COAST & HARBOR
ENGINEERING

Oil Spill Analysis for WesPac Pittsburg Energy Infrastructure Project EIR Pittsburg, CA

1. Introduction

The following Technical Memorandum describes analysis performed by Coast & Harbor Engineering, Inc. (CHE) as a subconsultant to Reese-Chambers, Inc. (Reese-Chambers) in support of EIR efforts for the City of Pittsburg for the proposed WesPac Marine Terminal modernization and reactivation. The Scope of Work included coastal engineering analysis, hydrodynamic numerical modeling of San Francisco Bay, San Pablo Bay and Suisun Bay tidal and river current circulation, modeling of oil spills at the terminal and spill trajectory analysis. The modeling assumptions, methodology and overall approach employed in the study were approved by CA State Lands Commission (CSLC) and are motivated by and responsive to CSLC comments dated August 26, 2011 regarding the NOP issued on July 21, 2011. The study methodology and assumptions were developed with input and concurrence from CSLC. The WesPac Marine Terminal is located north of the City of Pittsburg in Suisun Bay, as shown in Figure 1.

Figure 1. WesPac Marine Terminal project site location

2. Development of Hydrodynamic Conditions

Previous project experience and analysis of previous oil spill analysis results within the San Francisco Bay system indicated that tidal and river current circulation dominate the transport of oil from marine spills and potential shoreline impacts. The vast majority of the spilled material is likely to be beached within very short time periods. Winds and wind-waves, while potentially affecting transport during strong wind conditions, are not statistically likely to result in important changes to spill impact probability maps. It was determined prior to the study and coordinated with CA State Lands Commission that inclusion of only Bay-wide tidal and river current hydrodynamics was appropriate for the analysis.

CHE performed numerical modeling of tidal and river current circulation in the San Francisco Bay system (including San Pablo Bay and Suisun Bay) and a portion of the Bay Delta using the three-dimensional (3D) hydrodynamic model SELFE (Baptista et al., 2005). The San Joaquin River extension in the model reached approximately 20 miles upstream from the proposed WesPac Marine Terminal. The Sacramento River extended approximately 38 miles upstream from the proposed WesPac Marine Terminal, and the western boundary of the domain was extended into the Pacific Ocean approximately 45 miles offshore of the Golden Gate. The model resolution ranged from approximately three miles in the offshore areas to approximately 150 ft near the WesPac Marine Terminal and in other areas of interest. Figure 2 shows the Bay-wide modeling grid.
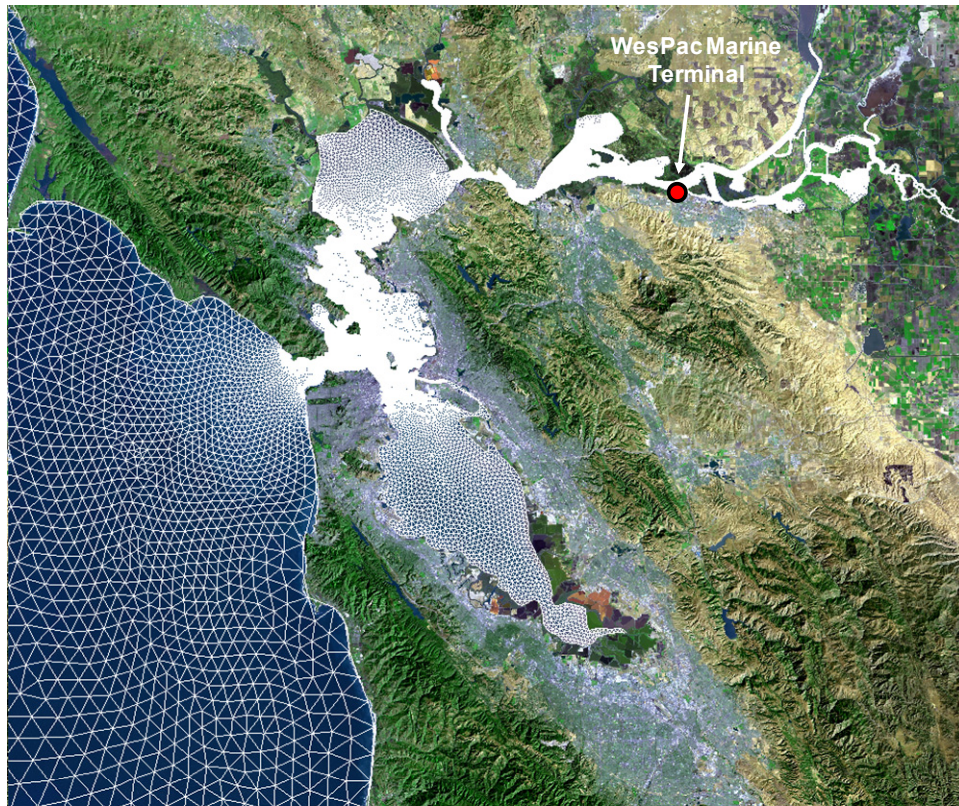

Figure 2. Bay-wide numerical modeling grid

The SELFE model was previously validated using measured current data at the Richmond Bridge and predicted water surface elevation data at Point San Pedro. The validation is shown in Figure 3 through comparison of model results with these measured currents and predicted tides. The comparison indicates that the SELFE model provides an accurate representation of the Bay tides and tidal currents.
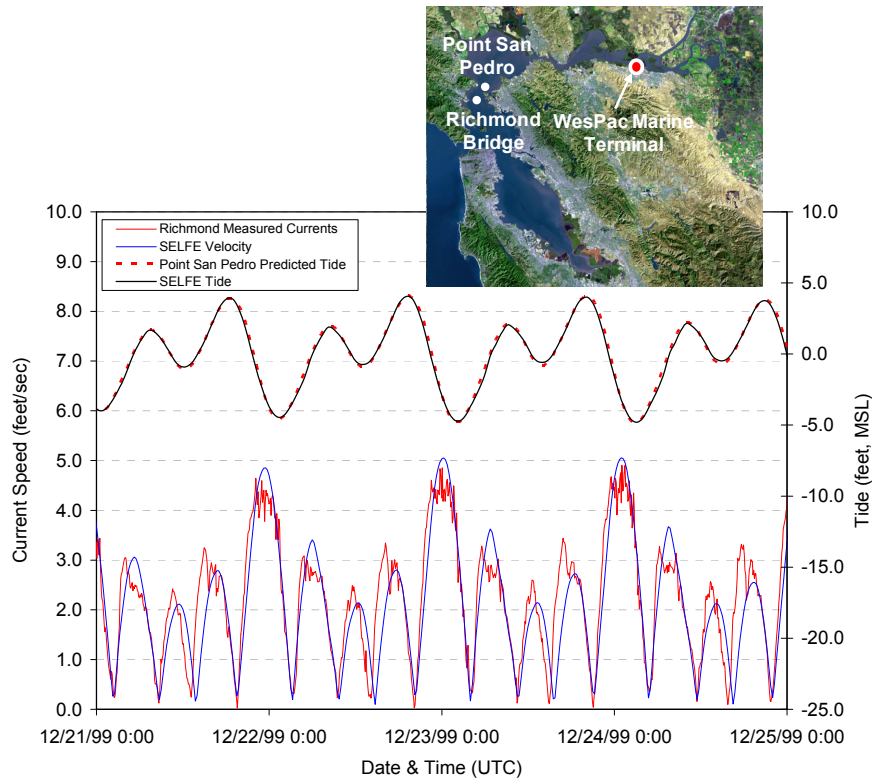

Figure 3. SELFE validation with measured current data at the Richmond Bridge and predicted water surface elevation data at Point San Pedro

The SELFE model was forced with predicted tidal constituents (Le Provost, 1994) at the ocean boundary and river flows (discharges) at the San Joaquin River and Sacramento River boundaries that capture the complete predicted Delta influx. The model was run for two different periods, the "winter" period (12/1/96 to 3/17/97) and the "summer" period (3/18/97 to 4/1/97). The winter period was chosen to represent time periods with both low and high river discharges, and the summer period was chosen to represent only periods with low river discharge and hence tidally-dominated circulation. River discharges in the form of complete Delta freshwater influx were extracted from results of the DAYFLOW model (California Department of Water Resources, 1978). Figure 4 shows the time history of river discharge (complete freshwater influx) that was used as input to the SELFE model. Salinity was not included in the hydrodynamic modeling simulations.

SELFE surface velocities were used as input to the OILTOX oil spill model described in Section 3.1. Figure 5 shows an example of ebb depth-averaged results on a Bay-wide scale

during the summer simulation, and Figure 6 shows ebb surface flows in the vicinity of the WesPac Marine Terminal during the winter simulation.
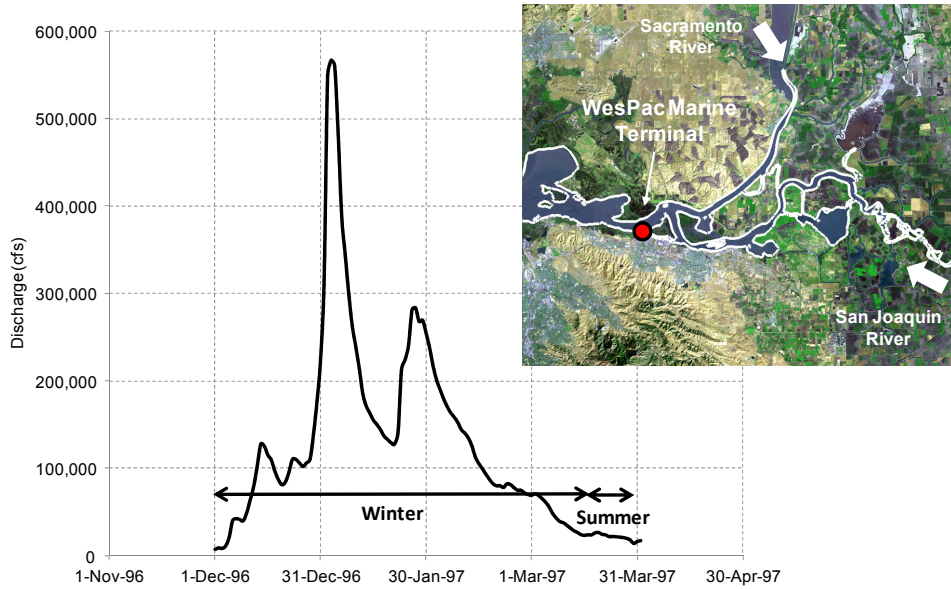

