Port of Los Angeles

Sea Level Rise Adaptation Plan

FINAL DRAFT

September 2018

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Note:
The Port of Los Angeles Sea Level Rise Adaptation Plan was funded by the Port of Los Angeles (POLA) and prepared by AECOM and POLA Engineering Division. The final draft incorporates comments from several POLA divisions (City Attorney, Environmental, Real Estate, Construction & Maintenance, Executive Management, Planning, Public Affairs, Risk Management), Agencies including the California Coastal Commission, and City of Los Angeles Departments including Bureau of Engineering and Bureau of Sanitation.

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Executive Summary

The Port of Los Angeles (POLA) Engineering Division has developed a Sea Level Rise Adaptation Plan (SLR Plan). This plan is in accordance with Assembly Bill 691, which requires POLA, as local trustee of the lands granted by the State Lands Commission, to address the impacts of SLR for all of its legislatively granted public trust lands.

POLA is vital to the nation, region, and locally as an economic engine and public resource. With twenty-seven (27) terminals and forty-three (43) miles of waterfront, it is an important gateway for international commerce on the west coast as well as the nation, handling 41% and 18% of all loaded twenty-foot equivalent units (TEU), respectively. As a public resource POLA offers a multitude of community/commercial assets including parks and recreational areas, retail establishments, cruise facilities, and marinas. The Port's operations have created an estimated 1.6 million jobs nationwide, over 500,000 regionally, and almost 150,000 locally, making it critical to the lives of millions of Americans.

SLR is a significant risk that challenges the long-term viability of this national asset. If left unmitigated, business operations will be temporarily impacted, international cargo may move elsewhere, and community/commercial or natural habitat assets could be destroyed. These consequences would have an enormous impact locally, regionally, and nationally.

Project Overview

This SLR Plan follows the general planning process provided in the California Coastal Commission Sea Level Rise Policy Guidance (2015) document.

The purpose of this SLR Plan is to identify the areas that are projected to be exposed to SLR by 2030, 2050, and 2100, provide an overview of the Port's asset vulnerabilities, and to present a suite of strategies to both adapt over time and become more resilient to SLR.

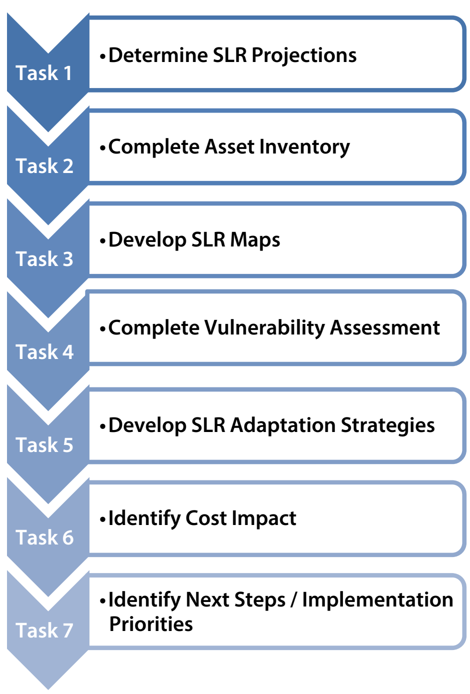


Figure E-1. POLA SLR Adaptation Plan planning process

SLR Projections

Mean sea levels have risen four inches in the Los Angeles area over the last century[1]. With global sea levels projected to continue to rise, public and private shoreline assets will become more vulnerable to an increase in the frequency and magnitude of coastal flood events.

SLR projections used for this SLR Plan are based on the National Research Council (NRC) 2012 projections (See Table E-1).

To understand the implications of a worst-case scenario, and to include a factor of safety, the high-end SLR range is used for each planning timeframe. This rationale aligns with the State Guidance from the Ocean Protection Council[2] and California Coastal Commission[3]. Additionally, because there is increased uncertainty for SLR after the year 2050, both the mid- and high-end SLR ranges were selected to guide the planning for 2100.

It should be noted that future SLR levels may change as climate science continues to evolve. Therefore, the Port is committed to monitoring SLR science and State Guidance updates every 5 years and will reevaluate vulnerabilities based on the most current information.

Table E-1. POLA SLR projections with timeframe

Year	Range	POLA SLR Study
2030	2–12 inches	**12 inches**
2050	5–24 inches	**24 inches**
2100	17–66 inches	**37 inches** **66 inches**

Inventory of Port Assets

Port assets are categorized as follows:

- **Cargo Wharves and Miscellaneous Operations,**
- **Critical Facilities,**
- **Transportation (rail/roads),**
- **Community/Commercial Assets, and**
- **Natural Habitats.**

This inventory includes detailed information on each asset type, such as cargo type, berth length/height, tenant name, estimated cargo volume and value, type of wharf structure, backland structures, utilities, roadway pavement condition index, construction dates, relationship to other facilities, type of public facilities, ecosystems, etc.

The inventory includes a classification for each asset according to how critical it is to the functioning of the Port and the community. The ***Critical*** (life safety) classification includes all Los Angeles Fire Department and Port Police Department facilities, the Port Pilots Station, main access roadways, bridges, pump stations and critical electrical infrastructure. The ***Important*** (Business / Value / Economy) classification highlights assets that are important for economic value, but not life safety, and primarily includes cargo wharves and terminals. The ***Important*** (Community / Nature) identifies assets are important to the community and natural habitats, but not from a life safety perspective.

The purpose of developing a detailed inventory was to provide a framework to identify which assets are vulnerable to SLR.

SLR Maps

SLR maps depicting the inland extent of flooding and inundation for existing and future water level conditions were created. Eight future condition maps were produced to illustrate each of the four SLR (12, 24, 37, and 66 inch) scenarios under two conditions: (1) average daily high tide and (2) storm tide.

In this SLR Adaptation Plan, inundation is permanent and refers to flooding that occurs during normal, daily tide cycles. Flooding refers to temporary flooding that only occurs during elevated water levels associated with storm tides which uses the 100-year Stillwater elevation (SWEL) and is the summation of astronomical tides and storm surge (without wave effects). Flooding is temporary and less frequent. Therefore, areas that are anticipated to be temporarily flooded are less vulnerable than areas than might be permanently inundated.

1 National Oceanic and Atmospheric Administration (NOAA) Mean Sea Level Trend: 9410660 Los Angeles, California. Accessed October 19, 2016. http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9410660

2 California Ocean Protection Council (2011). Resolution of the California Ocean Protection Council on Sea-Level Rise. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_SeaLevelRise_Resolution_Adopted031111.pdf

3 California Coastal Commission (2015). Sea Level Rise Policy Guidance. https://documents.coastal.ca.gov/assets/slr/guidance/August2015/0_Full_Adopted_Sea_Level_Rise_Policy_Guidance.pdf

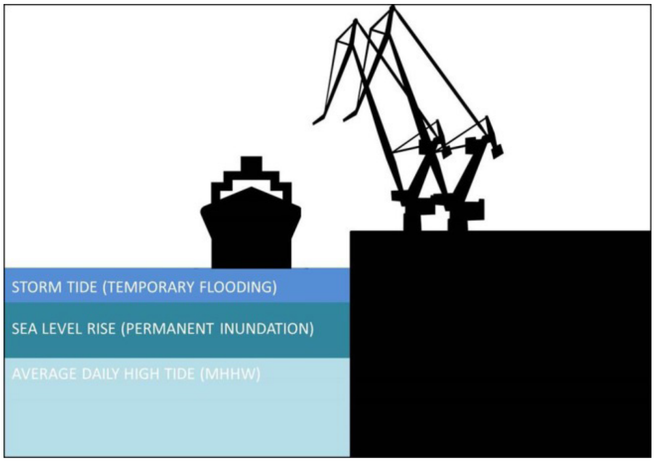


Figure E-2. Graphic representation of SLR and storm tide

In addition to the flooding and inundation mapping, an overtopping analysis was performed to identify the most vulnerable areas and create targeted adaptation strategies. The overtopping analysis consisted of identifying the locations along the shoreline that were lower elevation than the future conditions' water level, which pinpointed the locations of shoreline overtopping and the critical flood pathways that cause flooding and inundation.

The following maps are the product of the inundation and overtopping analyses and illustrate the extent of exposure. The legend on each map, see Figure E-4, depicts that the lighter blue areas have lower flood depths and darker blue areas have greater flood depths. Green low-lying areas are below the mapped water surface elevation but not hydraulically connected to the flooding and are shown to highlight possible vulnerability to stormwater ponding, elevated groundwater and backflow into stormwater system. Overtopping depths are shown by color at the shoreline.

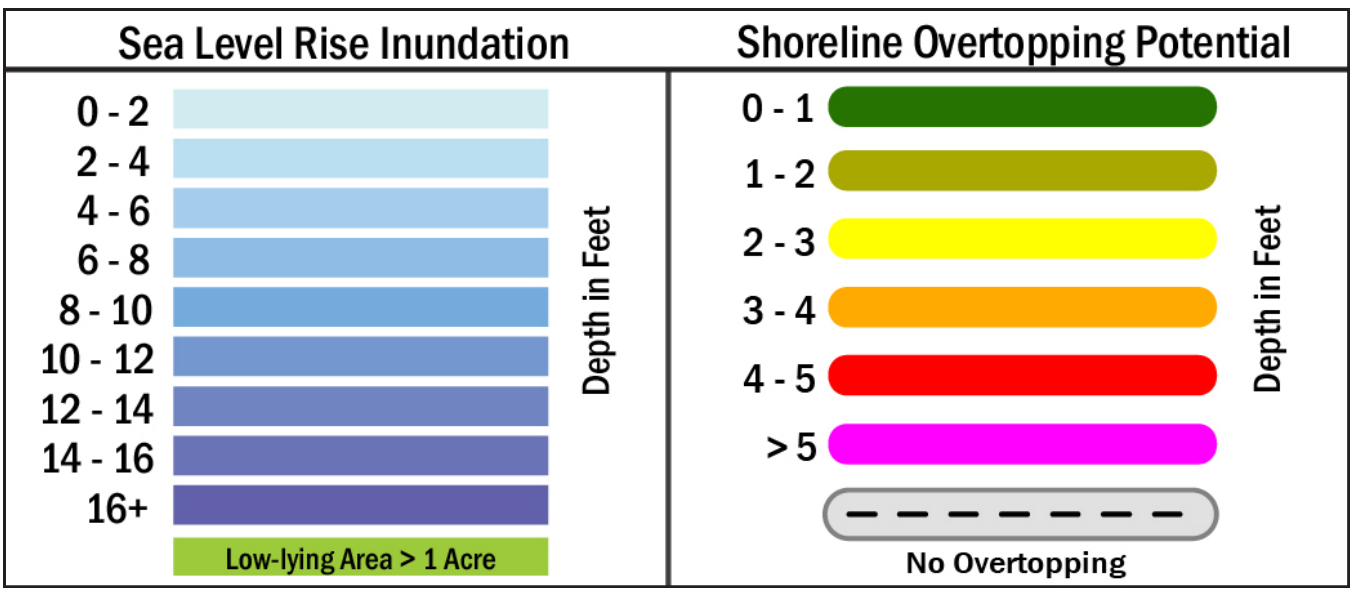
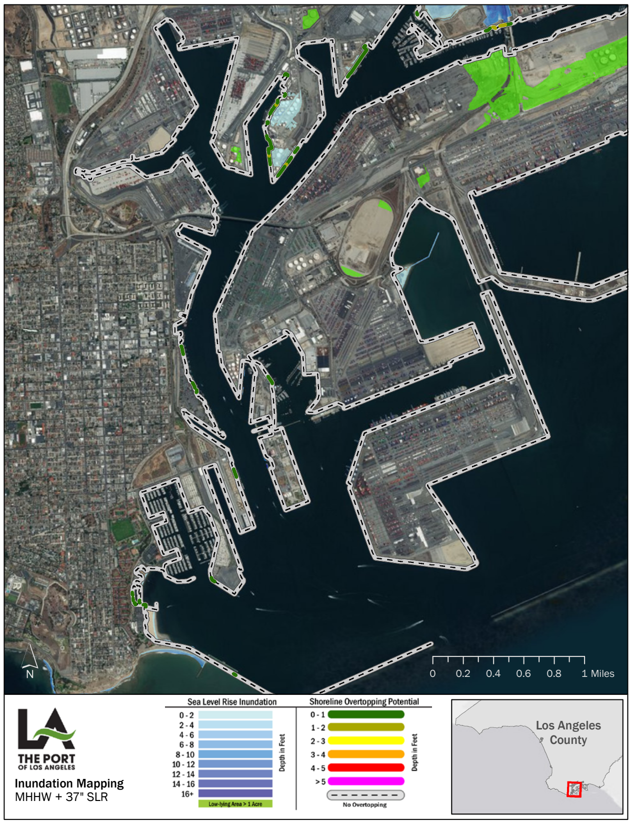
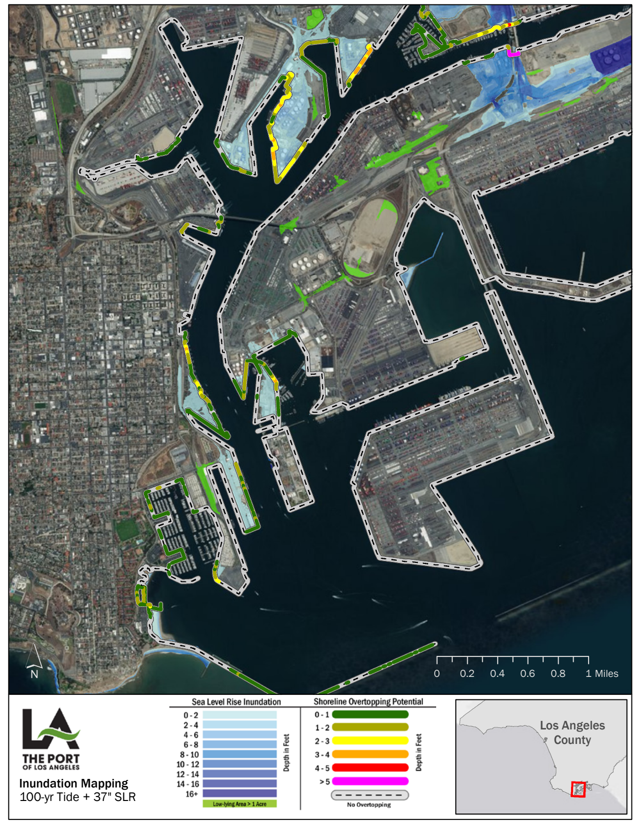


Figure E-3. Map Legend

Figure E-4. Thumbnail images of SLR and storm tide maps


0 0.2 0.4 0.6 0.8 1 Miles
N
THE PORT OF LOS ANGELES
Inundation Mapping
MHHW + 37" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Los Angeles County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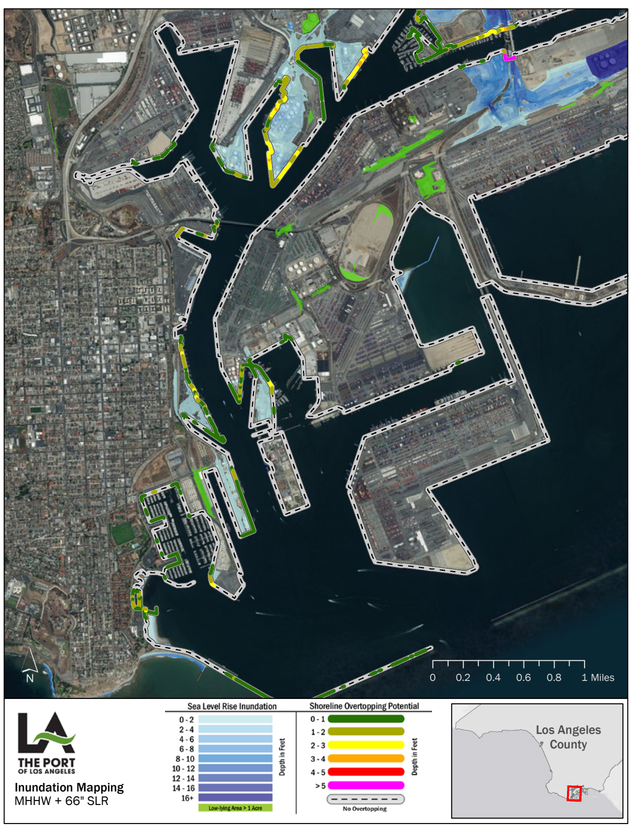
12 - 14
14 - 16
16+
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Los Angeles County


0 0.2 0.4 0.6 0.8 1 Miles
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THE PORT OF LOS ANGELES
Inundation Mapping
MHHW + 66" SLR
Sea Level Rise Inundation
0 - 2
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Shoreline Overtopping Potential
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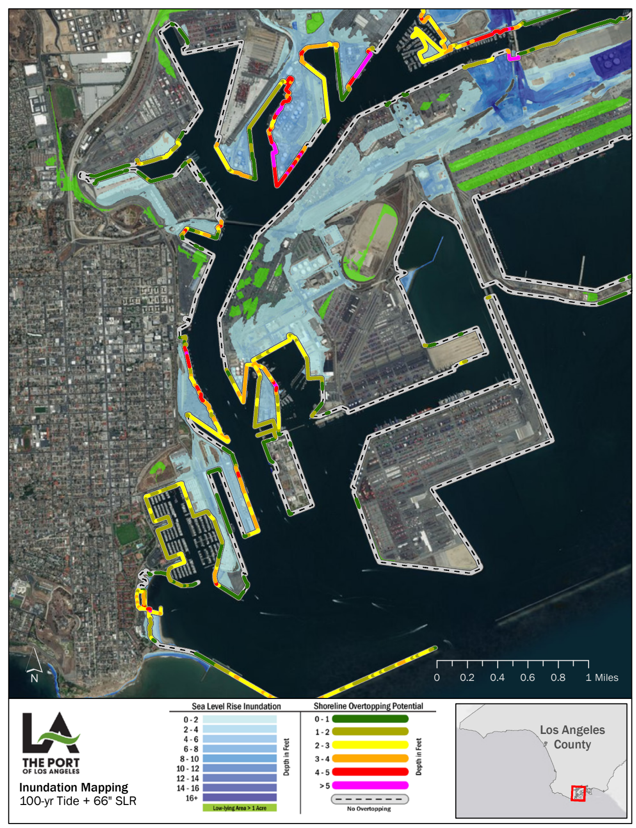
No Overtopping
Los Angeles County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14 - 16
16+
Shoreline Overtopping Potential
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1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Los Angeles County

Vulnerability Assessment

Individual assets within each infrastructure category have been reviewed for exposure, sensitivity, and adaptive capacity.

Exposure provides information on both permanent inundation and temporary flooding (e.g. a building may be permanently inundated by a 37 inch SLR scenario, but temporarily flooded by a 12 inch SLR + storm tide scenario), which is evaluated quantitatively.

Sensitivity provides information on the degree to which an asset would be impaired by flooding and is evaluated qualitatively. For example, roadways are generally not highly sensitive to temporary flooding because they are unlikely to be damaged, unless the flood waters are very fast flowing, and therefore can be used again once the waters recede. In contrast, a substation would be considered very sensitive to flood events if exposed to water as it may be damaged beyond repair.

Adaptive Capacity provides information on existing redundancy or an asset's ability to adapt (e.g. alternative roadway, back-up generator, ability to raise a seawall), which is also evaluated qualitatively.

As illustrated in Figure E-5, only assets that were found to be exposed to SLR were moved on to the sensitivity assessment. Similarly, assets found to be exposed and sensitive were evaluated for adaptive capacity. Assets are considered most vulnerable if they are exposed to flooding, have high sensitivity, and low adaptive capacity.

The vulnerability assessment also included an evaluation of potential **economic, social, and environmental consequences**, taking into consideration the magnitude of the impact that may occur under the various future SLR and storm tide scenarios. Reviewing the consequences of failing to address SLR is useful in prioritizing assets for adaptation planning. SLR has the potential to cause a broad range of consequences. Generally a dollar value relating to goods and services potentially impacted can be estimated where market prices are available, allowing for measurement of economic impact. However, the consequence to coastal environments, including public trust lands like beaches and wetlands that are vulnerable to SLR should also be considered, as they provide a number of important ecological, social and cultural services. It is harder to put an explicit market value on these services.

Vulnerability profiles were created to summarize the primary vulnerabilities of each of the asset types (Cargo Wharves & Other Misc. Operations, Critical Facilities (including critical electrical infrastructure), Transportation (roads and rail), Community/ Commercial assets, and Natural Habitats and include information on exposure, sensitivity, adaptive capacity and consequences.

The key vulnerabilities are mostly related to exposure and include the following:

Cargo Wharves and Miscellaneous Operations

- Container terminals have very low vulnerability
- Liquid bulk (Nustar, Valero, Shell, Vopak) could be temporarily flooded by 2030 (12 inch SLR + ST)

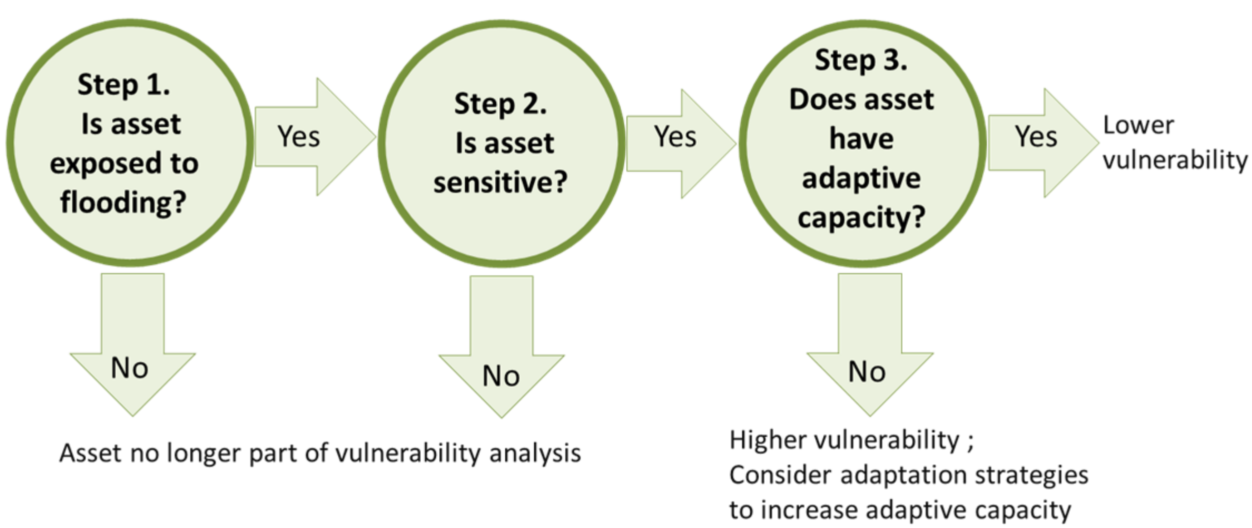


Figure E-5. Graphic representation of the Vulnerability Analysis

- Other Cargo terminals (Vopak, Rio Tinto Minerals) could be temporarily flooded by 2050 (24 inch SLR + ST)
- Misc. Operations (Pilots Station, LAHD Construction/ Maintenance, & breakwater) could be temporarily flooded by 2100 (37 inch SLR + ST)

Critical Facilities and Utilities

- Millennium Maritime and SD Pump Station could be temporarily flooded by 2050 (24 inch SLR + ST)
- Some life safety facilities (Fire Station #110, and Pilots Station) could be temporarily flooded by 2100 (37 inch SLR + ST)
- Several utilities (pumping plants and electrical substations could be temporarily flooded by 2100 (37 inch SLR + ST)

Transportation Network (rail and roadway)

- Vopak rail could be temporarily flooded by 2030 (12 inch SLR + ST)
- WBCT and TraPac rail leads could be temporarily flooded by 2100 (37 inch SLR + ST)
- Anaheim St, east of Dominguez Channel, and Fries (Berths 161-169) could be temporarily flooded by 2030 (12 inch SLR + ST)
- Access to the Marinas could be temporarily flooded by 2030 (12 inch SLR + ST)
- The underside structure of the Pier 400 Corridor Bridge and LACFCC Bridges could be impacted by high water levels starting at 24" SLR.
- The Vincent Thomas Bridge could experience increased operational disruptions to vessel navigation resulting from reduced bridge clearances starting at 12" SLR, particularly for large container vessel

Community/Commercial Assets

- Al Larson's Boat shop and Cerritos and Island Yacht anchorages could be temporarily flooded by 2030 (12 inch SLR + ST)
- Ports O' Call, LA Waterfront Sports Fishing and Cruises, and Alta Sea could be temporarily flooded by 2100 (37 inch SLR + ST)

Natural Habitats

- North of Pier 300 sand area habitat could be temporarily flooded by 2030 (12 inch SLR + ST)
- Brackish water marsh at Wilmington Marinas and the Ficas Trees Heron Nesting habitat could be temporarily flooded by 2100 (37 inch SLR + ST).

Adaptation Strategies

Based on the vulnerability assessment, over 100 potential adaptation strategies were developed for consideration. The strategies fall into three categories: (1) governance, (2) initiatives, and (3) infrastructure.

Governance strategies address port-wide planning and design documents. Strategy types include adding SLR language to existing planning documents; developing SLR design guidelines; adding SLR considerations to current projects; and community education. **Initiative strategies** address SLR initiatives that would provide additional relevant data. Strategy types include informational data gaps; feasibility studies; collaboration with organizations beyond the Port; and identifying funding opportunities. And **infrastructure strategies** address physical vulnerabilities. Strategy types include both temporary asset protection measures (e.g. sand bags, tiger dam) and permanent measures (retrofit existing walls, build a sea wall). Further, there are some strategies that would benefit from a more port-wide approach, which have been identified as a 'collective area'.

Each adaptation strategy includes the following data: POLA Engineering area ID, focus area/location, SLR exposure scenario, draft strategy, timeframe, collective area option, the Harbor Department Champion, and implementation cost. It should be noted that the strategies are high-level and not developed to a detailed design.

After the list of potential SLR adaptation strategies was developed, a workshop was held to collaborate with Port stakeholders to review and refine the proposed adaptation strategies.

In summary, it was recommended to prioritize governance strategies so that SLR projections become a standard design consideration for all future projects. The existence of governance strategies can help raise awareness of SLR within Port staff, with tenants and the general public. With regards to infrastructure strategies, it is recommended to focus on the assets that are vulnerable under the 12 inch (year 2030) and 24 inch SLR (year 2050) scenarios because they will be impacted within the existing asset lifespan. For assets that will only be temporarily flooded during a storm-tide condition, it may make sense to provide temporary protection only (such as sandbags or Aqua Fence). For assets that will be permanently inundated, it will be necessary to provide permanent protection (such as retrofitting a sheet pile wall or building a seawall). It is also possible that some vulnerable assets may benefit from a more collective approach if multiple assets are impacted. In this case, the initiative strategies are important so that Port stakeholders collaborate and agree on the most appropriate strategy and develop a cost sharing plan.

Financial Impact

An estimate of the financial cost of the impact of SLR on its public trust lands was prepared and focuses on (1) the anticipated cost to prevent or mitigate potential damage and (2) the cost of repair of damage and value of lost use of improvements and land.

Anticipated cost to prevent or mitigate potential damage

The governance and initiative strategies can be implemented through the use of staff time. The time (and therefore the cost) to develop and implement these strategies varies, in particular in relation to the number of divisions necessary for coordination; however, even despite these considerations, the overall cost of implementation remains low.

The infrastructure adaptation strategies include a range of costs for both temporary and permanent solutions. The cost of three types of temporary asset protection measures has been evaluated for each asset: Tiger Dam (low cost), sand bags (medium cost) and Aqua Fence (high cost). The cost of two types of permanent protection measures (either along the shoreline or around the asset) has been evaluated: extension of existing sea wall (low cost) and a new sheet pile wall (high cost). Roadway strategies focus on the costs associated with elevating the road (fill, structural, curbs, signals, etc.).

Cost of repair of damage and value of lost use

The cost of damage includes the value of lost assets, cargo, transportation, and operations. A qualitative estimate was prepared to categorize value of lost use as low (no loss of critical assets and infrastructure and operations are maintained), medium (temporary loss of critical port assets and operations), or high (impacts to life and safety, loss of critical port assets and infrastructure, loss of transportation network, and impacts to high value cargo).

Cargo terminals, critical facilities, and transportation networks were all ranked as High in terms of the value of lost use because these are all critical to the functioning and revenue of the Port. Community/commercial assets and natural habitats were ranked as Low in terms of the value of lost use because these are not critical to Port operations.

Next Steps

Taking into consideration the vulnerabilities to SLR and the proposed adaptation strategies, a top 10 recommended actions list was developed to provide guidance and a short-term road map to increase resiliency.

1. Monitor SLR science and State Guidance updates every 5 years and reevaluate the list of vulnerable assets if necessary.
2. Add language regarding SLR and potential impacts and adaptation strategies to planning documents and design guidelines.
3. Create a SLR Adaptation Working Group with stakeholders from all relevant Divisions.
4. Complete a study to determine the most appropriate temporary flood protection in the case of a future storm event.
5. Develop a general one-page SLR vulnerability zone map.
6. Update terminal lease requirements to reference this SLR Adaptation Plan to highlight to tenants that they may be located in an area that is vulnerable to SLR.
7. Collaborate with tenants (terminal and community/commercial assets) that have assets in areas that are potentially exposed under the 12 inch SLR scenario.
8. Identify funding opportunities that would support implementation of SLR adaptation strategies.
9. Monitor and inventory natural resources and existing habitats (wetlands, subtidal, species, etc.) and identify strategies to protect, enhance, and adapts to future sea level rise.
10. Participate in the CAPA (California Association of Port Authorities) Sea Level Rise group.

1 Introduction

Purpose

The purpose of this SLR Adaptation Plan is to provide an overview of vulnerabilities to sea level rise (SLR), accompanied by a suite of strategies that will allow the Port to both adapt over time, become more resilient to SLR, and remain a strong economic engine locally, regionally, and nationally. The development of the Plan has helped to increase SLR awareness and the need to integrate its consideration into day to day operations.

The SLR Plan also serves to address all the components of Assembly Bill 691 (2013). AB 691 requires POLA, as local trustee of the lands granted by the State Lands Commission, to address the impacts of SLR for all its legislatively granted public trust lands. More specifically, AB 691 requires the following:

- An assessment of the impact of SLR on granted public trust lands (see Chapter 5)
- Maps showing the areas that may be affected by SLR plus 100-year storm-events in the years 2030, 2050, and 2100 (see Chapter 4)
- An estimate of the financial cost of the impact of SLR on granted public trust lands (see chapter 7)
- A description of how the Port proposes to protect and preserve natural and man-made resources and facilities located, or proposed to be located, on trust lands and operated in connection with the use of the trust lands (see Chapter 6).

Document Overview

The following paragaphs give an overview of each of this subsequent paragraphs.

Chapter 2 Sea Level Rise Projections: Discusses the SLR projections and storm tide scenarios that were used for this project, which are: 12 inch, 24 inch, 37 inch, and 66 inch.

Chapter 3 Inventory of Port Assets: Highlights all of the data that was collected to develop the Port's asset inventory. The inventory is organized by asset type:

- Cargo Wharves and Miscellaneous Operations,
- Critical Facilities and Utilities,
- Transportation Network (rail and roads),
- Community/Commercial Assets, and
- Natural Habitats

Chapter 4 Sea Level Rise Maps: Includes all of the inundation maps that illustrate each of the four SLR scenarios under two conditions: (1) average daily high tide and (2) storm tide. Overtopping locations are also included in these maps.

Chapter 5 Vulnerability Assessment: Summarizes the key SLR vulnerabilities, in terms of exposure, sensitivity, and adaptive capacity, for each asset. Potential economic, social, and environmental consequences are also considered. Stand-alone vulnerability profiles have been developed for each asset type.

Chapter 6 Adaptation Strategies: Includes strategies that have been developed to address the key vulnerabilities. Over 100+ SLR adaptation strategies are provided, organized by governance, initiative, and infrastructure.

Chapter 7 Financial Impact: Provides an understanding of the cost of inaction (do nothing) and the cost of adaptation (implement strategies to protect the Port).

Chapter 8 Next Steps: Provides guidance on where to begin the implementation of the proposed adaptation strategies to minimize long-term SLR-related asset damage, cargo damage, and operation disruptions. A top 10 recommended actions list was developed for the next five years.

2 Sea Level Rise Projections

Introduction

This chapter provides an overview of the SLR and storm tide scenarios used for the SLR Adaptation Plan.

Mean sea levels have risen nearly four inches in the Los Angeles area over the last century[4]. With global sea levels projected to continue to rise, public and private shoreline assets will become more vulnerable to the increase in the frequency and magnitude of coastal flood events.

Sea Level Rise Projections

In March 2013, the State of California adopted the National Research Council's (NRC) 2012[5] report of global and regional (West Coast) SLR estimates as the best-available science on SLR for the state[6].

Table 2-1 provides the NRC SLR estimates for future year scenarios and includes the projection (mean ± one standard deviation) and range of SLR models (from low to high).

Table 2-1. Regional Sea Level Rise Projections at Los Angeles Relative to Year 2000

Year	Projection (NRC)	Range
2030	5.8 in ± 2.0 in	2–11.8 in
2050	11.2 in ± 3.5 in	5.0–23.9 in
2100	36.7 in ± 9.8 in	17.4–65.6 in

To understand the implications of a worst-case scenario, and to include a factor of safety, the high-end SLR range is recommended to be used for each planning timeframe. This rationale aligns with the State Guidance from the Ocean Protection Council[7] and California Coastal Commission[8]. Because there is increased uncertainty for SLR after the year 2050, both the projection and high-end SLR range were selected to guide the planning for 2100.

It should be noted that the California Ocean Protection Council Science Advisory Team (OPC-SAT) is currently in the process of updating SLR projections for the State of California. The final report was adopted March 2018[9] and the revised projections now include probability of occurrence. In general, the updates still align with our study: Year 2030 = 11" SLR with a 1-in-200 chance; Year 2050 = 24" SLR with a 1-in-200 chance; and Year 2100 = 55" SLR with a 1-in-20 chance or 85" SLR with a 1-in-200 chance.

4 National Oceanic and Atmospheric Administration (NOAA) Mean Sea Level Trend: 9410660 Los Angeles, California. Accessed October 19, 2016. http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9410660

5 National Research Council (2012). Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. http://www.nap.edu/catalog.php?record_id=13389

6 Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) (2013). State of California Sea-Level Rise Guidance, March 2013 Update.

7 California Ocean Protection Council (2011). Resolution of the California Ocean Protection Council on Sea-Level Rise. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_SeaLevelRise_Resolution_Adopted031111.pdf

8 California Coastal Commission (2015). Sea Level Rise Policy Guidance. https://documents.coastal.ca.gov/assets/slr/guidance/August2015/0_Full_Adopted_Sea_Level_Rise_Policy_Guidance.pdf

9 Draft report: Rising Seas in California – An Update on Sea-Level Rise Science: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

Future SLR levels will continue to change as climate science evolves. The Port is committed to monitoring SLR science and State Guidance updates every 5 years and will reevaluate vulnerabilities based on the most current information.

In summary, the following SLR scenarios were selected for this study: 12 inches for year 2030, 24 inches for year 2050, and 37 and 66 inches for 2100.

Each SLR estimate was combined with two different tide conditions: (1) average daily high tide (represents permanent inundation) and (2) 100-year storm tide (represents temporary flooding). See Figure 2-1 for graphic representation.

