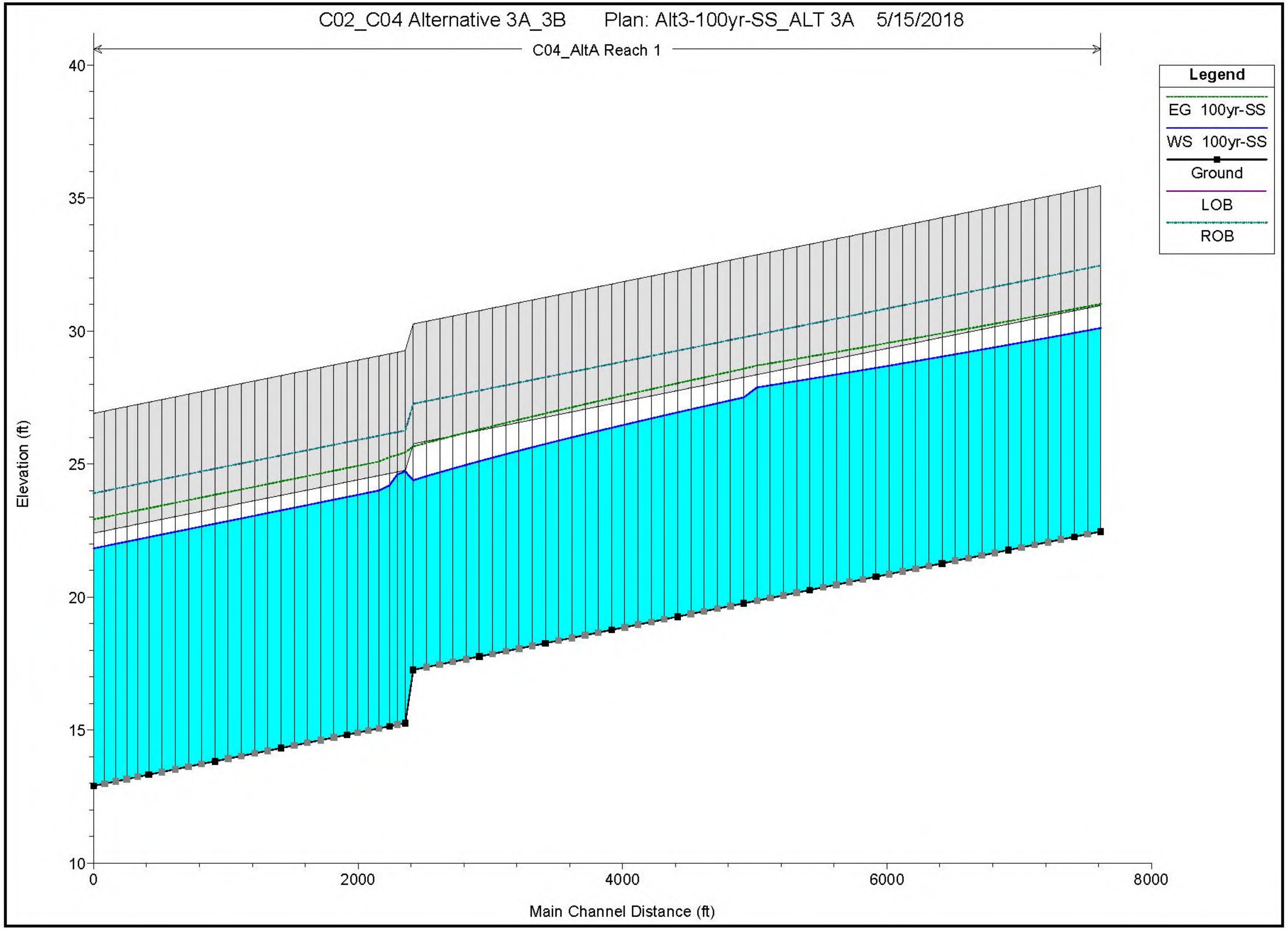


Figure 5: Alternative 3A Profile Results – Diversion Route (Hoover to Bolsa & Edwards)

