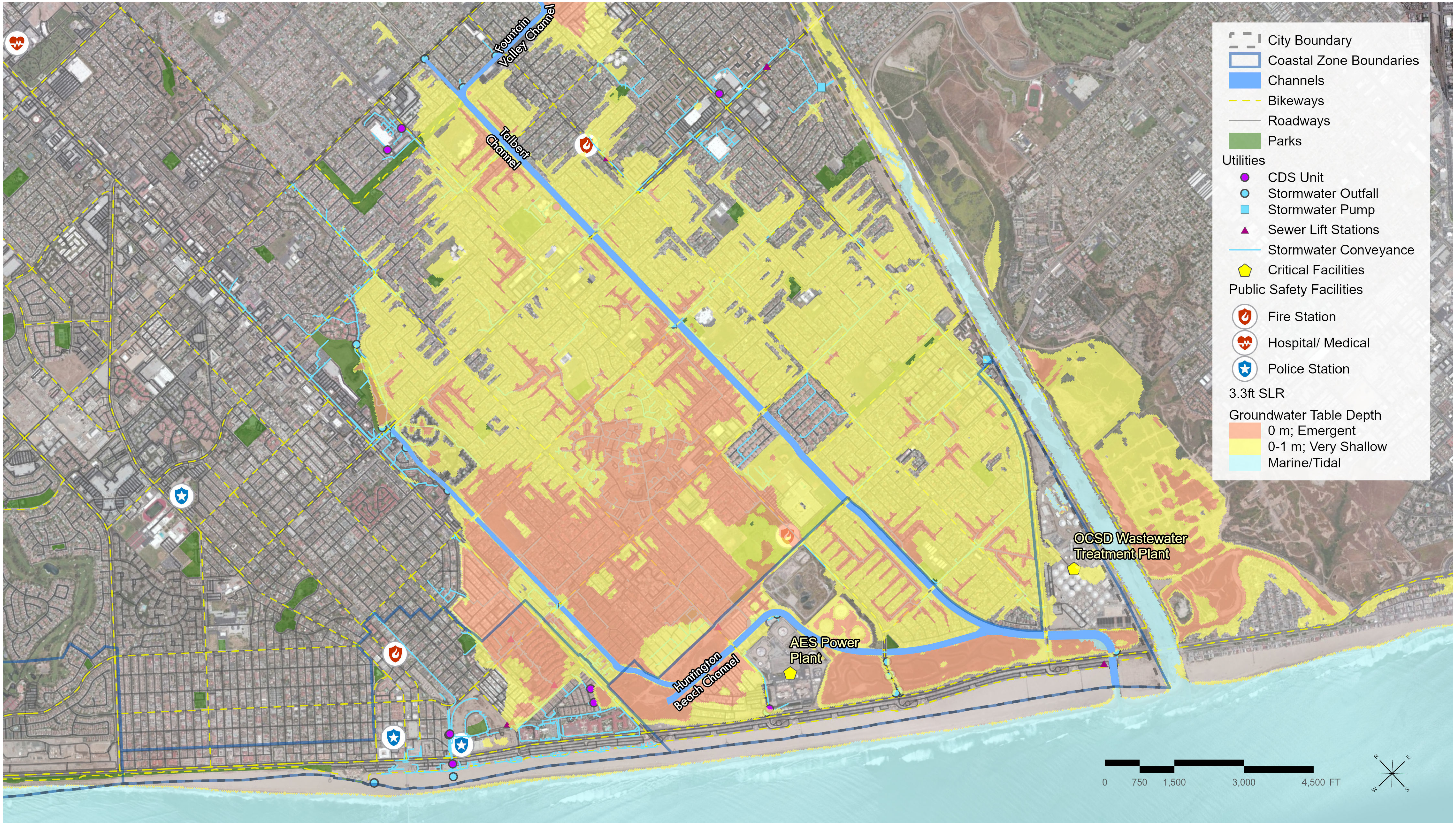

FIGURE 6-25: PROJECTED GROUNDWATER EMERGENCE HAZARD AREAS AND SHALLOW DEPTH AREAS, SOUTHERN STUDY AREAS, 3.3 FT SLR

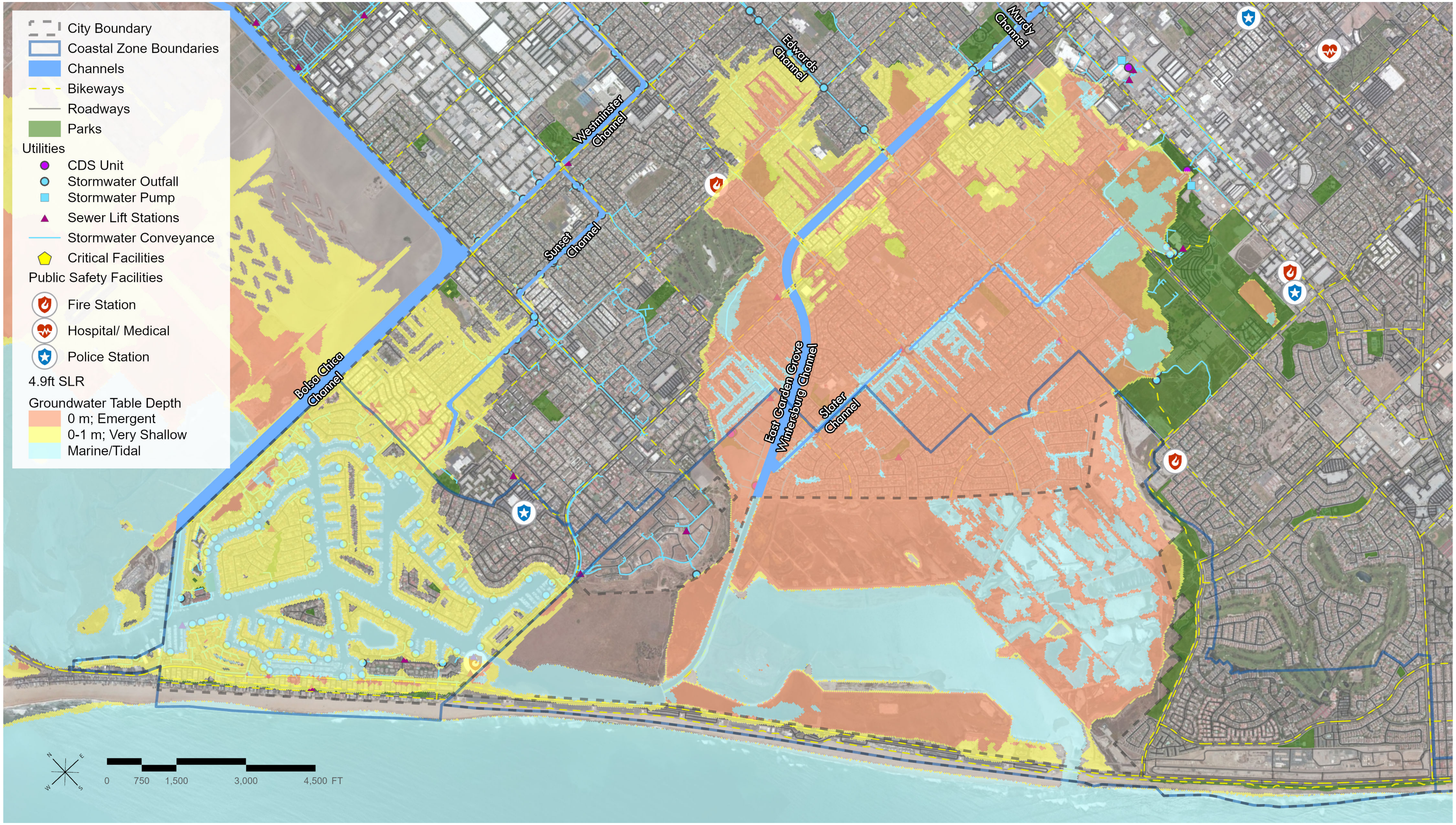

FIGURE 6-26: PROJECTED GROUNDWATER EMERGENCE HAZARD AREAS AND SHALLOW DEPTH AREAS, NORTHERN STUDY AREAS, 4.9 FT SLR

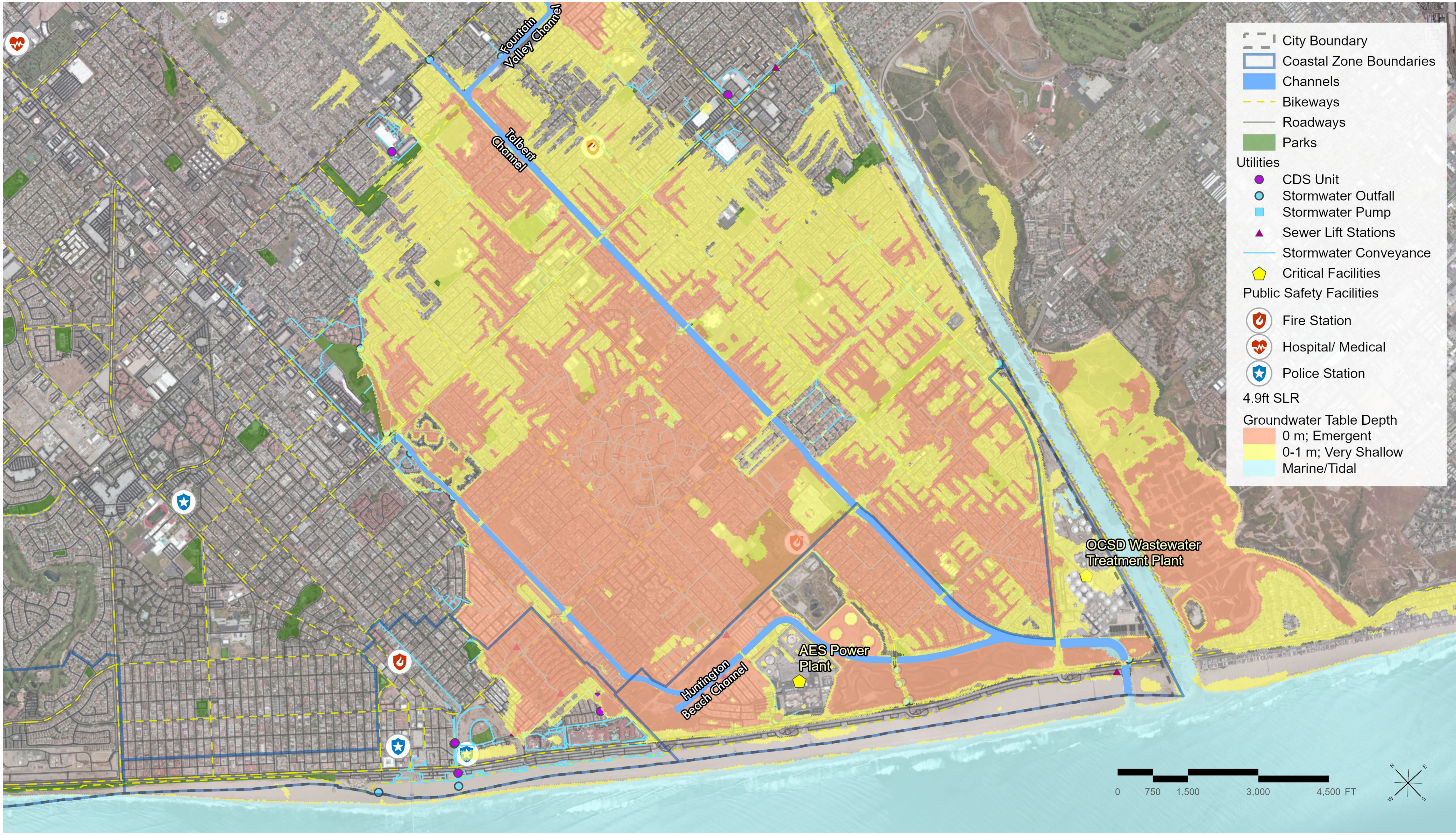

FIGURE 6-27: PROJECTED GROUNDWATER EMERGENCE HAZARD AREAS AND SHALLOW DEPTH AREAS, SOUTHERN STUDY AREAS, 4.9 FT SLR

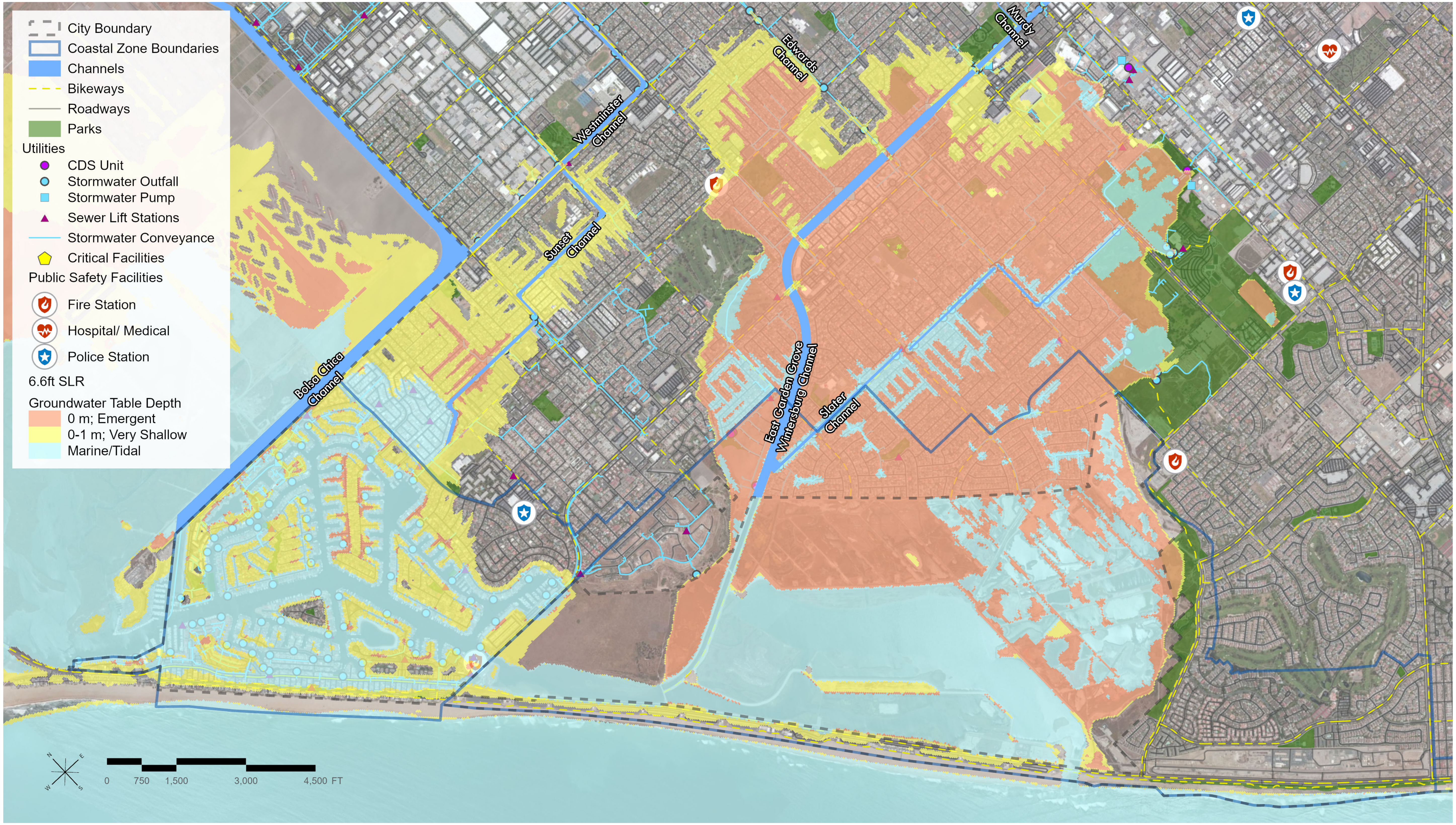

FIGURE 6-28: PROJECTED GROUNDWATER EMERGENCE HAZARD AREAS AND SHALLOW DEPTH AREAS, NORTHERN STUDY AREAS, 6.6 FT SLR

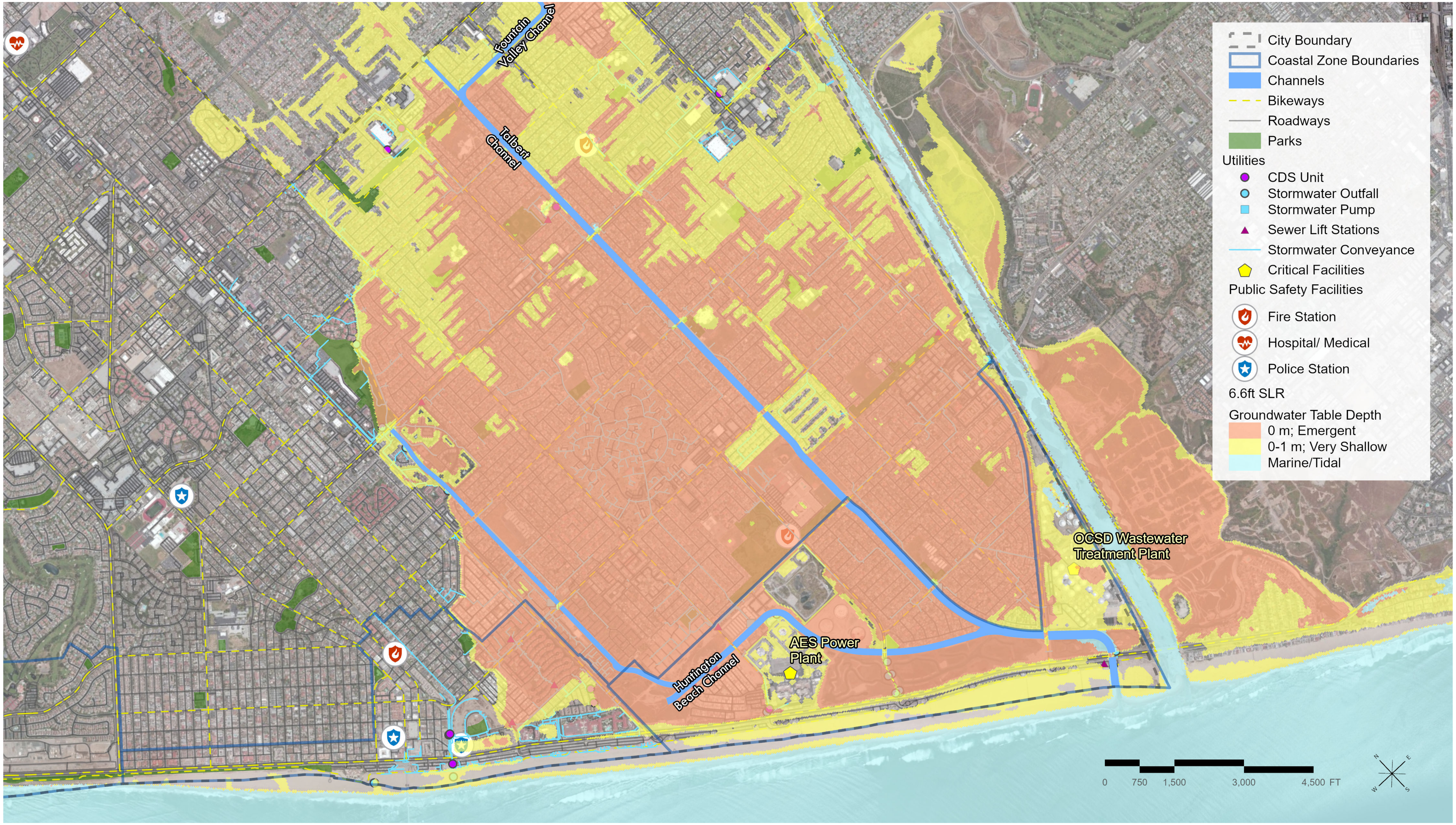

FIGURE 6-29: PROJECTED GROUNDWATER EMERGENCE HAZARD AREAS AND SHALLOW DEPTH AREAS, SOUTHERN STUDY AREAS, 6.6 FT SLR

7. Vulnerability Assessment

This SLR Vulnerability Assessment provides a qualitative evaluation of coastal resources that could be impacted by future SLR hazards. Hazard exposure, hazard sensitivity, and adaptive capacity of coastal resources are given qualitative ratings based on Table 7-1.

TABLE 7-1: EXPLANATION OF VULNERABILITY ASSESSMENT RATING DESIGNATIONS

Category	Rating	Explanation
Hazard Exposure	Low	Exposure to storm flooding in select areas.
	Moderate	Significant exposure to storm flooding and/or partial exposure to non-storm inundation.
	High	Significant exposure to non-storm inundation.
Hazard Sensitivity	Low	Minimal impacts to structure and function due to coastal hazards unless inundated on a regular basis.
	Moderate	Moderate impacts to structure and function during temporary storm flooding. Significant impacts if inundated.
	High	Significant impacts to structure and function from short-term storm flooding or inundation.
Adaptive Capacity	Low	Limited options for adaptation. Adaptation likely to have significant costs.
	Moderate	Multiple options for adaptation over time with relatively moderate effort and cost.
	High	Multiple options for adaptation over time with minor additional cost.

