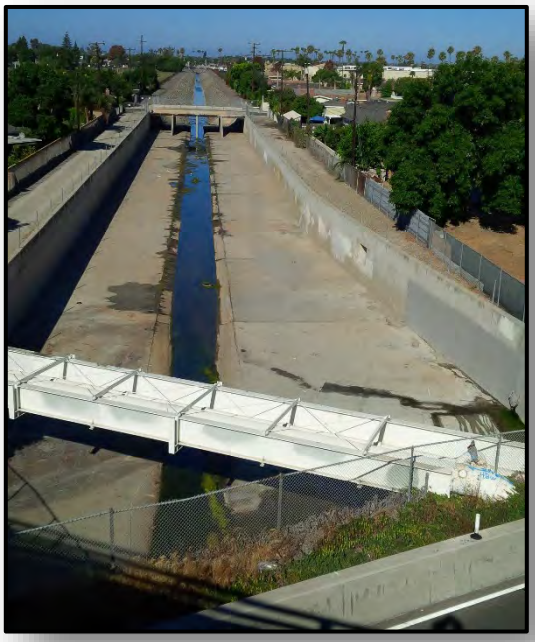
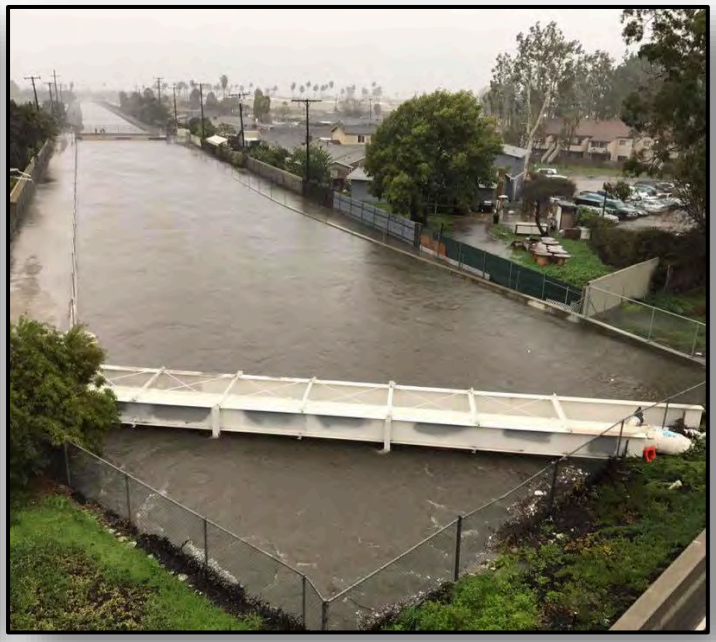
APPENDIX H - PLAN FORMULATION

For

WESTMINSTER, EAST GARDEN GROVE, CA

FLOOD RISK MANAGEMENT STUDY





April 2020

U.S.ARMY

US Army Corps of Engineers®
Chicago District

COUNTY OF ORANGE CALIFORNIA

Page intentionally left blank

Contents

1.0 Purpose 1
2.0 Preliminary Alternative Development 1
2.1 Plan Formulation Strategies 1
2.2 Initial Array of Alternatives 1
3.0 Siting Channel Modification Measures 3
3.1 Study Channels 3
3.2 Channel Reaches 3
3.3 No Action Alternative 19
3.4 Minimum Channel Modifications Plan 21
3.5 Maximum Channel Modifications Plan 24
3.6 Cost Estimates for Minimum and Maximum Alternatives 28
3.7 Annualized Costs and Benefits for Minimum and Maximum Alternatives 28
3.8 Optimization to Potentially Develop a Moderate Channel Modifications (Hybrid) Plan 29
3.9 Full Tidal Basin Outlet Alternative 29
4.0 Comparison of Final Array of Alternatives 31
4.1 National Economic Development Plan 31
4.2 Identification of a Locally Preferred Plan 32

Appendix H – Plan Formulation

Figures:

Figure 1: Drainage channels within the study area. 1

Figure 2: The study area considers the CO2, CO4, CO5, and CO6 drainage channels. 2

Figure 3: Study channels divided into 23 discrete reaches for siting in-channel modifications. 4

Figure 4: Reach 1 is a soft-bottom leveed reach. 5

Figure 5: Reach 2 is concrete lined rectangular channel 5

Figure 6: Reach 3 transitions from riprap lined trapezoidal (left) to concrete lined rectangular (right). 5

Figure 7: Concrete rectangular channel downstream (left) and riprap trapezoidal channel upstream (right) on Reach 4 6

Figure 8: Reach 5 is predominantly riprap lined trapezoidal channel 6

Figure 9: Reach 6 is concrete lined trapezoidal channel. 6

Figure 10: Reach 7 is concrete rectangular conduit that passes under Rosita Park. 7

Figure 11: Reach 8 is concrete lined trapezoidal channel. 7

Figure 12: Reach 9 is concrete lined trapezoidal channel. 7

Figure 13: Reach 10 is concrete rectangular conduit that daylights just downstream of the Haster Basin outlet. 8

Figure 14: Reach 11 is concrete rectangular conduit that daylights at the inlet to Haster Basin. 8

Figure 15: Reach 12 is predominantly concrete lined trapezoidal channel 8

Figure 16: Earthen trapezoidal near the confluence of C05/C06 (left), transitions to riprap trapezoidal upstream (right) 9

Figure 17: Reach 14 is concrete rectangular channel 9

Figure 18: Reach 15 is concrete rectangular conduit from Riverbend Drive (left) to I-405 (right). 9

Figure 19: Reach 16 is concrete rectangular channel 10

Figure 20: Reach 17 transitions from riprap lining downstream (left) to earthen channel further upstream (right). 10

Figure 21: Drainage channel through Mile Square Park. 10

Figure 22: Reach 19 is riprap lined trapezoidal channel. 11

Figure 23: Outlet of C02 at Edinger Bridge (left) and downstream view from C02/C04 confluence (right) 11

Figure 24: Reach 20 is earthen and tidally influenced downstream (left), with increased riprap applied upstream (right)..... 11

Figure 25: Reach 21 goes under the Westminster Mall, downstream outlet and upstream inlet of conduit (respectively)..... 12

Figure 26: Reach 21 is concrete rectangular from I-405 (left) to Hazard Ave (right) 12

Figure 27: Cedarwood Ave to Beach Blvd. is concrete rectangular 12

Figure 28: Beach Blvd. to Brookhurst Ave is concrete rectangular 13

Figure 29: Reach 22 becomes riprap lined trapezoidal from Brookhurst St to Westminster Blvd. 13

Figure 30: Reach 22 becomes concrete lined trapezoidal from Westminster Blvd. to Route 22..... 13

Figure 31: CO2, the confluence of CO2/CO4 near Bolsa Chica St., and the downstream reach of CO4... 14

Figure 32: CO4 is divided into 3 reaches..... 15

Figure 33: CO5 outlets into Outer Bolsa Bay near the Bolsa Chica ecological Reserve..... 16

Figure 34: CO5 and CO6 run from west to east through a densely populated urban project area..... 17

Figure 35: The upstream reaches of the CO5 channel flow from north to south..... 18

Figure 36: Minimum Channel Modifications Plan 23

Figure 37: Maximum Channel Modifications Plan..... 26

Figure 38: Proposed alignment of diversion channel at Westminster Mall 27

Figure 39: FWOP inundation areas are mostly concentrated at downstream leveed reaches and just upstream of the 405..... 30

Figure 40: the NED Plan is the Minimum Channel Modifications Plan..... 32

Figure 41: The LPP is the Maximum Channel Modification Plan..... 33

Appendix H – Plan Formulation

Tables:

Table 1: Forming preliminary study alternatives from retained measures 2

Table 2: Existing channel reach extents 3

Table 3: Existing channel conditions in CO2/CO4 19

Table 4: Existing channel conditions in CO5/CO6 20

Table 5: Minimum channel modifications in CO2/CO4 21

Table 6: Minimum channel modifications in CO5/CO6 22

Table 7: Maximum channel modifications in CO2/CO4 24

Table 8: Maximum channel modifications in CO5/CO6 25

Table 9: Project First Costs by Plan, FY 2020 Price Levels ($000). 28

Table 10: EAD for the without project condition 28

Table 11: The Minimum Channel Modifications Plan is the NED. 31

Table 12: The LPP is the Recommended Plan. 33

Attachments:

1. Briefing Placemat (revised)

Appendix H - Plan Formulation

For

WESTMINSTER, EAST GARDEN GROVE

FLOOD RISK MANAGEMENT STUDY

1.0 Purpose

The purpose of the Plan Formulation Appendix is to provide additional details on the plan formulation process that were not included in the body of the main report.

2.0 Preliminary Alternative Development

2.1 Plan Formulation Strategies

The initial screening of measures demonstrated that the urban nature of the project area (high land values and a lack of available real estate) tended to self-select for measures that limit property acquisition, such as nonstructural measures and measures that are implemented within existing rights of way. Based on these considerations, the following strategies were used for developing study alternatives

- Maximize Nonstructural and Flood Proofing – This strategy aims to reduce the impacts of flooding by retrofitting existing buildings and infrastructure to be more flood resistant.
- Focus on Improving Channel Conveyance – This strategy aims to reduce the risk and impacts of flooding by more efficiently transporting flood waters, especially in upstream channel reaches where the watershed has more slope.
- Focus on Increasing Channel Capacity – This strategy aims to reduce the risk and impacts of flooding by increasing flood water storage within the existing drainage channels.
- Focus on Improving Downstream Conveyance – This strategy aims to reduce the risk and impacts of flooding by more efficiently transporting flood waters received from the channels. While downstream conveyance improvements are unlikely to provide significant flood damage risk reduction alone, it is recognized that any improvements to conveyance and capacity upstream would exacerbate existing flow restrictions downstream.

2.2 Initial Array of Alternatives

Based on the remaining measures and the VT alignment that came out of the August 2017 In-Progress Review (IPR), five alternatives were identified to be carried forward in the initial array of alternatives.

1. No action alternative
2. Nonstructural alternative
3. In-channel modification alternative (Minimum Channel Modifications)
4. In-channel modification alternative (Maximum Channel Modifications)
5. Diversion tunnel alternative

Table 1: Forming preliminary study alternatives from retained measures.

		Initial Array of Alternatives					Optimization Analysis
		No Action	Nonstructural	Minimum Channel Modifications (slickening)	Maximum Channel Modifications (contains 100yr consistent with NFIP)	Diversion Tunnel	Moderate Channel Modifications (Hybrid)
Nonstructural Measures	Floodplain regulation	Screened Out					
	Emergency response						
	Evacuation planning						
	Flood proofing						
	Flood warning system						
	Razing/Removing structures						
	Removal of impediments to flow		X	X	X	X	X
In-Channel Modifications	Trapezoidal channels converted to concrete lining			X	X		Incremental Analysis
	Trapezoidal channels converted to concrete rectangular channels				X		Incremental Analysis
	Additional flood wall along channels				X		Incremental Analysis
	Pump station improvements	Screened Out					
Upstream Improvements	Diversion/Bypass channels				X		X
	Storage/Retention basins	Screened Out					
	Dams						
	Levees						
	Santa Ana River (SAR) diversion						
Downstream Improvements	Raising Pacific Coast Highway	Screened Out					
	Floodwall along Pacific Coast Highway (PCH) in OBB			X	X		X
	Remove tide gates on CO5			X	X	X	X
	Replace/relocate tide gates on CO5			X	X	X	
	Warner Ave widening (and associated BCER)			X	X	X	
	Dredging in Outer Bolsa Bay	Screened Out					
	Breach levee on N/W side of CO5 into muted tidal pocket						
	Construct new ocean outlet (approx 30' diam tunnel)					X	

Table 1 was not included in the Draft Integrated Feasibility Report (IFR), but it is included here to demonstrate the earliest steps in the process of screening and combining management measures into preliminary alternatives. The optimization analysis referenced in Table 1 is discussed in more detail in Section 3.8.

2.2.1 Relocation versus Removal of Existing Tide Gates

Only one of the retained measures of tide gate removal or tide gate relocation/replacement shown in Table 20 could be reasonably implemented. In previous conversations with stakeholders and resource agencies, concern was expressed that a tide gate structure was needed to prevent salt water infiltration and tidal fluctuations upstream of the existing structure. However, the current tide gates already leak and therefore allow saltwater habitat to exist upstream in C05 in the future without project condition. This saltwater influence extends upstream of Outer Bolsa Bay for approximately 2.5 miles. Similarly, saltwater intrusion has not been demonstrated in the future without project condition in which the existing tide gates are already leaking and allowing saltwater to pass upstream. Due to these factors, the tide gate relocation/replacement measure was screened out because it would represent an unnecessary project feature and cost. Tide gate removal was retained.

3.0 Siting Channel Modification Measures

Following the decisions to screen out the standalone nonstructural and diversion tunnel alternatives described in section 2.2, the remaining alternatives (except for the No Action Alternative) all focused specifically on the study drainage channels and key downstream infrastructure.

- No Action Plan
- Minimum Channel Modifications Plan
- Maximum Channel Modifications Plan
- Potential Moderate Channel Modifications (Hybrid) Plan

In order to begin siting the potential channel modifications included in these alternatives, it is important to clearly define the extent of the study channels. Then, the channels needed to be subdivided into discrete reaches based on size, geometry, and material in order to indicate where specific measures would be sited and, ultimately, develop cost estimates.

While the process described here is used to define and justify the federal interest and investment in a study alternative, it does not inherently represent the goals of the project's NFS. In instances where the NFS has identified goals that are not addressed by the tentatively selected plan, development and consideration of a Locally Preferred Plan (LPP) may be warranted. In the case of this study, the Federal Government's goal is to maximize net benefits, while OCPW's goal is to contain the 1% ACE storm event within the study channels. Since the National Economic Development (NED) Plan does not meet the NFS's objectives but additional project features would, an LPP was identified and submitted for approval. See Section 4.2 for more information on a potential LPP.