Figure 4. Complete freshwater influx from DAYFLOW model used as input to the SELFE model
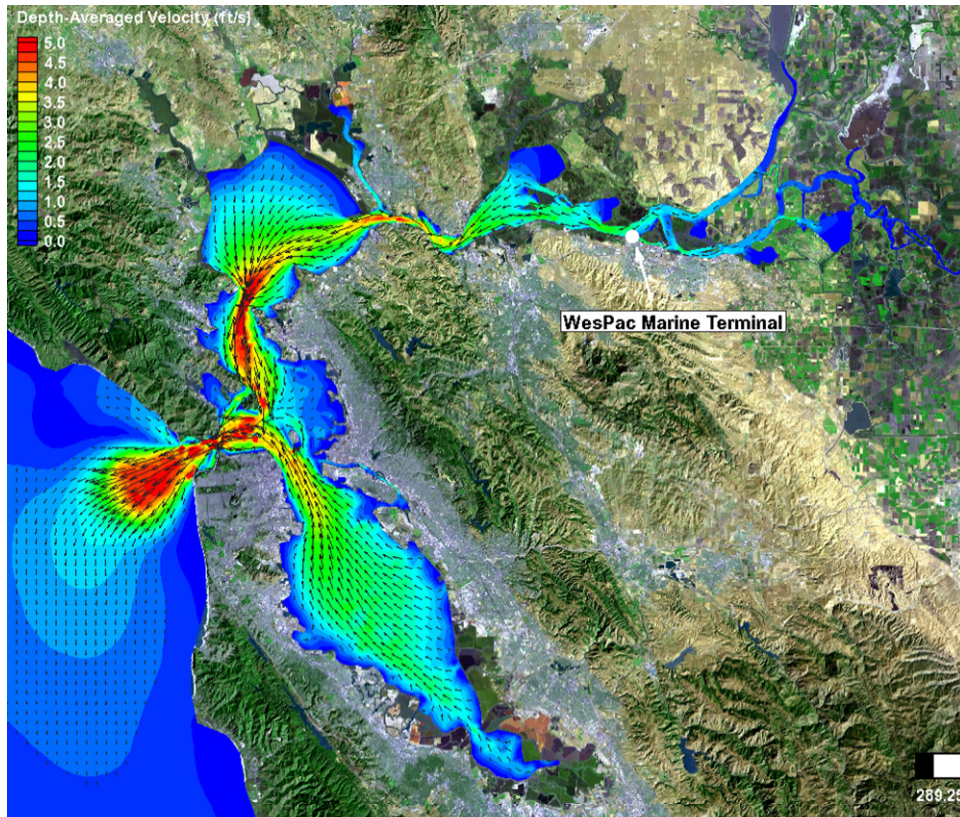

Figure 5. Bay-wide SELFE depth-averaged velocity example results for summer simulation during peak ebb currents
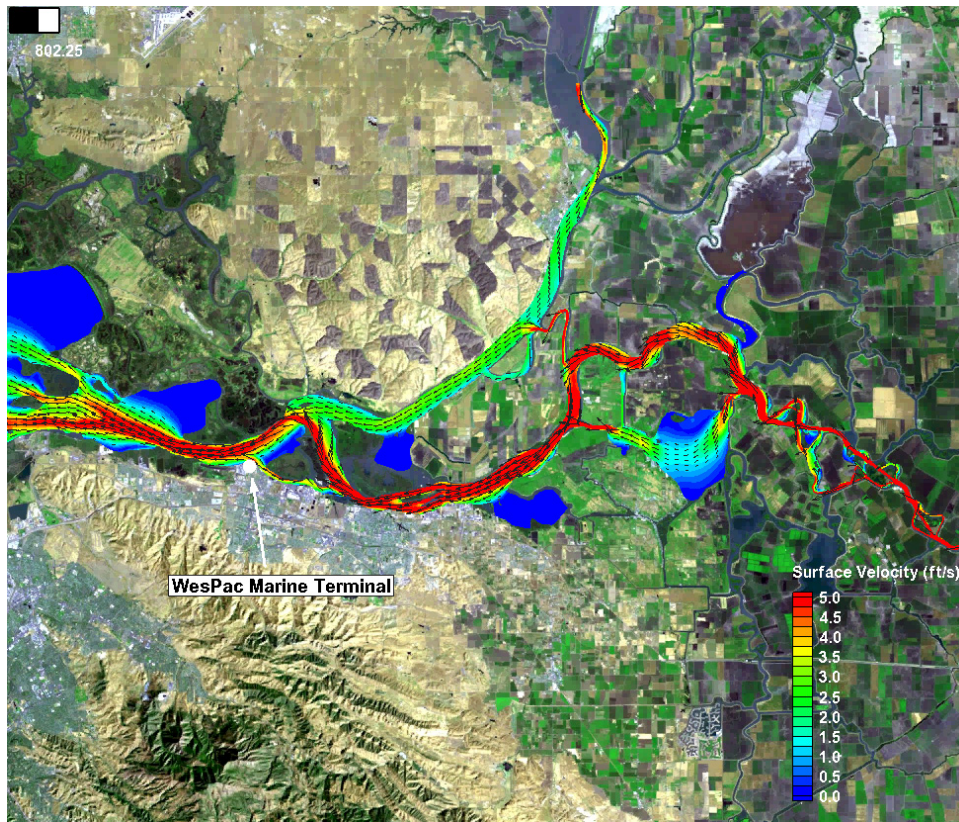
Figure 6. SELFE surface velocity example results for winter simulation during peak ebb in the vicinity of the WesPac Marine Terminal

3. Oil Spill Modeling and Trajectory Analysis

CHE performed analysis of oil spills at the WesPac Marine Terminal to assist the project team in evaluation of potential environmental impacts. Modeling of oil spills at the terminal was performed using the proprietary model OILTOX (Brovchenko and Maderich, 2002).

3.1. OILTOX Model Description and Methodology

OILTOX is a Lagrangian model that describes the main transport and weathering processes of oil spills, including spreading due to gravity and surface tension forces, transport by surface currents, evaporation and oil-shore interaction. Oil spill dynamics are simulated using a Lagrangian (i.e. particle tracking) approach. In this approach the surface oil is modeled as a collection of "particles", which have spatially distributed mass. To simulate oil spreading, an approach based on the Smoothed Particle Hydrodynamics (Hockney and Eastwood, 1981) is used. The water velocity is decomposed in a deterministic advective component and a random component, which is caused by horizontal turbulent diffusion. The advective velocity component is taken from the SELFE hydrodynamic model results. The random component is

simulated using the random walk method. An experimental relation (Okubo, 1971) was used for the coefficient of horizontal diffusion. A simple empirical approach (Fingas, 1999) was used to describe evaporation. It is assumed that the fraction of evaporated oil depends only on temperature, time and oil properties. The changes in mass of particles due to evaporation are simulated by "birth" or "death" of particles to satisfy the mass conservation equation. The shoreline is represented as a sequence of straight line segments with shore type attributes; each particle moves until it "crosses" one of the shoreline segments. After the particle has been beached, it may remain on the shore or refloat after a specified time depending on the shoreline type. The refloating algorithm is based on the specified half-time of the oil (Torgrimson, 1980), see Section 3.3.

SELFE model surface currents described in Section 2 were used as input to the OILTOX model. Winds and wind-waves were not explicitly included in the hydrodynamic modeling; however the effects of random winds and wind-waves were included parametrically in the OILTOX modeling through turbulent diffusion. For a given modeling scenario (consisting of different spill volumes, times of year that the spill would occur and spill material, see Section 3.2, Table 1), a large number of OILTOX runs were conducted with different start times. This was done in order to cover a wide range of combinations of tide and tidal and river currents present at the time of the spill that potentially affect the transport of oil within the modeling domain. Following this intensive oil spill modeling, OILTOX results were used in trajectory analysis to determine probabilities of concentrations exceeding the project level of concern. The OILTOX model was used to calculate the maximum spill volume to accumulate within each segmented shoreline impact area (called "shoreline zones", see Section 3.2) over a five-day simulation period. Following each individual simulation, the oil remaining within each shoreline zone was evaluated to determine if the threshold concentration of concern was exceeded. Then in the trajectory analysis, the results of all spill modeling runs were used to determine the percentage of spills that exceeded the concentration (level of concern) within each shoreline zones. This approach is similar to that used by the NOAA Trajectory Analysis Planner II (TAPII) software (NOAA, 2000).

3.2. Oil Spill Scenarios and Approach

Modeling scenarios were developed prior to the analysis using United States Coast Guard (USCG) spill response spill volume planning protocols and consultation with the project team. All modeled spills occurred at the WesPac Marine Terminal (no in-transit spills were simulated). Table 1 shows the modeling scenarios, which consist of different spill volumes, times of year that the spill would occur (summer/winter) and spill material. Spill materials considered during the analysis were provided by Reese-Chambers, and included Fuel Oil #6 and Alaska North Slope Crude (ANS Crude). The modeling scenarios were developed in coordination with Reese-Chambers and pre-approved by the project team. Material properties were obtained from the Environment Canada website (http://www.etc-cte.ec.gc.ca/databases/OilProperties/oil_prop_e.html).