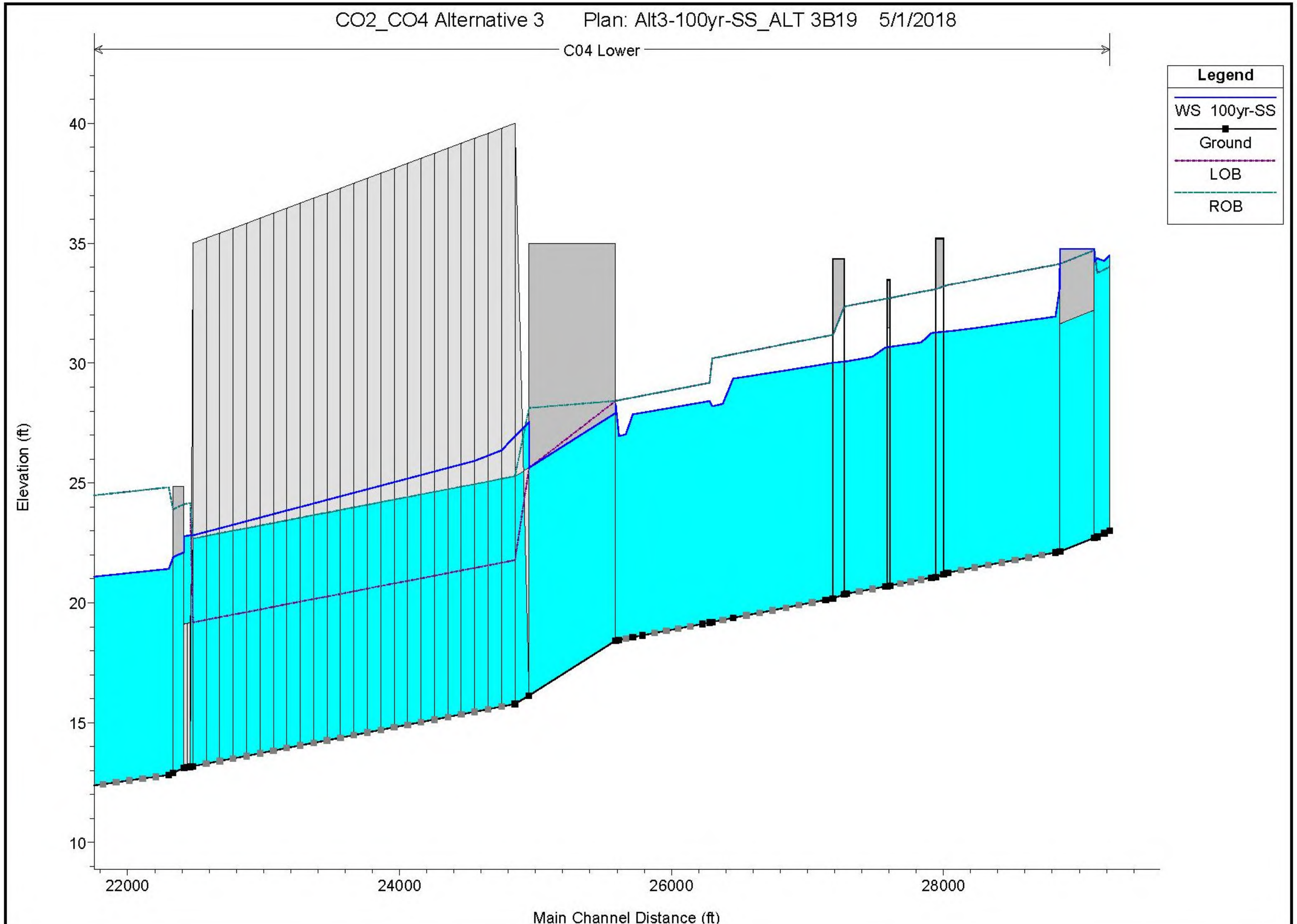


Figure 6: Alternative 3B Profile Results

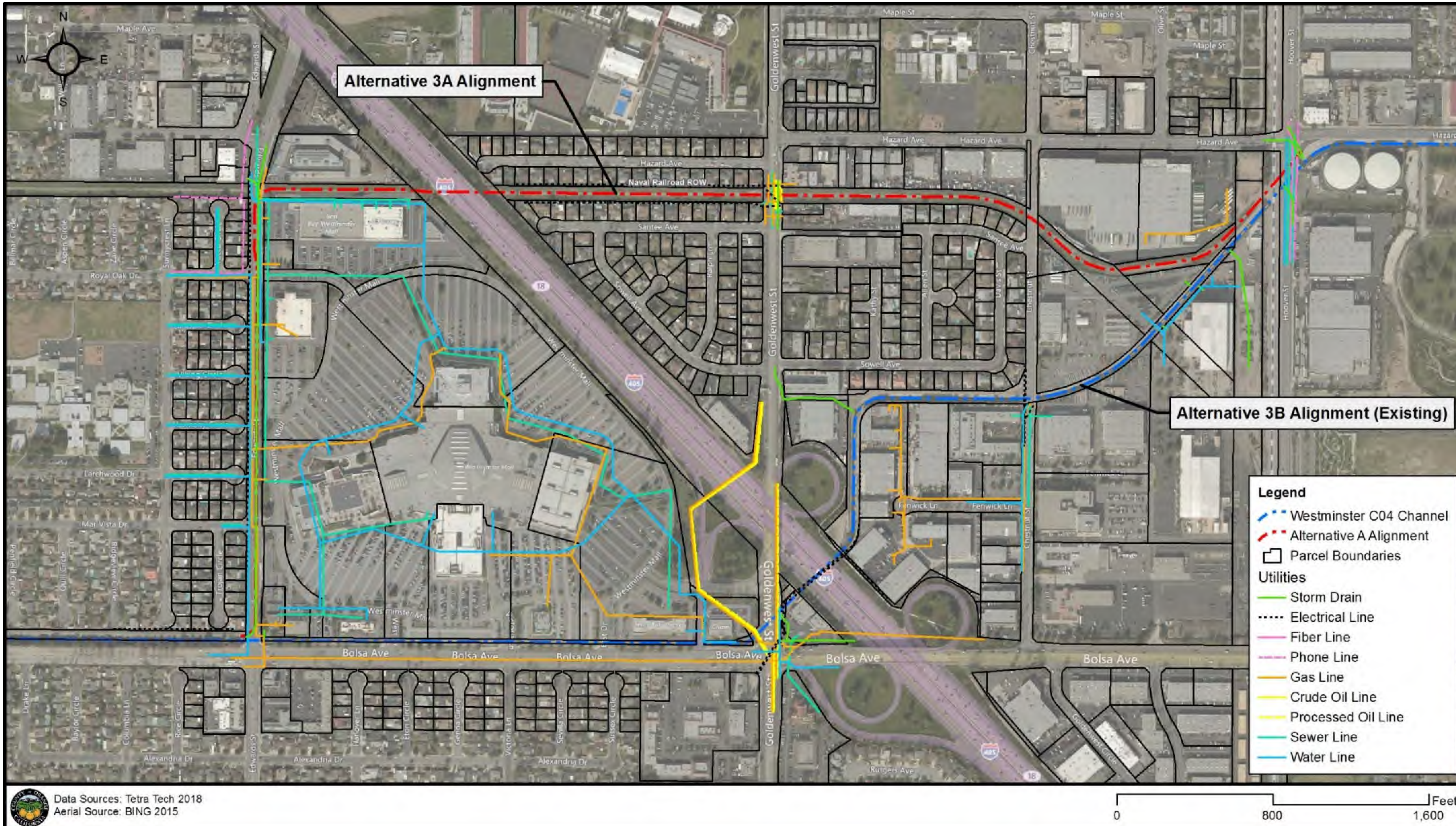


Figure 7: Utilities Overview Map