7.1. Coastal Development

7.1.1. Hazard Exposure

The total value of coastal development projected to be exposed to flood hazards under non-storm and storm conditions is presented in Table 7-1 and Table 7-2. These values are intended to provide an order of magnitude estimate of exposed development value. Property value for each building exposed to flood hazards was taken from City GIS data. The value of exposed buildings was calculated based on the total value of the structure. A building was counted as flooded if the center of the structure was located within projected flood hazard boundaries under each SLR scenario. If flood projections reached only the outer portions of a structure it was not included as flooded in exposure calculations. Exposure is then discussed on a study area by study area basis.

TABLE 7-2: CITY-WIDE FLOOD HAZARD EXPOSURE FOR DEVELOPMENT UNDER NON-STORM CONDITIONS

SLR	Number of Buildings Exposed to Flood Hazards	Total Value of Exposed Development ($)
0ft	37	37,034,743
1.6ft	332	161,517,269
3.3ft	2,460	1,480,887,447
4.9ft	3,587 (17,712*)	2,229,929,928 (9,932,112,254*)
6.6ft	10,532 (26,813*)	5,944,198,584 (14,958,495,085*)

*includes exposure from supplementary bathtub flood modelling

TABLE 7-3: CITY-WIDE FLOOD HAZARD EXPOSURE FOR DEVELOPMENT UNDER 100-YEAR STORM CONDITIONS

SLR	Number of Buildings Exposed to Flood Hazards	Total Value of Exposed Development ($)
0ft	259	158,423,901
1.6ft	1,888	1,093,567,611
3.3ft	3,480	2,158,010,201
4.9ft	6,835	3,769,159,817
6.6ft	25,433	14,531,926,892

Huntington Harbour: High

Development within the Huntington Harbour study area has the highest exposure to flood hazards as SLR increases. Select areas currently experience flooding during the highest tides of the year, also known as king tides, and anomalous high tides seen during El Nino events. Storm and non-storm flood projections becoming widespread with 1.6ft SLR and 3.3ft of SLR, respectively. Areas inland of the Harbour also show significant flood projections under 3.3ft and greater SLR scenarios. These 3.3ft SLR and 1.6ft SLR hazard thresholds are largely what contribute to the jumps in value of development exposed to flood hazards shown in Table 7-1 and Table 7-2.

Additional erosion hazards are also present along the shoreline of Sunset Beach. Shoreline position is projected to migrate landward with 1.6ft SLR. Continuous sandy beach area is projected to remain in place across the sub-area under this SLR scenario with beach width decreasing to approximately 150ft in select areas. Under the 3.3ft SLR scenario the shoreline is projected to retreat to within 20ft of development in select locations, leaving only narrow portions of dune habitat or sandy beach area fronting structures. Under 4.9ft and greater SLR scenarios the shoreline is projected to retreat to the current development line across the majority of the sub-area, leaving only small sandy beach and dune areas as a buffer to coastal hazards. As discussed in Section 2.3, beach width in this area is heavily influenced by the Surfside-Sunset beach nourishment program, and so future exposure to erosion hazards is likely to vary based on future sand placement volume and timing.

Bolsa Chica: Moderate
Projected hazards to development from flooding within the Bolsa Chica study area are largely absent under SLR scenarios up to 3.3ft, and flood hazard projections under the 4.9ft SLR scenario appear only in limited areas under severe storm conditions. It is not until 6.6ft SLR that a tipping point is reached, and projected hazard exposure becomes widespread under non-storm conditions. While overall exposure remains low up to this point, this exposure threshold warrants a moderate rating given the potential for non-storm flood impacts over a large area.

Erosion hazards are also projected within the sub-area. Some landward shoreline migration is projected with 1.6ft SLR, but relatively wide sandy beach areas remain in place across the sub-area. With 3.3ft SLR the shoreline is projected to approach facilities at Bolsa Chica State Beach and reach the bluff toe in select areas south of Bolsa Chica inlet. Projected shoreline position is close to or at the current line of development across the majority of the sub-area under 4.9ft and greater SLR scenarios.

Groundwater modeling results show potential groundwater emergence hazard areas within the Bolsa Chica sub-area that could potentially impact development. Groundwater emergence hazard area projections are concentrated in areas surrounding the Bolsa Chica wetlands due to the high groundwater table and low elevation in this area. Significant groundwater hazard areas are projected present under current conditions. Hazard area projections then expand incrementally as SLR increases. While these projections do not fully capture local conditions that may impact the extent of hazard areas, discussed further in Section 5.1.4, the extent of the hazard areas under current conditions and lower SLR conditions warrants consideration of groundwater hazards for development in these areas.

Huntington Beach: Low
Projected flood hazard exposure for coastal development within the Huntington Beach study area remains minimal up to the 6.6ft SLR scenario, with exposure in earlier scenarios primarily limited to the Huntington Beach Pacific House Condo Complex located seaward of the Pacific Coast Highway. Storm flood projections extend across select portions of the study area with 6.6ft SLR, stemming from inland flooding in areas surrounding Huntington Beach Channel. While shoreline position is projected to move landward over time, projections do not approach development under any SLR scenario examined.

Huntington Beach Wetlands: High
Flood hazard exposure projections within the Huntington Beach Wetlands study area follow a similar pattern to the Bolsa Chica study area. Projected hazard exposure is minimal for the 1.6ft and 3.3ft SLR scenarios. CoSMoS flood hazard projections become more widespread with 4.9ft SLR but remain limited to severe storm events, while bathtub modelling shows potential for widespread non-storm flood hazard impacts under this scenario. CoSMoS storm flood projections increase dramatically under the 6.6ft SLR scenario, with non-storm flood projections based on supplementary bathtub modelling increase incrementally. Similar to the Huntington Beach sub-area, shoreline projections show a pattern of retreat but not encroach on any developed areas.

Groundwater emergence hazard areas are also projected within the Huntington Beach wetlands sub-area. Hazard areas are limited under current conditions and with 1.6ft SLR. With 3.3ft SLR hazard areas become more widespread in areas between the Huntington Beach Channel and Talbert Channel. Potential hazard areas extend further landward in these areas under 4.9ft and 6.6ft SLR scenario and also become more widespread south of Talbert Channel.

7.1.2. Hazard Sensitivity

High
Coastal development has a high overall sensitivity to both storm and non-storm flood hazards, particularly those structures with a first floor that sits at ground level. Though temporary, widespread storm flood impacts as projected under a 1.6ft SLR within the Huntington Harbour study area and 4.9ft and greater SLR scenarios within other study areas are likely to cause substantial damage to any flooded structures, potentially disrupting use of major residential, commercial, and recreational resources for an extended amount of time as repairs are made. Non-storm flood projections are likely to frequently result in structural damages and disruption of use and services within affected areas, significantly impacting any development in inundated areas. Erosion of beach areas or other natural habitat fronting development additionally reduces the buffer to coastal hazards such as storm impacts and flooding and in severe cases may

undermine the structural integrity of development, leading to significant damages or loss. Rising groundwater elevations may also exert force on underground structural elements that may cause damage if they exceed current design capacity.

As is the case with hazard exposure, development within the Huntington Harbour study area has increased hazard sensitivity compared to other areas of the City. Development in this area is highly valuable and concentrated in low-lying waterfront locations including several islands. A system of bulkheads currently provides protection from coastal hazards, but select areas remain unprotected and bulkhead heights are variable from different areas and properties. Bulkhead failure or insufficient bulkhead height at one location has the potential to cause flooding across a wide area given the low elevations of developed areas, particularly on the developed islands within the Harbour. Limited access points to these areas also compound hazard sensitivity, as damage or flooding at a single bridge could cut off transportation into or away from large developed areas under hazardous conditions.

7.1.3. Adaptive Capacity

Low

Overall adaptive capacity is low for coastal development due to the challenges and costs associated with implementing traditional flood hazard mitigation measures such as structure elevation, flood protection, or floodproofing, especially when considering the potential for widespread non-storm flood hazard impacts under severe, long-term SLR scenarios. This is particularly true for the Harbour study area, where the majority of protective seawalls vary in type, condition, and elevation and have a relatively low crest with limited ability to accommodate SLR without significant structural improvements. Options for adaptation within the Harbour study area are further limited by the lack of space between coastal protection structures and development and the overall lack of available space on islands. Given these limitations, adaptation strategies for current developed areas may rely on relatively costly measures such as floodproofing, elevating structures over time, or ongoing improvements to existing coastal protection structures to keep pace with increased coastal hazards. Continued improvement or expansion of bulkheads or other structures to protect development may also cause potential adverse impacts on recreational activities within the Harbour such as swimming or kayaking if waterfront access points are restricted.

Despite overall low adaptive capacity, select development areas that have finished floors on an elevated building pads may have improved capacity for adaptation. Options also remain present over the short-to-medium term for low lying development areas in the form of low-cost flood barriers designed to limit damage from temporary, storm-related flooding. However, reliance on temporary measures may not be adequate to accommodate the full extent of potential hazards identified within this study. Barriers may have more limited functionality if flooding stems from groundwater emergence rather than from coastal storms or elevated tidal elevations.

7.2. Stormwater and Sewer Infrastructure

7.2.1. Hazard Exposure

Stormwater and sewer infrastructure projected to be exposed to flood hazards under non-storm and storm conditions is presented in Table 7-3 and Table 7-4. The projected exposure of stormwater and sewer infrastructure was calculated based on the total number of infrastructure located within projected flood hazard boundaries under each SLR scenario.

TABLE 7-4: CITY-WIDE FLOOD HAZARD EXPOSURE FOR STORMWATER AND SEWER INFRASTRUCTURE UNDER NON-STORM CONDITIONS

SLR	Number of Stormwater Outfalls	Number of Stormwater Pump Stations	Number of Sewer Lift Stations
0ft	30	0	2
1.6ft	57	0	5
3.3ft	77	4	9
4.9ft	81 (98*)	4 (39*)	15 (27*)
6.6ft	145 (180*)	24 (42*)	24 (37*)

*includes exposure from supplementary bathtub flood modelling

TABLE 7-5: CITY-WIDE FLOOD HAZARD EXPOSURE FOR STORMWATER AND SEWER INFRASTRUCTURE UNDER 100-YEAR STORM CONDITIONS

SLR	Number of Stormwater Outfalls	Number of Stormwater Pump Stations	Number of Sewer Lift Stations
0ft	55	0	3
1.6ft	80	1	9
3.3ft	84	4	15
4.9ft	102	7	19
6.6ft	170	63	35

Huntington Harbour: High

A number of stormwater outfalls, stormwater pump stations, and sewer lift stations lie within projected flood hazard areas within the Huntington Harbour study area, resulting in high overall hazard exposure. Impacts to stormwater and wastewater systems could be felt as soon as the 1.6ft SLR scenario as storm flood projections extend across the majority of outfalls, lift stations, and the stormwater pump stations located within the Harbour. Higher tidal elevations under non-storm conditions may also impact the numerous stormwater outfalls located along local waterways. 3.3ft SLR again represents a potential impact threshold as non-storm flooding is projected across the study area, likely to cause frequent disruption in the use and function of stormwater and sewer utilities.