Table 1. Spill Modeling Scenarios

Scenario	Spill Volume (bbl)	Season	Spill Material
1	1,267	Winter	Fuel Oil #6
2	1,267	Summer	Fuel Oil #6
3	126.7	Winter	Fuel Oil #6
4	126.7	Summer	Fuel Oil #6
5	50	Winter	Fuel Oil #6
6	50	Summer	Fuel Oil #6
7	1,267	Winter	ANS Crude
8	1,267	Summer	ANS Crude
9	126.7	Winter	ANS Crude
10	126.7	Summer	ANS Crude
11	50	Winter	ANS Crude
12	50	Summer	ANS Crude

For each of the 12 modeling scenarios, 100 individual oil spills occurring during winter and 100 individual oil spills occurring during summer were simulated with the OILTOX model, for a total of 2,400 oil spill modeling runs. Figure 7 shows the complete Delta freshwater influx used as input to the SELFE model (black line) and the timing of the individual oil spill modeling runs performed for each scenario represented by red dots). Figure 7 shows that the oil spill modeling runs, which were spread evenly over each time period, have sufficient frequency to cover the complete range of Delta freshwater influx conditions including the peak winter discharges.
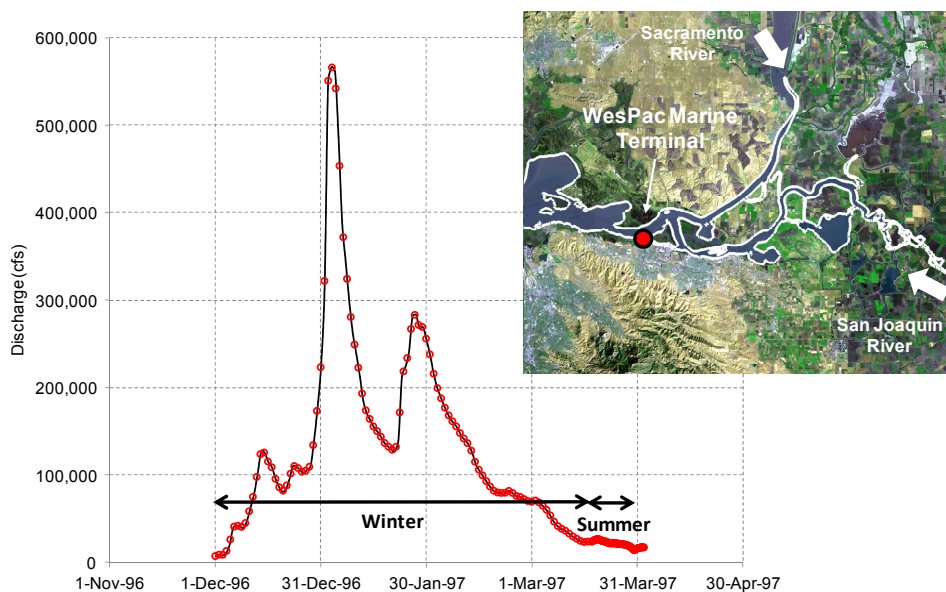

Figure 7. Delta freshwater influx used as input to the SELFE model (black line) and timing of individual OILTOX spill modeling runs (red dots)

Figure 8 shows an example spill modeling result at three different times during the simulation. Red particles are those that have been "beached", whereas yellow particles are those still moving in the water.

Shoreline zones were defined by the land-hugging sides of the triangular cells of the hydrodynamic modeling grid. The results of the OILTOX model consisted of concentrations within each shoreline zone and in the water throughout the five-day simulation. Concentrations are reported in this Technical Memorandum at point locations approximately 8,200 ft apart to remain analogous with reporting of results from the TAPII system, as TAPII results are also intended to be used as part of the analysis in the EIR.

From each of these runs, the maximum concentration at each shoreline zone during the simulation is recorded and evaluated to determine if it exceeded the level of concern. The approach to calculating concentration level of concern (a critical parameter for the analysis) was coordinated with and approved by the project team prior to analysis. The concentration level of concern was determined based on sheen thickness. Wikipedia (2011) provides oil sheen thickness information for different appearance criteria ranging from "barely visible" to "colors are much darker". Wikipedia (2011) reports that sheen thickness resulting in a "silvery sheen" (herein chosen as the level of concern for oil spill impact analysis) is such that 50 gallons are present in one square mile. This level of concern has been used on previous EIRs for marine terminals in San Francisco Bay, including the Crude Tank Replacement Project EIR (Shell Terminal, Martinez), and has been previously accepted by CA State Lands Commission. The oil concentration based on this reported sheen thickness was the basis upon which probabilities of impact were calculated in the trajectory analysis.

Sensitivity analysis indicated that due to strong tidal currents, most parameters included in the model have little effect on the results. However, the un-beaching behavior was a parameter that did affect the results; therefore CHE performed sensitivity analysis to determine a conservative value for the oil-on-shore "half-life".

The oil-on-shore "half-life" is a parameter characteristic of the type of shoreline and beach material that indicates the period of time after which "beached" oil is prone to be un-beached by transport processes. Oil-on-shore half-life values range from one hour to one year. Tests using values of one day and one month were chosen for the sensitivity analysis, with the results indicating that for trajectory analysis (not for individual spill modeling runs), use of a smaller oil-on-shore half-life (one day) resulted in more conservative results. An oil-on-shore half-life value of one day was used further in the analysis.
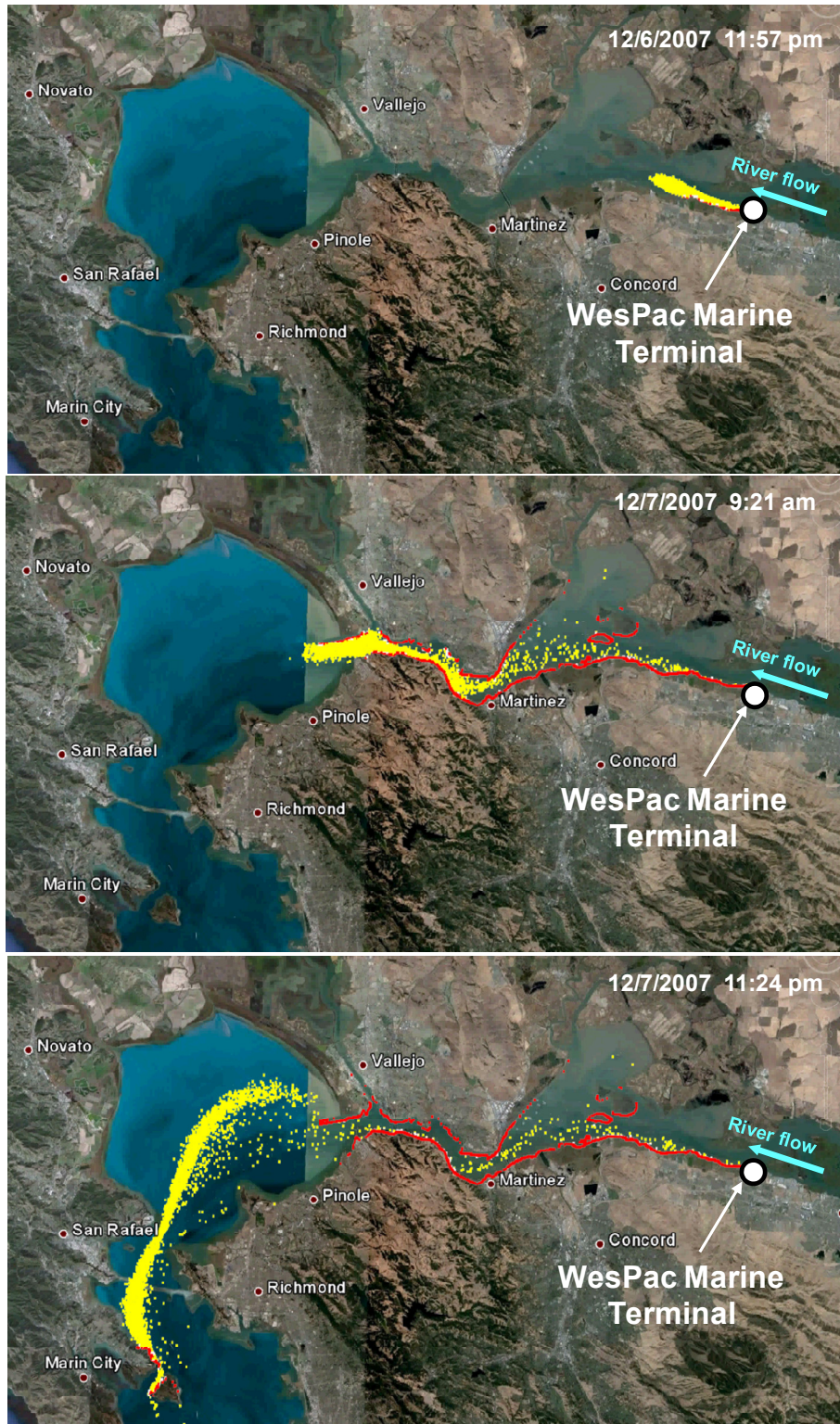
Figure 8. Example spill trajectory for a winter OILTOX simulation at three different times

3.3. Modeling Results

The OILTOX model was used to simulate the modeling scenarios described in Section 3.2 and the results were analyzed in coordination with Reese-Chambers. The following is a general discussion of the results of the trajectory analysis. Analysis results for each Scenario consist of the percentage of oil spills (probability) that will exceed the level of concern ("silvery sheen") within each shoreline zone. Appendix A contains plan view plots of the OILTOX model trajectory analysis results for each Scenario.

The results show common trajectory patterns mainly depending on the spill volume and season (winter vs. summer). The type of spilled material (Fuel Oil #6 vs. ANS Crude) has a negligible influence on the trajectory analysis results because evaporation is not a significant factor in shoreline impacts in this location. Scenarios with the largest (1,267 bbl) spill volume (Scenario 1 and 7 for winter, and 2 and 8 for summer) generate the highest percentages of oil spills exceeding the level of concern at the shoreline zones farthest from the terminal.