3.1 Study Channels

The channels within the Westminster Watershed collect local storm water runoff and vary in size, geometry, and material. Typical channel configurations are described below and vary throughout the channel systems.

- Concrete rectangular channels: vertical channel walls with concrete lined sides and bottom.
- Riprap-lined trapezoidal channels: sloped channels that are lined with riprap; soft or unpaved bottom.
- Concrete-lined trapezoidal channels: sloped channels with concrete lined sides and bottoms.
- Enclosed culverts: rectangular or box conduits that are not expressed at the surface.
- Levees: earthen berms are located along channels in the flattest downstream extents of the watershed.
- Steel Sheet Pile: rectangular channels comprised of vertical sheet pile walls with soft channel bottom in between.

The original study scope included all of the drainage channels within the watershed. In consultation with OCPW and a review of existing conditions in the watershed, it was determined that the study would instead focus only on channel reaches C02, C04, C05, and C06 (Figure 1).

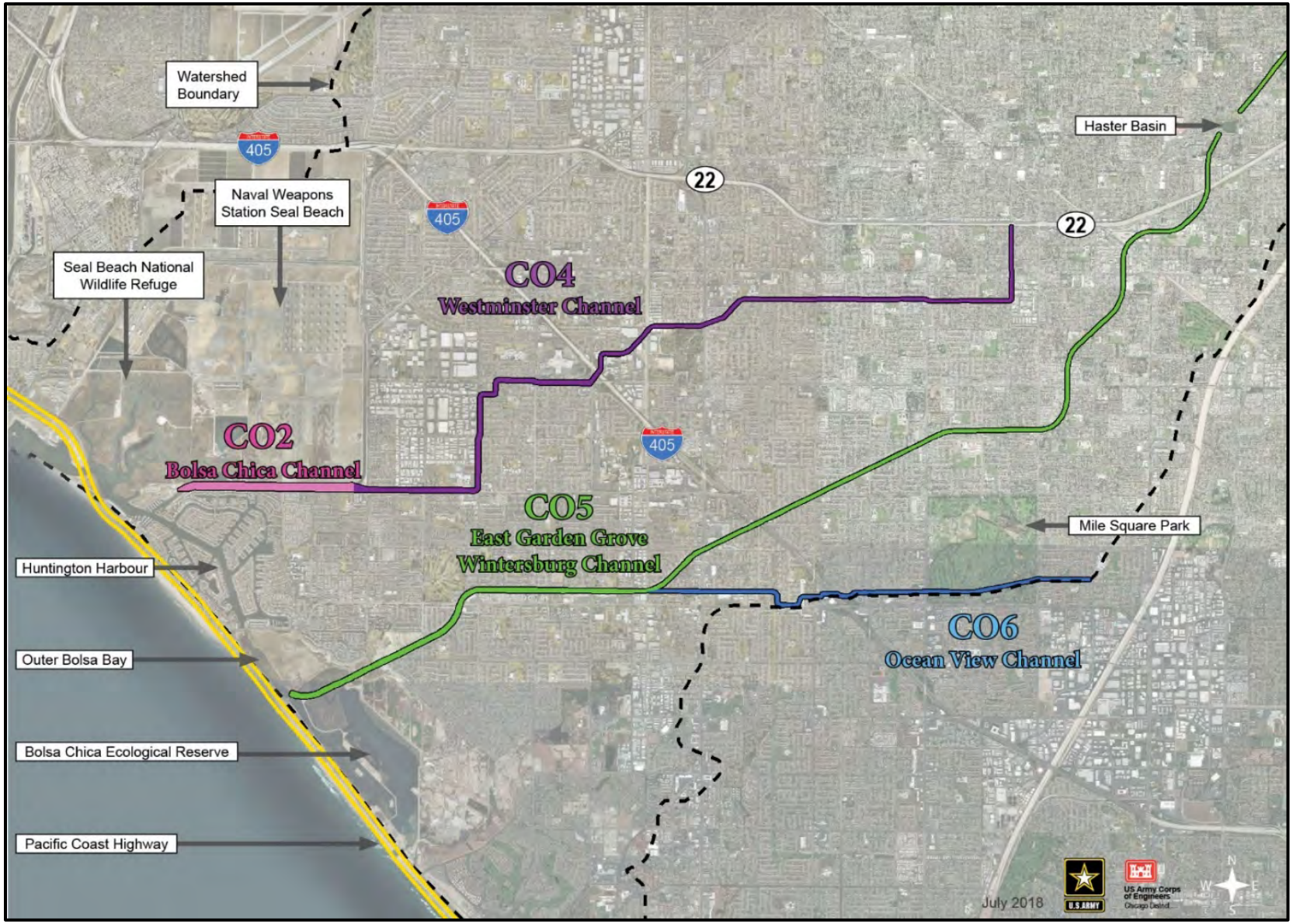


Figure 1: Drainage channels within the study area.

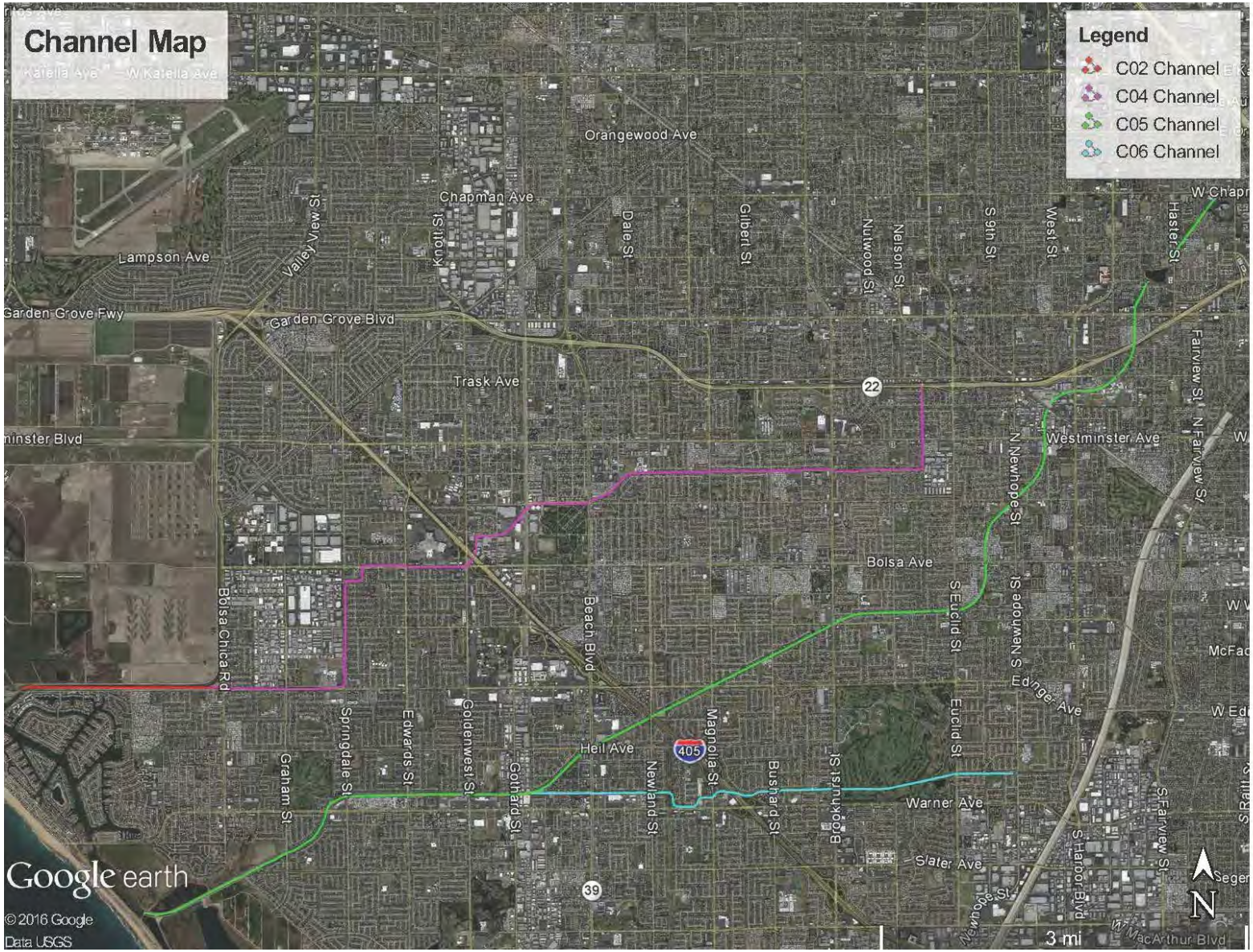


Figure 2: The study area considers the CO2, CO4, CO5, and CO6 drainage channels.

3.2 Channel Reaches

The drainage channels that this study considers are broken up into discrete smaller segments, or reaches, to facilitate the siting of channel modification measures throughout the study area. Once all of the individual reaches were inventoried and classified, the PDT was then able to determine where along their length modifications could be implemented to improve conveyance efficiency and/or provide additional storage capacity within the channels. The reaches were originally delineated by dividing the drainage channels according to characteristics such as cross-sectional geometry, bottom material, and side-slope material.

Table 2: Existing channel reach extents.

Channel	Reach	Description
C05	1	From the tidal gate to Golden West St.
C05	2	Golden West St to the confluence with C06.
C05	3	Confluence with C06 to I-405 FWY.
C05	4	I-405 FWY to Bushard St.
C05	5	Bushard St to 3rd St.
C05	6	3rd St to Roosevelt Ave.
C05	7	Roosevelt Ave to Hazard Ave.
C05	8	Hazard Ave to Woodbury Rd.
C05	9	Woodbury Rd to Garden Grove Blvd.
C05	10	Garden Grove Blvd to the Haster Basin outfall.
C05	11	Haster Basin inlet to Twintree Cir.
C05	12	Twintree Cir to approximately Chapman Ave.
C06	13	From the confluence with C05 to Ross Ln.
C06	14	Ross Ln to Riverbend Dr.
C06	15	Riverbend Dr to I-405 FWY.
C06	16	I-405 FWY to Bushard St.
C06	17	Bushard St to Brookhurst St.
C06	18	Brookhurst St to Euclid St (Mile Square Regional Park).
C06	19	Euclid St to Newhope Ave.
C04	20	From the confluence with C02 all the way to the I-405 FWY.
C04	21	I-405 FWY to Beach Blvd.
C04	22	Beach Blvd to SR-22 (Garden Grove FWY).
C02	23	From the Edinger Ave/Sunset Bay East bridge to the confluence with C04 (near Bolsa Chica St and Edinger Ave).

The north side of Reach 23 was removed from consideration in this study based on expected damages in the Future Without Project Condition (FWOP) and due to the non-federal sponsor's desire to carry out maintenance activities in the reach without affecting the feasibility study. Bordering the channel to the north of Reach 23 is the Seal Beach Naval Weapons Station (NWSSB). The primary source of flooding on this property originates from the ocean side in both the FWOP and the Future With Project Condition (FWP). The minor flooding of this property that does originate from the study channel does not affect structures, infrastructure, or communities in the FWOP or the FWP. Additionally, the non-federal sponsor intends to undertake operations and maintenance activities on the north side of the channel separate from the recommended federal project, potentially including regrading, installation of geotextiles, and/or other slope stabilization techniques.

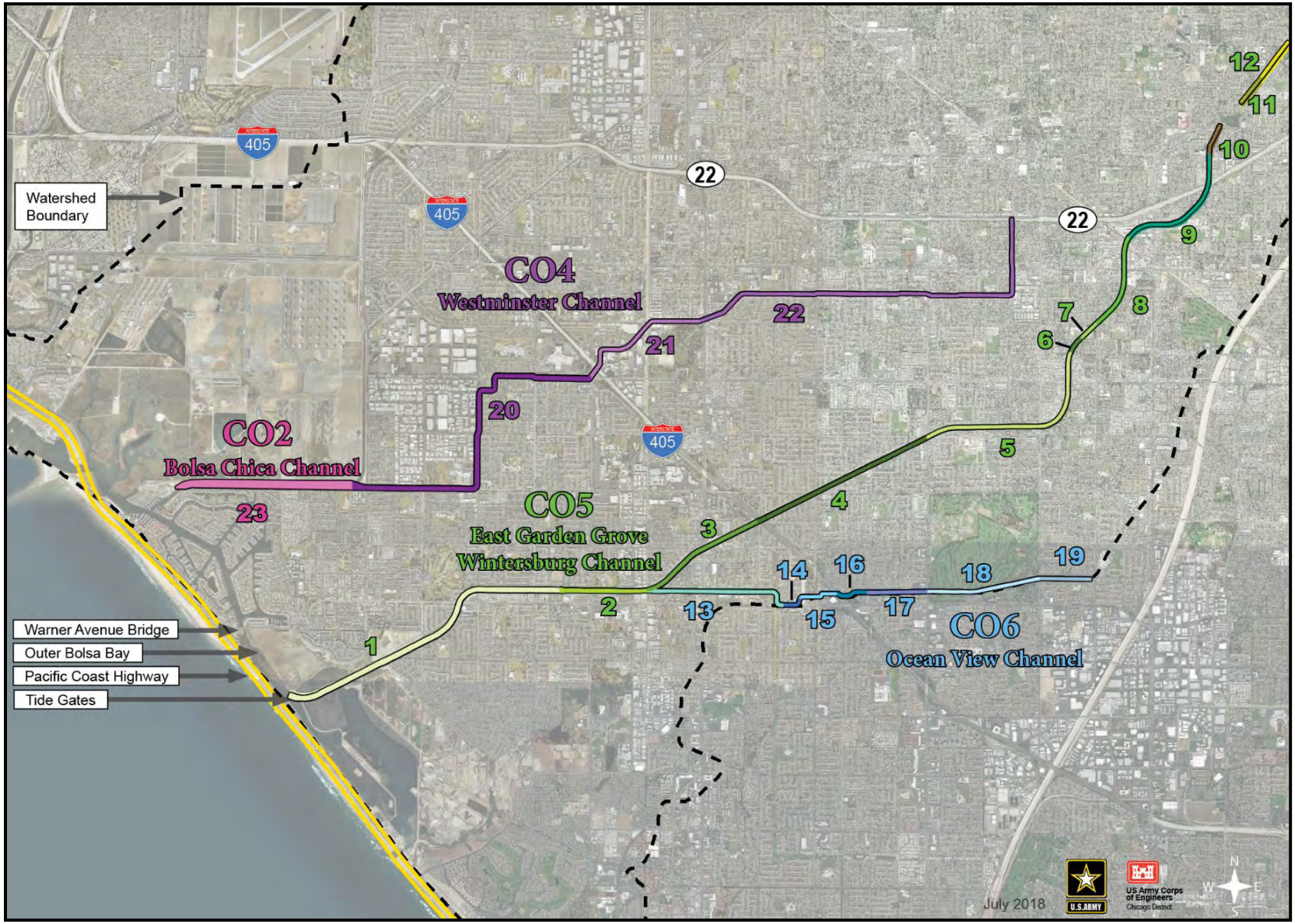


Figure 3: Study channels divided into 23 discrete reaches for siting in-channel modifications.