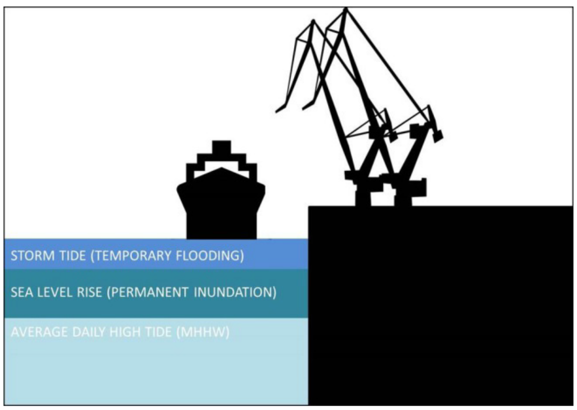


Figure 2-1. Conceptual diagram of water levels contributing to flooding

The **average daily high tide** (also referred to as mean higher high water (MHHW)) is used as the baseline and is defined as the long-term average of the higher of the two high tides each day. The various SLR scenarios were added to MHHW and represent the future level of permanent inundation.

The **storm tide** was evaluated using the 100-year stillwater elevation (SWEL), which is a summation of astronomical tides and storm surge (without wave effects). It is a water level that has a one percent chance of occurring in a given year and represents the future level of temporary flooding

Table 2-2. Estimates of SLR plus Average Daily High Tide and Storm Tide

Average Daily High Tide (MHHW) (feet NAVD88‡)					Storm Tide (100-year SWEL) (feet NAVD88)				
Existing	+ 12 in SLR	+ 24 in SLR	+ 37 in SLR	+ 66 in SLR	Existing	+ 12 in SLR	+ 24 in SLR	+ 37 in SLR	+ 66 in SLR
5.3	6.3	7.3	8.4	10.8	7.9	8.9	9.9	11.0	13.4

Note: The North American Vertical Datum of 1988 is the current national standard to which elevations are referenced.

Assumptions

The approach described above does not account for other processes that may modify the tide range or storm surge in the future or other climatic factors that may affect the frequency and magnitude of future storm conditions.

Various physical processes are typically grouped together under the term "storminess," including frequency and intensity of storms, shifts in storm tracks, magnitude of storm surges, and changes in mean and extreme wind speed and wave heights. There is general consensus among scientists that climate change will affect aspects of storminess such as the intensity, frequency, and paths of coastal storms; however, a clear consensus has not emerged on the nature of these changes in the North Pacific Ocean. One common trend among recent studies is a tendency towards increases in wind speed and wave height, especially in the northeast Pacific from Northern California to Washington. Further research is needed to confirm these findings and determine their relevance for the Southern California coast. As a result, changes in storminess and its effect on storm surge and storm tide levels have not been considered.

Summary

The SLR scenarios for the SLR study are based on the NRC projections: 12, 24, 37 and 66 inches. The inundation maps (Chapter 4) illustrate each of the four SLR scenarios under two conditions: (1) average daily high tide and (2) storm tide.

3 Asset & Operation Inventory

Introduction

An inventory of assets was completed to assess their vulnerability to SLR. The main goal of the inventory was to capture key assets, components, and operations.

Methodology

The inventory is organized by asset type:

- Cargo Wharves & Other Misc. Operations,
- Critical Facilities (including critical electrical infrastructure),
- Transportation (roads and rail),
- Community/Commercial assets, and
- Natural Habitats.

Each asset includes the following critical asset classifications:

- **Critical (Life Safety) = 1.** Includes all Los Angeles Fire Department and Port Police Department facilities, the Port Pilots Station, main access roadways, bridges, pump stations and critical electrical infrastructure.
- **Important (Business / Value / Economy) = 2.** Assets are important for economic value but not life safety and primarily include cargo wharves and terminals.
- **Important (Community / Nature) = 3.** Assets are important to the community and natural habitats, but not from a life safety perspective.

Detailed methodologies and sources used to complete the inventory are in Appendix A.

Cargo Wharves & Misc. Operations

These are six main types of cargo terminals in the port: container, liquid bulk, dry bulk, roll-on roll-off, breakbulk, and passenger.

There are also a number of miscellaneous operations in the Port that service cargo operations, such as tugboats, bunkering, warehouses, etc. This section also includes the breakwater.

The Cargo Wharves & Misc. Operations inventory is organized into the following sections:

- ***Critical Port Asset:*** Most assets have been classified as a '2' based on economic value.
- ***Facility Information:***
  + Cargo type,
  + Berth numbers, and
  + Tenant(s) name.
- ***Terminal Functional Characteristics:***
  + Estimated terminal cargo volume,
  + Terminal acreage,
  + Berth length and height,
  + Percentage of cargo via truck, rail, or pipeline, and
  + Estimated annual cargo value moved.

- ***Wharf Assets:*** Indicates whether various types of key structures are present, including:
  + Type of wharf structure,
  + Quay walls,
  + Rock dikes,
  + Fender systems,
  + Alternative Marine Power,
  + On-dock rail, and
  + Cargo loading / unloading equipment.
- ***Backland Assets:*** Indicates whether various types of key backland structures are present, including:
  + Pavements,
  + Contaminated materials storage,
  + Gate facilities,
  + Buildings, and
  + Various types of cargo storage.
- ***Utilities:*** Indicates whether various types of utility structure are present, including:
  + Water distribution systems,
  + Sewer pumps/lift stations,
  + Storm drain conveyance or pump/lift stations,
  + Electrical distribution systems,
  + Lighting systems,
  + Communication systems, and
  + Security systems.

Critical Facilities

The Port includes critical facilities for which there would be high consequence for even small levels of exposure to flooding or inundation. Many of these facilities (e.g. fire stations, police stations, Pilots Station, tugboat fleets) are necessary for ensuring life safety.

The critical facilities category also includes assets that are necessary for business continuity, including administration, operations and maintenance facilities, and a federal correctional institution.

Providing the only freight access to/from Catalina Island, Avalon Freight Services is also considered a critical facility. The livelihood of island residents and businesses relies on regular shipments of goods.

There are also select utilities that have been identified as critical. Several substations and transformers providing power to many of the berths and facilities are located within the Harbor District. The functionality of this electrical infrastructure ensures Port operations. Several pump stations serve an important function of pumping excess stormwater from low-lying areas of the Port. This is essential to ensure certain areas of the Port remain operable following storm events.

The Critical Facilities inventory includes the name and location for each critical asset.

The critical port asset classification is a '1' for all facilities based on life safety.

Transportation – Road and Rail

Road

The road network inventory includes freeways, bridges, roads, traffic signals, and street lights.

Each road asset was identified as primary, secondary or tertiary. Primary roads consist of critical business and/or emergency access routes to Port assets or public safety. Secondary roads provide alternative access routes to assets, while tertiary roads are smaller and provide minor access to assets.

The road inventory is organized into the following sections:

- ***Road information:***
  + Pavement Condition Index (PCI),
  + Last constructed,
  + Rank (Primary / Secondary / Tertiary),
  + Outside Port boundary, and
  + Critical Port Asset classification.
- ***Berths:*** includes which roadways provide access to each berth segment.
- ***Critical Facilities:*** includes which roadways provide access to facilities which are critical for life safety, such as fire stations.
- ***Bridges:*** includes vehicle bridges and addresses potential operational disruptions and structural damage.

Rail

The Port is home to the nation's largest on-dock rail assets, providing intermodal access to major freight hubs across the United States. This extensive rail network is vital to moving cargo from each terminal into the regional network. Most terminals include rail access for containerized cargo and up to 35% of all containerized cargo is transported using the rail network.

The rail inventory is organized into the following sections:

- ***Rail information:***
  + Rail title
  + Storage / Classification
  + Location, and
  + Critical Port Asset classification.
- ***Berths:*** includes which rail infrastructure serves each geographic berth segment.
- ***Bridges:*** includes rail bridges and addresses potential operational disruptions and structural damage.

Community/Commercial Assets

The Port has a world class urban waterfront that includes marinas, public docks, a cruise ship terminal, parks and trails, plazas, markets and town squares, and a continuous promenade that also serves walking path connections to the California Coastal Trail. These facilities are important to the livelihood and business community of the Port, for tourism, and to provide amenities for adjacent neighborhoods with future development opportunities for both public and private investments.

The community/commercial assets inventory includes numerous long-standing public facilities along with recently completed projects and planned future developments, such as the Ports O' Call Village Redevelopment (2017) and the Ports O' Call Promenade (2018). The inventory includes the name and nearest berth number or street address for each asset, as well as whether or not each asset is critical.

Most assets have been classified as a '3' for community value.

Natural Habitats

The Port has several natural habitats that provide home to a diversity of wildlife and plant species and serve important ecological functions. Natural habitats within the Port include beach and sandy areas, coastal scrub, marshland, heron roosting grounds, resident least tern nesting colony areas, and aquatic eelgrass and kelp beds.

Eighteen total habitats are included in the inventory, with the type and approximate location of each indicated. All Natural Habitat assets have been classified as a 3' for value to the community and nature.

Asset Inventory Spreadsheet

The asset inventory spreadsheet, detailed methodologies, and sources are provided in full in Appendix A.

Summary

This chapter summarizes how the Port-wide asset inventory was developed and the data that is included. The main goal of this effort was to identify and categorize the key assets, including cargo terminals and related operations, facilities critical to life safety, the transportation network, community/commercial assets, and natural habitats.

This inventory provided the framework to identify which assets are exposed to SLR and to complete the vulnerability assessment.

4 Sea Level Rise Maps

Introduction

This chapter summarizes the coastal flooding and SLR inundation analysis and mapping.

The purpose of this analysis was to develop existing and future condition coastal water levels and to map the inland extent of flooding and inundation. Future condition water levels were developed by combining existing daily high tide and storm tide water levels with future projections of SLR. The flooding and inundation mapping layers were then used to identify the most exposed assets within the Port.

In this report, **inundation** refers to flooding that occurs during normal, daily tide cycles. Areas that are expected to be inundated under a particular SLR scenario are expected to be permanently flooded if no adaptive actions are taken by the Port.

Flooding refers to temporary flooding that only occurs during elevated water levels associated with coastal storms ("storm tides"). Flooding is temporary and less frequent. Therefore, areas that are anticipated to be temporarily flooded are less vulnerable than areas than might be permanently inundated.

Methodology

Development of Topographic Data

Base Topography

The project team leveraged a merged bathymetric/topographic digital elevation model (DEM) for use in this project. The DEM was created in 2012 for a coastal flood study of Los Angeles County for the Federal Emergency Management Agency (FEMA)[10]. It was developed using airborne bathymetric and topographic light detection and ranging (LiDAR) survey data collected in late 2009 and hydrographic sonar data collected between 2005 and 2010. All building, structure (i.e., bridges, walls), and vegetation points were removed during the processing to create what is referred to as a "bare earth" topographic dataset. Many areas of the Port bathymetry were not completely resolved, although this doesn't matter for this project as the SLR exposure analysis was conducted for assets along the shoreline and inland areas. The resulting bare earth, 3.3-foot (1 meter) resolution DEM extends approximately 500 meters inland and formed the base DEM for the project.

10 BakerAECOM 2015. Pacific Coast Topographic and Bathymetric Data Los Angeles County, California. Prepared for FEMA Region IX. April 9, 2015

Supplemental Topographic Data

Accurate flooding and inundation analysis and mapping is dependent upon up-to-date topographic data. Additional survey data for recent infrastructure projects constructed after 2009 that were not captured in the base DEM was provided. These included the following project sites:

- 22nd Street Park and Parking Lot
- Berth 200 Site
- Berth 46
- Berth 88
- Berth 136-157
- China Shipping (multiple sites)
- Harry Bridges Boulevard
- Sampson Way
- Wilmington Waterfront Park
- Cabrillo Way Marina Phase II

These elevation data were added to the DEM to reflect current shoreline conditions and elevations. Additional survey data from as-built drawings were manually added using AutoCAD® software[11]. Figure 4-1 shows an example of added survey data at the Berth 200 site.

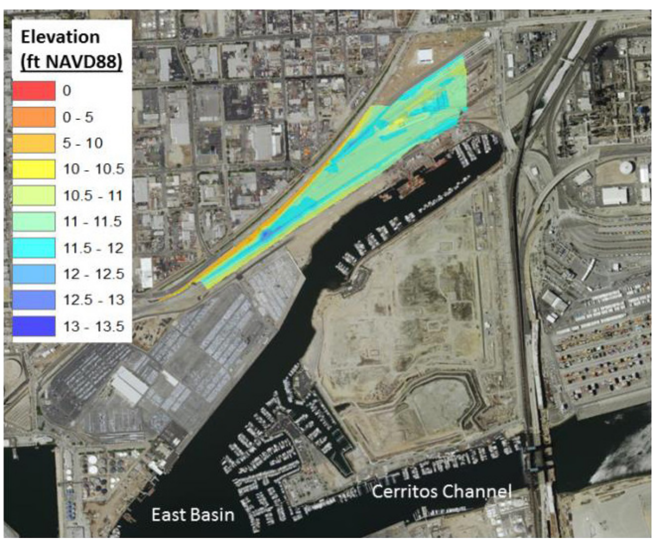


Figure 4-1. Example of supplemental elevation data

Shoreline Delineation

Accurate shoreline delineation was required to identify the locations of shoreline overtopping and the critical pathways that result in coastal flooding and inundation.

The shoreline was delineated manually in ArcGIS® using the DEM, orthoimages, and oblique aerial photographs (Figure 4-2). In most armored areas, the hard edge of a sheet pile wall or crest of a revetment was delineated as the shoreline. In areas without a hard coastal structure, the delineation followed the local high ground along the shoreline. Segments of the neighboring Port of Long Beach are also highlighted because they could act as critical flood pathways for POLA as the two ports are adjacent.

Development of Water Levels

Establishing the existing and future condition water levels was a critical component of this project. Water levels corresponding to the existing average daily high tide and storm tides were established based on a review of historical tide station data at the Port. Future condition water levels were then estimated by adding specific SLR amounts to the existing water levels. The purpose of this analysis was to estimate future water level conditions to evaluate the impact of permanent inundation and temporary storm flooding.

Figure 4-2. Delineated shoreline for POLA

11 This work was completed by Coast Surveying, Inc.

Daily and Storm Tide Levels – Existing Conditions

Average daily tidal datums are estimated by the National Oceanographic and Atmospheric Administration (NOAA) using observed water level data at long-term tide stations.

The mean higher high water (MHHW) tidal datum was selected to represent the average daily high tide for the flooding and inundation analysis. MHHW was estimated by NOAA using observed water level data from 1983-2001 at the Los Angeles tide station (#9410660).

Coastal flooding from storm tides was evaluated using FEMA's 100-year storm tide level[12]. The 100-year storm tide includes the effects of astronomical tides, storm surge (due to atmospheric pressure and meteorological effects), and El Niño conditions. It does not include wave effects such as wave setup and wave runup. The existing 100-year storm tide was estimated by FEMA using a statistical analysis of 84 years of measured annual maximum water level data at the NOAA Los Angeles tide station. Historical water level data were adjusted to current mean sea level to account for sea level rise that has occurred over the last century. Daily and storm tide levels at the POLA are shown in Table 4-1.

Table 4-1 also presents a comparison of NOAA's published tidal datums with a datum conversion sheet provided by the Port: Vertical Datum Planes for Long Beach Harbor and Los Angeles Harbor. The upward shift in the elevation of tidal datums (relative to the NAVD88 datum) from the Long Beach Harbor Department Survey Section to the published NOAA values of approximately 0.2 feet is believed to be the result of SLR that occurred since the establishment of the Harbor Department's vertical datum planes.

Vertical datum conversions of topographic data conducted for this project relied on the Harbor Department's published datums. Estimates of the existing daily high and storm tide levels used for the SLR flooding and inundation mapping relied on the more recently published values from NOAA and FEMA (see Table 4-1).

Table 4-1. Existing Daily and Storm Tide Levels at Port of Los Angeles

	Los Angeles Tide Station (#9410660) †		Long Beach Harbor Department Survey Section ‡	
Datum	NAVD88 (feet)	MLLW (feet)	NAVD88 (feet)	MLLW (feet)
100-year Storm Tide Level*	7.94	8.14	-	-
10-year Storm Tide Level*	7.45	7.65	-	-
Highest Observed Tide	7.72	7.92	7.16	7.54
Highest Astronomical Tide	7.14	7.34	-	-
Mean Higher High Water (MHHW)	5.29	5.49	5.05	5.43
Mean High Water (MHW)	4.55	4.75	4.33	4.71
Mean Tide Level (MTL)	2.64	2.84	2.45	2.83
Mean Sea Level (MSL)	2.62	2.82	2.42	2.80
Mean Low Water (MLW)	0.74	0.94	0.57	0.95
North American Vertical Datum of 1988 (NAVD88)	0.0	0.20	0.0	0.38
Mean Lower Low Water (MLLW)	-0.20	0.0	-0.38	0.0

Notes:
† Daily and storm tide levels were estimated based on 19 years of observed water level data from 1983-2001 at the Port of Los Angeles tide station (#9410660).
‡ Daily tide levels were estimated based on 9 years of observations by the U.S. Coast & Geodetic Survey (dates unknown but believed to be many decades old) at the Port of Los Angeles tide station.
* Source: BakerAECOM 2015. California Coastal Analysis and Mapping Project, Open Pacific Coast Study, Intermediate Data Submittal #2 Offshore Waves and Water Levels, Southern California. Prepared for: FEMA Region IX. January 6, 2015

12 The 100-year tide level is a commonly used term for FEMA's 1-percent-annual-chance stillwater elevation (SWEL). The 1-percent-annual-chance SWEL is the stillwater elevation that has a 1-percent chance of occurring in any year and is a commonly used water level design criteria for coastal development and flood protection in areas where waves are insignificant.

Daily and Storm Tide Levels – Future Conditions

Several SLR scenarios were selected from a 2012 National Research Council (NRC) report on west coast SLR[13] to represent a range of projections for planning and adaptation purposes. Each SLR scenario – 12 inches, 24 inches, 37 inches, and 66 inches – was combined with the two tide conditions: (1) daily and (2) the 100-year storm tide to represent permanent inundation and temporary flooding, respectively. See Chapter 2 for more details on the SLR projections. The results of the analysis are shown in Table 4-2.

Table 4-2. Existing and Future Daily and Extreme Tide Levels at Port of Los Angeles

SLR Scenario	Tide Level MHHW (ft NAVD88)	Tide Level 100-yr Tide (ft NAVD88)
Existing Conditions	5.3	7.9
+ 12" SLR	6.3	8.9
+ 24" SLR	7.3	9.9
+ 37" SLR	8.4	11.0
+ 66" SLR	10.8	13.4

Notes: MHHW is the mean higher high water level (the average of the higher of two high tides each day) as estimated by NOAA. 100-year tide is the 1-percent-annual-chance extreme tide elevation based on FEMA's statistical analysis of 84 years of annual maximum water level data at the Los Angeles tide station (see Table 4-1).

Flooding and Inundation Analysis and Mapping

The flooding and inundation analysis consisted of two main components: (1) development of flooding and inundation extent and depth layers and (2) a shoreline overtopping analysis.

Flooding and Inundation Extent and Depth Mapping Layers

Flooding and inundation mapping layers were created for the two existing and eight future conditions water levels in Table 4-2. The mapping layers were developed by comparing the existing and future conditions water levels to the topographic DEM at each grid cell. The topographic elevation was subtracted from the water surface elevation to estimate the depth of inundation. The inundated areas were combined to create a single mapping layer showing extent and depth of inundation for each water level and SLR scenario. An example of the 100-year storm tide + 24 inches of SLR is shown in Figure 4-3.

Lighter blue areas have lower flood depths and darker blue areas have greater flood depths. Green areas are below the mapped water surface elevation but not hydraulically connected to the flooding. Overtopping depths are shown by color at the shoreline.

Figure 4-3. Example flooding and inundation map

The applied mapping methodology also considers low-lying areas that are hydraulically disconnected from the flood source (the Pacific Ocean).[14] This methodology is an improvement over earlier inundation methods that considered a grid cell to be inundated solely based on elevation. These low-lying, hydraulically disconnected areas are shown on the inundation maps and represent areas that may be vulnerable to elevated groundwater or drainage issues. Low-lying, disconnected areas may also be exposed to flooding in the event of failure of the existing flood protection infrastructure along the shoreline.

13 National Research Council 2012. Sea Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Academy Press.

14 Marcy, D., William, B., Draganoz, K., Hadley, B., Haynes, C., Herold, N., McCombs, J., Pendleton, M., Ryan, S., Schmid, K., Sutherland, M., and Waters, K. 2011. New Mapping Tool and Techniques for Visualizing Sea Level Rise and Coastal Flooding Impacts, Proceedings of the 2011 Solutions to Coastal Disasters Conference, Anchorage, AK

Shoreline Overtopping Analysis

The SLR inundation mapping layers provide a wealth of information related to SLR and flooding vulnerabilities; however, identifying the source of flooding along the shoreline is difficult through examination of the inundation maps alone. The critical flood pathways at the shoreline must also be identified. A critical flood pathway is a low-lying shoreline segment that facilitates flooding and inundation of inland areas (Figure 4-4).

Figure 4-4. Example of critical flood pathways

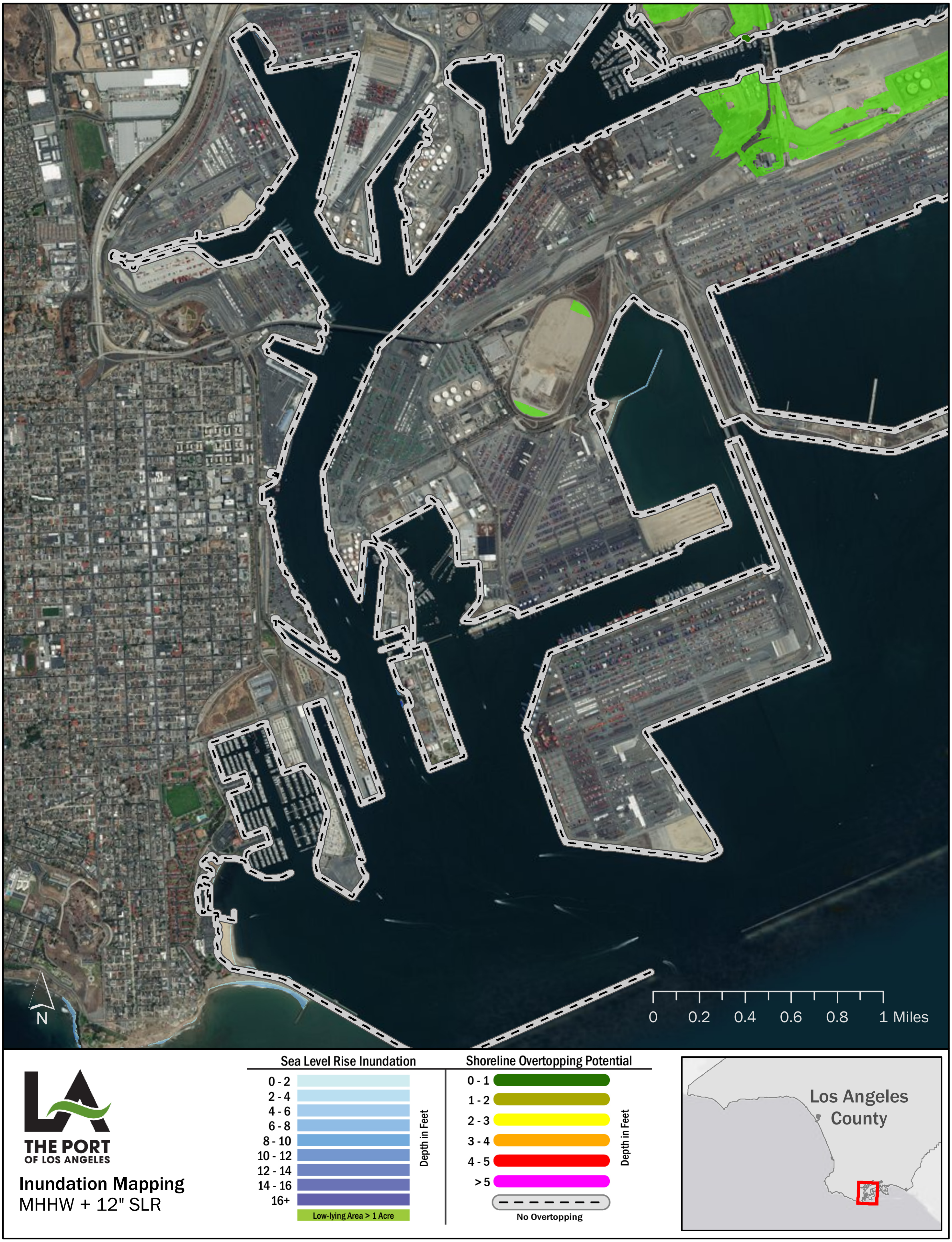
Overtopping potential data layers were created for each water level and SLR scenario using the shoreline delineation developed with the topographic DEM. The shoreline delineation was overlaid on the flooding and inundation layer for each SLR scenario and the depth of inundation was extracted at each location along the shoreline to identify flood pathways.

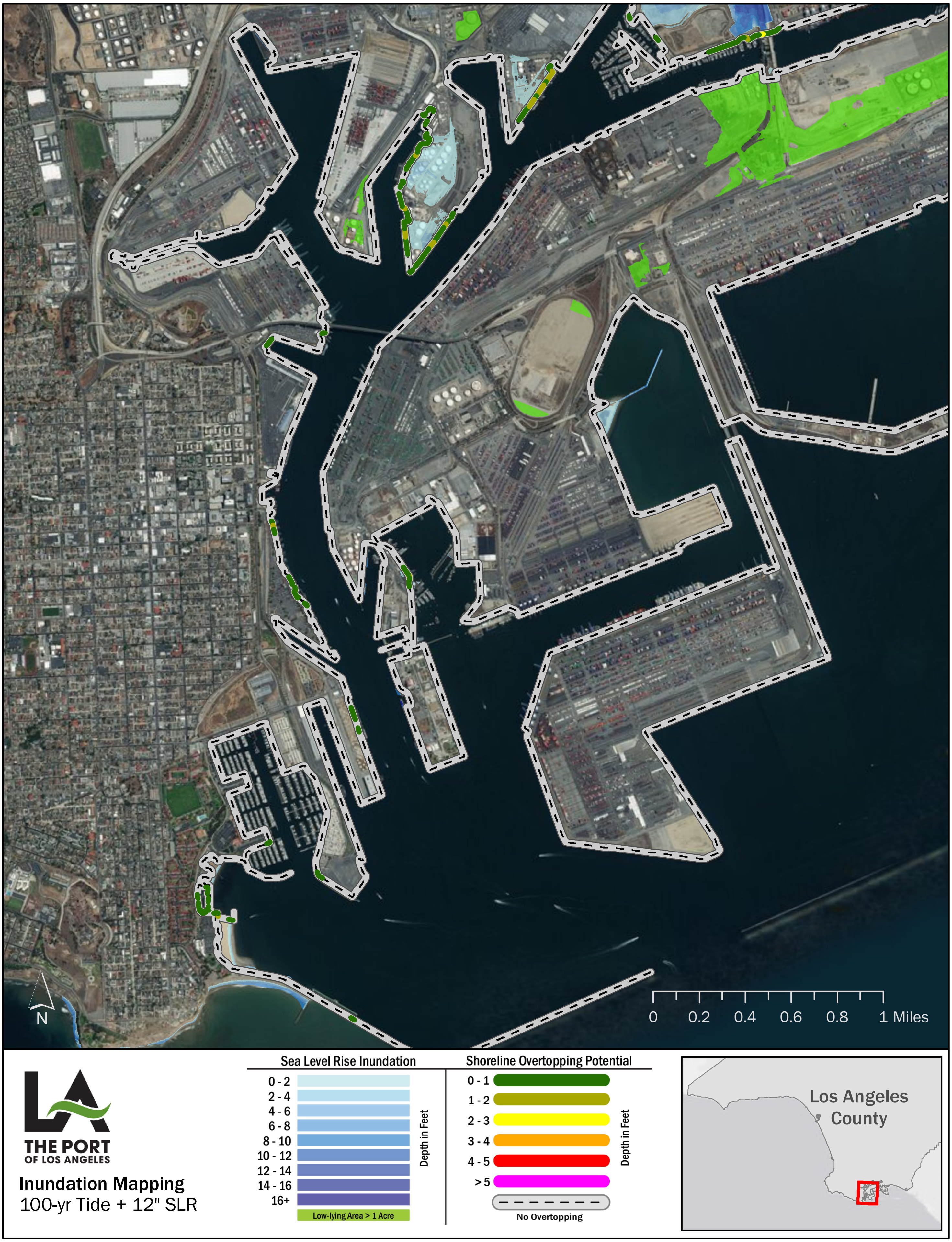
Segments of shoreline with lower elevations have higher overtopping potential depths than higher elevation segments of shoreline. Areas of overtopping that act as flood pathways for inland areas are locations where implementing flood control measures will be considered in the future.

Summary

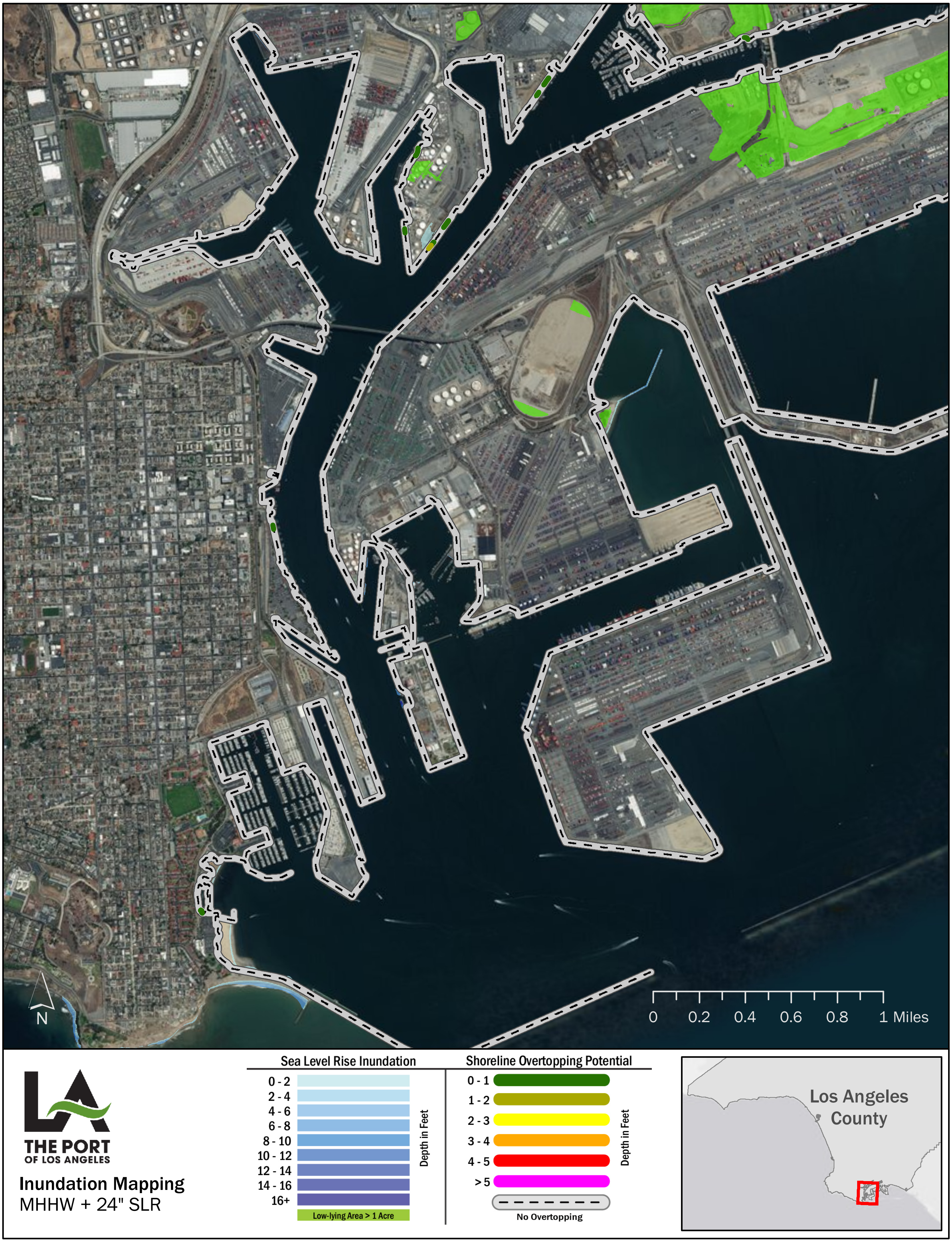
This chapter presented the results of the SLR inundation mapping effort. SLR inundation maps were developed using the depth and extent mapping layers and shoreline overtopping potential to help visualize daily inundation, storm tide flooding, and overtopping potential along the shoreline.

The maps on the following pages present four SLR scenarios, resulting in eight mapped scenarios. Each SLR scenario—12, 24, 37, and 66 inches—was evaluated under two tide conditions: (1) daily high tide and (2) storm tide.