For winter scenarios (1 and 7), the highest percentages (75-100%) can be found both at the terminal and in shoreline zones west of the terminal because large river discharges occur during winter that tend to push the oil downstream from the terminal. West of the terminal, percentages decrease with distance from the spill location, and then increase again in Carquinez Strait between the Benicia-Martinez Bridge and the Carquinez Bridge; this is due to shore-directed surface currents predicted by the 3D model in this area. Relatively high percentages (up to 30%) of spills exceeding the level of concern can be found in San Pablo Bay and as far as Tiburon. The shoreline along Tiburon is also an area of higher probabilities of impacts for many scenarios due to shore-directed surface currents. East of the terminal, percentages of spills exceeding the level of concern decrease to less than 5% in the San Joaquin River and Sacramento River.

Summer scenarios (2 and 8) are characterized by tidally-dominated hydraulic regime, as river discharges are small and have a negligible effect on hydrodynamics. Therefore the highest percentages (75-100%) can be found both at the terminal and immediately west and east of the terminal. Summer simulations also indicate high probabilities of impacts in Carquinez Strait between the Benicia-Martinez Bridge and the Carquinez Bridge due to shore-directed surface currents.

Scenarios with small spill volumes (126.7 and 50 bbl) result in lower percentages of spills causing impacts relative to the 1,267-bbl scenarios. For these low-volume spills, winter scenarios are still characterized by river flow-dominated hydrodynamic regimes that push the oil mostly downstream of the terminal, while for summer scenarios the flows are tidally-dominated and the higher probabilities of impact are located symmetrically around the terminal. For these lower spill volumes, high probabilities of impacts in Carquinez Strait between the Benicia-Martinez Bridge and the Carquinez Bridge due to shore-directed surface currents are found only in winter scenarios.

4. Conclusion

Analysis of potential spills and original oil spill modeling simulations were performed in support of EIR efforts for the City of Pittsburg for the proposed WesPac Marine Terminal modernization and reactivation. Spill modeling was performed using the proprietary OILTOX model forced by a Bay-wide 3D SELFE hydrodynamic model. Oil spill modeling results were analyzed and trajectory analysis was performed, resulting in a Bay-wide spatial representation of percentages of oil spills (i.e. probability) exceeding a given oil concentration of concern in shoreline areas around the Bay. These data were provided to the project team for environmental analysis and inclusion in the EIR.

5. References

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APPENDIX A

**Maps of Percentages of Oil Spills Exceeding the
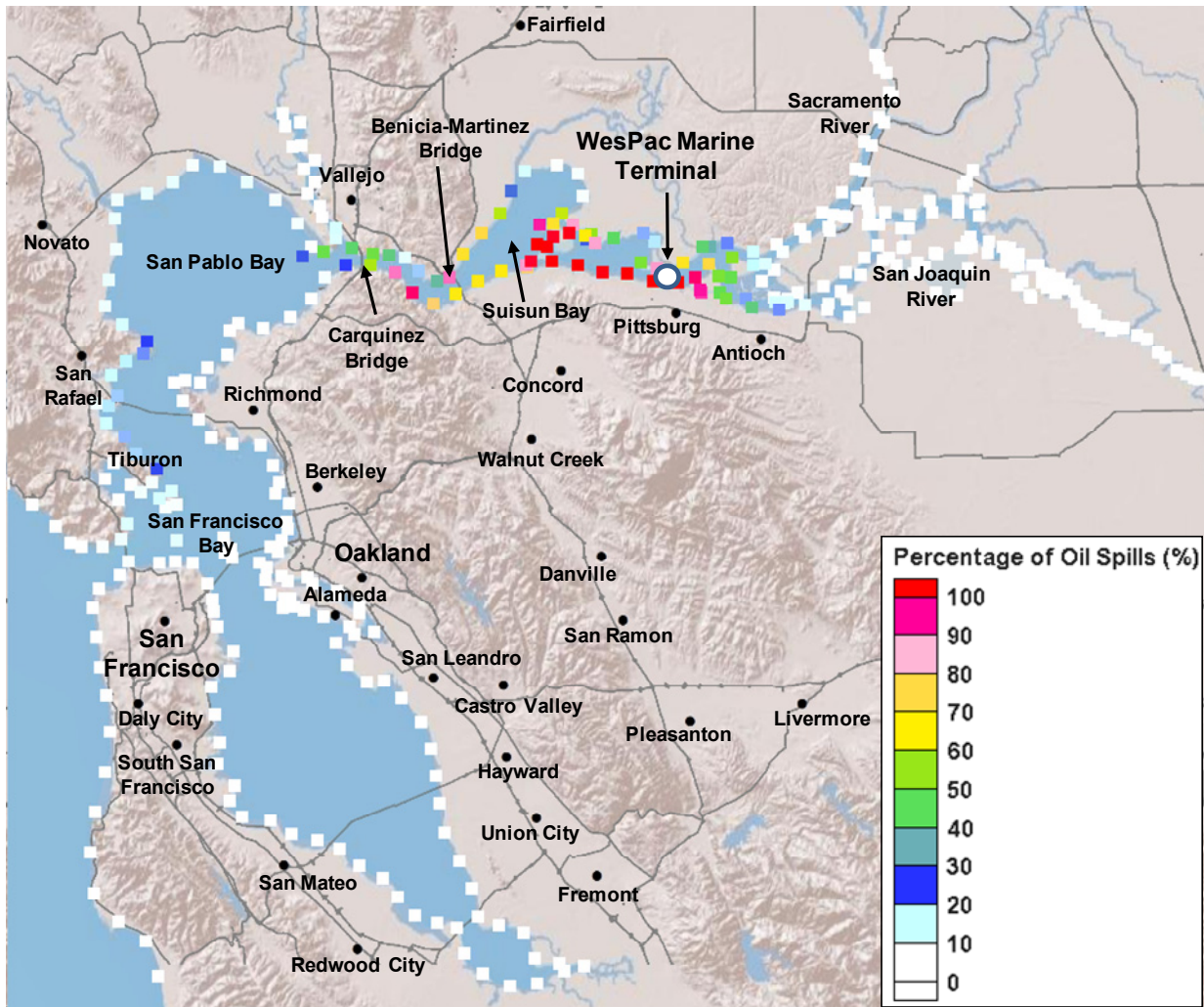Level of Concern in Each Shoreline Zone, Scenarios 1-12**

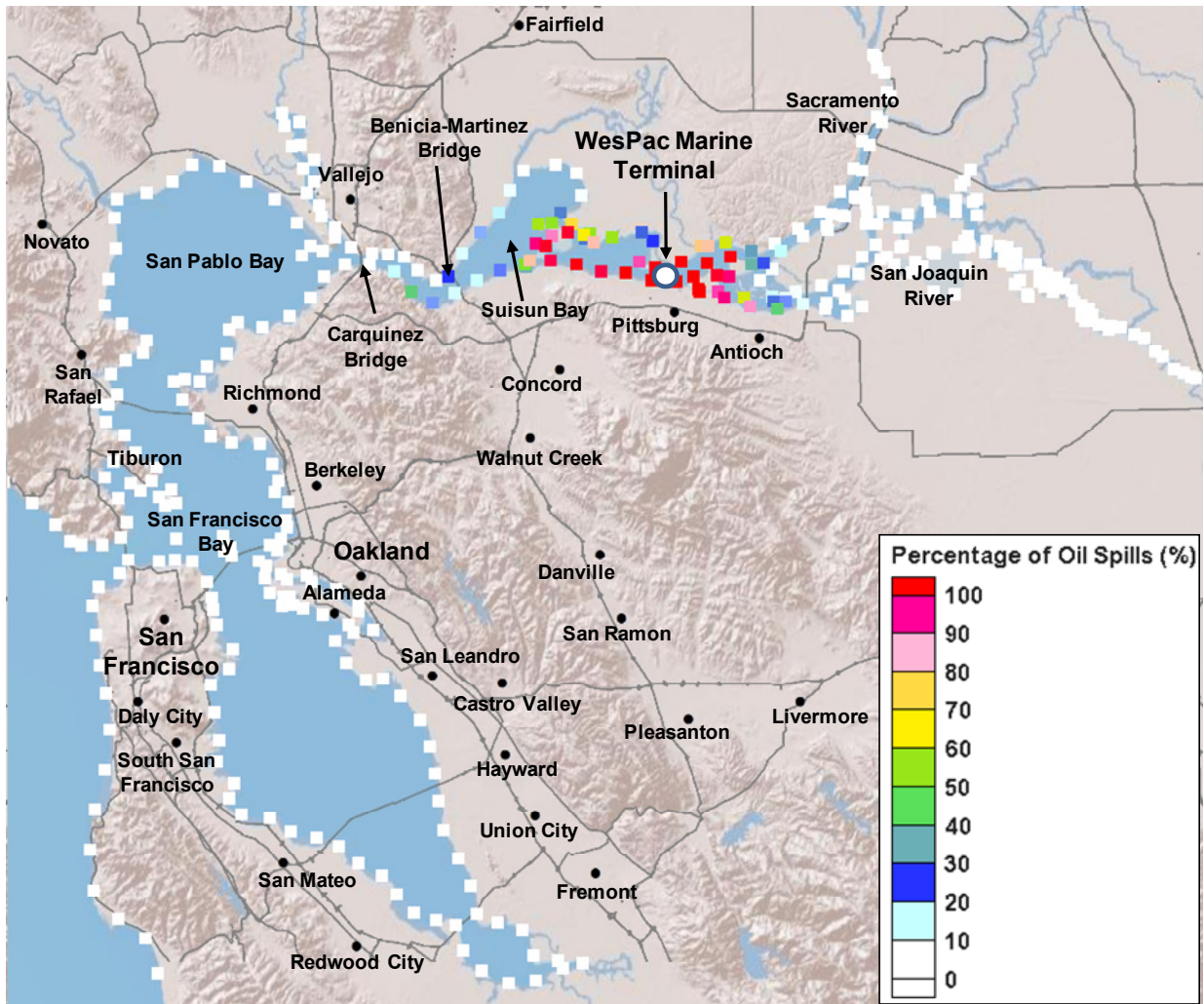**Figure A1. Scenario 1, Fuel Oil #6 Spill, 1,267 Barrels, Winter**

