SAN FRANCISCO CENTRAL BAY
ROCK REMOVAL PROJECT

San Francisco, California

FEASIBILITY STUDY

REFERENCE REPORT

Prepared by
US Army Corps of Engineers
San Francisco District

and

California State Lands Commission

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Executive Summary

The San Francisco Bay Rock Removal Feasibility Study was initiated in April 2000, pursuant to House Resolution, Docket 2516, adopted May 7, 1997. Four underwater rock mounds are considered, by the U.S. Coast Guard and by the Harbor Safety Committee (as mandated by the California Oil Spill Prevention and Response Act of 1990), as a major hazard to navigation within the San Francisco Bay. Removing these hazards would significantly reduce the possibility of a major oil spill resulting from a vessel striking one of these mounds. Although there are other obstructions to navigation within the Bay, these rock mounds are especially dangerous due to their close proximity to the confined shipping lanes.

Working with the California State Lands Commission (the study's non-Federal sponsor), the Harbor Safety Committee and it's Underwater Rocks Technical Subcommittee, other Federal and state agencies, and representatives from industry, the Corps of Engineers investigated the economic and environmental feasibility of lowering the four rock mounds (know as Harding, Shag, Arch, and Blossom Rocks) to depths greater than the current deep draft fleet. The focus of the study was to develop a structural alternative (i.e., physically lower some or all of the rock mounds).

During the study, a number of field investigations were performed, as well as a significant amount of effort expended to develop and run mathematical simulations in order to help identify the existing condition and to predict possible outcomes. These tasks are as follows:

- A detailed **Hydrographic Survey**, utilizing Single- and Multi-beam technology to map the underwater topography of the rock mounds and the surrounding area.

- A **Seismic Survey**, utilizing side-scan sonar, acoustic sub-bottom reflection techniques, and marine magnetometer to define the geologic make-up of the rock mounds. These data were also used to determine the existence of any cultural resources found in or on the rock formations.

- A **Benthic Survey**, utilizing a remote controlled vehicle to collect video and still photography of the habitat found on the surface of the rock mounds and of the surrounding areas.

- A **Risk Assessment Simulation** study to apply risk analysis techniques to identify the causes, which could potentially lead to a vessel grounding on the rocks, forecast the frequency of these incidents, and predict the potential quantity of oil spills resulting from these scenarios.

- A **Bio-Economic Oil Spill Simulation** study to evaluate the ecological and financial consequences of an oil spill in the San Francisco Bay. This simulation was comprised of a three-dimensional oil fate model to predict oil trajectories, surface distribution, shoreline oiling, and concentrations of the fuel components in water and sediments. A bio-economic impact model addressed the potential impacts of each spill simulation by evaluating exposure of aquatic habitats and organisms, resident and migratory species impact, and developed costs to restore equivalent resources. Response costs were determined based on the different possible response strategies, and the socioeconomic impacts determined as damages to real and personal property, loss of natural resources and loss of income and expenses.

As a result of more than two (2) years of study, it was determined there was not a Federal interest in pursuing a structural alternative. Given the current practices in place, which ensure the safe passage of vessels within the Bay, the probability of a vessel actually grounding on the rocks became extremely remote. This low probability of occurrence, when applied to the potential damages that may result from a spill, reduced the project benefits well below the cost to lower the rocks. Since evaluating non-structural measures (e.g., aids to navigation, tug support, emergence response) is continually being evaluated by others under the overall navigation safety mission of the Harbor Safety Committee, the Feasibility study was halted. There has been a significant amount of valuable information collected during this investigation, which may be applicable to others when confronting similar navigation hazards. It is the objective of this Reference Report; therefore, to make available the information to as wide an audience as possible.

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SAN FRANCISCO CENTRAL BAY ROCK REMOVAL PROJECT

FEASIBILITY REFERENCE REPORT

1.0 STUDY INFORMATION

1.1 STUDY AUTHORITY

The Congressional authority for the San Francisco Bay Rock Removal Study was stated in House Resolution, Docket 2516, adopted May 7, 1997:

"Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on the San Francisco Harbor, California, published as House Document 50, 72nd Congress, 2nd Session, and other prior reports, with a view to determining whether any modifications to the existing navigation project in San Francisco Bay are advisable at this time in the interest of improved navigational safety by removal of submerged rocks, shoals, and other hazards to deep-draft vessels traversing the existing navigation channels. In conducting the benefit/cost analysis and selecting a final project design, the Secretary shall consider the economic and environmental benefits attributable to the reduction in actual or threatened oil spills upon completion of a final project. In considering these special benefits and in conducting the overall study, the Secretary shall maintain close coordination with the United States Coast Guard."

1.2 PURPOSE AND SCOPE

1.2.1 Purpose of Project

The purpose of the San Francisco Central Bay Rock Removal Project is to identify actions to prevent groundings on the rock mounds in Central San Francisco Bay near the existing deep-draft channels. The prevention of groundings could significantly reduce the risk of oil and fuel spills from occurring in the Central Bay. These actions would further serve to improve navigational safety and reduce significant environmental and economic damages within San Francisco Bay.

1.2.2 Scope of Project

There are four underwater topographic features (rock mounds) in Central San Francisco Bay composed of hard materials at depths ranging from -36 feet to -39 feet Mean Lower Low Water (MLLW) that are adjacent to, or close by, the present designated navigation lanes. A fifth feature was determined to be of soft material and at a depth of –55 feet MLLW during the Geophysical and Hydrographic Surveys. No longer being considered a potential threat to shipping, it was excluded from the study. These rock formations are, in the opinion of San Francisco Harbor Safety Committee, a safety hazard to modern navigation, particularly for deep draft vessels such as cargo ships and oil tankers. The San Francisco Harbor Safety Committee is an organization comprised of representatives from governmental, industrial, navigational, recreational, economic, and environmental groups whose formation was mandated by the State Oil Spill Prevention and Response Act (1990). The rock removal recommendation arose out of a perceived threat of a Valdez-like oil spill. To date, there have been no serious accidents involving oil tankers in the Bay, but the threat of a fully loaded inbound tanker losing power or being forced onto one of the rocks by severe weather conditions is apparent.

1.3 STUDY AREA AND LOCATION

1.3.1 Study Area

The study area for the without project conditions surveys covers part of the Central San Francisco Bay, California and comprises natural topographic formations known as Harding, Shag, Arch, Blossom and Unnamed Rocks. Four of these five underwater topographic features in the Central San Francisco Bay are composed of hard materials at depths ranging from -36 to -39 feet MLLW, and are adjacent to, or close by, the designated navigation lanes. Unnamed Rock was excluded from further study as described in Section 1.2.2 above.

1.3.2 Location

Harding Rock is located approximately 6,500 feet north-northwest of Alcatraz Island and the pinnacle rises to an elevation of -36.4 feet MLLW. Approximately 1,000 feet southeast of Harding Rock is Shag Rock, which rises to an elevation of -37.5 feet MLLW. Arch Rock, which is the largest of the rocks, is located approximately 1,600 feet south of Shag Rock, and rises to a peak elevation of –36.0 feet MLLW. Approximately 3,000 feet west of Shag Rock is Unnamed Rock at an elevation of –55.0 feet MLLW. Blossom Rock is located approximately 5,500 feet southeast of Alcatraz Island and 8,300 feet west of Treasure Island and rises to a depth of –39.5 feet MLLW. See the Vicinity Map, PLATE 1.

US Congressional Districts are 6, 7, 8, and 12.

1.4 HISTORY OF THE INVESTIGATION AND EXISTING PROJECTS

The San Francisco Harbor Project was initially authorized in 1868. The River and Harbor Act of July 3, 1930 authorized improvements for navigation safety. The improvements included "… removal of Blossom Rock and Alcatraz Shoal to a depth of 40 feet; and removal of Arch Rock, Shag Rock, and Harding Rock to a depth of 35 feet…". Other improvements to San Francisco Harbor Project were authorized in 1927, 1935, 1937, and 1965. Since 1950, floating debris was collected to remove hazards to navigation by on going maintenance under San Francisco Harbor Project, as authorized by the River and Harbor Act of 1950. San Francisco Harbor Main Ship Channel provides a channel 2,000 feet wide, 55 feet deep, and 20,400 feet in length through the San Francisco Bar. All deep draft vessels entering the Bay enter through this channel and pass through the area of the submerged rocks mounds.

1.5 PREVIOUS REPORTS

Below is a summary of the previous studies, reports and existing projects:

a. Rock Removal Interim Report Initial Appraisal, April 1994. Initial Appraisal found rock removal would not be justified based on traditional navigation benefits.

b. San Francisco Bay Bar Channel Deepening, Initial Appraisal, March 1995, San Francisco District, US Army Corps of Engineers. The Initial Appraisal found that Channel deepening would be in the Federal interest for depths up to –62 feet MLLW. A non-Federal sponsor was not identified.

c. San Francisco Central Bay Rock Removal Navigation Safety Issues, 4 April 1996, Subcommittee on Underwater Rocks of Harbor Safety Committee of the San Francisco Bay Region. The study examined further alternatives for navigation safety, in addition to those considered in the initial appraisal.

d. San Francisco Bay Bar Channel Deepening, Section 905(b) (WRDA 86) Analysis, July 1997, U.S. Army Corps of Engineers. Analysis included discussion of alternatives for Bar Channel Deepening, Shallow Rock removal and Southampton Shoal Channel Deepening and Widening. Based on traditional navigation benefits, the estimated net benefits for rock removal alternatives were less than one.

e. Redwood City Harbor Deepening Section 905(b) Analysis, September 1998, U.S. Army Corps of Engineers. Project would dredge the San Bruno Channel to –35 feet MLLW to accommodate larger vessels at the Port of Redwood City.

f. Oakland Harbor Navigation Improvement (-50 Foot) Project, Section 203; Chief's Report signed April 21, 1999, prepared by Port of Oakland and U.S. Army Corps of Engineers. Project would dredge present Inner and Outer Harbor Channels to –50 feet MLLW to support larger deep-draft container ships.

g. San Francisco Bay to Stockton Phase III (John F. Baldwin) Navigation Channel Project, General Reevaluation Report; issued October 1997. Project would dredge shoaling area near the proposed Richmond Marine-Link Pipeline Terminal Project to –45 feet MLLW.

2.0 NEED FOR AND OBJECTIVES OF ACTION

2.1 NATIONAL OBJECTIVES

2.1.1 The Federal Objective

The Federal Objective of water and related land resources planning is to contribute to national economic development (NED) consistent with protecting the Nation's environment, in accordance with national environmental statutes, applicable executive orders, and other Federal planning requirements.

Contributions to national economic development (NED outputs) are increases in the net value of the national output of good and services, expressed in monetary units, and are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services, which are marketed, and of those which may not be marketed. Protection of the Nation's environment is achieved when damage to the environment is eliminated or avoided and important cultural and natural aspects of our Nation's heritage are preserved.

2.1.2 National Ecosystem Restoration

Ecosystem restoration is one of the primary missions of the Corps of Engineers Civil Works program. The objective of ecosystem restoration planning is to contribute to national ecosystem restoration (NER). Contributions to national ecosystem restoration (NER outputs) are increases in net quantity and/or quality of desired ecosystem resources. Measurement of NER is based on changes in ecological resource quality as a function of improvement in habitat quality and/or quantity and expressed quantitatively in physical units or indexes (but not monetary units). These net changes are measured in the planning area and in the rest of the Nation

Per ER 1105-2-100, App E., ER-1165-2-501, and EP 1165-2-502, protection may be included as part Civil Works NER initiatives and activities, when such measures involve efforts to protect and preserve elements of an ecosystem's structure and functions against future degradation. A significant number of San Francisco Bay habitats, plants, and animals are currently at risk to catastrophic damage due to an oil spill created by a tanker running aground on one of the three rocks. The large number of bayland plants and animals that are under special protection currently reflects the effects of habitat loss or degradation. Today there are 51 species of plants and animals that occur in or near the baylands that are threatened or endangered under the state and Federal endangered species acts. These include ten invertebrates, six fishes, one amphibian, two reptiles, nine birds, two mammals, and twenty-one plants. (California Department of Fish and Game, 1998). Approximately 343,000 acres of bayland habitat, comprised of the following habitat types, are at risk from catastrophic damage due to an oil spill:

Deep and Shallow Bay Habitats-250,000 acres
Tidal Flats-30,000 acres
Tidal Marsh-40,000 acres
Moist Grasslands-7,000 acres
Moist Grassland/Vernal Pools-15,000 acres
Riparian Forest and Willow Groves-700 acres

2.2 PUBLIC CONCERNS

The rocks are, in the opinion of the Harbor Safety Committee of the San Francisco Bay Region (Committee), a safety hazard to modern navigation particularly for deep draft vessels such as cargo ships and oil tankers. The rock removal recommendation of the Committee arose out of a perceived threat of a Valdez-like oil spill. The threat of a fully loaded inbound tanker losing power or being forced onto one of the rocks by severe weather conditions does exist.

The Committee is an organization comprised of representatives from governmental, industrial, navigation, recreational, economic, and environmental groups whose formation was mandated by the State Oil Spill Prevention and Response Act of 1990.

2.3 PROBLEMS AND OPPORTUNITY

Problem: There are four underwater rock mounds in the Central San Francisco Bay composed of hard materials at depths ranging from –36 feet to -39 feet MLLW that are adjacent to, or close by, the present designated deep navigation lanes. These rock mounds are, in the opinion of the San Francisco Harbor Safety Committee, a safety hazard to modern navigation particularly deep draft vessels such as cargo ships and oil tankers.

To date, there have been a few accidents involving oil tankers in the Bay. There was a collision between two oil tankers, under the Golden Gate Bridge spilling nearly one million gallons of oil in 1971. The San Jose Mercury News reported February 21, 1997, "In recent years, there have been at least four near-collisions or mechanical failure involving tankers or other large ships near Harding Rock."

Opportunity: The opportunity is taking actions to prevent groundings on rock mounds in Central Bay near existing deep-draft channels. Prevention of groundings could significantly reduce the risk of oil and fuel spills from occurring in the Central Bay. These actions would further serve to improve navigation safety and reduce significant environmental and economic damages within all of San Francisco Bay

2.4 PLANNING OBJECTIVES

The national objectives (NED and NER) are general statements and not specific enough for direct use in plan formulation.

The objectives of the feasibility study are to:

a. Develop alternatives, which address navigational safety, only with respect to the rocks.
b. Alternatives should minimize the impact on the environment.
c. Alternatives should result in a lower risk of vessels striking the rocks.
d. Alternatives should contribute to the preservation of oil spill damages to the threatened and endangered habitats and the fish and wildlife of the entire Bay.

2.5 PLANNING CONSTRAINTS

Study-specific Constraints are to:

a. <u>Protect fisheries and significant habitat</u>. The fisheries and any significant habitat areas near the rocks will be protected to the maximum extent practical.

(1) There will be no massive, uncontrolled explosions.
(2) The use of any type of explosive or expansive material will be scientifically controlled.
(3) The time of year for the activity may be managed to avoid harm to any threatened or endangered species.

b. <u>Minimize effect on water quality and turbidity</u>. The effects on the water quality and turbidity of the Bay water surrounding the removal area will be as temporary as practical.

c. <u>Ensure safety of vessels</u> Ensure safety of vessels in the vicinity of the rocks during construction. Safety for the surface vessels, boats, small craft, and personal craft will be a critical priority.

d. <u>The removal activities will be limited</u>. The removal activities will be limited to no more than the four rock mounds identified in the feasibility study.

3.0 DATA COLLECTION STUDIES & RESULTS

All the surveys and modeling efforts are completed. The information and data presented below are based on those reports.

3.1 Hydrographic Survey

3.1.1 Methods: The contractor performed both single-beam and multi-beam hydrographic surveys.

<u>Single-beam:</u> Single-beam data was collected during the side-scan sonar survey. A Fathometer recorded water depth by recording soundings into a navigation computer to a resolution of 0.1 feet. Analysis of this data utilized variations between the echo sounder trace and the depth of the acoustic target to achieve maximum accuracy in the depth readings. Survey was completed 18 – 22 September 2000. Survey was completed 18 – 22 September 2000. (Appendix A)

<u>Multi-beam:</u> The Multi-beam survey collected sonar data along 27 miles of track line over the sites. The equipment consisted of a submerged acoustical transducer head, an onboard processor and a video monitor. Soundings were generally collected along track lines spaced at 200-foot intervals with 100-foot intervals over the shallower area directly above the rocks. Survey was completed 16 – 20 October 2000. Survey was completed 16 – 20 October 2000. (Appendix A)

3.1.2 Blossom Rock: Blossom Rock is located near the center of the ship lane approximately 12,000 feet from the other rock masses. Blossom Rock is southeast of Alcatraz and approximately 4,000 feet north of San Francisco's North Point. This rock has a flattened top with a maximum elevation of –39.5 feet MLLW and a surface area of 100,400 square feet measured at the –55-foot elevation. Figure 3.1-1 is a topographic map.

3.1.3 Harding Rock: Harding Rock is located approximately mid-way between Alcatraz Island, Angel Island and the Marin County coastline. The rock has a flattened top with two high areas 4-6 feet higher than the surrounding area; the maximum elevation of the rock is –36.4 feet MLLW. Surface area above the –55-foot elevation is 173,000 square feet. Figure 3.1-2 is a topographic map.

3.1.4 Shag Rock: Shag Rock is located at the southeast end of a 0.5-mile ridge, which extends to Harding Rock. Shag's top consists of two flattened mounds at about elevation –40 feet MLLW with a 5-foot depression between the mounds and a high point of –37.5 MLLW. Numerous pinnacles and boulders –55 feet and lower surround the mounds. The whole rock has a surface area of 164,000 square feet, above the –55-foot elevation. Figure 3.1-3 is a topographic map.

3.1.5 Arch Rock: Arch Rock is located approximately 1,500 feet south of Shag Rock and 4,500 feet west of Alcatraz Island. Arch Rock has a flattened top at –38 feet MLLW with the highest point –36 feet MLLW. Surface area above –55 feet MLLW is 461,000 square feet. Figure 3.1-4 is a topographic map.

3.1.6 Unnamed Rock ("Golden Gate Mound"): Unnamed Rock is located 0.5 miles west of Shag Rock and 1.5 miles east of the Golden Gate Bridge. The contactor named the Rock "Golden Gate Mound". It is composed of two steep, sharply pointed parallel ridges. The western ridge is slightly taller with a height of –55 feet MLLW. Figure 3.1-5 is a topographic map.

3.2.Geophysical Survey

3.2.1 Methods: The characteristics of the rocks were studied using side-scan sonar, seismic reflection, seismic refraction and marine magnetometer.

Side-Scan Sonar: The Side-Scan Sonar Survey used a transducer with a unit towed behind a survey vessel with a computer system to collect data and process images onboard the vessel. The survey was run along lines spaced 150 feet apart and oriented in the direction of the tidal currents. Results of the survey provided a graphic view of surface features of the rocks and surrounding seafloor. Survey was completed 18 – 22 September. (Appendix A)

Seismic Reflection: The Seismic Reflection Survey used a towed device emitting acoustic pulses followed on the towline by a hydrophone receiving the reflected acoustic signals. This gives an acoustical profile of the sea floor and sediment layering of the sub-bottom. Sediment thickness was determined to within 0.5 feet.

Survey lines were ran to south then east to west over all 5 sites at intervals of 100 feet to 400 feet. Survey was completed 2 – 5 October 2000. (Appendix A)

Seismic Refraction: The Seismic Refraction Survey discharged an acoustic energy source off the survey boat. An array of towed hydrophones picked up the energy refracted along interfaces and contacts. Calculations from the time of arrival of these sound waves were used to compute the compressional wave velocity of the rock to characterize the geology of the subsurface. Refraction lines were run parallel and perpendicular to the axis of each rock The energy source was a black powder Seisgun discharged below the surface of the water every 200 feet to 300 feet. Survey was completed 2 – 5 October 2000. (Appendix A)

Marine Magnetometer: The Marine Magnetometer was used for a separate archaeological investigation. It measures variations in the earth's magnetic field using a sensor towed 200 feet behind the vessel. Survey lines were 150 feet apart. Survey was completed 1 – 3 November 2000. (Appendix B)

3.2.2 Blossom Rock: Side-scan sonar showed a cover of unconsolidated sediments and some rock debris. A sunken barge approximate 120 feet long and 30 feet wide is located 100 feet south of the edge of the rock. This also shows up on the magnetometer survey. The seismic surveys indicate Blossom Rock is very symmetrical dropping off sharply on all sides. Compressional velocities vary from 10,400 to 11,000 ft/sec.

3.2.3 Harding Rock: Side-scan sonar showed no sediment cover. The magnetometer survey showed nothing unusual. The seismic surveys showed a ridge of bedrock overlain by 25 feet of sediment joining Harding to Shag Rock. It also showed rock debris on the northeast flank. Compressional velocities varied from 10,000 to 10,600 ft/sec.

3.2.4 Shag Rock: Side-scan sonar showed no sediment cover. The sonar did show surrounding sediments are coarse grain. The magnetometer survey found some minor metallic objects. The seismic surveys showed compressional velocities between 10,000 and 10,700 ft/sec.

3.2.5 Arch Rock: Side-scan sonar showed the rock mass surrounded by unconsolidated sediments. It also showed several man-made objects such as a cable and deep gouges in the sediments probably from anchor scour. The magnetometer survey showed two anomalies that might be objects left from the U.S. Navy drilling of the rock. The seismic surveys had compressional velocities generally varied from 10,400 to 11,000 ft/sec with one velocity of 9,300 ft/sec.

3.3 Unnamed Rock (Golden Gate Mound): The side-scan sonar showed a relatively featureless seafloor indicative of fine-grained sediments. Magnetometer survey found no significant anomalies. The seismic surveys had compressional velocities from 5,000 to 5,100 ft/sec despite using a longer geophone array to get higher velocities down to 100 feet.

3.3 Geological Research

3.3.1 Geotechnical Investigation

Sampling: A scope of work was written to sample and test the Rocks. The work was then bid upon, however, the bid exceeded the funds available. It was therefore decided to do the sampling and testing during the design phase when more funds could be available for the work.

Historical Data: The exposed surface area surrounding the rocks has had its geology mapped. Alcatraz is massive greywacke sandstone. Angel Island is interbedded Franciscan schist, metavolcanics, graywackes, cherts, shales and serpentines. The Marin County Headlands is similar and so is north San Francisco.