Bolsa Chica: Low

Projected hazard exposure for stormwater and sewer utilities within the Bolsa Chica study area is low given the overall limited amount of exposed infrastructure up to the 6.6ft SLR scenario, though impacts from higher groundwater elevations may occur sooner. Flood projections become widespread under the 6.6ft SLR scenario, the relatively low density of stormwater conveyance lines in inland areas helps to limit exposure. If the 6.6ft SLR flood threshold is exceeded the pump locations along the East Garden Grove Wintersburg Channel and the Bolsa Chica wetland levee system would pose the greatest risk. Flood projections also cover several CDS units under 4.9ft and greater SLR scenarios.

Huntington Beach: Low

Projected hazard exposure for stormwater and sewer utilities infrastructure within the Huntington Beach study area is low, as flood hazard projections are largely absent up to the 6.6ft SLR scenario. Storm flood projections cover several sewer lift stations and CDS units within the study area with 6.6ft SLR. Stormwater outfall locations surrounding the Huntington Beach Pier are also projected to become exposed to flooding under non-storm conditions under this scenario.

Huntington Beach Wetlands: High
Stormwater and sewer utilities infrastructure within the Huntington Beach Wetlands study area is given a high rating due to the relatively high concentration of stormwater pump stations along Huntington Beach Channel and Talbert Channel and widespread stormwater conveyance lines located in surrounding areas. While flood hazard projections within the area are limited to severe storm conditions under 3.3ft and lower SLR scenarios, the potential for widespread impacts and disruption of utility infrastructure function under more severe SLR scenarios due to higher tidal elevations and potential groundwater emergence contributes to the high exposure rating.

Two additional critical utility facilities, the AES Power Plant and OCSD Wastewater Treatment Plant (WWTP), are also projected to become exposed to flood hazards under 4.9ft and greater SLR scenarios. CoSMoS flood hazard projections show limited flooding under storm conditions with 4.9ft SLR and increased flooding under the 6.6ft SLR scenario. Supplementary bathtub modelling shows the potential for flooding in significant portions of the OCSD WWTP under extreme high tide conditions with 4.9ft SLR, with flooding also projected in select areas of the AES Power Plant. With 6.6ft SLR extreme high tide inundation projections extend across the majority area of each facility.

7.2.2. Hazard Sensitivity

High
Hazard sensitivity for stormwater and sewer utilities infrastructure is high overall, as the normal operation of stormwater infrastructure can be affected if water levels rise to the point where backwater effects occur. A backwater effect occurs when a channel restriction or obstruction at the downstream end raises the surface of the water upstream from it, potentially leading to flooding. Trash filtration systems such as CDS units can also become damaged or lose functionality if inundated frequently. Non-storm flood projections in areas such as Huntington Harbour under 3.3ft and greater SLR scenarios are likely to impact stormwater operations if outfall locations become inundated for extended periods of time. Any stormwater infrastructure that relies on gravity flow is also likely to experience some reduction in capacity due to higher downstream water levels. Wastewater lift stations are also likely to experience disruptions in service if inundated during flood events. Underground storage vaults may also be subject to increased buoyancy forces with higher groundwater levels. The AES Power Plant and OCSD WWTP are also highly sensitive to SLR hazards, as even minor structural damages or disruptions in service may have extensive impacts to surrounding areas.

7.2.3. Adaptive Capacity

Low
Adaptive capacity of stormwater infrastructure, sewer infrastructure, and critical facilities such as the AES Power Plant and OCSD WWTP are low overall due the built nature of the infrastructure in fixed locations and the need to maintain utility functions if any adaptation measures are implemented. Any adaptation measures for stormwater and sewer infrastructure in highly exposed areas would likely require additional hydraulic studies if significant changes are made to ensure utility functions are not adversely impacted as a result. Though a potential challenge, opportunities exist to coordinate elevation of infrastructure such as outfalls, pumps, and lift stations with any future improvements to or elevation of coastal infrastructure if necessary.

7.3. Potable Water Infrastructure

7.3.1. Hazard Exposure

Moderate

Potable water infrastructure projected to be exposed to flood hazards under non-storm and storm conditions is presented in Table 7-5 and Table 7-6. The projected exposure of potable water infrastructure was calculated based on the total number or length of infrastructure located within projected flood hazard boundaries under each SLR scenario. All water infrastructure was evaluated under non-storm conditions. Only above-ground water infrastructure was evaluated under 100-year storm conditions, as any temporary flood impacts to underground infrastructure during a storm event are expected to be minimal.

TABLE 7-6: CITY-WIDE FLOOD HAZARD EXPOSURE FOR POTABLE WATER INFRASTRUCTURE UNITS UNDER NON-STORM CONDITIONS

Infrastructure Type	0ft SLR	1.6ft SLR	3.3ft SLR	4.9ft SLR	6.6ft SLR
Anode Beds	0	0	4	4	6
Blow Off Risers	0	18	72	80	213
Check Valves	0	0	0	0	0
Fire Service Back Flow	1	13	56	69	189
Monitor Devices	0	0	0	0	0
Plugs	1	14	20	24	31
Pressure Relief Valves	1	1	1	1	3
Pump Outs	0	0	0	0	10
Reducers	0	1	3	4	6
Sample Stations	0	1	4	5	10
Turn Outs	0	0	0	0	0
Valves	8	236	764	955	2525
Water Pipes (mi)	0.84	8.56	28.35	35.10	102.02
Air Vacs	1	3	4	5	17
Cathode Protection	1	1	7	7	26
Hydrants	0	58	240	305	827
Manhole Access Points	0	0	0	0	2
Wells	0	0	0	0	1

TABLE 7-7: CITY-WIDE FLOOD HAZARD EXPOSURE FOR POTABLE WATER INFRASTRUCTURE UNITS UNDER 100-YEAR STORM CONDITIONS

Infrastructure Type	0ft SLR	1.6ft SLR	3.3ft SLR	4.9ft SLR	6.6ft SLR
Air Vacs	1	4	5	8	44
Cathode Protection	1	7	7	7	39
Hydrants	33	206	301	636	2225
Manhole Access Points	0	0	0	0	7
Wells	0	0	0	0	2

Hazard exposure for potable water infrastructure is limited under current conditions and the 1.6ft SLR scenario. The majority of infrastructure types show minimal to non-existent exposure for non-storm conditions under these scenarios, the exceptions being valves, water pipes, and hydrants that are located throughout the potable water infrastructure network. Hazard exposure for hydrants increases for the 1.6ft SLR scenario under 100-year storm conditions, but hazard exposure for other above-ground infrastructure remains limited.

Hazard exposure increases among select infrastructure types under the 3.3ft and 4.9ft SLR scenarios. Underground infrastructure including anode beds, blow off risers, fire service back flow valves, and plugs show increased exposure under non-storm conditions. Above ground infrastructure such as air vacs and cathode protection devices additionally show potential exposure under non-storm and 100-year storm conditions. The 6.6ft SLR scenario represents a significant hazard exposure threshold for potable water infrastructure. The only infrastructure types that are not projected to be exposed to hazards under non-storm conditions for the 6.6ft SLR scenario are check valves, monitor devices, and turn outs. Hazard exposure for the majority of other infrastructure types shows a significant increase in terms of number or length of infrastructure impacted, increasing by a factor of 2-3 in many cases.

7.3.2. Hazard Sensitivity

Moderate

Hazard sensitivity for potable water infrastructure is moderate overall considering the balance of underground and above-ground infrastructure. Underground infrastructure has significantly lower sensitivity than above-ground infrastructure. Impacts to underground infrastructure are limited to flooding under non-storm conditions, where infrastructure access and maintenance activities have the potential to be disrupted on a regular basis. Direct damage to underground infrastructure is unlikely to result from above-ground flooding but may occur if elevated groundwater levels apply forces beyond the current design capacity. Damage may also occur if elevated saltwater levels cause increased corrosion to water infrastructure. The potential for corrosion damage is dependent on the material water infrastructure is made of. Infrastructure such as anode beds and cathode protector are unlikely to be damaged by contact with salt water. Ductile iron or cast iron can experience increased corrosion if exposed to salt water, but degrade at rates much slower than metals such as copper.

Above-ground infrastructure has a higher hazard sensitivity as even temporary flood impacts can damage infrastructure and impact overall potable water system functions. The potential for corrosion damage is also increased due to direct contact with salt water during flood events. In addition to corrosion damage, potential damage to different types of above-ground infrastructure is listed in Table 7-7.

TABLE 7-8: POTENTIAL DAMAGE TO ABOVE-GROUND POTABLE WATER INFRASTRUCTURE DURING FLOOD EVENTS

Infrastructure Type	Potential Flood Damage
Air Vacs	Structural degradation due to corrosion. Flood waters could prevent air from escaping if flooding occurs frequently or over an extended period of time. Damage may occur due to pressure build up if air is unable to exit. Potential contamination of potable water system with flood water.
Cathode Protection	Though resistant to corrosion, any structural damage to cathode protection units could lead to increased corrosion throughout the water utility system until units are repaired or replaced.
Hydrants	Structural degradation due to corrosion. Loss of access during flood events. Impacts to emergency services.

Manhole Access Points	Structural degradation due to corrosion. Loss of access during flood events. Impacts to utility network monitoring and maintenance. Risk of flooding and corrosion to any underground infrastructure located near manhole. Potentially increased loads to water treatment systems and pressure in storm drain systems.
Wells	Structural degradation due to corrosion. Loss of access during flood events, Potential structural damage during floods if hydrostatic forces exceed structural design, leading to extended loss of functions. Potential contamination of groundwater or oil spill.

7.3.3. Adaptive Capacity

Low
Similar to stormwater and sewer infrastructure, the adaptive capacity of potable water infrastructure is low overall due to the potential difficulty of relocating infrastructure and the need to maintain overall infrastructure system functionality. Hydraulic studies would again likely be required if significant changes are made to the potable water infrastructure network, and any adaptation measures for above ground potable water infrastructure would need to consider elevation of surrounding infrastructure such as roadways and development. Long-term corrosion protection may also require replacing existing infrastructure with more corrosion resistant material such as PVC in high hazard areas. Corrosion protection can also be increased within high-hazard areas through measures such as polyethylene encasement, application of metallized arc spray zinc coating, or cathodic protection retrofits.