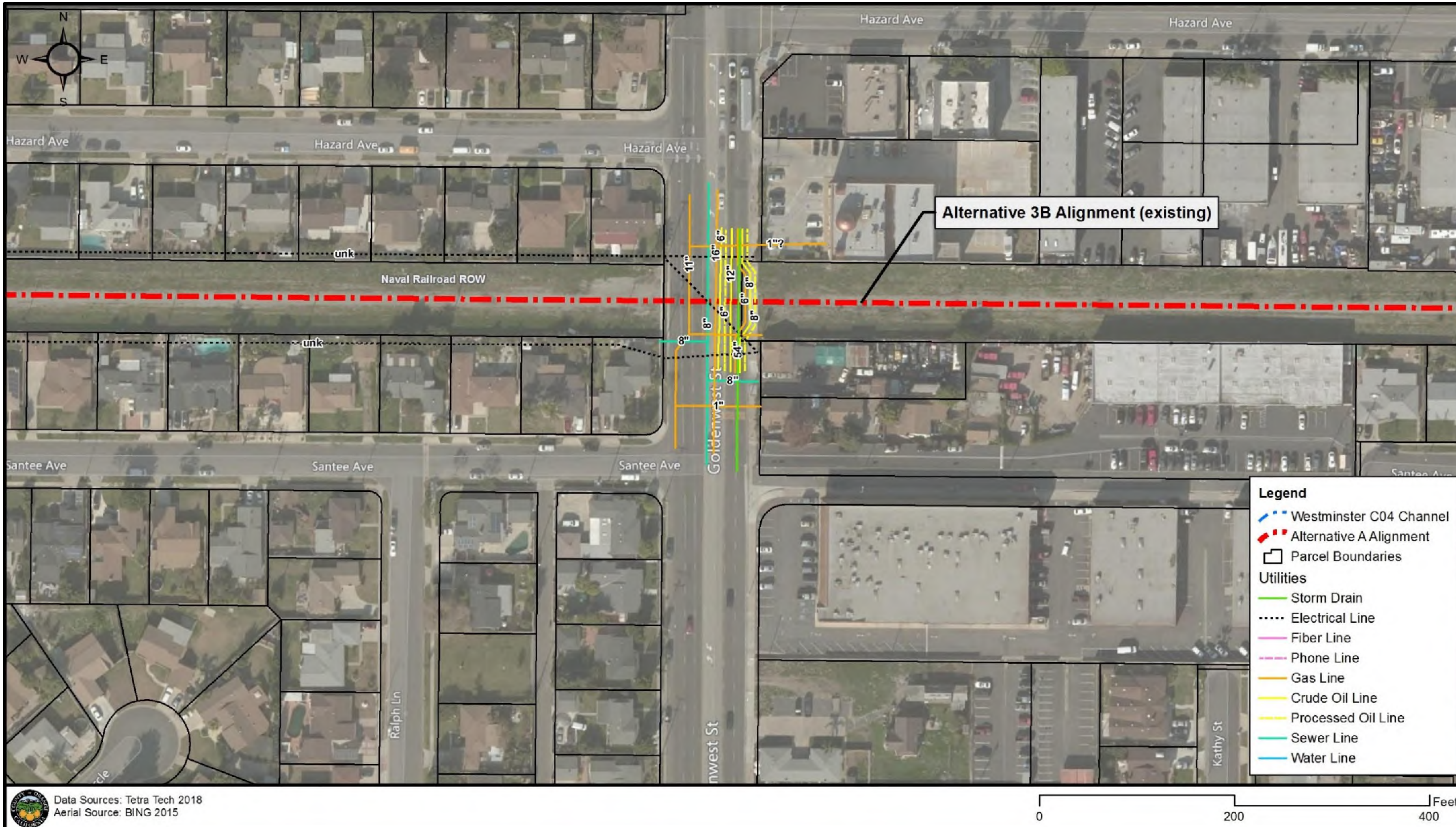


Figure 8: Utilities at Goldenwest (Alt 3A)

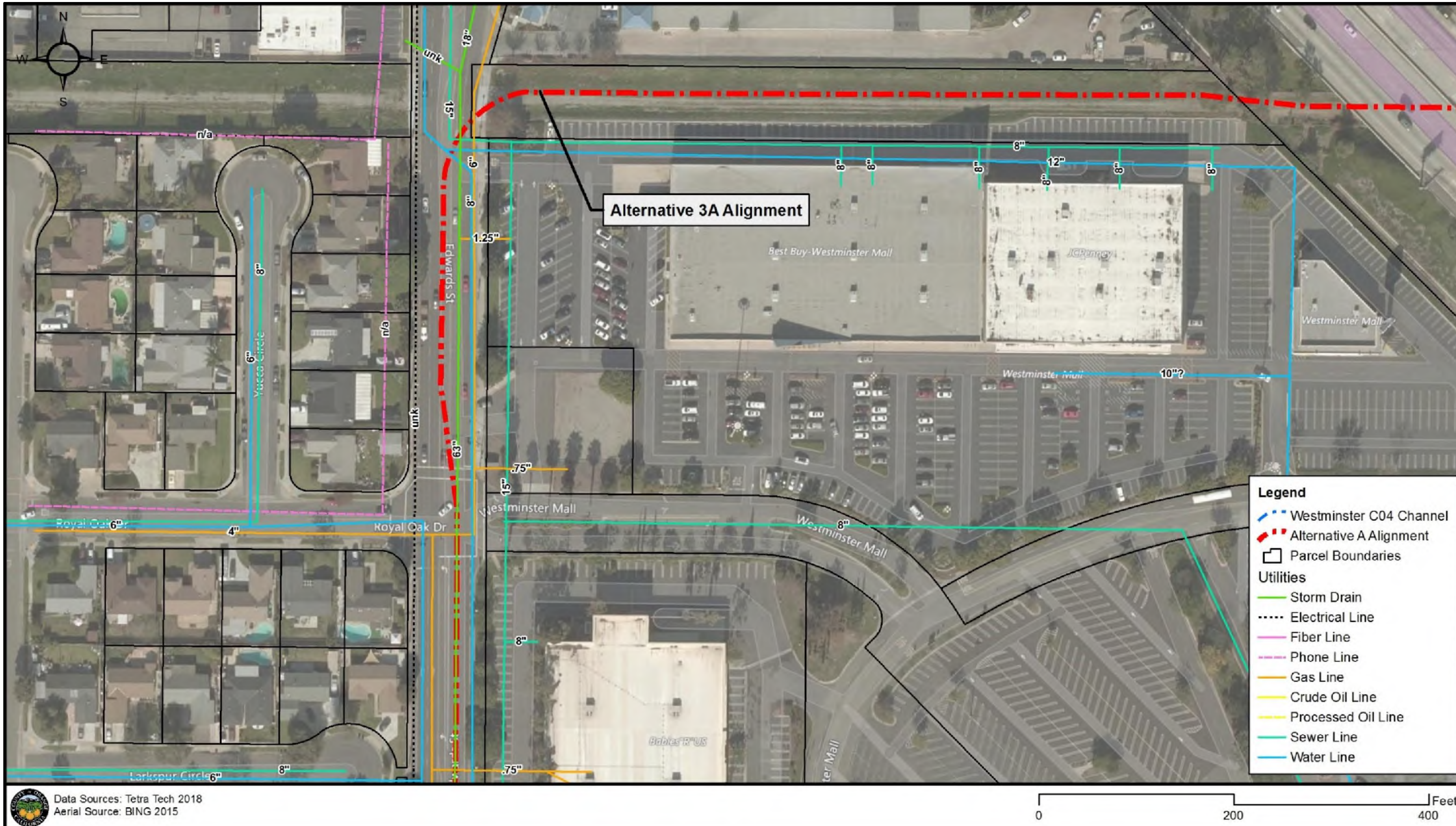


Figure 9: Utilities at Edwards 1 of 2 (Alt3A)