N
0 0.2 0.4 0.6 0.8 1 Miles
THE PORT
OF LOS ANGELES
Inundation Mapping
MHHW + 12" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Low-lying Area > 1 Acre
Depth in Feet
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Depth in Feet
Los Angeles
County

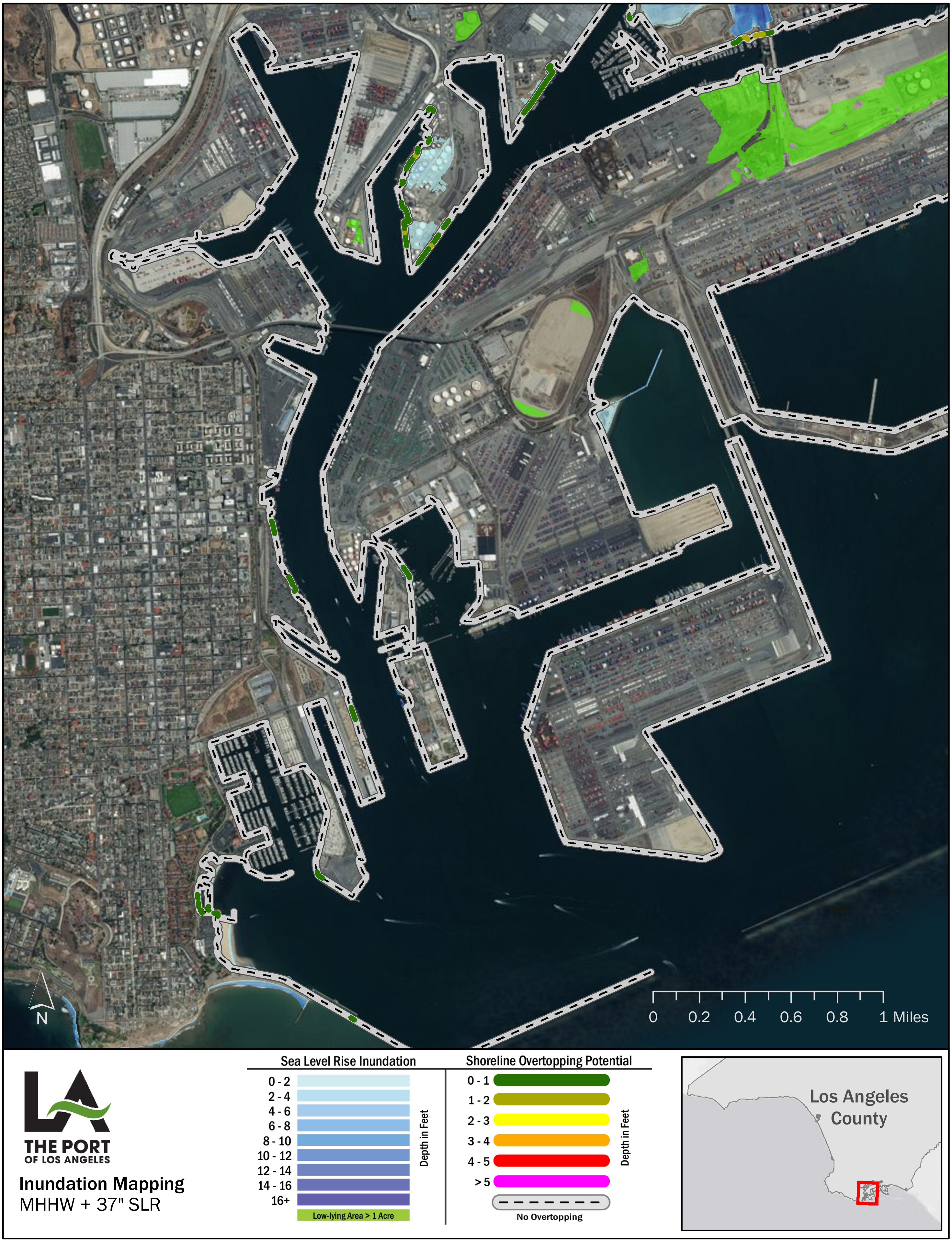


Inundation Mapping
100-yr Tide + 12" SLR

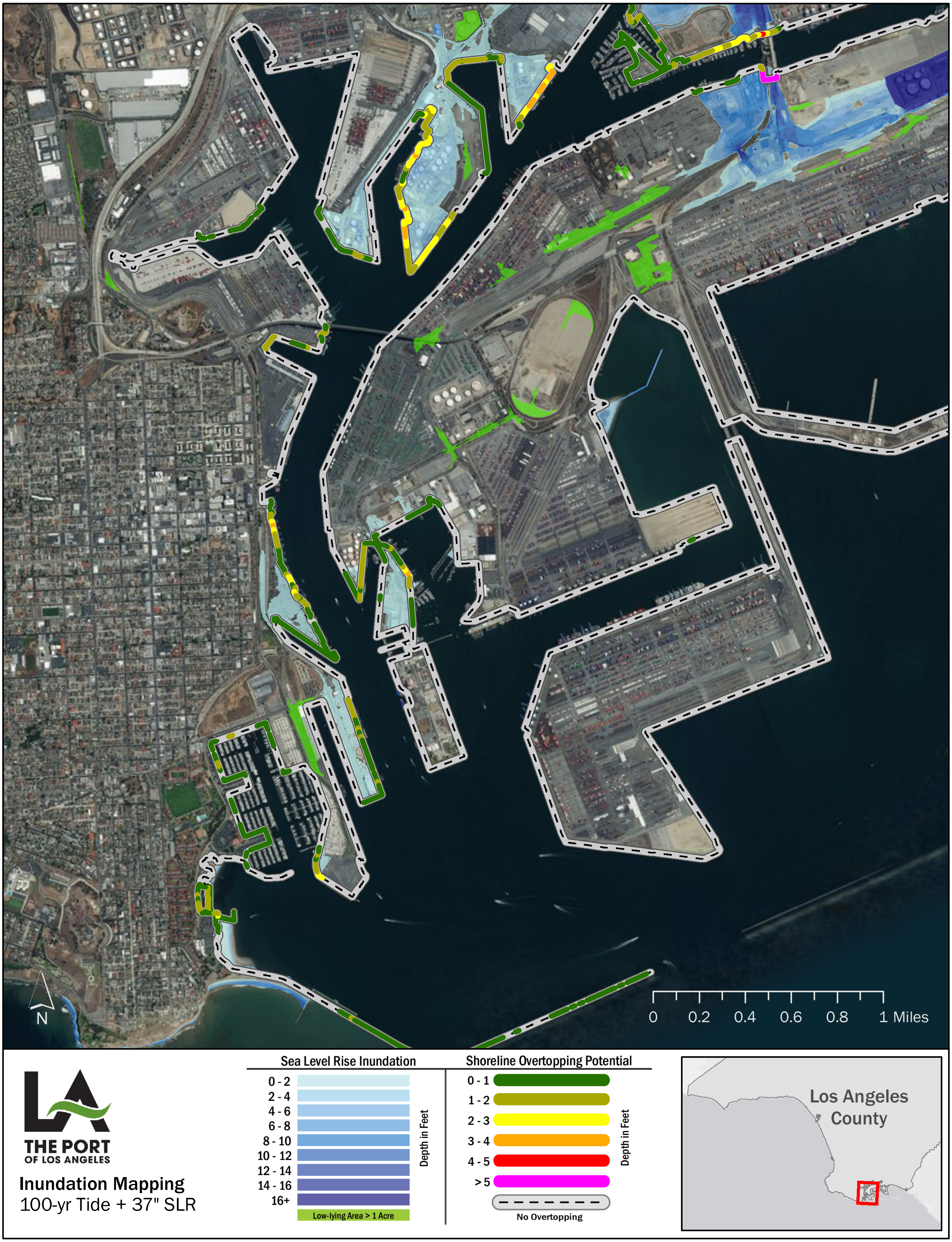

N
0 0.2 0.4 0.6 0.8 1 Miles
THE PORT
OF LOS ANGELES
Inundation Mapping
MHHW + 24" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Low-lying Area > 1 Acre
Depth in Feet
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Depth in Feet
Los Angeles
County

N
0 0.2 0.4 0.6 0.8 1 Miles
THE PORT OF LOS ANGELES
Inundation Mapping
100-yr Tide + 24" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Low-lying Area > 1 Acre
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
Los Angeles County

FINAL DRAFT

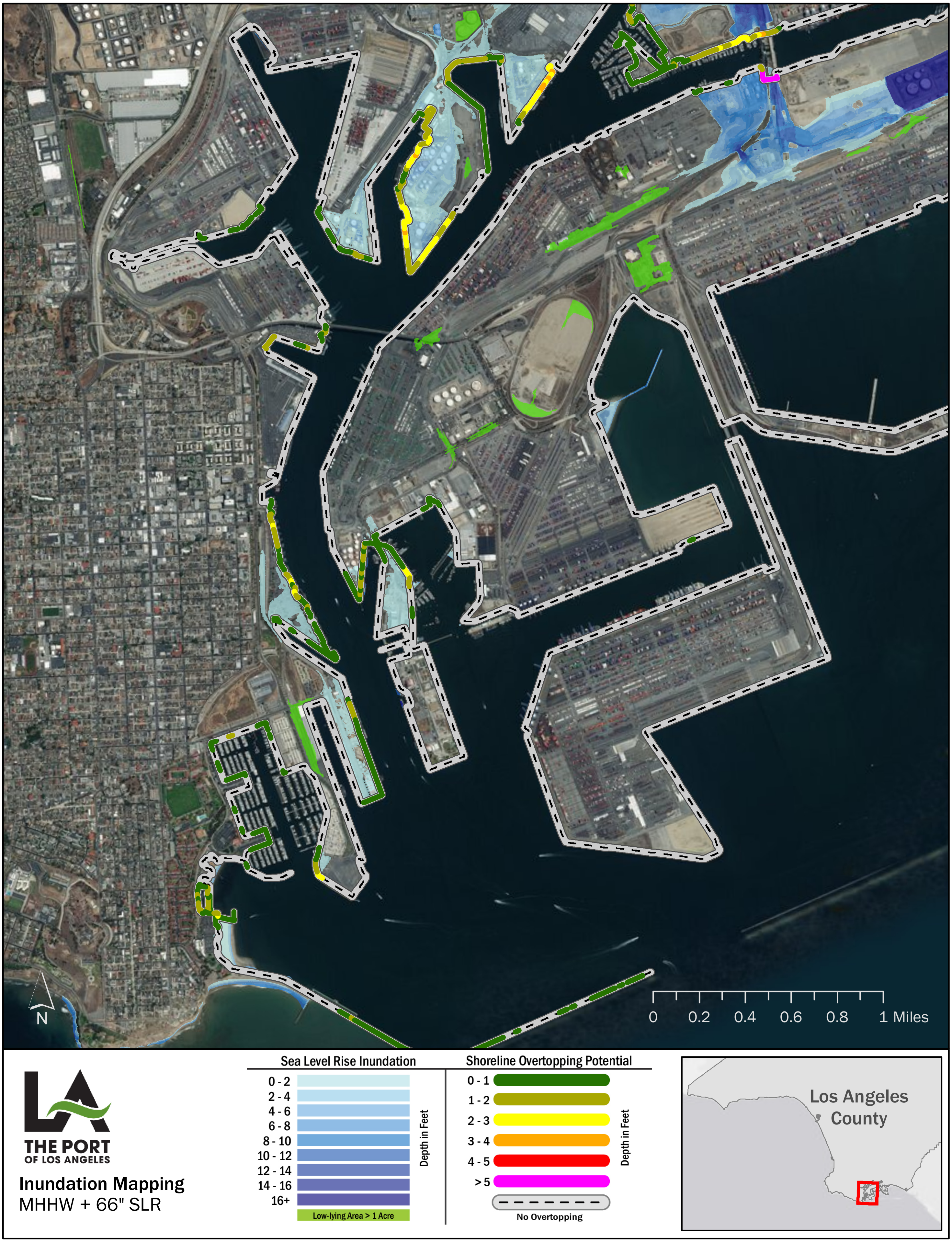

N
0
0.2
0.4
0.6
0.8
1 Miles
THE PORT
OF LOS ANGELES
Inundation Mapping
MHHW + 37" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Low-lying Area > 1 Acre
Depth in Feet
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Depth in Feet
Los Angeles
County

FINAL DRAFT

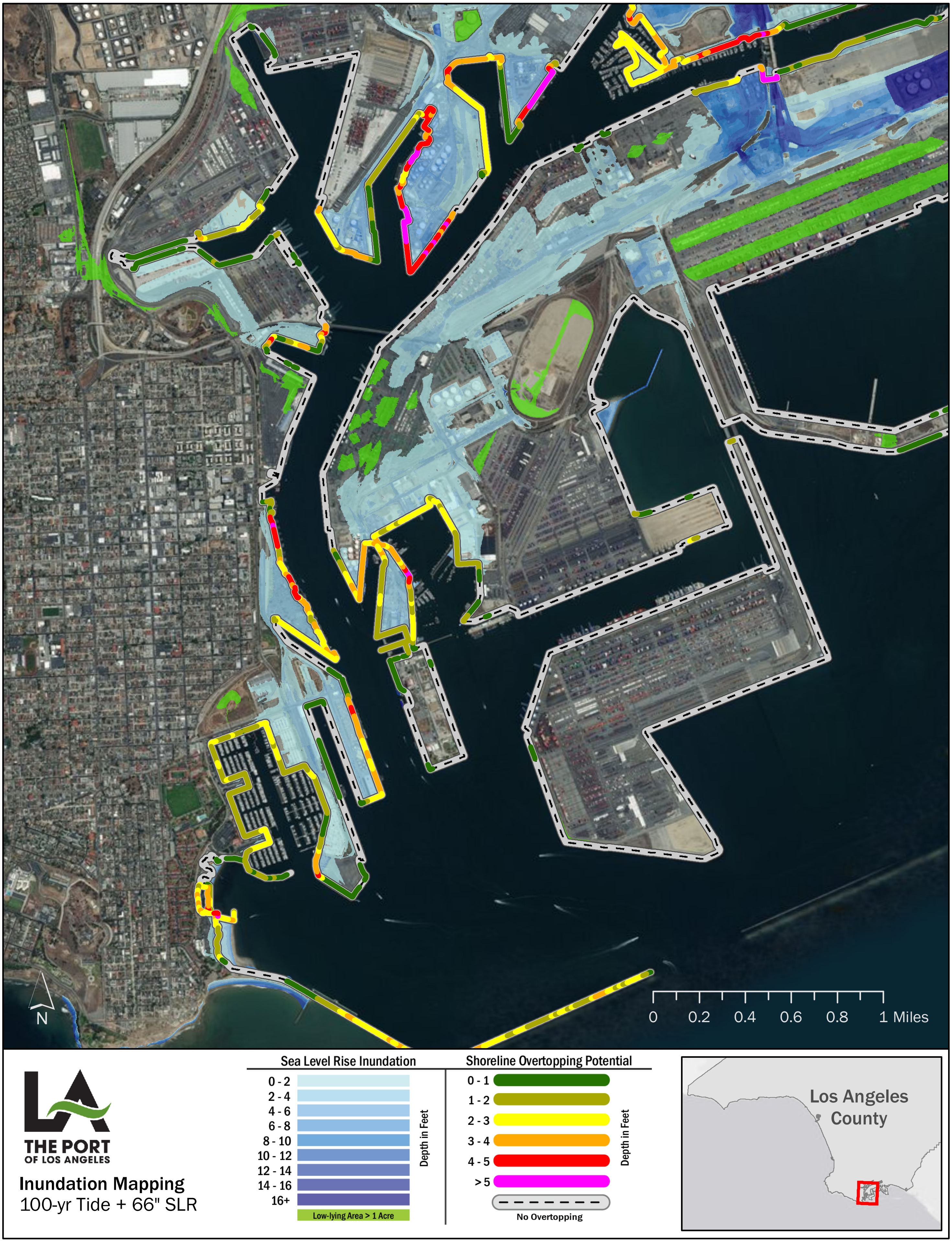


N
0
0.2
0.4
0.6
0.8
1 Miles
THE PORT
OF LOS ANGELES
Inundation Mapping
100-yr Tide + 37" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Low-lying Area > 1 Acre
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
Los Angeles
County

FINAL DRAFT



N
0 0.2 0.4 0.6 0.8 1 Miles
THE PORT OF LOS ANGELES
Inundation Mapping
MHHW + 66" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Low-lying Area > 1 Acre
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
Los Angeles County



N
0 0.2 0.4 0.6 0.8 1 Miles
THE PORT OF LOS ANGELES
Inundation Mapping
100-yr Tide + 66" SLR
Sea Level Rise Inundation
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Low-lying Area > 1 Acre
Depth in Feet
Shoreline Overtopping Potential
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping
Depth in Feet
Los Angeles County

FINAL DRAFT

5 Vulnerability Assessment

Introduction

Individual assets within each infrastructure category (of the inventory) have been reviewed for exposure, sensitivity, and adaptive capacity. The potential consequences of inaction to SLR exposure are also qualitatively presented in terms of economic, social, and environmental impacts.

Results of the analysis have been summarized in vulnerability profiles, which were created for each infrastructure category and used as a basis for establishing priorities for future SLR adaptation planning.

There is one vulnerability profile for each of the following asset types:

- Cargo Wharves and Miscellaneous Operations,
- Critical Facilities,
- Transportation Network (rail and road),
- Community/Commercial Assets, and
- Natural Habitats.

Methodology

The SLR vulnerability assessment follows a standardized step-by-step approach to evaluate exposure, sensitivity, and adaptive capacity.

Exposure: Provides information on flooding, both permanent inundation and temporary flooding (e.g. a building may be permanently inundated by a 37 inch SLR scenario, but temporarily flooded by a 12 inch SLR + storm tide scenario). This is evaluated quantitatively.

Sensitivity: Provides information on the degree to which an asset would be impaired by flooding. For example, roadways are generally not highly sensitive to temporary flooding because they are unlikely to be damaged, unless the flood waters are very fast flowing, and therefore can be used again once the waters recede. In contrast, a substation would be considered very sensitive to flood events if exposed to water as it may be damaged beyond repair. This is evaluated qualitatively.

Adaptive Capacity: Provides information on existing redundancy or an asset's ability to adapt (e.g. alternative roadway, back-up generator, ability to raise a seawall). This is evaluated qualitatively.

As illustrated in Figure 5-1, only assets that were found to be exposed to SLR were moved on to the sensitivity assessment. Similarly, assets found to be exposed and sensitive were evaluated for adaptive capacity. Assets are considered most vulnerable if they are exposed to flooding, have high sensitivity, and low adaptive capacity.

Consequences: Considers the magnitude of the impact that may occur under selected SLR and storm tide scenarios.

Reviewing the consequences of failing to address SLR is useful in prioritizing assets for adaptation planning. SLR has the potential to cause a broad range of consequences to the Port. Generally, a dollar value relating to goods and services potentially impacted can be estimated where market prices are available, allowing for measurement of economic impact. However, the consequence to coastal environments, including public trust lands like beaches and wetlands that are vulnerable to SLR should also be considered, as they provide a number of important ecological, social and cultural services. It is harder to put an explicit market value on these services.

For each asset, consequence was assessed qualitatively based on a set of considerations.

- Economic loss
- Social impacts
- Environmental damage

Vulnerability profiles were then created to summarize the primary vulnerabilities of each of the asset types. These profiles are provided after the key vulnerabilities are highlighted below.

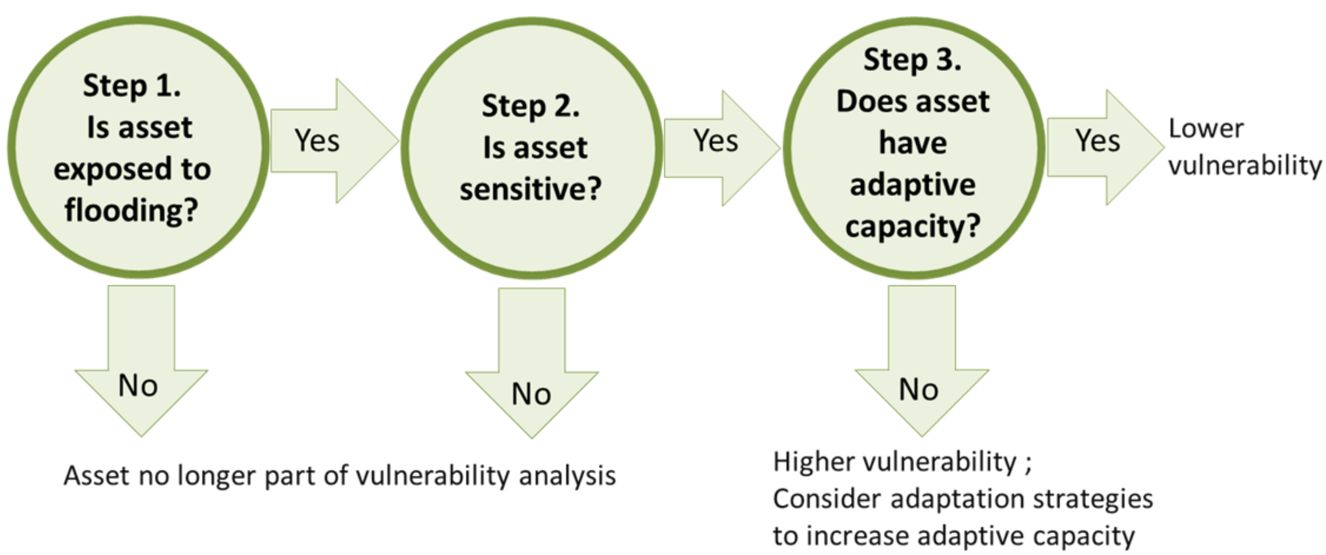


Figure 5-1. Graphic representation of the Vulnerability Analysis

Key Vulnerabilities

Cargo Wharves and Miscellaneous Operations

- Container terminals have very low vulnerability
- Liquid bulk (Nustar, Valero, Shell, Vopak) could be temporarily flooded by 2030 (12 inch SLR + ST)
- Other Cargo terminals (Vopak, Rio Tinto Minerals) could be temporarily flooded by 2050 (24 inch SLR + ST)
- Misc. Operations (Pilots Station, LAHD Construction/ Maintenance, & breakwater) could be temporarily flooded by 2100 (37 inch SLR + ST)

Critical Facilities and Utilities

- Millennium Maritime and SD Pump Station could be temporarily flooded by 2050 (24 inch SLR + ST)
- Some life safety facilities (Fire Station #110, and Pilots Station) could be temporarily flooded by 2100 (37 inch SLR + ST)
- Several utilities (pumping plants and transformers) could be temporarily flooded by 2100 (37 inch SLR + ST)

Transportation Network

- Vopak rail could be temporarily flooded by 2030 (12 inch SLR + ST)
- WBCT and TraPac rail leads could be temporarily flooded by 2100 (37 inch SLR + ST)
- Anaheim St, east of Dominguez Channel, and Fries (Berths 161-169) could be temporarily flooded by 2030 (12 inch SLR + ST)
- Access to the Marinas could be temporarily flooded by 2030 (12 inch SLR + ST)
- The underside structure of the Pier 400 Corridor Bridge and LACFCC Bridges could be impacted by high water levels starting at 24" SLR.
- The Vincent Thomas Bridge could experience increased operational disruptions to vessel navigation resulting from reduced bridge clearances starting at 12" SLR, particularly for large container vessels.

Community/Commercial Assets

- Al Larson's Boat shop and Cerritos and Island Yacht anchorages could be temporarily flooded by 2030 (12 inch SLR + ST)
- Ports O' Call, LA Waterfront Sports Fishing and Cruises, and Alta Sea could be temporarily flooded by 2100 (37 inch SLR + ST)

Natural Habitats

- North of Pier 300 sand area habitat could be temporarily flooded by 2030 (12 inch SLR + ST)
- Brackish water marsh at Wilmington Marinas and the Ficas Trees Heron Nesting habitat could be temporarily flooded by 2100 (37 inch SLR + ST)

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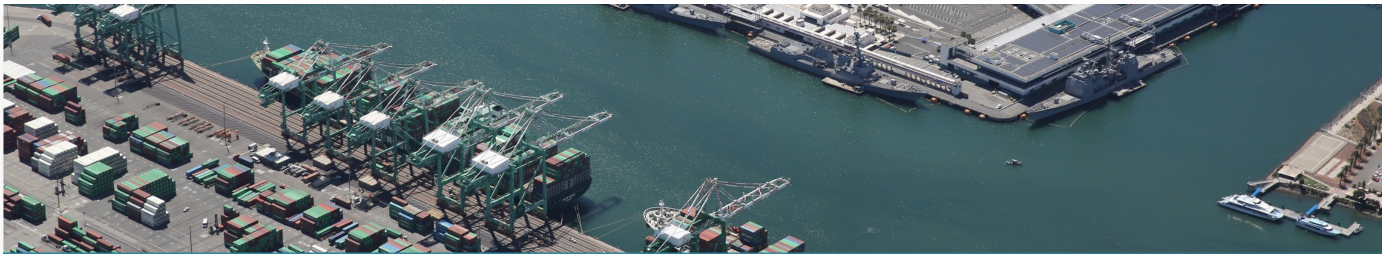


Cargo Wharves/Misc. Operations SLR Vulnerability Profile

Asset Overview

There are six main types of cargo terminals in the Port: container, liquid bulk, dry bulk, ro-ro, breakbulk, and passenger. There are also a number of miscellaneous operations and services related to cargo operations.

Container Terminals

For the past decade, the Port has moved more containers than any other port in the nation, more than doubling past volumes. There are eight major container terminals. Key assets of container terminals that may be vulnerable if exposed to flooding include: pavements and container storage yards, buildings, railyards, refrigerated container storage (reefer) racks, electrical infrastructure including substations and Alternative Marine Power (AMP), and container handling equipment such as quay cranes and rubber-tire gantry cranes (RTGs).

Liquid Bulk Terminals

There are seven liquid bulk facilities comprising a total of 114 acres to handle various types of commodities for both import and export. Handling facilities include tankers, barges, bulk carriers and storage tanks with convenient rail access.

Other Cargo Terminals

There are several cargo terminals which serve a variety of breakbulk, dry bulk, and RoRo commodities, as well as passenger terminals. Key assets at these facilities which may be vulnerable to sea level rise (SLR) include paved open-air storage areas; buildings such as storage warehouses, maintenance buildings, and cruise terminal buildings; and railyards. Electrical infrastructure includes substations and AMP at the World Cruise Center.

Miscellaneous Operations & Services

In addition to the cargo terminals, there are many miscellaneous operations and services that are vital for business continuity. These services include but are not limited to: tugboats, vessel fueling and repair, the LA Port Pilots, US Water Taxi, and other waterfront and wharf services. The Port also includes a breakwater (maintained by the U.S. Army Corps of Engineers [USACE]), which protects the Port from waves.

Exposure

The following tables summarize the exposed container terminals, liquid bulk terminals, other cargo terminals, and miscellaneous operations and services according to when they first become inundated.

Maps illustrating the exposure to SLR and storm tide are provided at the end of the profile. The exposure maps include an overtopping layer which illustrates the lowest lying points along the shoreline.

The terminals are most vulnerable to temporary inundation (starting at 12 inches of SLR) and only a few berths are permanently inundated by the mid to end of century (37 inches of SLR) scenario.

Most of the berth overtopping that exposes cargo operations to flooding is confined to specific terminal segments. The length and depth of berth overtopping increasing with rising sea levels.

Table 1: Timing of Container Terminal Exposure

(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	**Assets Exposed (By Berth Numbers)**
12 inch (2030)	• None • None
24 inch (2050)	• None • None
37 inch (2100 mid-range)	• None • None
66 inch (2100 high-range)	• None • 100-120 China Shipping | WBCT • 212-215 Yusen Terminal • 226-236 Everport

Table 2: Timing of Liquid Bulk Terminal Exposure

Table 2: Timing of Liquid Bulk Terminal Exposure
(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	Assets Exposed (By Berth numbers)
12 inch (2030)	• None • 163-164 NuStar, Valero • 167-169 Shell • 187-190 Vopak
24 inch (2050)	• None • 148-151 Phillips 66
37 inch (2100 mid-range)	• 163 & 164 NuStar, Valero • 167-169 Shell • 238-240 ExxonMobil
66 inch (2100 high-range)	• 148-151 Phillips 66 • 187-190 Vopak • 238-240 ExxonMobil • 118-120 Kinder Morgan

Table 3: Timing of Other Cargo Terminal Exposure
(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	Assets Exposed (By Berth numbers)
12 inch (2030)	• None • None
24 inch (2050)	• None • 153-155 POLA | Pasha • 165-166 Rio Tinto Minerals • 191 Vopak | CPC
37 inch (2100 mid-range)	• None • 174-181 Pasha • 195-199 WWL Vehicles
66 inch (2100 high-range)	• 153-155 POLA | Pasha • 165-166 Rio Tinto Minerals • 174-181 Pasha Stevedoring • 191 Vopak | CPC • 195-199 WWL Vehicles • 46 POLA Multi-Use • 54-55 SSA Breakbulk • 95 Catalina Sea and Air • 206-209 Pasha Breakbulk • 210-211 SA Recycling

Table 4: Timing of Misc. Operations Exposure
(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	Assets Exposed (By Berth numbers)
12 inch (2030)	• None • None
24 inch (2050)	• None • 186 Public Service Marine
37 inch (2100 mid-range)	• None • 57-74 AltaSea • US Water Taxi • LA Pilots Station • Jankovich & Son • Millennium Maritime • 156-161 LAHD Construction & Maintenance • Breakwater
66 inch (2100 high-range)	• 57-74 AltaSea • US Water Taxi • LA Pilots Station • Jankovich & Son • Millennium Maritime • 156-161 LAHD Construction & Maintenance • 186 Public Service Marine • Breakwater • 56 CA Dept. of General Services • 200X Williamson Marine • 267 Coast Maritime • 270-271 American Marine

Sensitivity

There is a wide range of sensitivity levels to SLR among cargo, other wharf, and waterborne operations. Key considerations to determine sensitivity include the age of the asset and the presence of: electrical equipment or electrical infrastructure, buildings, liquid bulk or other cargo storage facilities, railyards, or pumping stations.

Container Terminals

Container terminals are considered highly sensitive to SLR impacts due to their immense global economic significance. In addition to the terminals themselves, it is important to maintain continuous ongoing operations of container vessel movement and the road and rail network connections necessary to ensure containers continue moving through the region. Containerized cargo and container terminal infrastructure are sensitive to damage if exposed to water even temporarily. Sensitive assets at container terminals include buildings (e.g., maintenance shops), electrical infrastructure (e.g., substations and

AMP), and container handling equipment. While container terminal assets are sensitive to SLR impacts, their exposure level is low, with terminals exposed only to temporary flooding in the 66 inch SLR scenario.

Liquid Bulk

Most of the liquid bulk storage facilities, including Berth 163 NuStar and Berth 164 Valero terminals, are among the earliest permanently inundated at 37 inches of SLR.

Every liquid bulk terminal is projected to be flooded by storm tides accompanied by 12 inches and 37 inches of SLR. Some liquid bulk facilities have walls around storage tanks, but these are not necessarily designed for flood protection. There is potential for contamination of the surrounding Port waters if liquid bulk storage is flooded.

Other Cargo Terminals

While none of the breakbulk, dry bulk, RoRo, or passenger cargo terminals are exposed to permanent inundation prior to the 66 inch SLR scenario, some of these assets are exposed to temporary flooding at 24 inches and 37 inches of SLR as listed in Table 3.

Breakbulk, dry bulk, and RoRo cargo stored on terminals may be damaged by flooding. Aside from the WWL Vehicles terminal, each of the exposed terminals have buildings that are also flooded. Exposed buildings include: cruise passenger terminal buildings, maintenance shops, and warehouses, which could suffer permanent damage if exposed. The WWL Vehicles facility also includes an exposed railyard that is vital to ongoing terminal operations.

Miscellaneous Operations & Services

The most sensitive cargo-related assets with the highest levels of exposure are along berths 60-80, 148-194, and 237-240.

Berths 60-80 are flooded during storm tides by 37 inches of SLR. Flooding of this area exposes the following individual assets: the Pilot's Station, tugboat operations, and the Jankovich & Son vessel fueling berth. The Pilot's Station is particularly sensitive as it is necessary for cargo ships to move in and out of the Port.

Any buildings on the waterfront are considered sensitive as they may be damaged by flooding. Vulnerable waterfront buildings include: AltaSea facility, CA State Department of General Services, Los Angeles Pilots Station, and Harbor Department Construction & Maintenance building.

The breakwater is highly sensitive to SLR and storm tides as it may be damaged and/or overtopped by increasing water levels.

Adaptive Capacity

Container Terminals

In the short term, container terminals have low adaptive capacity in terms of their ability to be easily or quickly elevated or relocated in response to storm tide events.

In the long term, container terminals will require regular upgrades to maintain functionality and ongoing operations. Container terminals have a typical life span of 30-50 years. With new developments and/or major upgrade projects, the option of raising terminals can be evaluated. Other options include building sea walls along low-lying berths projected to be overtopped. This is particularly applicable to the Ports container terminals as their earliest exposure level is at 66 inches of SLR during storm tides (end-of-century).

In some cases, it may be possible to move vulnerable container terminals out of projected flood areas to prevent cargo damage. For example, some containers could be moved to China Shipping where only a small area of the container yard is expected to flood. Another relocation option is Everport where most of the interior sections of the yard are not exposed.

The Yang Ming, TraPac, Eagle Marine, and California United container terminals are not expected to be exposed to SLR. Therefore, they provide some redundancy to Port-wide container movement in case of disruptions due to temporary flooding in exposed areas.

Liquid Bulk

While physical liquid bulk terminal infrastructure cannot be easily relocated in response to an approaching storm tide event, it is possible to move the liquid bulk. Most liquid bulk facilities are connected to offsite tank farms, making it possible to potentially move all liquid bulk cargo out of the Port. As with container terminals, liquid bulk terminals require regular upgrades to maintain ongoing operations. Along with new development projects, upgrades present opportunities in the long term to address exposure by reinforcing existing interior walls, raising terminals, or building barriers along berths projected to be overtopped. Liquid bulk terminals often handle unique commodity types. Several of the terminals are exposed simultaneously to temporary flooding by 12 inch to 24 inch SLR scenarios, which may significantly reduce Port-wide liquid bulk handling capacity. Therefore, liquid bulk has limited Port-wide redundancy, particularly under storm tide conditions.

Other Cargo Terminals
There is a variable degree of adaptive capacity among the Port's other cargo terminals. The dry bulk, RoRo, and passenger terminals are all unique operations without redundancy, but breakbulk terminal operations are generally more flexible. For example, Berth 206-209 Pasha operation has a low level of exposure (66 inches plus storm tide only) and could provide redundancy to exposed breakbulk operations during a temporary flooding event.

The RoRo terminal is only exposed to temporary flooding at a small portion of its storage area, providing the ability to temporarily relocate cargo on the property during storm events. It may be more difficult to relocate all exposed cargo in advance of a storm tide event for breakbulk or dry bulk terminals.

As with other cargo terminal types, the best opportunity to adapt breakbulk, dry bulk, RoRo, and passenger terminals is to reduce exposure to SLR during planning of new development and upgrade projects.

Miscellaneous Operations & Services
Tugboat and other waterborne operations are able to adapt to SLR. However, during storm surge events, some tugboat and other waterborne operations may temporarily lose access to their berths due to flooded roadways. A disruption in tugboat operations may result in disruption to the flow of cargo and vessel movement.

The Pilot's station facility is particularly critical and has a relatively low adaptive capacity. The building itself can be protected by temporary flood barriers, such as sandbags. However, operations may still be disrupted as the entire pier along Berths 57-73 is projected to be flooded, blocking access to the Pilot's Station. An area adaptation approach, such as installing barriers along low-lying berths projected to be overtopped may protect individual assets and access to the area.

It is possible to elevate the breakwater to provide enhanced protection against higher water levels. However, the structure is owned and maintained by the USACE. Any enhancements made to the breakwater will be analyzed and completed by the USACE.

Consequences

The Port of Los Angeles is the largest in the US, handling billions of dollars in trade value annually. Therefore, interruptions in cargo operations due to flooding may have extensive economic consequences including potential loss of valuable cargo stored on terminals in a storm tide event or damage to cargo handling assets. Any damage to cargo-handling assets may reduce the ability to move cargo on a long-term basis, which could result in a loss of business.

Interruptions in cargo operations may have large social consequences. The Port provides one in nine jobs in the region. Even temporary disruptions in ongoing cargo operations can result in lost wages for both employees and segments of the economy which depend on the Port for importing or exporting cargo. Disruptions to cargo operations may result in economic and social consequences on a national scale, as the Port enables trade across the country and is a vital component of a global trade network.

Impacts to the Pilots Station may prevent cargo vessels from accessing the Port. If vessels cannot enter or leave the Port facilities, disruptions may extend to all ongoing cargo operations.

The breakwater is also a vital asset that protects the entire Port from waves. Overtopping of the breakwater may have significant Port-wide impacts, including potential damage to both Port vessels and terminals along with disruption to Port-wide cargo operations.

In some cases, the public may lose access to coastal facilities such as AltaSea and the Catalina Sea and Air terminal, which provides passenger services to Catalina Island.

Potential contamination from liquid bulk exposure to a flood event poses environmental consequences for the area.

Summary

Container Terminals

- Overall, container terminals have a low level of exposure to SLR, with the only impacts occurring during temporary storm tide events at 66 inches of SLR. Only the China Shipping, Everport, and YTI facilities are exposed by this scenario.