7.4. Public Safety Facilities

7.4.1. Hazard Exposure

Low
Projected flood hazard exposure for public safety facilities such as fire stations, police stations, and major medical facilities is low overall. The only facility projected to be impacted up to 3.3ft SLR is the Warner Avenue fire station within Huntington Harbour. Additional facilities projected to be impacted under 4.9ft SLR are the Magnolia Street and Bushard Street fire stations based on supplementary bathtub modelling. Projected facility exposure increases slightly with 6.6ft SLR, including the Pacific Coast Highway police station under extreme high tide conditions based on supplementary bathtub hazard modelling. The only facility located within a projected groundwater emergence hazard area is the Magnolia Street fire station under 3.3ft and greater SLR scenarios.

7.4.2. Hazard Sensitivity

High
Hazard sensitivity for public safety facilities is given a high rating as these facilities are often major structures containing highly specialized equipment. The services provided by these facilities are also critical to the health and safety of surrounding communities, and so even a short-term disruption in service caused by structural damage or lack of access to facilities could potentially have high consequences.

7.4.3. Adaptive Capacity

Moderate
Overall adaptive capacity for public safety facilities is moderate given that the primary hazard projection is flooding in select areas under severe storm conditions. Traditional flood mitigation actions such as wet or dry floodproofing remain as options to address these temporary, storm-driven flood impacts. Facilities could also potentially be relocated as part of long-term planning efforts if other adaptation measures prove to no longer be feasible.

7.5. Transportation Infrastructure

7.5.1. Hazard Exposure

Transportation infrastructure, including roadways and bikeways within City limits, that is projected to be exposed to flood hazards under non-storm and storm conditions is presented in Table 7-5 and Table 7-6. The projected exposure of transportation infrastructure was calculated based on the total length of infrastructure located within projected flood hazard boundaries under each SLR scenario. Bikeways include both dedicated bike paths and bike lanes as defined in City GIS data.

TABLE 7-9: CITY-WIDE FLOOD HAZARD EXPOSURE FOR TRANSPORTATION INFRASTRUCTURE UNDER NON-STORM CONDITIONS

SLR	Roadways (mi)	Bikeways (mi)
0ft	0.6	0.3
1.6ft	11.8	2.2
3.3ft	35.1	5.4
4.9ft	46.1 (217.7*)	9.9 (43.5*)
6.6ft	148.1 (344.3*)	25.9 (65.7*)

*includes exposure from supplementary bathtub flood modelling

TABLE 7-10: CITY-WIDE FLOOD HAZARD EXPOSURE FOR TRANSPORTATION INFRASTRUCTURE UNDER 100-YEAR STORM CONDITIONS

SLR	Roadways (mi)	Bikeways (mi)
0ft	8.4	2.8
1.6ft	33.2	5.7
3.3ft	46.6	10.3
4.9ft	108.5	21.9
6.6ft	350.9	64.3

Huntington Harbour: High
Projected hazard exposure for transportation infrastructure within the Huntington Harbour study area is high overall. Storm flooding is projected to impact major coastal roadways such as the Pacific Coast Highway under current conditions. With 1.6ft SLR non-storm flood projections extend across the Pacific Coast highway and several local roadways, resulting in frequent inundation and loss of service. Nearly all roadways within the Harbour are projected to flood under non-storm conditions with 3.3ft SLR as flood extents extend inland.

Bolsa Chica: Moderate
Though the flood exposure of transportation infrastructure within the Bolsa Chica study area does not become widespread until the 6.6ft SLR scenario, hazard exposure for this study area is rated as moderate due to the projected impacts to the Pacific Coast Highway, the only coastal roadway, and primary means of transportation across the area. Select areas of the Highway are projected to flood under current conditions during a severe storm event. Non-storm flood projections are seen in select areas with 1.6ft SLR, becoming more widespread with 3.3ft SLR. Bluff erosion projections south of Bolsa Chica Inlet also show potential impacts to Pacific Coast Highway under 3.3ft and greater SLR scenarios in areas where rock

revetment or other coastal protection structures are not currently in place. A number of locations along the highway are projected to become exposed to non-storm flood impacts with 4.9ft SLR. With 6.6ft SLR nearly the entirety of the Pacific Coast Highway upcoast of the Bolsa Chica Inlet is projected to flood under non-storm conditions. Local roadways inland of the Bolsa Chica wetlands are also projected to become inundated on a widespread basis with 6.6ft SLR. Local roadways inland of the Bolsa Chica wetlands are also within potential groundwater emergence hazard areas that could lead to flooding without sufficient drainage.

Huntington Beach: Low
Hazard exposure for transportation infrastructure within the Huntington Beach study areas is highly limited, with flood projections absent until the 4.9ft SLR scenario. Even under 4.9ft and greater SLR scenarios projected hazard exposure is largely limited to select areas of the Pacific Coast Highway and local roadways in the downcoast portion of the study area under severe storm conditions.

Huntington Beach Wetlands: High
Though flood hazard projections for transportation infrastructure within the Huntington Beach Wetlands study area show exposure only under 4.9ft and greater SLR scenarios, the potential for widespread non-storm flood impacts under the 4.9ft SLR scenario seen in supplementary hazard modelling warrants a high exposure rating. These non-storm flood projections with 4.9ft SLR include major roadways such as the Pacific Coast Highway as well as the majority of local roadways in the area. Flood hazard exposure increases incrementally with 6.6ft SLR as flood projections extend further inland. Local roadways surrounding Huntington Beach Channel and Talbert Channel are also within potential groundwater emergence hazard areas under 3.3ft and greater SLR scenarios.

7.5.2. Hazard Sensitivity

Moderate
The hazard sensitivity for transportation infrastructure is moderate overall, but is variable based on the type of hazard and level of use. This single hazard sensitivity rating is intended to provide an indication of the overall sensitivity of transportation infrastructure across the City. Transportation infrastructure typically has a low sensitivity to shallow and short duration flooding, as minor flooding is unlikely to result in significant damage. This sensitivity can be reduced further if roadways subject to coastal flooding are constructed with marine corrosion resistant materials. An exception would be highly trafficked roadways such as Pacific Coast Highway where even short-duration flooding could lead to extensive travel disruptions, especially in the Huntington Harbor and Bolsa Chica study areas where limited alternative transportation routes are available. Due to the potential for additional adverse impacts the sensitivity for Pacific Coast Highway can be considered high.

As flooding becomes more frequent and severe, transportation infrastructure across the City becomes more sensitive to hazards as longer interruptions in service and more extensive damage become likely along roadways. Infrastructure along the shoreline is also sensitive to erosion and undermining, which can result in prolonged closures, safety concerns, and costly repairs. Widespread flooding, traffic congestion from road closures, or damage to key roads may also impact emergency response times.

7.5.3. Adaptive Capacity

Moderate
Transportation infrastructure has a moderate adaptive capacity overall. In a similar manner to hazard sensitivity, this single adaptive capacity rating represents the overall sensitivity of transportation infrastructure across the City. Roadways such as Pacific Coast Highway have a lower adaptive capacity due to their high traffic volume and limited alternative routes. Strategies such as elevation are generally more feasible for select portions of roadways as compared to residential or commercial development, but the location of coastal roadways is often inflexible due to the lack of available area landward and the need to connect multiple high-use coastal recreational services within the City. The adaptive capacity of these coastal transportation corridors is also dependent on the ability of existing natural and constructed features along the shoreline to dissipate wave energy during extreme events, preventing recurring structural damages. Given these factors, adaptation strategies will likely require measures to accommodate extreme storm flood impacts and limit potential for more frequent tidal inundation events along coastal roadways as SLR increases.

7.6. Coastal Access and Recreation

7.6.1. Hazard Exposure

Park areas projected to be exposed to flood hazards under non-storm and storm conditions are presented in Table 7-7 and Table 7-8. The projected exposure of park areas was calculated based on the total acreage of park areas within projected flood hazard boundaries under each SLR scenario.

TABLE 7-11: CITY-WIDE FLOOD HAZARD EXPOSURE FOR PARKS UNDER NON-STORM CONDITIONS

SLR	Parks (acres)
0ft	2.8
1.6ft	3.6
3.3ft	7.6
4.9ft	17.4 (129.3*)
6.6ft	189.3 (314.2*)

*includes exposure from supplementary bathtub flood modelling

TABLE 7-12: CITY-WIDE FLOOD HAZARD EXPOSURE FOR PARKS UNDER 100-YEAR STORM CONDITIONS

SLR	Parks (acres)
0ft	3.4
1.6ft	8.4
3.3ft	16.4
4.9ft	44.9
6.6ft	333.2

Huntington Harbour: Moderate

Coastal access and recreational resources, including sandy beaches and parks in coastal areas, have a moderate exposure to SLR hazards within the Huntington Harbour study area. Usable beach area is projected to remain in place with 1.6ft SLR, with areas becoming more limited with 3.3ft SLR. Beach areas are projected to be largely absent with 4.9ft SLR, the same threshold at which the Sunset Beach Linear Park is projected to become regularly inundated. Access to Harbour waterways along Pacific Coast Highway are projected to be impacted under high spring tides with 1.6ft SLR, with the degree of impact varying based on site-specific coastal access infrastructure. Loss of these access points could diminish access to recreational activities such as kayaking, paddle boarding, and swimming within the Harbour in the absence of adaptation measures. Access to Harbour waterways throughout the study area are projected to be impacted with 3.3ft SLR as non-storm flood projections become widespread. Coastal access to beach areas is also likely to be diminished under this SLR scenario due to landward migration of the shoreline.

Bolsa Chica: Moderate

Continuous sandy beach areas are projected to remain in place along Bolsa Chica State Park under both the 1.6ft and 3.3ft SLR scenarios. Limited beach areas are projected to remain in place with 4.9ft SLR, located in areas just upcoast of the Bolsa Chica Inlet. Access to remaining beach areas is also likely to be impacted due to shoreline retreat in areas fronting parking lots within Bolsa Chica State Beach. With 6.6ft SLR these remaining areas are projected to be minimal. Parking lots along the State Park are projected to experience flooding in select areas during severe storms with 3.3ft SLR. These impacts become more widespread with 4.9ft SLR, and regular inundation of parking lots is projected with 6.6ft SLR.

The bluffs area to the south of Bolsa Chica Inlet has greater exposure at earlier SLR thresholds. Beach areas narrow with 1.6ft SLR, and select beach areas are projected to become absent with 3.3ft SLR as the shoreline extends back to existing protection structures. Beach areas are projected to be virtually non-existent along this stretch of shoreline with 4.9ft and greater SLR. Bluff erosion projections along Bluff Top Park remain fixed where existing toe stabilization infrastructure is present, while unprotected upcoast areas of the park are projected to receded landward over time. Access to coastal areas fronting the bluffs would be further diminished if bluff erosion caused damage to existing parking lots, bikeways, and other coastal access infrastructure across the blufftop.