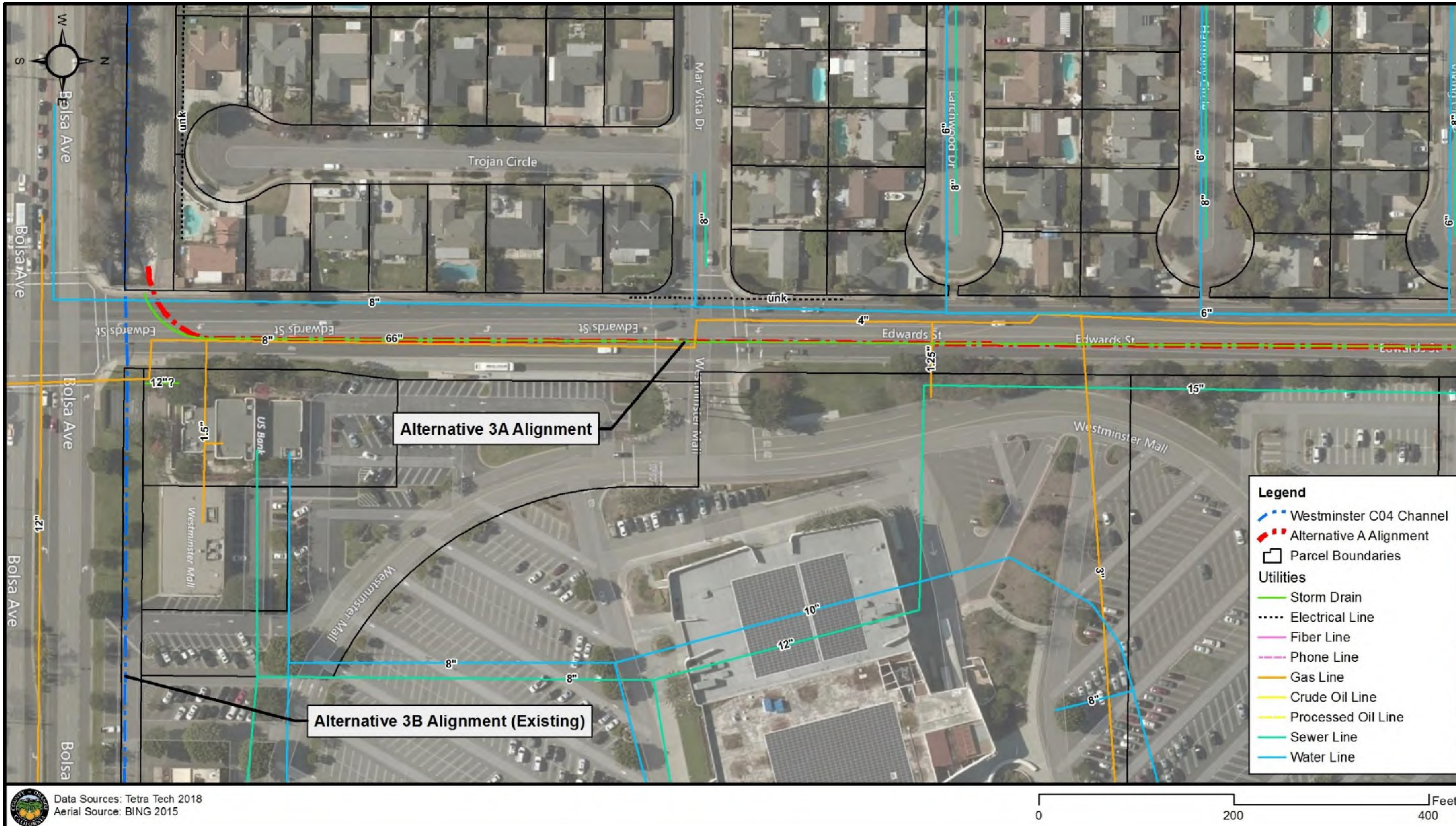


Figure 10: Utilities at Edwards 2 of 2 (Alt3A)

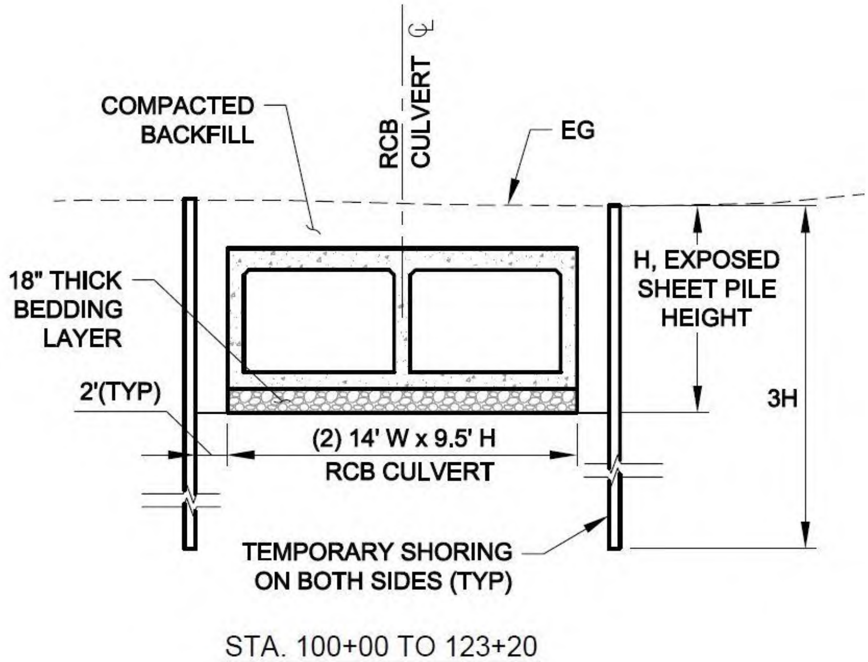


Figure 11: Typical Section along Edwards Street (Alt3A)

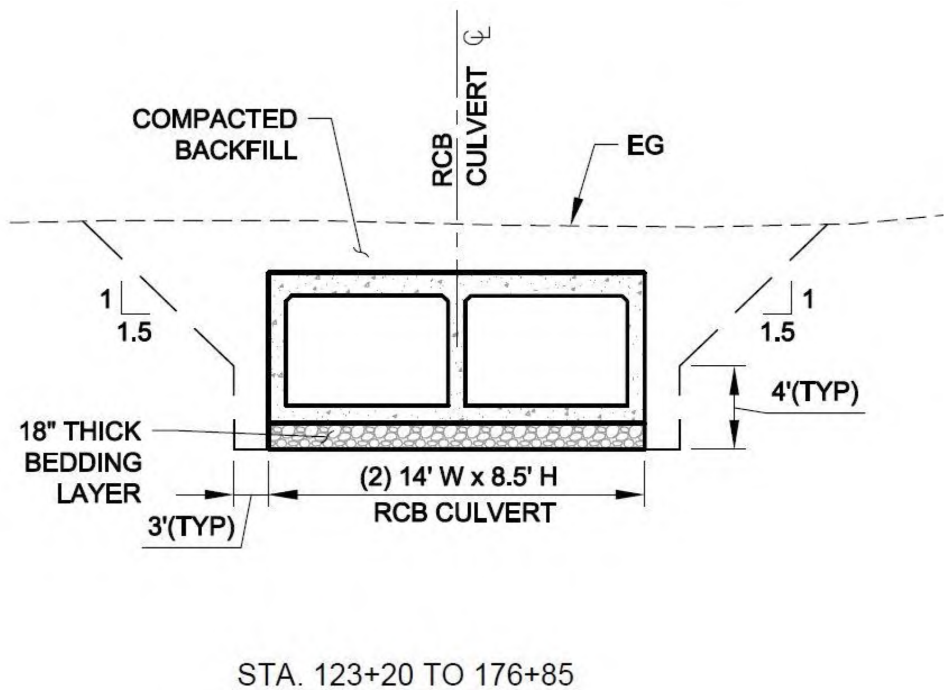


Figure 12: Typical Section along Railroad Right-of-Way (Alt3A)