Liquid Bulk Terminals

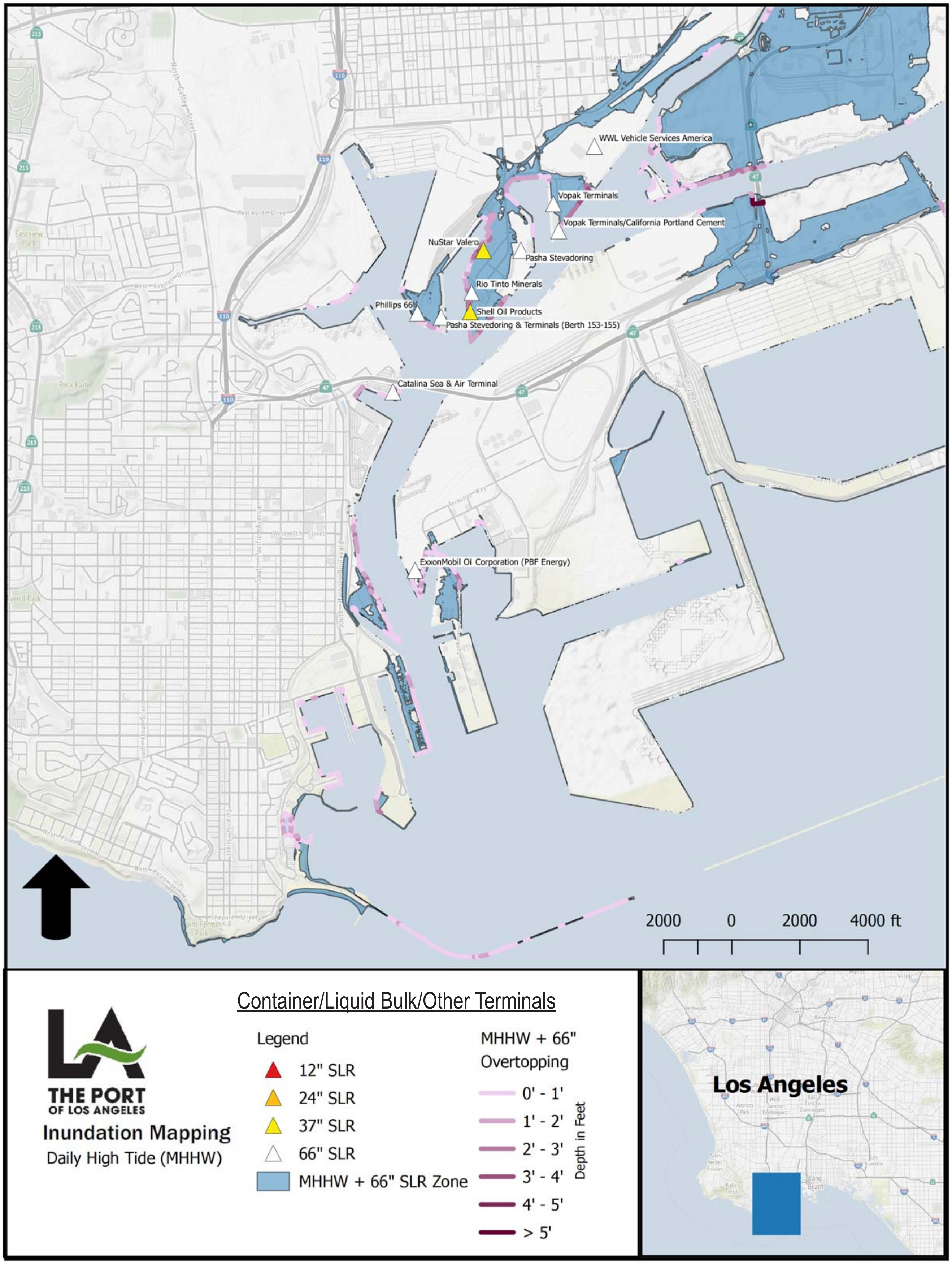
- The Valero, NuStar, Shell and Vopak liquid bulk facilities are exposed due to overtopping along berths 161-173 and 192-192 by 12 inches of SLR plus storm tide. By 24 inches of SLR plus storm tide, overtopping in this region expands to include the Phillips 66 terminal. The depth of inundation also increases (up to three feet for some berths). By 37 inches of SLR, Valero, NuStar, and Shell become permanently inundated.
- The ExxonMobil terminal along berths 237-240 is exposed to flooding by 37 inches of SLR during storm tides.

Other Cargo Terminals

- Some dry bulk and breakbulk facilities are among the most exposed. The Rio Tinto and Vopak | CPC dry bulk terminals and breakbulk and warehousing operations along berths 153-155 are all exposed to temporary flooding at 24 inches of SLR.
- Exposure extends to include Pasha’s berth 174-181 breakbulk terminal and the WWL Vehicle Services terminal at 37 inches of SLR.

Misc. Operations and Services

- The most vulnerable assets are along berths 60-80, and 184-189, and the breakwater.
- Overtopping along berths 182-186 Public Service Marine at 24 inches of SLR with storm tides.
- Overtopping along berths 60-80 begins at 37 inches of SLR during storm tides, leading to temporary flooding of key facilities including the Pilots Station, Millennium tugboat operation, and the Jankovich & Son vessel fueling berths.
- The breakwater is also overtopped by storm tides at 37 inches of SLR.


WWL Vehicle Services America
Vopak Terminals
Vopak Terminals/California Portland Cement
NuStar Valero
Pasha Stevedoring
Rio Tinto Minerals
Phillips 66
Shell Oil Products
Pasha Stevedoring & Terminals (Berth 153-155)
Catalina Sea & Air Terminal
ExxonMobil Oil Corporation (PBF Energy)
2000 0 2000 4000 ft
Container/Liquid Bulk/Other Terminals
LA THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66" Overtopping
0' - 1'
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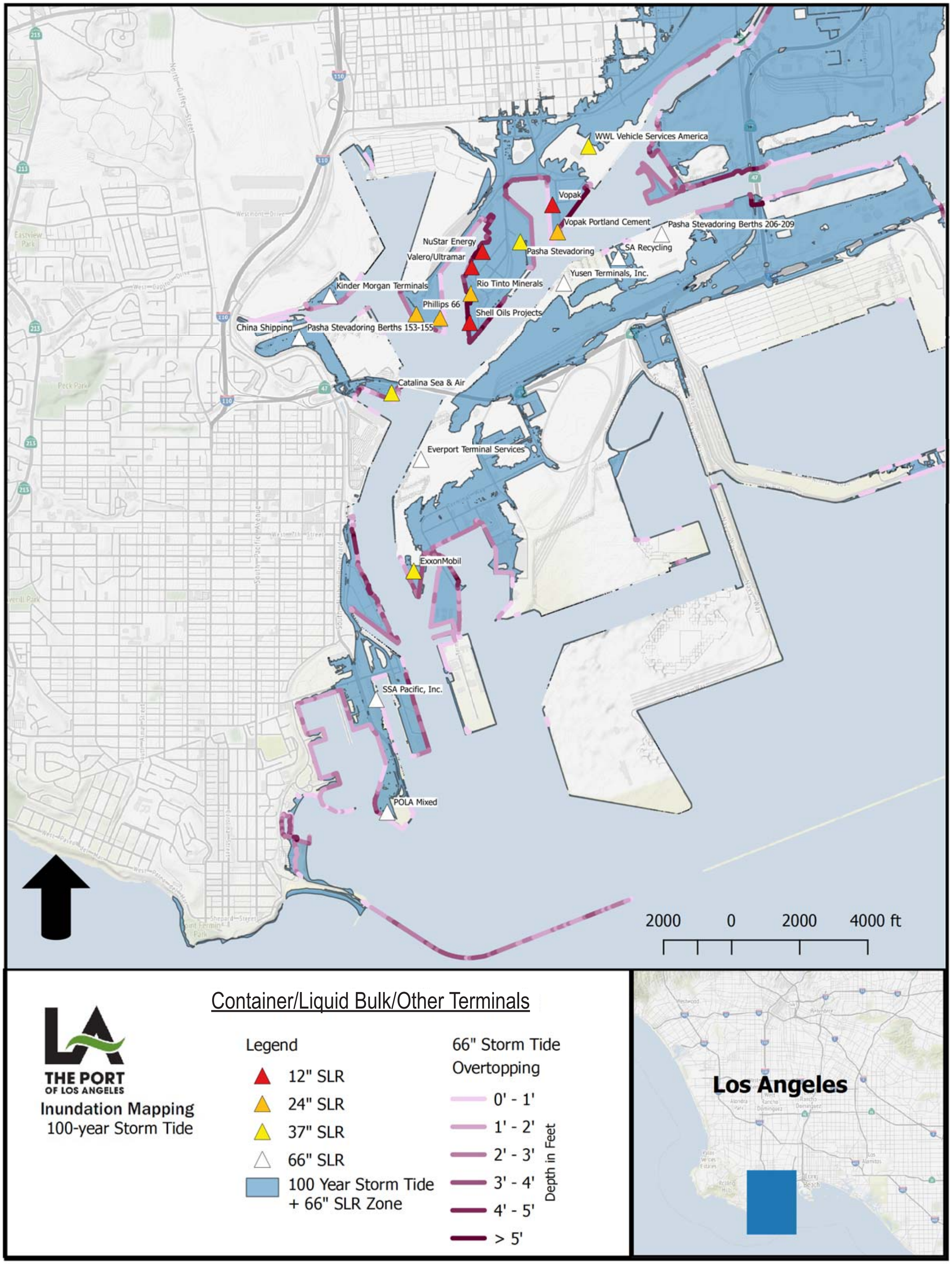
> 5'
Depth in Feet
Los Angeles


WWL Vehicle Services America
Vopak
Vopak Portland Cement
Pasha Stevadoring Berths 206-209
NuStar Energy
Valero/Ultramar
Pasha Stevadoring
SA Recycling
Yusen Terminals, Inc.
Kinder Morgan Terminals
Rio Tinto Minerals
Phillips 66
Shell Oils Projects
China Shipping
Pasha Stevadoring Berths 153-155
Catalina Sea & Air
Everport Terminal Services
ExxonMobil
SSA Pacific, Inc.
POLA Mixed
2000 0 2000 4000 ft
Container/Liquid Bulk/Other Terminals
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
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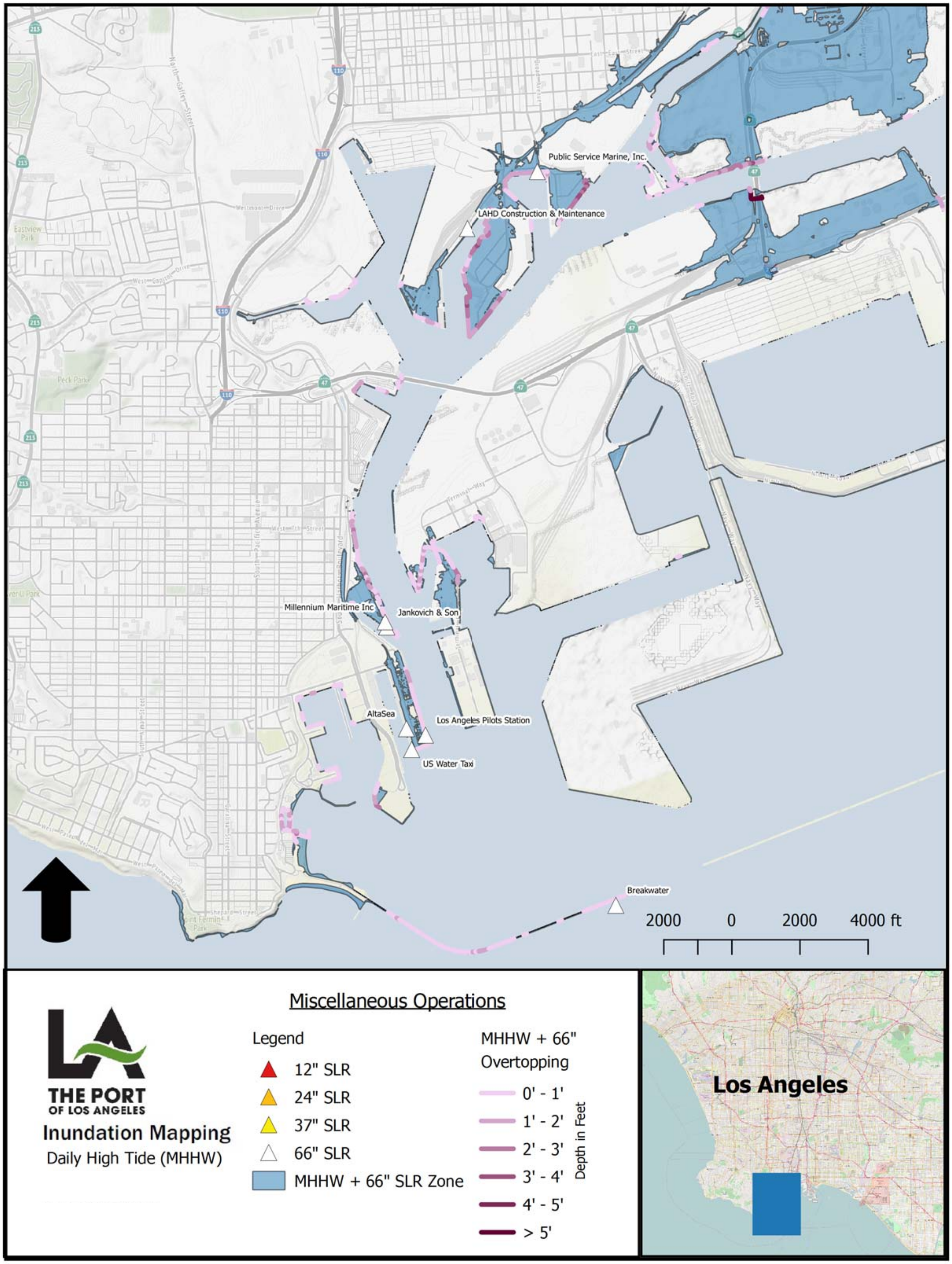
Depth in Feet
Los Angeles


Public Service Marine, Inc.
LAHD Construction & Maintenance
Millennium Maritime Inc
Jankovich & Son
AltaSea
Los Angeles Pilots Station
US Water Taxi
Breakwater
2000 0 2000 4000 ft
Miscellaneous Operations
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66" Overtopping
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3' - 4'
4' - 5'
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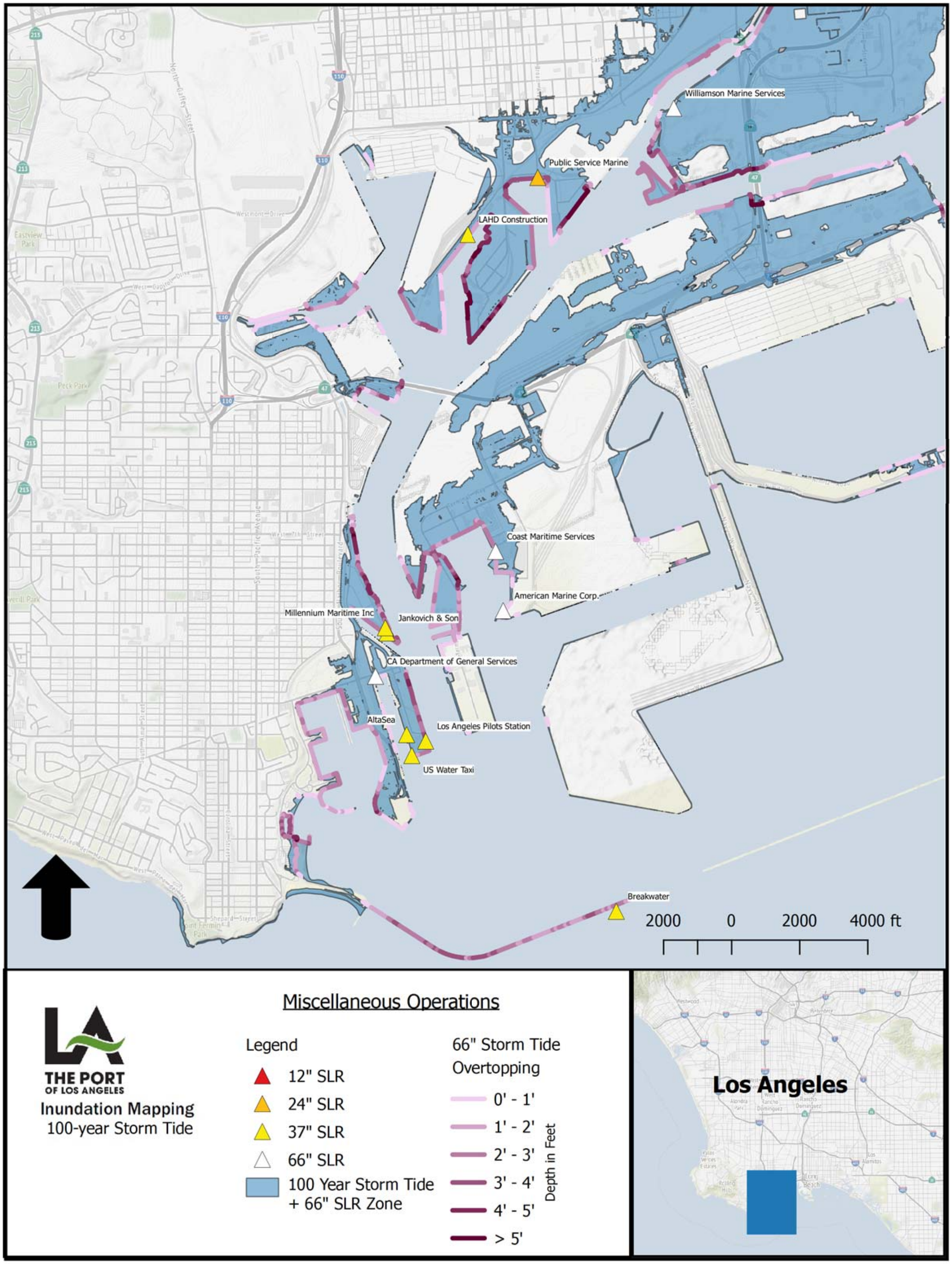
Depth in Feet
Los Angeles


Williamson Marine Services
Public Service Marine
LAHD Construction
Coast Maritime Services
American Marine Corp.
Millennium Maritime Inc
Jankovich & Son
CA Department of General Services
AltaSea
Los Angeles Pilots Station
US Water Taxi
Breakwater
2000 0 2000 4000 ft
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Miscellaneous Operations
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
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2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles

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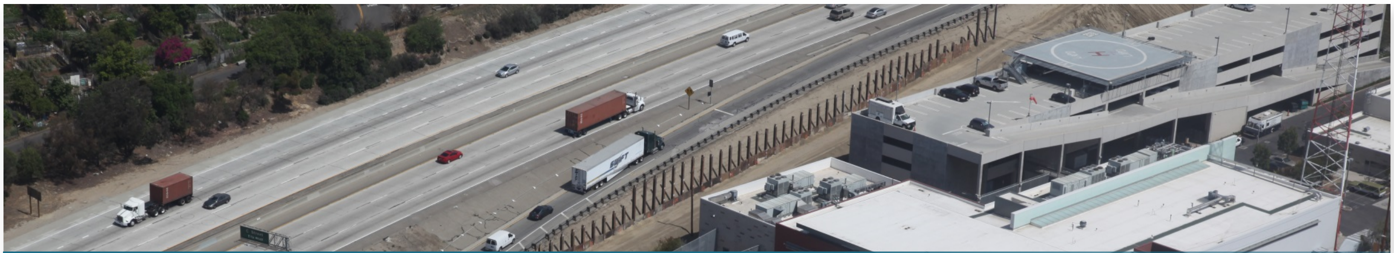


Critical Facilities SLR Vulnerability Profile

Asset Overview

Critical facilities are those that are considered high risk to even a slight chance of exposure to flooding or inundation. Many of these facilities (fire stations, police stations, Pilots Station, and tugboat fleets) are necessary for ensuring life safety.

The critical facilities category also includes assets considered necessary for business continuity including administration, operation and maintenance facilities, and a federal correctional institution.

Providing the only freight access to/from Catalina Island, Avalon Freight Services is also considered a critical facility. The livelihood of island residents and businesses relies on regular shipments of goods.

Several substations and transformers providing power to many of the berths and facilities are located within the boundary of the Port. The functionality of this electrical infrastructure is critical to ensure Port operations.

There are several pump stations that are considered to be critical facilities because they serve an important function of pumping excess stormwater from low-lying areas. This is essential to ensure certain areas of the Port remain operable following storm events.

Designated critical facilities should be provided a higher level of protection so they can continue to function and provide services during a flood event (or shortly afterward).

Exposure

The table summarizes when critical facility assets first become inundated. Maps illustrating the exposure to sea level rise (SLR) and storm tide (for both critical facilities and pump stations) are provided at the end of the profile. The exposure maps also include an overtopping layer, illustrating the lowest lying points along the shoreline.

Critical facilities first experience temporary flooding by the 24 inch SLR and storm tide scenario. Permanent inundation first occurs by the 66 inch SLR scenario.

Table: Timing of Asset Exposure

(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	**Assets Exposed**
12 inch (2030)	• None • None
24 inch (2050)	• None • Millennium Maritime Inc. • SD Pump Station
37 inch (2100 mid-range)	• None • Fire Station #110 • Los Angeles Pilots Station • Avalon Freight Services • Alta Sea • E7- Transformer - 120/240V 1 φ 600A (Port Pilots Berth) • E12-Transformer - C&M 480/277V 800A • SS Pumping Plant #681 • SS Pumping Plant #666
66 inch (2100 high-range)	• Fire Station #110 • Los Angeles Pilots Station • Millennium Maritime Inc. • Avalon Freight Services • Alta Sea • Fire Station #111 • Fire Station #49 • American Marine Corp. • E7- Transformer - 120/240V 1 φ 600A (Port Pilots Berth) • E12- Transformer - C&M 480/277V 800A • SD Pump Station • SD Pump Plant #681 • SS Pump Plant #666 • E1- Transformer - 480/277V 3 φ 600A (Berth 38) • E2- Transformer - 480/277V 3 φ 2000A (Berth 40) • E3- Transformer - 480/277V 3 φ 600A (Berth 41A) • E4- Transformer - 480/277V 3 φ 800A (Berth 41)

Continued: 66 inch (2100 high-range)	• E5- Transformer - 480/277V 3 φ 800A (Berth 42) • E6- Transformer - 480/277V 3 φ 1200A (Berth 43) • E8- 34.5kV Substation (servicing Berth 91-93 AMP) • E9- 34.5kV & 4.16kV Substations (servicing Berth 100-102) • E10- Transformer - 240V 3 φ 350A (servicing Berth 116-120) • E11- 35kV Substation (Berth 142-147 ICFT) • E13- 4.16 kV Substation (servicing Berth 181-174) • E14- 34.5kV & 4.16kV Substations (servicing Berth 212-222) • E15- 34.5kV & 4.16kV Substations (servicing Berth 226-230) • E16- Transformer - 4800V servicing Berth 228-232 lighting & pump station • SS Pump Plant #680 • SS Pump Plant (Evergreen)

Sensitivity

Critical facilities have a high sensitivity to flooding. All of the facilities rely on electrical equipment and many assets are reliant on substations and transformers located throughout the Port. Electrical equipment may be damaged if exposed, even temporarily, to flooding.

Several critical facilities have been identified as aged buildings in poor condition that would be more likely damaged by flood exposure. Aged assets include: all pump stations and pump plants, and several vessel support services (Millennium Maritime Inc., American Marine Corp., Pilots Station).

Adaptive Capacity

Critical facilities typically have a low adaptive capacity. The facilities are not easily modified by elevating the structure. Many critical facilities depend on their existing location to operate, but some facilities may have the ability to be relocated outside of the flood vulnerability zone.

Critical facilities also tend to lack redundancy, another form of measuring adaptive capacity (meaning there is only one facility and it would be challenging to function at the same capacity without the asset). Many of the public safety assets are isolated at the far end of terminals with no alternative access.

While pump stations may have a backup generator on site, it is often also located at flood elevation.

Consequence

The Port is dependent on its critical facilities to maintain safe and functional operations. If exposed to flooding, the impact to individual critical facility assets may have significant economic and life safety consequences.

Any facilities relying on a power supply from local transformers or substations may experience electrical disruptions or failure if these electrical-source assets are exposed to flooding. Several substations and transformers are critical for operations. These include: Transformer - 120/240V 1 φ 600A (servicing Port Pilots Berth); a 35kV Substation (servicing Intermodal Container Transfer Facility); Transformer - C&M 480/277V 800A (servicing LAHD Construction & Maintenance); and a 4.16 kV Substation (servicing Pasha Terminal).

Several pump stations (such as SS Pump Plan #666 and SS Pump Plant on Evergreen) service terminals storing cargo. Loss of service at pump stations may cause flood damage to nearby cargo and cause operational disruption if terminals flood and/or remain flooded for an extended period of time.

The Pilots Station ensures the safe flow of ship traffic to and from the Terminals. If flooded, the loss of this asset would greatly impact operations at the Port. Buildings may need repair or replacement due to flood damage, impacting short term cash flow, business operations and/or administrative operations.

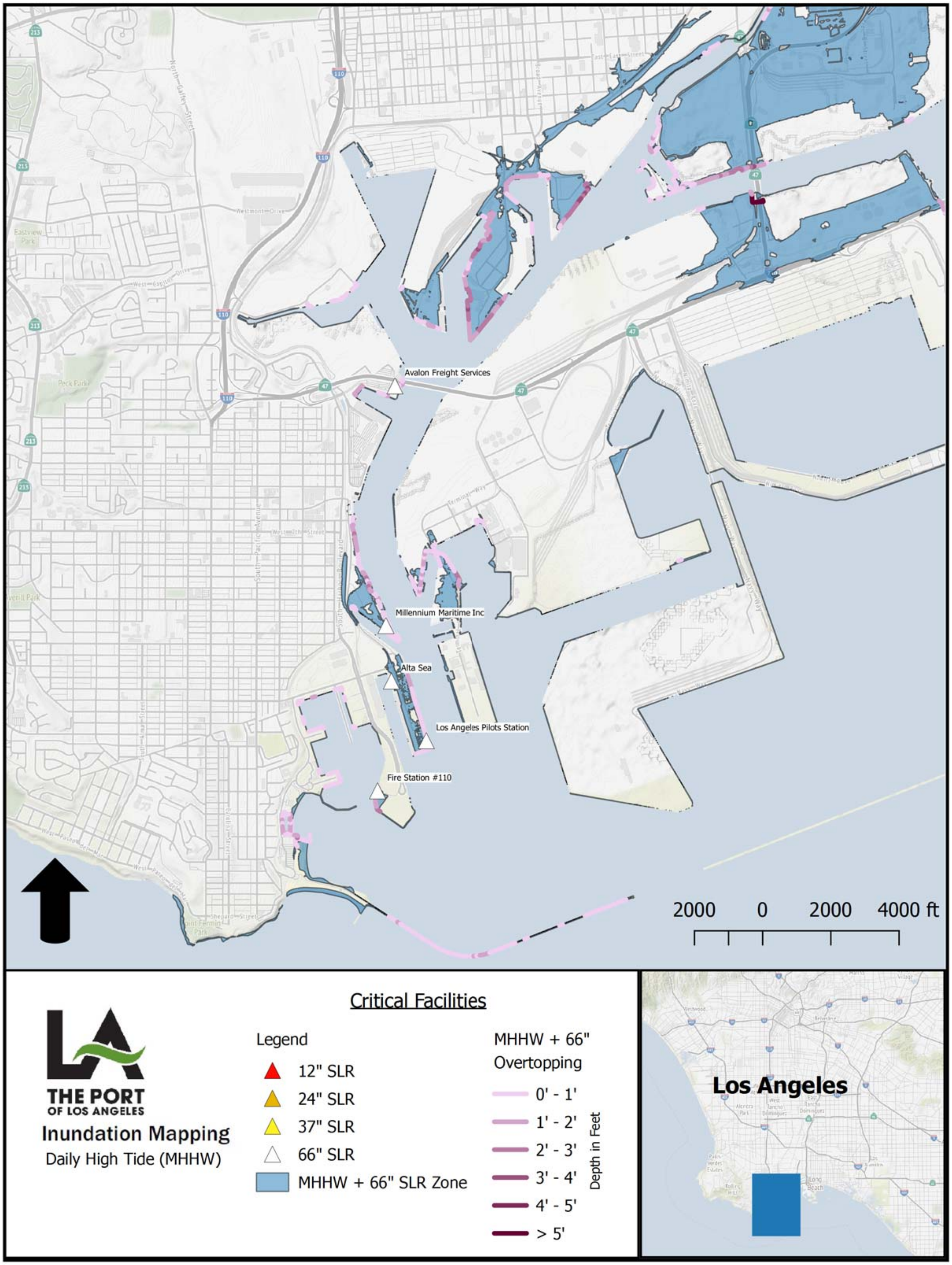
Social consequences may be widespread if critical facilities are exposed to flooding. Many of the facilities are public safety assets (fire stations), which may jeopardize access to at-risk communities and infrastructure.

If pump stations fail, environmental consequences may include exposed cargo, which could contain hazardous materials that would be introduced to Port waters.

The Port is a major artery of imports and exports for the nation. Beyond damage to individual Port assets, exposure of critical facilities may disrupt operations, which will have regional and global consequences.

Summary

- Public safety and Port operations could be severely compromised if critical assets are exposed to temporary flooding and/or permanent inundation.
- Millennium Maritime Inc. and the SD Pump Station are the first critical assets to experience temporary flooding (by the 24 inch SLR and storm tide scenario).
- There are several critical assets that will be temporarily flooded by the 37 inch SLR and storm tide scenario including: Fire Station #110, the Pilots Station, SS Pump Plant #681, SS Pump Plant #666, SD Pump Station, Millennium Maritime Inc., E7 Transformer - 120/240V 1 φ 600A, and E12 Transformer - C&M 480/277V 800A.
- The Port operation would be greatly impacted without the Pilots Station and therefore additional protection measures should be established to ensure its access and functionality.
- Permanent inundation of critical assets does not occur until the 66 inch SLR scenario. Based on the lifespan of a building (approximately 50 years), many of the exposed buildings may receive renovations or have changed ownership. Any modifications to the buildings should account for projected increases in water elevations.



Avalon Freight Services
Millennium Maritime Inc
Alta Sea
Los Angeles Pilots Station
Fire Station #110
2000 0 2000 4000 ft
Critical Facilities
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66" Overtopping
0' - 1'
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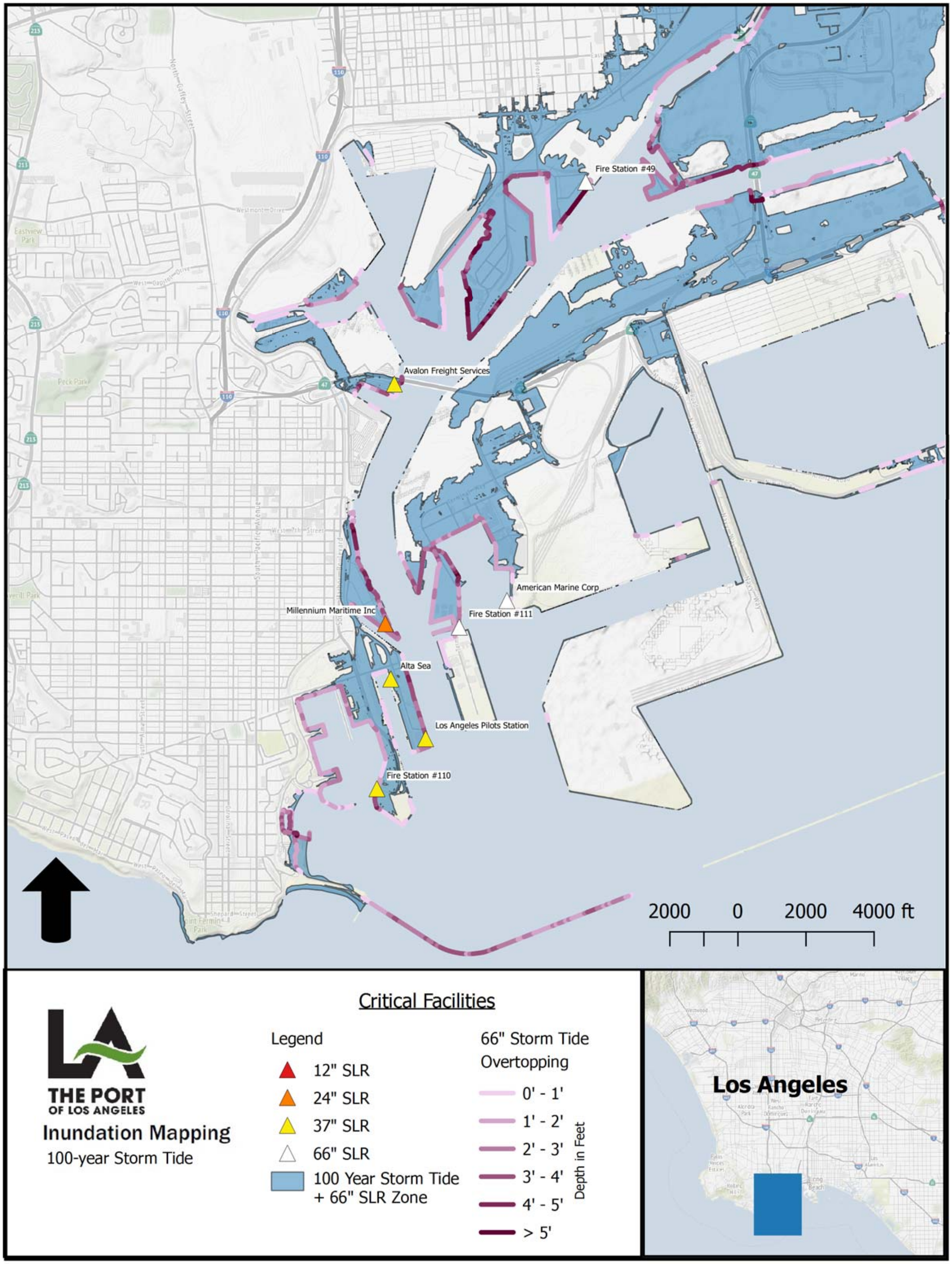
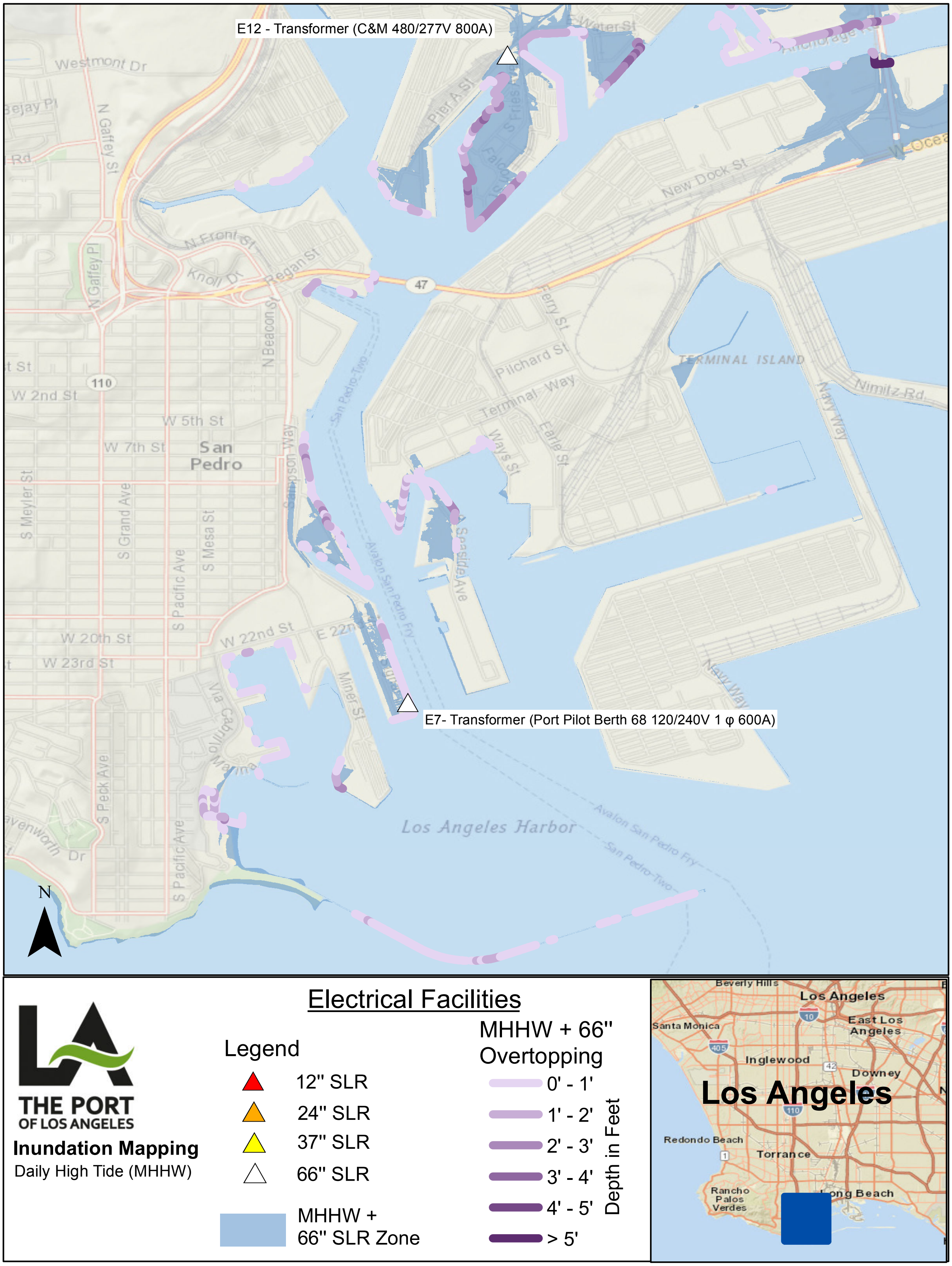
Depth in Feet
Los Angeles