Reach 1 – C05

Figure 4: Reach 1 is a soft-bottom leveed reach. Recent and ongoing work has started the process of replacing earthen levees (left) with steel sheet pile walls (right).

Reach 2 – C05

Figure 5: Reach 2 is concrete lined rectangular channel.

Reach 3 – C05

Figure 6: Reach 3 transitions from riprap lined trapezoidal (left) to concrete lined rectangular (right).

Reach 4 – C05

Figure 7: Concrete rectangular channel downstream (left) and riprap trapezoidal channel upstream (right) on Reach 4.

Reach 5 – C05

Figure 8: Reach 5 is predominantly riprap lined trapezoidal channel.

Reach 6 – C05

Figure 9: Reach 6 is concrete lined trapezoidal channel.

Reach 7 – C05

Figure 10: Reach 7 is concrete rectangular conduit that passes under Rosita Park.

Reach 8 – C05

Figure 11: Reach 8 is concrete lined trapezoidal channel.

Reach 9 – C05

Figure 12: Reach 9 is concrete lined trapezoidal channel.

Reach 10 – C05

Figure 13: Reach 10 is concrete rectangular conduit that daylights just downstream of the Haster Basin outlet.

Reach 11 – C05

Figure 14: Reach 11 is concrete rectangular conduit that daylights at the inlet to Haster Basin.

Reach 12 – C05

Figure 15: Reach 12 is predominantly concrete lined trapezoidal channel.

Reach 13 – C06

Figure 16: Earthen trapezoidal near the confluence of C05/C06 (left), transitions to riprap trapezoidal upstream (right).

Reach 14 – C06

Figure 17: Reach 14 is concrete rectangular channel.

Reach 15 – C06

Figure 18: Reach 15 is concrete rectangular conduit from Riverbend Drive (left) to I-405 (right).

Reach 16 – C06

Figure 19: Reach 16 is concrete rectangular channel.

Reach 17 – C06

Figure 20: Reach 17 transitions from riprap lining downstream (left) to earthen channel further upstream (right).

Reach 18 – C06

Figure 21: Drainage channel through Mile Square Park.

Reach 19 – C06

Figure 22: Reach 19 is riprap lined trapezoidal channel.

Reach 23 – C02

Figure 23: Outlet of C02 at Edinger Bridge (left) and downstream view from C02/C04 confluence (right)

Reach 20 – C04

Figure 24: Reach 20 is earthen and tidally influenced downstream (left), with increased riprap applied upstream (right)

Reach 21 – C04

Figure 25: Reach 21 goes under the Westminster Mall, downstream outlet and upstream inlet of conduit (respectively)

Figure 26: Reach 21 is concrete rectangular from I-405 (left) to Hazard Ave (right)

Figure 27: Cedarwood Ave to Beach Blvd. is concrete rectangular

Reach 22 – C04

Figure 28: Beach Blvd. to Brookhurst Ave is concrete rectangular

Figure 29: Reach 22 becomes riprap lined trapezoidal from Brookhurst St to Westminster Blvd.

Figure 30: Reach 22 becomes concrete lined trapezoidal from Westminster Blvd. to Route 22

Figure 31: CO2, the confluence of CO2/CO4 near Bolsa Chica St., and the downstream reach of CO4.

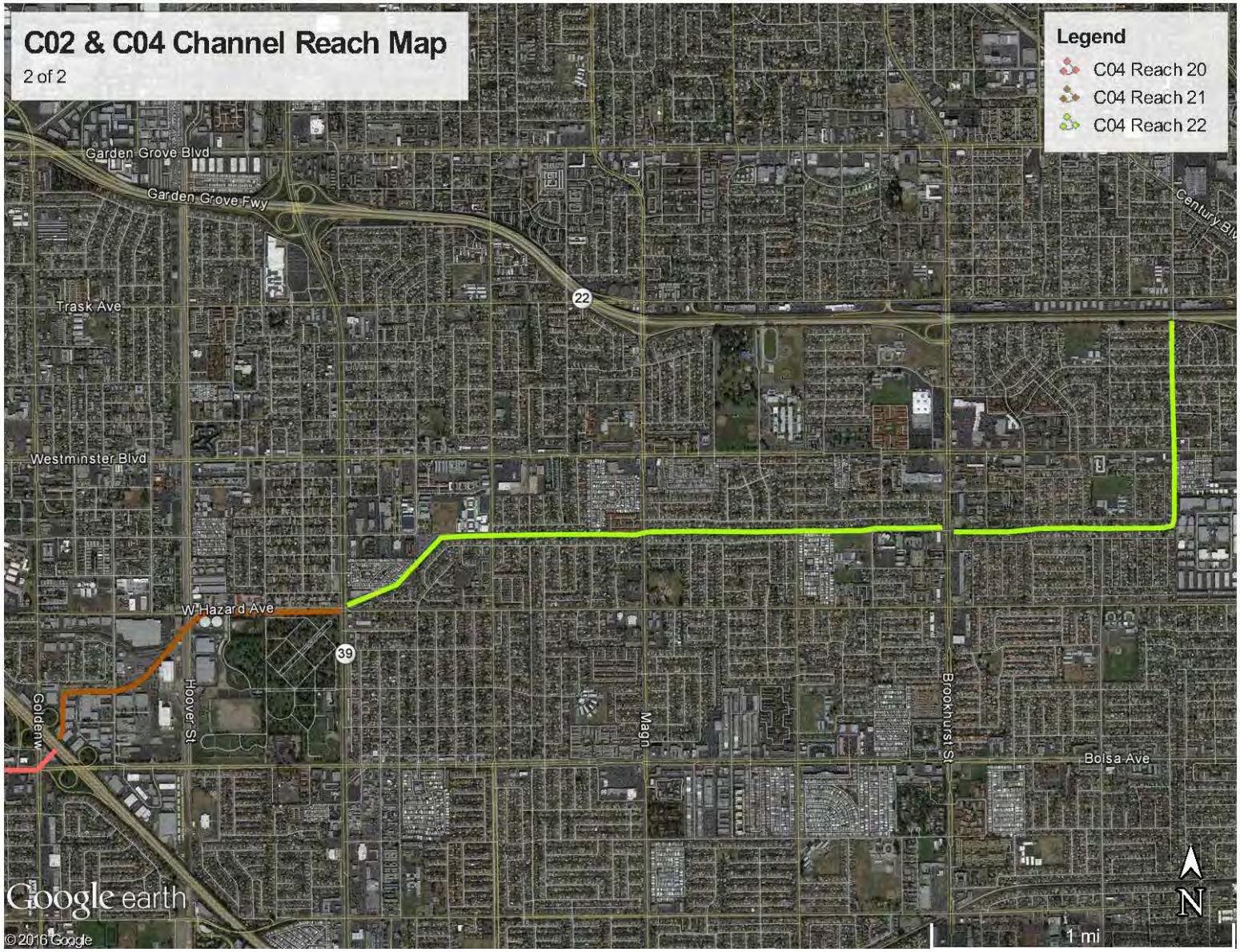


Figure 32: CO4 is divided into 3 reaches.

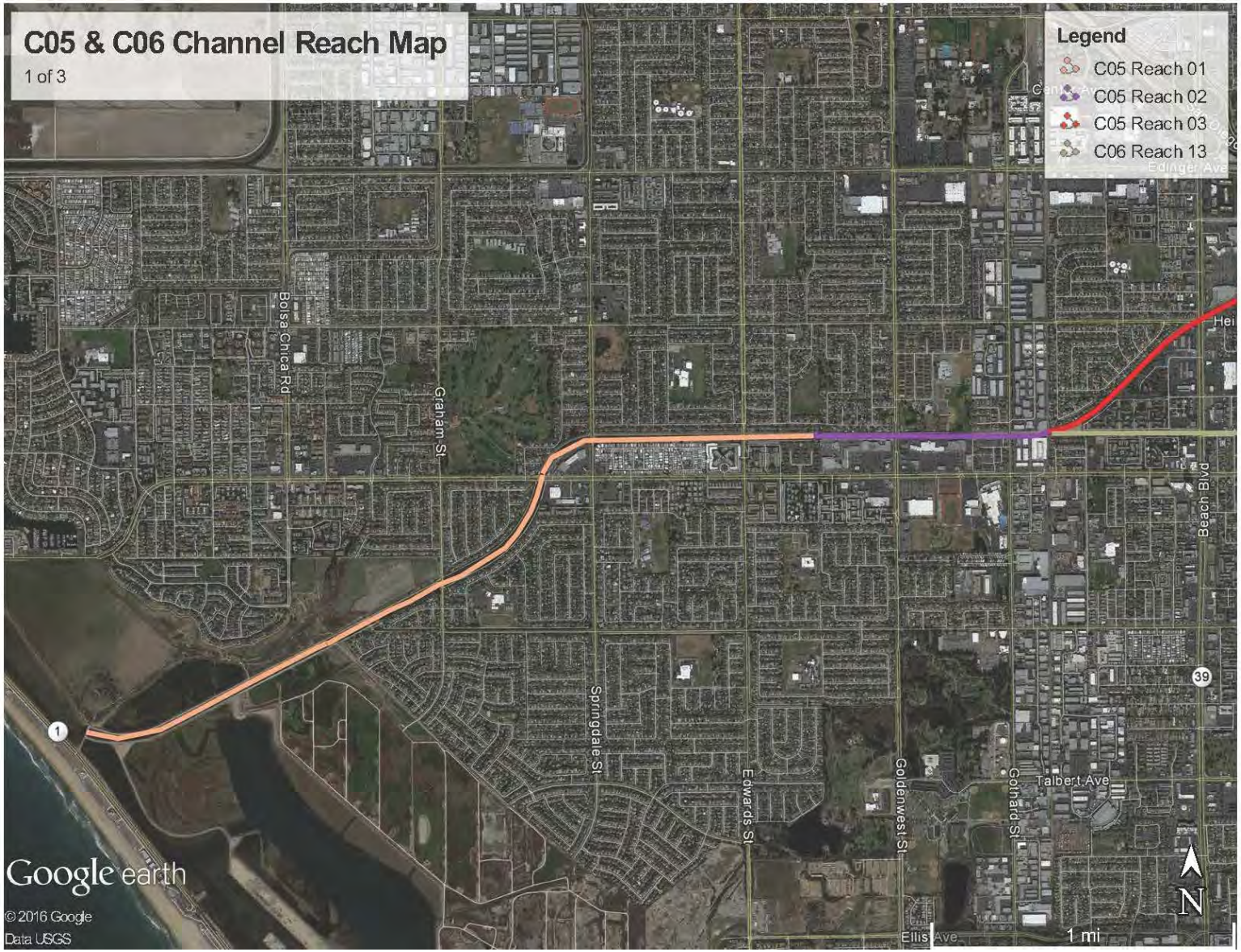


Figure 33: CO5 outlets into Outer Bolsa Bay near the Bolsa Chica ecological Reserve. The confluence of CO5/CO6 is located just east of Gothard Street.