Huntington Beach: Low
Relatively wide sandy beach areas are projected to remain in place along the Huntington Beach study area across all SLR scenarios examined, except for the far upcoast portions of the study area and areas fronting the Huntington Pacific Beach House Condo Complex, where beach width narrows under the 6.6ft SLR scenario. Parking lots surrounding the Huntington Beach Pier and Huntington State Beach also have low hazard exposure, with flood projections seen only in 4.9ft and greater SLR scenarios under severe storm conditions.

Huntington Beach Wetlands: Low
Wide sandy beach areas are projected to remain in place along the Huntington Beach Wetlands study area across all SLR scenarios examined. Flood projections within coastal parking lots are only observed in 4.9ft and greater SLR scenarios.

7.6.2. Hazard Sensitivity

Moderate
Overall hazard sensitivity for coastal access and recreation resources within the City can be characterized as moderate based on the relatively low potential for hazard impacts within the Huntington Beach and Huntington Beach Wetlands study areas combined with the higher potential for impacts within the Bolsa Chica and Huntington Harbour study areas. Beaches fronting development or protective structures within these areas are the most sensitive to erosion hazards as potential landward migration to higher elevations is limited, a process referred to as “coastal squeeze”. This sensitivity is exacerbated in areas where beaches are currently narrow or experience erosion over time following significant nourishment events.

7.6.3. Adaptive Capacity

High
Coastal access and recreation resources within the City have a high overall adaptive capacity. The wide beaches present across significant portions of the City provide a significant buffer to SLR impacts, with many areas in southern portions of the City showing the ability to maintain recreational use even under 6.6ft SLR. While adverse impacts to coastal access and recreation are unlikely to be entirely absent with 6.6 ft SLR, the persistence of beach areas even under this low-probability, long-term SLR scenario demonstrates an inherent ability of many City beaches to adapt to rising water levels over time. A brief review of CoSMoS shoreline modeling results under a “No Nourishment” scenario also shows persistent sandy beach areas within the Huntington Beach and Huntington Beach Wetland study areas, again demonstrating the adaptive benefit provided by current beach width. Inherent adaptive capacity of beach areas is reduced within the Bolsa Chica and Huntington Harbour study areas due to relatively narrower beach widths. With limited ability to migrate landward these sandy beach areas are projected to decline significantly under 3.3 ft and greater SLR scenarios in the absence of adaptation measures, but adaptive capacity is aided by the ongoing the major federal beach nourishment program in the area that could potentially be augmented over time to meet increased demand.

7.7. Environmental Resources

7.7.1. Hazard Exposure

High

Coastal environmental resources such as wetlands have a high exposure to SLR hazards as these areas are continuously exposed to changes in tidal water elevations over time. While specific impact thresholds are challenging to quantify due to the number of interdependent ecological process involved, potential thresholds can potentially be estimated based on changes in non-storm flood projections within current wetland areas. Non-storm flood projections within the Huntington Beach Wetlands remain absent up to the 4.9ft SLR scenario where flood projections extend across all current wetland areas, indicating the potential for complete inundation of these areas on a frequent basis, which will result in major habitat conversion from vegetated salt marsh to subtidal areas.

7.7.2. Hazard Sensitivity

High

Though wetlands are largely resistant to temporary inundation hazards, coastal wetlands can be highly sensitive to consistently elevated non-storm water levels, as these changes can significantly alter the structure and function of wetland ecosystems. This is particularly true if the inland migration of tidal floodwaters exceeds the landward migration rate or sediment accretion rate of wetland areas. If wetlands areas cannot match the gradual increase in tidal elevations due to SLR these systems will gradually transition to subtidal areas, covered by water at all states of the tide.

7.7.3. Adaptive Capacity

Moderate

The adaptive capacity of wetland areas is highly dependent on the ability of these natural features to maintain their relative elevation to water levels over time. In natural systems, sediment supply from river discharge or bluff erosion can offset the impacts of SLR on wetland areas through sediment accretion, which increases land elevation over time. This potential adaptive capacity is highly dependent on a number of dynamic processes including rates of SLR, coastal sediment accretion, and the ability of wetland species to colonize new areas, and as such may require ongoing monitoring efforts to ensure preservation of ecological functions. Given the relative lack of open space surrounding wetlands within Huntington Beach, alternative methods such as thin-layer sediment placement may also be employed to mitigate SLR impacts by gradually elevating wetland areas as SLR increases.

7.8. Socioeconomic Vulnerability and Environmental Justice

Environmental justice components of future SLR hazards were evaluated using the 2018 Social Vulnerability Index (SVI), published by the U.S. Center for Disease Control (CDC), and the results of CalEnviroScreen 4.0, an environmental health screening tool developed by the California Environmental Protection Agency (CalEPA) and the Office of Environmental Health Hazard Assessment (OEHHA). The SVI program uses 15 socioeconomic and demographic factors at the census tract level to detect socially vulnerable areas where populations may be more adversely affected during disaster events. These variables are organized into four themes: socioeconomic status, household composition and disability, minority status and language, and housing and transportation. Analyses presented within this study are based on summary variables within each theme, generated through percentile ranking of each variable for all census tracts within the state of California. Percentile ranking values range from 0 to 1, with higher values indicating greater vulnerability.

CalEnviroScreen data are also available at the census tract level. Pollution burden within each census tract is characterized using a wide variety of statewide indicators on pollution exposure and environmental effects. Similar to the SVI, percentiles are used to assign scores for each indicator in each geographic area. Percentile scores of each indicator are averaged and combined to produce an overall pollution burden score for each census tract relative to other tracts within California. The score is scaled with a range of 0 to 10, with 10 representing the highest pollution burden. Specific variables included in pollution burden scoring and each SVI theme are detailed below.

The socioeconomic status summary variable (Figure 7-1) is based on four factors: percentage of persons living below the poverty line, percentage of civilians age 16+ that are unemployed, per capita income, and the percentage of persons age 25+ with no high school diploma. Socioeconomic status vulnerability is very low along the coast in areas that would be most exposed to the effects of sea level rise. One exception is the census tract directly east of Huntington Harbour, whose socioeconomic vulnerability was slightly higher than the median value. Within that tract 16% of the 4,975 inhabitants fall below the poverty line. Large areas of this census tract have been predicted to flood in SLR scenarios >3 ft. High poverty rates provide elevated challenges for disaster planning as inhabitants may struggle to afford the heightened expenses that accrue from a natural disaster.

Most inland census tracts were also in the lower half of vulnerability except for the census tract encompassing Oak View, those directly north and east of Oakview, and a small tract on the eastern side of I-405. It should be noted that these regions are safely away from any risk of flooding from SLR.

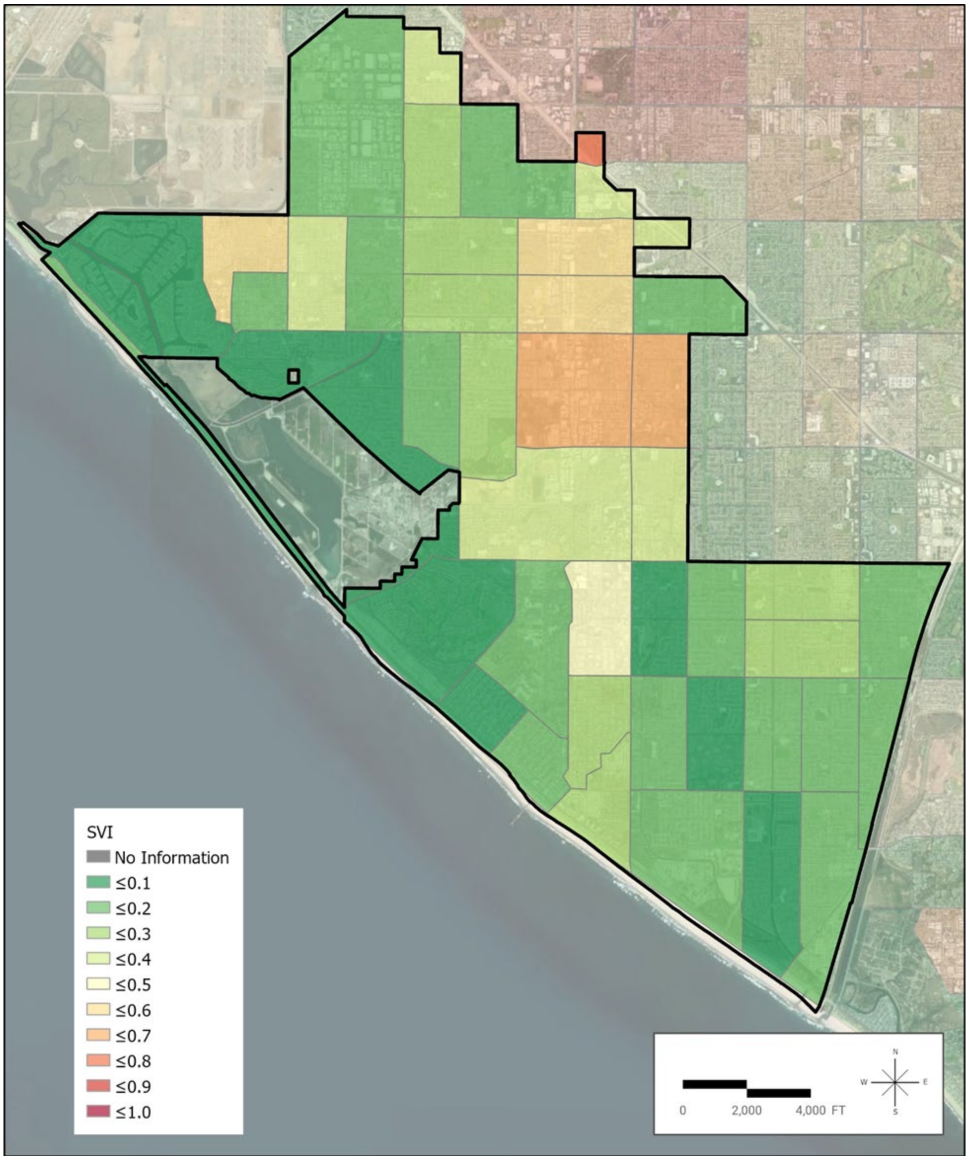

FIGURE 7-1: CDC SVI SOCIOECONOMIC STATUS SUMMARY DATA.