Interpretative Geology: Based on known surrounding geology and geophysical data the rocks are most probably greywacke sandstone. Their compressional velocities would indicate, in general, the rock is sound and just slightly fractured. The relatively lower velocity value at Arch Rock would indicate more fracturing. The fractured sandstone recovered by the U.S. Navy when they drilled a few feet into this Rock verified this. The compressional wave velocities of the Unnamed Rock and its side-scan radar indicate it is composed of marine sediments not rock.

3.3.2 Lowering Techniques and Mitigation

Techniques**:** Four rocks are under evaluation for lowering because of their height. The compressional velocities indicate the four rocks are moderately hard and sound with some fracturing at least in the top few feet. These properties may to eliminate dredging and mechanical techniques for lowering. Expansive grouts remove relatively thin vertical sections or just fracture the rock; so, may not be practical for the entire lowering. Controlled blasting combined with other techniques seems like the most efficient approach to lowering the Rocks. (Appendix G)

Mitigation: The St Louis District of USACE has two of the leading experts in the field of the effects of underwater blasting and its effect on marine life, methods to mitigate any of these effects and the effectiveness of these mitigation methods These experts will assist in the design of the techniques used to lower the Rocks.

3.4 Cultural Resources Survey

3.4.1 Area of Potential Effects: Any Federal undertaking or project that can change character or use of a prehistoric or historic property requires examination for adverse effects under 36 CFR 800.5. Therefore a literature and records search to identify significant cultural resources was conducted and significant data gathered to assess potential for shipwrecks in San Francisco Bay.

The proposed project's Area of Potential Effect (APE) would include any geographic area where project activities could affect the ground surface or sea bottom where potentially significant cultural resources may be located, including

Native American religious sites, archaeological sites, and potentially historic structures. Examples of areas considered would include those disturbed during channel dredging, dredged material disposal, new construction, and construction equipment staging areas.

The APE for the SF Rocks project is situated around five separate geologic rock formations in the central portion of San Francisco Bay. Blossom, Harding, Shag, Arch, and Unnamed rocks the length, width and depth of each rock and an additional 60-foot circumference around the rock.

3.4.2 Records Search: In conjunction with the remote sensing survey and data analysis James Allen, Senior Associate, William Self Associates, Orinda, California under subcontract to Sea Surveyor, Inc., Benicia, California, conducted a records search of the local maritime archives, J. Porter Shaw Maritime Library, Oakland Public Library, National Archives Pacific Sierra Region, SF History Center of the SF Public Library, Bancroft Library (UC Berkeley) and Doe Library and Map room (UC Berkeley), California Shipwreck Inventory of the State Lands Commission and Automated Wreck and Obstruction Information System (AWOIS) of the National Oceanographic and Atmospheric Administration (NOAA), and Wreck Reports made by the SF Customs Office and retained in the National Archives in Washington D.C. The Coast Guard Station SF, and SF Port Authority were contacted in an effort to identify one of the remote sensing targets.

3.4.3 Marine Survey: Since side-scan sonar, magnetometer, and bathymetric studies were conducted as part of the initial geophysical investigation. The surveys were completed in September through November 2000. The records obtained during the initial investigation were analyzed and subsequent side-scan sonar surveys were concentrated over Blossom, Harding, Shag and Arch rocks to identify cultural resources and potential historic properties. Descriptions of each rock and its associated anomalies are detailed in the *Maritime Archaeology Study in Support of the San Francisco Bay Rocks Removal Project* report (on file at the U.S. Army Corps of Engineers, San Francisco District, 333 Market Street, San Francisco, California 94105, and on the Corps web page at http://www.spn.usace.army.mil)

Seven targets were identified as possible maritime-related cultural resources. Subsequently, two were not eliminated as potentially significant cultural resources. One of the two remaining targets, most likely an abandoned anchor and chain, did not meet the criteria of eligibility for the National Register of Historic Places (NRHP).

The second target lies off Blossom Rock and could not be completely identified. It is a possible sunken barge reported by the Coast Guard to be an obstruction on November 6, 1986. Its definitive potential to meet the criteria of eligibility for the NRHP has not been made; however, having sunk not much earlier than 1986 it is doubtful that the barge would be eligible to meet any of the four NRHP criteria for significance. In addition, the target is located 100 feet south of Blossom Rock and is outside the project APE. No further study is recommended at this time.

No known or presently detectable prehistoric or historic resources, eligible for the NRHP, were identified within the APE. The Corps has determined that no historic properties will be affected by the undertaking. (Appendix B)

3.5 Oil Spill Model Report

3.5.1 Model Outputs

In order to evaluate ecological and economic impacts of an oil spill from either an oil tanker or the fuel tanks of a freighter, a bio-economic oil spill study was performed. Since this study was based upon risk analysis, a stochastic approach was used. The model took into account different oil types, spill sizes, and environmental conditions. The output of the oil spill model included: (Appendix C)

(1) The mass or volume of oil on the water surface.
(2) The mass or volume of oil on the shoreline.
(3) The quantities and locations of habitat types effected.
(4) Time of first oil impact after initial spill.
(5) The probability of exceeding a predetermined threshold.
(6) The time when the amount first exceeded the threshold.
(7) The mean expected maximum mass or concentration at the location.
(8) The maximum amount deposited at a location based on all the runs and model input conditions causing the event.

With this information the impact of the oil spills was determined. The three main categories of damage and cost that were determined are provided below.

(1) Shoreline and Habitat Impacts
Quantities of habitat and wildlife affected by oil exposure and coverage.

(2) Response Costs
Based upon information from agencies such as the U.S. Coast Guard and California Fish and Game, and Office of Spill Prevention and Response (OSPR). Typical response costs, clean up costs, monitoring costs, etc., were compiled.

(3) National Resource Damage Assessment (NRDA) Costs
Costs determined based on latest NRDA specifications and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations.

3.5.2 Model Services Contract

The United States Army Corps of Engineers contracted Applied Sciences Associates (ASA) to perform the bio-economic oil spill modeling. ASA has particular technical expertise in the area of Natural Resource Damage Assessment (NRDA) for oil and hazardous material spills. ASA developed the CERCLA Type A, Natural Resource Damage Assessment models (NRDAM/GLE and NRDAM/CME) that are now written into US law for use in oil and chemical spill damage assessment for US coastal waters and the Great Lakes. ASA has developed an updated commercial Spill Impact Assessment System (SIMAP) from the CERCLA Type A model in order to estimate impacts due to oil and chemical spills. SIMAP includes model algorithms and data input tools to evaluate the effects of response activities, such as dispersant application, booming and mechanical cleanup. The models algorithms for oil movement and behavior include both horizontal and vertical transport, shoreline stranding, spreading, evaporation, entrainment, emulsification, dissolution, volatilization, adsorption into sediment, degradation, and water column concentration. Working as subcontractors to ASA, Environmental Research Consulting (ERC) and Herbert Engineering Corp. (HEC), provided a determination of oil spill size distribution, factoring in the effect of future ship improvements (double hull tankers). ERC also developed detailed estimates of response costs and socio-economic costs for select spills events.

Excerpts and summary data from the *Final Report Bio-Economic Modeling for Oil Spills from Tanker/Freighter Groundings on Rock Pinnacles in San Francisco Bay, Volumes I through VII,* by ASA, ERC, and HEC, May 2003 (Bio-Economic Report) are given in the following sections. See Report for additional details.

3.5.3 Results and Study Status

<u>Oil Spill Size Determination:</u> ERC and HEC determined the four types of oil that transit the bay most often. The types of oil were ascertained using Coast Guard Vessel Traffic Service and ship registries, while spill size distribution for each oil type was inferred using national and international historical spill data. Methodology and assumptions used were developed in consultation with the project team to ensure a correct and satisfactory result. A summary of the spill size distribution data from ERC's final report is provided as Table 3.5-1. Twelve basic spill scenarios were identified. The values given represent the situation as it is anticipated by the year 2010. Spill size was corrected to account for the future use of double hulled tankers. Additional information is available in the Bio-Economic Report, Volume II *Spill Volume Report,* May 2003.

Oil Spill Scenarios For Vessel Groundings on Rock Pinnacles In San Francisco Bay			
Oil Type	20^{th} Percentile	50^{th} Percentile	95^{th} Percentile
Gasoline (Product Tanker)	50,000 gallons	270,000 gallons	1,250,000 gallons
No. 2 Diesel (Product Tanker)	50,000 gallons	270,000 gallons	1,250,000 gallons
North Slope Crude (Crude Tanker)	100,000 gallons	600,000 gallons	3,000,000 gallons
Heavy Fuel Oil (Freighter)	25,000 gallons	100,000 gallons	410,000 gallons

Table 3.5-1 Oil type and spill size summary.

<u>Oil Spill Modeling:</u> The SIMAP (Spill Impact Model Application Package) used for the study is a modification of the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) model (developed by ASA for the Department of the Interior in CERCLA NRDA Type A regulations). It is comprised of three-dimensional oil fate and bio-economic impact models that address impacts, NRDA and response costs. The model was run in stochastic mode to produce results and statistics for multiple model runs under a variety of environmental conditions.

Mapping: The area modeled includes the San Francisco Bay from the Sacramento-San Joaquin Delta to the South Bay and the coastal area from Monterey Bay to Point Reyes. SIMAP uses a rectilinear grid to designate shoreline location, water depth and shore or habitat types. Bathymetric data was acquired from the National Geophysical Data Center, NOAA (1998), and habitat types were determined using equivalent Environmental Sensitivity Indices (ESI) and the Environmental Sensitivity Atlas Geographical Information System (NOAA, 1999). Other subtidal areas were assumed to be either sand (outside the bay) or silt-mud bottom (inside the bay).

Ecological habitat types are categorized into either intertidal or subtidal and divided by the spring low water tide level. A complete list of habitats used by SIMAP is given in Table 3.5-2. All habitats inside the bay are designated as landward, while all habitats outside the bay are seaward. All data is gridded using the ESRI Arc/Info compatible Spatial Analyst program.

Wind Data: Wind data from the Golden Gate, Richmond, and Alameda gauges as well as the San Francisco offshore NOAA buoy were used to determine the level of wind field variation across the study area and what level of detail was needed to accurately represent the oil movement. As wind field variation increases across the bay, computational time for the model increases substantially. The hourly mean wind speed and direction used for the model runs were from SFPORTS (San Francisco Physical Oceanographic Real Time System) for the five year period from 11 February 1996 to 31 May 2001. This is the longest data record available that was not missing data at one or more of the stations. While a longer historic record would have been preferred, statistical analysis of the longer-term buoy records showed relatively low year to year variability, while spatial variability between stations was quite high. Given that the focus of the study was on median and distribution consequences, and not extreme events, the shorter more spatially variable-complete wind record was considered more appropriate and adequate. The wind data was used in a Monte Carlo Simulation, and was therefore considered adequate to provide a fair representation of the seasonal and annual variation in the wind field. Wind driven surface current were calculated within the SIMAP fates model.

Zone	Ecological Habitat	F or W
Intertidal	Rocky Shore	F
	Gravel Beach	F
	Sand Beach	F
	Fringing Mud Flat	F
	Fringing Wetland (Saltmarsh)	F
	Macrophyte Bed	F
	Mollusk Reef	F
	Coral Reef	F
Subtidal	Rock Bottom	W
	Gravel Bottom	W
	Sand Bottom	W
	Silt-mud Bottom	W
	Wetland (Subtidal of Saltmarsh)	W
	Macroalgal (Kelp) Bed	W
	Mollusk Reef	W
	Coral Reef	W
	Seagrass Bed	W
Intertidal	Man-made, Artificial	F
	Ice Edge	F
	Extensive Mud Flat	W
	Extensive Wetland (Saltmarsh)	W

Table 3.5-2 Classification of habitats. (Fringing types indicated by (F) are only as wide as intertidal zone in that province. Others (W = water) are a full grid cell wide and must have a fringing type on the land side.).

Hydrodynamic Model: SIMAP uses an historical record of wind and current data to predict spill behavior following an oil release. ASA used the hydrodynamic, numerical model, BFHYDRO, to generate current data from tidal forcing at the ocean boundary and freshwater inflow from the Sacramento-San Joaquin Delta. BFHYDRO was applied in the two-dimensional (2-D), vertically averaged mode. The model was calibrated using water surface elevation data from SF PORTS. The results were then compared to previously conducted analyses by the US Army Corps of Engineers (USACE) and the United States Geological Survey (USGS). See Bio-Economic Report, Volume I for further details. Figure 3.5-1 shows the extent of the hydrodynamic model grid (this also shows extent of oil spill model effort). The size of the model grid (extent of potential oil coverage), time steps, simulation durations, output sampling frequency, etc. were confirmed with Chris Barker from the National Oceanographic and Atmospheric Administrations Hazardous Material

Office in Seattle, WA. The coverage into Monterey Bay is on the conservative side, but the relatively small increase in model cells had minimal affect on the model speed and no affect on project cost.

SIMAP Components: SIMAP includes several components including (1) an oil physical fates model, (2) interfacing to a hydrodynamics model for simulation of currents (BFHYDRO), (3) a biological effects model, (4) an oil physical, chemical and toxicological database, (5) environmental databases (winds, currents, salinity, temperature), geographical data (in GIS), (7) a biological database, and (8) a response module to analyze effects of response activities. A brief summary of these components is given below. Additional detail can be found in the Bio-Economic Report, Volume I *Physical Fates, Biological Effects, Natural Resource Damages, and Summary of Total Costs for Shag and Blossom Rock Spills.*

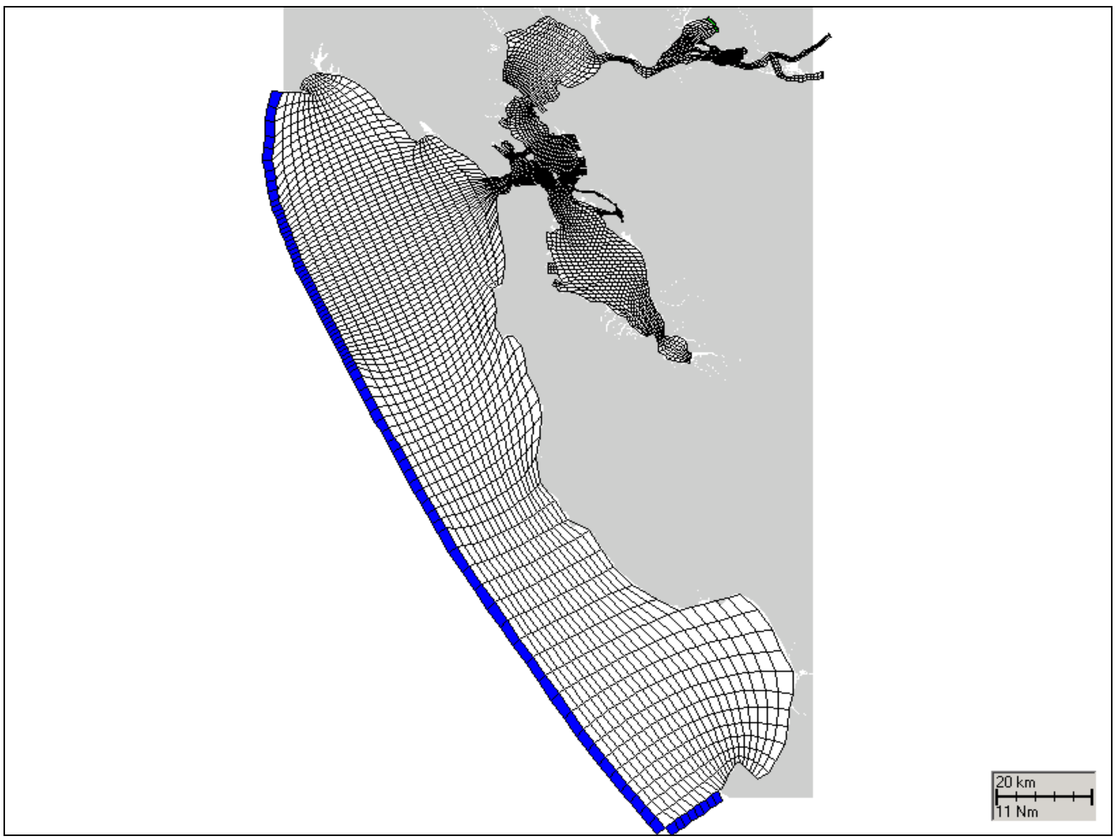

Figure 3.5-1. Model Grid

Fates Model: The physical fates model estimates the distribution of oil (as mass and concentrations) on the water surface, on shorelines, in the water column and in sediments. The model is three dimensional (3-D) and uses a latitude-longitude grid to define environmental and geographical data. Algorithms, based on state-of-the-art, published research, include spreading, evaporation, transport, dispersion, emulsification, entrainment, dissolution, volatilization, partitioning, sedimentation, and degradation. Oil mass is tracked separately for toxic, low molecular weight aromatics (1 to 3-ring), other volatiles, and non-volatiles. The physical-chemical characteristics of each component are defined separately.

In the SIMAP fates model, crude oils and petroleum products are represented by seven components. The seven modelled pseudo-components are listed below. Six of the pseudo-components (all but the residual) evaporate in the model.

(1) MAHs (Mononuclear Aromatic Hydrocarbons)
(2) 2-ring PAHs (Polynuclear Aromatic Hydrocarbons)
(3) 3-ring PAHs (Polynuclear Aromatic Hydrocarbons)
(4) Volatile aliphatics;
(5) Semi-volatile aliphatics;
(6) Low volatility aliphatics; and
(7) Residual fraction (both aromatics and aliphatics).

Tables 3.5-3 and 3.5-4 define the characteristics of the seven pseudo-components. Specific compounds as well as physical-chemical properties and characteristics are listed in the Bio-Economic Report, Volume I.

All hydrocarbons	Volatiles	Semi-volatiles	Low Volatility	Residual (non-volatile)
Aromatics	MAHs (1 ring)	2 ring PAHs	3 ring PAHs	≥4 ring aromatics
Non-aromatics	Volatile aliphatics	Semi-volatile aliphatics	Low volatility aliphatics	High molecular weight aliphatics
Number of Carbons	C4 – C10	C10 – C15	C15 – C20	> C20
Distillation cut #	1	2	3	4
Boiling Point (^oC)	< 180	180 - 265	265 - 380	>380
Boiling Point (^oF)	< 356	356 - 509	509 -716	> 716

Table 3.5-3 Definition of four distillation cuts in the model

Extent of Oil Spill Distribution: Inside the Bay a significant spill could reach north into Carquinez Strait and Richardson Bay, as well as south past Redwood City. The spill could flow out of the Bay and along the Coast, north to Point Reyes and south past Half Moon Bay, possibly reaching out into the Pacific Ocean as far as the Farallon Islands. Distribution is dependant on wind and current conditions, as well as the type of oil and volume of spill.

ASA conducted a set of model runs to determine the sensitivity of the analyses to spill location given that the rocks extend over a 3 square mile area. They also evaluated wind data source location since there is a fair amount of wind field variability in the study area, which can affect oil movement. ASA found that there does appear to be some difference between spills that occur at Shag and Blossom Rocks. The oil spilled at Blossom Rock tends to affect the South Bay more and a spill at Shag Rock has more of an impact on the open coast. This is illustrated by Figures 3.5-2 and 3.5-3, which show the mean maximum oil mass expected at each model cell assuming the same amount and type of oil is spilled, first at Shag Rock (Figure 3.5-2) and then at Blossom Rock(Figure 3.5-3). Using this type of information, two separate sets of model runs were conducted for each of the twelve oil spill scenarios, one for the Shag Rock location and one at the Blossom Rock location. Given the close proximity of Harding Rock and Arch Rock, the Shag Rock spill location was assumed to represent conditions for all three sites.

Characteristic	Volatile and and Highly Soluble	Semi-volatile and Soluble	Low Volatility and Slightly Soluble	Residual (non-volatile and insoluble)
Aromatic category	MAHs (1 ring)	2 ring PAHs	3 ring PAHs	≥4 ring aromatics
MAHs included	BTEX, MAHs to C3-benzenes	C4-benzenes	-	-
PAHs included	-	2-ring to C2-naphthalenes	C3-,C4-naphthalenes, 3-4 ring PAHs with log(Kow) < 5.6	PAHs with log(Kow) > 5.6 (insoluble)
Molecular Weight	50 - 125	125 - 168	152 - 215	> 215
Mean Mol. Wt.	111	142	186	>215
Log(Kow)	2.1-3.7	3.7-4.4	3.9-5.6	>5.6
Mean Log(Kow)	3.3	4.0	4.9	>5.6

Table 3.5-4 Definition of four aromatic pseudo-components in the model

Stochastic Model: In order to determine risks to ecological resources, multiple scenarios and conditions were evaluated to develop an expectation of risk of oil reaching each site of concern. An historical record of wind and current speed and direction was used to predict a range of travel distances and directions for oil spilled at a particular site. A Monte Carlo simulation approach was used. The spill date is randomized, providing a probability distribution of wind and current conditions during the spill. The stochastic model performs a large number of simulations for a given spill site (100 was found adequate to provide statistical significance based on tests with up to 200 runs). Output of the model is the time histories of a hundred spill trajectories. These distributions are used to generate probabilities that water surface, water column, sediments, and shoreline areas will be affected by a release from a certain type of spill at a given site. The same random set of spill dates and times was used for all oil type/volume scenarios, removing that potential source of variability between scenarios and facilitating comparisons.

The outputs of the stochastic model are (1) probabilities of oil exceeding thresholds of concern reaching each location mapped and (2) maximum exposure (thickness or concentration) at the location at any time after the spill. The 3D stochastic model quantifies, in space and over time, for each individual model run: (1) oil thickness (or g/m^2) on water surface, (2) oil thickness (or g/m^2) on shorelines, (3) subsurface oil droplet concentration, as total hydrocarbons, and (4) dissolved aromatic concentration. The results of multiple model runs were evaluated to develop the following statistics, for each location and for each of the components listed above:

(1) Probability of exposure (probability that a threshold thickness or concentration will be exceeded at each location at any time following the spill).
(2) Time (hours) to first exceedance of the threshold at each location.
(3) Worst case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (i.e., maximum peak exposure for all the model runs), calculated as follows. For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. Then the runs are evaluated to determine the greatest or highest amount possible at each location.
(4) Mean expected maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (i.e., mean peak exposure of all model runs), calculated as follows. For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. The runs are evaluated to determine the mean expected peak exposure (mean exposure for all runs) at each location.