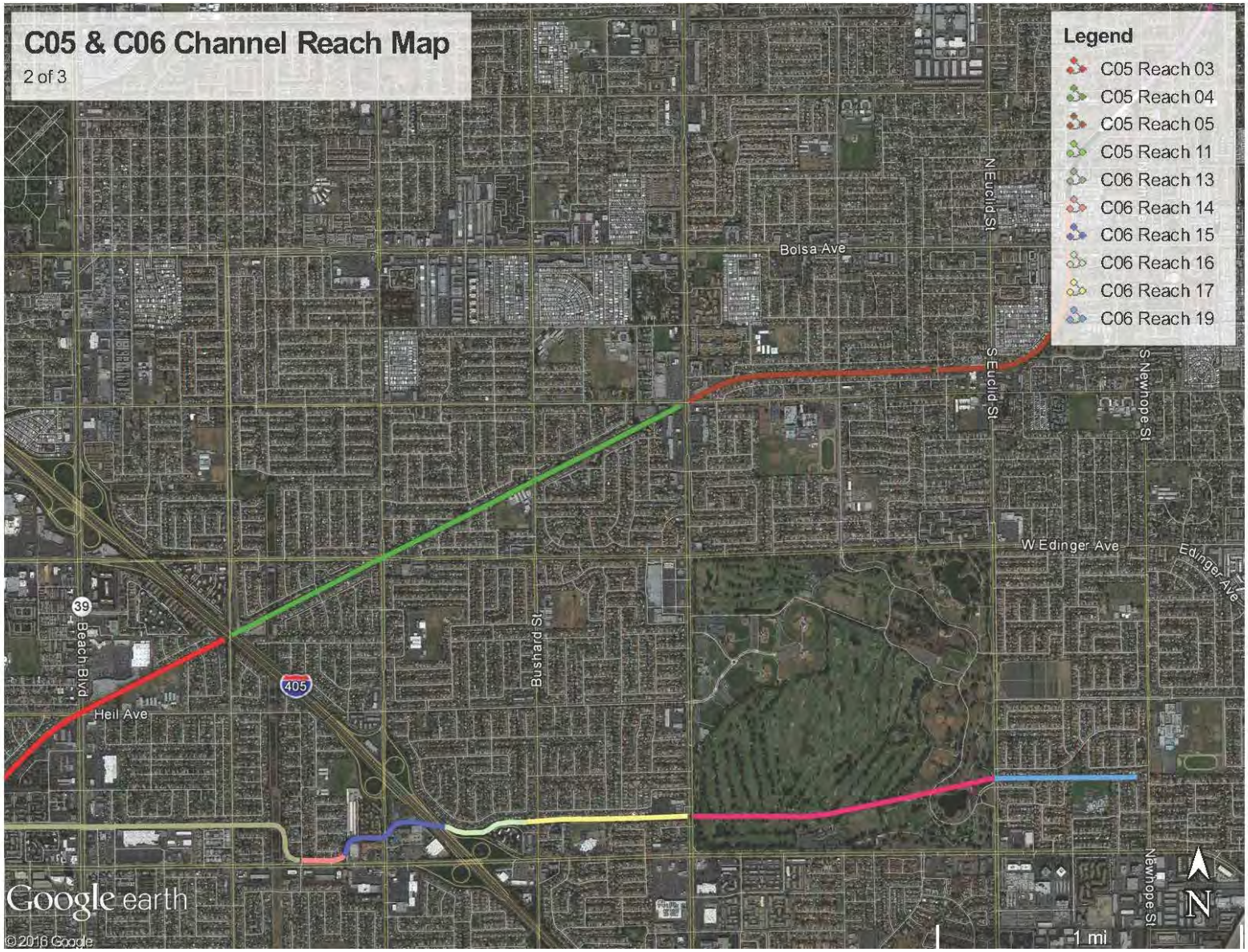


Figure 34: CO5 and CO6 run from west to east through a densely populated urban project area.

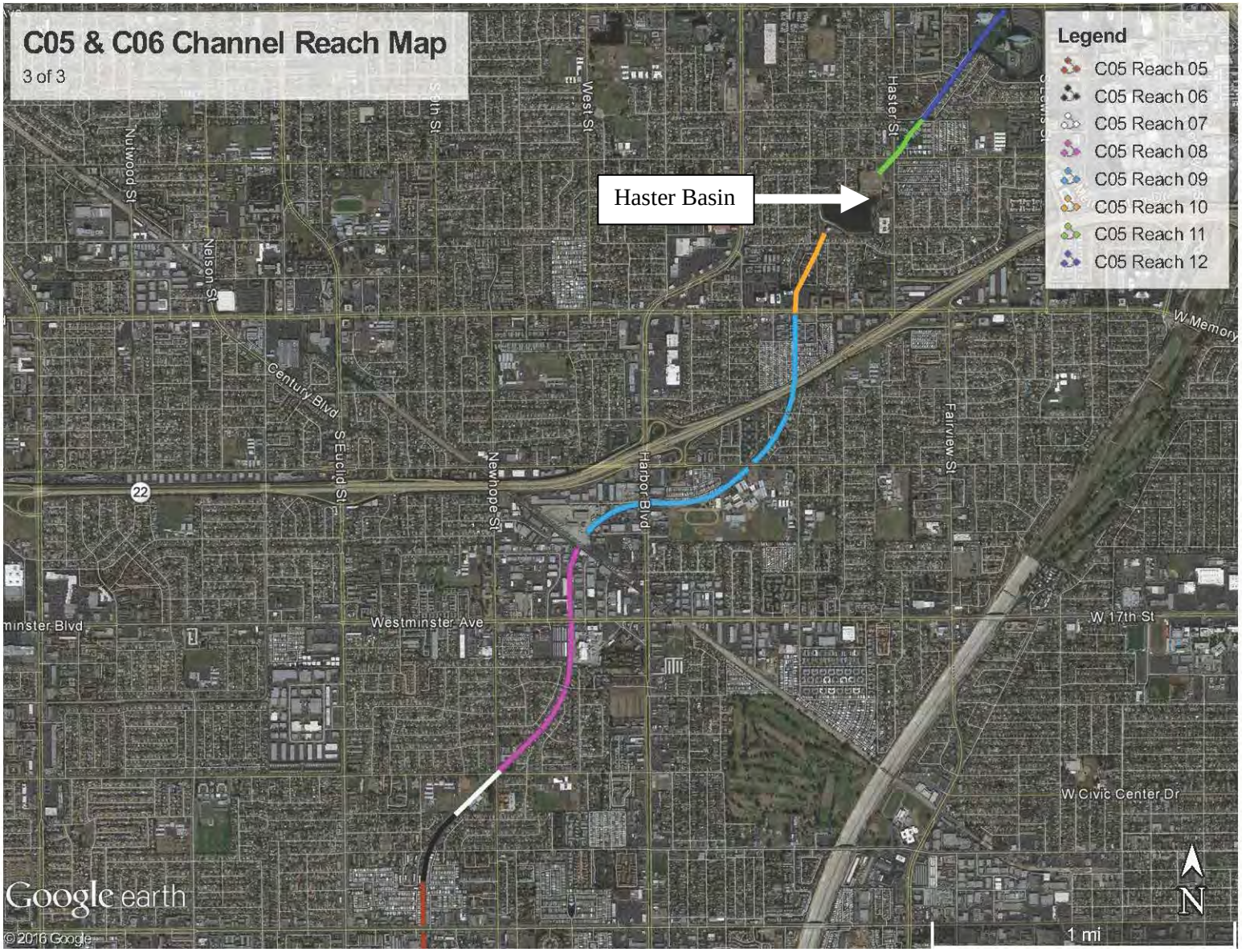


Figure 35: The upstream reaches of the CO5 channel flow from north to south, crossing the Haster Basin reservoir and State Route 22

3.3 No Action Alternative

Under the No Action Alternative, no management measures would be implemented to reduce the current risk of flood damage in the project area. Flooding will continue throughout the Westminster watershed due to the insufficient capacity of the existing channel systems. This will continue to cause damages to structures and road closures in the project area as a result of channel overtopping.

Outer Bolsa Bay will continue to flood during frequent storm events, impacting traffic on Pacific Coast Highway. The oil wells in the BCER will remain at risk of inundation by flows that overtop the CO5 channel upstream of the reserve and travel overland into the Muted Tidal Basin and Seasonal Pond area.

Under the No Action Alternative, these channel conditions would remain unchanged, as described in Table 3 and Table 4. Overtopping of the levees on CO2 and CO5 would continue to occur during 2% and 20% ACE storm events, respectively.

Table 3: Existing channel conditions in CO2/CO4 on a reach-by-reach basis.

Channel	Reach	EXISTING CONDITIONS / NO ACTION
CO2/CO4		
CO2	23	Earthen trapezoidal
CO4	20	Riprap lined trapezoidal from CO2 to Bolsa Chica Street; Earthen & riprap trapezoidal from Bolsa Chica Street to Graham Street; Earthen trapezoidal from Graham Street to McFadden Avenue; Riprap trapezoidal from McFadden Avenue to Bolsa Avenue; Earthen & riprap trapezoidal from Bolsa Avenue to Edwards Street Concrete lined rectangular from Edwards Street to I-405
CO4	21	Concrete lined rectangular
CO4	22	Concrete lined compound from Beach Blvd to Magnolia Street; Concrete rectangular with soft bottom from Magnolia Street to Brookhurst; Riprap trapezoidal from Brookhurst Street to Westminster Avenue; Concrete lined trapezoidal from Westminster Avenue to SR-22

Table 4: Existing channel conditions in CO5/CO6 system on a reach-by-reach basis.

Channel	Reach	EXISTING CONDITIONS / NO ACTION
CO5/CO6		
CO5	1	Earthen levee from tide gates to Warner Avenue w/ some SSP on south bank near Graham Street; SSP rectangular from Graham Street to Warner Avenue; Earthen levees from Warner Avenue to 1,300 ft upstream of Edwards Avenue
CO5	2	Concrete lined rectangular
CO5	3	Riprap lined trapezoidal from CO5/CO6 confluence to Woodruff Street; Concrete rectangular from Woodruff Street to I-405
CO5	4	Concrete lined rectangular from I-405 to Quartz Street; Riprap lined trapezoidal from Quartz Street to Bushard Street
CO5	5	Riprap lined trapezoidal from Bushard Street to Brookhurst Street; 1,300 ft of concrete lined trapezoidal upstream of Brookhurst Street; Riprap lined trapezoidal to 3rd St
CO5	6	Concrete lined trapezoidal
CO5	7	Covered concrete conduit
CO5	8	Concrete lined trapezoidal
CO5	9	Concrete lined trapezoidal
CO5	10	Covered concrete conduit
CO5	11	Covered concrete conduit
CO5	12	Concrete lined trapezoidal (first 1400') and covered concrete conduit (next 1000')
CO6	13	Earthen trapezoidal from CO5/CO6 confluence to Bolsa Avenue/RT-39; Riprap lined trapezoidal from Bolsa Avenue/RT-39 to Ross Lane
CO6	14	Concrete lined rectangular
CO6	15	Covered concrete conduit
CO6	16	Concrete lined rectangular
CO6	17	Earthen and riprap lined trapezoidal
CO6	18	Mile Square Park - concrete low flow v-channel
CO6	19	Riprap lined trapezoidal

3.4 Minimum Channel Modifications Plan

Under the Minimum Channel Modifications Alternative, earthen or riprap lined channels would be paved with concrete to increase conveyance efficiency. H&H modeling determined that widening Warner Avenue Bridge and removing the tide gates on C05 Reach 1 were all necessary measures to implement in the Minimum Channel Modifications plan.

The leveed areas in the downstream reaches of C02 and C05 (reaches 23 and 01, respectively) would be improved to reduce the risk of levee failure. Modifications in reach 01 would include installation of dual-steel sheet pile channel walls and preservation of existing soft bottom, tidally-influenced habitat. In Reach 23, a single line of sheetpile would be driven at the crest of the existing levee along the entire south side of the channel within the reach and tied back into C04 near Bolsa Chica Street. This would reduce the risk of levee failure in this reach.

Table 5: Minimum channel modifications in CO2/CO4 on a reach-by-reach basis compared to existing conditions.

CO2/CO4			
Channel	**Reach**	**EXISTING CONDITIONS**	**MINIMUM CHANNEL MODIFICATIONS**
CO2	23	Earthen trapezoidal	Single steel sheet pile driven at levee crest on south side of channel only. No excavation of material in the channel. Top of sheet pile may extend ~3 feet above current levee crest elevation. Tie back into C04 at Bolsa Chica Street.
CO4	20	Riprap lined trapezoidal from CO2 to Bolsa Chica Street; Earthen & riprap trapezoidal from Bolsa Chica Street to Graham Street; Earthen trapezoidal from Graham Street to McFadden Avenue; Riprap trapezoidal from McFadden Avenue to Bolsa Avenue; Earthen & riprap trapezoidal from Bolsa Avenue to Edwards Street Concrete lined rectangular from Edwards Street to I-405	Concrete lined trapezoidal from CO2 to Edwards Street; Concrete lined rectangular from Edwards Street to I-405 (existing);
CO4	21	Concrete lined rectangular	No Action
CO4	22	Concrete lined compound from Beach Blvd to Magnolia Street; Concrete rectangular with soft bottom from Magnolia Street to Brookhurst; Riprap trapezoidal from Brookhurst Street to Westminster Avenue; Concrete lined trapezoidal from Westminster Avenue to SR-22	Concrete lined compound from Beach Blvd to Magnolia Street; Concrete rectangular from Magnolia Street to Brookhurst; Concrete lined trapezoidal from Brookhurst Street to SR-22;

Table 6: Minimum channel modifications in CO5/CO6 on a reach-by-reach basis compared to existing conditions.