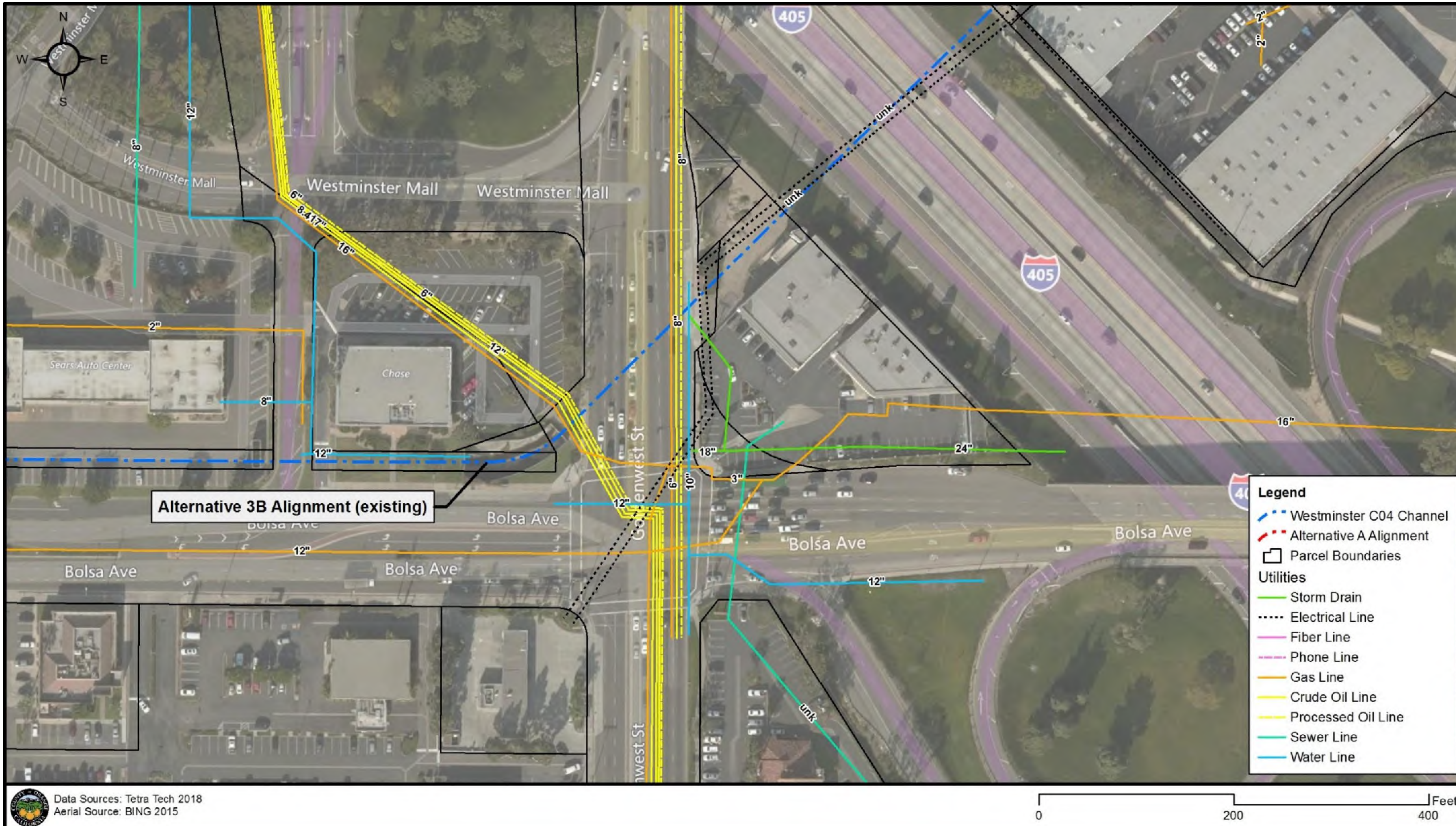


Figure 13: Utilities at Goldenwest/Bolsa (Alt3B)

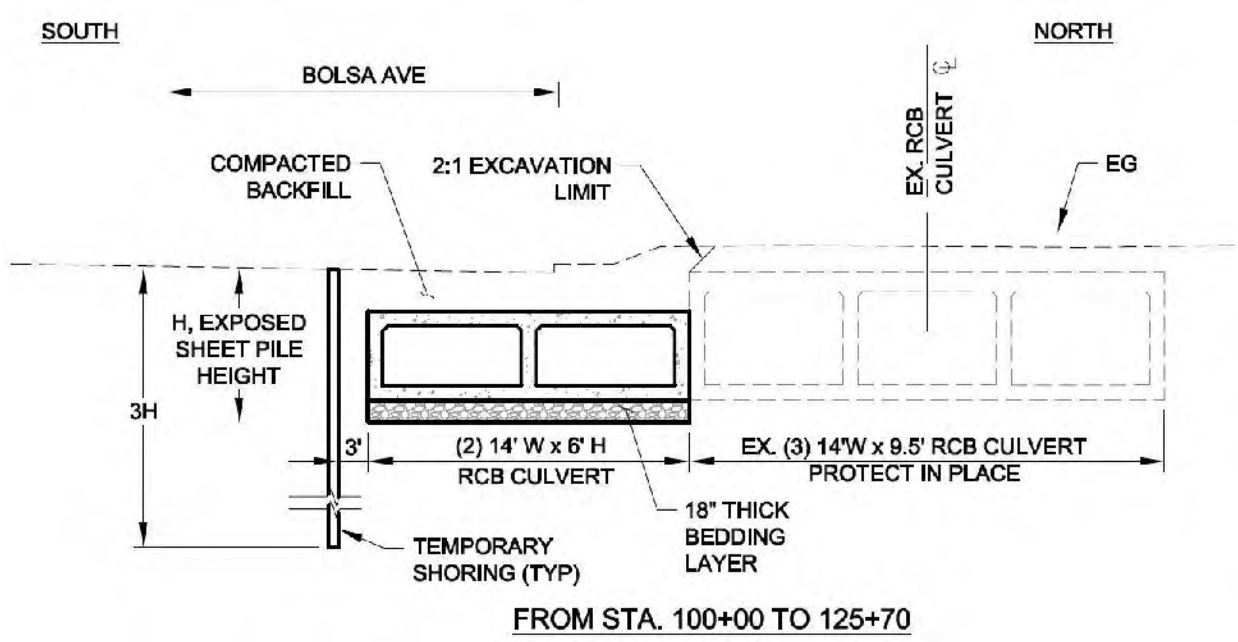


Figure 14: Typical Section along Bolsa Avenue (Alt3B)