The stochastic modeling outputs provided a probability distribution of results, which were summarized by statistics such as mean and standard deviation. The results were ordered into a probability density function (PDF) such that the 50th (median) and 95th (worst for this study) percentile spill dates-times could be identified. (For the stochastic model output, the PDF was based on oil distribution by area of shoreline oiled or water column exposure, not NRDA costs). For each of the twelve scenarios, the 50th and 95th percentile runs, in terms of consequences, were examined in detail for NRDA, Socioeconomic, and response costs.

Biological Effects Modeling: The biological effects model was run for each of the individual 50th and 95th percentile runs. SIMAP was also used to evaluate exposure of aquatic habitats and organisms to whole oil and potentially toxic components from the fuels, resulting in mortality and ecological losses. The biological effects model uses habitat-specific and seasonally-varying estimates of fish, shellfish, bird, mammal and reptile abundances, and productivity of plant and animal communities at the base of the food chain, to determine biological effects resulting from the spill. The model performs these calculations by first estimating the portion of a stock or population affected. The fractional loss is multiplied by abundance or biomass per unit area to quantify an impact as number or kg of biomass lost.

A rectangular grid of habitats represents the area potentially affected by the spill, with each grid cell coded for habitat type. The habitat grid matches the grid set up for the physical fates model using a GIS database. Figure 3.5-4 shows an example of the habitat data.

The NRDAM/CME contains mean seasonal or monthly abundances for 77 biological provinces in US coastal and marine waters. The biological data for fish and invertebrates in province 46, San Francisco Bay, are assumed in the SIMAP simulations of spills. Fish and invertebrates are input as average abundances by species (or group) per unit area in assigned habitats. Fish and invertebrates abundance varies by open water and structured habitat In the NRDAM/CME, the abundances are for fished stocks and the biomass includes those animals greater than the age of recruitment to fishing. In the biological effects model the age/size distribution is computed from fishery modeling parameters. In Figures 3.5-2, and 3.5-3: the oil mass units are in grams per meter squared.

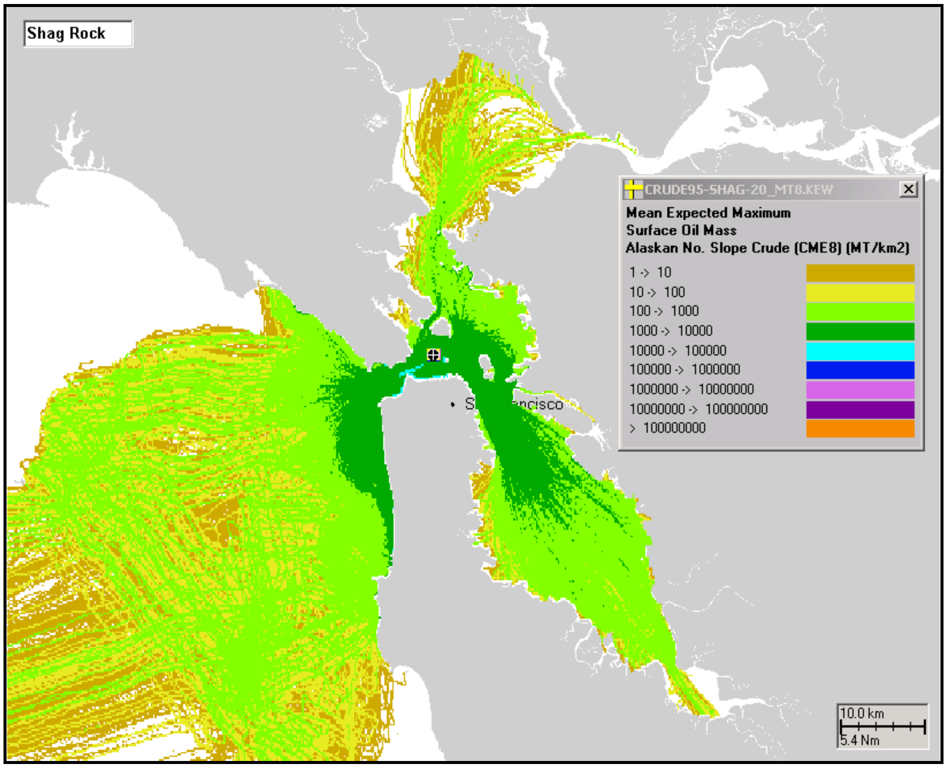

Figure 3.5-2. Mean expected maximum surface oil mass (Shag Rock Spill Location)

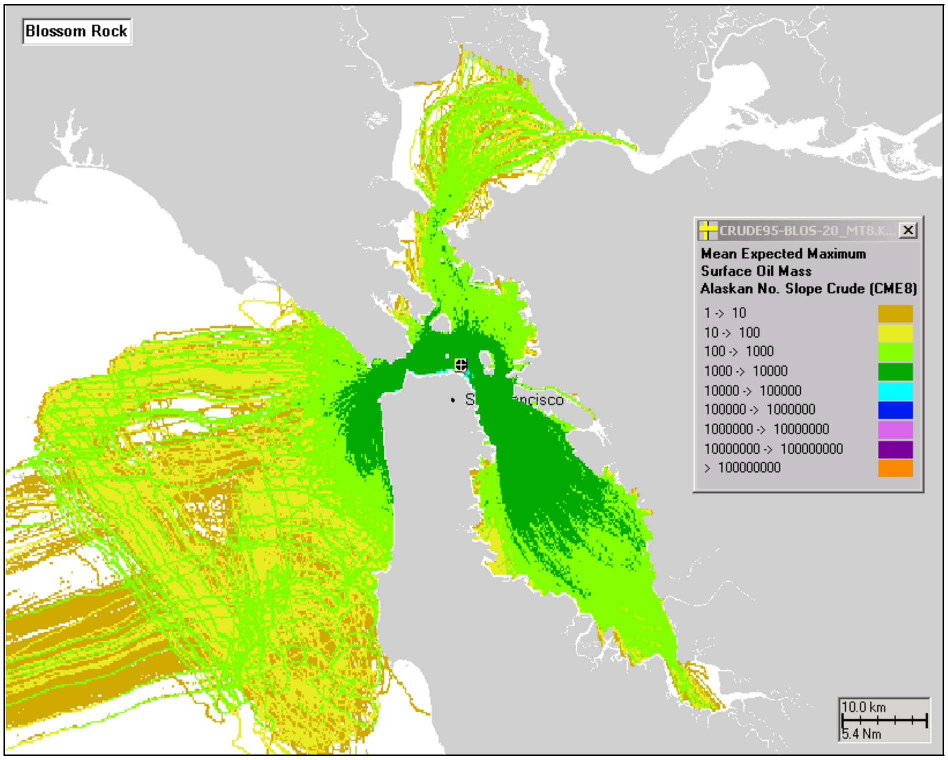

Figure 3.5-3. Mean expected maximum surface oil mass (Blossom Rock Spill Location)

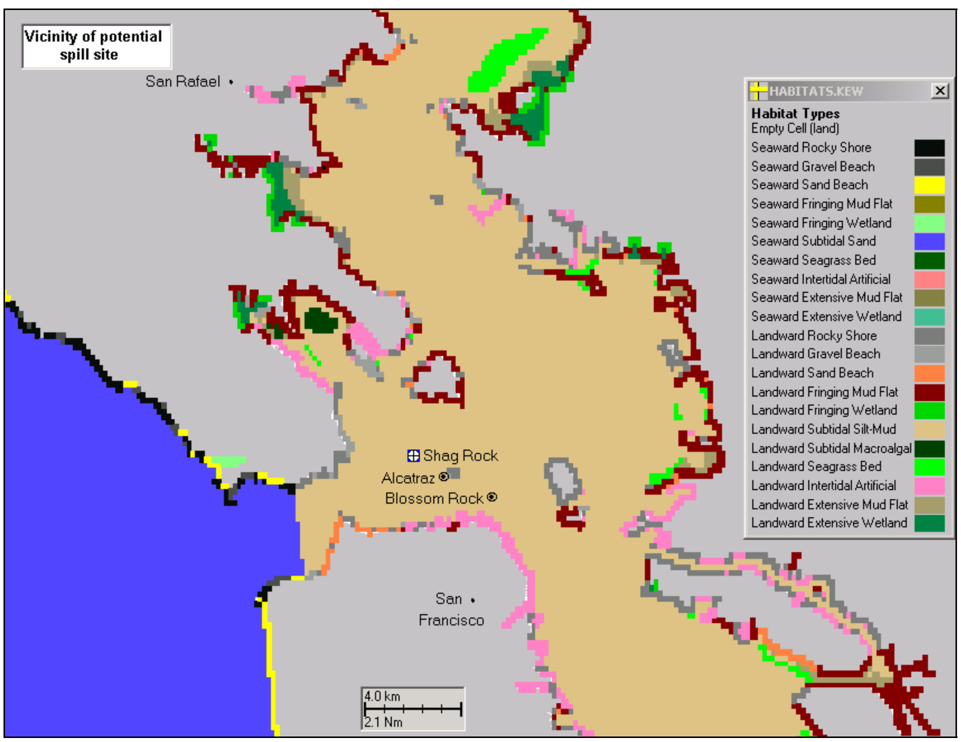

Figure 3.5-4. Habitat/Shoreline Delineation Map.

Wildlife species include aquatic birds and marine mammals. The model uses average number per unit area in appropriate habitats. ASA and ERC, as part of an update to the NRDAM/CME, compiled bird abundance data in 1997 for California Fish and Game (i.e., for NRDAM/CAL). Abundance varies monthly or seasonally. Separate data sets were developed and used here for inside San Francisco Bay and in coastal waters just outside the bay.

Toxicity: Toxicity thresholds of concern are modeled using the oil toxicity model, OilToxEx and is defined for both whole oil and various components. The most toxic components of oil to water-column and benthic organisms are lower-molecular-weight compounds, which are both volatile and soluble in water, especially the aromatic compounds (Anderson et al., 1987; French et al., 1996a; French 1998a, 2000; French McCay 2001). Oil has been well documented to cause impacts to wildlife and habitats when it is floating on the water surface and stranded on shorelines. The impacts of surface and shoreline oil are modeled as described in French et al. (1996a). Unweathered oil containing MAHs and PAHs appears to be more toxic to coated organisms than weathered oil where these compounds have evaporated.

The Toxic Unit (TU) model is used to estimate the toxicity of a mixture of narcotic chemicals. A TU is defined as the exposure concentration divided by the LC50 (lethal concentration to 50% of exposed organisms). For a mixture, the toxic units are additive. When Σ TU = 1, the mixture is lethal to 50% of exposed organisms. The oil toxicity model is used to estimate the LC50 for the dissolved aromatic mixture originating from the spilled oil. The thresholds for effects were used in the stochastic model analysis to determine potential for impacts and the needed duration of model simulations.

Retention of oil on a shoreline depends on the shoreline type, width and angle of the shoreline, viscosity of the oil, the tidal amplitude, and the wave energy. In the NRDAM/CME (French et al., 1996a,b), shore holding capacity was based on observations from the *Amoco Cadiz* spill in France and the *Exxon Valdez* spill in Alaska (based on Gundlach (1987) and later work summarized in French et al., 1996a). These data are used here. The shore width (intertidal zone width) was assumed to be typical widths for the region, based on French et al. (1996a).

According to the Oil Pollution Act (OPA) NRDA regulations and current practice, NRDA damages are based on the cost to restore ecological and human resource services equal in value to those lost due to the spill. Thus, a common ecological "currency" of value must be used to measure injury and to scale restoration projects to equally compensate the public for the injury. The methods used here are those currently in practice by federal and state Trustees performing NRDAs. The methods were developed as part of the largest NRDA case performed since the publication of the OPA NRDA rule in January 1996, the *North Cape* spill in RI (French et al 2001).

Summary of Exposure: A matrix of the scenarios analyzed for this study at both the Shag Rock and Blossom Rock locations is given in Figure 3.5-5.

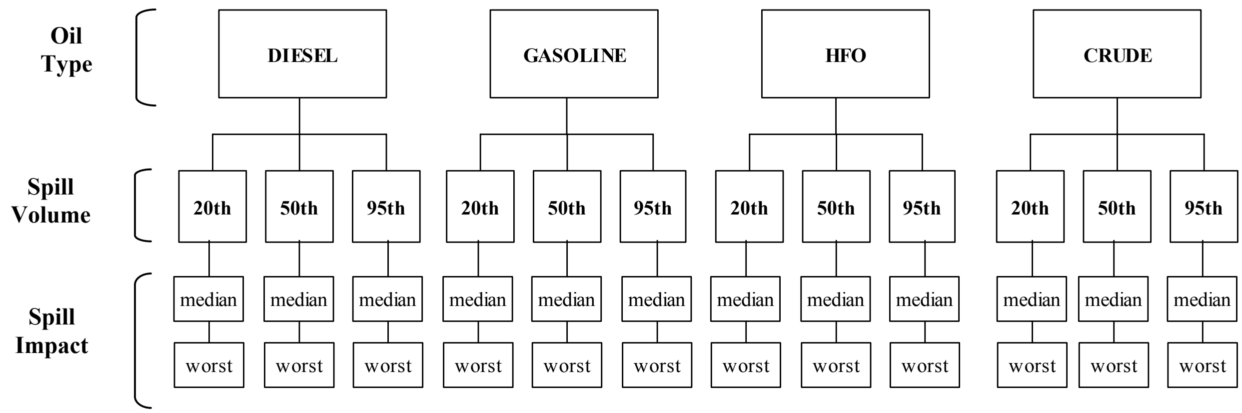

Figure 3.5-5. Oil Spill Scenarios (Median is 50th percentile run, Worst is 95th percentile run)

Tabular model output for a scenario were saved for the following matrix:

- For each model run (i.e., for each of the runs in a scenario)
- For each resource (habitat or shore) type
- For each exposure level over 6 order-of-magnitude intervals (i.e., if H = threshold used in the modeling: 1H-10H, 10H-100H, 100H-1000H, 1000H-10000H, 10000H-100000H, >100000H)

The following impact measures were calculated and saved for each combination of the above matrix for maximum extent (m^2) of contamination (where exposure level = peak exposure of each grid cell at any time after the spill):

- Water surface oiling (area) for each exposure level (mass/area or thickness)
- Shoreline oiling (area or length) for each exposure level (mass/area or thickness)
- Dissolved aromatic contamination in water: peak exposure (area) for each exposure level (concentration)
- Subsurface oil (total hydrocarbon) contamination in water: peak exposure (area) for each exposure level (concentration)
- Sediment total hydrocarbons: (area) for each exposure level (mass/area or concentration)
- Sediment dissolved aromatic: (area) for each exposure level (concentration)

Total dosage measures were also calculated for each model run for contamination that changes rapidly in time:

- Water surface oiling: Slick mass per unit area times time present (mass per area - time) for each run and by dosage level ($g\text{-}m^{-2}$-hrs)
- Dissolved aromatic contamination in water: Water area (entire water column) exposed at each dosage level (concentration-time, i.e., ppb-hrs)
- Total hydrocarbon contamination in water: Water area (entire water column) exposed at each dosage level (concentration-time, i.e., ppb-hrs)

The tabular results for each oil constituent (water surface, shoreline, etc.) and resource (habitat or shore) type are analyzed over all runs to determine the median and 95th percentile conditions (using the above impact measures) expected for that scenario. The runs producing the 50th and 95th percentile result were identified for further impact analysis.

Note that the same model run is not the 50th or 95th percentile case for water surface, shoreline, and water column impacts, simultaneously. In fact, when shoreline impacts are highest, water column impacts tend to be relatively low, and *visa versa*. The impact measures from the stochastic modeling provide a quantitative method for determining which runs are 50th and 95th percentile cases for the resource of interest.

Birds and other wildlife are impacted in proportion to the water and shoreline surface area oiled above a threshold thickness for effects. Shoreline habitat impacts are proportional to surface area oiled above a threshold thickness for effects.

For the heavy fuel and crude oil, environmental costs are largely driven by the impacts of surface oil, particularly by the shoreline cleanup costs. The wildlife and habitat impacts are generally proportional to shoreline oiling and cleanup costs. Thus, the 50th and 95th percentile runs to examine in detail were selected based on the frequency distribution of the shoreline cleanup costs. The order of model runs from lowest to highest impact is very similar for area of shore oiled by > 0.1 mm and cleanup costs, varying only by the differences in cleanup costs per unit area for different shore types (see companion reports on cleanup costs, Vols. III and IV).

For the diesel and gasoline spills, cleanup costs are much lower because there is much less oil that remains on the water surface and shorelines after the rapid evaporation period just after the spill. In addition, diesel and gasoline are much more easily entrained into the water and would be expected to cause more water column effect than the heavier oils. Thus, theoretically, the environmental costs are more driven by the NRDA costs for impacts to the fish and invertebrates in the water than would be the crude and heavy fuel oil scenarios. Using this reasoning, the index for water column effects, the dissolved aromatic dose (ppb-hours) in the volume of water where concentration exceeds 1 ppb at some time after the spill, was used to identify the 50th and 95th percentile runs to be examined further. (This argument was presented to the ACOE at the time the runs were selected, and it was agreed that this was a reasonable criteria to use for determining the runs to examine further). The expectation was that water column impacts would be significant for the large spills, and these would dominate the NRDA costs. However, based on the model results, only the diesel and crude oil spills were estimated to have significant impacts on fish and invertebrates in the water column. In model simulations, the gasoline volatilized quickly, minimizing exposure in the water column. Contamination from HFO was not dissolved in to the water in significant amounts. The majority of the fish and invertebrate injuries were squid and small pelagic fish, such as herring. Thus, the individual model runs, which were examined in detail, were used to scale the stochastic model results for all runs, resulting in PDFs for each of water column (fish and invertebrates) and wildlife impacts from which the 50^{th} and 95^{th} percentile impact could be estimated.

<u>Oil Fates Results:</u> San Francisco Bay is a very dynamic area due to presence of strong tides and the influence of variable winds. The different oils would have varying effects on the surface waters, shorelines and water column based on their chemical and physical properties. Gasoline is the most soluble and volatile of the four oils, and would be predicted to have more of an effect to the water column. Diesel is the most toxic to the water column, but it is less soluble than gasoline. Crude oil and heavy fuel oil are less likely to affect the water column than diesel, and would remain floating on the water for a much longer period of time.

Table 3.5-5 contains the range of surface water exposure to floating hydrocarbons for spills of each type of fuel.

Oil Type	Surface Water >1 g/m^2 (m^2-hours)	Shoreline >100 g/m^2 (millions m^2)
Gasoline	200 - 6,000	0 - 0.3
Diesel	1,000 - 20,000	0.03 - 2
Crude oil	1,000 - 18,000	0.03 - 3
Heavy Fuel Oil	500 - 4,000	0.02 – 1.6

Table 3.5-5. Range of surface water and shoreline exposure to oil.

Maps depicting total shoreline oiled and the extents of water column impacts were developed to illustrate each of the spill scenarios. To illustrate the scope and physical extents of some of the stochastic results from SIMAP, plots of peak exposure mass and concentrations are given for a 95^{th} percentile crude oil spill at Blossom Rock in Figures 3.5-6 through 3.5-11 and at Shag Rock in Figures 5.6-12 through 5.6-17. Complete numerical results and plots are given in the Bio-Economic Report Appendices.

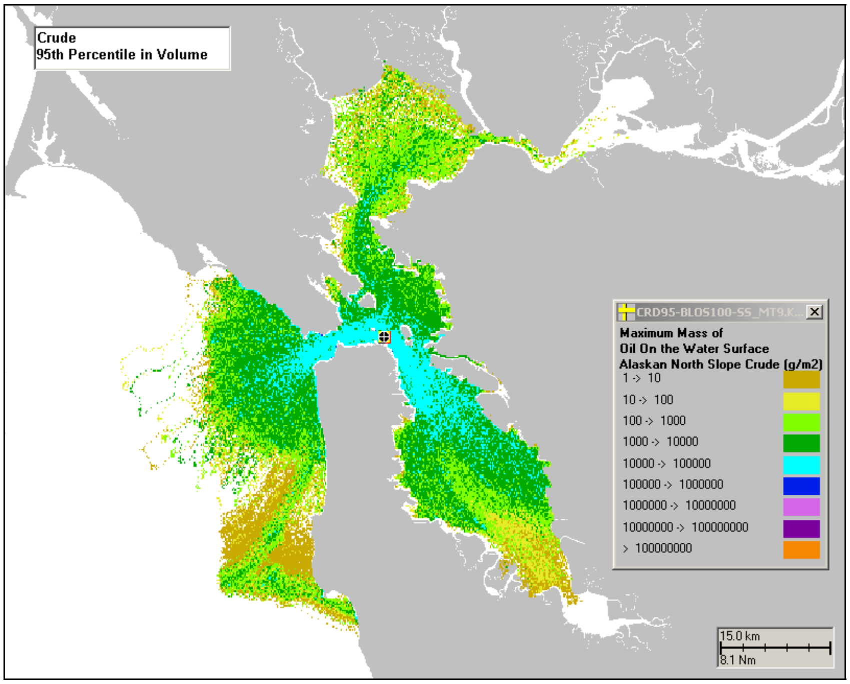

Figure 3.5-6 Blossom Rock Spill Scenario: Crude Oil, 95th percentile by volume. Water surface exposure to floating hydrocarbons (g/m^2) under worst case (95th percentile) environmental conditions.