CO5/CO6			
Channel	**Reach**	**EXISTING CONDITIONS**	**MINIMUM CHANNEL MODIFICATIONS**
CO5	1	Earthen levee from tide gates to Warner Avenue w/ some SSP on south bank near Graham Street; SSP rectangular from Graham Street to Warner Avenue; Earthen levees from Warner Avenue to 1,300 ft upstream of Edwards Avenue	Sheet pile/soft bottom/splash walls (various heights) from tide gates to existing rectangular channel west of Golden West Street 3 crossings replaced of different sizes
CO5	2	Concrete lined rectangular	Concrete rectangular with 1' splash walls from Goldenwest to Gothard St; Concrete rectangular from Gothard Street to C05/C06 confluence
CO5	3	Riprap lined trapezoidal from CO5/CO6 confluence to Woodruff Street; Concrete rectangular from Woodruff Street to I-405	Concrete lined trapezoidal from confluence with C06 to Beach Blvd; Concrete lined rectangular from Beach Blvd. to I-405
CO5	4	Concrete lined rectangular from I-405 to Quartz Street; Riprap lined trapezoidal from Quartz Street to Bushard Street	from I-405 to Quartz Street; concrete lined trapezoidal from Quartz Street to Bushard Street
CO5	5	Riprap lined trapezoidal from Bushard Street to Brookhurst Street; 1,300 ft of concrete lined trapezoidal upstream of Brookhurst Street; Riprap lined trapezoidal to 3rd St	Concrete lined trapezoidal
CO5	6	Concrete lined trapezoidal	No Action
CO5	7	Covered concrete conduit	No Action
CO5	8	Concrete lined trapezoidal	No Action
CO5	9	Concrete lined trapezoidal	No Action
CO5	10	Covered concrete conduit	No Action
CO5	11	Covered concrete conduit	No Action
CO5	12	Concrete lined trapezoidal (first 1400') and covered concrete conduit (next 1000')	No Action
CO6	13	Earthen trapezoidal from CO5/CO6 confluence to Bolsa Avenue/RT-39; Riprap lined trapezoidal from Bolsa Avenue/RT-39 to Ross Lane	Concrete lined trapezoidal
CO6	14	Concrete lined rectangular	No Action
CO6	15	Covered concrete conduit	No Action
CO6	16	Concrete lined rectangular	No Action
CO6	17	Earthen and riprap lined trapezoidal	Concrete lined trapezoidal
CO6	18	Mile Square Park - concrete low flow v-channel	No Action
CO6	19	Riprap lined trapezoidal	Concrete lined trapezoidal

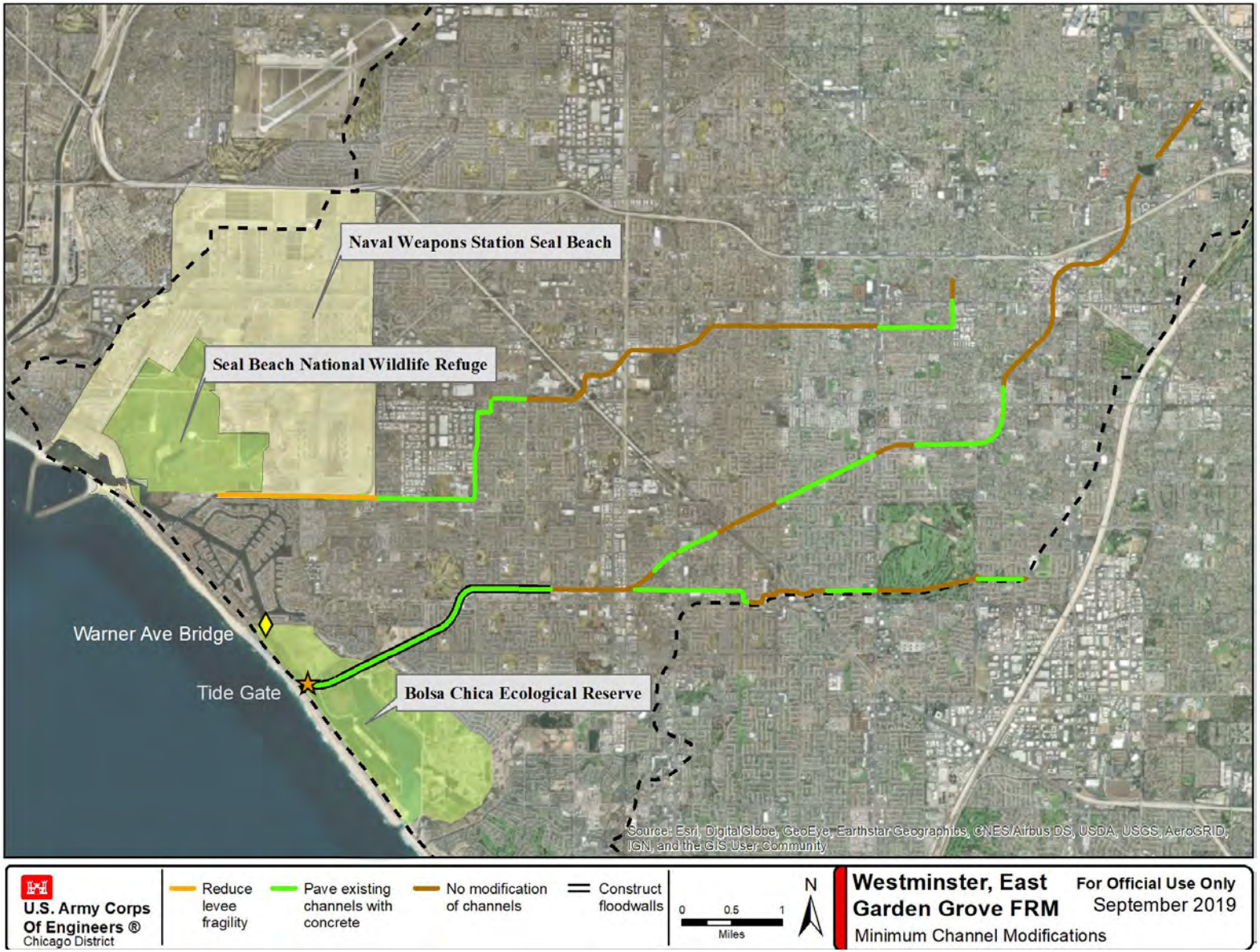


Figure 36: Minimum Channel Modifications Plan

3.5 Maximum Channel Modifications Plan

Under the Maximum Channel Modifications Alternative, trapezoidal channels would be reconfigured to have a rectangular cross sectional geometry. This would increase both conveyance and capacity. This alternative is designed to contain the 1% ACE storm event. For reaches that do not contain the 1% ACE event after conversion to a concrete rectangular channel, floodwalls are added.

H&H modeling determined that widening Warner Avenue Bridge and removing the tide gates on C05 Reach 1 were all necessary measures to implement in the Maximum Channel Modifications plan.

Table 7: Maximum channel modifications in CO2/CO4 on a reach-by-reach basis compared to existing conditions.

CO2/CO4			
Channel	**Reach**	**EXISTING CONDITIONS**	**MAXIMUM CHANNEL MODIFICATIONS**
CO2	23	Earthen trapezoidal	Sheet pile with anchor system located at existing levee crest on south side of channel only. Excavation of material on the channel side of the sheet pile.
CO4	20	Riprap lined trapezoidal from CO2 to Bolsa Chica Street; Earthen & riprap trapezoidal from Bolsa Chica Street to Graham Street; Earthen trapezoidal from Graham Street to McFadden Avenue; Riprap trapezoidal from McFadden Avenue to Bolsa Avenue; Earthen & riprap trapezoidal from Bolsa Avenue to Edwards Street Concrete lined rectangular from Edwards Street to I-405	80' Concrete rectangular with middle 48' left earthen from C02 to McFadden Avenue; 68' Concrete rectangular with middle 40' left earthen from McFadden Avenue to Bolsa Avenue; 55' Concrete rectangular from Bolsa Avenue to Edwards Street; 3 crossings replaced of different dimensions
CO4	21	Concrete lined rectangular	Diversion Channel at Westminster Mall *(See Appendix B – Civil Engineering)*
CO4	22	Concrete lined compound from Beach Blvd to Magnolia Street; Concrete rectangular with soft bottom from Magnolia Street to Brookhurst; Riprap trapezoidal from Brookhurst Street to Westminster Avenue; Concrete lined trapezoidal from Westminster Avenue to SR-22	Base of concrete lined channel increased to 35' from Beach Blvd to Magnolia Street; Soft bottom channel from Magnolia Street to Brookhurst Street concrete lined; Concrete lined trapezoidal from Brookhurst Street to Westminster Avenue; 18' Concrete rectangular from Westminster Avenue to SR-22; 12 crossings replaced of different dimensions

Table 8: Maximum channel modifications in CO5/CO6 on a reach-by-reach basis compared to existing conditions.

CO5/CO6			
Channel	**Reach**	**EXISTING CONDITIONS**	**MAXIMUM CHANNEL MODIFICATIONS**
CO5	1	Earthen levee from tide gates to Warner Avenue w/ some SSP on south bank; SSP rectangular from Graham Street to Warner Avenue; Earthen levees from Warner Avenue to 1,300 ft upstream of Edwards Avenue	Sheet pile/soft bottom/splash walls (various heights) from tide gates to existing rectangular channel west of Golden West Street 3 crossings replaced of different sizes
CO5	2	Concrete lined rectangular	Concrete rectangular with 1' splash walls from Goldenwest St to Gothard St; Concrete rectangular from Gothard Street to C05/C06 confluence
CO5	3	Riprap lined trapezoidal from CO5/CO6 confluence to Woodruff Street; Concrete rectangular from Woodruff to 405	Concrete lined rectangular; Some section of 1' splash wall between Beach Blvd and Woodruff Road; 2 crossings replaced of different sizes
CO5	4	Concrete lined rectangular from 405 to Quartz; Riprap trapezoidal from Quartz Street to Bushard Street	Concrete lined rectangular with splash walls (various heights); 3 crossings replaced of different sizes
CO5	5	Riprap lined trapezoidal from Bushard Street to Brookhurst Street; 1,300 ft of concrete lined trapezoidal upstream of Brookhurst Street; Riprap lined trapezoidal to 3rd St	Concrete lined rectangular with splash walls (various heights); 6 crossings replaced of different dimensions
CO5	6	Concrete lined trapezoidal	Concrete lined rectangular; 1 crossing replaced
CO5	7	Covered concrete conduit	Replace crossing at New Hope & Hazard
CO5	8	Concrete lined trapezoidal	Concrete lined rectangular; 3 crossings replaced of different sizes
CO5	9	Concrete lined trapezoidal	Concrete lined rectangular; 5 crossings replaced of different sizes
CO5	10	Covered concrete conduit	Replace crossing at Aspenwood; Haster Basin inlet culverts modified
CO5	11	Covered concrete conduit	No Action
CO5	12	Concrete lined trapezoidal (first 1400') and covered concrete conduit (next 1000')	No Action
CO6	13	Earthen trapezoidal from CO5/CO6 confluence to Bolsa Avenue/RT-39; Riprap lined trapezoidal from Bolsa Avenue/RT-39 to Ross Lane	Concrete lined rectangular at confluence; Concrete lined trapezoidal from confluence to Ross Street; 2 crossings replaced of different sizes
CO6	14	Concrete lined rectangular	Concrete lined rectangular from Ross Street to Asari Lane; Concrete lined rectangular with splash walls (1.5-2') from Asari Lane to Riverbend Drive
CO6	15	Covered concrete conduit	Covered concrete conduit; 1 crossing replaced
CO6	16	Concrete lined rectangular	Concrete lined rectangular, widened to 30’
CO6	17	Earthen and riprap lined trapezoidal	Concrete lined trapezoidal, ~1ft splash walls
CO6	18	Mile Square Park-concrete low flow v-channel	No Action
CO6	19	Riprap lined trapezoidal	Concrete lined trapezoidal

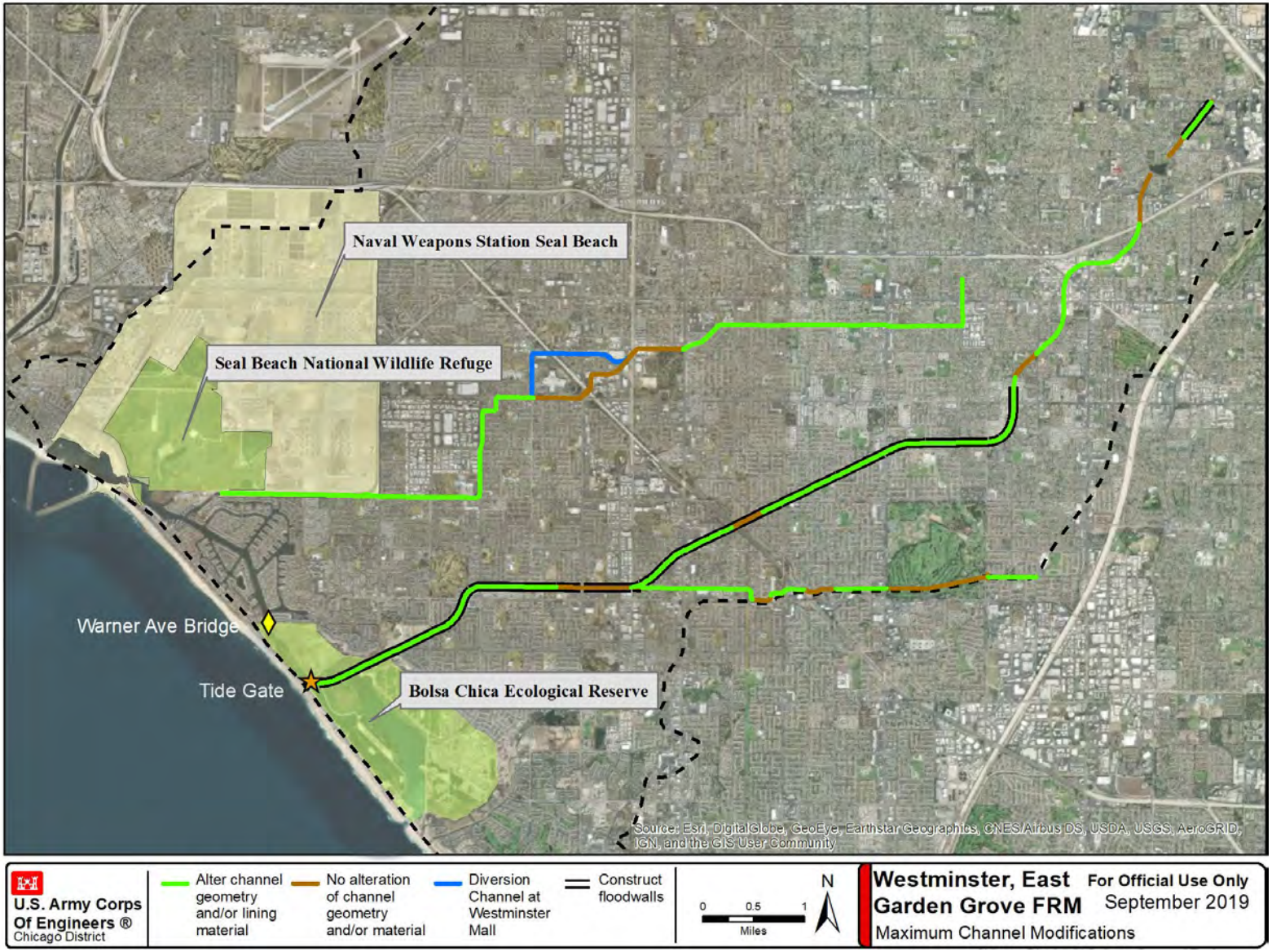


Figure 37: Maximum Channel Modifications Plan

Diversion Channel at Westminster Mall

To address flooding caused by a restriction where flows in C04 are directed into a long reach of covered conduit that runs under I-405 and the Westminster Mall, a bypass channel would be constructed to direct flows around this existing bottleneck (Figure 38).