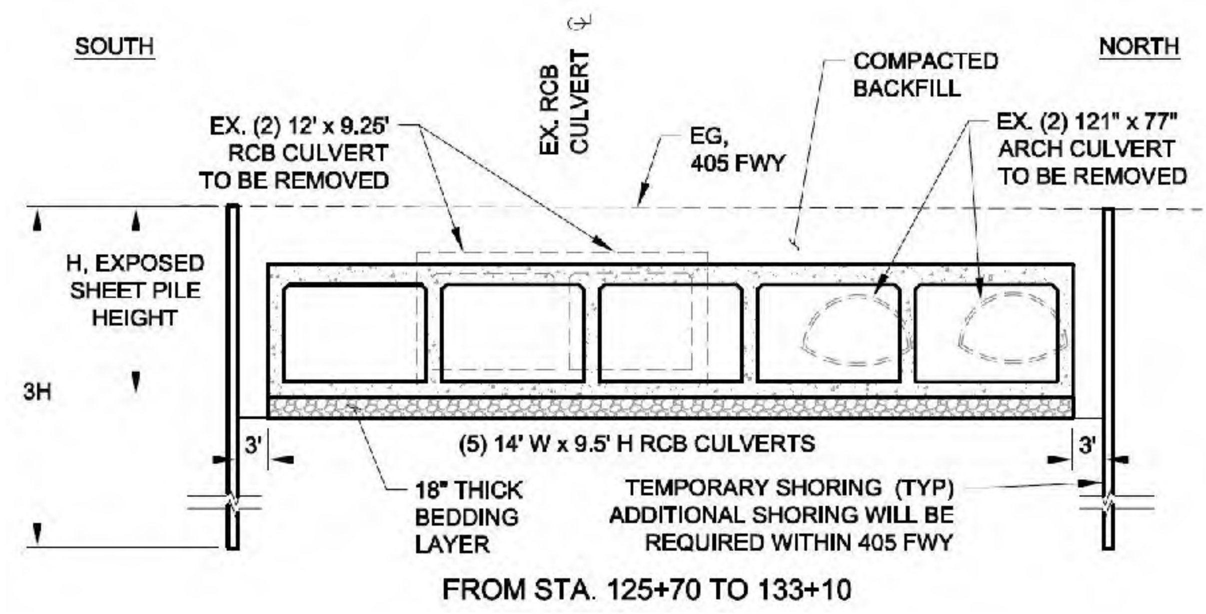


Figure 15: Typical Section under I-405 (Alt3B)

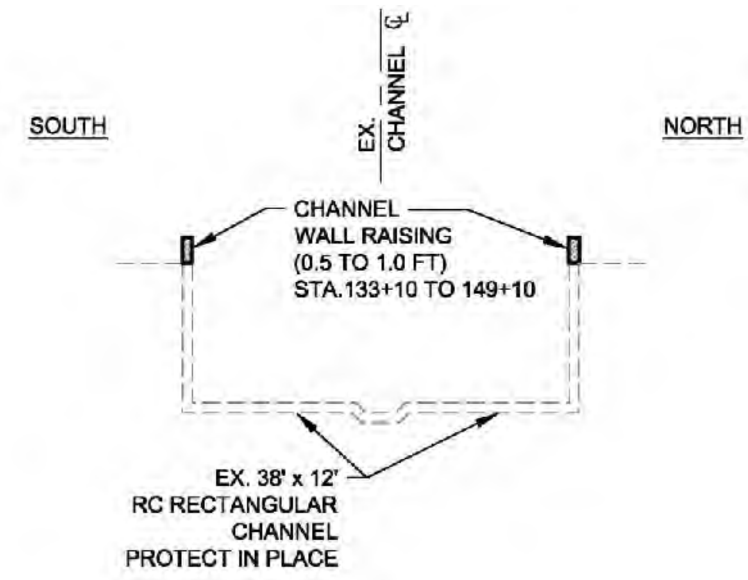
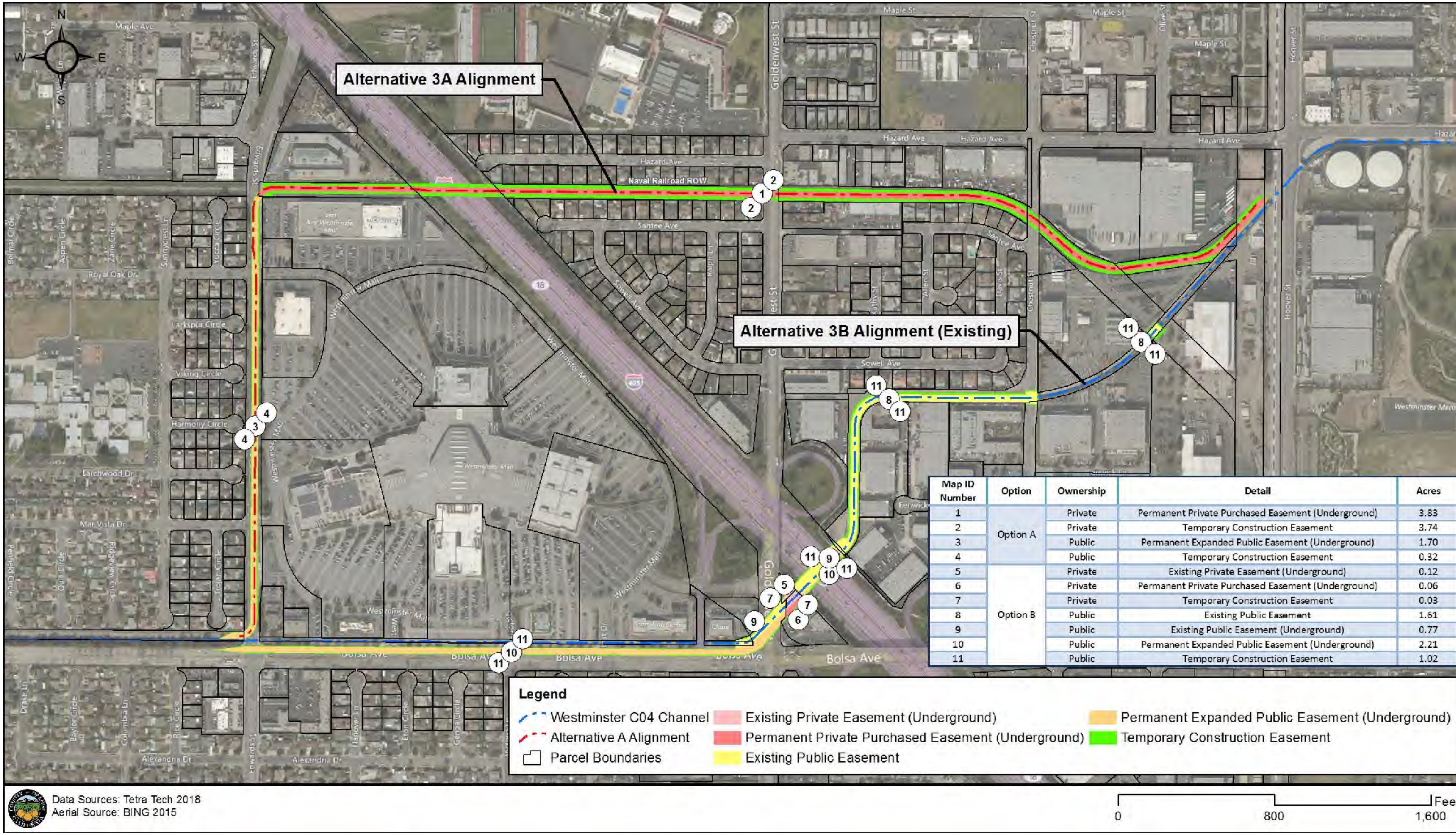
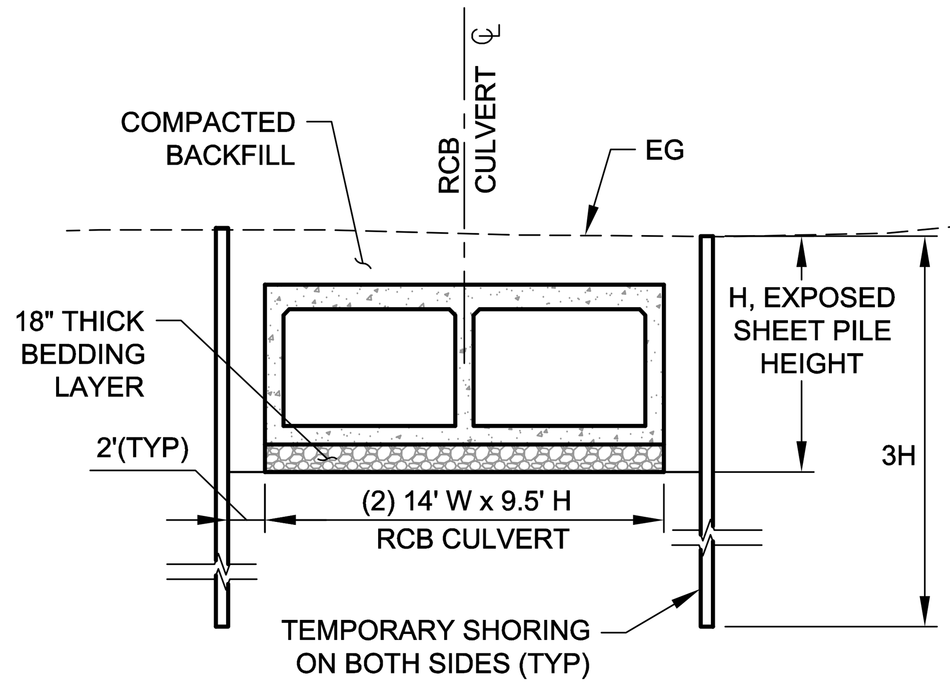