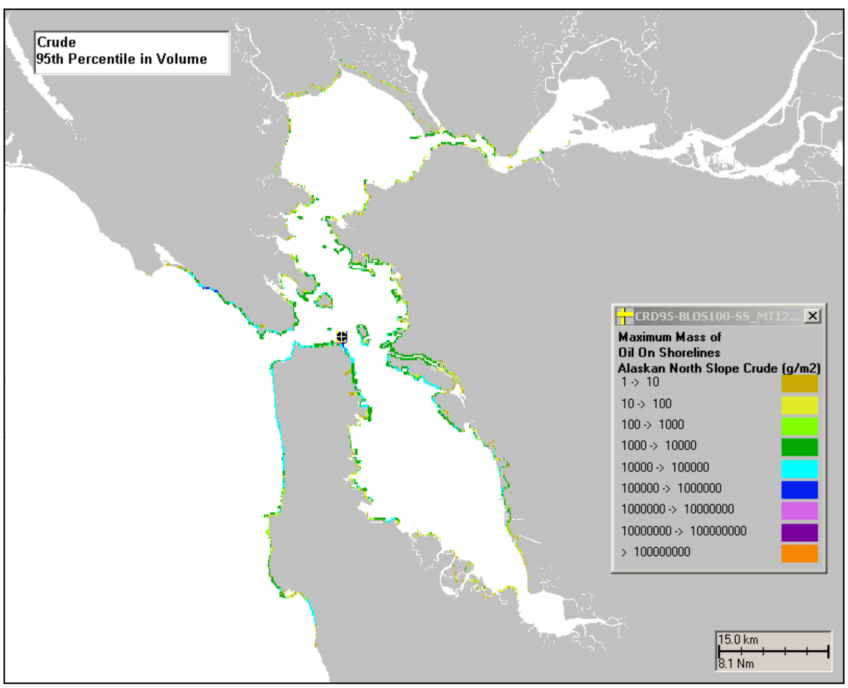

Figure 3.5-7 Blossom Rock Spill Scenario: Crude Oil, 95th percentile by volume. Shoreline exposure to hydrocarbons (g/m^2) under worst case (95th percentile) environmental conditions.

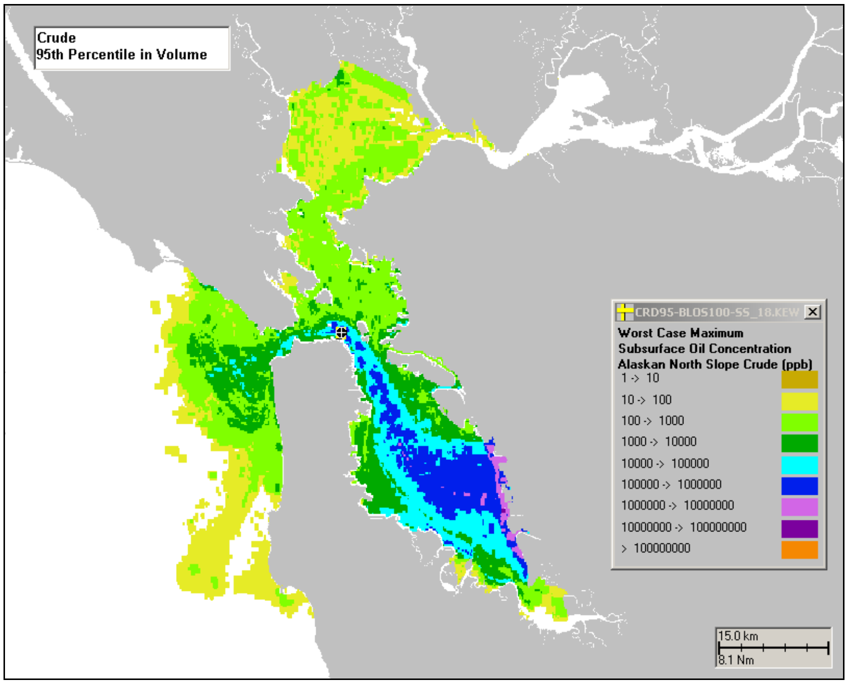

Figure 3.5-8 Blossom Rock Spill Scenario: Crude Oil, 95th percentile by volume. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst case (95th percentile) environmental conditions.

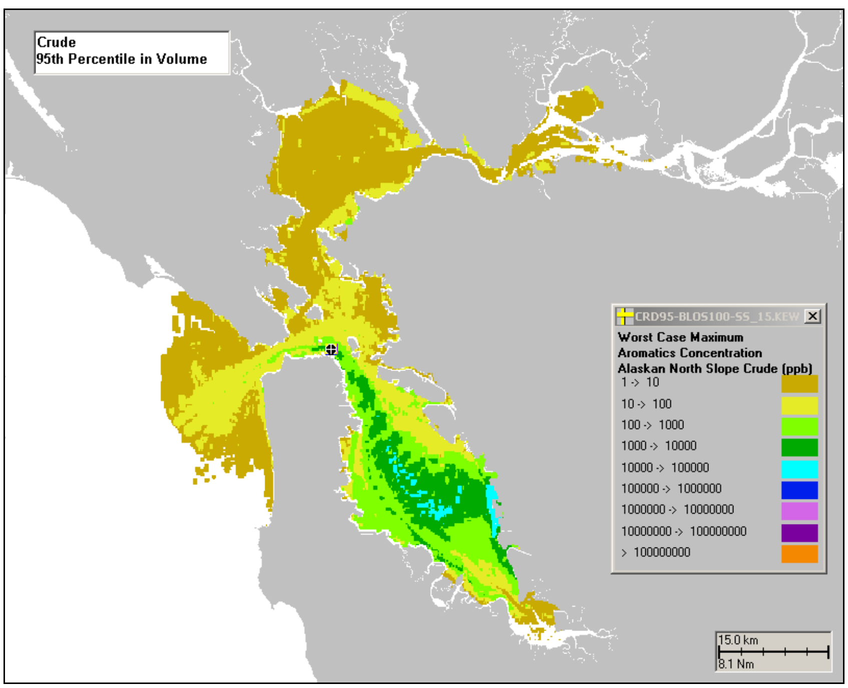

Figure 3.5-9 Blossom Rock Spill Scenario: Crude Oil, 95th percentile by volume. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst case (95th percentile) environmental conditions.

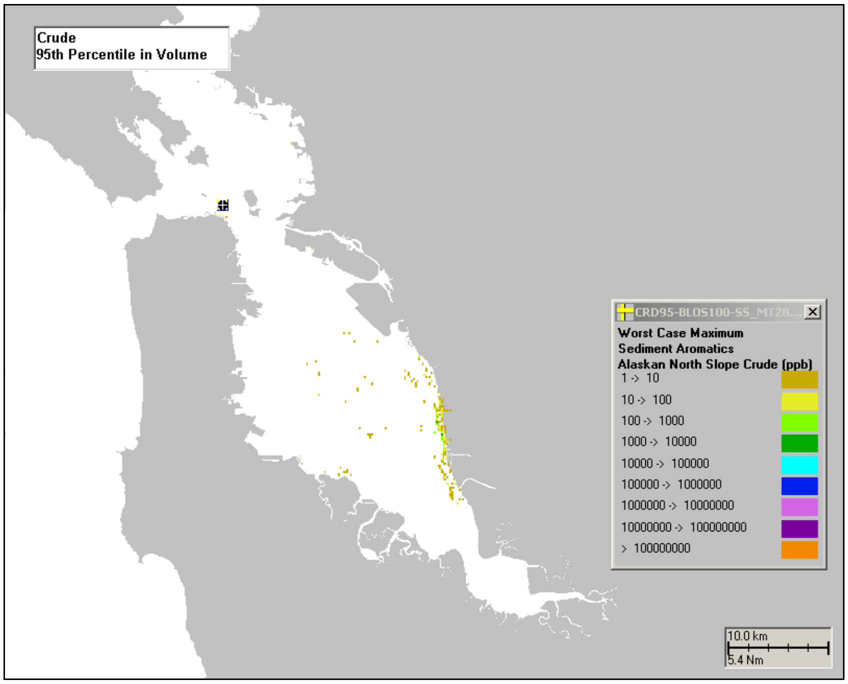

Figure 3.5-10 Blossom Rock Spill Scenario: Crude Oil, 95th percentile by volume. Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst case (95th percentile) environmental conditions.

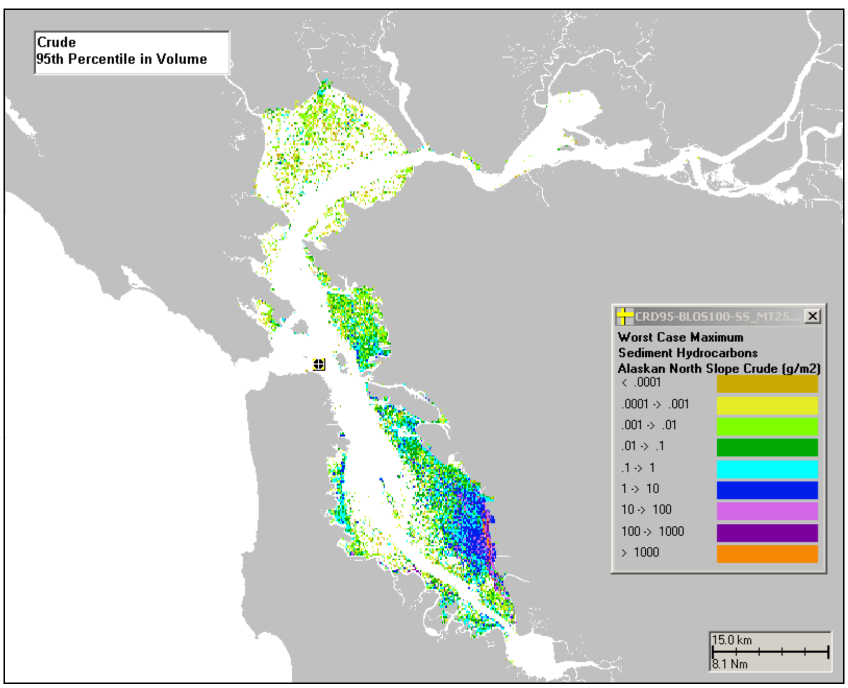

Figure 3.5-11 Blossom Rock Spill Scenario: Crude Oil, 95th percentile by volume. Sediment exposure to total hydrocarbons (g/m^2) under worst case (95th percentile) environmental conditions.

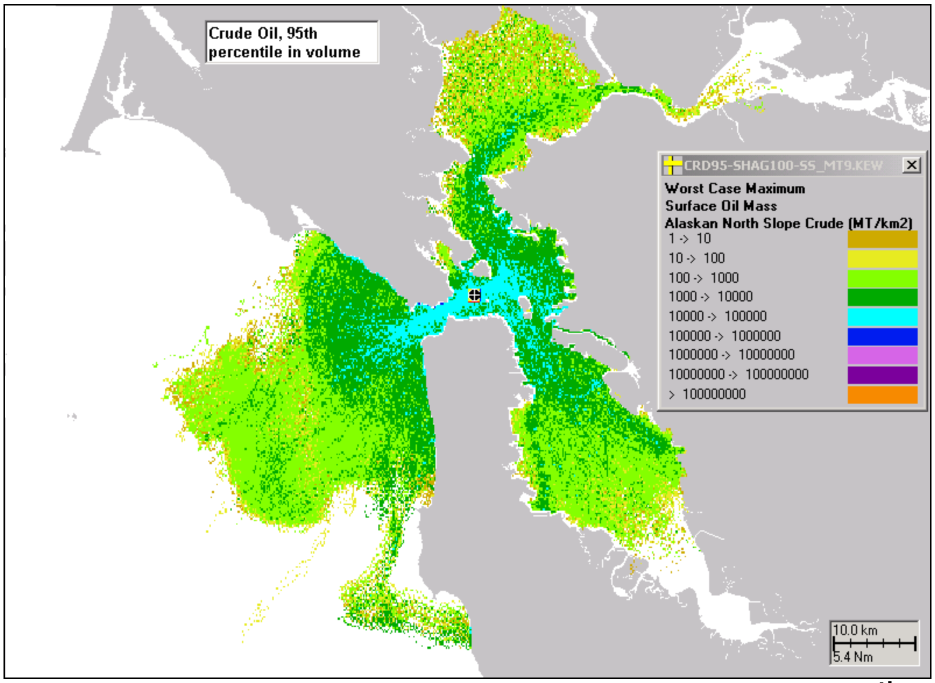

Figure 3.5-12 Shag Rock Spill Scenario: Crude Oil, 95th percentile by volume. Water surface exposure to floating hydrocarbons (g/m^2) under worst case (99th percentile) environmental conditions.

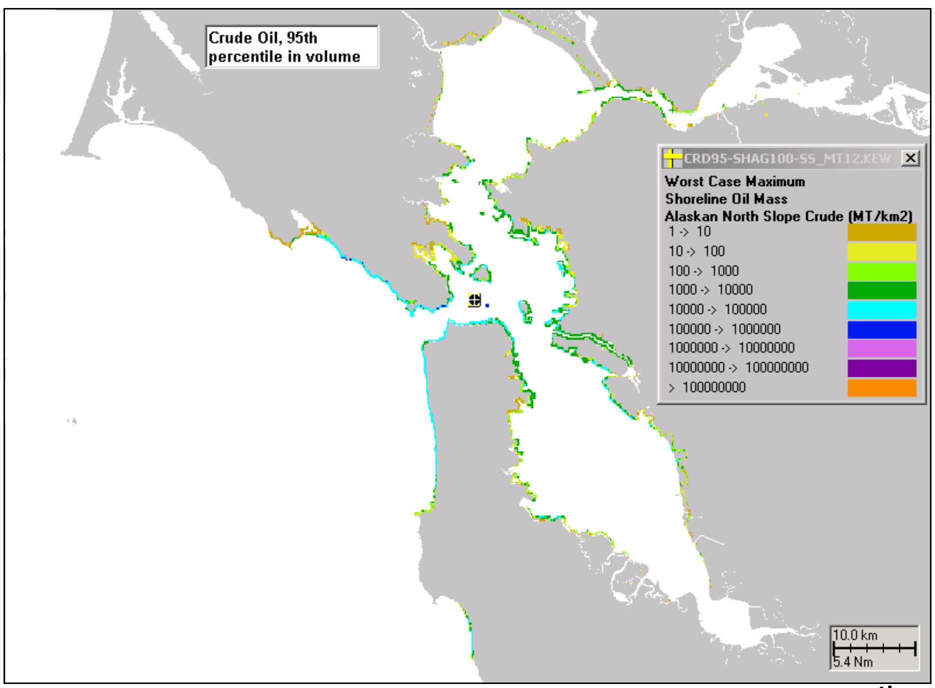

Figure 3.5-13 Shag Rock Spill Scenario: Crude Oil, 95th percentile by volume. Shoreline exposure to hydrocarbons (g/m^2) under worst case (99th percentile) environmental conditions.

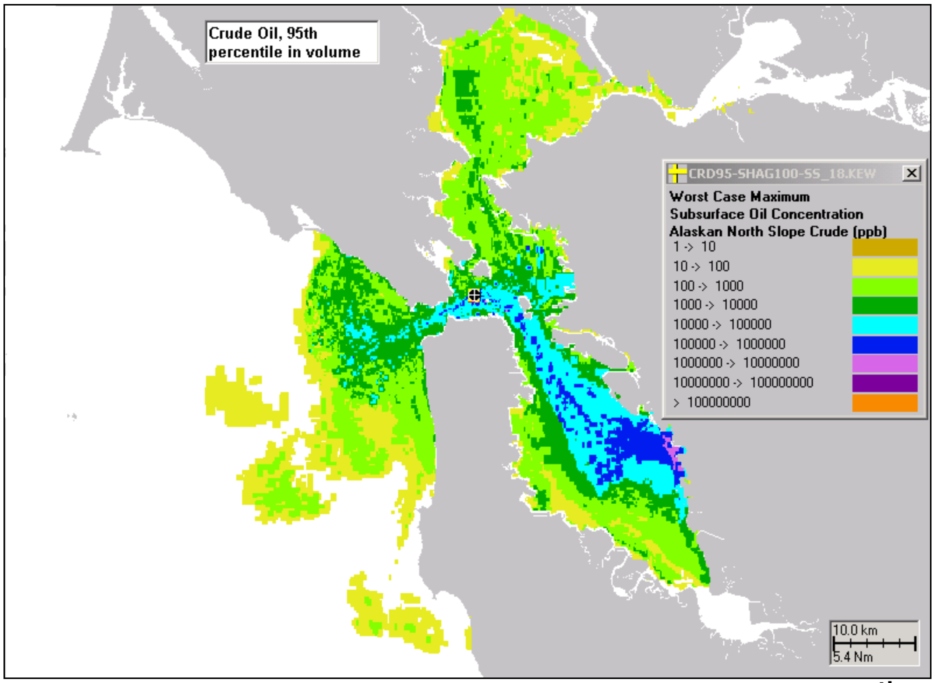

Figure 3.5-14 Shag Rock Spill Scenario: Crude Oil, 95th percentile by volume. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst case (99th percentile) environmental conditions.

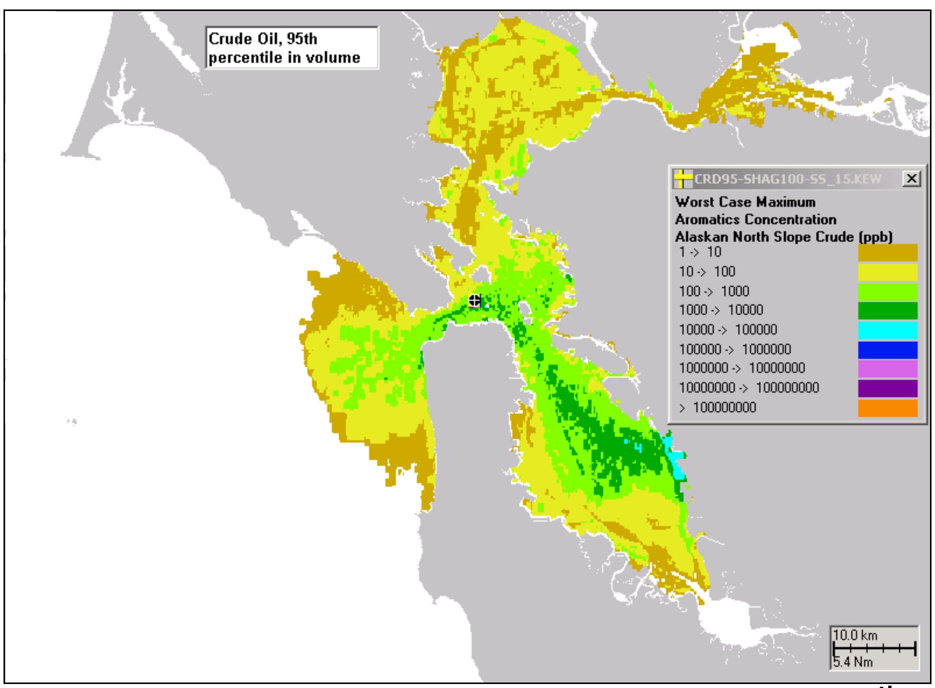

Figure 3.5-14 Shag Rock Spill Scenario: Crude Oil, 95th percentile by volume. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst case (99th percentile) environmental conditions.

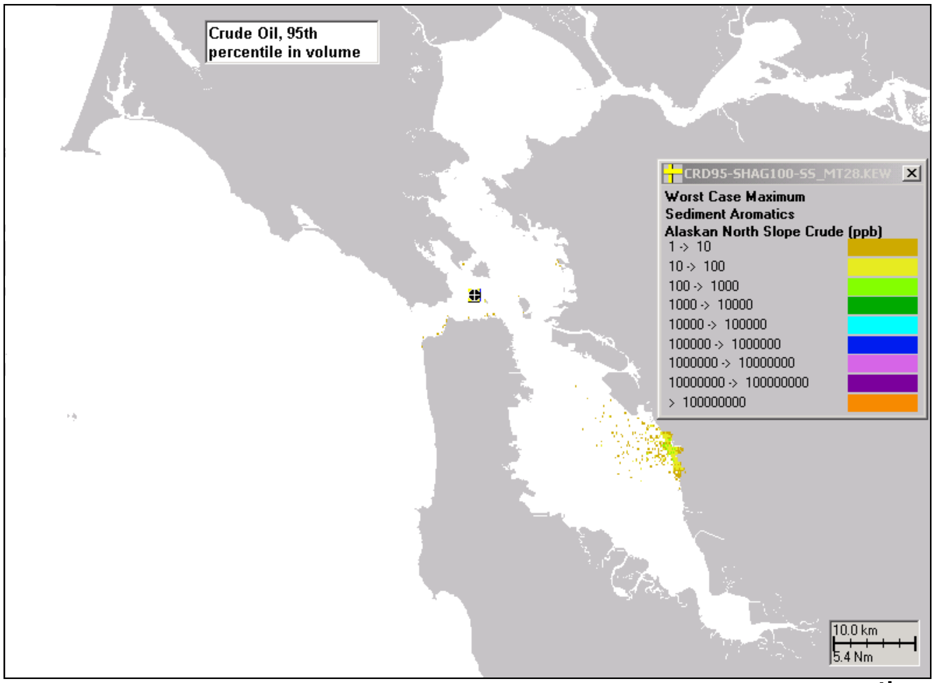

Figure 3.5-15 Shag Rock Spill Scenario: Crude Oil, 95th percentile by volume. Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst case (99th percentile) environmental conditions.

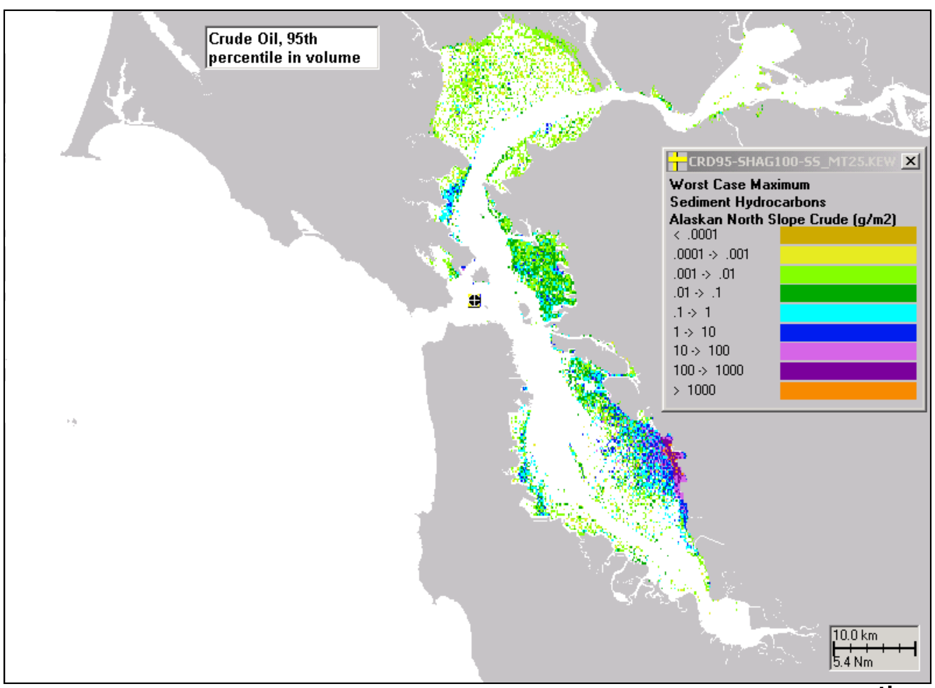

Figure 3.5-16 Shag Rock Spill Scenario: Crude Oil, 95th percentile by volume. Sediment exposure to total hydrocarbons (g/m^2) under worst case (99th percentile) environmental conditions.