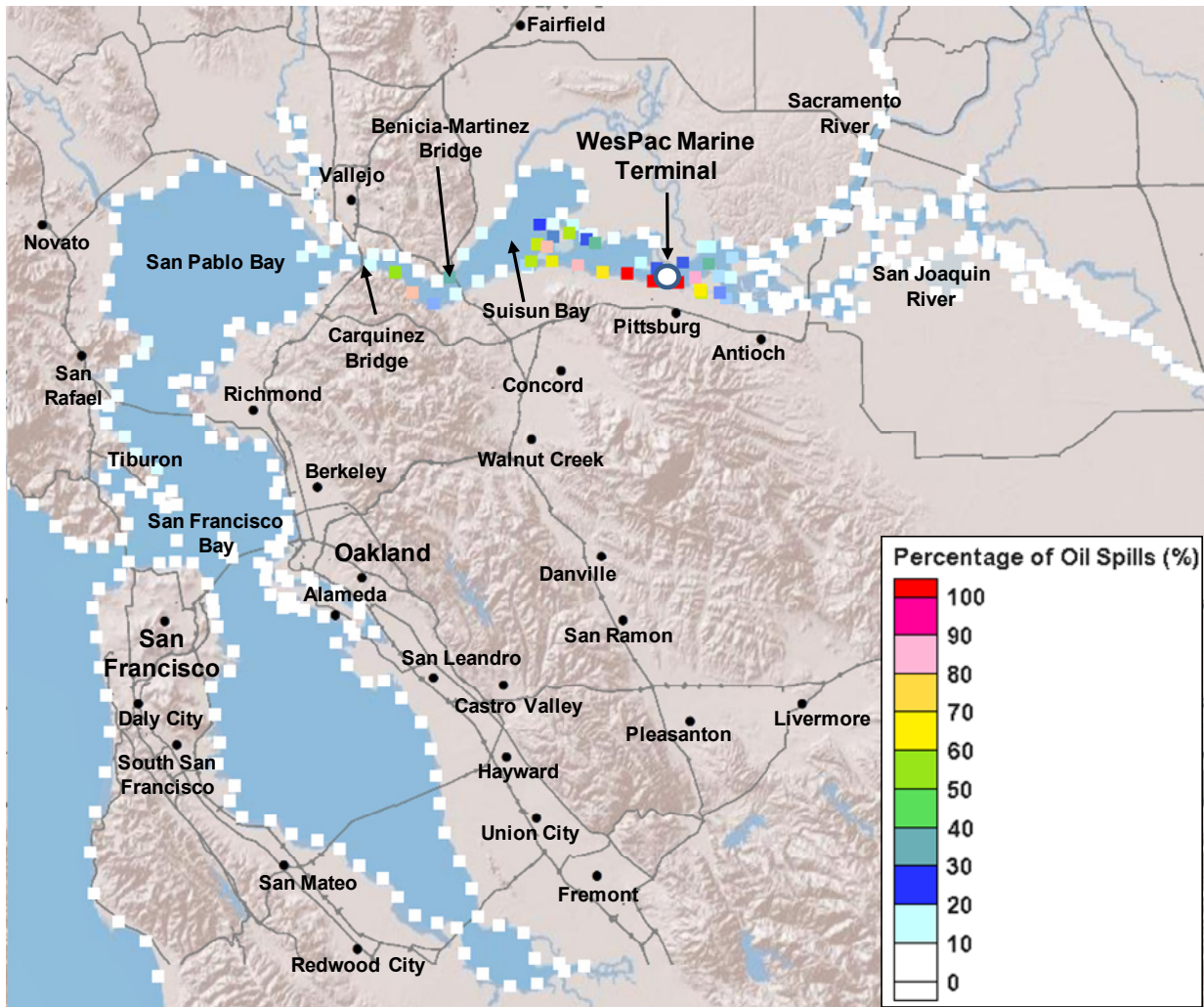**Figure A2. Scenario 2, Fuel Oil #6 Spill, 1,267 Barrels, Summer**

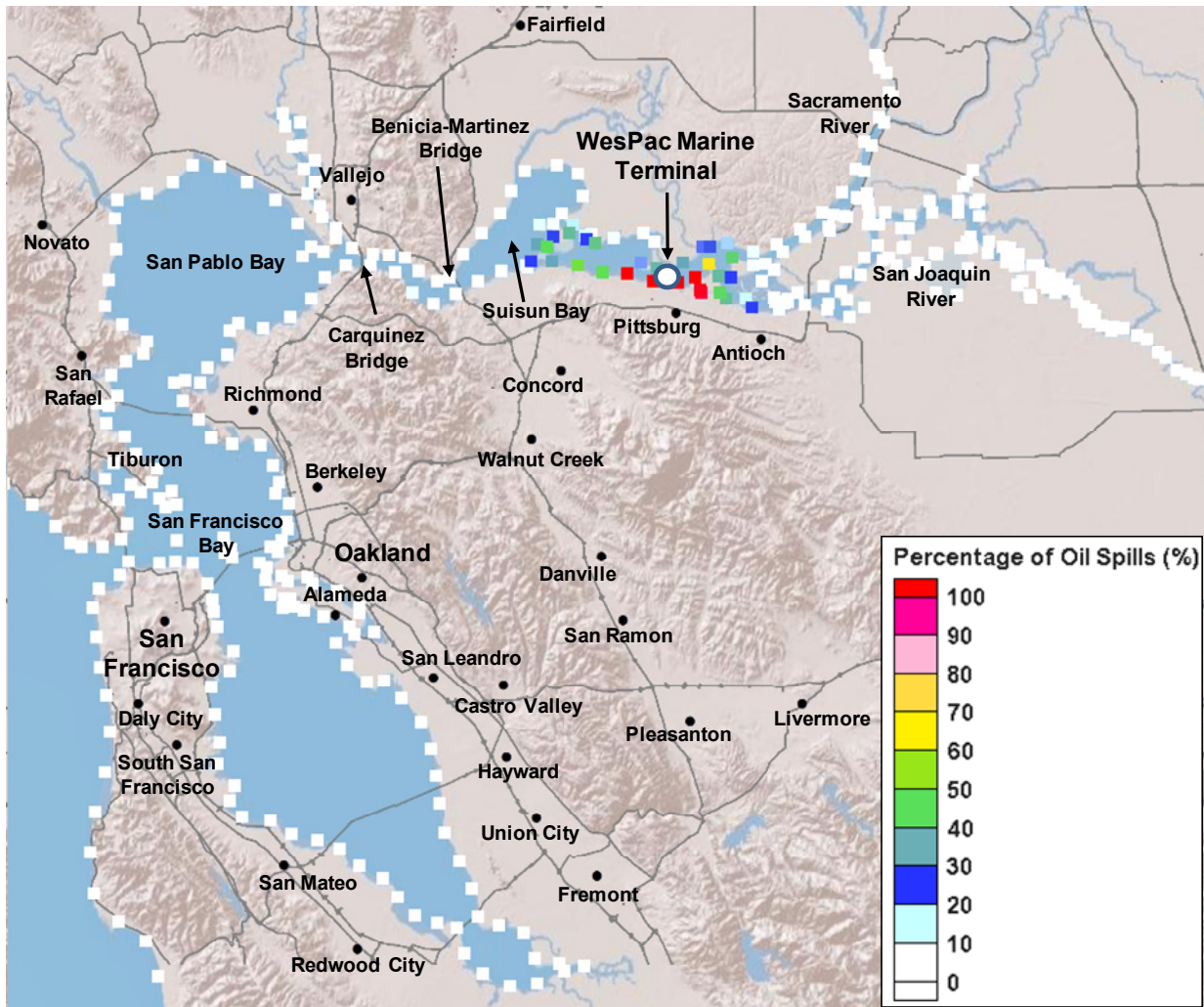**Figure A3. Scenario 3, Fuel Oil #6 Spill, 126.7 Barrels, Winter**