The household composition and disability summary variable (Figure 7-2) is based on the following factors: percentage of persons aged 65 and older, percentage of persons aged 17 and younger, percentage of non-institutionalized civilians with a disability, and percentage of single parent households with children under 18. Most waterfront regions show low vulnerability when considering household composition and disability. However, there are pockets of higher-than-average vulnerability including, 3 out of 4 of the southernmost waterfront census tracts, the census tracts that make up Huntington Harbour, and census tracts east and north of the harbour that border the Bolsa Chica Channel.

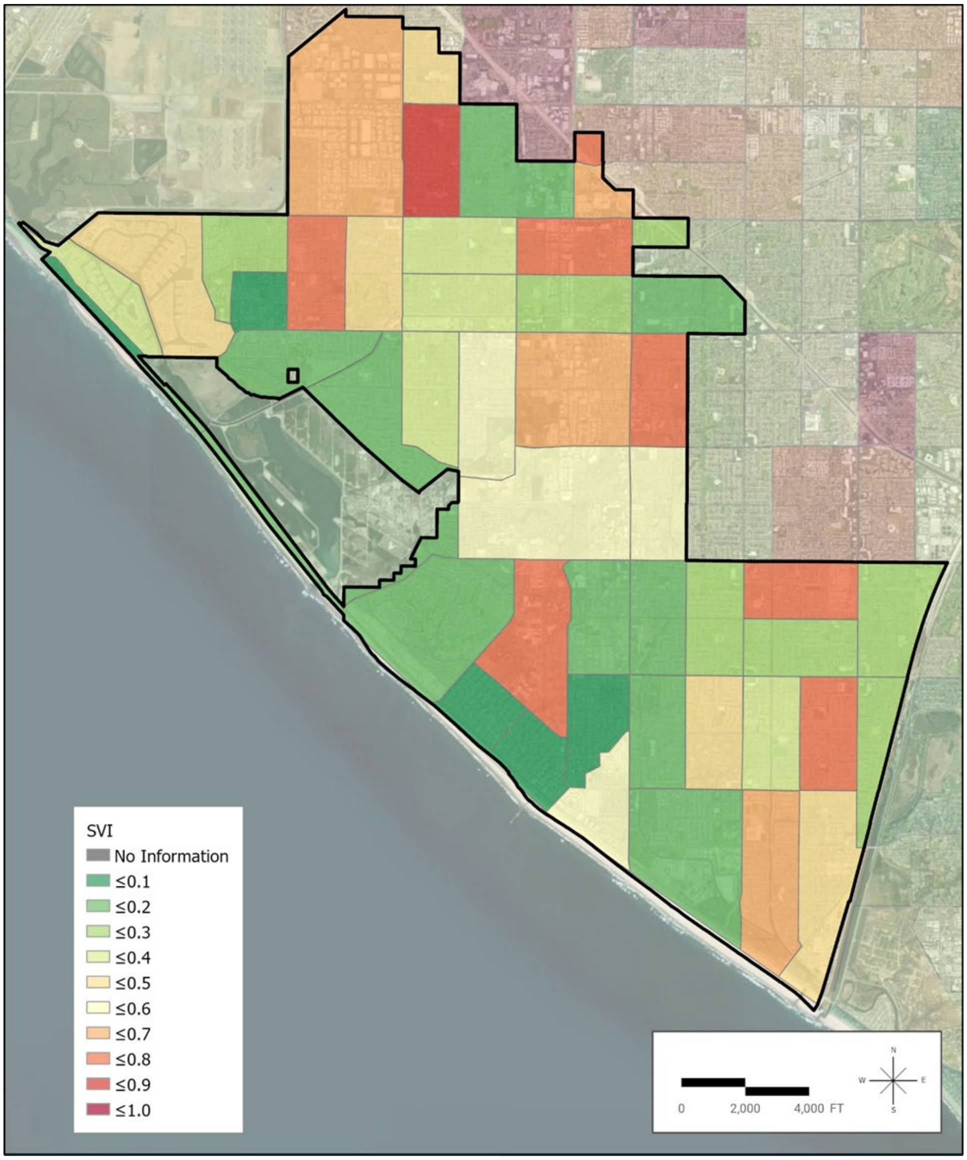

FIGURE 7-2: CDC SVI HOUSEHOLD COMPOSITION AND DISABILITY SUMMARY DATA.

Huntington Harbour has a high elderly population with 33% of the 7,013 residents being over the age of 65. 12% of the 7,013 residents were non-institutionalized with a disability. The southernmost waterfront census tracts and census tracts bordering the Bolsa Chica Channel also had higher than typical amounts of elderly people. Areas of Huntington Harbour are expected to flood during a 100-year storm event in every SLR scenario (including no SLR rise at all). Additionally, the harbor is expected to flood under normal SLR conditions in almost every scenario with more extreme scenarios predicting the entire harbor to flood. Large areas surrounding the Talbert Channel in the southern waterfront regions and Bolsa Chica Channel east and north of the Huntington Harbor are also predicted to flood due to extreme storm and SLR events. The additional needs and reduced capabilities presented by a high volume of elderly people should be accounted for in disaster planning.

It is also important to consider the location of the large inland areas throughout Huntington Beach that also have high household composition vulnerability. While these areas are safe from flooding it is important to have knowledge of their location when considering evacuation routes and destinations of potential evacuees along the coast.

The minority status and language summary variable (Figure 7-3) is based on two factors: the percentage of persons that do not identify as white, non-Hispanic, and the percentage of persons age 5+ who identify as speaking English "less than well". The majority of Huntington Beach has limited vulnerability due to minority status and language, with census tracts along the coast ranking in the least vulnerable. The two small exceptions include the census tract encompassing and directly east of Oak View, and a small tract on the eastern side of the 405. However, both these areas are far enough east to be safely away from any risk of flooding from sea level rise.

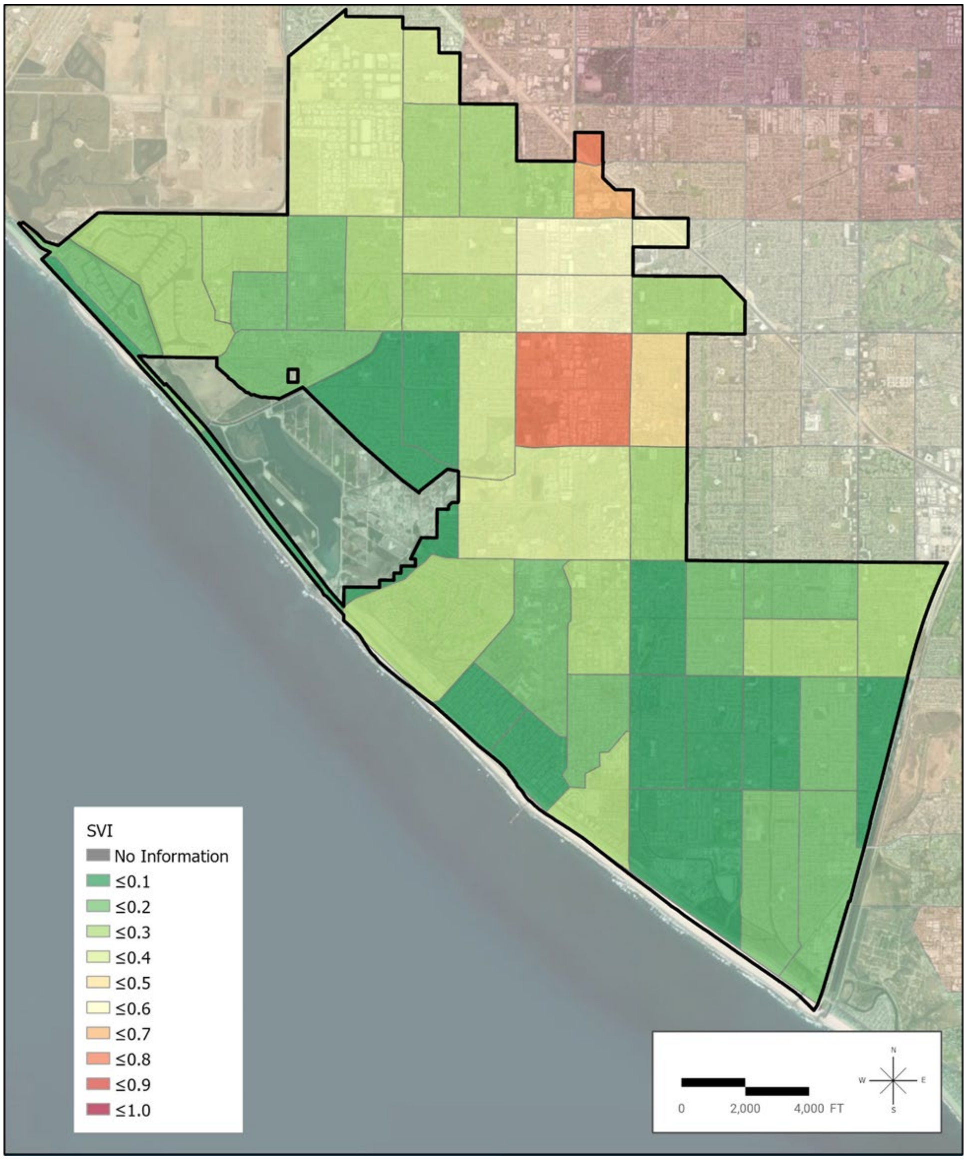

FIGURE 7-3: CDC SVI MINORITY STATUS AND LANGUAGE SUMMARY DATA.

The Housing and Transportation summary variable (Figure 7-4) is based on several factors including the percentage of housing structures with 10 or more units, the percentage of mobile homes, the percentage of household with more people than rooms, percentage of houses with no vehicles, and the percentage of persons in institutionalized group quarters. Census tracts along the coast all rank below the median value and thus show low social vulnerability for housing and transportation. However, large inland areas rank above the median values tracts encompassing and directly south of Oakview, the small tract on the eastern side of the 405, as well as the census tract directly east of Huntington harbor are in the top 10% of most vulnerable tracts in California.