Biological Effects Results: Mortality of the vegetation in marshes occurs above about 14 mm of oil, according to literature reviewed in French et al. (1996a). None of the wetlands exceeded this threshold dose. The concentrations of PAHs did not exceed the lethal threshold (LC50 for average species) in any wetland habitat areas. Thus, mortality of the *entire habitat* is not indicated by the model.

The month of a spill is particularly significant to the wildlife impacts. It has implications to water temperature, which affects the rate of evaporation, and the biological impacts. The month is particularly significant to the wildlife impacts. The birds are highly variable in abundance by month of the year. Waterfowl are about 10 times more abundant in fall and winter than in spring-summer. Shorebirds are also more abundant in fall and winter. Outside San Francisco Bay, seabirds are 5 times as abundant in summer as in winter, whereas inside the bay seabird abundance does not vary much seasonally. Seabird abundance in the bay is the same order of magnitude as outside the bay in winter. The high seabird abundance outside the bay in summer is primarily common murre and cormorants. Thus, summer spills exiting the bay and winter spills would impact the most birds. This complicates the interpretation of the results.

The wildlife abundances in some cases are the same within a season. If the paired runs are within the same season, and the abundance is the same for all months of that season, the 95th percentile run has a larger impact than the 50th percentile run. However, for pairs with varying abundance, the result is highest for the month with the higher abundance. Given that different species are most abundant in different months of the year, it would be difficult to identify a single worst-case month for impacts to wildlife based on abundance. In other words, the estimated wildlife kills are directly proportional to abundance. Given this proportionality, the seasonal variability in abundance for wildlife was removed by scaling the results for each run to the other three seasons. A seasonal mean was taken of the four seasonal impact estimates for the same fates model result (i.e., wind, currents, and other environmental conditions are constant over the four seasons).

A second source of variability is due to the particular path and area swept by the surface floating oil, as well as the amount of shoreline oiled. Wildlife impacts are proportional to these exposure measures. The 50th and 95th percentile runs were selected for gasoline and diesel based on relative impact to the water column, and for crude and heavy fuel oil based on relative shoreline impacts in terms of cleanup costs. The percentile values of the selected "50th"and "95th" percentile runs using the alternate index are listed in Table 3.5-6 for the 95th percentile volume at Shag Rock. Thus, the gasoline 50th percentile run evaluated would be the 8th percentile result for shoreline cleanup cost. The gasoline 95th percentile run evaluated here is the 94th percentile result for shoreline cleanup cost, and so on. Again, this indicates the complexity of the results, which is caused by the particular path of the oil (i.e., in-coming versus out-going tide and wind conditions when the oil is released). As the individual runs examined were the 50th and 95th percentile results for either water column impacts (gas, diesel) or shoreline cleanup cost (crude, HFO), they were not 50th and 95th percentiles for wildlife impacts (as these three exposure measures are uncorrelated or bear inverse relationships).

Fuel	Volume Percentile	Water Column Dose: Percentile	Shoreline >0.1mm: Percentile
Gasoline	95	50	8
Gasoline	95	95	94
Diesel	95	50	28
Diesel	95	95	53
Crude	95	55	50
Crude	95	34	95
Heavy Fuel Oil	95	61	50
Heavy Fuel Oil	95	57	95

Table 3.5-6. Percentile result by alternate indices of impact for Shag Rock spills: dissolved aromatic dose in the water column versus shoreline cleanup costs based on area oiled >0.1mm thickness.

The results of the 24 individual model runs (2 sites, 12 scenarios) were used to construct probability distributions of wildlife impacts for all possible environmental conditions as follows. The water surface exposure (m^2-hours) and impact for an individual model run were used to calculate an index of wildlife oiled per m^2-hours surface oil exposure in subtidal (water) areas. The area of shoreline oiled (m^2) and number of shorebirds plus waders oiled for the individual model run provide an index of wildlife impacted per area of intertidal habitat oiled. The total wildlife impacted for all runs is calculated from these indices and the degrees of exposure to floating and shoreline oil, generating a probability distribution for 100 potential environmental conditions that might occur after a spill of the specific volume and oil type.

If a scenario (i.e., spill volume, oil type, wind conditions, and current conditions) were to occur in a different month of the year, the impact to a species would change according to the ratio of abundance in the two months. The probability distribution for other seasons was calculated using the ratios of abundance. Finally, median and 95th percentile results were tabulated for each seasonal distribution.

Similar methods were used to determine fish and invertebrate impacts. Using methods analogous to those used for the wildlife probability distributions, the fish and invertebrate impacts for the other 98 model runs were calculated using the ratio of water column exposure, ppb-hours of exposure to dissolved aromatics, averaged over the plume volume exceeding 1ppb. For gasoline and diesel, the results are identical to the runs performed (as the water column exposure was the criteria for selection of the percentiles). For crude and HFO, the scaled 50th and 95th percentile impacts are truly the estimates for those percentiles. The scaled results show a clearer pattern relative to other results, as the variability due to the scenario actually run was removed. While the seasonal variability was not removed for the scaled fish and invertebrate impacts, this variation is expected to be relatively small.

It should be noted that these fish and invertebrate impacts were calculated assuming all the species were of average sensitivity to dissolved aromatics. Some species will be much more sensitive, and impacts to those species would be higher. There would also likely be species less sensitive than average. As there are insufficient toxicity data available to quantify the degree of sensitivity to aromatics for all species in San Francisco Bay, there is considerable uncertainty around the results based on average sensitivity. Experience with past modeling efforts indicate the uncertainty in the injury estimate related to species sensitivity is on the order of a factor ten higher or lower (95% confidence range). As there is a mix of species sensitivity present, the uncertainty in the total fish and invertebrate injury would be less than a factor ten.

Potential Damages Based on Restoration Costs: NRDA costs associated with impacts are included in the type A CERCLA regulations (NRDAM/CME). However, under the 1990 Oil Pollution Act NRDA regulations published in January of 1996 by NOAA, the approach to NRDA has been focused on use of compensatory restoration costs rather than the type of economic valuation methodology that is included in the NRDAM/CME. While the NRDAM/CME does include restoration costs, these are only applied in that model for so-called primary restoration of the injured resources when that is feasible. In the NRDAM/CME, when primary restoration is not feasible (i.e., the recovery rate of the injured resources cannot be accelerated over natural recovery), economic valuation of injured resources is used. Present practice by NRDA Trustees is to use and cost restoration of resources similar in ecological and human use value to the injured resources when primary restoration of the injured resources is not feasible. Thus, this refocusing of the NRDA cost functions is used in the present analysis and restoration costs are used for both primary and compensatory restoration of injured resources.

The scaling of the compensatory restoration uses methods currently in practice by NOAA and state trustees, such as Habitat Equivalency Analysis (HEA) and Resource Equivalency Analysis (REA). REA, which involves the estimation of costs to restock, directly enhance or otherwise restore target species (in kind or of equivalent value), is the most likely approach for seabird restoration, and so was the basis of NRDA costs for seabird species. HEA was used to estimate the required amount of habitat (saltmarsh) restoration for NRD compensation of injuries to other wildlife, fish and invertebrate species. Production by the restored habitat ultimately benefits wildlife, fish and invertebrates, and equivalency is assumed if equal production of similar species (i.e., the same general taxonomic group and trophic level) results. NOAA recommends HEA as a preferred method for calculating damages (Mazotta et al., 1994; Unsworth and Bishop, 1994, and NOAA, 1995). Scaling methods used here were developed for NRDA cases under contract to government trustees (NOAA Damage Assessment Center), for example as described in French et al. (2001). In addition to REA, HEA was applied to the seabird injuries as an alternative that might be considered. However, the final summaries of NRDA costs use REA for seabirds and HEA for all other wildlife, fish and invertebrates. NRDA costs are summarized in Tables 3.5-7 and 3.5-8.

Oil Type	Volume Percen-tile	Impact Percen-tile	Cost for Restoration of Seabirds	HEA Cost for Other Wildlife	HEA Cost for Fish and Invertebrates	Total NRDA Costs for Ecological Damages
Gasoline	95	50	5,024,000	3,571,000	20	8,595,000
Gasoline	95	95	5,900,000	31,821,000	100	37,721,000
Gasoline	50	50	4,838,000	1,615,000	0	6,454,000
Gasoline	50	95	25,179,000	11,054,000	7	36,233,000
Gasoline	20	50	810,000	1,124,000	0	1,934,000
Gasoline	20	95	1,799,000	4,899,000	0	6,698,000
Diesel	95	50	9,093,000	23,562,000	126,000	32,781,000
Diesel	95	95	19,505,000	62,672,000	407,000	82,584,000
Diesel	50	50	4,286,000	11,105,000	30	15,391,000
Diesel	50	95	30,793,000	24,690,000	276,000	55,760,000
Diesel	20	50	1,156,000	2,287,000	100	3,443,000
Diesel	20	95	755,000	7,918,000	7,000	8,680,000
Crude oil	95	50	12,451,000	12,636,000	604,000	25,692,000
Crude oil	95	95	46,402,000	46,415,000	853,000	93,671,000
Crude oil	50	50	8,782,000	4,910,000	117,000	13,809,000
Crude oil	50	95	9,659,000	13,578,000	59,000	23,296,000
Crude oil	20	50	9,867,000	8,329,000	23	18,196,000
Crude oil	20	95	17,059,000	34,311,000	2,300	51,372,000
Heavy fuel oil	95	50	192,000	2,884,000	109,000	3,186,000
Heavy fuel oil	95	95	98,000	6,814,000	21,000	6,933,000
Heavy fuel oil	50	50	36,000	2,374,000	0	2,410,000
Heavy fuel oil	50	95	62,000	3,997,000	0	4,059,000
Heavy fuel oil	20	50	14,000	663,000	0	677,000
Heavy fuel oil	20	95	19,000	1,291,000	0	1,310,000

Table 3.5-7 Summary of NRDA costs for ecological damages (2001$), assuming restoration of seabird species is performed and other species are compensated by HEA (saltmarsh restoration): Shag Rock scenarios.

Oil Type	Volume Percen-tile	Impact Percen-tile	Cost for Restoration of Seabirds	HEA Cost for Other Wildlife	HEA Cost for Fish and Invertebrates	Total NRDA Costs for Ecological Damages
Gasoline	95	50	1,479,000	9,058,000	490	10,538,000
Gasoline	95	95	10,621,000	50,888,000	8,700	61,517,000
Gasoline	50	50	168,000	1,245,000	4	1,413,000
Gasoline	50	95	4,656,000	1,781,000	0	6,437,000
Gasoline	20	50	260,000	1,100,000	0	1,360,000
Gasoline	20	95	1,744,000	641,000	8	2,386,000
Diesel	95	50	3,024,000	25,879,000	99,000	29,002,000
Diesel	95	95	4,344,000	48,252,000	4,365,000	56,961,000
Diesel	50	50	1,702,000	11,583,000	90	13,285,000
Diesel	50	95	6,726,000	62,645,000	30,000	69,402,000
Diesel	20	50	1,491,000	11,655,000	25,000	13,172,000
Diesel	20	95	3,330,000	24,763,000	610	28,093,000
Crude oil	95	50	2,916,000	16,161,000	2,290,000	21,367,000
Crude oil	95	95	6,539,000	61,743,000	1,981,000	70,263,000
Crude oil	50	50	3,158,000	5,948,000	252,000	9,358,000
Crude oil	50	95	2,011,000	13,363,000	37,000	15,411,000
Crude oil	20	50	3,760,000	51,492,000	1,200	55,254,000
Crude oil	20	95	9,969,000	109,920,000	1,500	119,890,000
Heavy fuel oil	95	50	5,833,000	14,455,000	77,000	20,365,000
Heavy fuel oil	95	95	3,555,000	20,330,000	150	23,886,000
Heavy fuel oil	50	50	1,452,000	13,001,000	10	14,453,000
Heavy fuel oil	50	95	5,283,000	37,228,000	0	42,511,000
Heavy fuel oil	20	50	348,000	1,557,000	0	1,905,000
Heavy fuel oil	20	95	434,000	3,122,000	0	3,557,000

Table 3.5-8 Summary of NRDA costs for ecological damages (2001$), assuming restoration of seabird species is performed and other species are compensated by HEA (saltmarsh restoration): Blossom Rock scenarios.

3.6 ECONOMIC AND RISK ANALYSIS

Historically, underwater rocks in Central San Francisco Bay, California were problematic to navigation and several efforts were made in the past to eliminate the hazards created by these underwater rocks. This report documents comparison between the costs of the rocks removal to the risk and subsequent damage in the without project condition.

3.6.1 Steps in the analysis

Determining whether a structural project is economically justified can be summarized in a series of steps:

1. Gather data on the number and types of vessels, which are at risk
2. Determine the probability of an accident using risk assessment tools

3. Compute the oil spill likely to result from an accident for different types of vessels and determine the oil's dispersal to various SF Bay locations..
4. Determine the monetary damages, which would result from a spill
5. Determine the cost of lowering the rocks.
6. Determine the discounted cash flow and its associated net benefits and benefit-cost ratio

3.6.2 Transits of Vessels at Risk

San Francisco Bay is a host to a multitude of sizes of watercraft from Very Large Crude Carriers (VLCCs)—tankers, to personal pleasure craft such as kayaks. In this study, the vessels of interest are those over 160,000 DWT, i.e., those vessels regulated by the Vessel Traffic Service, and in particular, vessels of greater than 35 feet draft, Table 3.6-1, reproduced from the ABS Consulting Final Report (ABS Report), classifies the number of transits made by tanker and container vessels during the year June 2000 through June 2001. Table B-1 in Appendix X, ABS Report, presents a more detailed summary of this data including distributions by size and hull type. (Appendix D)

TABLE 3.6-1. SUMMARY OF TRANSIT DATA

Vessel Type	Total Transits	Draft > 35 Feet	Draft > 42 Feet
Tankers	1376	330	96
Container Vessels	3564	884	21
Other Vessels	1263	118	0
Total	6203	1332	117

(The number of transits plays a crucial role in determining the probability of an accident.)

3.6.3 Summary of the Results of the Fault-Tree Quantification

The purpose of the ABS Consulting (ABS) study was to develop an assessment of the probability of an accident when there are no incidents with which to construct an empirical frequency distribution. Anyone interested in understanding the fault tree approach should consult the consulting report. The following paragraph summarizes the methodology used:

> A fault tree is a tool, which analysts use to look at possible failures and into what might cause these failures to occur. Fault trees identify the sequences of events that lead up to a single fault condition. A fault tree shows, in graphical form, the logical relatinship between a particular system failure mode, known as the "top event", and the basic failure causes, known as events, using "AND" or "OR" gates. An AND gate denotes all events below the gate must occur for the event above the AND to occur. An OR gate denotes any event below the OR gate will, occurring alone, cause the vent above the OR to occur. (*ABS Consulting)*

The analysis proceeds by identifying, at the event level, situations in which failure might occur, e.g, a shaft might break which would result in a loss of propulsion. This would, in turn, lead to a drift grounding—the top event. Proprietary software is used to multiply the dozens of event probabilities to produce a conditional probability of the top event. For example, the probability of drift grounding has a "subvariable" of mechanical failures, which have "subvariables" of loss of propulsion, which in turn have subvariables of muliple screws loss, lost shafts, etc.(Figure A-1c, ABS Report). Actual fault tree models generally are too large to be Shown in this analysis.

Table 3.6-2: Summary of the Results of Fault Tree Quantification

Causes of Grounding	Frequency (Events/Year)			
	North Rocks		Blossom Rock	
	Contribution	Percent of Total	Contribution	Percent of Total
Tankers				
Powered grounding	0.00132	17.1	0.00129	59.9
Drift grounding	0.000207	2.68	0.000196	9.10
Non-Tankers				
Powered grounding	0.00414	53.6	0.000406	18.8
Drift grounding	0.00027	26.9	0.000204	9.47
Total tankers	0.00152	19.7	0.00153	71.00
Total Non-tankers	0.00621	80.3	0.000624	29.00
Total vessels	0.00773	100.00	0.0025	100.00

Interpreting the data developed by the ABS Consulting's Riskman software yields the result of the likelihood of an accident on the North Rocks when all vessels are considered is 1 in 129 years. (1 divided by 0.00773). Because there are far fewer tanker vessels, one would expect the likelihood of an accident would be considerably less for them. Table 3.6-2 shows this is indeed the case and predicts the probability of an accident is 1 in 658 years (1 divided by 0.00152).

The probability of an accident at Blossom Rock for all vessels is substantially less than for the Northern Rocks because it is seven feet lower and hence far fewer container vessels are at risk. The result is a 1 in 465 years as the probability of an event (1 divided by 0.00215) when all vessels are considered. The relative importance of tanker events is, however, much larger. With their greater draft, they are more at risk than container ships. Their smaller number (96), which should decrease the probability of an event, is offset by a larger number of hazardous elements. The result is the likelihood of an accident, 1 in 654 years (1 divided by .00153), is approximately the same as it is for the Northern Rocks

3.6.4 Determining the Hull Breach

Having determined the likelihood of an accident, it then becomes necessary to determine the likely outflow from the vessels involved in a collision. For this analysis, specific vessels similar to those transitting San Francisco Bay were selected from an ABS data base. The consultants report; unfortunately, there is no program available capable of both analyzing the damage done to a vessel upon collision and the likely oil outflow. Hence their analysis proceeds in two steps. The first estimates the damage to the hull and is obtained from a program which resembles MIT's DAMAGE software, an industry standard. This program determines the damage to a hull of a collision, given the rocks, the size of a ship, its speed, the angle of the collision, etc. See Table 3.6-3.

Table 3.6-3: Hull Breach Sizes for Grounding on Harding Rock

Vessel Type	Size	Speed	Damage (meters)	Damage (feet)
Single hull	50,000 DWT	5 knots	16.6	54.5
Single hull	100,000 DWT	5 knots	24.3	79.7
Single hull	160,000 DWT	5 knots	31.2	102.4
Single hull	300,000 DWT	5 knots	57.9	190.0
Double hull	50,000 DWT	5 knots	21.2	69.6
Double hull	100,000 DWT	5 knots	30.3	99.4
Double hull	160,000 DWT	5 knots	35.9	117.8
Double hull	300,000 DWT	5 knots	53.6	175.9
Containership	8,000 DWT	15 knots	35.0	114.8
Containership	20,000 DWT	15 knots	85.5	281.5
Containership	40,000 DWT	15 knots	124.7	409.1
Containership	60,000 DWT	15 knots	142.5	467.5

3.3.5 Determining Oil Outflow

The second part of the study uses a commercially available software program (HECSAV) to determine the likely oil outflow. Using estimates of loads consistent with the draft limitations of the San Francisco Bar and the damage parameters from the hull breach program, HECSAV similulations were run to determine oil outflow.

Table 3.6-4 provides estimates for the catagories of vessels used in the risk assessment analysis. The maximum outflow column shows the total amount of oil in the tanks,which would be breached for a ship in a collision with the rocks. The simulated outflow column indicates the amount of oil, which would be likely flow out of the tanks in the face of hydrostatic pressures. These simulated outflows were determined by the application of the HECSAV modeling software. (37 of the 330 tanker vessels were of unknown configuration and no effort was made to determine a simulated outflow.)

A weighted average spill of the the single hull tanker vessels is 3,433,127 gallons. The weighted average of the double hull vessels is 2,003,085. These figures represent the deterministic outcome of the outflow simulation. Sensitivity analyses will be needed to test the robustness of the benefit-cost conclusion in the face of this uncertainty.

Table 3.6-4. Oil Outflow for Grounding on North Rocks

Vessel Type	Size	Number	Speed	Simulated Outflow for Representative Vessel	Maximum Outflow for Representative Vessel
				(gallons)	(gallons)
Single hull	50,000 DWT	63	5 knots	757,554	3,018,372
Single hull	100,000 DWT	40	5 knots	1,101,534	5,607,588
Single hull	160,000 DWT	50	5 knots	4,200,000	4,500,000
Single hull	300,000 DWT	17	5 knots	4,926,180	11,333,784
Double hull	50,000 DWT	25	5 knots	403,074	908,670
Double hull	100,000 DWT	20	5 knots	1,640,856	3,190,026
Double hull	160,000 DWT	78	5 knots	2,608,788	4,604,040
Double hull	300,000 DWT	0	5 knots	5,029,600	7,316,022
Containership	8,000 DWT		15 knots	0	242,214
Containership	20,000 DWT		15 knots	0	520,800
Containership	40,000 DWT		15 knots	512	582,120
Containership	60,000 DWT		15 knots	3,163	389,298

The estimate of the likelihood of an annual occurrence of an accident and the oil outflow, which would be associated with it, provide the data needed to estimate annual expected outflow. For example, assume all 330 tank vessels were single hulled carrying crude oil. The relevant likelihood of an annual event under this assumption would be 0.00152 (Table 2). The weighted average of a spill (3,433,127) times the probability of the accident, is 5,218 gallons (0.00152 x 3,433,127), which represents the annual expected outflow.

3.6.6 Estimating Damages

Determining potential damages—the benefits from the project—requires an estimate of the response costs, socio-economic costs, and oil lost from the spill. The modeling performed by Applied Science Associates (ASA) and Environmental Research Consultants (ERC) provided the necessary data. Their "worst case" scenario of 3,000,000 million gallons is sufficiently close to the spill assumed in the ABS Consulting study for their per gallon figures to be used to determine costs.