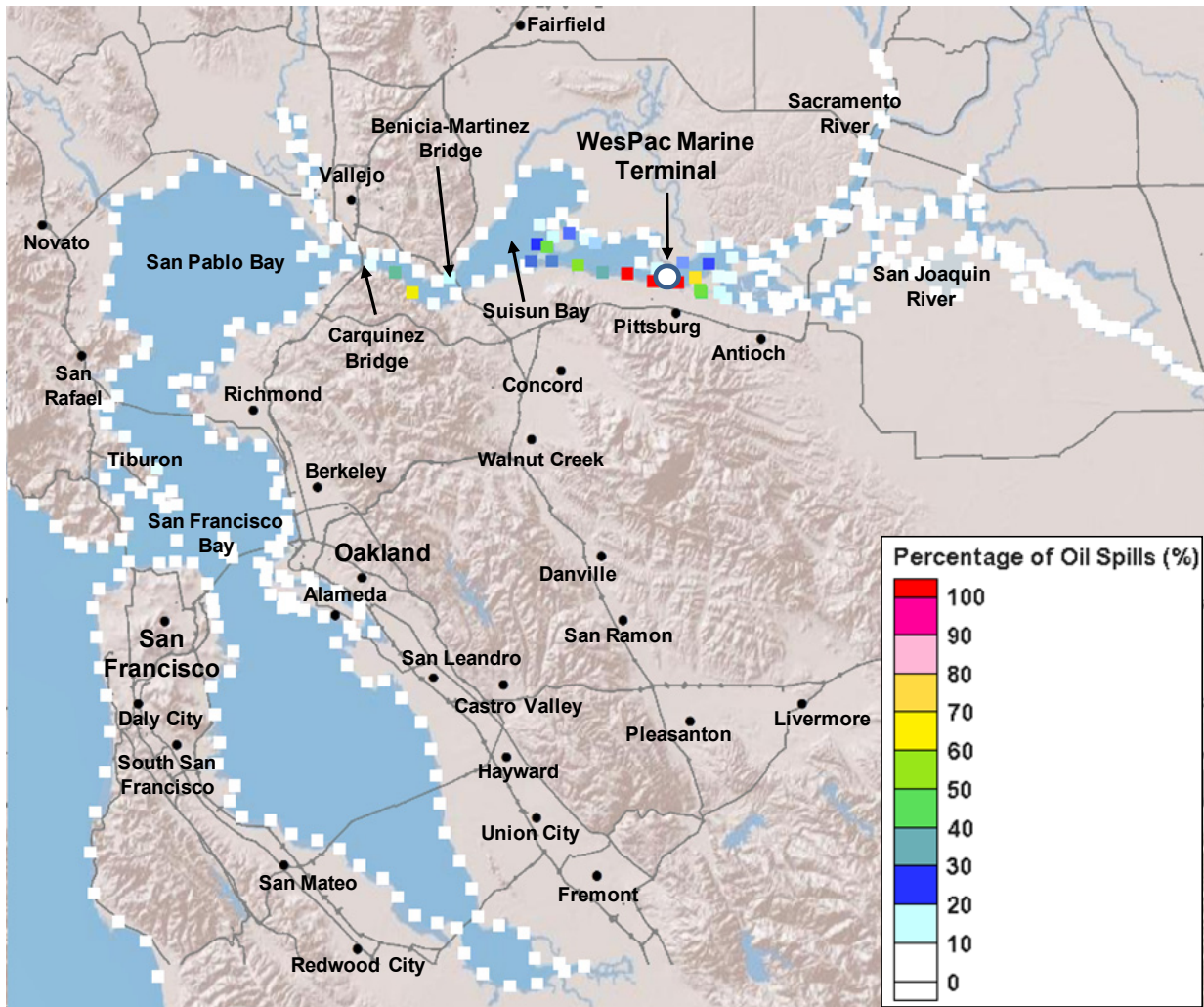**Figure A4. Scenario 4, Fuel Oil #6 Spill, 126.7 Barrels, Summer**
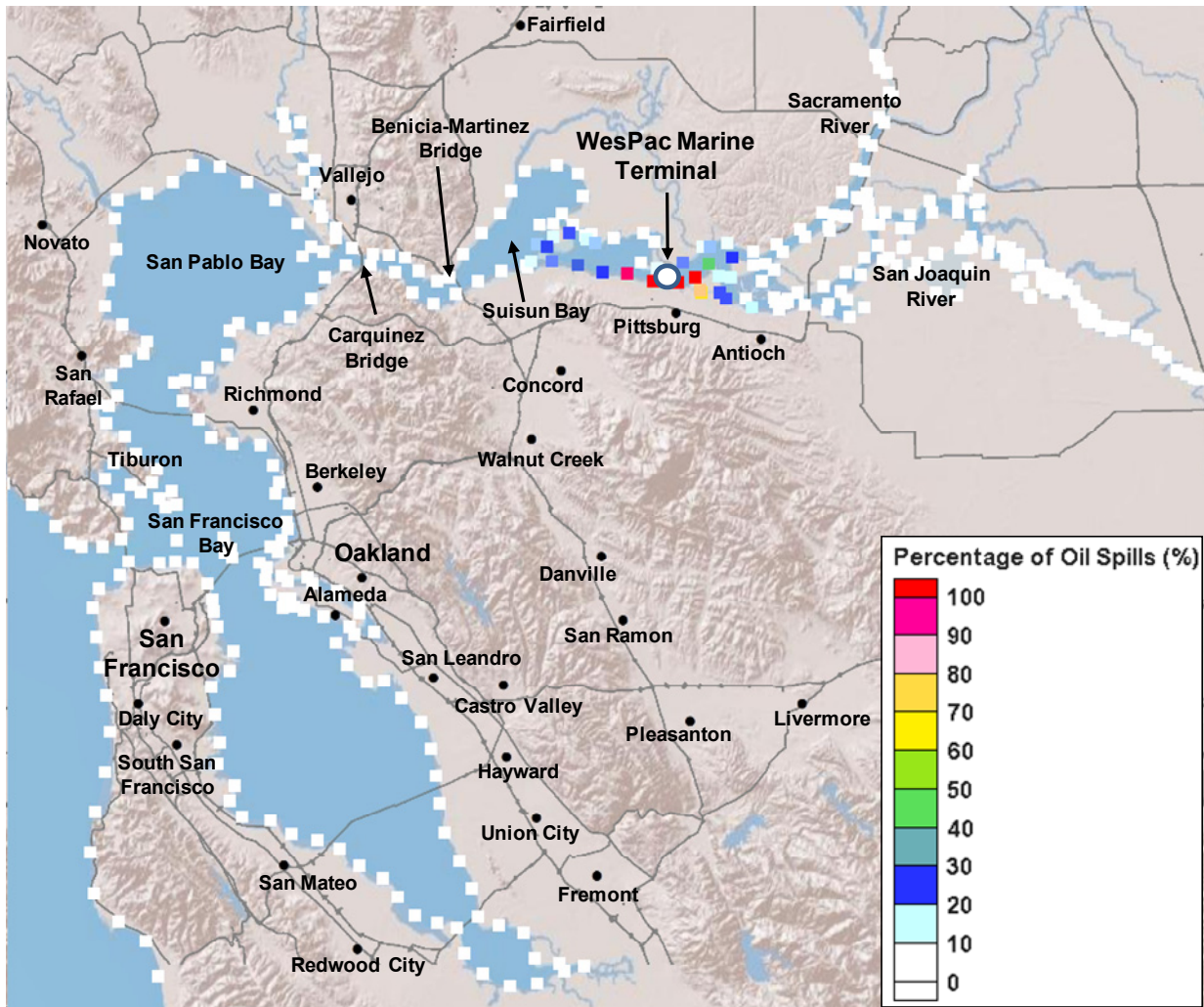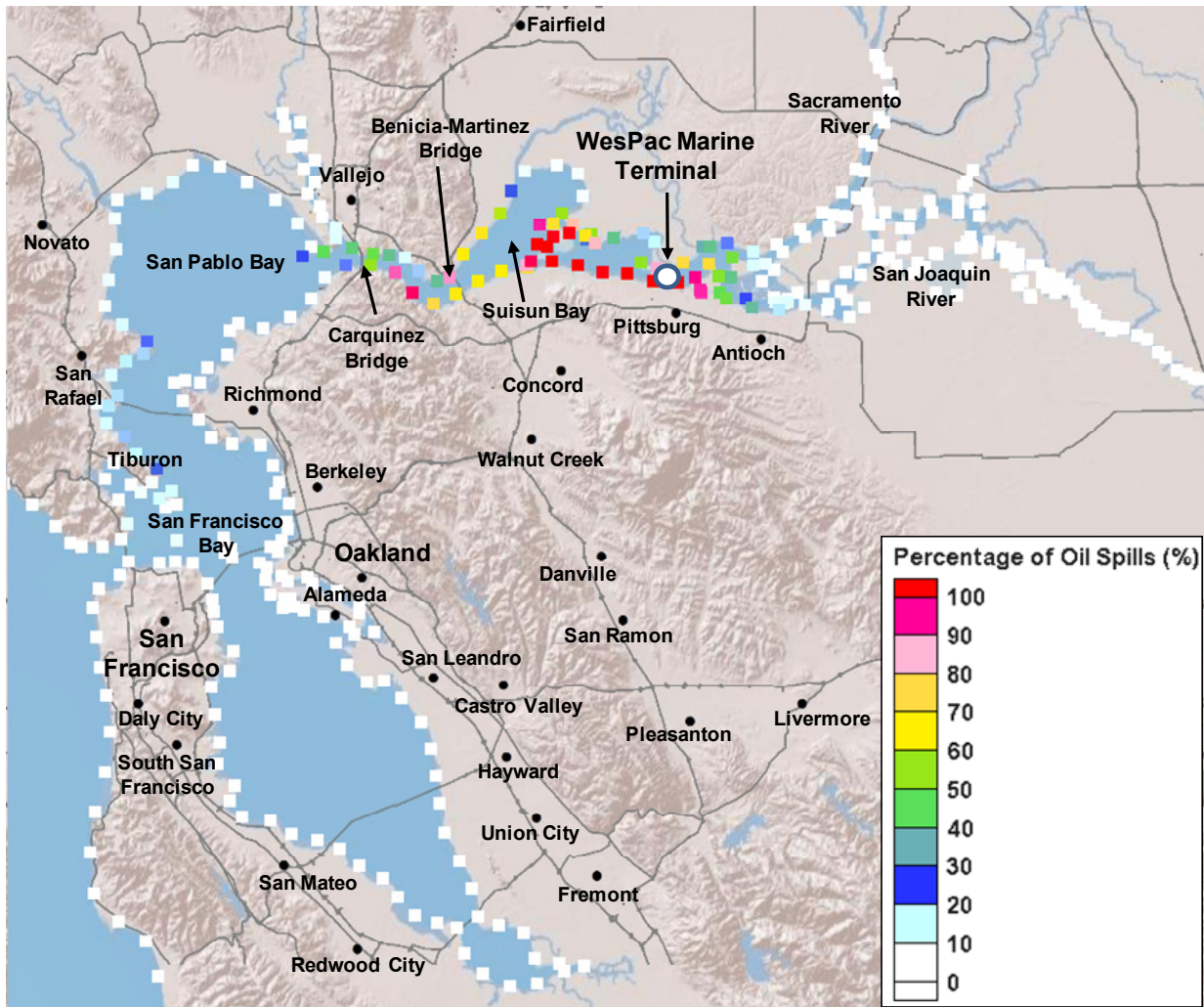
Figure A5. Scenario 5, Fuel Oil #6 Spill, 50 Barrels, Winter