This diversion would span 2 reaches in C04 (reaches 20 and 21) and be a combination of open channel and reinforced concrete box (RCB). It would split off of reach 21 at the intersection of Hoover and Hazard streets, run west along an abandoned Navy railroad line to the north of Westminster Mall, and then turn south underneath Edwards Street until it reconnects with reach 20 (where reach 20 goes underground) near the intersection of Edwards Street and Bolsa Avenue (Figure 38).

A more detailed description of this diversion that includes channel and RCB dimensions, preliminary drawings, and cost estimates in is included as an attachment to *Appendix B – Civil Engineering*.

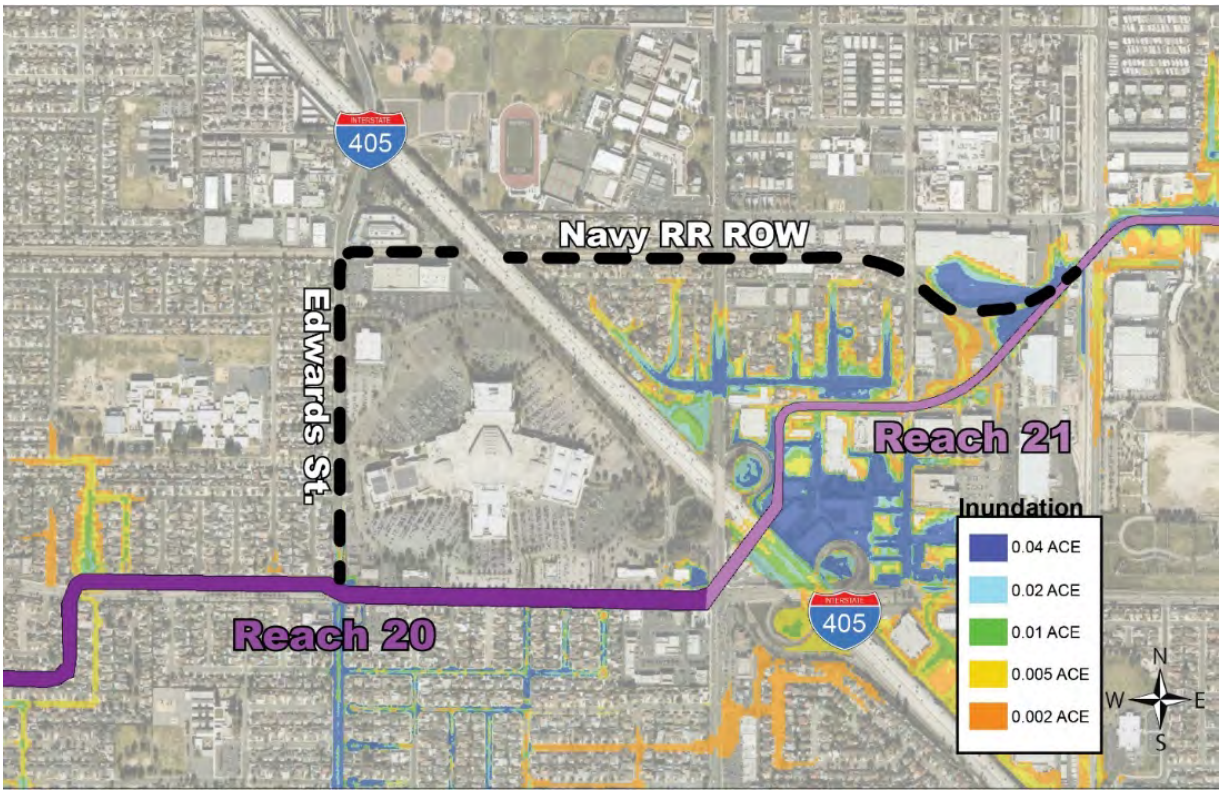


Figure 38: Proposed alignment of diversion channel at Westminster Mall (Black Dashed Line) would reduce flooding on C04 Reach 21 where it crosses I-405.

3.6 Cost Estimates for Minimum and Maximum Alternatives

The current cost estimate for C05 includes reaches 1-12. C06 includes reaches 13-19. C02 includes reach 23 and C04 includes reaches 20-22.

Table 9: Project First Costs by Plan, FY 2020 Price Levels ($000).

Project Component	Plan		% of Construction Cost by Component - Min Plan	% of Construction Cost by Component - Max Plan
	Minimum Improvement	Maximum Improvement		
C02-C04	83,992	445,741	17%	36%
Reach C02	37,582	99,314	8%	8%
Reach C04	46,409	346,427	10%	28%
C05-C06	348,767	726,107	72%	59%
Reach C05	328,879	595,606	68%	49%
Reach C06	19,888	130,501	4%	11%
Non Reach-Specific	51,097	52,749	11%	4%
Widen Warner Ave	36,888	36,888	8%	3%
Remove Tide Gates	3,791	3,791	1%	0%
Mitigation	7,813	7,813	2%	1%
Real Estate	2,605	4,257	1%	0%
Total First Costs[1]	**483,856**	**1,224,598**	100%	100%

[1] *Construction costs include bridge replacement costs by reach; annual O&M costs not included*

3.7 Annualized Costs and Benefits for Minimum and Maximum Alternatives

A comparison of expected annual damages (EAD) for the without project condition for both the Minimum and Maximum Channel Modifications plans are shown in **Error! Reference source not found.**. EAD is different from average annual equivalent (AAE) estimates as each is provided with a different base year and timing considerations. The EAD estimates are in a 2020 base year, providing an approximate benefit that would occur if the measure was implemented today. The AAE estimates account for the full construction schedule and are presented in a base year of 2035, after the construction is assumed to be completed. The following tables include the impacts for the without project condition, the Minimum Channel Modifications Plan, and the Maximum Channel Modifications Plan.

Table 10: EAD for the without project condition, as well as the minimum and maximum alternatives are displayed by channel FY 2020 Price Level ($000's).

Reach	Structure and Structure Contents	Other Related Flood Damage Categories	Total Without Project Damages	EAD for Minimum Alternative	EAD for Maximum Alternative
Reaches C02-C04	**2,518**	**1,125**	**3,643**	**570**	**1**
Reach C02	1,615	907	2,522	569	1
All Reaches C04	902	218	1,120	1	0
Reaches C05-C06	**50,983**	**17,105**	**68,088**	**1,034**	**1**
All Reaches C05	50,858	17,077	67,935	921	1
All Reaches C06	125	28	153	113	1
Total Damages	**53,500**	**18,230**	**71,730**	**1,604**	**2**
Total Damages Reduced	**-**	**-**	**-**	**70,127**	**71,728**

3.8 Optimization to Potentially Develop a Moderate Channel Modifications (Hybrid) Plan

Once cost information was developed for each measure and channel reach, an incremental analysis was carried out to determine whether the Minimum Channel Modifications and Maximum Channel Modifications plans could potentially be hybridized to optimize net benefits.

The incremental analysis started at the downstream channel limits (Huntington Harbour for C02/C04 and Outer Bolsa Bay for C05/C06) and moved upstream for each channel system in an attempt to identify where the maximum channel modification measure may no longer create the greatest net benefits. Upstream of this point all reaches would have the minimum channel modification measure applied.

Considerations made for developing the potential hybrid alternative included (1) if the combination was hydraulically complete and (2) if the next increment would likely result in increased net benefits. A hydraulically complete plan accounted for the interaction and linkages of modifications from the Minimum and Maximum Channel Modifications plans across the various channels and reaches. For example, maximum channel modifications could not be made upstream of minimum channel modifications. This would potentially result in conveyance issues and induced damages downstream.

Apart from the leveed downstream reaches (01 and 23), flooding originates most commonly on the upstream side of the 405 (see Figure 39). Based on the assumptions above, implementing maximum channel modifications in these areas would also require implementing maximum modifications in all preceding reaches downstream of the 405 first, adding major additional costs before achieving those benefits. Therefore, this analysis led to the conclusion that there is unlikely to be a hybrid plan that increases net benefits over the Minimum Channel Modifications Plan already described.

3.9 Full Tidal Basin Outlet Alternative

During public review, a comment was received requesting that USACE consider an alternative layout to the drainage channel that breached the south levee of C05 Reach 01 into the Full Tidal Basin of BCER and eventually the Pacific Ocean from there, rather than following the existing alignment through Outer Bolsa Bay, Huntington Harbor, and Anaheim Bay. A screening level analysis was undertaken to determine whether this alternative warranted further consideration. Ultimately, it was determined that this alternative had a higher risk of disturbing hazardous, toxic, and radioactive waste (HTRW) material, and the habitat created by the existing restoration project in that part of BCER. Since a viable project had already been identified with a lower risk of causing significant adverse impacts to the human and natural resources, this proposed alternative was not considered further. Additional information on the subject is located in *Appendix J - Coordination* and in a white paper attached to that appendix.

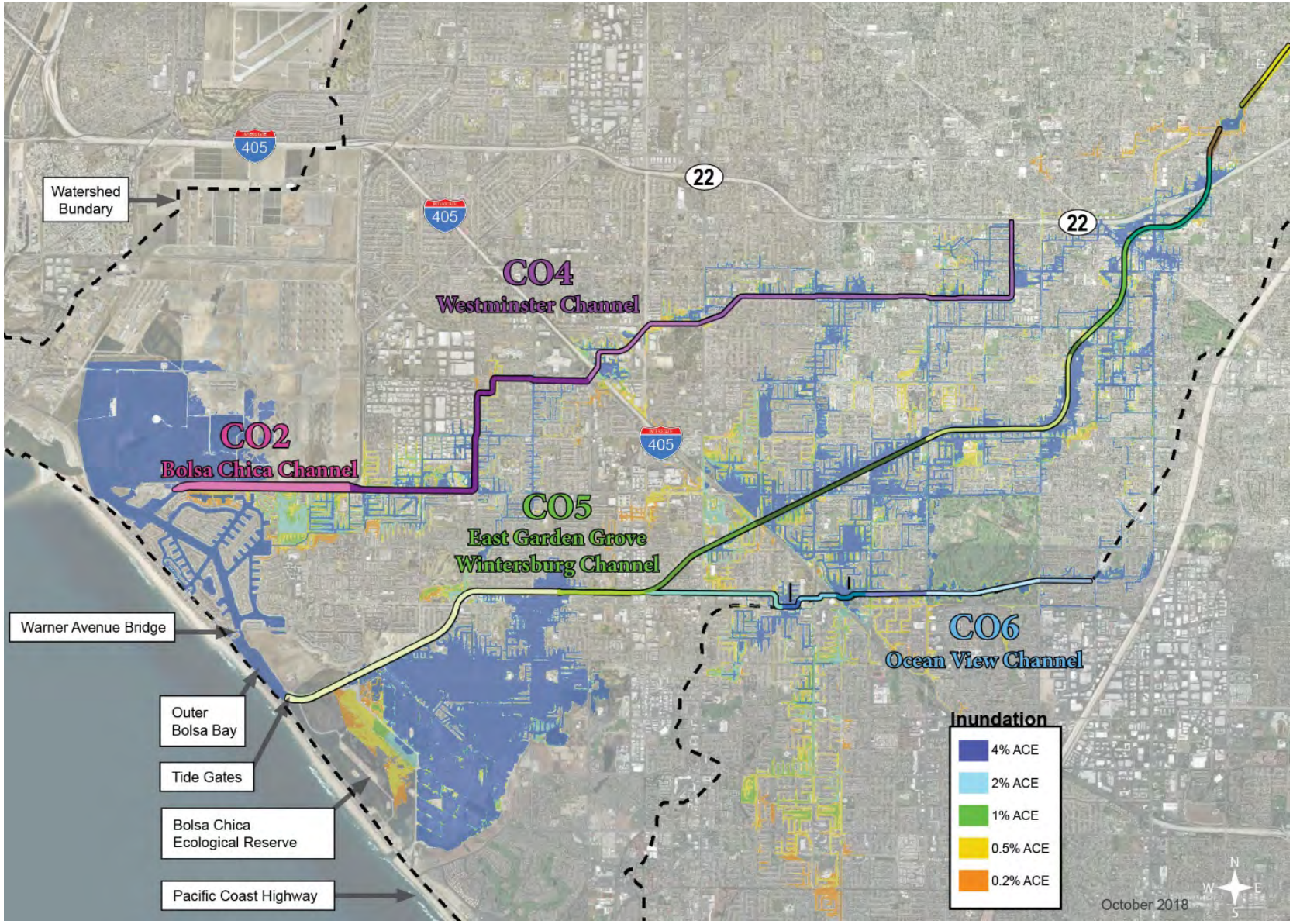


Figure 39: FWOP inundation areas are mostly concentrated at downstream leveed reaches and just upstream of the 405.