Table 3.6-5 is drawn from p. 38. of the ERC study of response cost modeling. The figures are for the median spill outcome for different types of oil and percentiles of spills. The estimates differ significantly by type of spill because of the substantial overhead costs in organizing a spill response. The equipment and manpower, which would be devoted to cleaning up a small spill is proportionately much greater per gallon of oil spilled than is the case with a large spill.

Table 3.6-5. Estimated Total Per-Gallon Response Costs of Oil Spills in San Francisco Bay

Scenario	SPILL SIZE	Primary On-Water Response Strategy		
Oil Type	(Gallons)	Mechanical	Dispersant	Dispersant
			Low Effective	High Effectiveness
Diesel	50,000	$211	$189	$186
Diesel	270,000	53	42	38
Diesel	1,250,000	24	17	12
Gasoline	50,000	201	184	184
Gasoline	270,000	41	36	36
Gasoline	1,250,000	11	10	9
Heavy fuel oil	25,000	473	314	258
Heavy fuel oil	100,000	258	142	96
Heavy fuel oil	410,000	156	78	45
Crude	100,000	276	173	142
Crude	600,000	101	48	31
Crude	3,000,000	56	21	12

A continuing area of controversy is the role, which each of the response strategies can play in the event of a spill. For example, using a highly effective dispersant would be significantly less expense per gallon of oil as compared to mechanical cleanup methods. Dispersants, however, have undesirable environmental effects as the dispersed oil sinks to the bottom of the Bay. Dispersant technology is improving steadily but, for the time being, it is unlikely it can be the sole protection against the effects of a spill, especially under unfavorable weather conditions.

TABLE 3.6-6. ESTIMATED SOCIO-ECONOMIC COSTS PER GALLON OF OIL SPILLED

	SPILL SIZE	Socio-Economic Costs Per Gallon						
Oil Type	(Gallons)	Port	Tourism	Recreation	Total Use	Fishing	Marina	Total
		Blockage	Loss	Loss	Loss	Loss	Loss	
Diesel	50,000	$190.88	346.00	5.39	9.10	16.32	0.12	567.81
Diesel	270,000	19.95	153.78	2.39	2.78	17.41	0.48	196.49
Diesel	1,250,000	9.43	83.04	1.29	1.29	12.43	0.24	107.72
Gasoline	50,000	69.95	346.00	5.39	2.85	16.21	0.03	440.43
Gasoline	270,000	18.13	153.78	2.39	1.31	5.78	0.02	181.42
Gasoline	1,250,000	0.70	83.04	1.29	0.67	3.05	0.03	88.78
HFO	25,000	48.96	692.00	10.78	7.71	79.21	0.48	839.15
HFO	100,000	78.60	415.20	6.47	14.37	43.31	1.44	559.38
HFO	410,000	10.80	177.22	2.76	22.48	20.49	4.00	237.76
Crude	100,000	22.44	242.20	3.77	38.87	17.19	0.96	325.44
Crude	600,000	4.42	103.80	1.62	2.74	21.68	0.96	135.22
Crude	3,000,000	2.92	48.44	0.75	2.20	7.10	1.68	63.10

Table 3.6-7
Summary of NRDA costs for ecological damages, socioeconomic costs, and response costs (2001$) for a spill at Shag Rock, assuming a mechanical-only response strategy.

Oil Type	Volume Percen-tile	Impact Percen-tile	NRDA for Ecological Damages	Socio-economic Costs	Response Costs (Mechanical)	Total Costs
Gasoline	95	50	8,595,000	110,979,000	13,402,000	132,977,000
Gasoline	95	95	37,722,000	110,494,000	15,025,000	163,241,000
Gasoline	50	50	6,454,000	48,982,000	11,044,000	66,480,000
Gasoline	50	95	36,233,000	47,921,000	11,010,000	95,163,000
Gasoline	20	50	1,934,000	22,022,000	10,021,000	33,976,000
Gasoline	20	95	6,698,000	22,022,000	10,007,000	38,727,000
Diesel	95	50	34,136,000	134,653,000	26,895,000	195,684,000
Diesel	95	95	86,812,000	133,265,000	31,665,000	251,742,000
Diesel	50	50	15,392,000	53,051,000	18,789,000	87,231,000
Diesel	50	95	59,861,000	56,006,000	13,079,000	128,946,000
Diesel	20	50	3,445,000	28,390,000	12,206,000	44,041,000
Diesel	20	95	8,764,000	25,515,000	14,386,000	48,665,000
Crude oil	95	50	25,692,000	189,297,000	182,144,000	397,133,000
Crude oil	95	95	93,671,000	195,303,000	230,184,000	519,159,000
Crude oil	50	50	13,809,000	81,130,000	65,498,000	160,437,000
Crude oil	50	95	23,296,000	91,491,000	83,698,000	198,484,000
Crude oil	20	50	18,196,000	32,544,000	29,549,000	80,289,000
Crude oil	20	95	51,372,000	28,995,000	36,029,000	116,396,000
Heavy fuel oil	95	50	3,186,000	97,481,000	78,087,000	178,754,000
Heavy fuel oil	95	95	6,933,000	90,780,000	122,207,000	219,920,000
Heavy fuel oil	50	50	2,410,000	55,937,000	35,107,000	93,454,000
Heavy fuel oil	50	95	4,059,000	52,352,000	50,537,000	106,948,000
Heavy fuel oil	20	50	677,000	20,979,000	11,619,000	33,275,000
Heavy fuel oil	20	95	1,310,000	20,539,000	13,919,000	35,767,000

Source: *Draft Report, San Francisco Rocks Removal Study, Bio-Economic Oil Spill Modeling,* by Applied Science Associates, prepared for USACE, July, 2002.

3.6.7 Benefit Estimation

As noted earlier, the 3,000,000-gallon spill modeled by ASA and ERC is quite close to the weighted average of single hulled tankers in the ABS report. The ERC per gallon damages can therefore be used for a provisional benefit estimate. Assuming all response costs are mechanical ($56) and all socio economic costs, Table 3.6-6, are admissible in a NED benefit calculation ($63.10), both very conservative assumptions, the benefits per gallon would be $119.10. ERC adds another $0.43 for oil lost which brings the total potential damages per gallon to $119.53. When multiplied times the expected annual spill (5,218 gallons), the expected annual cost is $623,707. Assuming an interest rate of 6.35% and a span of 3 years before the project becomes effective, the present value of the cost stream over the 50-year planning period would be $7,740,346, far below any cost estimate calculated for the Northern Rocks removal.

A variety of off-setting assumptions underscore this is a preliminary estimate. For example, because the expected losses are so small, container ships were not included in the analysis. The reduction in costs, which would result from the use of dispersants, was not incorporated. These technologies could cut the cost of response in half. Under the heading of socio-economic costs, tourism foregone is the largest component. According to the National Economic Development methodology used by the Corps of Engineers, lost tourist income is largely recoverable from a national economy point of view. Tourist dollars diverted from San Francisco are likely to be spent elsewhere in the U.S. (e.g., Los Angeles) and hence they are not lost to the national economy. These issues, plus a number of others, need to be incorporated into the discussion before a definitive figure becomes available.

Table 3.6-7 summarizes and totals the NRDA, Socio-economic and Response Costs from the separate tables above. The largest damages determined from the Oil Spill Model were nearly $220 Million.

3.6.8 Conclusions

By following this systematic approach, those areas, which present the greatest threat for causing an oil spill can be identified and presents management with a tool which focuses on where the real problems are and develop solutions to mitigate them.

The fault tree quantification results are developed in the form of a frequency of groundings per year at each of the specified rocks. The results show the leading causes of powered grounding of tankers are human error due to physiological impairment (32%), followed by the failure of navigational aides (buoy (30%), pilot/tug impairment (19%) and VTS (7%)). Combined these contribute 88% to the total tanker powered grounding frequency at both rocks.

The leading causes of tanker drift groudning are engine failure and screw failure, totalling 79% of the drift grounding frequency at both rocks.The leading causes of non-tanker powered groundings are human error due to physiological impairment (31%), followed by the failure of navigational aides (bouy (28%), pilot/tug error (13%) and VTS (7%)). Additionally, human error caused by distraction contributed more significantly to non-tankers (9%) as compared to tankers (3%). Combined these contribute 88% to the non-tanker powered grounding frequency for both the North and Blossom Rocks.

The leading causes of non-tanker drift groundings are flooding and ship-to-ship collision that result in termination of the engines, totalling 74.5% of the drift grounding frequency at both rocks. Another 20% of the contibution comes from engine failure.

3.6.9 Sensitivity Analysis

The estimates of the parameters used in the Riskman model to compute the likelihood of annual events are the most critical parameters in the benefit-cost model. Consequently, varying this number is one of the most important tests of the model's robustness. Based on the argument 50 years have gone by without an accident, assume the probability of a tanker spill is 1 year in 50 rather than 1 in 655. The probability of an event would then be .02 instead of .001527. Leaving figures for amount of oil flow and damages per gallon the same would yield a figure of $101,855,788, an order of magnitude greater than the $7 million estimated earlier. However, it is still well below some preliminary cost estimates, which have ranged as high as $200,000,000.

It is also conceivable the response costs per gallon could be higher. Assume these costs would be $200 per gallon instead of $119.53 used in the initial estimate. The discounted cash flow, assuming a 0.02 probability, would yield approximately $170 million in project benefits based on spilled oil from tankers. This is still below the estimate of $200 million as the cost of lowering the rocks. Only with damages in the $300 per gallon area (and a probability of 0.02 for an annual event) does the project yield a benefit-cost ratio greater than 1. Given most of the data were not be included in the analysis bias the results in a negative direction, it is difficult to see how the analysis will yield a benefit-cost ratio greater than 1.0.

3.6.10 Limitations to the Analysis

The analysis used conservatively high assumptions of vessel loads and oil—the degree of damage is probably lower. According to Carl Gotch, Professor Emeritus of Stanford University,

> "No distinction has been made by the direction of travel of the crude oil vessels. Inbound ships are loaded with either foreign or domestic oil (largely Alaskan) and often are carrying only partially loaded because they could not transit the San Francisco Bar (-55 MLL) if they were at capacity. However, the outbound ships are essentially empty. Removing all cargo and carrying only ballast raises most to the point where their draft is less then 35 feet. It is unclear, however, if

this includes every vessel or if some of the largest tankers will have a draft of more than 35 feet while carrying only ballast. For such vessels, a collision with the rocks would produce only minimal spills." (Gotch, 2002)

The effect of the considerations mentioned above does not diminish the probability of a tanker accident, but both considerations reduce the damages, which could be expected from such an event.

3.7 Benthic Survey Report

In general, the habitats at Harding, Shag, Arch, and Blossom rocks are typified by boulders and cobble overlaying rocky reef features from the shallowest depths (35-40 feet) to about 70 to 80-100 feet depending on the site. Below these depths the substrate grades into coarse sand and gravel that commonly is dark color, interspersed with shell debris. Fine-grained sediments cover most of the hard bottom areas, consistent with the very high levels of turbidity that were present during the entire survey, and which are typical of San Francisco Bay waters. The combination of fine-grained sediments in many parts of the Bay and the strong currents (e.g., 2 to more than 3 knots) likely contribute to the high particle loads, particularly at Blossom Rock, compared to the other sites.

The biological communities observed on the four rock features are consistent with those at similar depths in many hard-bottom marine habitats of the central California coast. However, these represent relatively isolated "islands" of habitat that are uncommon in the overall San Francisco Bay region. The most common species on each of the four features were seastars, "turf" organisms (comprised of low growing mixtures of hydroids, bryozoans, anemones, and sponges, etc.), encrusting sponges, and Rock crabs (*Cancer spp*.). Seastars were particularly abundant at Harding (locally from 1 to 4 per square meter), and also at Shag and Arch but in reduced numbers, from the shallowest depths (35-40 feet) to the deepest extent of rocky substrate. The dominant seastar on these three features was the bat star (*Asterina miniata*), followed by *Pesaster* spp (*P. brevispinus* and *P. ochraceous*). Rock crabs were most abundant at Harding Rock (e.g., locally to about 1 per 100 square meters). Turf abundance ranged from about 25 to almost 100% cover in localized areas, influenced by sediment cover, and was most common at shallower depths (e.g., less than about 60 feet). Incidental invertebrate species on all but Blossom Rock included anemones (*Urticina* spp. and the jewel anemone (*Corynactis California*). The only seastar observed at Blossom Rock was *P. brevispinus*, potentially due to the apparently higher sedimentation and turbidity at this site since this species is more tolerant of these conditions (e.g., Smith and Carlton 1975). Relatively few fish species were observed at the rock features, mainly due to the poor visibility during the surveys. The fishes that were observed, including lingcod, rock greenling, and yellowtail rockfish (Table 3-2), are typical of rocky areas at similar depths throughout the region. Some pelagic schooling fishes and bottom-dwelling fishes (likely halibut) that could not be identified to species were observed in the water column and over soft-bottom habitats. Overall taxonomic diversity (species richness) was low (ranged from 7 to 12 taxa) compared to many hard-bottom areas of similar depth. Diversity and abundance are limited in part by stressful natural conditions (high turbidity, sediment cover, and strong currents), but also influenced by very poor visibility that limited photographic documentation.

3.8 Environmental Conditions of the Fishery

The project area is well known as a prime fishing location. This section describes the existing commercial and sport fishing activities in the Project area.

3.8.1 Commercial Fishing: The commercial catch of fish and shellfish by the San Francisco commercial fishing fleet includes: Chinook salmon, albacore tuna, swordfish, several species of rockfish and sole, ling cod, squid, pink shrimp, Dungeness crab, sea urchin, and numerous other species.

The Port of San Francisco's new Hyde Street Commercial Fishing Harbor, which opened in June 2001, features 62 new berths, bringing the total berths now available for San Francisco's commercial fishing fleet to 190. Along with the Pier 45 Fish Processing Complex at Fisherman's Wharf, the Port of San Francisco is now the preeminent full-service commercial fishing center on the West Coast (Port of San Francisco 2001).

Due to commercial fishing restrictions in San Francisco Bay, most commercial fishing occurs outside the Bay on the open ocean. No commercial salmon fishing is permitted in San Francisco Bay. Gillnet, trawl net, and driftnet fishing is not permitted in the Bay. Some restrictions on fishing methods extend beyond the Bay, for example, gill and trawl net fishing are not permitted within 3 miles of the coast, and drift net fishing for swordfish and shark is not permitted out to 75 miles except during a 4-month open season.

3.8.2 Sport Fishing: San Francisco Bay generally is regarded as a sport fishing paradise. At least 34 sport fishing boats (also called charter boats or party boats) are based in San Francisco Bay and offer daily departures and charter services. The San Francisco sport fishing fleet, which consists of 10 boats, is located at Fisherman's Wharf along Jefferson Street. Numerous other boats operate out of other ports in the study area, including Sausalito (7 boats), Emeryville (8 boats), and Berkeley (7 boats). Just north of the Richmond-San Raphael Bridge, the marinas at Point San Pablo and San Rafael each have one or more sport fishing boats (sfsportfishing.com 2001).

Sport fishing boat operators regularly exit the Bay through the Golden Gate to fish the open ocean, especially for tuna, but destinations within the Bay are most common. Depending on the conditions, season, and location, an impressive quantity and variety of fish may be caught. The West Bay is a favored part of the Bay for fishing, because changing conditions caused by the great tidal influences provide a large variety of fish. The most popular game fish are striped bass, salmon, and halibut; but sturgeon, leopard shark, surfperch, rockfish, and lingcod are also sought.

The rock formations that are the subject of this study are popularly recognized as prime fishing locations. In *California Fishing – The Complete Guide to More than 1,200 Fishing Spots* (Stienstra 2001), the author describes fishing for striped bass just inside the Golden Gate, "Earlier in the day during incoming tides, stripers congregate along the rocky reefs west of Alcatraz: the rock pile, Harding Rock, Shag Rock, and Arch Rock. This is some of the fastest fishing of the year, and greatness is possible."

In *California Guide – Great Saltwater Fishing* (Rychnovsky 2001), the author describes fishing in the West Bay, "Here you will find great fishing areas like Alcatraz Island, Angel Island, Raccoon Strait, Harding Rock, Shag Rock, and the south tower of the Golden Gate Bridge. Striped bass are the number one fish caught in this part of the bay, and it ranks as one of the best places to catch them."

Published fishing reports based on daily catches frequently refer to fishing action at the rocks, for example: "The hotspot for the past few days has been Arch and Shag rocks west of Alcatraz. Party boats are working the rocks during the flood tide with some of the best action coming just after max current. (June 19, 2000)" "On the rockpiles, boats found steady action on both Arch and Shag rocks. (July 31, 2000)" "We saw the best action during the morning flood on the rockpiles. Party boats for the most part reported in with limits of bass averaging 6 to 10 pounds with a few larger fish to 20 pounds. (July 14, 2000)" "The best striper action remains on the rocky reefs around the Central Bay. The rock piles are the top producers during the flood tide, but don't overlook Mels Reefs or Blossom Rock. (July 16, 2000)" (The Bait Guys # 2000)

In addition to the sport fishing industry, many private boat owners fish the waters of San Francisco Bay from their own craft, and many marinas rent small boats for fishing. Private and rental boats usually depart from one of the at least 28 marinas, yacht harbors, and anchorages that line the shore of the Central Bay, with another 10 along the East Bay shoreline.

Pier fishing also is a common form of recreational fishing. Popular pier fishing locations in the study area include the Fort Point piers (at the Presidio), the Fort Mason piers (between the Presidio and Fisherman's Wharf), San Francisco Municipal Pier 7 (a designated public access fishing pier), the Ferry Building Pier (north of the Bay Bridge), Paradise Park and Elephant Rock piers (in Tiburon), Sausalito Public Pier, and Fort Baker Pier (at the north end of the Golden Gate Bridge). (Jones 1998)

Source: San Francisco Rock Removal Project, Environmental Impact Study and Report, 50-percent Administrative Draft; dated December 2001, prepared by GAIA Inc. for U.S. Army Corps of Engineers, San Francisco District. The reference notes in the text are listed in the bibliography of this source.

3.9 Environmental Conditions of the Central Bay and Vicinity

Inside the Bay a significant spill would reach north into Carquinez Strait and Richardson Bay, then to the south past Redwood City. The spill would flow out of the Bay and along the Coast, north to Point Reyes and south past Half Moon Bay. It could possibly reach out into the ocean as far as the Farallon Islands. Therefore, nearly all of San Francisco Bay could be affected by an oil spill from a grounding at any of the four rocks.

Bay habitats are divided into two categories: baylands shoreline areas and in-Bay areas of deep water (Deep Bays and Channels) and areas of shallow water (Shallow Bays and Channels).

3.9.1 Baylands: The baylands consist of shallow water inter-tidal habitats around the San Francisco Bay between the maximum and minimum tidal elevations. These lands fall into two categories, natural and altered. The altered land is that which has been developed in any way that precludes their use as habitat. The natural lands are either salt marsh or mud flats.

Baylands Ecosystem: The baylands ecosystem includes baylands, adjacent habitats, and their associated plants and animals. The boundaries of the ecosystem vary with the bayward and landward movements of fish and wildlife dependent upon the baylands for survival. For example, several species of fish, such as Pacific herring and Chinook salmon, rely on the baylands, but also utilize local streams or deeper portions of the Bay at certain times in their life cycles. Schools of Pacific herring mobilize in deep channels of the Bay and then move toward the shoreline to lay their eggs in shallow water. Adult Chinook salmon migrate upstream through the deeper channels of the bays to spawn in the watersheds of the Estuary, and young salmon forage in shallow water habitats on their way to the ocean. Marine mammals, such as the harbor seal and California sea lion, use the baylands at certain times for resting and feeding. Smaller mammals, such as the salt marsh harvest mouse, take refuge on levees and in the adjacent uplands to avoid the highest tides. Great blue herons forage in the baylands, but may roost in the adjacent uplands. Some songbirds, such as the salt marsh common yellowthroat move up and down local streams, from the brackish zones of tidal reaches to the riparian forests.

Area of Baylands: The area of the baylands has changed. In Suisun, North Bay, and Central Bay, and area have increased; in South Bay; it has decreased. Overall, the area of the baylands has increased from about 242,000 acres (circa 1800) to about 262,000 acres today. This does not contradict the fact that San Francisco Estuary downstream of the Delta (i.e., the combined area of all tidal and subtidal habitats) has been reduced in size by about one-third since the Gold Rush.

- Some important details about changes in habitat acreage can be quantified, as described below:

- Deep and shallow bay habitats have decreased from about 270,000 acres to about 250,000 acres. This is a result of sediment deposition from Gold Rush hydraulic mining and of bayshore fill.
- Tidal flat habitat has decreased from about 50,000 acres to about 30,000 acres. This is primarily a result of reclamation, bay fill, natural conversion of tidal flat to low tidal marsh, and erosion.
- Tidal marsh habitat has declined about 190,000 acres to about 40,000 acres. This is a result of bay fill and diking to create managed marsh, agricultural baylands, and salt ponds.
- Moist grasslands have declined from about 60,000 acres to about 7,000 acres. This is a result of farming and urban uses.
- Moist grassland/vernal pool habitat has declined from about 24,000 acres to about 15,000 acres. This is a result of farming and urban uses. Riparian forest and Willow Grove habitats have declined from about 5,000 acres to about 700 acres. This is a result of farming, urban uses, and channel-modifications for flood control.

3.9.2 In-Bay Habitats: The in-bay habitats are intricately tied to the baylands and are components of the baylands ecosystem. They are especially important for aquatic organisms, sea birds, and some mammals that move back and forth between deep and shallow waters. Bay habitats are divided into two categories: areas of deep water (Deep Bays and Channels) and areas of shallow water (Shallow Bays and Channels).

Deep Bays and Channels: The deep bays and channels are the parts of the Project area that are deeper than 18 feet below Mean Lower Low Water (MLLW). They include the deepest portions of the Bay and the largest tidal channels. This habitat accounts for about one-third of the Bay's area and occurs in all four sub regions. The deepest portion is in Central Bay at the Golden Gate.

The sediments of deep bay and channel habitat vary widely in character, from coarse sand to very fine clays and silts. In the parts of the Bay where currents are strong, especially as in the deeper reaches of San Pablo Bay and Central Bay, the bottom is mostly coarse sand. In Suisun Bay and South Bay, however, most of the bottom is covered with mud, a mixture with more than 80 percent silt and clay.