Figure A6. Scenario 6, Fuel Oil #6 Spill, 50 Barrels, Summer

Figure A7. Scenario 7, ANS Crude Spill, 1,267 Barrels, Winter
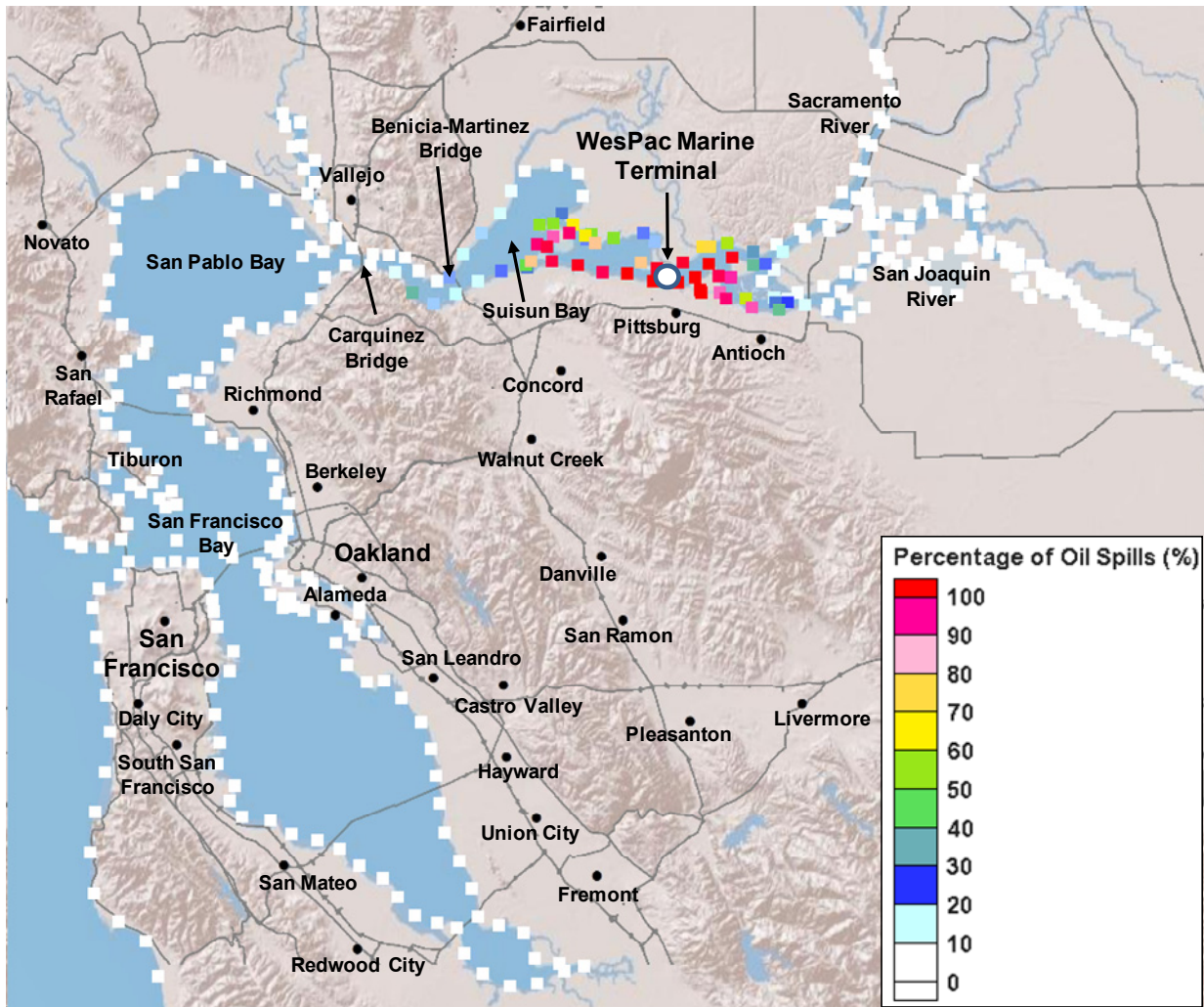
Figure A8. Scenario 8, ANS Crude Spill, 1,267 Barrels, Summer
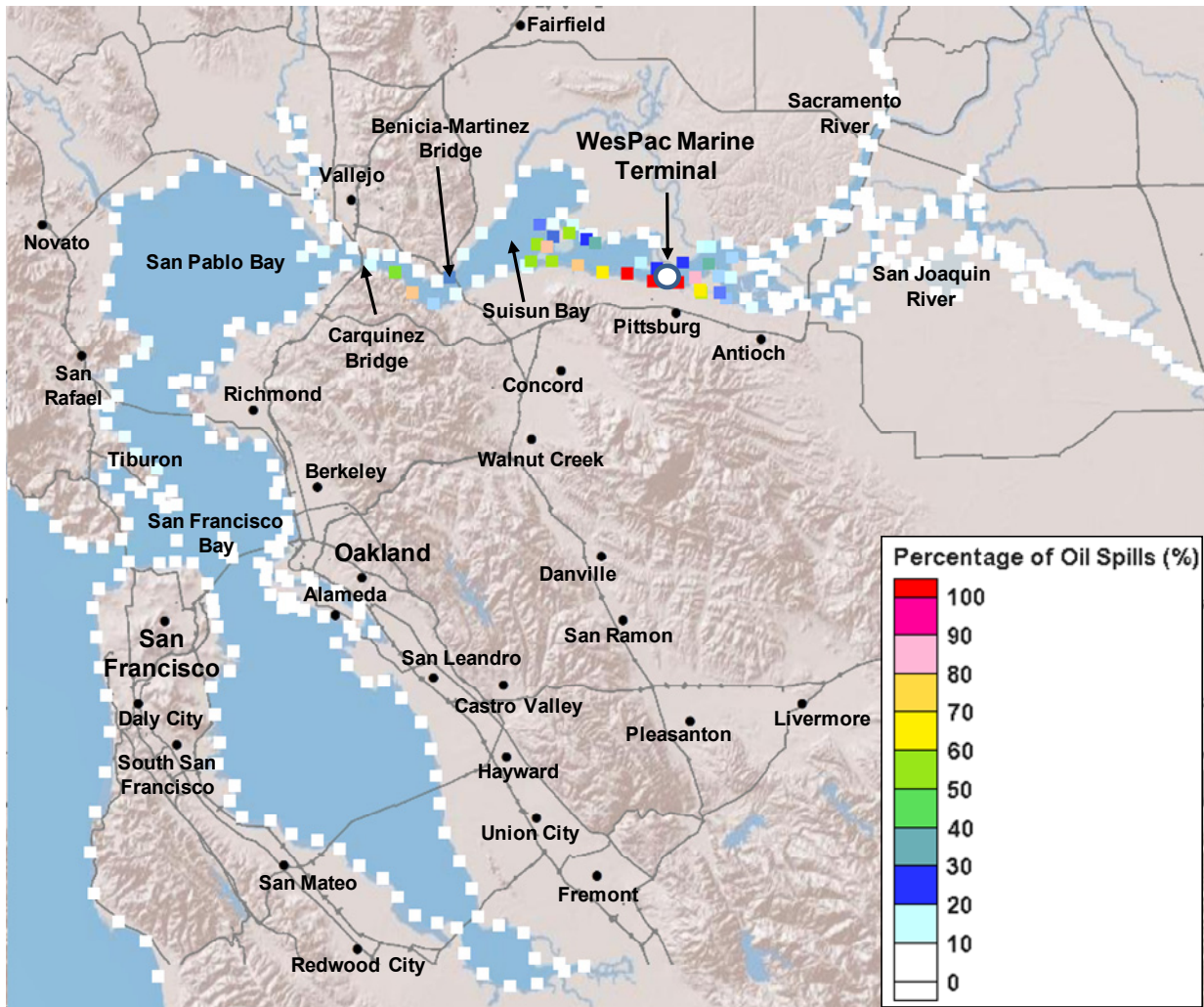
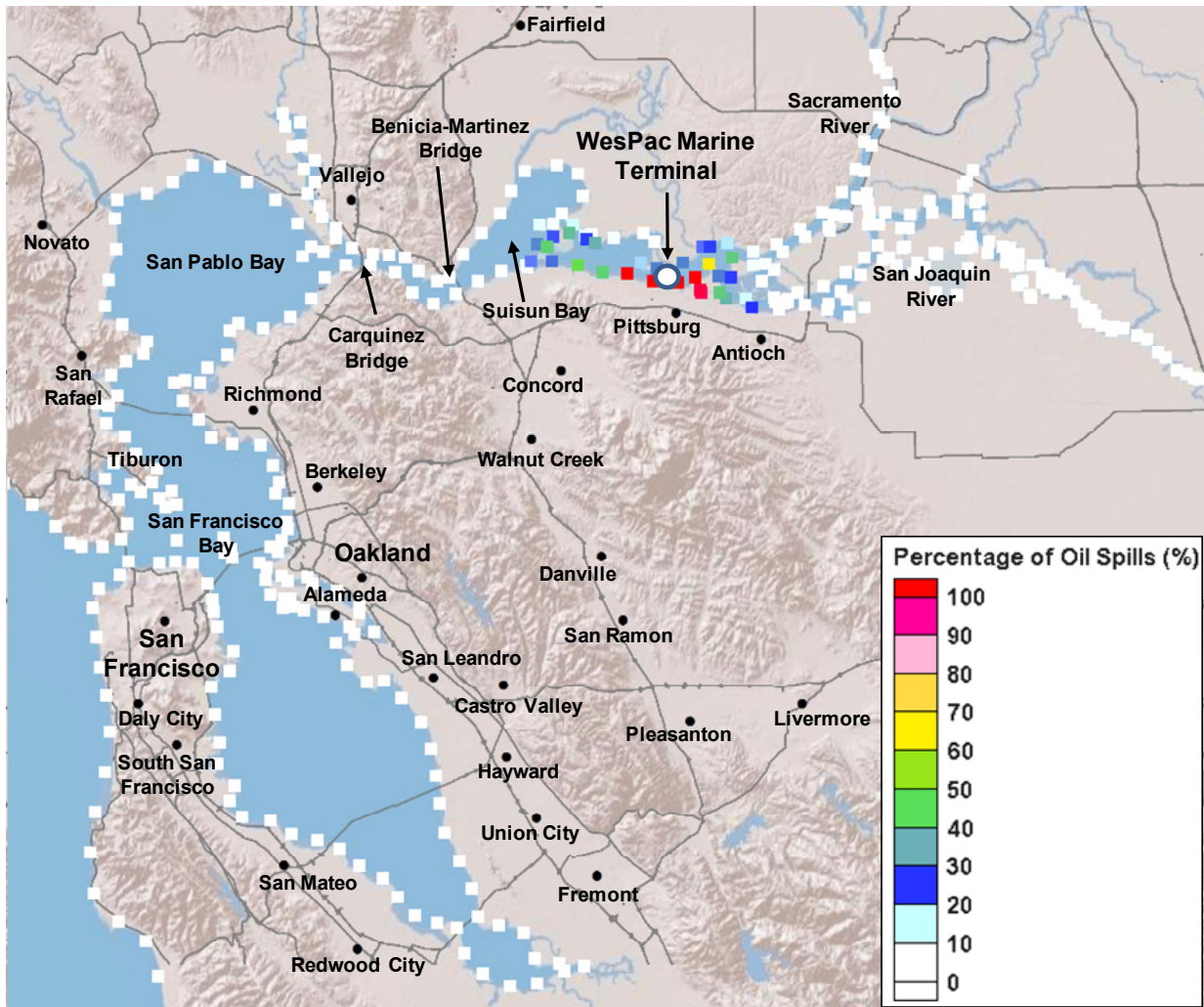**Figure A9. Scenario 9, ANS Crude Spill, 126.7 Barrels, Winter**