4.0 Comparison of Final Array of Alternatives

Per USACE Guidance, the PDT identified the alternative that maximizes net benefits, or the NED Plan.

4.1 National Economic Development Plan

Based on the cost and benefit analysis of the final array of alternatives, the NED Plan is the Minimum Channel Modifications Plan. This plan is estimated to produce $101,743,000 in AAE benefits at an AAE cost of $24,119,000 (total project cost of $483,856,000), for a benefit to cost ratio (BCR) of 4.2 at the current Federal Discount Rate (FDR) of 2.75%.

Table 11: The Minimum Channel Modifications Plan is the NED.

Name	Total First Cost ($1,000)	Equivalent Average Annual Values ($1,000s)		
		Benefits	Costs	Net Benefits
No Action	-	-	-	-
Minimum Channel Modifications				
C02/C04	83,992	4,307	3,875	432
C05/C06	399,864	97,437	20,244	77,192
TOTAL	**483,856**	**101,743**	**24,119**	**77,624**
Maximum Channel Modifications				
C02/C04	445,741	8,974	20,786	-11,812
C05/C06	778,856	107,281	37,425	69,856
TOTAL	**1,224,598**	**116,255**	**58,211**	**58,044**

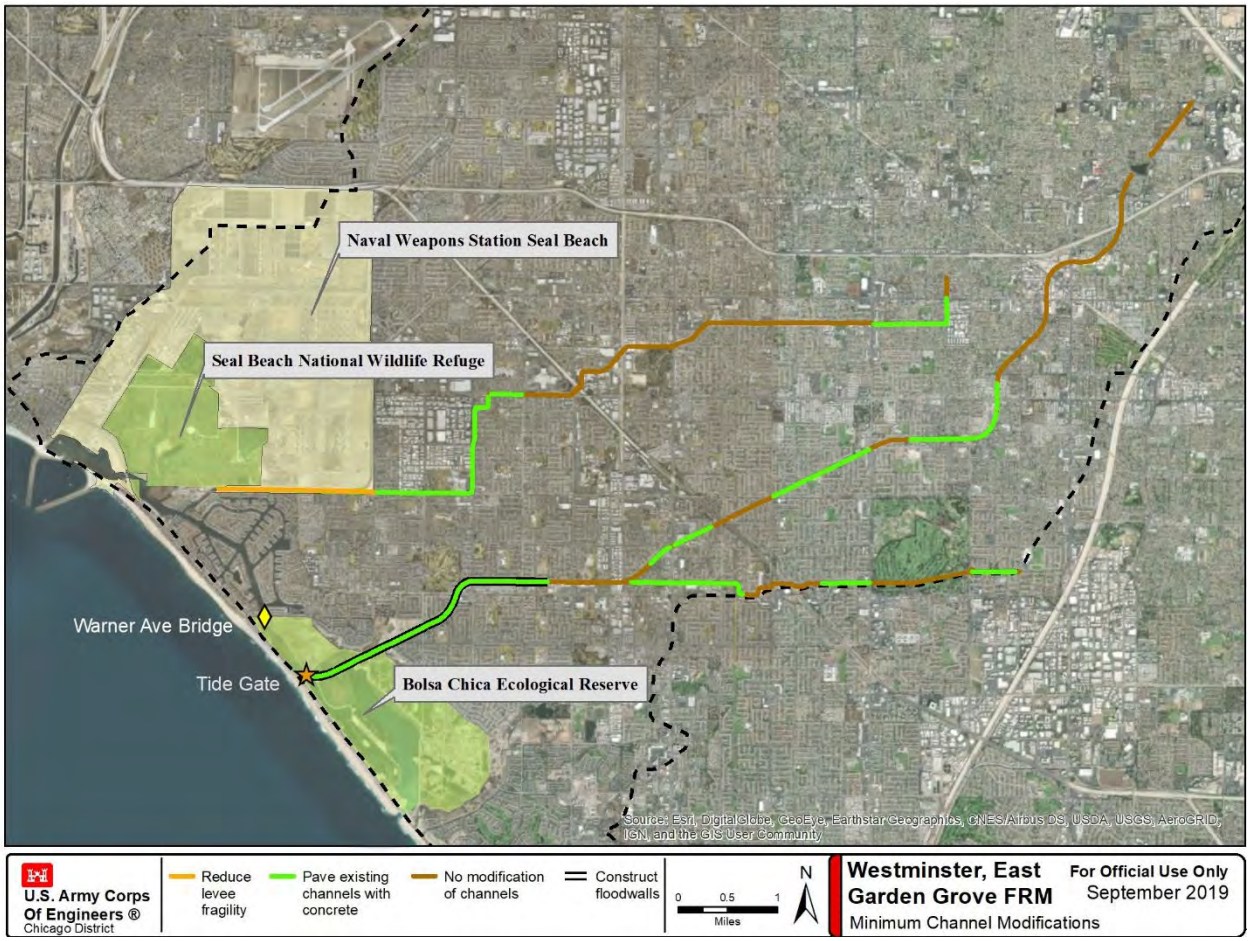


Figure 40: the NED Plan is the Minimum Channel Modifications Plan.

4.2 Identification of a Locally Preferred Plan

The NFS has expressed an interest in pursuing a LPP from one of the final array of alternative plans that was not identified as having the highest average annual net benefits. The LPP is the Maximum Channel Modifications Plan and it is estimated to produce $116,255,000 in AAE benefits at an AAE cost of $58,211,000 (total project cost of 1,224,598,000), for a BCR of 2.0 at the current FDR of 2.75%. LPPs may be selected as the Recommended Plan pending approval from HQUSACE and the Assistant Secretary of the Army for Civil Works (ASA(C)W)), and have a BCR greater than 1. The LPP, or the Maximum Channel Modifications Plan, was approved as the Recommended Plan by the ASA(CW) in a memo dated October 16, 2019: *Westminster, East Garden Grove, California, Flood Risk Management Study – Exception Request for Locally Preferred Plan (LPP).*

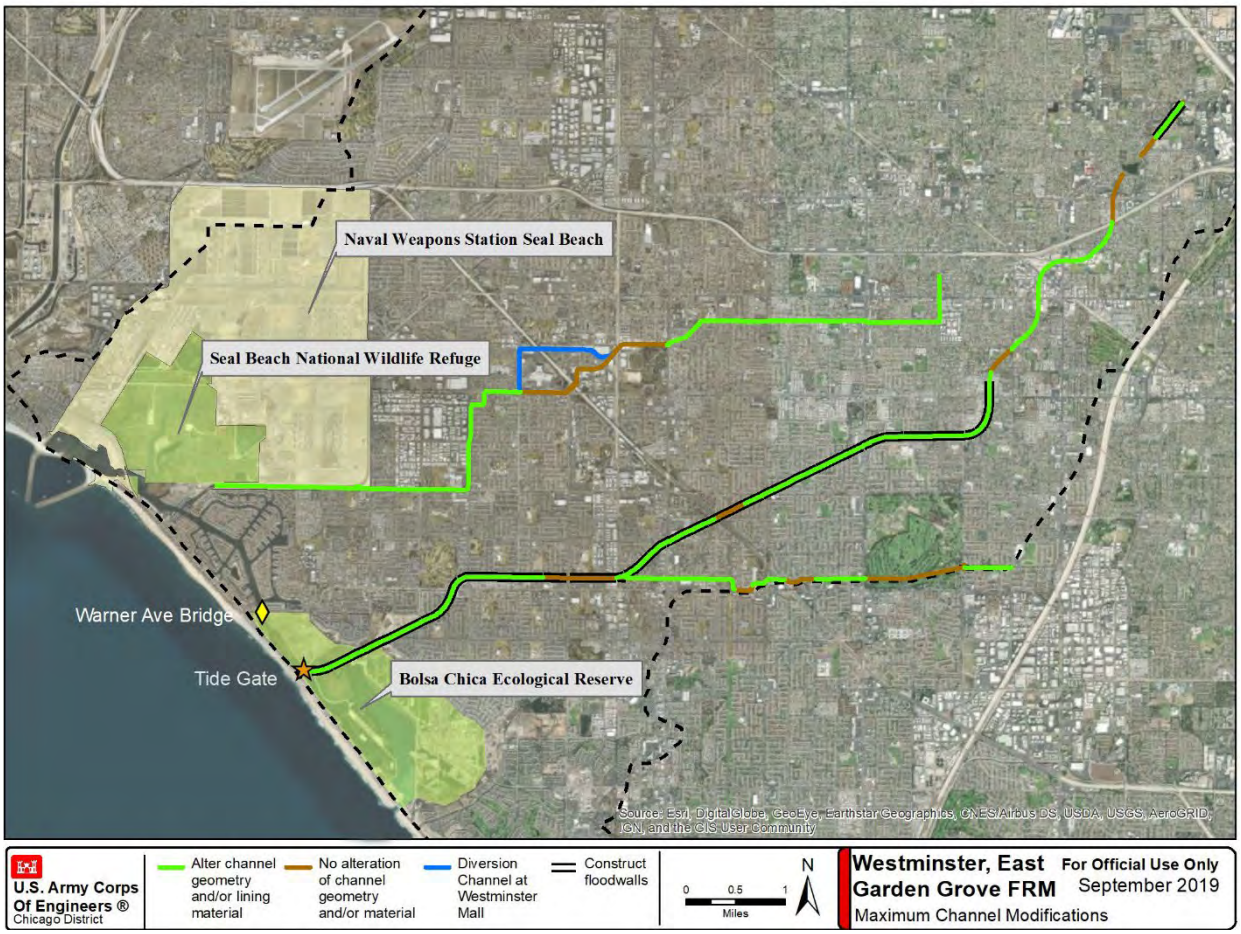


Figure 41: The LPP is the Maximum Channel Modification Plan.

Table 12: The LPP is the Recommended Plan.

Plan	Name	Total First Cost ($1,000)	Average Annual Equivalent Values ($1,000s)			BCR
			Benefits	Costs	Net Benefits	
NED	Minimum Channel Modifications	483,856	101,743	24,119	77,624	4.2
LPP	Maximum Channel Modifications	1,224,598	116,255	58,211	58,044	2.0

Attachments

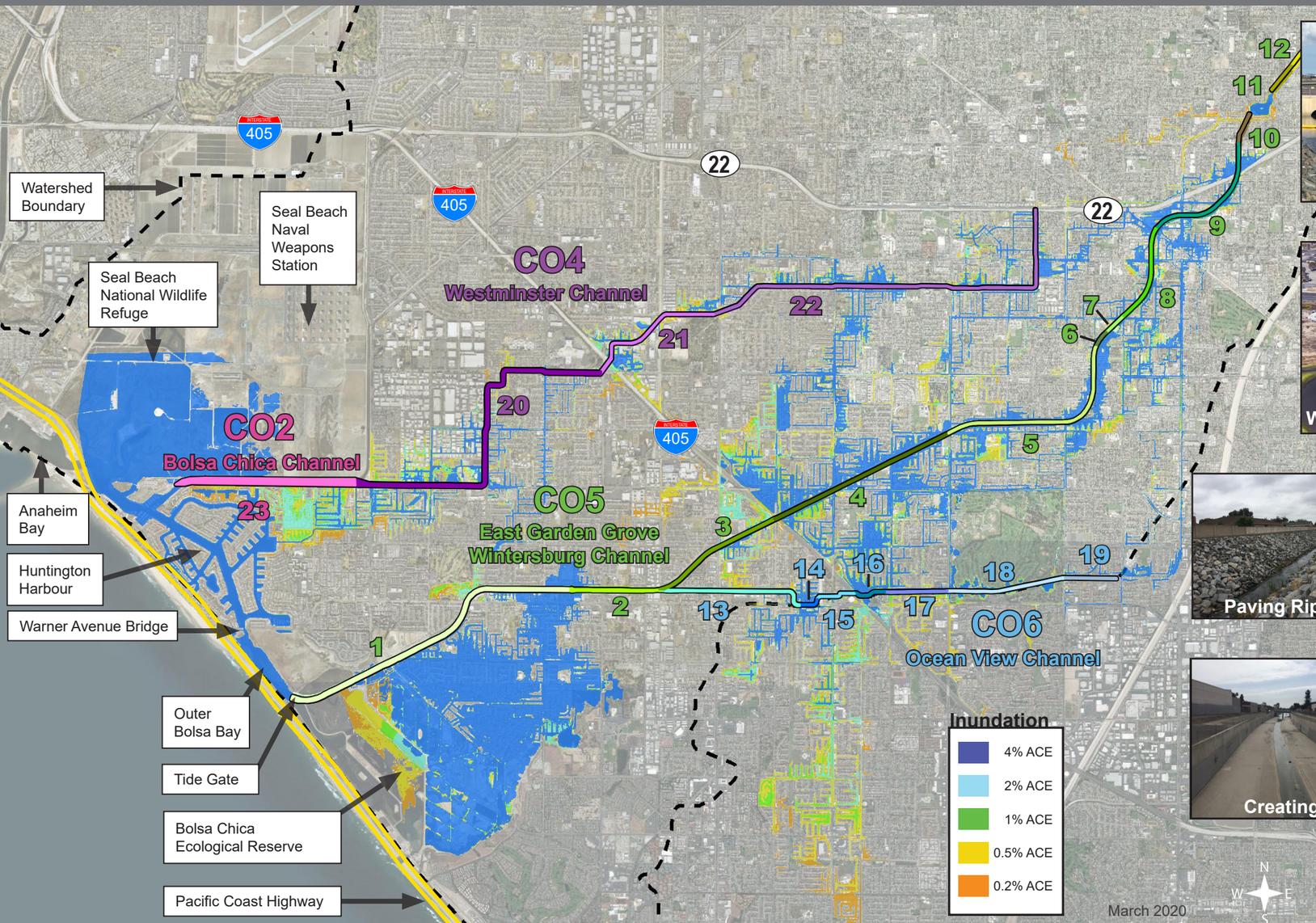
A number of intermediate and supplemental documents related to the plan formulation process are presented in the following pages. These documents were created to increase clarity of communication with the PDT, the NFS, and the VT. Descriptions of the documents are included below:

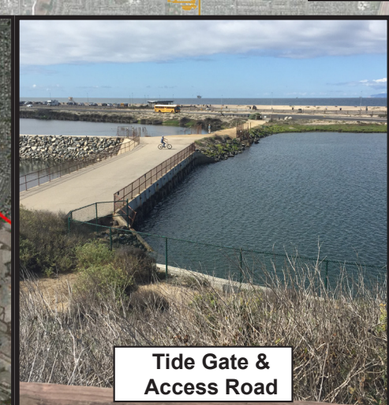
1. Project Placemat (revised)

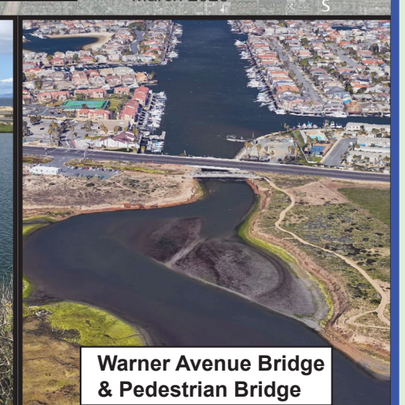
- This double sided "placemat" was created and distributed prior to the 25 July 2018 TSP Milestone Briefing to serve as a quick reference for attendees form the VT and the NFS. The placemat provides general information about the project, calls out important features and place names in the project area, and presents summary information regarding the NED/TSP and LPP Plans. The attached version was updated to reflect changes in the study alternatives between TSP and the final report in October 2019.

WESTMINSTER, EAST GARDEN GROVE, FLOOD RISK MANAGEMENT STUDY

US Army Corps of Engineers
Chicago District







National Economic Development Plan

C02/C04

- ~17,700 LF of paving trapezoidal channels
- ~5,100 LF of paving rectangular channel bottom
- ~9,000 LF of sheet pile along the south bank of C02. Includes:
  - + No excavation of the toe
  - + Preserving soft bottom habitat in the center

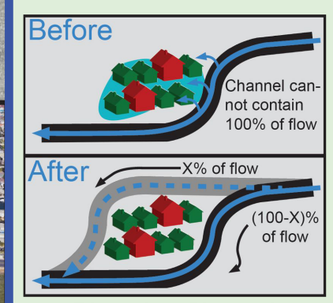
C05/C06

- ~2,700 LF of trapezoidal channel to rectangular concrete channel
- ~27,700 LF of paving trapezoidal channels
- ~14,500 LF of steel sheet pile channel
  - + habitat maintained in the center
- Up to ~18,000 LF of 1-foot to 2-foot floodwalls
- Removal of tide gate
- Installation of replacement access bridge at tide gate location
- Widening of Outer Bolsa Bay at Warner Avenue
  - + Expansion of Warner Ave Bridge
  - + Removal of pedestrian bridge at Bolsa Chica Conservancy
  - + Replacement of pedestrian bridge
- Replacement of 3 roadway crossings

Locally Preferred Plan

C02/C04

- Converting ~11,600 LF of trapezoidal channel to rectangular concrete channel
  - + soft bottom maintained in the center
- Creation or improvement of ~15,000 LF of concrete rectangular channels
- ~5,000 LF of paving trapezoidal channels
- ~7,500 LF diversion channel around Westminster Mall
- ~9,000 LF of sheet pile along the south bank of C02. Includes:
  - + Excavation of the toe
  - + Preserving and expanding soft bottom habitat in the center



Diversion Channel

C05/C06

- ~25,000 LF of trapezoidal channel to rectangular concrete channel
- ~2,300 LF of paving trapezoidal channels
- ~14,500 LF of steel sheet pile channel
  - + habitat maintained in the center
- Up to ~40,000 LF of 1-foot to 2-foot floodwalls
- Removal of tide gate
- Installation of replacement access bridge at tide gate location
- Widening of Outer Bolsa Bay at Warner Avenue
  - + Expansion of Warner Ave Bridge
  - + Removal of pedestrian bridge at Bolsa Chica Conservancy
  - + Replacement of pedestrian bridge
- Replacement of 4 pedestrian channel crossings

- Replacement of 43 roadway crossings (across study area)

WESTMINSTER, EAST GARDEN GROVE, FLOOD RISK MANAGEMENT STUDY

Without Project Damages

Expected Annual Damages

C02 / C04 = $ 3,643,000
C05 / C06 = $68,088,000
Total = $71,730,000

Event Based Impacts Watershed

% ACE	Structures	Expected Damages ($000)
10	2671	$ 292,379
2	4058	$ 742,401
1	4820	$ 886,444
0.2	7244	$1,060,965

National Economic Development (NED) Plan

	C02/C04	C05/C06	Total
Total First Cost [1]	$83,992	$399,864	$483,856
Average Annual Cost [1]	$ 3,875	$ 20,244	$ 24,119
Average Annual Benefits [1]	$ 4,307	$ 97,437	$101,743
Net Benefits [1]	$ 432	$ 77,192	$ 77,624
BCR [1]	1.11	4.81	4.22
BCR at 7% Fed. Discount Rate	0.52	2.20	1.95

FY2020 Price Levels ($1000s); 50 year period of analysis; 2035 base year
[1] - at a Federal Discount Rate of 2.75%

Locally Preferred Plan (LPP)

	C02/C04	C05/C06	Total
Total First Cost [1]	$445,741	$778,856	$1,224,598
Average Annual Cost [1]	$ 20,786	$ 37,425	$ 58,211
Average Annual Benefits [1]	$ 8,974	$107,281	$ 116,255
Net Benefits [1]	$ -11,812	$ 69,856	$ 58,044
BCR [1]	0.43	2.87	2.00
BCR at 7% Fed. Discount Rate	0.27	1.47	1.05

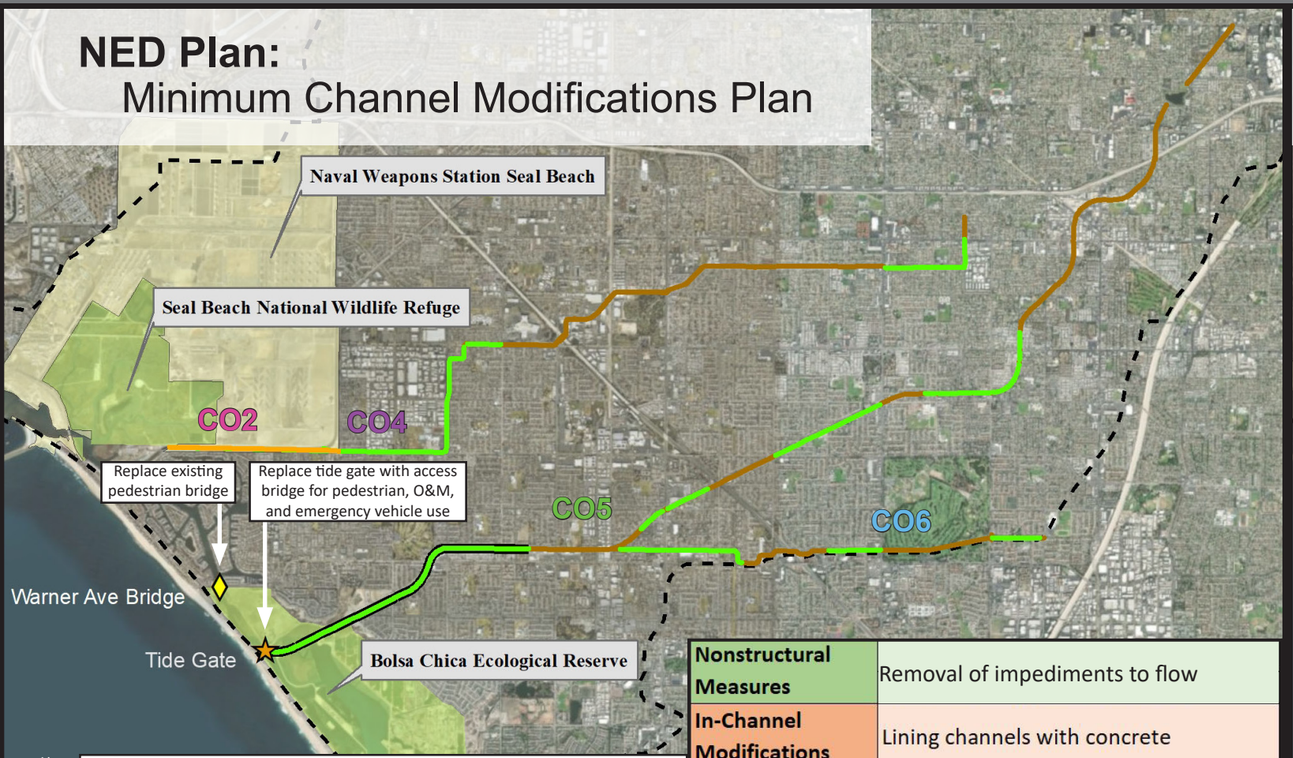
FY2020 Price Levels ($1000s); 50 year period of analysis; 2035 base year
[1] - at a Federal Discount Rate of 2.75%

Federal and Non-Federal Investment

	NED	LPP
Project First Cost		
Federal	$314,506	$ 314,506
Non-Federal	$169,349	$ 910,091
TOTAL	$483,856	$1,224,598

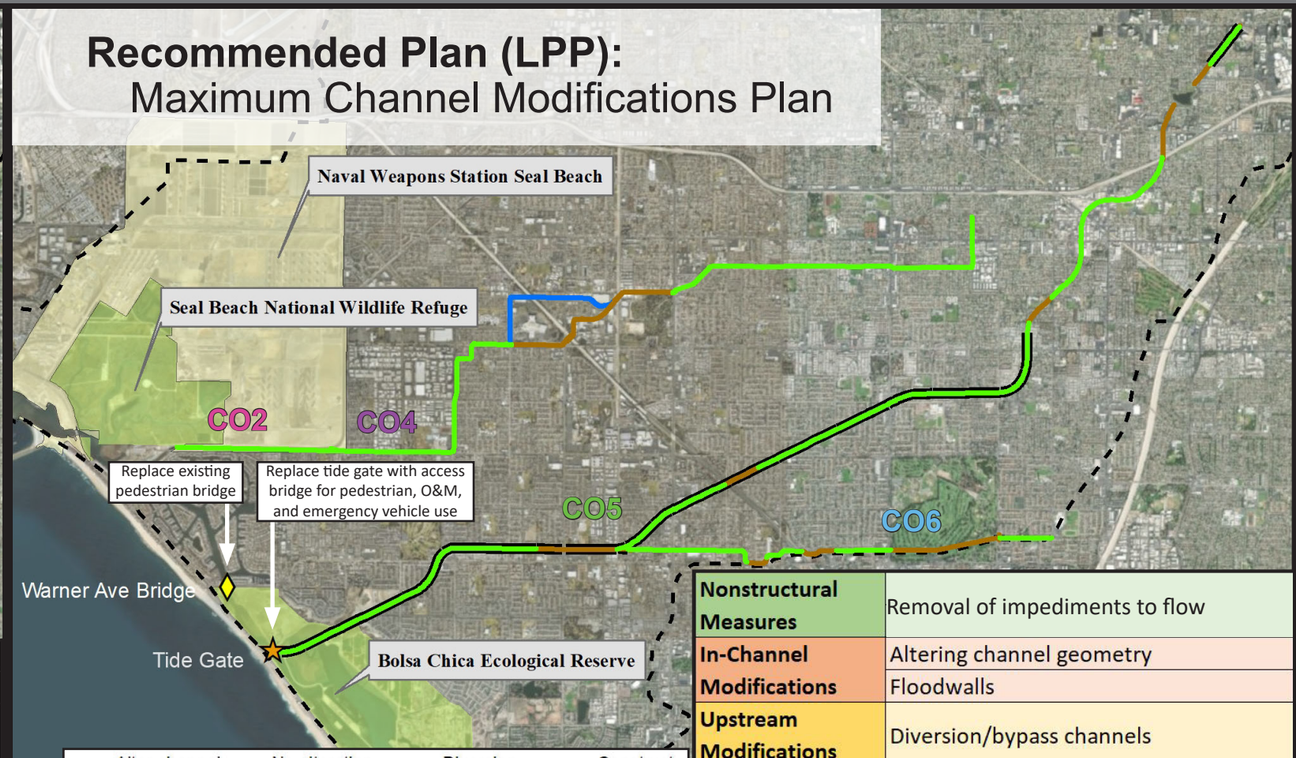
FY2020 Price Levels ($1000s); 50 year period of analysis; 2035 base year

NED Plan: Minimum Channel Modifications Plan



Nonstructural Measures	Removal of impediments to flow
In-Channel Modifications	Lining channels with concrete
Downstream Modifications	Removal of tide gates on C05
	Widening bottleneck at Warner Avenue

Recommended Plan (LPP): Maximum Channel Modifications Plan



Nonstructural Measures	Removal of impediments to flow
In-Channel Modifications	Altering channel geometry
	Floodwalls
Upstream Modifications	Diversion/bypass channels
Downstream Modifications	Removal of tide gates on C05
	Widening bottleneck at Warner Avenue