Fire Station #49
Avalon Freight Services
American Marine Corp
Fire Station #111
Millennium Maritime Inc
Alta Sea
Los Angeles Pilots Station
Fire Station #110
2000 0 2000 4000 ft
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Critical Facilities
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles

FINAL DRAFT


E12 - Transformer (C&M 480/277V 800A)
E7- Transformer (Port Pilot Berth 68 120/240V 1 φ 600A)
Los Angeles Harbor
San Pedro
TERMINAL ISLAND
N
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Electrical Facilities
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66" Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
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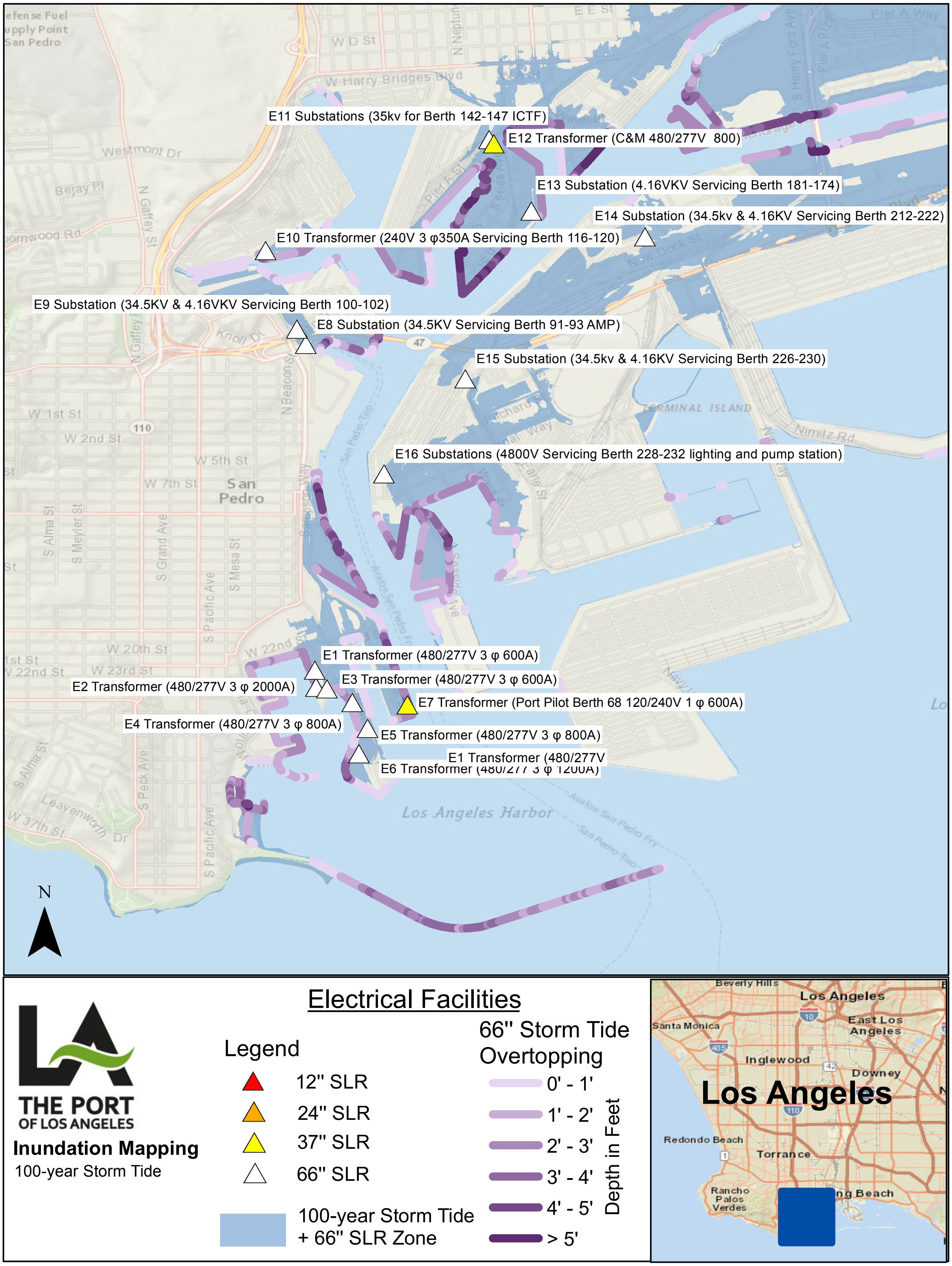
> 5'
Depth in Feet
Los Angeles
Santa Monica
Inglewood
Downey
Redondo Beach
Torrance
Rancho Palos Verdes
Long Beach


E11 Substations (35kv for Berth 142-147 ICTF)
E12 Transformer (C&M 480/277V 800)
E13 Substation (4.16VKV Servicing Berth 181-174)
E14 Substation (34.5kv & 4.16KV Servicing Berth 212-222)
E10 Transformer (240V 3 φ350A Servicing Berth 116-120)
E9 Substation (34.5KV & 4.16VKV Servicing Berth 100-102)
E8 Substation (34.5KV Servicing Berth 91-93 AMP)
E15 Substation (34.5kv & 4.16KV Servicing Berth 226-230)
E16 Substations (4800V Servicing Berth 228-232 lighting and pump station)
E1 Transformer (480/277V 3 φ 600A)
E3 Transformer (480/277V 3 φ 600A)
E2 Transformer (480/277V 3 φ 2000A)
E7 Transformer (Port Pilot Berth 68 120/240V 1 φ 600A)
E4 Transformer (480/277V 3 φ 800A)
E5 Transformer (480/277V 3 φ 800A)
E1 Transformer (480/277V
E6 Transformer (480/277 3 φ 1200A)
San Pedro
Los Angeles Harbor
Terminal Island
N
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Electrical Facilities
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100-year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
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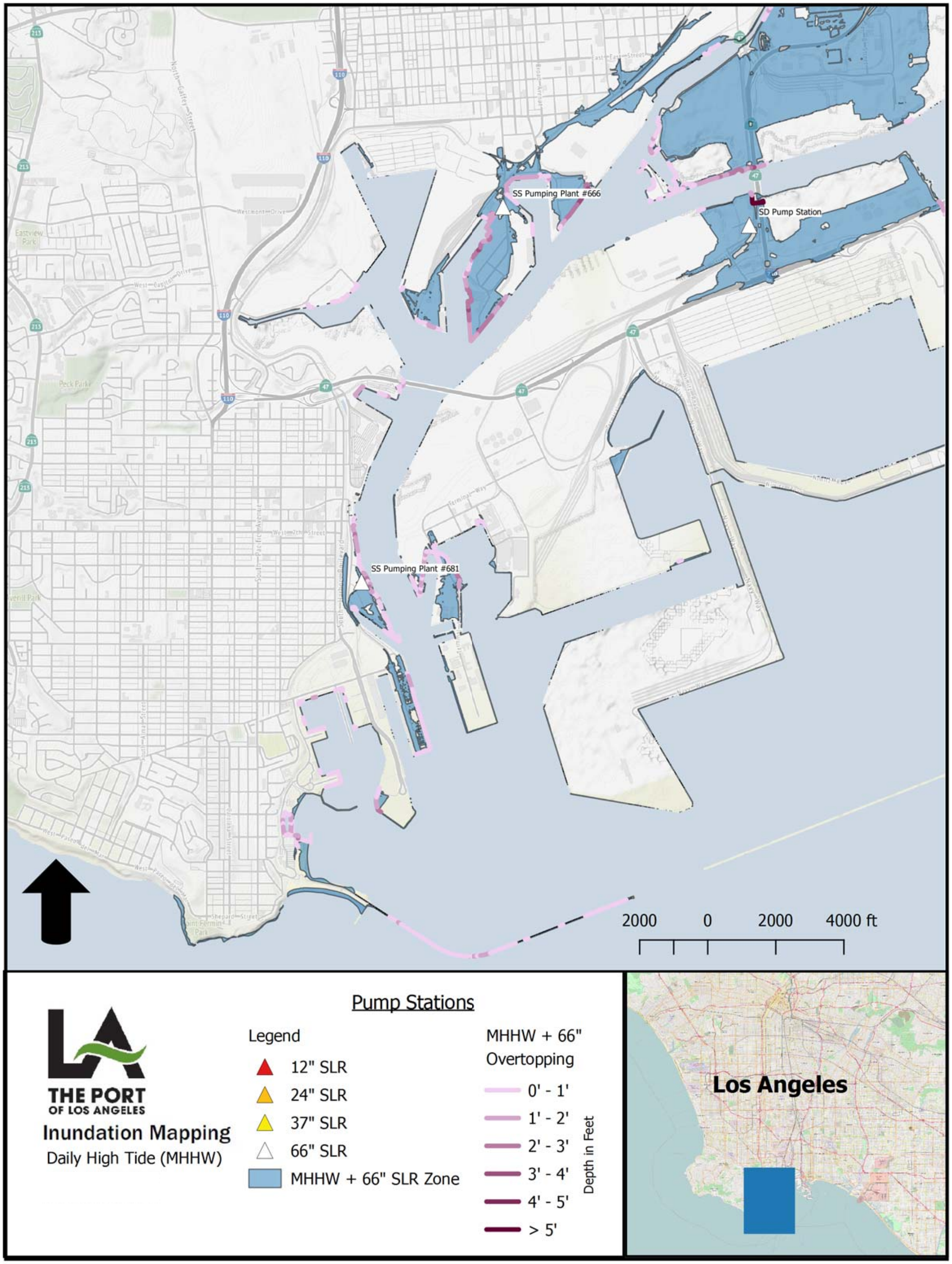
Depth in Feet
Los Angeles
Beverly Hills
Santa Monica
East Los Angeles
Inglewood
Downey
Redondo Beach
Torrance
Rancho Palos Verdes


SS Pumping Plant #666
SD Pump Station
SS Pumping Plant #681
2000
0
2000
4000 ft
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Pump Stations
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66"
Overtopping
0' - 1'
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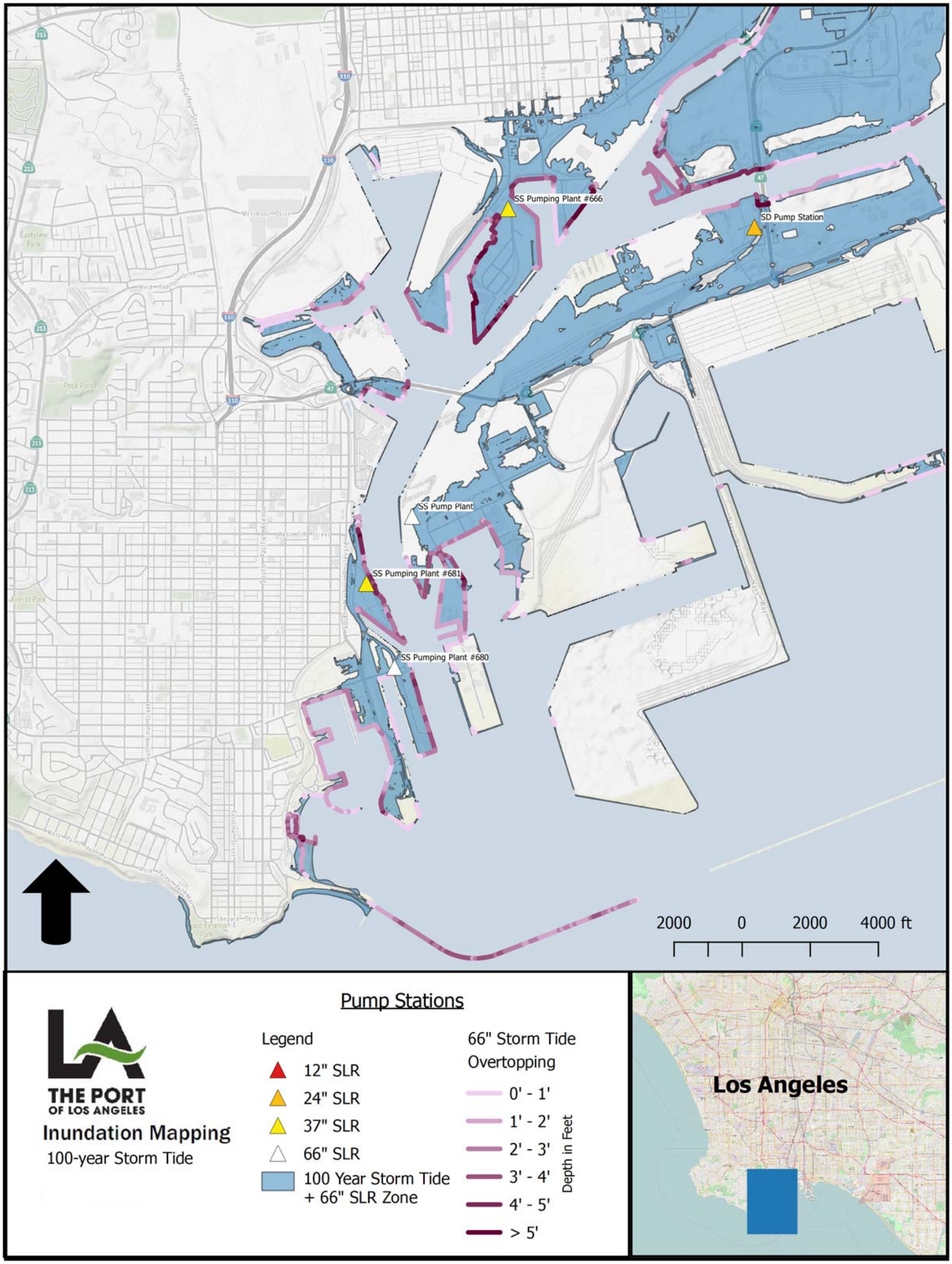
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles


SS Pumping Plant #666
SD Pump Station
SS Pump Plant
SS Pumping Plant #681
SS Pumping Plant #680
2000 0 2000 4000 ft
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Pump Stations
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
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Depth in Feet
Los Angeles

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Transportation Network SLR Vulnerability Profile

Rail Network

Asset Overview

Home to the nation's largest on-dock rail assets, the Port of Los Angeles (POLA) provides the highest frequency of intermodal access to 14 major freight hubs across the United States. This extensive rail network is key for moving cargo from each terminal into the regional network. Most terminals include rail access for liquid and containerized cargo and up to 35% of all containerized cargo is transported using the rail network.

The rail network relies on diesel locomotives for power. Rail construction consists of steel rails on mostly concrete ties resting on ballast and sub-ballast. The rails are typically embedded in pavement inside the terminals, providing a very sturdy system to protect the roadbed from storm water infiltration and degradation. Some railyards feature power switches, power derails, and signalization, while others are manually operated.

The rail network is connected and shared with the rail lines at the adjacent Port of Long Beach (POLB). Together they form the San Pedro Bay Ports Rail network and function together as a system. Any inundation and resulting impacts to the rail network within POLB may have an impact on rail operations at POLA, and vice versa.

The rail network includes two rail bridge crossings: Badger Avenue Bridge and the Pier 400 Corridor Bridge.

Exposure

The rail network is not exposed until the 66 inch sea level rise (SLR) scenario, where exposure is limited to two main areas. The first area is the access into Berth 200 along with the lead tracks west of Berth 200. If inundated, loss of these tracks could have significant impact on overall rail productivity. The second area is the SA Recycling on the north side of Terminal Island. During storm tide events, the biggest concern is the northerly area from the TraPac leads and Pasha to Berth 200.

Overtopping from Berths 161 to 199 is the primary source of flooding for the TraPac lead tracks and other leads west of Berth 200.

The Badger Avenue Bridge maintains sufficient clearance during the evaluated SLR scenarios, and navigation does not appear to be impacted (since a low fixed bridge is constructed adjacent to the Badger Avenue Bridge). The Pier 400 Corridor Bridge may be impacted by waves and uplift forces starting at 24" SLR and may experience periods of submergence starting at 66" SLR.

The table summarizes when the rail assets first become inundated. Maps illustrating the exposure to SLR and storm tide are provided at the end of the profile.

The exposure maps include an overtopping layer which illustrates the lowest lying points along the shoreline.

Table: Timing of Asset Exposure
(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	**Assets Exposed**
12 inch (2030)	• None • Vopak (Canal Street)
24 inch (2050)	• None • Pier 400 Corridor Rail Bridge (structure exposed) • Pasha (Berths 174-182) • SA Recycling (Berths 210-211)
37 inch (2100 mid-range)	• None • TraPac Lead Tracks (Berths 142-147) • Rear Berth 200 (Northerly and Lead Tracks) • Wilmington Lead • Gaffney St Lead • Potential Industries Spur

66 inch (2100 high-range)	• TraPac Lead Tracks (Berths 142-147) • Rear Berth 200 (Northerly and Lead Tracks) • SA Recycling (Berths 210-211) • Wilmington Lead • Potential Industries Spur • Vopak • Pier 400 Corridor Rail Bridge (submergence) • Pasha (Berths 174-182) • Maersk Lead and Storage Tracks (Pier 400) • TICTF • WWL Vehicle Services (Berths 195-199) • CP Mole / CP LAXT

Sensitivity

Rail infrastructure materials have a moderate sensitivity to temporary flooding, especially when embedded in pavement. If tracks are submerged, train movement will stop but should be able to resume quickly after waters recede. Rail infrastructure will be inoperable under permanent inundation.

Power switches, derails, and signals may be damaged by flooding events. Repair time for these is not expected to be significant.

Aged rail infrastructure may have degraded track structure with poor drainage capacity, possibly making it more susceptible to damage from temporary flooding.

Rail equipment (railcars and locomotives) has the ability to be moved away from flood zones and will not likely be impacted by inundation.

Rail bridge structures have a moderate sensitivity to temporary flooding. The exposed location of the Pier 400 Corridor Bridge exposes the structure to potential additional wave and uplift forces, and more significant wave overtopping due to SLR.

Adaptive Capacity

Rail networks have a moderate to low adaptive capacity. Track mainlines and lead tracks can be elevated above projected flood elevations; however, this is typically an extensive effort due to adjacent terminal connections and roadways, pavement grades, and other related necessary improvements for both paved and non-paved infrastructure. Raising tracks in either case would likely interrupt daily operations for an extended period of time.

While there is very little rail infrastructure redundancy at specific locations, the system has redundancy through shipping alliances, and their ability to divert rail destined cargo to operating terminals.

Consequence

Depending on the section of rail exposed to flooding, large portions of POLA and POLB could be disrupted.

Without a means to transport cargo via rail, the Port may face economic losses due to delayed cargo shipments, or terminal shutdown. Losses will be reduced where cargo movement can be diverted to the road network.

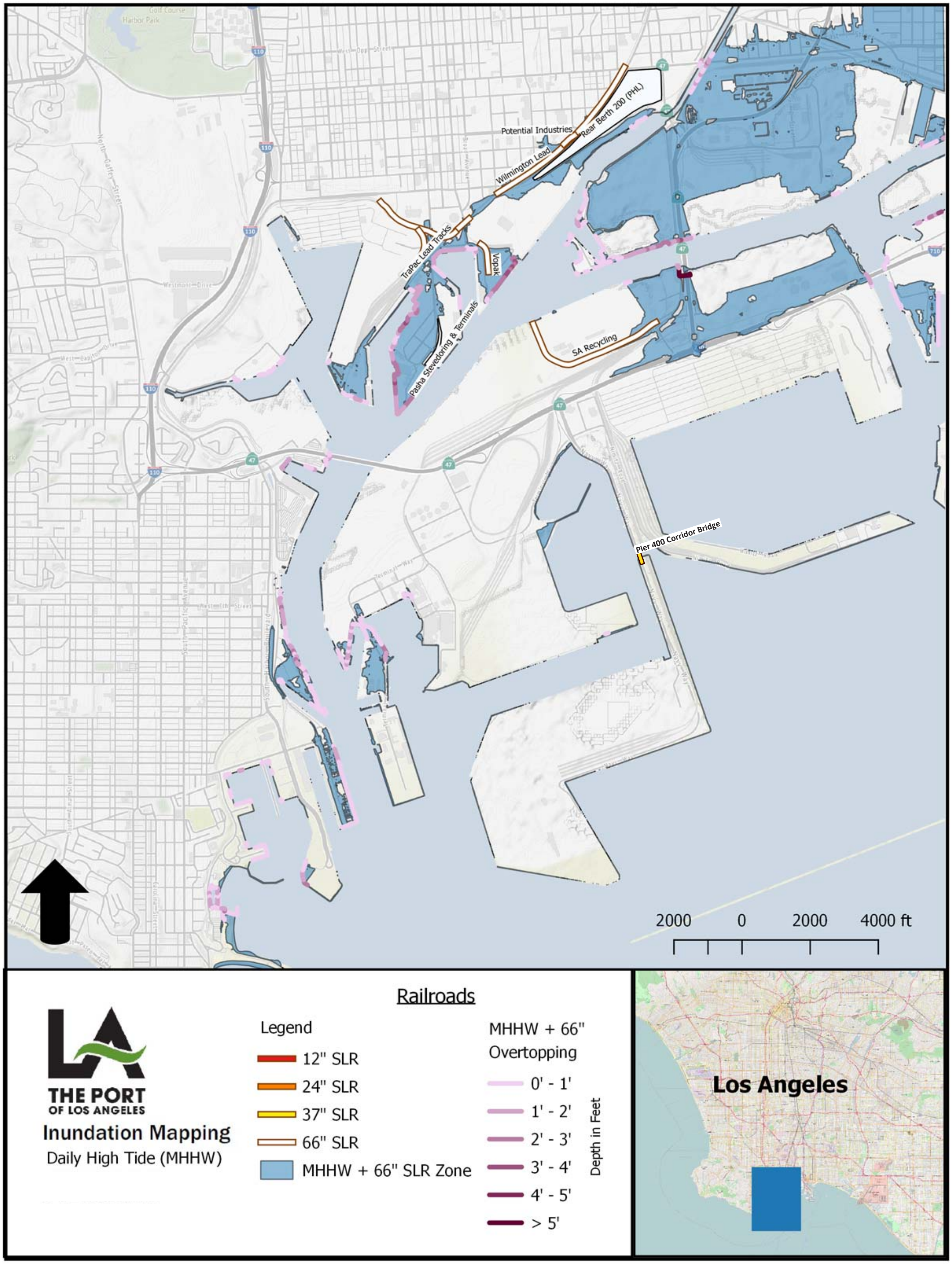
Reduced or stoppage of cargo movement could also have social consequences by affecting hourly jobs of Port employees and those involved in regional shipping.

Oil runoff from tracks may pose an environmental consequence to the Port waters.

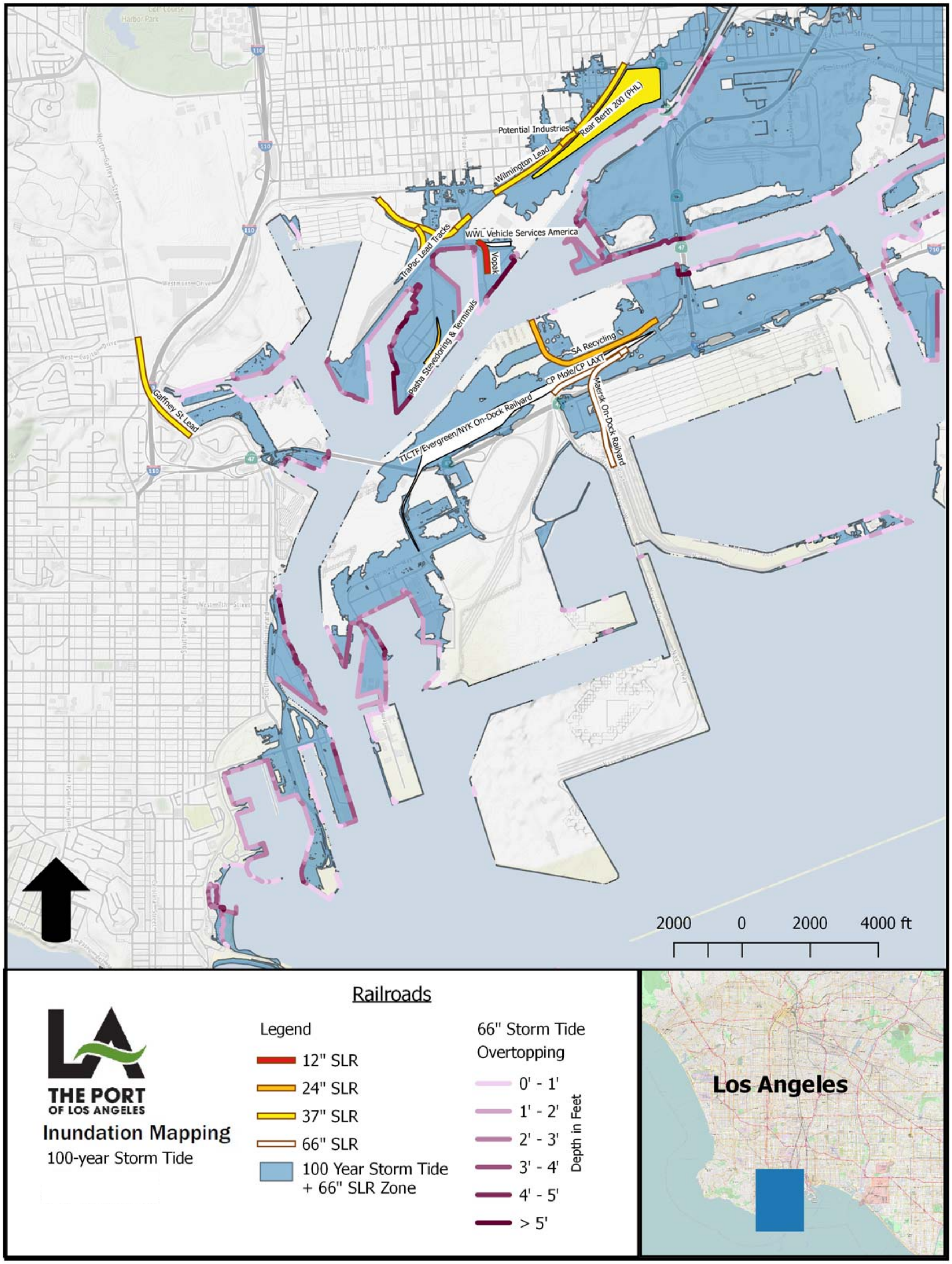
The Pier 400 Corridor Bridge structure could be damaged by flooding, causing temporary or permanent shutdown of rail traffic to Pier 400.

Summary

- Vopak is the most vulnerable based on 12 inch SLR plus storm tide, followed by Pasha and SA Recycling at 24 inch SLR plus storm tide.
- Berth 200 and West Basin rail access become temporarily inundated by the 37 inch SLR plus storm tide scenario, with all of TICTF, CP Mole, and the access into Piers 300 and 400 inundated by the 66 inch SLR plus storm tide scenario.
- No rail facilities are permanently inundated until the 66 inch SLR scenario.
- By the 66 inch SLR scenario, lead tracks into and out of Berths 200 will be permanently inundated, which will have a significant impact on many surrounding rail terminals. SA Recycling, West Basin rail access, Pasha, and the TraPac lead tracks also become permanently inundated by the 66 inch SLR scenario.
- The Pier 400 Corridor Bridge may be impacted by waves and uplift forces starting at 24" SLR and may experience periods of submergence starting at 66" SLR.



Potential Industries
Rear Berth 200 (PHL)
Wilmington Lead
TraPac Lead Tracks
Vopak
Pasha Stevedoring & Terminals
SA Recycling
Pier 400 Corridor Bridge
2000 0 2000 4000 ft
Railroads
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66" Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles



Potential Industries
Rear Berth 200 (PHL)
Wilmington Lead
TraPac Lead Tracks
WWL Vehicle Services America
Vopak
Pasha Stevedoring & Terminals
SA Recycling
CP Mole/CP LAXT
Maersk On-Dock Railyard
TICTF/Evergreen/NYK On-Dock Railyard
Gaffney St Lead
2000 0 2000 4000 ft
Railroads
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
0' - 1'
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2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles

Road Network

Asset Overview

The road network includes freeways, bridges, primary/secondary/tertiary roads, traffic signals, and street lights that have a mixture of ownership amongst POLA, City of L.A. BOE, and Caltrans.

Primary roads consist of critical business and/or emergency access routes to Port assets or public safety. Secondary roads provide alternative access routes to assets, while tertiary roads are smaller and provide minor access to assets.

Roads are mostly asphalt construction with many of the newer roadways having curbs, gutters, and drainage systems that prolong their design life.

The main vehicle types utilizing the roadway network are container trucks and standard vehicles (cars and light trucks). Roads enable trucks to collect and transport roughly 65%-80% of containerized cargo to/from the terminals, provide the public access waterfront developments, and allow port personnel to access critical port and community facilities that ensure public safety in emergency situations.

The road network includes 4 bridges: The Vincent Thomas Bridge that crosses the main channel; Pier 400 Corridor road Bridge; and two road bridges crossing the Los Angeles County Flood Control Channel (LACFCC).

Exposure

There are a few areas of the roadway infrastructure that are exposed to permanent inundation from SLR. Water Street and the area serving the marinas near Pier A West are of primary concern, followed by the Ports O' Call and Terminal Island areas.

Nagoya Way and Water Street are currently planned to be redeveloped, offering a potential opportunity to address vulnerability to various flooding scenarios. Overtopping from Berths 161 to 199, and 200X to 205D causes much of the inundation around Water Street/Fries and the northeasterly marinas, respectively. Similarly, overtopping from Berths 74 to 85 causes much of the inundation for roadways around the Ports O' Call.

The Pier 400 Corridor Bridge and the LACFCC Bridge structures may be impacted by high water levels reaching the underside of the structures starting at 24" SLR and may experience periods of submergence starting at 66" SLR.

The LACFCC Bridge structures may also be impacted by an increase in the riverine flood profile in response to SLR (not evaluated in this assessment).

The Vincent Thomas Bridge will experience a decrease in vessel clearance height as a result of SLR.

The table summarizes when the rail assets first become inundated. Maps illustrating the exposure to SLR and storm tide are provided at the end of the profile. The exposure maps also include an overtopping layer which illustrates the lowest lying points along the shoreline.

Table: Timing of Asset Exposure

(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	Assets Exposed
12 inch (2030)	• None • Vincent Thomas Bridge (navigation) • Fries/Falcon /Hermosa /La Paloma /San Clemente (~Berths 161-169) • Henry Ford Ave (~marinas) • Anaheim St (E of Dom. Channel) • Yacht Street (~Berth 194, FS#49)
24 inch (2050)	• None • Pier 400 Corridor Rd Bridge (structure exposed) • LACFCC Bridges (structure exposed) • Anchorage Rd • Fries (~Berth 174-181) • New Dock St (~Berths 206-215) • Pier A Street • Canal St/ Water

Transportation Network SLR Vulnerability Profile

37 inch (2100 mid-range)	• Falcon/Fries/Hermosa/La Paloma (~Berths 161-169) • Henry Ford Ave (to multiple marinas) • Anaheim St (E of Dom. Channel) • 22nd St/Sampson(S)/Signal/ Adm. Higbee (~Berths 57-72) • Sampson(N)/Nagoya Way (Ports O' Call) • Shore Rd (marinas) • S Seaside Ave (~Berths 237-261) • Ways / Tuna St • Alameda St • Avalon
66 inch (2100 high-range)	• Pier A St/Water/Fries/ Avalon/Canal/Yacht (~Berths 148-194) • Nagoya Way (Ports O' Call) • 22nd St/Sampson(S)/Signal/ Adm. Higbee (~Berths 57-72) • Anchorage/Shore (~marinas) • S Seaside Ave (~Berths 237-261) • Ways St • New Dock St • Alameda St • LACFCC Bridges (submergence) • Cannery/Barracuda/ Marina/Earle/Terminal Way/Ferry/Pilchard/ Sardine/Eldridge/ S Seaside (~Berths 226-236, 262-301) • Henry Ford(N)/Anaheim St • Miner St (~Berths 37-56) • Sampson (~Berths 80-85) • Reeves Ave • Regan/Swinford St • Harry Bridges • A Street • Peninsula Rd • Shoshonen Rd

Sensitivity

Road materials are not very sensitive to damage as a result of temporary flooding. If roads are submerged by a depth of more than a few inches, vehicle movement will stop (depending on vehicle size), but should be able to resume quickly after waters have receded. It should be noted that high velocity flows of floodwater may cause erosion of the road foundation.

Repeated temporary inundation may start to cause roadway and bridge deterioration. Aged roadways that have a low Pavement Condition Index (PCI) may be particularly susceptible to substructure damage due to water infiltration. Exposure of reinforcing steel in bridge structures would lead to increased rate of corrosion.

The Port has an efficient pavement management program in place for the roadway network and traffic signals. Therefore, flood-related disruptions that could be exacerbated by pavement deterioration are expected to be addressed prior to the event.

Once permanently inundated, roadways will become inoperable.

Road bridge structures have a moderate sensitivity to temporary flooding. The exposed location of the Pier 400 Corridor Bridge exposes the structure to potential additional wave and uplift forces, and more significant wave overtopping due to SLR.

Adaptive Capacity

Road networks typically have a high adaptive capacity due to the presence of alternative routes (redundancy) and the relative ease of reconstruction. However, raising roadways above the flood elevation, or relocating roadways, is anticipated to have a high cost due to the extensive ancillary reconstruction required for connected facilities.

Areas of high redundancy include 22nd Street and Fish Harbor. However, by end-of-century, many alternative routes are also expected to be inundated. Areas where alternative routes are also inundated include: Ports O' Call area, South Seaside Ave, and Mormon Island roadways.

Consequence

When a portion of the road network is impacted by flooding, the effect ranges from low to severe depending on the facilities it connects and alternative viable routes.

The inundation of primary and life safety roadways (no route redundancy) will impact the flow of goods being transported from the terminal to the regional transportation network and public access.

Without a means to transport goods or provide public entrance, the Port may face economic and social impacts due to delayed cargo shipments, diversion of cargo to other terminals or Ports, and/or loss of public access. Reduced or stoppage of cargo movement may also affect jobs of Port employees and those involved in regional shipping.