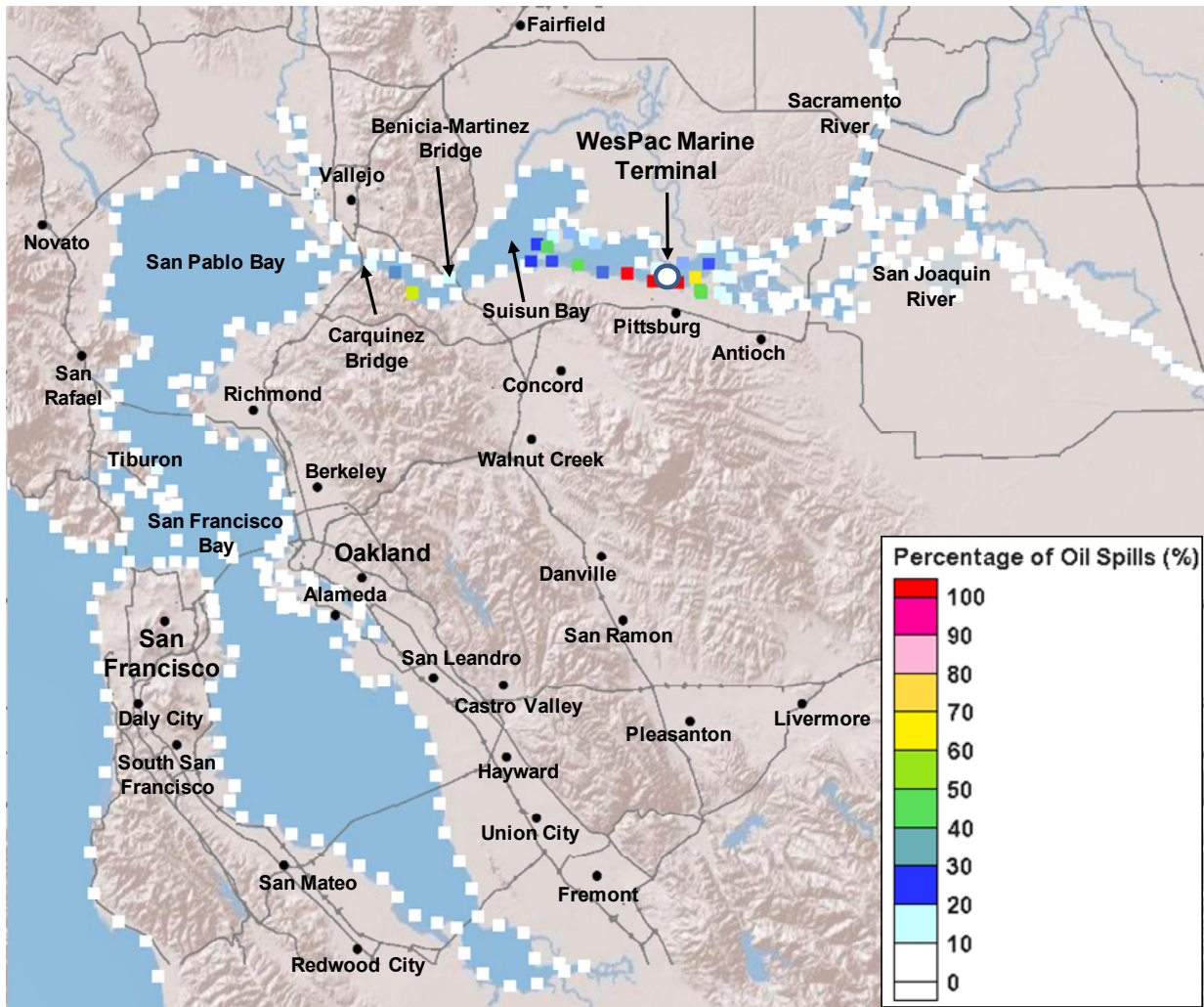Figure A10. Scenario 10, ANS Crude Spill, 126.7 Barrels, Summer

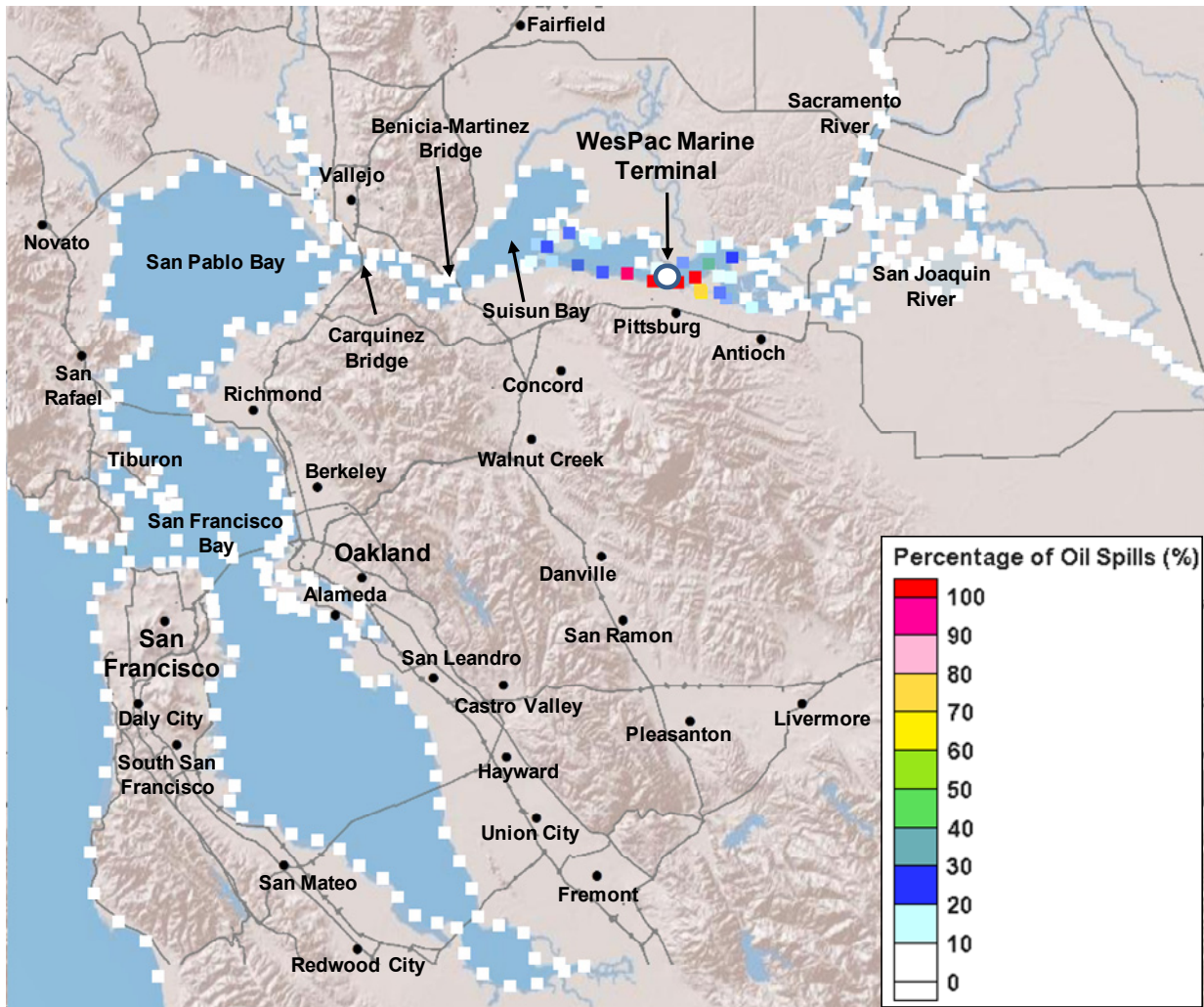**Figure A11. Scenario 11, ANS Crude Spill, 50 Barrels, Winter**

Figure A12. Scenario 12, ANS Crude Spill, 50 Barrels, Summer