Shallow Bays and Channels: The shallow bays and channels include the portion of the Project area where the bottom is entirely between Mean Lower Low Water and 18 feet below. Shallow bays and channels account for two-thirds of the Bay's area, and they occur in all four sub-regions. A good example of this habitat type is at the northern edge of San Pablo Bay.

The sediments of shallow bays and channels are primarily mud. An exception is a large portion of the eastern side of South Bay, which is covered with shell fragments, remnants of the native and introduced oysters that once occurred in the area.

3.9.3 Appendix F: See Appendix F for more details about the bay habitats.

4.0 PRELIMINARY ALTERNATIVES

4.1 Plan Formulation

4.1.1 Plan Formulation Process

Plan Formulation is the process of building plans that meet planning objectives and avoid planning constraints. It requires the knowledge, experience, and judgments of many professional disciplines. Planners define the combination of management measures that comprise a plan in sufficient detail that realistic evaluation and comparison of the plan's contributions to the planning objectives and other effects can be identified, measured, and considered. Plan formulation requires the views of stakeholders and others in agencies and groups outside the Corps to temper the process with different perspectives.

The first step in formulating alternative plans is to develop a list of possible management measures and formulate a set of preliminary alternatives from which a final set of plans can be chosen for detailed feasibility analysis.

4.1.2 Management Measures

A Management Measure (or "measure") is a feature or activity that can be implemented at a specific geographic site to address one or more planning objectives. Measures are the building blocks of which alternative plans are made. Measures become more specific and better defined as planning progresses.

4.1.3 List of Measures

4.1.3.1 Structural Measures: Lowering of the rocks would be between –50 feet and –55 feet MLLW. The final depth would depend on economic analysis. The formation known as Unnamed Rock is not a rock and is likely sand. The four rocks of concern are:

(1) Harding Rock, the first one south of the deep-water lane and northwest of Alcatraz Island.
(2) Shag Rock, the second one south of the deep-water lane and northwest of Alcatraz Island.
(3) Arch Rock, the third one south of the deep-water lane and west of Alcatraz Island.
(4) Blossom Rock, southeast of Alcatraz Island and separated from the other rocks.

<u>Rock Lowering Alternatives:</u>

(1) Lower Harding Rock.
(2) Lower Shag Rock.
(3) Lower Arch Rock.
(4) Lower Harding and Shag Rocks.
(5) Lower Harding and Arch Rocks.

(6) Lower Shag and Arch Rocks.
(7) Lower Blossom Rock.
(8) Lower Harding, Shag and Arch Rocks.
(9) Lower Harding, Shag, Arch and Blossom Rocks.
(10) Combine any one of the measures, 1. through 6. with Blossom Rock.

Construction Techniques:

(1) Mechanical breaking of the rocks (including such means as abrasion and breaking).
(2) Controlled blasting of the rocks (including use of such techniques as a "bubble curtain" and sequential timed detonations).

Disposal of Rock Rubble:

(1) Remove rubble to SF Deep Ocean Disposal Site.
(2) Deposit rubble in depressions on bay floor adjacent to the Rocks.
(3) Sell rubble to quarry operator.
(4) Relocate rubble to create habitat away from ship channels.

Channel / Lane Rerouting Alternatives

(1) A deep navigation channel to the south of Alcatraz Island.
(2) A Deep navigation channels north of Angel Island through Raccoon Strait.

4.1.3.2 Non-Structural Measures: There are also potential non-structural measures identified for this study at the present time to improve safety and reduce potential environmental impacts. The Harbor Safety Committee has identified and implemented several non-structural measures in the recent past. The Corp's and sponsor's technical advisory committee is the Under Water Rocks Work Group of the Harbor Safety Committee. The Work Group's assignment is to work on the lowering of the "rocks" exclusively. However, for purposes of NEPA and CEQA, non-structural measures and alternatives will be required to be identified and evaluated.

Enhanced Tug and Clean-up Capability:

(1) Additional tugs on alert to assist ships "not in control" of steering.
(2) Develop tug escort requirements for container ships and hazardous cargo ships.
(3) Additional clean-up crews on alert in case of spillage from a grounding or other form of accident.

Navigation Aids / Buoys / Lights:

(1) Lighted buoys with RACON and sound signals at all rocks.
(2) Add lighted buoys and sound signals only at Shag and Arch Rocks.

4.1.4 Preliminary Alternatives

The preliminary alternatives are sets of one or more management measures functioning together to address one or more objectives. A preliminary alternative can be one measure. It is usually a combination of measures. Each preliminary alternative consists of different measures or it combines the same measures in significantly different ways.

4.1.4.1 Structural Preliminary Alternatives: The preliminary alternatives consist of those future conditions most likely to prevail with the implementation of the project to improve navigational safety in Central San Francisco Bay. National Economic Development (NED) benefits and costs need to be evaluated after the results from the Oil Spill Model and the Risk Analysis Model are available.

Rock Lowering Alternatives:

(1) Lower Three Rocks Near Deep Water Channel: The lowering of three rock formations near the deep water shipping lanes is expected to reduce tidal delays and transit times experienced by very large crude carriers (VLCCs), product tankers, and container ships. In addition, this alternative will increase navigational safety and reduce the risk for oil spills in the San Francisco Bay. Harding, Shag, and Arch are located northwest to west of Alcatraz Island. Each one would need to be lowered approximately 20 feet to –55 feet MLLW.

The result of lowering the three rock formations would be to prevent a distressed, deep draft ship from grounding on one of them. In addition, there would be more time available for the distressed ship to regain control or for an assistance tug to reach the ship. If control were not regained, the distressed ship would run aground on Alcatraz Island or collide with the north shoreline of San Francisco. Timing is a critical issue in all the alternatives. The time for a distressed ship in severe weather conditions, at an unknown velocity, to make contact with something is unknown at this time.

The cost of rock lowering will vary significantly, depending on the methods to be employed to remove and dispose of the rocks and dredged material. Possible methods of removal include: rock dredging, chisel and hammer, expansive chemicals, and controlled explosions. Possible disposal methods include: side casting, in-Bay disposal, upland site disposal, or ocean site disposal. If the disposal site is other than side cast for the rock material, the cost increase will be significant.

(2) Lowering of Any One Rock Formation: In the same area and rock formations as in a) above, it may be possible that lowering one of the three rocks would provide a significant advantage in increasing navigation safety and reduced risk of oil spills. As discussed in a) above, timing of recovery and/or rescue is the critical issue. Which one of the three rock formations is more important to prevent a grounding, is hard to determine at this time. It would seem obvious that Harding is the most important. However, the location distress began in the navigation lane

and the directions of the wind and current could send a ship into any one of the three rock formations.

(3) <u>Lowering Blossom Rock in conjunction with 1) or 2) above:</u> Blossom Rock Formation appears to be “out in the open”, southeast of Alcatraz Island. (See PLATE 1.) However, it is very near the reach of the southbound shipping lane where the pilots align the ship to pass under the Bay Bridge. Many ships pass through this reach and under the Bay Bridge on their way to Port of Oakland, Port of San Francisco, and other Ports in the South Bay area. The Blossom Rock formation posses a similar threat to a distressed, deep draft ship in circumstances described in a) above.

<u>Channel / Lane Rerouting Alternatives:</u>

(1) <u>New Deep Draft Channel South of Alcatraz Island and Lower One Rock Formation:</u> At the present time there are inbound and outbound shipping lanes for ships in the 35-foot draft class, south of the three rock formations and Alcatraz Island and then turning before Blossom Rock Formation. (See PLATE 1.)

At the SF Rocks Alternative Workshop on June 4, 2001, one of the alternatives proposed was moving the deep draft navigation channels (inbound & outbound) south of Alcatraz Island. Based on the Workshop suggested preliminary alternative, it was investigated in some detail, using the SF Bay NOAA 1998 Navigation Chart No. 18650 (Nav. Chart).

Ships passing south of the three large rock formations could decrease the risk of a grounding occurring in the Bay west of Alcatraz Island. Analysis of the Navigation Chart revealed the following information:

(a) The two deep draft lanes north of Alcatraz Island are approximately 800 yards (yds) or 2400 feet wide. The assumption was made that a potential channel would be the same width.
(b) Most of the area is deeper than the 55 feet MLLW. However, there would need to be some dredging near the south side from Black Point, along Aquatic Park, along Pier 45, and Pier 39.
(c) The North side of the potential channel might need limited dredging along the south edge of the Alcatraz Disposal Site.
(d) The dredging and rock lowering area is 3100 yds (9,300 feet) long from approximately 122° 26′ to 122° 24′ longitude.
(e) The Most notable obstruction at the east end of the potential channel is Blossom Rock. Looking at the navigation chart, it seems clear, Blossom Rock would need to be lowered.

The purpose of this investigation was to determine if relocating deep draft navigation channels to south of Alcatraz Island was a possibility. Many details, questions, and issues remain to be investigated.

(2) Deep Draft Channel North of Angel Island Through Raccoon Strait: At the present time there is no designated shipping lane through Raccoon Strait.

At a recent SF Rocks Work Group meeting, one of the alternatives discussed was moving the deep draft navigation channels (inbound & outbound) north of Angel Island through Raccoon Strait. Based on the Work Group's suggested preliminary alternative, it was investigated in some detail, using the SF Bay NOAA 2000 Navigation Chart No. 18653 (Nav. Chart).

Ships could pass further north of the three large rock formations, which could decrease the risk of a grounding occurring in the Bay west of Alcatraz Island. Analysis of the Navigation Chart revealed the following information:

(a) The two deep draft lanes north of Alcatraz Island are approximately 800 yards (yds) or 2400 feet wide. The assumption was made that a potential channel would be the same width. The narrowest distance between Angel Island and Tiburon Peninsula is slightly less than 1000 yards.
(b) Most of the area between the island and peninsula is much deeper than -55 feet MLLW. However, there would need to be considerable dredging near the northwest corner of Angel Island from Point Knox Shoal and the north side of the island on the Raccoon Shoal. The navigation lane would need to enter a regulated navigation area, east of the island. Dredging would be required in a triangular shaped area of approximately 3000 yards by 1000 yards.
(c) The suggested navigation lane would need to cross a designated recreation area southwest of Angel Island. This area is restricted to ships of 300 gross tons.
(d) The construction areas are from approximately 122^{o} 27' to 122^{o} 24' longitude.
(e) The most notable obstruction to the suggested channel is the limited open water between Tiburon and Angel Island. After analysis of the navigation chart, it seems clear; a ship in the strait between the peninsula and the island, with lost control would run aground on one of them.

The purpose of this investigation was to determine if relocating deep draft navigation channels to north of Angel Island was a possibility. Many details, questions, and issues remain to be investigated.

These are the preliminary structural alternatives suggested for more detailed study and evaluation for the array of final alternatives. A discussion of the evaluation process follows.

4.1.4.2 Non-structural Preliminary Alternatives: The non-structural preliminary alternatives consist of those future conditions most likely to prevail with the implementation of the project to improve navigational safety in Central San Francisco Bay and reduce potential environmental impacts.

Enhanced Tug and Clean-up Capability:

(1) Additional tugs on alert to assist ships "not in control" of steering. Addition of "tractor" tugboats to the tug fleet would enhance the gaining of control for ships "not in control". The document, San Francisco Bay Escort Tug Analysis, Prepared for Foss Maritime Company, Seattle, Washington, Final Report, prepared by The Glosten Associates, inc., Seattle Washington, dated April 27, 1993 describes benefits of a tractor tug escort. The escort mode would seem the safer method of operation. The model study shows that with a four-minute delay of starting control efforts (thrust is applied to the ship) with a conventional tug, it would require at least 15 minutes and be a few thousand feet off course to control the ship. Because the operating method of the tractor tug is very different from the conventional tug, it can begin applying trust to the "not in control" ship in approximately one minute and recover the ship's course in a very few minutes and very short distance.

The primary unanswered question is cost. The cost of these tugs is expected to be "significant", especially if several are needed. The cost of crews for the tugs will also be "significant" over many years.

(2) Develop tug escort requirement for container and hazardous cargo ships. Some cargo ships carry hazardous materials as well as large quantities of fuel for their own operation. Container ships use large quantities of fuel for their own operation. These ships are not required to use tug escorts. The details of this possible alternative will need to be coordinated with the Tug Escort Work Group of the San Francisco Harbor Safety Committee.

The details of this possible alternative would need to be coordinated with the State Office of Oil Spill Prevention and Response (OSPR).

Navigation Aids / Buoys / Lights:

(1) Lighted buoys with RACON and sound signals at all rocks. It may be possible to prevent some types of "out of control" ships from a grounding by providing navigational aids near each rock mound. The kinds of aids near each rock mound are to be determined. The details of this possible alternative will need to be coordinated with the Navigation Work Group of the San Francisco Harbor Safety Committee.

(2) Add lighted buoys and sound signals only at Shag and Arch Rocks. This idea is related to (1) above but would add RACON aids for Shag and Arch rock mounds. The details of this possible alternative will need to be coordinated with the Navigation Work Group of the San Francisco Harbor Safety Committee.

Construction Techniques:

(1) Mechanical breaking of the rocks (including such means as abrasion and breaking). These were the methods considered in the 905(b) Analysis (WRDA 86)

for the preliminary cost estimate. Each method would require a very long time (years) to complete. Additionally, it could be very noisy above and below the water line.

(2) Controlled explosions for demolition of the rocks (including use of such techniques as a "bubble curtain" for underwater life protection and sequential timed detonations to control shock waves). These methods would occur during a very short time (weeks) after the holes are drilled for the explosives. The hole drilling may take several months.

Disposal of Rock Rubble:

The disposal methods below may all be possible to varying degrees. If one of the rock mound lowering alternatives is chosen, there will be a very large volume of rock for which to dispose.

(1) Remove rubble to SF Deep Ocean Disposal Site.
(2) Deposit rubble in depressions on bay floor adjacent to the Rocks.
(3) Sell rubble to quarry operator.
(4) Relocate rubble to create habitat away from ship channels.

4.1.5 Evaluation of Preliminary Alternatives

The essential purpose of the evaluation of preliminary alternatives is to determine whether or not an alternative is worthy of further consideration. It is a qualifying step. Each preliminary alternative is held up to a situation-specific criteria and the project delivery team and project manager must decide whether it deserves further consideration or not.

For preliminary alternatives, there are two major levels of evaluation. First, are qualifying criteria: Completeness, Effectiveness, Efficiency, and Acceptability. Second, are the analyses evaluations: Cost Estimating, Economic Benefit Evaluations, Environmental Evaluations and Impact Assessments, and Social Impact Assessments. At present, all background analyses and surveys are completed. The Lower Three Rocks structural alternative is the only one to have preliminary cost estimate and benefit/cost analysis developed. See Section 4.3 for more information concerning possible alternatives to carry forward.

4.2 Environmental Comparisons

An important part of the environmental comparisons is the No Action (or without project) Alternative. The No Action alternative consists of those future conditions that are most likely to prevail in the absence of the proposed project. It is expected that the No Action alternative will continue to present significant navigational restrictions and hazards to Very Large Crude Carriers (VLCCs) as well as hazardous product tankers and container ships that call on the San Francisco Bay Area. These restrictions and hazards are expected to cause transportation delays and increase the risk of oil spills in the San Francisco Bay. The consequences from oil spills of varying magnitudes can have significant economic and environmental costs.

According to the Federal On Scene Coordinator for the March 1989 Exxon Valdez 11.2 million-gallon oil spill in Alaska, the cleanup process took three years and exceeded $2.1 billion. In addition, the National Oceanic and Atmospheric Administration (NOAA) estimates the Exxon Valdez spill killed 350,000-390,000 waterfowl and 3,500-5,500 sea otters. The 8,000-gallon oil spill in San Francisco Bay in October 1996 caused an estimated $10 million in damages. The U.S. Coast Guard has estimated that a 500,000-gallon oil spill in the San Francisco Bay, over a 24-hour period, would spread across a 50 nautical mile area. Total oil skimming equipment available today would cover approximately 6 nautical miles in that time.

4.3 DETAILED ANALYSIS OF FINAL ALTERNATIVES

With all the information to date, a reasonable preliminary analysis of a structural alternative has been accomplished. Referred to as the Lower Three Rocks Alternative, this one includes Harding, Shag, and Arch rocks. A potential non-structural alternative may be viable. It is referred to as the Tractor Tug Alternative. However, it is expected this non-structural alternative would not be within the Corps mission. See Section 4.3.2 below for details.

4.3.1 Alternatives Eliminated

Most of the alternatives were found to be seriously lacking in effectiveness. In order to be effective an alternative must provide a means to prevent or protect a deep draft ship from grounding one of the three rocks. The two alternatives remaining could accomplish this task. Available costs, damages and risk factors are discussed in the sections below.

4.3.2 Tractor Tug Alternative

The Tractor Tug Alternative would make use of the special features of this new tug. The Tractor Tug is far more efficient than the standard model tug. The two primary features are: a) the driving propellers are near the center of the boat, making it more maneuverable and b) during a 'rescue' operation, the tug ties onto a ship and pulls in the opposite direction to bring it under control. This alternative would not be an USACE project. It would be the responsibility of the state of California, the ports and shippers to cover the costs of purchasing and operating the tugs. It is not possible to make a cost estimate at this time.

4.3.3 Lower Three Rocks

The Lower Three Rocks Alternative was investigated extensively. All the surveys included Harding, Shag, and Arch rocks. The Oil Spill Model used Shag Rock to represent one of the three rocks, upon which a deep draft ship could ground and spill its cargo. The model runs included four types of hydrocarbons. See Section 4.5.3 for details. The risk assessment model referred to the three rocks as the North Rocks. The model determined the risk of an accident (grounding) occurring and a deep draft ship spilling its cargo. The model distinguished between tanker, container, and other classes of ships.

If the Lower Three Rocks Alternative were to be approved, the construction project would be quite large. Construction tasks would include:

a) Sampling and Testing: Subsurface testing: drilling and sampling of the existing rock.
b) Mobilization and Demobilization: Equipment used on the project: drill barge, crane barge, support equipment, etc. Equipment could be moved to the Bay Area from as far as 500 miles.
Contractor Field Office: Normally under overhead cost; however, this project is of large enough to warrant a separate office; similar to the one used in the New York (NY) District.
c) Drilling and Blasting Operation:
Includes Bubble Curtain during the controlled explosion operation.
Includes Air Curtain for turbidity management
d) Dredging and Disposal of rock material: Clamshell dredge/barge disposal to SFDODs disposal site proximity (50 miles beyond the Golden Gate)
e) Sweeping: Clearing of any remaining rock after controlled explosions, dredge and disposal operations.
f) Additional Insurance: Type of work may dictate additional insurance from underwriter, similar to NY District project.
g) Factors applied: Overhead, Profit, Bond, Locality, Contingency, and Environmental Requirements
h) Cost Estimate at Time of Construction: Estimate includes an increase for construction to the possible mid-point of construction - July 2006.
i) Corps Support during construction:
E&D: Engineering and Design
S&A: Supervisory and Administration

The cost estimate for the Lower Three Rocks Alternative was calculated after making a moderately detailed cost analysis for Harding Rock alone; then, using the total volume to be removed from the three rocks. The resulting cost estimate was $221 Million for July 2006 price index, for the Lower Three Rocks Alternative.

4.4 Summary

Here is a brief summary of the results from the Oil Spill Model, Risk Factor Model, the estimated cost of lowering the three rocks, and the benefit to cost ratio.

The Oil Spill Model developed the coverage of an oil spill beginning from Shag Rock and Blossom Rock as shown in Section 3.5.3, Figures 3.5-2 and 3.5-3. This model provides a delineation map of the habitat and shoreline of San Francisco Bay. In addition, the model develops monetary damages for different classes of oil spills in Section 3.6, as shown in Table 3.6-7. The Risk Model determined the chance of a deep draft oil tanker grounding on any of the three rocks is 0.00152 or 1 accident in 658 years. The model also determined the length of an opening in the bottom of a deep draft ship if it was grounded at different speeds (at 5 & 15 mph). See Section 3.6.4, Table 3.6-3. The District's cost estimating engineers was $221 Million for July 2006 price index. There are more details in Sections 3.6.6 and 3.6.7. The District's Economics Section determined the benefit to cost ratio (B/C). Using the maximum damages, the risk factor and the cost estimate, it was determined the B/C ratio for lowering the three rocks was 0.06. NER benefits (non-monetary) were not estimated nor included in the above analysis.

5.0 RECOMMENDATION TO PREPARE REFERENCE REPORT

The District should not carry forward the final structural alternative shown in this report based solely on NED. See 4.4 Summary above. The District also considered the feasibility of the Lower Three Rocks Alternative under the Federal objective for national ecosystem restoration (NER). Headquarters rejected this idea based of the extremely low risk of an accident occurring.

As a result of more than two (2) years of study, it was determined there was not a Federal interest in pursuing a structural alternative. Given the current practices in place, which ensure the safe passage of vessels within the Bay, the probability of a vessel actually grounding on the rocks became extremely remote. This low probability of occurrence, when applied to the potential damages that may result from a spill, reduced the project benefits well below the cost to lower the rocks. Since evaluating non-structural measures (e.g., aids to navigation, tug support, emergence response) is continually being evaluated by others under the overall navigation safety mission of the Harbor Safety Committee, the Feasibility study was halted. There was a significant amount of valuable information collected during this investigation, which may be applicable to others when confronting similar navigation hazards. It is the objective of this Reference Report; therefore, to make available the information to as wide an audience as possible.

APPENDIX F

Environmental Conditions of the Central Bay and Vicinity

APPENDIX F

Environmental Conditions of the Central Bay and Vicinity

F.1 Definition of the Baylands

The baylands consist of the shallow water habitats around the San Francisco Bay between the maximum and minimum elevations of the tides (BCDC, 1982, Bay Institute 1987); they are the lands that are touched by the tides, plus the lands that would be tidal in the absence of any levees, sea walls, or other man-made structures that block the tides. Landward of the baylands are their watersheds. Bayward are the shallow and deep waters of the open bays and straits.

The baylands include tidal and diked habitats. Tidal baylands are subject to the daily action of the tides. Diked baylands are areas of historical tidal habitats that have been isolated from the usual action of the tides by the construction of habitats contain other kinds that are smaller, such that the baylands as a whole consist of many levels of ecological organization.