Figure 16: Typical Section for Channel Wall Raising (Alt3B)

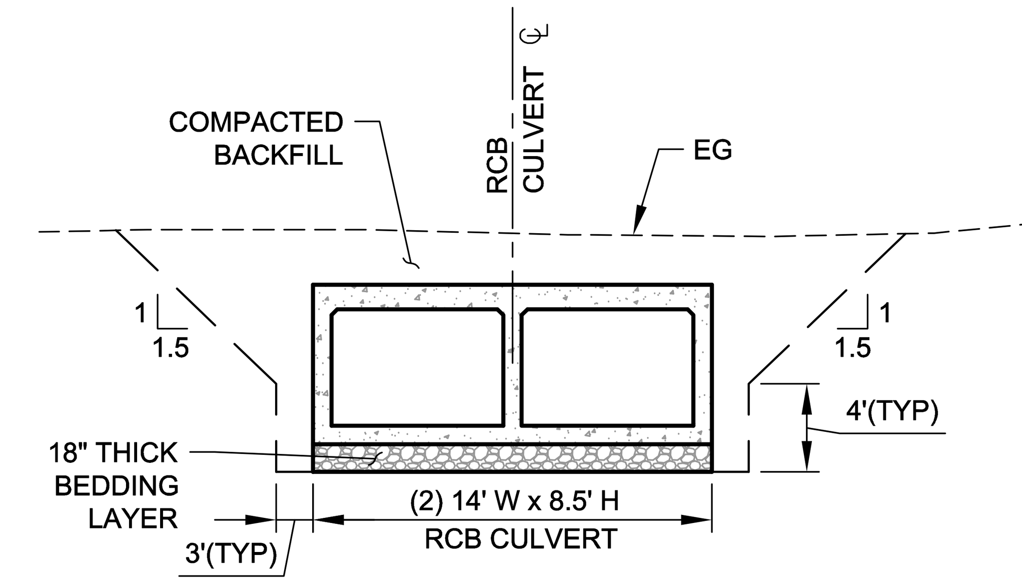


Map ID Number	Option	Ownership	Detail	Acres
1	Option A	Private	Permanent Private Purchased Easement (Underground)	3.83
2		Private	Temporary Construction Easement	3.74
3		Public	Permanent Expanded Public Easement (Underground)	1.70
4		Public	Temporary Construction Easement	0.32
5	Option B	Private	Existing Private Easement (Underground)	0.12
6		Private	Permanent Private Purchased Easement (Underground)	0.06
7		Private	Temporary Construction Easement	0.03
8		Public	Existing Public Easement	1.61
9		Public	Existing Public Easement (Underground)	0.77
10		Public	Permanent Expanded Public Easement (Underground)	2.21
11		Public	Temporary Construction Easement	1.02

Figure 17: Estimated Right of Way Requirements for Each Alternative Alignment



STA. 100+00 TO 123+20
TYPICAL RCB CULVERT SECTION
N.T.S.



STA. 123+20 TO 176+85
TYPICAL RCB CULVERT SECTION
N.T.S.

CONSTRUCTION NOTES

1. CONSTRUCT RCB CULVERT PER PLAN AND TYPICAL SECTION HEREON.
2. CONSTRUCT A DIVERSION OR JUNCTION STRUCTURE BETWEEN NEW RCB CULVERT AND EXISTING CHANNEL PER PLAN.
3. CONSTRUCT A JUNCTION STRUCTURE TO CONNECT WITH EXISTING EDWARDS STORM DRAIN PER PLAN.
4. DEMO AND REMOVE EXISTING 63"/66" DIAMETER STORM DRAIN RCP WITHIN FOOTPRINT OF NEW RCB CULVERT PER PLAN.
5. PROVIDE UTILITY CROSSING EXISTING UTILITY PER PLAN.
6. RELOCATE EXISTING UTILITY TO OUTSIDE OF NEW RCB CULVERT FOOTPRINT PER PLAN.

PLAN
1" = 250'

COUNTY OF ORANGE CALIFORNIA

MARK	DESCRIPTION	DATE	APPR.