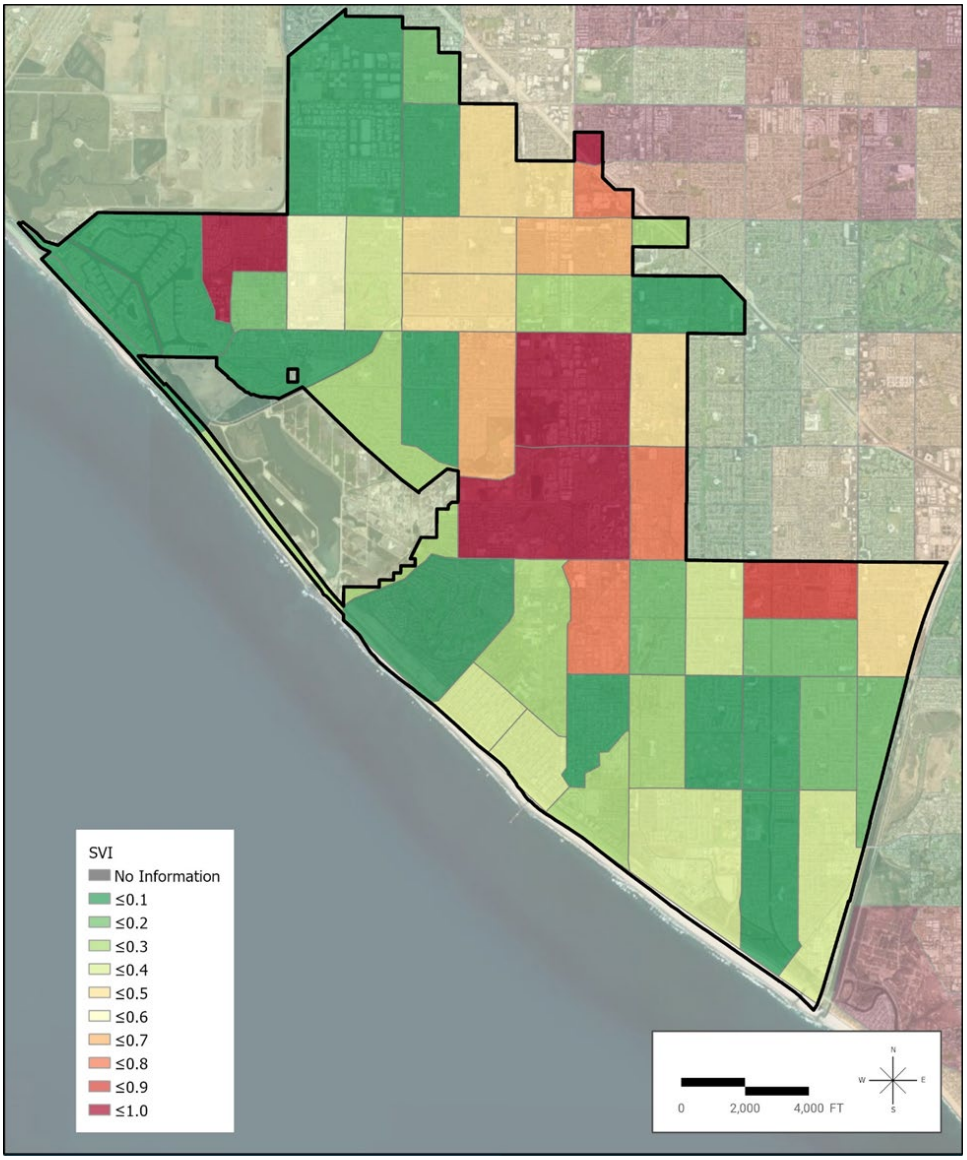

FIGURE 7-4: CDC SVI HOUSING AND TRANSPORTATION SUMMARY DATA.

The census tract directly east of Huntington Harbor is of primary concern because the upper end of SLR scenarios predict flooding in large areas of the region. Within the tract, 28.5% of the housing is in structures with 10 or more units, and 17.2% of the housing are mobile homes. Additionally, 10.4% of households have no vehicle. The scale of development, type of development, and lack of vehicle access all pose unique problems, and have the potential to hinder disaster response or recovery efforts for populations in the area. These problems are magnified when considering the higher-than-average poverty rates in the region as well. To mitigate the potential impacts to human health and safety housing and poverty that present in the event of a storm and/or flooding, ample planning and foresight are necessary.

The regions surrounding and encompassing Oak View are far enough east to be impacted by any potential flooding threats, but their location and the additional challenges presented by high housing and transportation vulnerability should be noted when planning for other potential natural disasters.

Environmental pollution burden indicators included in CalEnviroScreen assessments (Figure 7-5) are divided into exposure indicators and environmental effects indicators. Exposure indicators include measurements of ozone, airborne particulate matter, drinking water contaminants, pesticide use, toxic releases from facilities, and traffic density. Environmental effect indicators include data relating to cleanup sites, groundwater threats, hazardous waste generators and facilities, impaired water bodies, and solid waste sites and facilities. When determining final environmental pollution burden scores for each census tract environmental effect indicators were given one-half weight and exposure indicators were fully weighted.

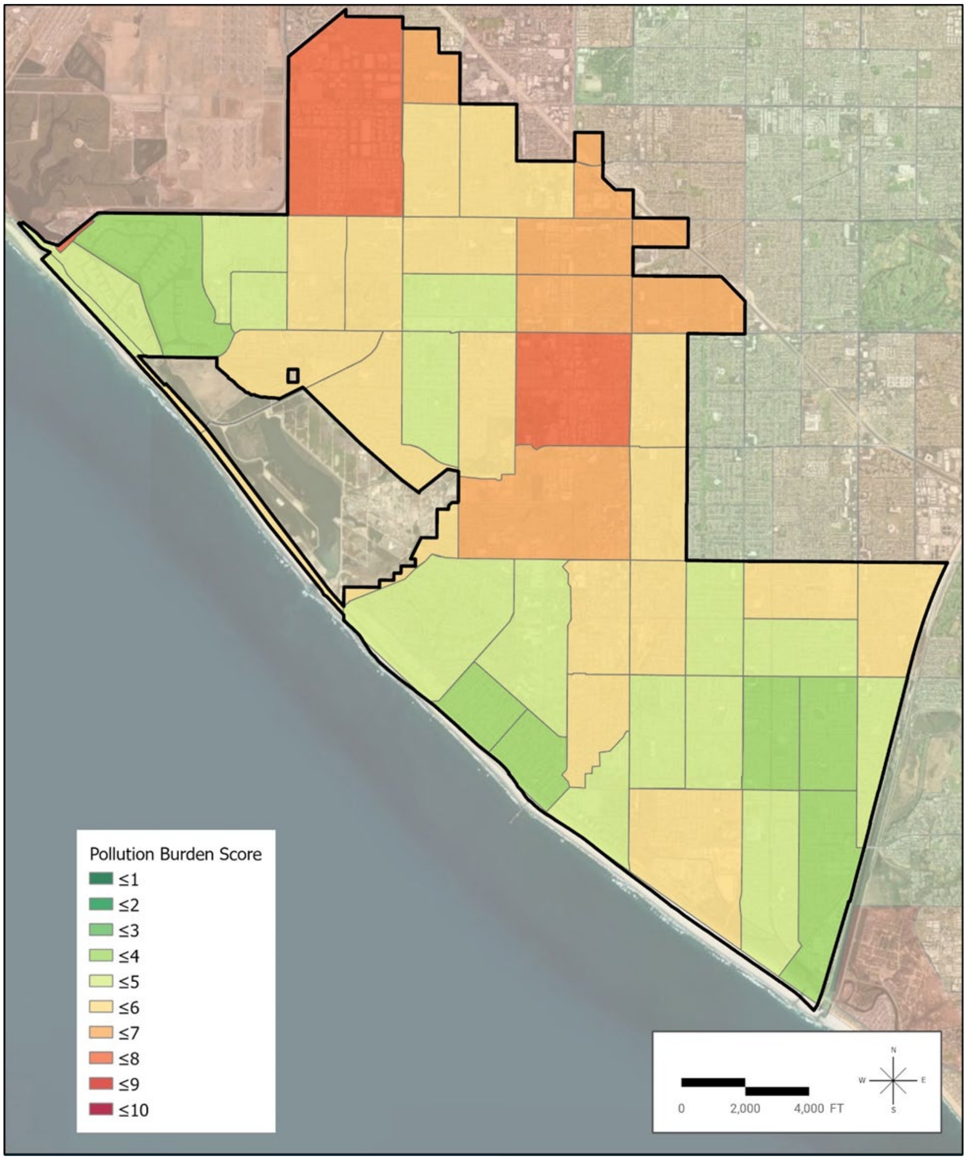

FIGURE 7-5: ENVIRONMENTAL POLLUTION BURDEN PER CALENVIROSCREEN 4.0.

Pollution Burden varies throughout Huntington Beach. However, census tracts along the coast generally ranked below the median value with a few tracts going slightly over, and thus displayed relatively low social vulnerability from pollution. Most inland tracts ranked above the median pollution burden with the highest regions encompassing and surrounding Oakview, bordering the 405 freeway, and bordering the Bolsa Chica Channel north and east of the Huntington Harbor.

Of the high pollution burden areas, the census tracts bordering the Bolsa Chica Channel are the only ones of concern, as large areas near the channel have been predicted to flood in extreme SLR rise events. Much of the environmental burden within these tracts can be attributed to higher-than-average proximity to hazardous waste generators and cleanup sites as well as exposure to toxic releases and particulate matter relative to other census tracts in California. Hazardous waste generators are defined as commercial or industrial activities that contain chemicals that may be dangerous or harmful to health. There are 10 such facilities located in the census tract bordering Bolsa Chica Channel in the northeastern portion of the City, including several related to aerospace engineering. Several facilities within the tract also make or use toxic chemicals that can potentially be released into the air. The particulate matter score is based on exhaust from trucks, buses, trains, ships, and other equipment with diesel engines that contain a mixture of gases and solid particles. This score is likely elevated due to the proximity to I-405, Bolsa Chica Road, and industrial use within the tract. The exposure to dangerous pollutants and the proximity to waste generating sites should be noted when considering the secondary repercussions of a storm or flood event. Pollution exposure could present heightened risk of illness to inhabitants with damaged or destroyed property, which in turn would result in even greater issues. City planners should also make note of other inland census tracts with high pollution burdens when planning against other natural disasters.

8. Next Steps

The following items represent additional recommendations to advance adaptation planning within the City:

- **Conduct high-resolution hydraulic modeling for assessing SLR impacts on local flood control infrastructure**
  - This vulnerability assessment primarily utilized regional modeling results to identify hazards in coastal areas of the City. Localized hydraulic modeling can supplement and refine the current assessment associated with flood control infrastructure, and it may be required to inform adaptation measure design and implementation.
- **Monitor and update the vulnerability assessment and any associated adaptation planning documents as needed to reflect changes in science and projections**
  - Uncertainty remains on the potential magnitude and timing of SLR both globally and regionally, especially with regards to extreme scenarios such as the H++ scenario. Continuously monitoring updates to SLR science, projections, and guidance will allow the City to make informed adaptation decisions moving forward.

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Appendix

FIGURE A-1: POTABLE WATER INFRASTRUCTURE WITHIN POTENTIAL FLOOD HAZARD AREAS, NORTHERN STUDY AREAS.

FIGURE A-2: POTABLE WATER INFRASTRUCTURE WITHIN POTENTIAL FLOOD HAZARD AREAS, SOUTHERN STUDY AREAS.