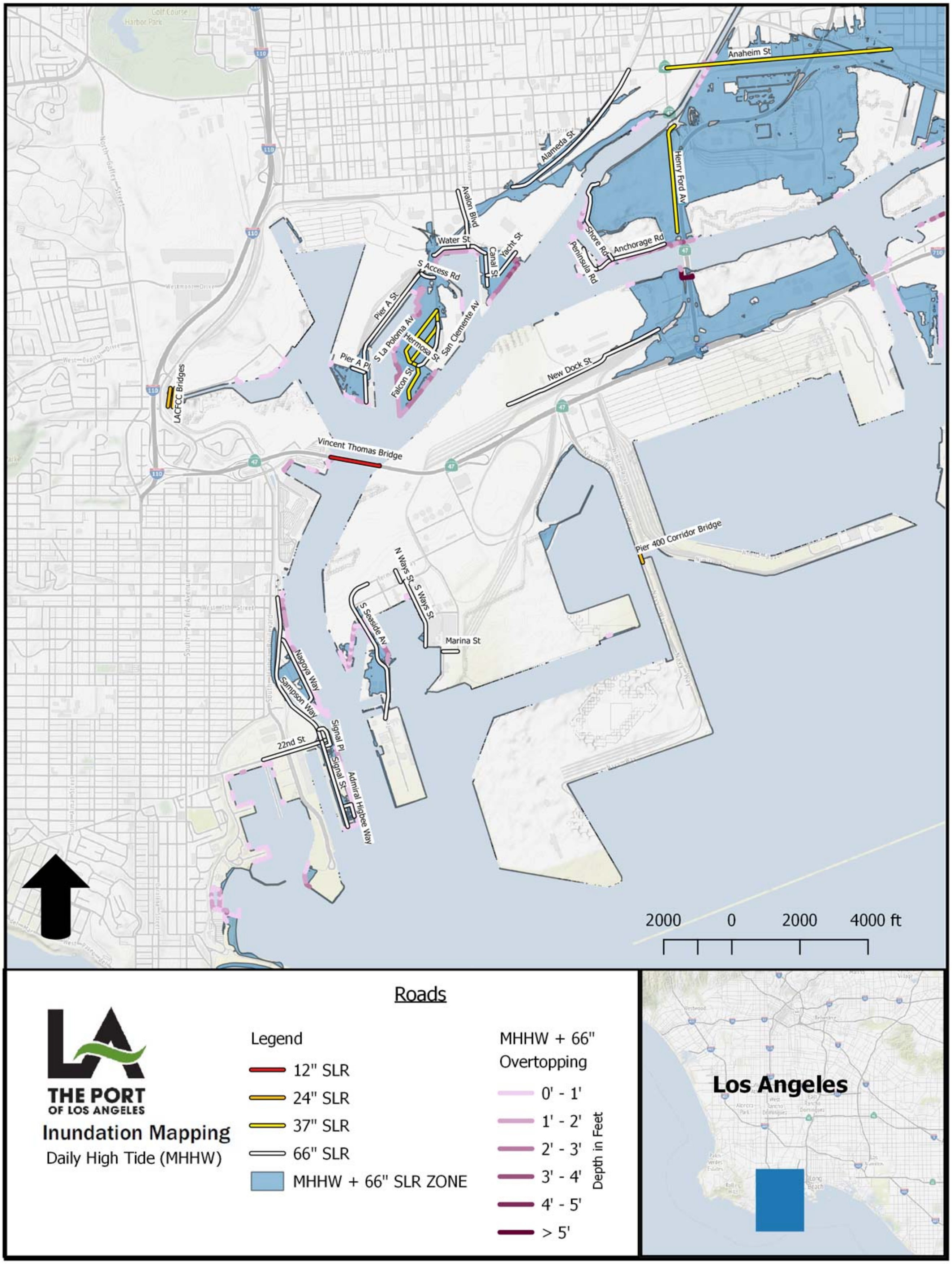
The roadway bridge structures can be damaged by flooding, causing temporary or permanent shutdown of road traffic to Pier 400 and internal terminal traffic on the west basin container terminals.

Increased operational restricted access (tide and draft) will occur for large container vessels with increased SLR over time resulting from the air draft limitations at the Vincent Thomas Bridge. The terminals in the West Basin are planned to receive New Panamax size vessels that need to pass under the Vincent Thomas Bridge. The largest vessels will already require scheduling the transit at low tide conditions, depending on loading conditions. Increased operational restricted access (tide and draft) will occur with increased SLR over time.

Oil runoff from roadways may be a potential environmental consequence.

Summary

- Storm tide events temporarily impact many roadways by the 12 inch SLR and storm tide and 24 inch SLR and storm tide scenarios. Temporary impacts for these scenarios occur mainly in the Water Street and south areas, but also along New Dock Street and Henry Ford Ave.
- Planned redevelopments in the Water Street and Ports O' Call area present opportunities to address various inundation scenarios.
- The roadways bordering the Nustar and Valero facilities are the first to become permanently inundated by the 37 inch SLR scenario. Access to several marinas via Henry Ford Avenue and a portion of Anaheim Street are also permanently affected by this scenario.
- By the 66-in SLR scenario many key access areas become permanently inundated, including: Ports O' Call, Mormon Island (Water Street and south), New Dock Street, South Seaside, and Signal Street.
- The Pier 400 Corridor Bridge and LACFCC bridges may be impacted by high water levels starting at 24" SLR and may experience periods of submergence starting at 66" SLR.
- The Vincent Thomas Bridge could experience increased operational disruptions to vessel navigation resulting from reduced bridge clearances starting at 12" SLR, particularly for large container vessels.


Anaheim St
Alameda St
Henry Ford Av
Avalon Blvd
Water St
Yacht St
Canal St
S Access Rd
Shore Rd
Anchorage Rd
Peninsula Rd
Pier A St
S La Paloma Av
Hermosa St
San Clemente Av
Pier A Pl
Falcon St
New Dock St
LACFCC Bridges
Vincent Thomas Bridge
Pier 400 Corridor Bridge
N Ways St
S Ways St
S Seaside Av
Marina St
Nagoya Way
Sampson Way
22nd St
Signal Pl
Signal St
Admiral Higbee Way
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Roads
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR ZONE
MHHW + 66" Overtopping
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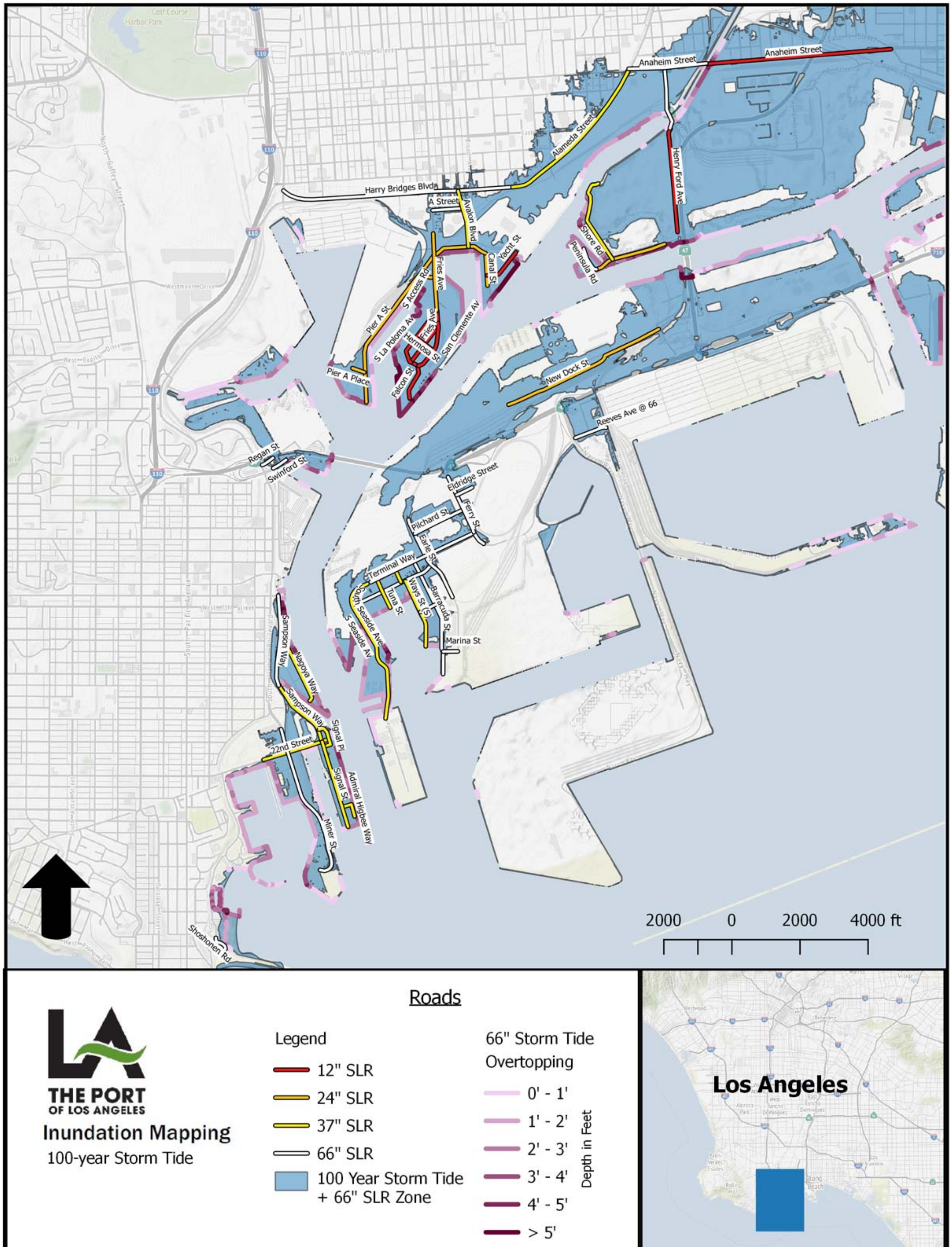
Depth in Feet
Los Angeles

FINAL DRAFT


Anaheim Street
Anaheim Street
Alameda Street
Henry Ford Ave
Harry Bridges Blvd
A Street
Avalon Blvd
Yacht St
Canal St
Shore Rd
Peninsula Rd
Fries Ave
S Access Rd
Pier A St
S La Paloma Av
Hermosa St
San Clemente Av
Falcon St
Pier A Place
New Dock St
Reeves Ave @ 66
Regan St
Swinford St
Eldridge Street
Ferry St
Pilchard St
Earle St
Terminal Way
South Seaside Ave
Tuna St
Ways St (S)
Barracuda St
Marina St
S Seaside Av
Sampson Way
Nagoya Way
Sampson Way
Signal Pl
22nd Street
Signal St
Admiral Higbee Way
Miner St
Shoshonen Rd
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Roads
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
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Depth in Feet
Los Angeles

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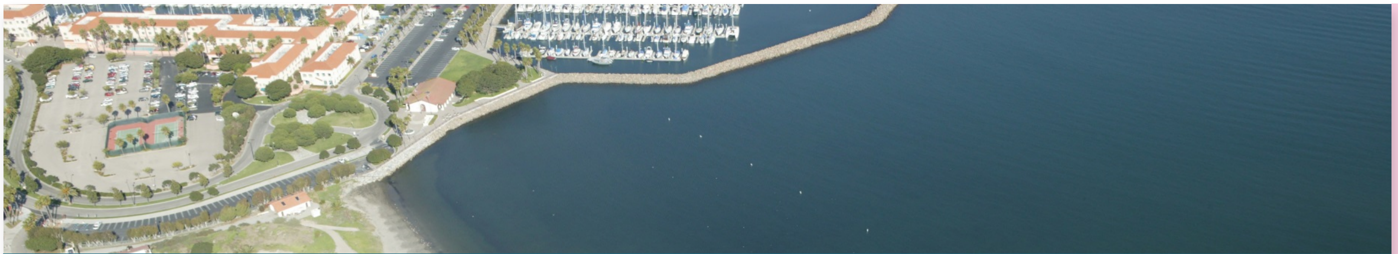


Community/Commercial Assets SLR Vulnerability Profile

Asset Overview

In addition to providing services for international trade, the Port of Los Angeles (POLA) incorporates an urban waterfront that includes visitor-serving marinas and public docks, a cruise ship terminal, parks and trails, plazas, markets and town squares, a continuous promenade that also serves walking path connections to the California Coastal Trail, bike paths and a bike sharing program, and linkages to adjacent communities. These facilities are important to the livelihood and business community of the Port, tourism, and amenities for adjacent neighborhoods with future development opportunities for both public and private investments.

Investment continues in community/commercial enhancement projects that provide additional open space and encourage public access. Recently completed projects include: the Downtown Harbor (2014) between Fire Station 112 and the L.A. Maritime Museum; Outer Harbor (2014) at Berths 45-49; Wilmington Marina Parkway (2014) just west of the Terminal Island Freeway in Wilmington; Catalina Sea and Air Terminal (2012) at Berth 92; the S.P. Waterfront Plaza at Berth 73; Cabrillo Way Marina (2011) located south of 22nd and Miner streets, and the Wilmington Waterfront Park (2011) between Harry Bridges Boulevard and C Street.

Existing and future waterfront enhancement projects include: Ports O' Call Village Redevelopment (2017); Ports O' Call Promenade (2018); Wilmington Waterfront Pedestrian Bridge (2018); and AltaSea renovations (2018).

Exposure

The table summarizes when community/commercial assets first become inundated. Maps illustrating the exposure to sea level rise (SLR) and storm tide are provided at the end of the profile. The exposure maps include an overtopping layer, illustrating the lowest lying points along the shoreline.

Several community/commercial assets are temporarily inundated by the 12 and 24 inch scenarios. The first permanently inundated community/commercial asset is the Al Larson's Marina & Boat Shop, which will occur by the 37 inch scenario.

Table: Timing of Asset Exposure

(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)

Scenario (Time-frame)	Assets Exposed
12 inch (2030)	• None • Al Larson's Marina and Boatshop • Cerritos Yacht Anchorage • Island Yacht Anchorage #1
24 inch (2050)	• None • San Pedro Marina • Banning's Landing Community Center • Lighthouse Yacht Landing • Holiday Harbor-Wilmington
37 inch (2100 mid-range)	• Al Larson's Marina & Boat Shop • California Yacht Marina • Leeward Bay Marina • Pacific Yacht Landing • Yacht Centre-Newmarks • Yacht Haven Marina • Municipal Fish Market • The Jankovich Company • Ports O'Call Village • LA Waterfront Sports Fishing & Cruises • Catalina Sea and Air Terminal • Municipal Warehouse #1 • AltaSea

66 inch (2100 high-range)	• Cerritos Yacht Anchorage • Holiday Harbor – Wilmington • Island Yacht Anchorage #1 • Leeward Bay Marina • Lighthouse Yacht Landing • Pacific Yacht Landing • San Pedro Marina • Municipal Fish Market • The Jankovich Company • Ports O'Call Village • LA Waterfront Sport Fishing and Cruises • Catalina Sea and Air Terminal • Bannings Landing Community Center • Municipal Warehouse #1 • Alta Sea • Cabrillo Beach Yacht Club • Cabrillo Way Marina • California Yacht Marina • LA Yacht Club • Holiday Harbor – Cabrillo Marina • Island Yacht Anchorage #2 • Cabrillo Marine Aquarium • 22nd Street Landing Restaurant & Sportfish • Watchorn Basin • Los Angeles Maritime Museum • Fish Harbor • Island Express

Sensitivity

Community/commercial assets have a high sensitivity to flooding, as many are buildings with electrical components that may be damaged if exposed to water.

Most of the community/commercial assets have been identified as aged and may be in poor condition, with the exception of the Cabrillo Way Marina, Island Yacht Anchorage #2, Cabrillo Marine Aquarium, Watchorn Basin, LA Maritime Museum, Island Express, Catalina Sea and Air Terminal, Banning's Landing Community Center, and AltaSea. If exposed to flooding, aged assets may experience worse damage.

Some community assets consist of marina access areas and parking lots, which are less sensitive to SLR exposure than a building, as when floodwaters subside they are likely to be functional without significant damage.

Adaptive Capacity

Community assets have a low adaptive capacity. Due to the waterfront appeal, most community/commercial assets are located along the water's edge without alternate routes of access available. The facilities also cannot be easily elevated or relocated outside of the flood exposure zone.

Consequence

If community/commercial assets are exposed to temporary flooding, many public facilities may experience damage or a loss of operations until repaired. Even if temporary, business closures due to flooding cause economic impacts for owners, buildings may also require renovation or complete replacement due to damages. If assets are exposed to permanent inundation, they may become inoperable, causing business closures.

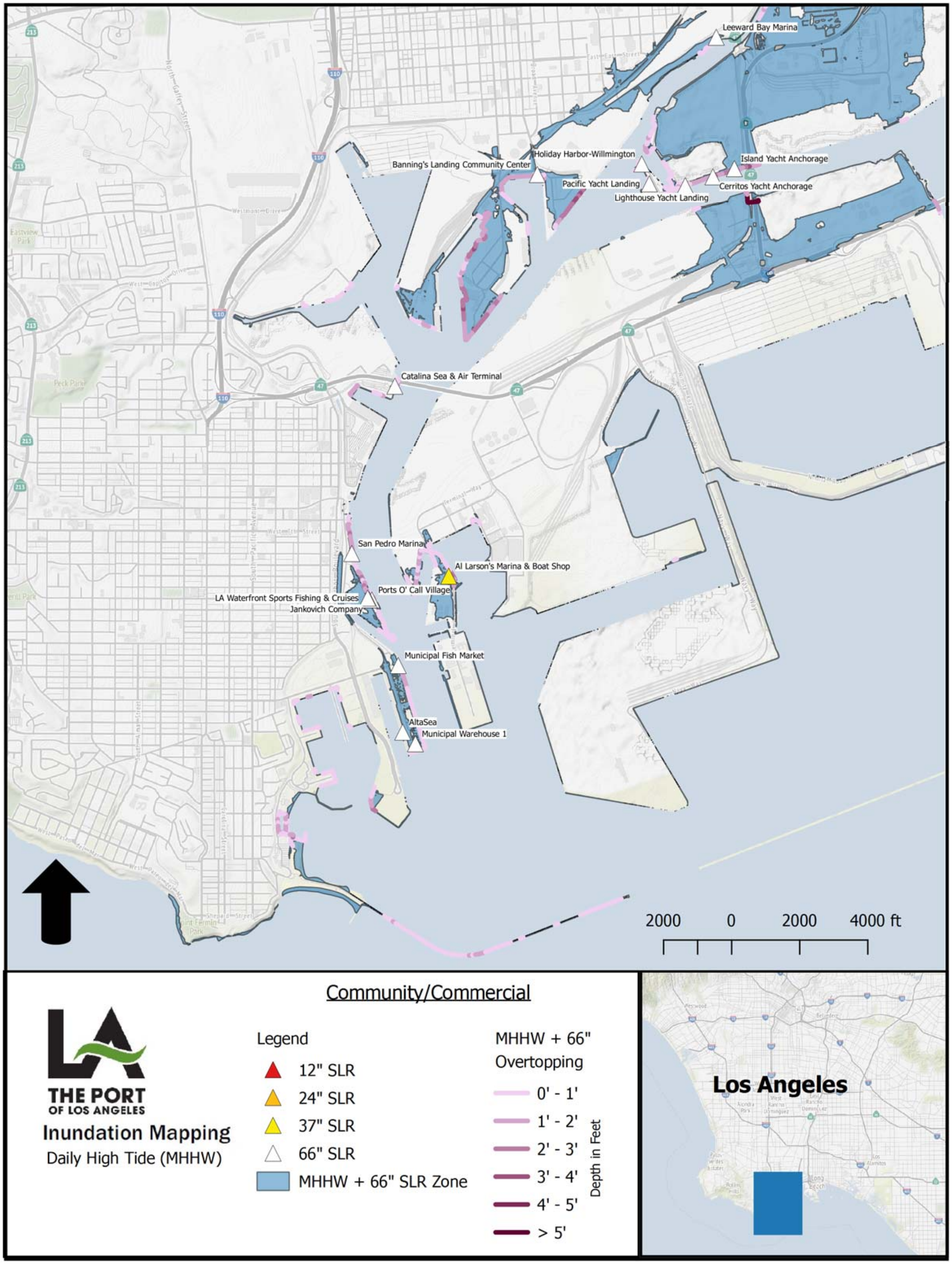
Social consequences may also be experienced if community/commercial assets are exposed to flooding. Many adjacent neighborhoods utilize the public waterfront for recreation and depend on the businesses for local employment. There are multiple marinas including the Cerritos Yacht Anchorage, Holiday Harbor-Wilmington, San Pedro Marina, Yacht Centre-Newmarks, and California Yacht Marina that are expected to experience temporary flood and permanent inundation of buildings and parking lots, which may prohibit access to privately owned boats stored on-site, as well as liveaboards.

Environmental consequences are expected to be limited if community/commercial assets are exposed to flooding.

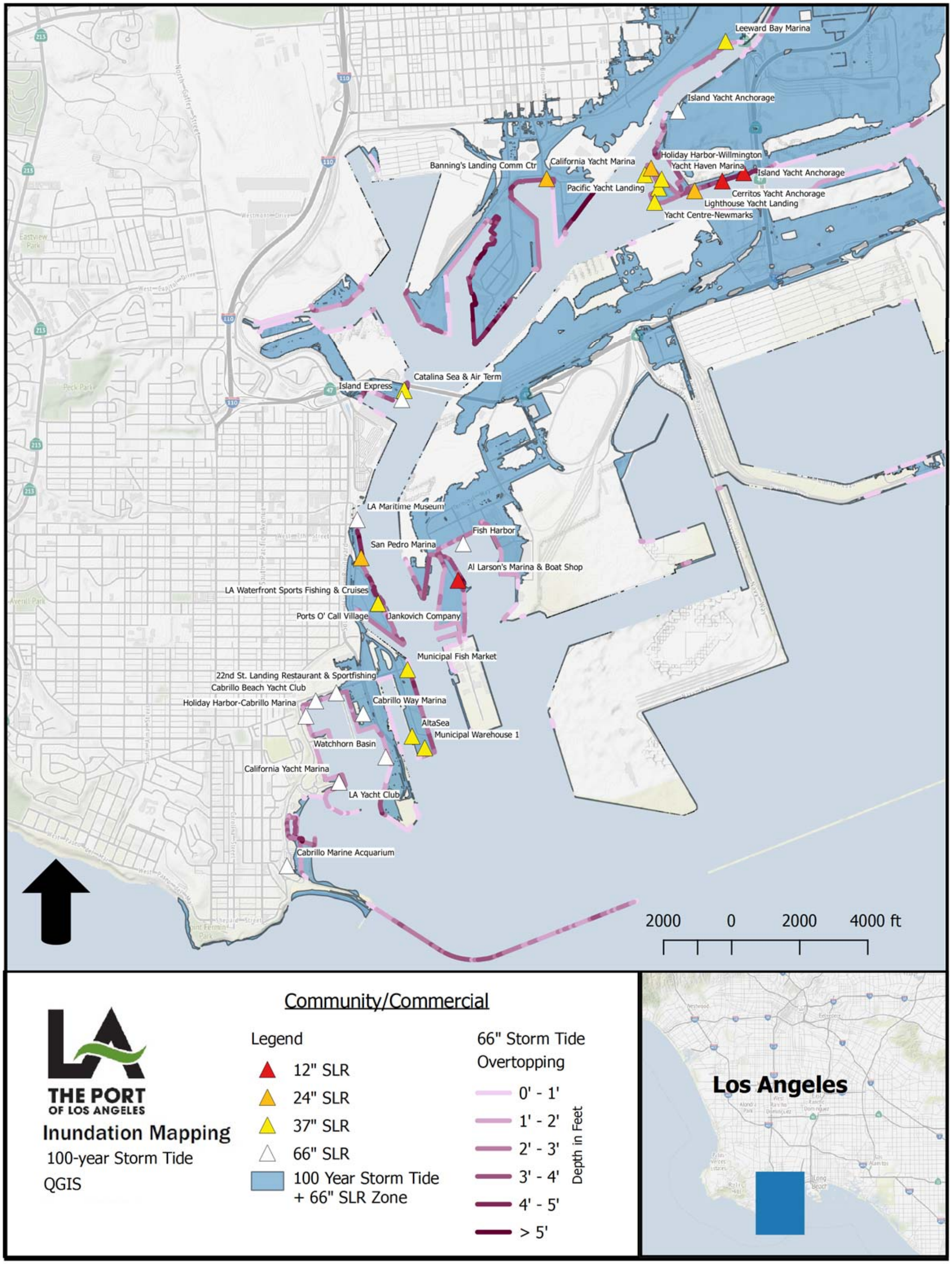
Summary

- Temporary flooding to the Al Larson's Marina and Boatshop, Cerritos Yacht Anchorage, and Island Yacht Anchorage #1 occurs by the 12 inch SLR and storm tide scenario.
- By 24 inch SLR and storm tide several other community/commercial assets are temporarily flooded: San Pedro Marina, the California Yacht Marina, Banning's Landing Community Center, Lighthouse Yacht Landing, and Holiday Harbor-Wilmington.
- The Al Larson Marina and Boatshop is the first community/commercial asset to be permanently inundated by 37 inches of SLR.
- The following community/commercial assets are temporarily flooded by 37 inch SLR and storm tide: California Yacht Marina, Holiday Harbor Wilmington, Leeward Bay Marina, Pacific Yacht Landing, Yacht Centre-Newmarks, Municipal Fish Market, the Jankovich Company, Ports O'Call Village, L.A. Waterfront Sportfishing and Cruises, Island Express, Catalina Sea and Air Terminal, Municipal Warehouse #1, and AltaSea.
- Many of the surrounding communities depend on the Port's waterfront for access to recreation opportunities and local jobs.

- Revenue generated through tourism will also be affected by a loss of community/commercial assets. The Port is currently investing in community/ commercial enhancement projects along the waterfront to increase public access and promote tourism. Several of these recently completed projects, such as Cabrillo Way Marina and the Catalina Sea and Air Terminal are impacted by SLR scenarios.


Leeward Bay Marina
Holiday Harbor-Wilmington
Banning's Landing Community Center
Island Yacht Anchorage
Pacific Yacht Landing
Cerritos Yacht Anchorage
Lighthouse Yacht Landing
Catalina Sea & Air Terminal
San Pedro Marina
Al Larson's Marina & Boat Shop
Ports O' Call Village
LA Waterfront Sports Fishing & Cruises
Jankovich Company
Municipal Fish Market
AltaSea
Municipal Warehouse 1
2000 0 2000 4000 ft
Community/Commercial
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66" Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles

FINAL DRAFT



Leeward Bay Marina
Island Yacht Anchorage
Holiday Harbor-Wilmington
Yacht Haven Marina
Island Yacht Anchorage
Banning's Landing Comm Ctr
California Yacht Marina
Pacific Yacht Landing
Cerritos Yacht Anchorage
Lighthouse Yacht Landing
Yacht Centre-Newmarks
Catalina Sea & Air Term
Island Express
LA Maritime Museum
Fish Harbor
San Pedro Marina
Al Larson's Marina & Boat Shop
LA Waterfront Sports Fishing & Cruises
Ports O' Call Village
Jankovich Company
Municipal Fish Market
22nd St. Landing Restaurant & Sportfishing
Cabrillo Beach Yacht Club
Holiday Harbor-Cabrillo Marina
Cabrillo Way Marina
AltaSea
Municipal Warehouse 1
Watchhorn Basin
California Yacht Marina
LA Yacht Club
Cabrillo Marine Acquarium
2000 0 2000 4000 ft
Community/Commercial
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
QGIS
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles

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Natural Habitats SLR Vulnerability Profile

Asset Overview

Natural habitats provide home to a diversity of wildlife and plant species and serve important ecological functions. Natural habitats include beach and sandy areas, coastal scrub, marshland, heron roosting grounds, resident least tern (*Sternula antillarum browni*) nesting colony areas, and aquatic eelgrass and kelp beds.

The habitats are fragmented and were formerly larger in scale. Special-status species occur at the Port or in the nearby vicinity, including the Federally and State Endangered California least tern and the California Fully Protected California brown pelican (*Pelecanus occidentalis californicus*).

Natural habitats serve important ecological functions. Coastal scrub provides potential habitat for several special-status species. Vegetated shallow water aquatic habitats, including eelgrass beds and kelp beds, are valuable near-shore habitats, providing shelter and breeding habitat for a diversity of marine life as well as important water quality and nutrient cycling ecosystem services that reach beyond the Port boundaries.

Vegetated shallow water habitats are protected under the Clean Water Act, as they stabilize substrate sediments, which help to maintain the health of the marine environments. Eelgrass bed and kelp forest habitats are also designated essential fish habitat under the Magnuson-Stevens Fishery Conservation and Management Act of 1996.

The resident least tern nesting colony currently occurs at Pier 400. However, records from the California Department of Fish and Wildlife show that least tern nesting has also occurred in vicinity of the sand area North of Pier 300, near Reeves Field, and at the Landfill Site south of Ferry Street. While the Pier 300 sand area may not presently support least tern nesting, it contains potentially suitable habitat. Therefore, it is an important area to consider as potential nesting grounds for this protected species under future sea level rise (SLR) conditions.

Exposure

The table summarizes the exposed natural habitats according to when they first become inundated. Maps illustrating the exposure to SLR and storm tide are provided at the end of the profile. A natural habitats map has also been included for reference.

Although the majority of habitats will eventually be exposed to SLR, either by temporary flooding or permanent inundation, the degree to which they are impacted varies based on habitat characteristics. Aquatic habitats are submerged by water and can adapt to increased water depths to a certain threshold, (noted in the table below by an asterisk). The exposure maps include an overtopping layer which illustrates the lowest lying points along the shoreline.

Table: Timing of Asset Exposure

(Note: Black text – inundated by average daily high tide
Green text – flooded by storm tide)
**Asset has a natural adaptive capacity*

Scenario (Time-frame)	**Assets Exposed**
12 inch (2030)	• **None** • Eelgrass beds at Cabrillo Beach* • Kelp beds at Cabrillo Beach* • Outer harbor shallow water habitat* • Pier 300 shallow water habitat* • Sand Area at Pier 300
24 inch (2050)	• Sand Area at Pier 300 • Pickleweed at Wilmington Marinas/East Basin*
37 inch (2100 mid-range)	• Eelgrass beds at Cabrillo Beach • Kelp beds at Cabrillo Beach • Outer harbor shallow water habitat • Pier 300 shallow water habitat • Brackish water marsh at Wilmington Marinas/East Basin* • Ficas trees at Berth 75-79*

66 inch (2100 high-range)	• Brackish water marsh at Wilmington Marinas/East Basin • Ficas trees at Berth 75-79 • Pickleweed habitat at Wilmington Marinas/East Basin • Salinas de San Pedro Salt Marsh* • Freshwater marsh*

Sensitivity

Natural habitats directly adjacent to open water are sensitive to increased frequency, duration, or depth of saltwater inundation. All habitats that are exposed to SLR and or storm tides have sensitivity to damage. However, natural habitats have an inherent resiliency to occasional storm tides. It is the recurring, or extreme events, which may permanently damage or destroy these habitats.

Aquatic habitats such as kelp beds and eelgrass beds are dependent on the existing sea level. Increases in water depth or turbidity may limit the amount of light required by the aquatic plant communities for photosynthesis to sustain net growth. By a 37 inch increase in water levels, aquatic habitats may not be able to sustain growth consistent with the rate of sea level rise.

Natural habitats also have a higher sensitivity if they provide potential or known habitat for Federal and State threatened or endangered species. The sand area North of Pier 300 is a known nesting area (even though it is not a designated area like Pier 400) for the California least tern, a migratory bird that breeds in bays along the Pacific Ocean. By the 24 inch SLR scenario, the open beaches that the least tern depends on for nesting may be inundated. Coastal scrub habitats also provide potential habitat for several threatened and endangered species and are not exposed to SLR or storm tide flooding under the scenarios evaluated.

Adaptive Capacity

The adaptive capacity of natural habitats is dependent upon the inherent resiliency of the habitat to change, ability to recover from individual extreme events, capability to migrate in response to climate pressures, and the location of nearby habitats that can serve as refugia.

Vegetated shallow water habitats, such as eelgrass and kelp beds, are an example of habitats with natural adaptive capacity. Located in an intertidal environment, they are able to withstand fluctuations in water levels. However, they may not be able to maintain a growth rate of future SLR projections, which will limit their ability to maintain their existing location.

Many habitats are already impacted by coastal development, dredging and fill, eutrophication in aquatic habitats, and industrial pollution. All of these factors may reduce the inherent abilities of habitats to recover and be resilient to change.

Due to the fragmented nature of the habitats amidst a highly developed setting, there is limited space for the majority of the habitats to migrate upwards and out of the flood zone. Although the sand area at Pier 300 may be able to maintain its habitat through natural shoreline evolution, by the 24 inch SLR scenario, the sand area may narrow and eventually become inundated.

Natural habitats, such as pickleweed and brackish water marsh, evolved in an intertidal saline water environment and have some inherent adaptive capacity to withstand temporary tidal flooding events. However, these habitats cannot sustain permanent inundation.

Natural habitats that have evolved in freshwater, or on dry land, have a low adaptive capacity to SLR and storm tides because they have a low tolerance for saline conditions. The freshwater marsh and the Ficas trees where the heron nesting colony is located at Berths 75-79 is an example of a habitat with low adaptive capacity.

Consequence

If exposed to SLR and storm surge flooding, potential environmental damage may include widespread conversion or loss of wetland habitats and beach or sand habitat. Loss of these environments equates to a loss in shelter/breeding areas for many dependent species.

Many coastal natural habitats provide ecological benefits such as filtering water and providing a buffer from coastal storms. Loss of these habitats may require investment in alternative means to protect water quality and coastal storm protection.

As a breeding location for migratory bird species, the natural habitat areas offer unique bird watching opportunities to the public. Loss of such habitats may decrease biodiversity and eliminate the exposure of the public to local species currently established in the area.

Summary

- The sand area North of Pier 300 is a vulnerable habitat as it provides nesting grounds for the California least tern and is inundated by the 12 inch SLR plus storm tide scenario.
- Coastal scrubs could potentially become refugia areas for natural habitats and should be protected.
- The aquatic habitats (eelgrass and kelp beds at Cabrillo Beach and outer harbor shallow water beds) become vulnerable by the 37 inch SLR scenario.
- It is likely that the Ficas trees around Berths 75-79 will not survive saltwater inundation expected to occur by the 66 inch SLR scenario. Therefore, the creation of a protected habitat for the heron nesting colony should be considered.