PREPARED UNDER THE RESPONSIBLE CHARGE OF:

DATE

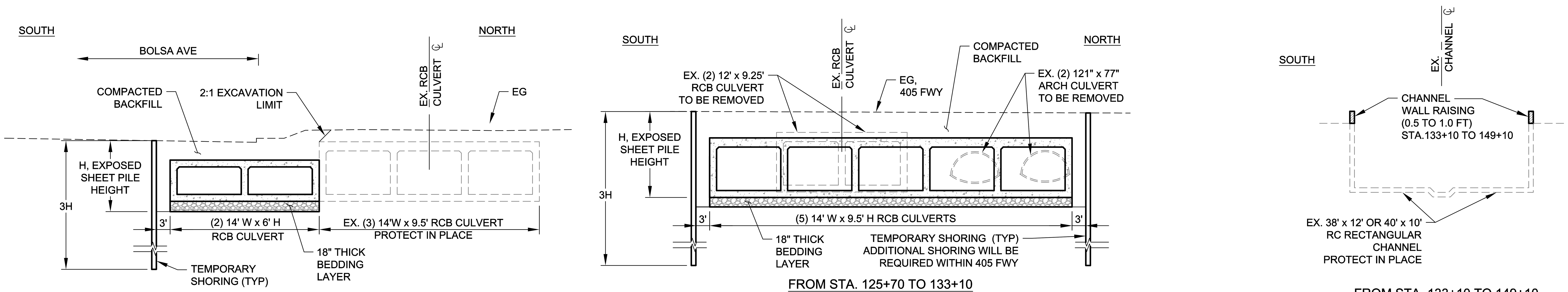
County of Orange
OC PublicWorks

DESIGNED BY: J.S.
DRAWN BY: J.S.
CHECKED BY: YHC
PREPARED BY: TETRA TECH
DRAWING NO.: XX-XXX-X
FILE NAME: XXXXX
PLOT DATE: 2018/04/XX
SCALE: AS SHOWN

WESTMINSTER WATERSHED STUDY
OC FACILITY NO. C02 & C04

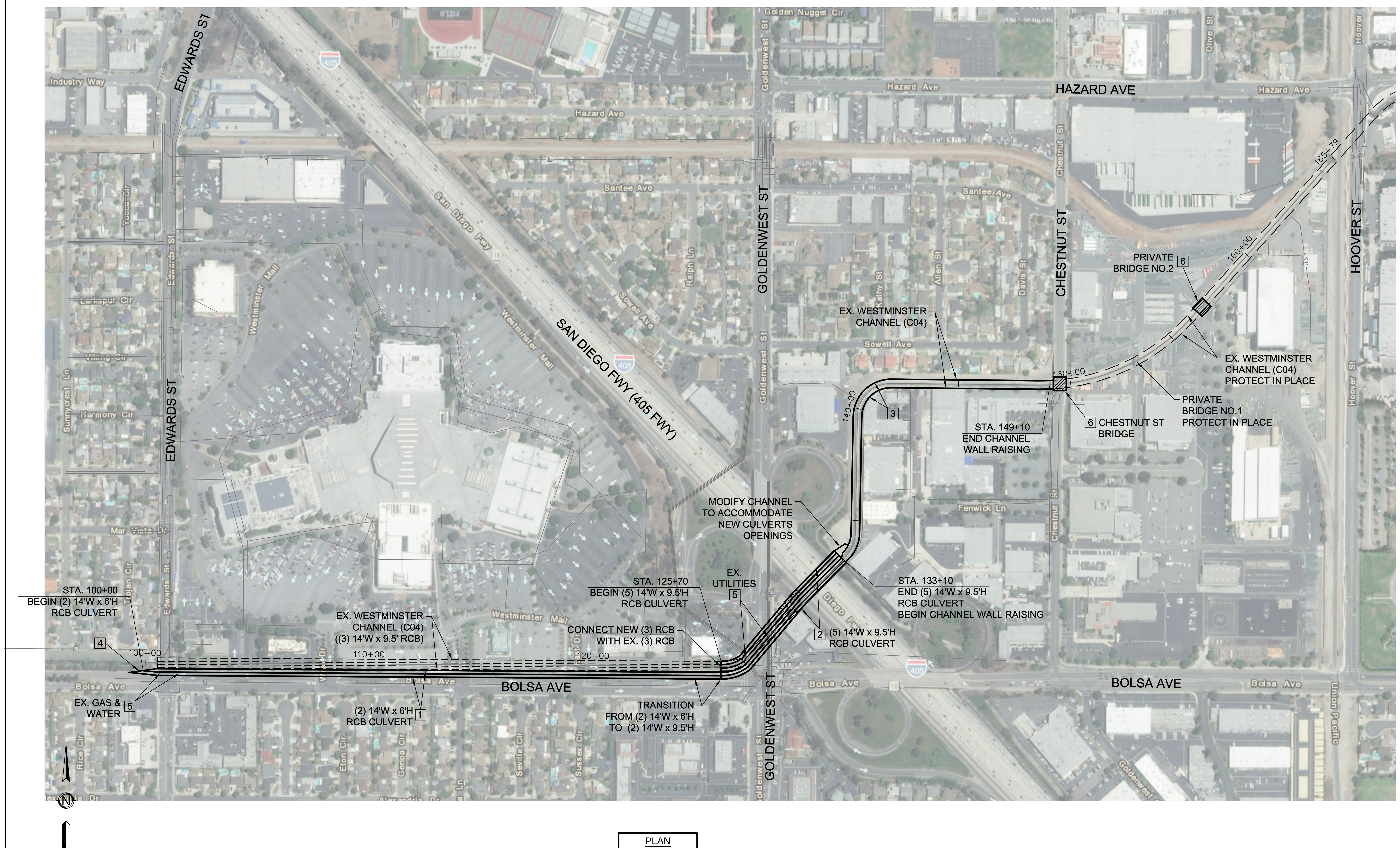
PLAN
ALTERNATIVE A

SHEET
1
OF 2



TYPICAL RCB CULVERT SECTION

N.T.S.



PLAN
1" = 250'

250' 125' 0 250' 500'

CONSTRUCTION NOTES

1. CONSTRUCT RCB CULVERT PER PLAN AND TYPICAL SECTION HEREON.
2. REPLACE EXISTING CULVERTS WITH (5) 14' W x 9.5' H RCB CULVERT UNDER FREEWAY PER PLAN AND TYPICAL SECTION HEREON.
3. CONSTRUCT RC CHANNEL WALL RAISING ON TOP OF EXISTING CHANNEL WALLS PER PLAN AND TYPICAL SECTION.
4. CONSTRUCT A DIVERSION OR JUNCTION STRUCTURE BETWEEN NEW RCB CULVERT AND EXISTING CHANNEL PER PLAN.
5. PROVIDE UTILITY CROSSING FOR EXISTING UTILITY PER PLAN.
6. REPLACE EXISTING BRIDGE CULVERT WITH A FREE-SPAN BRIDGE PER PLAN.

COUNTY OF ORANGE CALIFORNIA

MARK	DESCRIPTION	DATE	APPR.

PREPARED UNDER THE RESPONSIBLE CHARGE OF: DATE

County of Orange
OC PublicWorks

DESIGNED BY: J.S.	DRAWN BY: J.S.	CHECKED BY: YHC
PREPARED BY: TETRA TECH	DRAWING NO.: XX-XXX-X / FILE NAME: XXXXX	SCALE: AS SHOWN / PLOT DATE: 2018/04/XX

WESTMINSTER WATERSHED STUDY
OC FACILITY NO. C02 & C04

PLAN
ALTERNATIVE B

SHEET
2
OF 2