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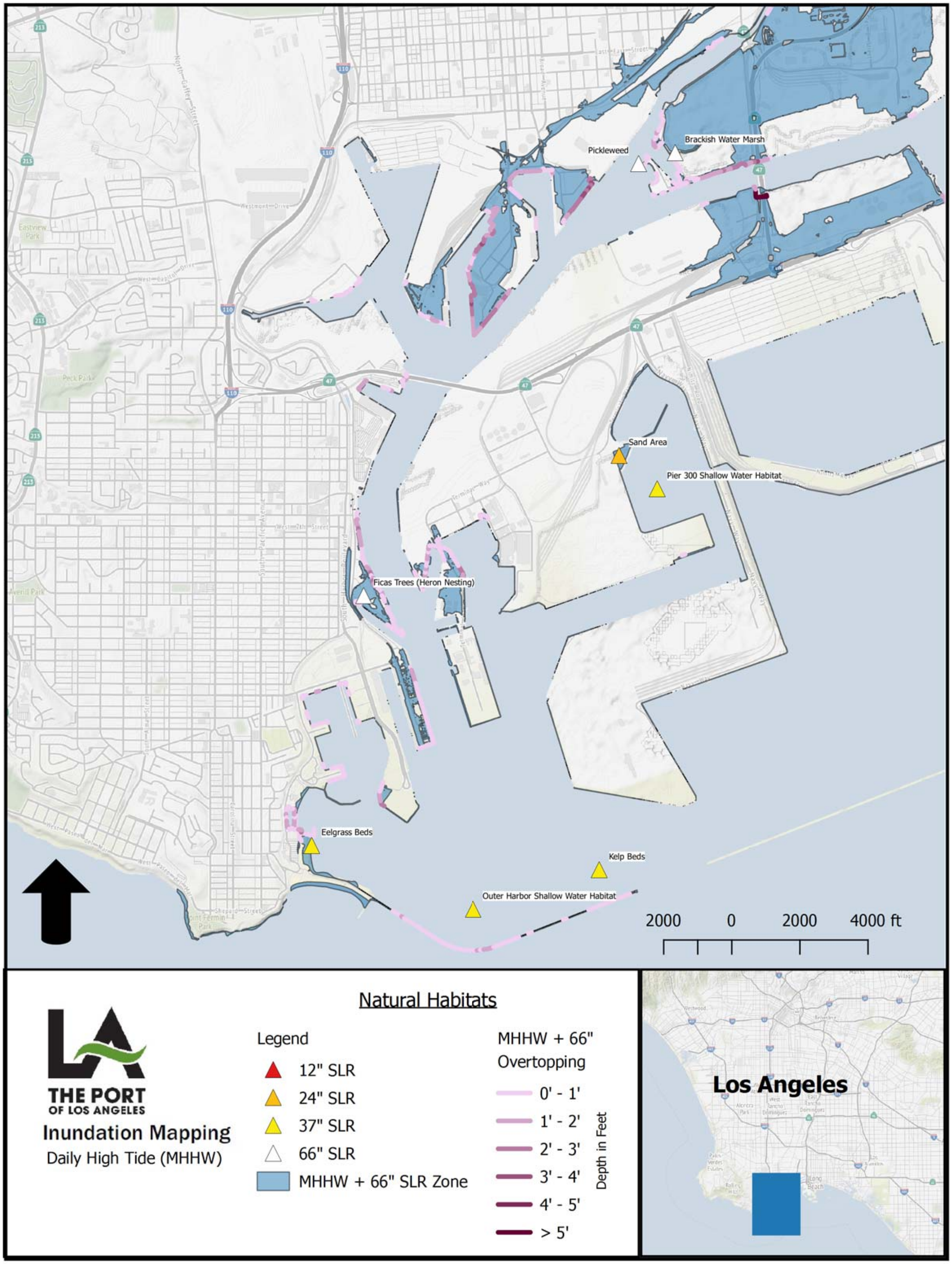
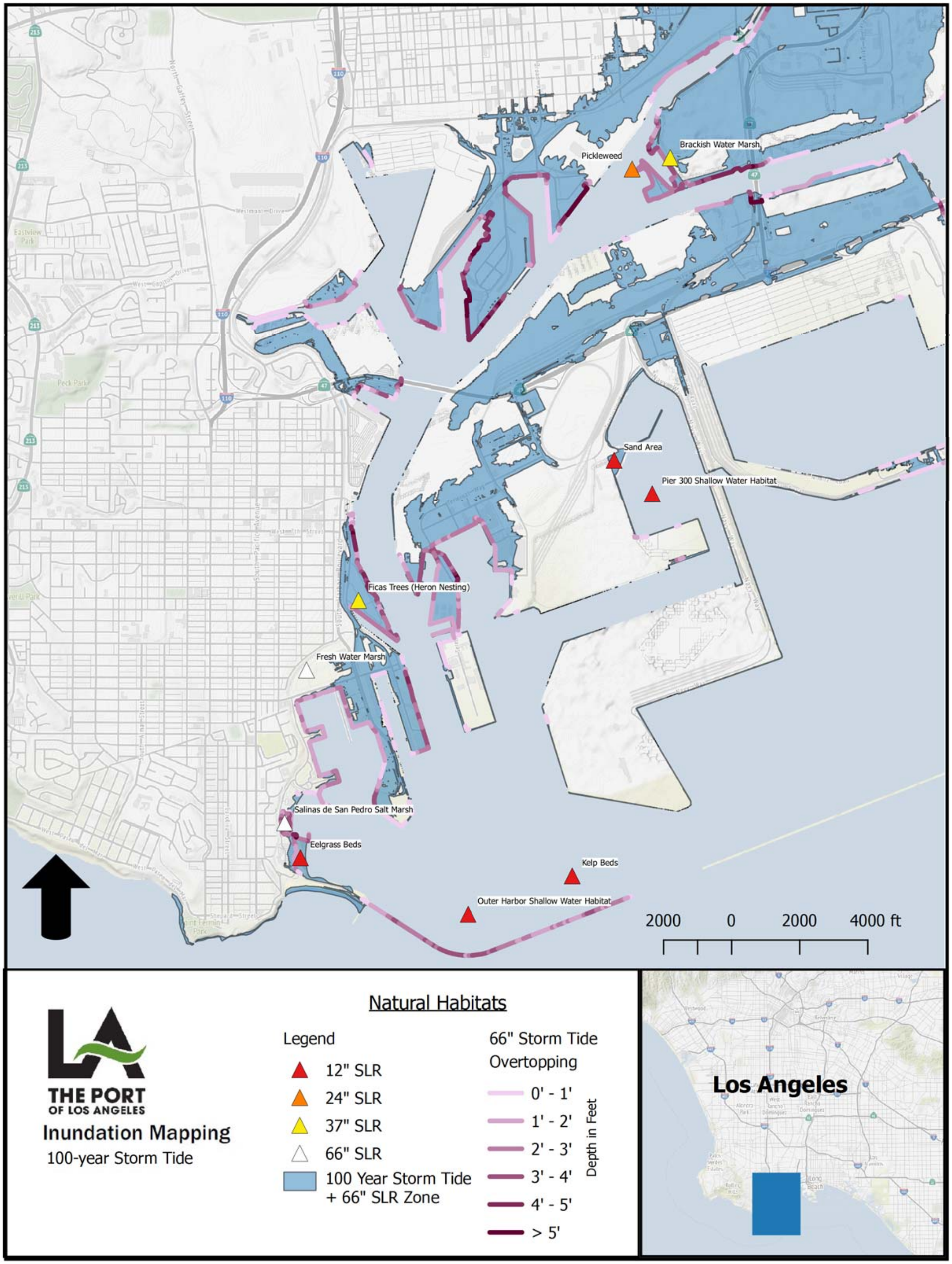
Geresberg, R.M. and T. Anderson, San Diego Bay Terrain Model Final Report. January, 2014. Available: https://www.portofsandiego.org/environment/environmental-downloads/environmental-committee-fund/progress-reports/5666-san-diego-bay-terrain-modelfinalreport-feb-2014/file.html. Accessed January 16, 2017.


Pickleweed
Brackish Water Marsh
Sand Area
Pier 300 Shallow Water Habitat
Ficas Trees (Heron Nesting)
Eelgrass Beds
Kelp Beds
Outer Harbor Shallow Water Habitat
2000 0 2000 4000 ft
Natural Habitats
THE PORT OF LOS ANGELES
Inundation Mapping
Daily High Tide (MHHW)
Legend
12" SLR
24" SLR
37" SLR
66" SLR
MHHW + 66" SLR Zone
MHHW + 66"
Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles


Brackish Water Marsh
Pickleweed
Sand Area
Pier 300 Shallow Water Habitat
Ficas Trees (Heron Nesting)
Fresh Water Marsh
Salinas de San Pedro Salt Marsh
Eelgrass Beds
Kelp Beds
Outer Harbor Shallow Water Habitat
2000 0 2000 4000 ft
THE PORT OF LOS ANGELES
Inundation Mapping
100-year Storm Tide
Natural Habitats
Legend
12" SLR
24" SLR
37" SLR
66" SLR
100 Year Storm Tide + 66" SLR Zone
66" Storm Tide Overtopping
0' - 1'
1' - 2'
2' - 3'
3' - 4'
4' - 5'
> 5'
Depth in Feet
Los Angeles


Biologically Sensitive Areas
Wilmington
San Pedro
Long Beach
West Basin
East Basin
Main Channel
Fish Harbor
West Channel
East Channel
Pickleweed
Brackish Water Marsh
Pickleweed
Coastal Scrub
Coastal Scrub
Eel Grass
Sand Area
Shallow Water
Ficas Trees (Heron Nesting)
Kelp
Coastal Scrub
Fresh Water Marsh
Least Tern Nesting Site
Native Plants
Salt Marsh
Eel Grass
Kelp
Shallow Water
City of Long Beach
City of Los Angeles
Kelp
Brackish Water Marsh
Coastal Scrub
Eel Grass
Ficas Trees (Heron Nesting)
Fresh Water Marsh
Least Tern Mgmnt Area
Least Tern Nesting Site
Native Plants
Pickleweed
Salt Marsh
Sand Area
Shallow Water
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1
Miles
CA State Plane Coordinate System, NAD 83, Zone V, US Survey Feet

6 Adaptation Strategies

Introduction

This chapter provides an overview of 100+ high-level adaptation strategies that were developed to consider, evaluate further, and implement to protect against SLR.

There are three categories of strategies, which have been reviewed and refined with Port stakeholders: governance, initiatives, and physical infrastructure.

Each of the infrastructure adaptation strategies developed fall into one of the following categories commonly used by the California Coastal Commission: protect, accommodate, and retreat. ***Protect*** refers to providing protection (either hard or soft defense measures) around an existing asset, such as building a seawall around a substation. ***Accommodate*** refers to modifying an existing asset in its existing location so that it can continue to function, such as elevating a substation above inundation. ***Retreat*** refers to relocating the asset to an area outside on inundation zone, such as moving the substation to higher ground. This context is important to understand as the high-level infrastructure strategies are further considered and developed into concept designs to determine that the most appropriate adaptation approach is implemented.

Methodology

Using the Vulnerability Profiles, a compendium of adaptation solutions were developed drawing on best management practices, technical expertise, and local knowledge.

Three categories of strategies were developed:

- **Governance:** Addresses port-wide planning and design documents. Strategy types include adding SLR language to existing planning documents; developing SLR design guidelines; adding SLR considerations to current projects; and community education.
- **Initiative:** Addresses SLR initiatives that would provide additional relevant data. Strategy types include informational data gaps; feasibility studies; collaboration with organizations beyond the Port; and identifying funding opportunities.
- **Infrastructure:** Addresses physical vulnerabilities. Strategy types include both temporary asset protection measures (e.g. sand bags, tiger dam) and permanent measures (retrofit existing walls, build a sea wall). Further, there are some strategies that would benefit from a more port-wide approach, which have been identified as a 'collective area'.

Each adaptation strategy includes the following data in the tables below: POLA Engineering area ID, focus area/location, SLR exposure scenario, draft strategy, timeframe, collective area option, and the Harbor Department Champion.

It is important to note that the strategies are not developed to a detailed design. Suggestions have been made for raising or building shoreline protection structures along a specified shoreline edge, but these have not be developed to an engineering design level. In summary, each strategy is described in a few sentences that can be further developed at a later date.

Table 6-1. Adaptation strategy data points

Data Points	SLR Adaptation Strategies Worksheet Description
Identification #	Strategy number for each asset type
Area ID #	Dept. of Engineering NomenclatureNote: only applies to infrastructure strategies
Focus Area	Port vulnerable area/asset - such as 'Berth 154' or 'Port-wide'
Exposure Scenario	All Scenarios 12 inch SLR 24 inch SLR 37 inch SLR 66 inch SLR 12 inch SLR + Storm Tide (ST) 24 inch SLR + ST 37 inch SLR + ST 66 inch SLR + ST
Strategy	Brief description of adaptation strategy Note: If a temporary or permanent flood protection barrier is recommended, approximate height and length are provided.
Timeframe I/ S / F	Implementation of strategy timeline: I = Immediate (up to 5 years) S = Soon (before 2030) F = Future (after 2030)
Collective Area?	Y/N – whether the asset should be part of a collective area consideration (means that multiple assets within an area would be protected) Note: Only applies to infrastructure strategies
Harbor Dept. Champion	Lead Department

Stakeholder Workshop

After the list of potential SLR adaptation strategies was developed, an internal workshop was held to review the proposed adaptation strategies and ensure a final comprehensive document. The key takeaways were:

- The Port will focus on physical infrastructure adaptation strategies for assets that are vulnerable under the 12 inch and 24 inch SLR scenarios (year 2030 - 2050) as they are the first to be impacted and could be impacted during the lifespan of that asset.
- The Port will develop clear policy and design guidance to consider future SLR for assets.
- The Port will collaborate with tenants that are most exposed to evaluate adaptation considerations (both temporary and permanent) and to help determine, if multiple tenants are impacted, if a more collective approach is more appropriate.

The strategies are organized by strategy category (governance, initiative, and infrastructure) in this chapter. Within the infrastructure category, the assets are organized by asset type (Cargo Wharves/ Misc. Operations, Critical Facilities, Transportation, Community/Commercial Assets, and Natural Habitats).

Additional Considerations

The 66 inch SLR Scenario

Infrastructure adaptation strategies were not developed for the 66 inch SLR scenario because, as most of the Port assets have a remaining lifespan of less than 50 years. It is anticipated that through the implementation of the governance strategies, the majority of assets will have been redesigned and reconstructed by the end of the century to account for the higher SLR scenario.

Individual vs. Collective Area

There are some areas within the Port that include several assets that are vulnerable that may benefit from a more collective approach. For example, every asset could be protected individually, or a seawall could be built along the shoreline edge that could protect multiple assets (facilities, roadways, any community/commercial assets, utilities, etc.).

There are three collective areas that include multiple assets that are vulnerable under the 12 inch and 24 inch SLR scenarios. The areas are identified by the Port's Engineering Department's nomenclature.

Figure 6-1. Scenario: 24" SLR + 100 Yr. Tide

Collective Area Infrastructure Strategies

Area ID# 38:

Build semi-permanent or temporary flood protection along the seaward edge of Canal St. and Yacht St. at Berths 191-195. Assets protected include:

- Vopak Liquid Bulk & CPC Terminal
- Fire Station #49 access
- Yacht St.
- Vopak CPC
- Public Service Marine, Inc.
- Water St.
- Canal St.
- Millennium Maritime
- Banning's Landing Community Center
- WWL Vehicle Services

Area ID# 34:

Construct a seawall along Berths 161-174. Assets protected include:

- NuStar Liquid Bulk Terminal
- Valero Liquid Bulk Terminal
- Shell Liquid Bulk Terminal
- Fries Ave.
- Falcon StAve.
- Rio Tinto Dry Bulk Terminal
- SD Pump Plant #666,
- Pasha Break Bulk Terminal, and
- LADH Construction & Maintenance facility.

Area ID# 6:

Build temporary or semi-permanent flood protection along terminal shoreline with low elevation where overtopping occurs at Berths 150-151. Assets protected include:

- Phillips 66 Terminal
- Warehouses (POLA/Pasha)
- Pier A St.
- E-12 Transformer,
- TraPac Lead Tracks, and
- West Basin lead tracks.

Although there are additional collective areas, they are not impacted until later SLR scenarios and it is assumed that they will be addressed over time through implementation of governance strategies.

On-going Operations and Implementation of Adaptation Strategies

Implementing several of the adaptation strategies will be challenging to some asset types given the demand for ongoing operations, touch points to adjacent assets, and design criteria.

Strategies to raise road and rail assets must consider the additional modifications that may be necessary to maintain operational and physical connectivity to the assets they serve. Ramps, walls, or other transition adaptation strategies to maintain roadway access could be required. Additionally, rail assets follow more stringent geometric criteria for vertical curves and grades than roadways, making them more difficult to raise in isolation without impacting the facilities to which they connect. The same access considerations apply to raising pump stations or electrical infrastructure.

Constructing or modifying sea walls around assets (oil facilities) or along entire waterfront (areas) for some SLR scenarios may not be cost effective. Access points (wharfs / docks) along the waterfront are required for ongoing operations.

Summary

In summary, it is recommended to prioritize governance strategies so that SLR projections become a standard design consideration for all future projects. The existence of governance strategies can help raise awareness of SLR within Port staff, with tenants and the general public.

Initiative strategies are important as they provide additional insight into potential SLR hazards and provide an opportunity to collaborate with stakeholders. For example, a study on which type of temporary flood protection barrier is best suited for deployment would consider cost, effectiveness, ease of installation, etc. will lead to a better prepared Port. Additionally, participation with other local organizations that are focused on SLR may lead to collaboration efforts that would benefit multiple stakeholders. In general, these strategies will increase awareness and the ability to adapt.

With regards to infrastructure strategies, it is recommended to focus on the assets that are vulnerable under the 12 inch (year 2030) and 24 inch SLR (year 2050) because they will be impacted within the existing asset lifespan. For assets that will only be temporarily flooded during a storm-tide condition, it may make sense to provide temporary protection only (such as sandbags or aquafence). For assets that will be permanently inundated, permanent protection will be necessary to continue operations (such as retrofitting a sheet pile wall or building a seawall). It is also possible that some vulnerable assets may benefit from a more collective approach if multiple assets are impacted. In this case, Port stakeholders would need to collaborate and agree on the most appropriate strategy and develop a cost sharing plan.

It is likely that the assets vulnerable under 37 inch and 66 inch SLR (year 2100 mid- and high-range) will be addressed through governance strategies over time, since the projected lifespan of most Port facilities is less than 50 years and there will be an opportunity to rebuild many of these assets prior to them being exposed to these higher, end-of-century SLR scenarios.

Governance SLR Adaptation Strategies For Consideration

Table 6-2. Governance SLR Adaptation Strategies For Consideration

#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Harbor Department Champion
1	Port-wide	All scenarios	***Add language regarding SLR*** and potential impacts and adaptation strategies to the following guiding policy, planning documents, and design guidelines: 1. Port Master Plan 2. Engineering Design Guidelines (2009) 3. LA Waterfront Design Guidelines (2011)	I	Planning & Engineering
2	Port-wide	37 inch	Develop a general ***one-page vulnerability zone map*** for a select Port SLR planning scenario. The map should show temporary flood and permanent inundation vulnerability zones. This will be a tool and reference for Port staff (to be used by all departments) to help determine if future projects are vulnerable to SLR based on the selected scenario and can be used for several governance strategies. Consider including as a layer on GeoPOLA. It is recommended that the Port base the map on the 37 inch SLR scenario (years 2065 - 2100), as this is the most-likely projection for 2100 and is in compliance with state guidance	I	Planning & Engineering
3	Port-wide	All scenarios	Update ***Coastal Development Permit*** and ***Harbor Engineers Permit*** applications to include language about SLR potential impacts and adaptation strategies.	I	Planning & Strategy
4	Port-wide	All scenarios	Add standard language regarding SLR and potential impacts and adaptation strategies to future ***Port RFP's/RFQ's***, as applicable.	I	Contracts/ Purchasing
5	Port-wide	All scenarios	Update ***terminal lease requirements*** to reference this SLR Adaptation Plan. The intent of this strategy is to highlight to tenants that they may be located in an area that is vulnerable to SLR. Additionally, this provides tenants the opportunity to think about adaptation strategies early.	I	Real Estate
6	Port-wide	All scenarios	Engage with the community to provide ***SLR education opportunities***, such as developing and distributing a pamphlet	I	Community Relations
7	Port-wide	All scenarios	Monitor SLR science and State Guidance ***updates every 5 years*** and reevaluate the list of vulnerable assets, as necessary.	I	Planning & Engineering

Initiative SLR Adaptation Strategies For Consideration

Table 6-3. Initiative SLR Adaptation Strategies For Consideration

#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Harbor Department Champion
1	Port-wide	All scenarios	Develop a management system to ***track extreme weather events and associated damage and disruption*** to justify the need to provide dedicated funding for future SLR-related projects and validate future conditions.	I	Public Safety& Emergency Management
2	Port-wide	All scenarios	Complete ***study*** to determine the most appropriate temporary flood protection based on evaluation of several options (e.g., sandbags, self-inflating sandless bags, Aquafence, Tiger Dams, etc.) considering a storage, cost, erection, and maintenance. This preemptively prepares the Port for a future storm event.	I	Engineering & Planning & EMD
3	Port-wide	All scenarios	***Regional collaboration*** - Work with POLB, the City of Los Angeles and City of Long Beach on strategy coordination. All four entities are developing climate adaptation plans individually. There may be mutually beneficial strategies or cost-sharing opportunities available. For example, New Dock St. is vulnerable to SLR and runs through POLA and POLB.	I	Planning & Strategy
4	Port-wide	All scenarios	***Regional collaboration*** - Participate in the Aquarium of the Pacific Climate Change Working Group.	I	Planning & Strategy
5	Port-wide	All scenarios	***Ports collaboration*** - Participate in the CAPA (California Association of Port Authorities) Sea Level Rise group.	I	Planning & Strategy
6	Port-wide	All scenarios	Discuss SLR ***breakwater*** vulnerabilities and potential adaptation strategies with the Army Corp of Engineers. Note: breakwater is overtopped by the 37 inch SLR + ST scenario.	I	Engineering
7	Port-wide	All scenarios	Identify ***funding opportunities*** that would support implementation of SLR adaptation strategies.	I	Risk Management (RMD)
8	Port-wide	All scenarios	***Tenant collaboration*** - Work with tenants in collective areas (Area ID# 34, 38, 6, and 4) that could benefit from a collaborative approach so that the most appropriate long-term sea level rise protection strategies are can be implemented.	I	Planning & Strategy
9	Port-wide	All scenarios	***Port collaboration*** – Create a Port SLR Adaptation Working Group – to work with stakeholders from all relevant Divisions to guide implementation of adaptation strategies.	I	Planning & Strategy
10	Port-wide	All scenarios	Evaluate the ***condition and elevation of the identified critical pump stations*** (and components) that are exposed to sea level rise to determine which are most sensitive (are they on raised platforms? Do they include flood protection measures? etc.). Note: pump stations are not expected to be flooded until the 24 inch SLR + ST. A total of 3 pump stations could be impacted.	S	Engineering & Construction
11	Port-wide	All scenarios	Monitor and inventory natural resources and existing habitats (wetlands, subtidal, species, etc.) and identify strategies to protect, enhance, and adapts to future sea level rise.	I	Planning & Strategy
12	Port-wide	All scenarios	Complete detailed evaluation of bridge vulnerabilities regarding ship movement considering the effects of sea level rise by collecting information on current and future vessel types and determining minimum clearance elevations for the underside of existing bridge structures (initial review completed as part of the transportation vulnerability assessment).	S	Engineering & Construction

Infrastructure SLR Adaptation Strategies For Consideration

Table 6-4. Infrastructure SLR Adaptation Strategies For Consideration – Cargo Wharves & Misc. Operations

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
1	34	Nustar	12 inch + ST	Reinforce or adapt existing walls around ***NuStar liquid bulk terminal*** to provide temporary flood protection for at least 3 feet of flooding. (500 Linear Feet (LF))	I	Y	Planning & Strategy
			24 inch + ST	Same approach as above.	S		
			37 inch + ST	Add 2 feet in height, same LF	F		
2	34	Valero	12 inch + ST	Reinforce or adapt existing walls around ***Valero liquid bulk terminal*** to provide temporary flood protection for at least 3 feet of flooding. (500 LF)	I	Y	Planning & Strategy
			24 inch + ST	Same approach as above.	S		
			37 inch + ST	Add 2 feet in height, same LF	F		
3	34	NuStar & Valero	37 inch	***Alternative to Terminal strategies 1&2:*** Build a seawall along berths 161-165 to prevent overtopping and protect the ***NuStar and Valero liquid bulk containers***, which would also protect LAHD C&M building from temporary flooding (1,670 LF, 5 feet high). Temporary protection of the asset through reinforcement of surrounding containment walls will not be sufficient as a sole flood protection strategy by 37 inches of SLR when permanent inundation is projected to occur.	F	Y	Planning & Strategy
4	34	Shell	12 inch + ST	Reinforce or adapt existing walls around ***Shell liquid bulk terminal*** to provide temporary flood protection for at least 3 feet of flooding. (1400 LF)	I	Y	Planning & Strategy
			24 inch + ST	Same approach as above.	S		
			37 inch + ST	Add 2 feet in height, same LF	F		
			37 inch	Build a seawall along berths 167-168 and 170-174 to prevent overtopping (3000 feet LF, 5 feet high). Temporary protection of the asset through reinforcement of surrounding containment walls will not be sufficient as a sole flood protection strategy by 37 inches of SLR when permanent inundation is projected to occur.	F		
5	38	Vopak & Vopak CPC	12 inch + ST	Reinforce or adapt existing walls around ***Vopak liquid bulk terminal*** to provide temporary flood protection for at least 3 feet of flooding. (2000 LF)	I	Y	Planning & Strategy
			24 inch + ST	Above recommendation also protects asset under 24 inch exposure.	S		
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
6	6	Phillips 66	24 inch + ST	Provide temporary flood protection around ***Phillips 66 bulk terminals*** and buildings (2,000 LF, 3 feet high).	S	Y	Planning & Strategy
			37 inch + ST	Plus 1,500 LF, same height.	F		
7	34	Rio Tinto Minerals	24 inch + ST	Provide temporary flood protection of ***Rio Tinto Minerals*** (2,500 LF, 3 feet high).	S	Y	Planning & Strategy
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
8	6	POLA/Pasha Warehouses	24 inch + ST	Protect all flood pathways (doors, vents, etc.) to the ***POLA/Pasha warehouses***. (Flood protection should be up to 1,500 LF and 3 feet high).	S	Y	Planning & Strategy
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
9	34	Pasha Break-bulk	37 inch + ST	Provide temporary flood protection of the ***Pasha breakbulk terminal*** (5500 LF, 3 feet high).	F	Y	Planning & Strategy
10	82	ExxonMobil Berth 237-240C	37 inch + ST	Provide temporary protection on the seaside of Wharf St. at Berths 238 - 240C to protect the ***ExxonMobil liquid bulk terminal*** and road access (2,180 LF, 3 feet high). Note: alternatively the existing walls around the liquid bulk terminal could be reinforced/adapted, but that would not protect the roadway.	F	N	Planning & Strategy
11	38	Public Service Marine building Berths 186-189	24-inch + ST	Provide temporary flood protection for the ***Public Service Marine building*** (630 LF, 3 feet high).	S	Y	Planning & Strategy
			37-inch + ST	Above recommendation also protects asset under 37 inch exposure.			
12	38	Berths 195-199	37-inch + ST	Relocate cars in ***WWL Vehicle Services*** away from affected areas in advance of storms.	F	Y	Planning & Strategy
13	4	US Water Taxi	37-inch + ST	Provide temporary flood protection around the ***US Water Taxi building*** (140 LF, 3 feet high).	F	N	Planning & Strategy
14	34	LAHD Construction	37-inch + ST	Provide temporary protection for the ***LAHD Construction building*** (800 LF, 3 feet high).	F	Y	Planning & Strategy

Table 6-5. Infrastructure SLR Adaptation Strategies For Consideration – Critical Assets

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
1	38	Berth 187	24 inch + ST	Provide temporary flood protection for ***Millennium Maritime, Inc.*** (620 LF, 3 feet high).	S	Y	Planning & Strategy
			37 inch + ST	Plus 80 LF, same height.	F		
2	38	Dock St behind Vopac (Port of Long Beach)	24 inch + ST	Elevate electrical equipment at ***SD Pump Station*** to be above the planning flood elevation. Submersible pumps could be installed, as they will be less likely to fail if flooded (elevate 9 feet).	S	Y	Engineering
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
3	63	Berth 43	37 inch + ST	Provide flood protection for ***Fire Station #110*** by establishing an elevated wall (400 LF, 3 feet high) at the low section of shoreline adjacent to the station. Access to the station should be ensured by constructing an elevated access road that is at least 3 feet high.	F	N	Planning & Strategy
4	4	Berth 68	37 inch + ST	Provide temporary flood protection for the ***Pilot's Station*** (480 LF, 3 feet high). Because the Pilot's Station is critical to Port operations, it is recommended that the most reliable form of flood protection, such as a Aquafence, be used because it is semi-permanent and can be installed quickly without extensive labor hours. It will also be important to protect access via Signal St.	F	N	Port Pilots
5	62	Ports O'Call	37 inch + ST	Elevate electrical equipment at ***SD Pump Plant #681*** to be above the planning flood elevation (at least 3 feet above existing elevation). Submersible pumps could be installed, as they will be less likely to fail if flooded. Alternatively, provide temporary flood barrier protection for pump station flood pathways, such as doors and vents (230 LF, 3 feet high).	F	N	Engineering
6	34	647 S Fries Ave	37 inch + ST	Elevate electrical equipment at ***SD Pump Plant #666*** to be above the planning flood elevation (at least 3 feet higher). Submersible pumps could be installed, as they will be less likely to fail if flooded. Temporary flood barrier protection (300 LF, 3 feet high) may also provide flood protection for pump station flood pathways, such as doors and vents.	F	Y	Engineering
7	4	E7-Transformer Berth 68	37-inch + ST	Provide temporary flood protection around the ***E7 – transformer (120/240V 1 φ 600A)***, as it provides critical access to the Pilot Station (60 LF, 3 feet high).	F	N	Engineering
8	6	E12-Transformer Berth 156–161	37-inch + ST	Provide temporary flood protection around the ***E12 – transformer LAHD Construction & Maintenance*** (60 LF, 3 feet high).	F	Y	Planning & Strategy
9	77	Berth 95	37-inch + ST	Provide temporary protection around the ***Avalon Freight Services*** (120 LF, 3 feet high).	F	N	Planning & Strategy

Table 6-6. Infrastructure SLR Adaptation Strategies For Consideration – Transportation

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
1	38	East side of Vopak Terminal	12 inch + ST	Elevate the following roadways: ***Water St.*** (170 LF), ***Nissan St.*** (225 LF), and ***Yacht St.*** (980 LF). When flooded, they prevent access to fire station #49. (Elevate all listed streets 3 feet above current elevation).	I	Y	Planning & Strategy
			24 inch + ST	Water St. plus 1,675 LF, Nissan St. plus 205 LF, and Yacht St. plus 35 LF.	S		
			37 inch + ST	Water St = above recommendation also protects asset under 37 inch exposure Nissan St. plus 185 LF, and Yacht St. plus 35 LF.	F		
2	80	Pier A West	12 inch + ST	Elevate the following roadways to protect access to marinas: ***Henry Ford Ave.*** (2935 LF, 12 feet high), ***Terminal Island Freeway*** (800 LF, 3 feet high).	I	N	Planning & Strategy
			24 inch + ST	Henry Ford Ave plus 52 LF, plus 1 foot height Terminal Island Freeway plus 1,000 LF, plus 2 feet height).	S		
			37 inch + ST	Henry Ford Ave. plus 13 LF, same height Terminal Island Freeway plus 450 LF, same height Add: Elevate the following roadways: ***Peninsula Rd.*** (300 LF, 3 feet high), ***Shore Rd.*** (600 LF, 3 feet high).	F		
3	80	Pier A West	12 inch + ST	Elevate sections of ***Anaheim St.*** (1900 LF, 3 feet high) to maintain the main artery access.	I	N	Planning & Strategy
			24 inch + ST	Plus 120 LF, same height	S		
			37 inch + ST	Plus 80 LF, same height	F		
4	34	Harbor Dept. Yards	12 inch + ST	Elevate ***Fries Ave.*** as access to SS Pump Plant #666, Volero, and Shell terminals are flooded (750 LF, 3 feet high).	I	Y	Planning & Strategy
			24 inch + ST	Plus 2,260 LF, same height	S		
			37 inch + ST	Plus 290 LF, same height	F		
			37 inch	Above 24 inch recommendation also protects asset under 37 inch exposure, however this would require permanent protection, not temporary.			
5	80	Pier A West	24 inch + ST	Elevate ***Anchorage Rd*** to provide access to the marinas (710 LF, 3 feet high).	S	N	Planning & Strategy
			37 inch + ST	Plus 790 LF, same height	F		
6	81	Near POLB Pier S	24 inch + ST	Elevate sections of ***New Dock St.*** to allow access to Berths 206-215 (3580 LF, 13 feet high). Note: POLB has identified an adaptation strategy to retrofit a seawall at Pier S along the Cerritos Channel. If implemented, this strategy may protect the section of New Dock Street running through POLA.	S	N	Planning & Strategy
			37 inch + ST	Plus 220 LF, same height	F		

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
7	38	North of Slip 5	24 inch + ST	Elevate ***Water St.*** (1390 LF, 3 feet high) and ***Canal St.*** (950 LF, 3 feet high) Note: If Canal St. is elevated; it will also provide access to the Banning's Landing Community Center.	S	N	Planning & Strategy
			37 inch + ST	***Water St.*** plus 860 LF, same height ***Canal St.*** Above recommendation also protects asset under 37 inch exposure.	F		
8	6	Phillips 66	24 inch + ST	Elevate sections of ***Pier A St.*** or provide temporary protection for the shoreline along Berth 148-155 to prevent inland flooding (2000 LF, 3 feet high). This road provides access to assets located on Terminal 6.	S	Y	Planning & Strategy
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
9	4	Berth 68-72	37 inch + ST	Elevate ***Signal St.***, as it provides critical access to the Pilot Station (2780 LF, 3 feet high).	F	N	Planning & Strategy
10	34	Harbor Dept. Yards	12 inch + ST	Elevate Falcon Ave as access to SS Pump Plant #666, Volero, and Shell terminals are flooded (700 LF, 3 feet high).	I	Y	Planning & Strategy
			24 inch + ST	Plus 340 LF, same height.	S		
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure, but need to increase height to 5 feet.	F		
11	6	TraPac lead lines	37 inch	Above 24 inch recommendation also protects asset under 37 inch exposure, however this would require permanent protection, not temporary and would need to increase 420 LF.	F	Y	Planning & Strategy
			37-inch + ST	Provide temporary flood protection along the TraPac lead lines (1180 feet length, 3 feet high).	F		
12	6	West Basin lead lines	37-inch + ST	Provide temporary protection for the West Basin lead tracks (2000 feet length, 3 feet high).	F	Y	Planning & Strategy

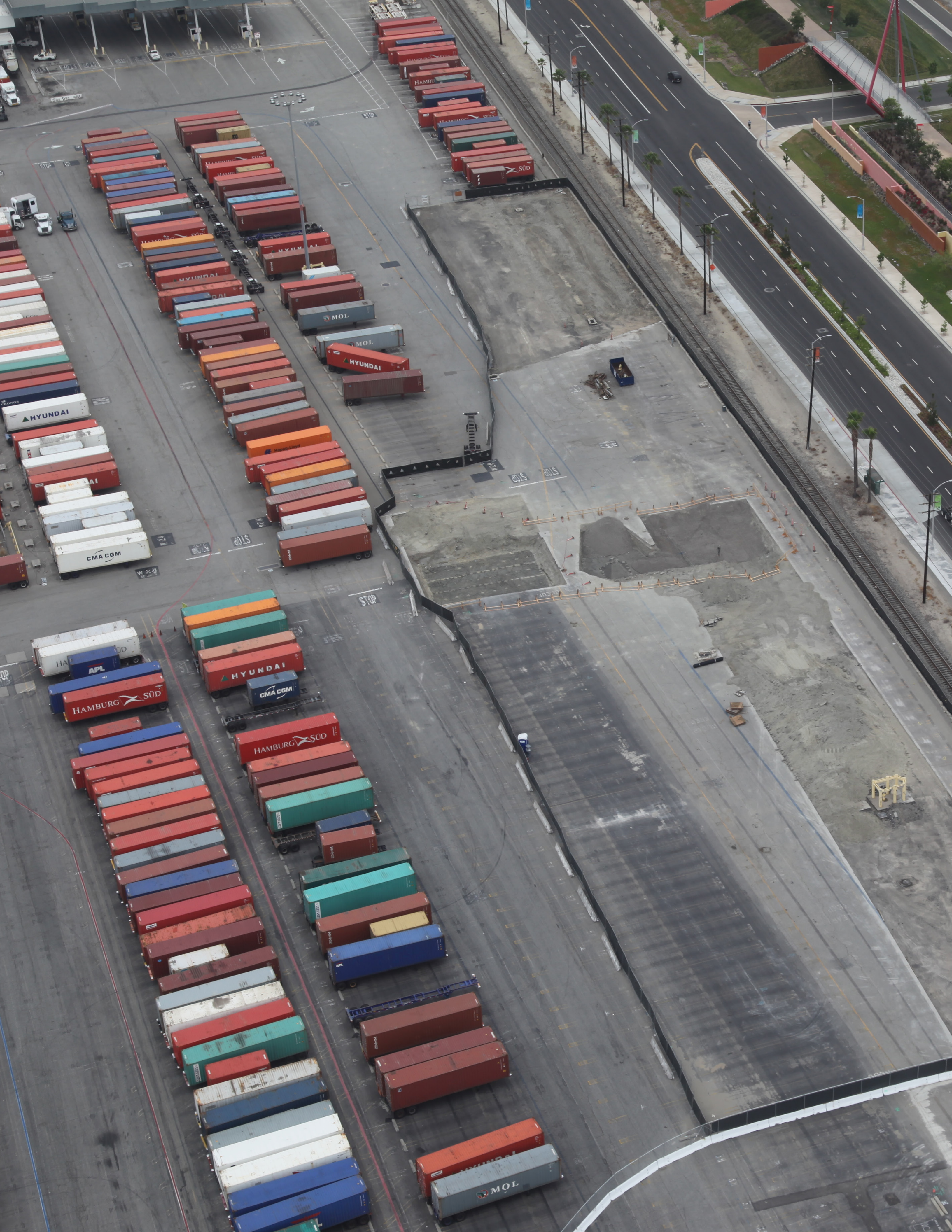
Table 6-7. Infrastructure SLR Adaptation Strategies For Consideration – Community/Commercial Assets

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
1	82	Berth 258-259	12 inch + ST	Provide temporary protection along the east side of the ***Al Larson Boat Shop property*** (400 LF, 3 feet high).	I	N	Planning & Strategy
			24 inch + ST	Plus additional 900 LF and additional 2 feet height.	S		
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
			37 inch	Elevate low portions of the shoreline or erect seawall at along Berth 258-259 to protect against permanent flooding (400 LF, 3 feet high).	F		
2	80	Berth 205D	12 inch + ST	Provide temporary protection around the ***Island Yacht Anchorage 1 building*** (230 LF, 3 feet high).	I	N	Planning & Strategy
			24 inch + ST	Above recommendation also protects asset under 24 inch exposure.	S		
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
3	80	Berth 205C	12 inch + ST	Provide temporary protection around the ***Cerritos Yacht Anchorage building*** (100 LF, 3 feet high).	I	N	Planning & Strategy
			24 inch + ST	Above recommendation also protects asset under 24 inch exposure.	S		
			37 inch + ST	Above recommendation also protects asset under 37 inch exposure.	F		
4	80	Berth 205B	24 inch + ST	Provide temporary protection around the ***Light House Yacht Landing building*** (150 LF, 3 feet high).	S	N	Planning & Strategy
			37 inch + ST	Plus additional 150 LF, same height.	F		
5	62	Berths 81-82	24 inch + ST	Provide temporary protection around the ***San Pedro marina buildings*** (350 LF, 3 feet high).	S	N	Planning & Strategy
			37 inch + ST	Plus additional 250 LF, same height.	F		
6	38	Berth 186	24 inch + ST	Provide sandbags for temporary asset-specific flood protection for ***Banning's Landing Community Center*** (250 LF, 3 feet high).	S	Y	Planning & Strategy
			37 inch + ST	Plus additional 350 LF, same height.	F		
7	80	Berth 201	24 inch + ST	Provide temporary protection around the ***Holiday Harbor-Wilmington building*** (130 LF, 3 feet high).	S	N	Planning & Strategy
			37 inch + ST	Plus additional 100 LF, same height.	F		
8	80	Berth 202	37 inch + ST	Provide temporary protection around the ***California Yacht Marina buildings*** (130 LF, 3 feet high).	F	N	Planning & Strategy
9	80	Berth 200H	37 inch + ST	Provide temporary protection for temporary flood protection for ***Leeward Bay Marina buildings*** (100 LF, 3 feet high).	F	N	Planning & Strategy
10	80	Berth 203	37 inch + ST	Provide temporary protection around the ***Pacific Yacht Marina buildings*** (150 LF, 3 feet high).	F	N	Planning & Strategy
11	80	Berth 204	37 inch + ST	Provide temporary protection around the ***Yacht Centre-Newmarks buildings*** (70 LF, 3 feet high).	F	N	Planning & Strategy;
12	80	Berth 201	37 inch + ST	Provide temporary protection around the ***Yacht Haven Marina buildings*** (30 LF, 3 feet high).	F	N	Planning & Strategy

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
13	62	Berth 74 - 75	37 inch + ST	Provide temporary asset-specific flood protection of the ***Jankovich Company*** infrastructure (500 LF, 3 feet high).	F	N	Planning & Strategy
14	62	Berth 77	37 inch + ST	Provide temporary asset-specific flood protection of the ***Ports O'Call*** infrastructure (2,800 LF, 3 feet high).	F	N	Planning & Strategy
15	62	Berth 79	37 inch + ST	Provide temporary asset-specific flood protection of the ***L.A. Waterfront Sportfishing and Cruises infrastructure*** (300 LF, 3 feet high).	F	N	Planning & Strategy
16	77	Berth 94	37 inch + ST	Provide temporary protection around the ***Catalina Sea and Air Terminal*** (120 LF, 3 feet high).	F	N	Planning & Strategy
17	4	Tip of Westway Liquid Bulk Terminal	37 inch + ST	Provide temporary asset-specific flood protection of ***Municipal Warehouse No. 1*** (1,400 LF, 3 feet high).	F	N	Planning & Strategy
18	4	Berth 57	37 inch + ST	Provide temporary asset-specific flood protection to ***Municipal Fish Market*** (530 LF, 3 feet high).	F	N	Planning & Strategy

Table 6-8. Infrastructure SLR Adaptation Strategies For Consideration – Habitats

#	Area ID#	Focus Area	Exposure Scenario	Strategy	Time-frame: I / S / F	Collective Area?	Harbor Department Champion
1	NA	Port-wide	All scenarios	***Wetland restoration*** - identify area that is unpaved wetland upland that could be restored to brackish water marsh wetland or pickleweed habitat to accommodate for expected loss of these habitats in in Wilmington Marina/East Basin under future SLR scenario.	S	N	Environmental Management
2	55	Sea Plane Lagoon	24 inch	Establish ***Sea Plane Lagoon*** as a mitigation area to promote, enhance, and sustain existing eelgrass, shallow water, and sand habitat for nesting CA least terns (North of Pier 300). Area could become a potential habitat refugia for least tern nesting in light of loss of other habitats to SLR.	S	N	Environmental Management
3	62	Main Channel	37 inch + ST	Identify alternative ***nesting habitat*** within the Port for herons (possible Fresh water marsh) to accommodate persistence of heron nesting under late century SLR. Heron nesting area in Ficas trees near Berth 75-79 are impacted by salt water intrusion, likely leading to a loss of nesting habitat.	M	N	Environmental Management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7 Financial Impact

Introduction

In accordance with AB 691, an estimate of the financial cost of the impact of SLR on its public trust lands was completed.

The cost estimate considers the following:

- Anticipated cost to prevent or mitigate potential damage,
- Cost of repair of damage, and
- Value of lost use of improvements and land.

Methodology and Summary

Anticipated cost to prevent or mitigate potential damage

Governance adaptation strategy costs

The governance strategies can be implemented through the use of staff time (full-time equivalent, also known as FTE). The time, and therefore the cost, to develop and implement these strategies varies, in particular in relation to the number of divisions necessary for coordination; however, even despite these considerations, the overall cost of implementation remains low.

Each SLR adaptation strategy was evaluated and assigned the respective department champion, resource staff cost, and associated duration for strategy implementation.

Initiative adaptation strategy costs

Implementing initiatives is also a relatively low cost. The time, and therefore the cost, to develop and implement these initiatives varies, but all can be implemented using staff hours (FTE).

These initiatives involve various levels of coordination for example, joining climate change coalitions, coordinating with other cities, participating on the CAPA SLR committee, and other POLA divisions; however, the overall cost of implementation remains low.

Each SLR adaptation strategy was evaluated and assigned a department champion, resource staff cost and associated duration for strategy implementation.

Infrastructure adaptation strategy costs

Below is the cost methodology based on the infrastructure strategy type to prevent or mitigate potential damage.

Permanent Adaptation Strategies:

- For permanent flooding, both low and high range cost solutions were evaluated. The low range solution consists of pouring a concrete extension onto the existing concrete cap with dowels to increase the height of the existing wall. The high range cost solution was based on a new, seismically-reinforced king pile, double sheet combination wall.

Temporary Adaptation Strategies:

- For temporary flooding, low, medium, and high cost solutions were evaluated. The low range solution estimate consisted of a tiger dam (3 ft. in height), the medium range solution included sandbags (3 ft. in height), and the high range solution consisted of an aqua fence. This cost estimate was evaluated based on current unit cost information for temporary protection measures.

Roadway Improvements:

- The roadway improvement cost per linear foot considered imported fill based on the height documented in each strategy.

Overview of each asset type

- ***Cargo Wharves and Miscellaneous Operations***
  + Cargo Terminals are not affected until the 66″ SLR scenario. In order to prevent SLR impacts, low–cost, temporary solutions or high–cost, permanent solutions can be implemented. Cost impacts would be further analyzed in the future.
  + Liquid Bulk Terminals are affected at the 12″ ST scenario; therefore, it is recommended that low–cost, temporary solutions are implemented. For long term management of ST impacts, high–cost, permanent solutions could be implemented.
  + Other terminals would be affected at 24″ ST scenarios. A low-cost, temporary solution could be implemented at this time or a high–cost, permanent solution.
- ***Critical Facilities*** are first affected at the 24″ ST scenario. The cost for implementation of solutions to protect these facilities range from low–cost, temporary solutions to high–cost, permanent solutions.
- ***Transportation rail network*** is first temporarily affected at the 12″ ST scenario and permanently at 66″. The prevention strategy to protect this asset involves raising the rail in and around this location. The cost to implement this strategy is high.
- ***The transportation roadway network*** is first temporarily affected in some areas at the 12″ ST scenario, and permanently at 37″. The prevention strategy to protect these assets in order to maintain port operations is to raise the road in this scenario. The cost to implement this strategy is high.
- ***Community/Commercial Assets*** are first permanently inundated at 37″ SLR. The cost for implementation strategies to protect these facilities range from low–cost, temporary solutions to high–cost, solutions.
- ***Natural Habitats*** and the financial costs associated with SLR and storm tide are, at this time, difficult to estimate. Further research is required.

Cost of repair of damage

A qualitative estimate was prepared for the repair cost for temporary inundation and is shown below in Table 7-1 (note: permanent inundation would be mitigated by implementing strategies to fully retreat and/or reconstruct at replacement cost).

Table 7-1. Cost of Repair

Cost of Repair (Temporary Inundation) *	
Low	Minimal damage, minor replacement of assets
Medium	Varied assets damaged, some replacement of assets
High	Major high value infrastructure damaged, full replacement necessary
*Permanent Inundation would require retreat and/or full replacement cost	
Cargo Terminals	Medium/High**
Critical Facilities	Medium/High**
Transportation Networks	Medium/High**
Community/Commercial Assets	Medium
Natural Habitats	Low/Medium**
**Cost of repair from temporary inundation can vary greatly depending on the extent of the damage and specific asset that needs repair.	

Cost of repair greatly depends on the scope of infrastructure that is damaged. For example, the transportation network damage may require a roadway asphalt section replacement which could be a medium cost, however, a damaged bridge section would require major reconstruction and would be a high cost. For critical facilities if an electrical transformer is damaged it would require replacement which would be high. If any pump station is flooded this could cause damage upstream to POLA facilities therefore resulting in a high repair cost.

Value of lost use of improvements and land

A qualitative estimate was prepared for the Value of Lost Use for each adaptation strategy defined by the criteria shown below in Table 7-2.

Table 7-2. SLR Adaptation Strategy Cost Summary

Value of Lost Use	
Low	No loss of critical assets and infrastructure. Port Operations are maintained.
Medium	Temporary loss of critical port assets and operations
High	Impacts to Life & Safety. Loss of critical port assets and infrastructure. Loss of Transportation Network. Impacts to high value cargo.

Cargo Terminals were ranked as High in terms of the value of lost use because container terminals, liquid bulk terminals, and other terminals – such as breakbulk terminals, port pilots, and tug boats – are a major source of the POLA revenue.

All critical facilities are considered High for value of lost use. This rating results from the fact that critical facilities, such as electrical substations, fire stations, and pump stations, are essential to maintain port operations that are the major source of POLA revenue.

Transportation networks were determined to be a High value of lost use. Several roadways serve as primary routes for trucks carrying cargo and passengers to access facilities. Rail cargo makes up approximately 40% of the Port's revenue, and if the access to road and rail facilities is impeded, the value lost would be significant.

Community/commercial assets were determined to have a Low value of lost use mainly because these areas are not critical to maintain POLA operations. Natural habitats were also found to have a Low value of lost use because port operations can still be maintained even if these areas are affected. Nevertheless, community/commercial assets and natural habitats are valued by the Port, and will be further studied in the future.

8 Next Steps

Introduction

The purpose of this chapter is to guide the implementation of the proposed adaptation strategies. Based on all of the adaptation strategies, a top 10 recommended actions list was developed for the next 5 years considering timeframe, influence/impact, and feedback from the stakeholder workshop. These actions are listed in no particular order.

Top 10 recommended actions

1. Monitor SLR science and State Guidance updates every 5 years and reevaluate the list of vulnerable assets if necessary (Governance Strategy #7).
2. Add language regarding SLR and potential impacts and adaptation strategies to policy, planning documents, and design guidelines, which will ensure that SLR considerations are included in future design projects (Governance Strategy #1).
3. Create a SLR Adaptation Working Group with stakeholders from all relevant Divisions, which will help guide the implementation of adaptation strategies (Initiative Strategy #9).
4. Complete a study to determine the most appropriate temporary flood protection options (e.g., sandbags, self-inflating sandless bags, Aquafence, Tiger Dams, etc.), storage, cost, erection, and maintenance. This preemptively prepares the Port for a future storm event (Initiative Strategy #2).
5. Develop a general one-page SLR vulnerability zone map, which will be a tool and reference for Port staff and tenants to help determine if future projects are exposed to SLR (Governance Strategy #2).
6. Update new terminal lease requirements to reference this SLR Adaptation Plan to highlight to tenants that they may be located in an area that is vulnerable to SLR and provides tenants the opportunity to think about adaptation strategies early (Governance Strategy #5).
7. Collaborate with tenants (terminal and community/commercial assets) that have assets in areas that are potentially exposed under the 12 inch SLR scenario to determine if individual asset temporary/permanent SLR protection measures are appropriate, and whether a collective approach would be more appropriate (Initiative Strategy #8).[15]
8. Identify funding opportunities that would support implementation of SLR adaptation strategies (Initiative Strategy #7).
9. Monitor and inventory natural resources and existing habitats (wetlands, subtidal, species, etc.) and identify strategies to protect, enhance, and adapts to future sea level rise (Governance Strategy #11).
10. Participate in the CAPA (California Association of Port Authorities) Sea Level Rise group (Initiative Strategy #5).

15 Under review for approval prior to publishing Plan

Additional Recommendations

This SLR Adaptation Plan includes several more governance, initiative, and infrastructure adaptation strategies that should be evaluated in the future based on proposed projects, funding opportunities, and Port priorities (see Chapter 6 Adaptation Strategies).

Key considerations to determine the implementation of additional adaptation strategies include:

- Timing of impact
- Life safety
- Criticality
- Magnitude of consequence (damage, disruption, and/or repair cost)
- Ease of implementation
- Opportunity to improve multiple assets
- Completes data gaps
- Collaboration and outreach
- Available funding

Summary

This chapter highlights the top 10 recommended actions to begin to incorporate SLR considerations and address key vulnerabilities. These actions provide a short term roadmap to help ensure that the Port is more resilient, prepared, and ready to adapt to SLR. Additional adaptation strategies are provided and shall be further evaluated at a later date.

Appendix A
Additional Methodologies & Sources

Inventory Detailed Methodology & Sources

A summary of the inventory methodology is included in Chapter 3 Inventory. This appendix focuses on the detailed methodology and sources.

The inventory is organized by asset type and was completed in Excel format:

- Cargo Wharves & Other Misc. Operations,
- Critical facilities (including critical electrical infrastructure),
- Transportation (roads and rail),
- Community/Commercial assets, and
- Natural habitats.

Each of the assets includes the following classifications:

1. Critical (Life Safety): includes all Los Angeles Fire Department and Port Police Department facilities, the Port Pilots Station, main access roadways, bridges, pump stations and critical electrical infrastructure.
2. Important (Business / Value / Economy): assets are important for economic value but not life safety and primarily include cargo wharves and terminals.
3. Important (Community / Nature): assets are important to the community and natural habitats, but not from a life safety perspective.

Cargo Wharves & Miscellaneous Operations

The Cargo & Misc. Ops Wharves inventory contains detail on berths with cargo operations, as well as miscellaneous operations and services which take place on or near wharves which are primarily related to cargo activity, such as tugboats, bunkering, warehouses, etc.

The following data was collected:

- ***Critical Port Asset:*** categorization is based on the three Critical Asset classifications. Most assets on this worksheet are category 2 based on their economic value.
- ***Facility Information:***

  + Cargo type (applicable to cargo terminals only),

  + Berth numbers, and

  + Tenant(s).
- ***Terminal Functional Characteristics:*** Terminal volumes are proprietary and thus data was not available. See the following section for a summary of the methodology used to estimate terminal volumes and annual cargo value based on publically available information. Categories included in the Terminal Functional Characteristics section include:

  + Estimated terminal volume,

  + Acreage,

+ Berth length and height,

+ Percentage of cargo via truck, rail, or pipeline, and

+ Estimated annual cargo value moved.

- ***Wharf Assets:*** Includes eighteen categories of types of wharf assets and indicates whether or not they are present. Information was sourced primarily from 2014-05-01_ POLA Wharf Assets.xls and aerial imagery. Wharf Asset categories include:

  + Type of wharf pile structure,

  + Quay walls,

  + Rock dikes,

  + Fender systems,

  + Alternative Marine Power,

  + On-dock rail, and

  + Cargo loading / unloading equipment.

- ***Backland Assets:*** Includes thirteen categories of backland asset types and indicates whether or not they are present at each terminal, including:

  + Pavements,

  + Contaminated materials storage,

  + Gate facilities,

  + Buildings, and

  + Various types of cargo storage.

- ***Utilities:***

  + Water distribution systems,

  + Sewer pumps/lift stations,

  + Storm drain conveyance or pump/lift stations

  + Electrical distribution systems,

  + Lighting systems,

  + Communication systems, and

  + Security systems.

Terminal Volume & Value of Cargo Methodology

Terminal-specific volumes were estimated primarily using Port-wide throughput data. The primary purpose of estimating terminal-specific volumes is to have a basis to assess the relative economic value of the cargo moving through each terminal based on the typical unit cost of each commodity type. These were rough order of magnitude figures to estimate which facilities would have the greatest economic impact if affected by sea-level rise.

The terminal volume estimation methodology for each commodity type is as follows:

- ***RoRo:*** All CY 2015 RoRo volume was assigned to the WWL Vehicle Services Americas terminal.
- ***Dry Bulk:*** 1.4M metric tons of dry bulk in FY 2015, which was divided among the three dry bulk terminals by proportional terminal area.
- ***Liquid Bulk:*** 10.3M metric tons of liquid bulk in FY 2015, which was divided among the seven liquid bulk terminals based on terminal priorities. Vopak was assigned 33% of the Port's volume, followed by Shell at 30%. The medium terminals, ExxonMobil, Kinder Morgan, and Valero were assigned 10%, 9%, and 8%, respectively. Phillips 66 and NuStar were each assigned 5%.
- ***Breakbulk:*** No total breakbulk throughput data is available. Dry bulk throughput density for FY 2015 averaged 36,000 metric tons per acre. For a rough order of magnitude estimate, the project team calculated estimated 11,800 tons of breakbulk per acre as breakbulk operations are typically less efficient than dry bulk operations. The Berth 206-209 facility is estimated to have 80% of this level due to its large size and to account for portions of the terminal being used for non-breakbulk activity.
- ***Mixed:*** Berth 46 has minimal cargo activity. It is analyzed as a breakbulk operation with a 20% utilization factor to estimate volume (11,800 tons per acre * 24 acres * 20% = 57,000 tons).
- ***Passenger:*** 592,335 passengers in CY 2015, which was divided among the two terminals by terminal area.
- ***Containers:*** Compiled year 2045 projected terminal volumes for all container terminals. The proportional volume split (individual terminal percent of Port-wide total) was applied to the CY 2015 8.2M annual TEU throughput to estimate individual container terminal volumes. Pier 400 was further split into APM vs. CUT throughput based on terminal area (note: Subsequent to this study, CUT vacated location).

The following values per cargo unit were used for each cargo type:

- ***RoRo:*** $20,000 per vehicle.
- ***Dry bulk:*** $130/ton per Port guidance.
- ***Liquid bulk:*** The December 2016 price of approximately $52 per barrel of oil from www.oil-price.net, converted to $364 per metric ton using seven barrels per metric ton
- ***Breakbulk and Mixed:*** $2,880 per ton assuming breakbulk is similar per-ton to containerized cargo and about 10 tons per TEU.
- ***Passenger:*** $500 per passenger assuming a mix of short cruises around $200 per person and longer cruises of around $2,000 per person.
- ***Containers:*** $28,800 per TEU ($236B of containerized cargo in 2015 at 8.2M TEU).

Critical Facilities

The Critical Facilities inventory contains a list of names and locations of assets considered critical to public safety. Designated critical facilities should be provided a higher level of protection so they can continue to function and provide services during a flood event (or shortly afterward).

This section of the inventory includes five fire stations (four with boats), the US Coast Guard Base, the Los Angeles Port Police Headquarters, the US Department of Justice Federal Correctional Institution, the Los Angeles Pilots Station, tugboat companies, the Marine Exchange of California, Avalon Freight Services, and the World Cruise Center. It also includes nine pump plants/ stations and sixteen electrical assets (substations and transformers).

The list of critical assets was developed based on which assets were most important from a public and life safety perspective. The list of pump stations and electrical infrastructure were given by Port staff.

Transportation – Road and Rail (RO and RA)

Road

The Transportation – Road inventory contains a list of roadways broken down by segments, sourced entirely from a document titled "POLA Street inventory-condition-10-12-2016.pdf". For each Roadway segment, the following information is provided:

- From street,
- To street, and
- Rank (Primary, Secondary, or Tertiary).

The following section, Berths, indicates each berth segment broken down geographically and will indicate which roadways are required to serve each berth segment.

The next section contains a column for key critical facilities for which access must be maintained, and indicates whether each roadway segment is required for ongoing operation at each critical facility. Primary roadways and those which connect to a Critical Facility are categorized as category 1 critical assets for life safety.

Rail

The Transportation – Rail inventory contains a list of rail infrastructure at the Port and its classification, sourced from the 2013 SP Bay RR Map. As with the Road inventory, the following section, indicates each berth segment broken down geographically, and indicates which rail link serves each berth segment.

Community/Commercial Assets

The community/commercial assets inventory contains a list of assets on Port property which are used by the general public, including public marinas, harbors, and anchorages, markets, parks, museums, and other public facilities of value to the local community. The list of community/commercial assets was developed using a combination of sources, including a listing of public marinas and harbors, Points of Interest on the LA Waterfront, and the AAA map of the Port area from 2015. A location is provided for each community asset, generally including either its berth location or the nearest berth to the asset; in a few cases a street address is provided.

Information regarding planned community/commercial assets such as the Downtown Harbor Project and the Wilmington Waterfront Promenade was also included in the inventory.

Natural Habitats (NH)

The Natural Habitats inventory contains a list of habitats within the Port area. It was sourced primarily from a map titled "Biologically Sensitive Areas.pdf", along with Chapter 9 of the February 2014 Port Master Plan.

Eighteen total habitats are included in the inventory, with the type and approximate location of each indicated. Habitats types include a salt marsh, a least tern habitat, eelgrass beds, shallow water habitats, a fresh water marsh, a brackish water marsh, kelp beds, coastal scrub, ficas trees (heron nesting), native plants, pickleweed, and a sand habitat area. Some habitat types are listed multiple times to identify multiple locations.

All Wharves – Asset Lifespan

The All Wharves - Asset Lifespan inventory is provided for reference purposes only. It primarily contains a list of various types of wharf assets, backland assets, and utilities and typical lifespans for each. This information is for reference in assessing the vulnerability of various types of assets to sea level rise and identifying strategies to adapt vulnerable assets as they approach the end of their usual lifespan.

Tenants

The Tenants inventory contains a list of Port tenants, their mailing address, and their location on Port property. The information is based on two documents, one titled "Port of Los Angeles information for Southern California Ports Handbook – as of 12/10/15", and the other "Port of Los Angeles - Berth Occupancy", dated 06-2015.

Vulnerability Assessment Detailed Methodology & Sources

A summary of the Vulnerability Assessment methodology is included in Chapter 5 Vulnerability Assessment. This appendix focuses on the detailed methodology and sources.

Using the Port inventory, individual assets within each infrastructure category have been assessed for exposure, sensitivity, and adaptive capacity. The potential consequences of inaction to SLR exposure has also been evaluated.

Step 1: Exposure Analysis

The exposure analysis evaluates an asset's susceptibility to projected future water levels, including permanent inundation by average daily high tides and temporary flooding by storm tides. The mean higher high water datum (MHHW) is used to represent the average daily high tide. Storm tide is defined as a temporary increase in water levels due to a combination of storm surge, precipitation runoff, and large tide events and is represented by the 100-year stillwater elevation (SWEL).

The SLR inundation maps have been used to evaluate exposure based on the time horizons for 2030, 2050, and 2100. For each asset, exposure is rated from very low to high to highlight the timing and extent of flooding and inundation.

- **Exposure to average daily high tide + SLR:**
  - + (VL) Very Low exposure = 66-inch SLR + Average Daily High Tide by 2100
  - + (L) Low exposure = 37-inch SLR + Average Daily High Tide by 2100
  - + (M) Medium exposure = 24-inch SLR + Average Daily High Tide by 2050
  - + (H) High exposure = 12-inch SLR + Average Daily High Tide by 2030

- **Exposure to storm tide + SLR:**
  - (VL) Very Low exposure = 66-inch + Storm Tide by 2100
  - (L) Low exposure = 37-inch SLR + Storm Tide by 2100
  - (M) Medium exposure = 24-inch SLR + Storm Tide by 2050
  - o (H) High exposure = 12-inch SLR + Storm Tide by 2030

Step 2: Sensitivity Analysis

The sensitivity analysis evaluates the degree to which an asset is affected by its exposure to inundation or flooding. For example, an asset is considered sensitive to flood waters if its function or construction materials can be impaired or damaged from being wet (wood structures are damaged more readily from water contact than concrete and are therefore more sensitive).

For each asset, sensitivity has been assessed qualitatively based on a set of considerations unique to each asset category. Assets found to be sensitive to the consideration receive a "Yes" and those that are not found sensitive receive a "No." The following characteristics would make an asset sensitive to SLR:

- **Terminals**
  - **Aged condition of infrastructure** (Assumes that terminal, including cranes, wharfs, etc. was not recently constructed and is more likely to be damaged with inundation; may need to be replaced/upgraded by 2050). Assessed through a combination of historical experience at POLA and through the use of historical Google Earth imagery; assets which have been constructed within the last 20 years were assumed to not be aged.
  - **Electrical equipment** (Inundation of electrical equipment may lead to operation malfunction or damage to asset). All terminals are assumed to have some electrical equipment.
  - **Buildings** (Buildings are likely to house equipment on lower floors that could be damaged if exposed to flooding).
  - **Liquid bulk storage** (Potential for contamination if liquid bulk storage is exposed to flooding)
  - **Cargo storage** (Cargo containers are not flood-proof and may contain goods that could be damaged if exposed to flooding). Includes non-liquid bulk cargo types (containers, dry bulk, breakbulk, and RoRo).
  - **Railyard** (A railyard with parked trains is more sensitive because the locomotives may be damaged if inundated). Includes all terminals with physical rail infrastructure on the terminal, e.g. excludes the China Shipping Terminal which has rail cargo but uses the railyard on the Yang Ming side of WBCT.
  - **Stormwater system** (Pump stations may be damaged if inundated) Note: Water distribution and sewer are generally not impacted because they are closed systems.
- **Critical Facilities**
  - **Aged condition of facility** (Assumes that facility was not recently constructed and is more likely to be damaged with inundation (may need to be replaced/upgraded by 2050). Assessed through the use of historical Google Earth imagery; assets which have been constructed within the last 20 years were assumed to not be aged.
  - **Life Safety assets** (Such as fire stations, security, command centers, pilot station)
- **Transportation Network (rail and road)**
  - **Electrical equipment** (Inundation of electrical equipment such street lighting, traffic signals, signage and train signal systems may lead to operation malfunction or require replacement)
  - **Aged substructure condition** (Roadbed of rail was not recently constructed and is more likely to be damaged or subside if exposed to flooding; roadways with a pavement condition index (PCI) of less than 50)
  - **Primary roadway** (Primary roadways are more sensitive because they connect critical nodes. Roadways designated as primary by the Port) – relevant only for roadways.
  - **Life safety access** (Roadways that connect to life safety structures or are the only access points for personnel are more sensitive because they need to function 24/7) – relevant only for roadways.

- **Community/Commercial Assets**
  + **Aged condition of asset** (Assumes that community asset was not recently constructed, is more likely to be damaged with inundation, and/or may need to be replaced/upgraded by 2050). Assessed through a combination of historical experience at POLA and through the use of historical Google Earth imagery; assets which have been constructed within the last 20 years were assumed to not be aged.
  + **Buildings** (Buildings are likely to house equipment on lower floors that could be damaged if exposed to flooding)
  + **Electrical equipment** (Inundation of electrical equipment may lead to operation malfunction or loss of asset)
- **Natural Habitats:**
  + **Threatened or endangered species** (Threatened or endangered coastal species often have specific habitat requirements that are in low-lying areas that would be vulnerable to permanent inundation and/or temporary flooding)[16]
  + **Susceptible to increased frequency, duration, or depth of saltwater inundation** (Many habitats have a narrow tolerance for salinity and water depth changes and, if exposed, may experience degradation or complete loss)

Step 3: Adaptive Capacity Analysis

The adaptive capacity analysis evaluates the asset's inherent ability to adjust to SLR in order to maintain its primary functions. An asset has a high adaptive capacity when its design or function allows for relatively easy retrofits that provide protection against damage from flood hazards. An asset does not need to have the same appearance as before the impact, but it must provide the same services and functions as it did before the impact occurred. For example, a seawall that is designed with panel extensions or having a foundation to support the additional loads of higher water levels would be considered to have higher adaptive capacity.

For each asset, adaptive capacity has been assessed qualitatively based on a set of considerations unique to each asset category. Assets meeting the considerations receive a "Yes" and those not meeting the considerations receive a "No." The following characteristics would contribute to greater adaptive capacity of an asset:

- **Terminals / Transportation Network / Critical Facilities / Community/Commercial Assets**
  + **Ability to elevate infrastructure** (Existing asset can easily be raised to reduce vulnerability to flooding).
    » Terminals: Physical infrastructure can technically be elevated, but it is difficult and expensive to do so, therefore this is a no for all terminals.
  + **Ability to relocate infrastructure** (Asset can be moved to higher elevation or outside of floodplain to protect from flood damage).
    » Terminals: Physical infrastructure can technically be relocated, but it is difficult and expensive to do so for large equipment such as dock cranes, therefore this is a no for all terminals, except the WWL Services America RoRo facility.
  + **Redundancy** (Multiple access paths to the asset, presence of back-up generator, or other means to provide an asset substitution).
    » Terminals: There is no redundancy for liquid bulk berth operations in a storm surge scenario because there may not be storage immediately available at other liquid bulk terminals for the product types needed. This will lead to liquid bulk vessels being unable to load or offload product if its original destination terminal is unavailable. There is also no redundancy for RoRo as there is currently only one RoRo terminal at the Port. All dry bulk terminals also handle unique commodity types that cannot be mixed and thus also do not have redundancy. Breakbulk and container cargo types can be worked at alternate facility locations and thus do have redundancy. The two passenger facilities are also unique, particularly the Catalina Sea and Air Terminal, which is Catalina Island's primary source to receive supplies from the mainland.
    » **Misc. Operations & Services:** For tugboat and fueling ship services, ability to elevate and relocate is considered not applicable as waterborne infrastructure such as ships are mobile.

16 The California Department of Fish and Wildlife (CDFW)'s Natural Diversity Database (CNDDB) and USFWS' Information for Planning and Conservation (IPaC) were queried for State and federally listed threatened and endangered species with potential to occur within the Port.

- **Natural Habitats**
  - + **Similar habitats nearby** (Nearby area that could support refugial communities currently dependent on asset)
  - + **Ability for habitat to be resilient to changes and recover from individual extreme events** (Some habitats are better able to withstand climatic changes and individual extreme events, which is in part due to species composition and diversity)
  - + **Habitat can migrate landward or vertically in response to SLR** (Some habitat types can naturally transition landward to accrete vertically to maintain function, if space allows)

Consequences

Consequence considers the magnitude of the impact that may occur under selected SLR and storm tide scenarios. Reviewing the consequence of failing to address SLR is useful in prioritizing assets for adaptation planning. SLR poses a broad range of consequences to the Port. Generally these risks are estimated with goods and services where market prices are available, allowing for measurement of economic vulnerability. However, coastal environments, including public trust lands like beaches and wetlands that are vulnerable to SLR should also be considered, as they provide a number of important ecological, social and cultural services that do not have an explicit market price.

For each asset, consequence has been assessed qualitatively based on a set of considerations. Assets meeting the considerations receive a "Yes" and those not meeting the considerations receive a "No." This assessment considers consequence using the following factors:

- **Potential Economic damage[17]:**
  - + **Asset damage** (Electrical or mechanical systems may be damaged from flooding)
  - + **Cargo damage** (Containers are not waterproof and may contain goods that will be damaged by flooding)
  - + **Operation Disruptions** (Flooding of some Port assets may cause lost revenue due to facility limitations or closure)
- **Potential Social impacts:**
  - + **Loss of jobs** (A Port closure, even if temporary, could affect direct and indirect Port employees with negative consequences for working families)
  - + **Loss of public access to the coast** (The Port funds and maintains public waterfront that attracts visitors and serves many communities in the area)
- **Potential Environmental damage:**
  - + **Conversion or loss of wetland and beach habitat** (Many existing habitats may be outpaced by SLR and may face deterioration or complete loss due to inundation)
  - + **Reduction in water quality** (Flooding could expose coastal waters to toxic soils or hazardous materials at the Port)
  - + **Loss of beach buffering against waves** (Beaches that cannot migrate landward due to SLR will gradually become inundated, exposing backshore infrastructure to waves and ship wake)

17 In addition to the qualitative assessment for consequences, the Port will be performing quantitative cost analysis associated with economic damages. Once this is performed, the dollar values could be used to refine the consequence analysis, e.g. providing low, medium, or high rating for the three economic damage factors.

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