The baylands ecosystem includes the baylands, adjacent habitats, and their associated plants and animals. The boundaries of the ecosystem vary with the bayward and landward movements of fish and wildlife that depend upon the baylands for survival. For example, several species of fish, such as Pacific herring and Chinook salmon, rely on the baylands, but also utilize local streams or deeper portions of the Bay at certain times in their life cycles. Schools of Pacific herring mobilize in deep channels of the Bay and then move toward the shoreline to lay their eggs in shallow water. Adult Chinook salmon migrate upstream through the deeper channels of the bays to spawn in the watersheds of the Estuary, and young salmon forage in shallow water habitats on their way to the ocean. Marine mammals, such as the harbor seal and California sea lion, use the baylands at certain times for resting and feeding. Smaller mammals, such as the salt marsh harvest mouse, take refuge on levees and in the adjacent uplands to avoid the highest tides. Great blue herons forage in the baylands, but may roost in the adjacent uplands. Some songbirds, such as the salt marsh common yellowthroat move up and down local streams, from the brackish zones of tidal reaches to the riparian forests.

F.2 Evolution of the Baylands

The evolution of the baylands is closely related to the history of changes in sea level. At the end of the last glacial period, some 15,000 to 18,000 years ago, the seas began their most recent rise, and about 10,000 years ago, ocean waters began to flood the valleys now occupied by the Estuary. Sea level rise slowed over time, from an initial rate of about 0.8 inch per year (Atwater 1979), to the current rate of about 0.1 inch per year, beginning about 6,000 years ago. (Atwater 1979, Hutchinson 1992, Byrne 1997). Between about 2,000 and 3,000 years ago, mudflats and tidal marshes began to form around the edges of western Suisun, North Bay, Central Bay, and South Bay.

The decreased rate of sea level rise helps explain the order of the marshes in the eastern part of the Estuary, towards the Delta. The marshes of the Delta are older than the marshes of the Bay Area. The Delta marshes of the ancient Sacramento and San Joaquin rivers formed behind the narrow passage now called Carquinez Strait, before the sea rose through the Golden Gate. After the rapidly rising sea passed through the Strait into Suisun, it slowed. The rapidly rising sea drowned some of the marshes in the far western part of Suisun, but the marshes further east survived. This partly explains why there are very large open bays downstream of Carquinez Strait, small bays in western Suisun, and no large natural open bays in the Delta (Collins and Foin 1993).

Some of the current global climate change models predict future rates of sea level rise that exceeds the early rates for the Estuary (Gleick et al. 1999). How the baylands might respond to such a rapid increase in sea level is unknown. Their response will depend on the supplies of sediment and runoff, which may increase or decrease with climate change, depending partly on how the land is managed.

F.3 Natural Habitat Controls

There are several major factors that influence the form and function of the baylands ecosystem. Some, such as climate and sea level rise, are global in nature and have affected the formation of the Estuary over the millennia. Others are more local, and these include topography; the ebb and flow of the tides; the volume, timing, and location of freshwater inflow; and the availability and types of sediments.

F.4 The Physical Effects of Development

Human activities have altered the baylands ecosystem in many ways. Overall, there has been a significant decrease in the size of the Estuary. Mainly diking and filling have caused this.

In many parts of the Bay, there have been shifts in the locations of the baylands and adjacent habitats. These shifts have resulted from a combination of urbanization of moist grasslands and vernal pool complexes, reclamation of tidal habitats, and sediment deposition in subtidal habitats. Reclamation has converted some tidal habitats into seasonal wetlands, while urbanization destroyed similar habitats in the adjacent uplands. Sedimentation has converted some subtidal areas to more shallow, tidal habitats. The combined effect of these changes has been to shift seasonal wetlands and the baylands bayward.

As a result of this bayward shift, the area of the baylands has changed. In Suisun, North Bay, and Central Bay, and area have increased; in South Bay; it has decreased. Overall, the area of the baylands has increased from about 242,000 acres (circa 1800) to about 262,000 acres today. This does not contradict the fact that San Francisco Estuary downstream of the Delta (i.e., the combined area of all tidal and subtidal habitats) has been reduced in size by about one-third since the Gold Rush.

Some important details about changes in habitat acreage can be quantified, as described below:

- Deep and shallow bay habitats have decreased from about 270,000 acres to about 250,000 acres. This is a result of sediment deposition from Gold Rush hydraulic mining and of bayshore fill.
- Tidal flat habitat has decreased from about 50,000 acres to about 30,000 acres. This is primarily a result of reclamation, bayfill, natural conversion of tidal flat to low tidal marsh, and erosion.
- Tidal marsh habitat has declined about 190,000 acres to about 40,000 acres. This is a result of bayfill and diking to create managed marsh, agricultural baylands, and salt ponds.
- Moist grasslands have declined from about 60,000 acres to about 7,000 acres. This is a result of farming and urban uses.
- Moist grassland/vernal pool habitat has declined from about 24,000 acres to about 15,000 acres. This is a result of farming and urban uses.
- Riparian forest and willow grove habitats have declined from about 5,000 acres to about 700 acres. This is a result of farming, urban uses, and channel-modifications for flood control.

F.5 Bay Habitats

Bay habitats are intricately tied to the baylands and are components of the baylands ecosystem. They are especially important for aquatic organisms, sea birds, and some mammals that move back and forth between deep and shallow waters. Bay habitats are divided into two categories: areas of deep water (Deep Bays and Channels) and areas of shallow water (Shallow Bays and Channels).

F.5.1 Deep Bay and Channel

Deep bays and channels are the parts of the Project area that are deeper than 18 feet below Mean Lower Low Water (MLLW). They include the deepest portions of the Bay and the largest tidal channels.

The sediments of deep bay and channel habitat vary widely in character, from coarse sand to very fine clays and silts. In the parts of the Bay where currents are strong, especially as in the deeper reaches of San Pablo Bay and Central Bay, the bottom is mostly coarse sand. In Suisun Bay and South Bay, however, most of the bottom is covered with mud, a mixture with more than 80 percent silt and clay (Nichols and Thompson 1985).

Deep bays and channels are important for large aquatic invertebrate including California bay shrimp, Dungeness crab, and rock crab, and for fishes such as white sturgeon and brown rockfish. They are also migratory corridors through which pass anadromous fishes including Chinook salmon and steelhead.

Deep bays and channels are habitat for several species of water birds including brown pelican, double-crested cormorant, greater and lesser scaup, surf scoter, and Caspian tern. Marine mammals such as harbor seal and California sea lion are also found here.

This habitat accounts for about one-third of the Bay's area and occurs in all four subregions. The deepest portion is in Central Bay at the Golden Gate.

F.5.2 Shallow Bay and Channel

Shallow bays and channels include the portion of the Project area where the bottom is entirely between MLLW and 18 feet below MLLW.

The sediments of shallow bays and channels are primarily mud. An exception is a large portion of the eastern side of South Bay, which is covered with shell fragments, remnants of the native and introduced oysters that once occurred in the area (Nichols and Pamatmat 1988).

Shallow bays and channels are important for many invertebrates, fishes, and water birds. This rich environment is an especially productive feeding area of many fishes including Pacific herring, splittail, northern anchovy, and jacksmelt. It is also an important migratory corridor for anadromous fishes such as Chinook salmon and steelhead.

A few of the many bird species that occur in this habitat include western grebe, American wigeon, canvasback, Forster's tern, and least tern. Some of the mammals found here are the harbor seal and California sea lion.

Eelgrass is a particularly important plant species found in the upper reaches of shallow bays and on mudflats in Central Bay. The Bay's only rooted seagrass, eelgrass provides feeding, escape, or breeding habitat for many species of invertebrates, fishes, and some waterfowl. The economically important Pacific herring spawns in eelgrass beds, and least terns forage on small fishes that are found there. Eelgrass also has been found to be an obligate food for black brant along the Pacific flyway (Einarsen 1965).

Shallow bays and channels account for two-thirds of the Bay's area, and they occur in all four subregions. A good example of this habitat type is at the northern edge of San Pablo Bay.

F.5.3 Bayland Habitats

Bayland habitats include the parts of the Project area that lie between MLLW and the highest observed tide. The baylands' boundaries and aerial extent have changed over the years as a result of sedimentation, diking, and filling.

Bayland habitats support a broad variety of plants and animals and provide areas for feeding, breeding, nesting, rooster, resting, and other functions. The discussion below divides bayland habitats into two categories: Tidal Baylands and Diked Baylands.

F.5.4 Tidal Flat

Tidal flat habitat includes mudflats, sandflats, and shellflats. It occurs from below MLLW (at the elevation of the lowest tides) to Mean Tide Level (MTL) and supports less than 10 percent cover of vascular vegetation, other than eelgrass. About 90 percent of intertidal flat habitat occurs on the edges of the Bay, and the remainder is associated with shallow tidal channels. Historically, a greater proportion of tidal flat occurred along the edges of tidal marsh channels (Bay Area EcoAtlas 1998).

Mudflats comprise the largest area of tidal flat habitat. These expanses of fine-grained silts and clays support an extensive community of diatoms, worms, and shellfish, as well as algal flora including green algae, red algae, and sea lettuce. Eelgrass, described previously under shallow bay and channel habitat, can also be a component of mudflats.

During the twice-daily high tides, Bay water inundates tidal flats and provides foraging habitat for many species of fishes including longfin smelt, staghorn scuplin, and starry flounder. During low tides, tidal flats are the major feeding areas for many species of shorebirds; mudflats, in particular, are rich in shorebird food times. Shorebird species that feed on tidal flats include semipalmated plover, American avocet, willet, marbled godwit, western sandpiper, and dunlin. Few mammals, however, frequent tidal flats; the harbor seal is the most notable exception (Fancher and Alcorn 1982).

F.5.5 Tidal Marsh

Tidal marsh is vegetated wetland that is subject to tidal action. It occurs throughout much of the Bay from the lowest extent of vascular vegetation to the top of the intertidal zone (at the maximum height of the tides). Tidal marsh also exists in the tidal reaches of local rivers and streams. In the fresher parts of the Estuary it occurs at lower elevations in the intertidal zone.

Tidal marsh plant communities vary markedly from one part of the Estuary to another. This variation correlates strongly to salinity patterns and to other factors such as substrate, wave energy, marsh age, sedimentation, and erosion.

In the more saline parts of North, Central, and South bays, tidal marsh is referred to as tidal salt marsh. In the more brackish areas, where there is significant freshwater influence-as in Suisun, along the middle reaches of the Petaluma and Napa rivers, and at the mouths of several streams in South Bay-it is referred to as tidal brackish marsh. Because the plant communities of these two general marsh types differ, tidal marshes in different parts of the Bay look very different. For example, a tidal marsh on Montezuma Slough in Suisun (with tall tulles and cattails along the channels) looks very different compared to a tidal marsh on the Palo Alto bayfront (with low-growing pickleweed and Pacific cordgrass along the channels).

Three general zones of vegetation, each of which is related to tidal elevation and distance from shore, typically characterize both tidal salt marsh and tidal brackish marsh. Low tidal marsh occurs between the lowest margin of the marsh and Mean high Water (MHW). Middle tidal marsh occurs between MHW and Mean Higher High Water (MHHW). High tidal marsh occurs between MHHW and the highest margin of the marsh.

The high marsh vegetation in a tidal salt marsh or tidal brackish marsh typically intergrades with upland plant species in the marsh/upland ecotone. Primarily the slope of the land in flatter areas determines the width of this zone. Such as in Suisun, it may be hundreds of yards wide, whereas in Central Bay, with its relatively steep shorelines, the zone is usually much narrower. The marsh/upland ecotone is very important ecologically as it is characterized by a diverse assemblage of vegetation and may provide especially valuable habitat for many species of wildlife.

High quality tidal marshes provide a complex habitat for many fish and wildlife. In Suisun Bay, splittail, Delta smelt, Chinook salmon, and longfin smelt occur in the marsh channels. Common fishes of Central Bay and South Bay tidal marshes include topsmelt, arrow goby, yellowfin goby, and staghorn sculpin. In North Bay, tidal marshes support gobies, sculpins, and three-spined stickleback. Some bird species associated with tidal marshes include snowy egret, northern harrier, California clapper rail, California black rail, willet, short-eared owl, salt marsh yellowthroat, Alameda song sparrow, San Pablo song sparrow, and Suisun song sparrow. Small mammal species that rely primarily on tidal marsh include salt marsh wandering shrew, Suisun shrew, and salt marsh harvest mouse. Red fox, coyote, and other predators prey on these species in middle and high marsh. Harbor seals utilize tidal marsh, especially areas adjacent to sloughs in South Bay, as resting or haul-out sites during high tides.

Tidal marsh occurs throughout the Bay area, but the largest patches are on the northern edge of San Pablo Bay and along the Petaluma River. Suisun Bay, too, supports a substantial acreage of tidal marsh, while Central Bay supports relatively little.

F.5.6 Diked Baylands

Diked baylands exist in parts of the Bay that once were tidal but are now isolated from the tides. Their physical origins are generally similar in that most were initially diked or “reclaimed,” beginning in the mid-1800s, for some kind of agricultural use or for salt production. Reclamation typically involved the construction of earthen levees along the margins of the marsh plains where they bordered mudflats or large tidal channels. Today, diked baylands consist of several major habitats, diked wetland, agricultural bayland, salt pond, and storage/ treatment pond.

F.5.7 Diked Wetlands

Diked wetlands are areas of historical tidal marshes that have been isolated from tidal influence by dikes or levees, but which maintain primarily wetland feature. In this report, diked wetlands are differentiated from diked agricultural baylands that they typically support much more wetland vegetation and they produce no agricultural crops.

The plant communities of diked wetlands vary greatly from site to site and can resemble those of local tidal salt marsh, tidal brackish marsh, non-tidal perennial freshwater marsh, or seasonally wet grasslands. Some also have characteristics similar to components of tidal marshes that are now regionally scarce or extinct, such as tidal marsh pans and alluvial high marsh/upland ecotones. However, they usually have fewer native species than their analogous natural plant communities, and often a larger component of exotic plant species. Common native plant species of diked wetlands include common pickleweed, saltgrass, alkali bulrush, bulrush, and cattail.

F.5.8 Agricultural Baylands

Agricultural baylands consists of diked, former tidal marshes that are intensively cultivated for agricultural production (primarily oat hay) or are grazed by cattle, sheep, or horses. This habitat type also includes ruderal areas where agricultural production ceased relatively recently. Most agricultural baylands support shallow, seasonally ponded wetlands and some upland plants, and would support a more diverse array of wetland and upland plants if active agricultural management were to cease.

During the wet season, large areas of agricultural baylands become waterlogged or inundated. The patterns of water logging and inundation depend principally on the relict tidal marsh topography, the extent effectiveness of artificial drainage, soil permeability, and the amount and seasonal distribution of rainfall. Successfully raising a crop such as oat hay in these areas requires careful management of ground water levels, soil salinity, and levees.

After many years of intensive draining and flushing with rainwater, baylands soils tend to become subsaline to nonsaline and support a variety of marsh plants in addition to cultivated crops. Agricultural fields that are disked annually typically support a mixture of native annual wetland plants (e.g., popcornflower, toadrush), and non-native annuals (e.g., loosestrife, brass buttons, barley) and perennials (e.g., birdsfoot trefoil, coyote thistle, and pacific bentgrass).

Agricultural baylands provide habitat for many species of wildlife. They are important as roosting and feeding habitat for wintering shorebirds including greater yellowlegs, long-billed curlew, least sandpiper, dunlin, and long-billed dowitcher.

They may be especially important for smaller shorebirds, whose size prevents them from foraging on nearby tidal mudflats during each tidal cycle for as long as longer-legged larger species (Page, pers. Comm.). Waterfowl such as mallard and northern pintail use fields when they pond. Other bird species commonly found on farm fields include snowy egret, black-crowned night heron, northern harrier, horned lark, savannah sparrow, red-winged blackbird, and western meadowlark. Some of the mammal species that use this habitat are California vole, California ground squirrel, striped skunk, coyote, and black-tailed deer.

Within agricultural baylands, areas of shallow seasonal ponds are the most important habitats for shorebirds and waterfowl. These ponds, typically less than six inches deep, have feathered edges and a minimum of emergent vegetation. The aerial extent and duration of ponding vary markedly from year to year and are highly influenced by pumping and rainfall patterns. Areas with the highest habitat values are those that pond every year and which are frequently or continuously inundated during the wet season.

Pastures in grazed agricultural baylands, especially those that are not frequently cultivated or mowed, provide abundant cover and food wildlife. They also allow year-round use by more wildlife species than do intensively farmed areas. As most pastures are allowed to pond more extensively and for longer periods than oat hay fields, they often provide better wintering habitat for shorebirds and waterfowl. And because grazing reduces dense plant cover, it improves access for birds.

Ruderal areas-uncultivated and ungrazed-support more upland grasses and other vegetation than do cultivated fields. Wild mustard, fennel, and poison hemlock are dominant members of the plant community. Some ruderal areas, especially the wetter lower portions of some sites, support a variety of amphibians, reptiles, birds, and small mammals.

Nearly all of the agricultural baylands are in the North Bay subregion, although some agricultural production occurs in Suisun Marsh and in South Bay. Examples of this major habitat type are at the northwestern edge of Suisun Marsh, Skaggs Island, Leonard Ranch, Twin House Ranch, Black Point, and Oliver West.

F.5.9 Salt Ponds

Salt ponds are large, persistent hypersaline ponds that are intermittently flooded with Bay water. They occur within the historical areas of tidal salt marsh in North Bay and South Bay.

Historically, there were natural salt ponds along the eastern edge of South Bay, primarily near San Lorenzo Creek and Mt. Eden Slough near Hayward (Ver Planck 1951, 1958). Native Americans obtained salt from these ponds for their own use and for trade; later, so did the region's Spanish and other settlers. The largest pond complex, extending over some 1,000 acres, was called Crystal Pond. In the mid-1800s, as the demand for salt rose, the first artificial salt ponds were developed in the East Bay as extensions and improvements of the natural salt ponds. Today, artificial salt ponds have entirely displaced their natural forerunners and no natural salt-crystallizing ponds remain the Bay.

Salt ponds, especially those with low to mid-salinities, provide important habitat for many species of wildlife, particularly birds. They are primary importance to migratory shorebirds and waterfowl, and they also provide year-round foraging habitat for a number of resident species such as American avocet, black-necked stilt, and western snowy plover. These and several other species-California gull, western gull, Forster's tern, and Caspian tern-nest on partly dry salt ponds, on levees, and on salt pond islets and islands. In all, more than forty species of birds are common on salt ponds. Ponds managed as crystallizers provide habitat for wildlife including shorebirds, gulls, and other water birds; however, given their comparatively high salinities, their habitat quality for most species of birds is not as high as the lower-salinity ponds.

The construction of artificial salt ponds in the Bay enabled increased populations of several bird species. These species include eared grebe, white pelican, bufflehead, western snowy plover, black-necked stilt, American avocet, Wilson's phalarope, red-necked phalarope, California gull, Caspian tern, and Forster's tern (Harvey et al. 1988). Eliminating artificial salt pond habitats without concomitantly restoring natural salt ponds and tidal salt marshes with pans could reduce or even extirpate some of these species from the Bay.

All salt ponds that are actively producing salt for commercial purposes are in South Bay, south of the San Mateo Bridge. In North Bay, none of the salt ponds west of the Napa River is managed to produce salt. The California Department of Fish and Game manages these "inactive" ponds for wildlife purposes.

F.5.10 Storage/Treatment Pond

The storage/treatment pond designation refers to diked, perennial shallow or deepwater pond habitat that has been constructed to store or treat runoff, sewage, or industrial discharges. These ponds support relatively little vascular vegetation. Most of them are parts of municipal wastewater treatment words that store treated effluent before it is recycled or discharged to the Bay. As they are similar in many respects to lagoons, they tend to support many o the same species, especially with regard to birds. Ponds typically provide habitat for mallard, northern shoveler, pied-billed grebe, scaup, bufflehead, and American coot.

F.6 Source

The source for the Appendix D, Environmental Conditions is the EPA, et. al. report "Goals Project, 1999, Baylands Ecosystem Habitat Goals. All the reference notes in the text refer to the EPA report. The official cite is:

Goals project, 1999, Baylands Ecosystem Habitat Goals, A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem

Goals Project, U.S. Environmental Protection Agency, San Francisco, Calif./S.F. Bay regional Water Quality Control Board, Oakland, Calif.

APPENDIX G

Controlled Explosions Research

Appendix G

G-1. Geotechnical Lessons Learned (Controlled Explosions Research)

G-1.1. Hydrographic Survey

a. The multibeam survey produced excellent topographic maps of the individual rocks. They generally had flat tops covered with debris due to previous lowering.

b. The coloring of height ranges on the topographic maps made a very good graphical representation of the shape of the individual rock.

G-1.2. Geophysical Survey

a. The side-scan sonar was very useful in producing a detailed view of the surface features of the rocks and the surrounding area.

b. The magnetometer surveys did show some man-made objects.

c. The seismic surveys were extremely useful since we did not sample the rocks. The compressional velocities were very similar to slightly fractured greywacke sandstone. It also showed Unnamed Rock is probably not rock but sediments.

G-1.3. Geological Investigation

a. The lack of physical data from the rocks themselves made it necessary to conduct a thorough literature search to verify the geology of the area as determined by the geophysical test data. USGS publications on the area suggest the rock is from the Franciscan formation. It is most probably predominately greywacke. This matches the geophysical data.

b. It was decided sampling the rock could be done as part of the next phase of the project.

G-1.4. Demolition Of The Rocks

a. General. A several methods of demolition were studied. Each of the rocks proposed for lowering had surfaces greater than a football field and would need to be lowered at least 20 feet. The technique with the greatest potential for performing the work in the shortest most economical manor was controlled blasting.

b. <u>Techniques</u>

1) Controlled <u>Blasting</u>. The St Louis District of the Corps of Engineers has the leading team for underwater demolition. Mssrs. Hempen and Keevin have written numerous papers on the subject. They consult extensively within and outside the Corps. Mr. Hempen designed a pattern of demolition, which consisted of approximately 5000 blast holes per rock. The holes would be 4-inches in diameter on approximately 5 ft centers. The holes would use low volumes of explosives to produce maximum rock breakage with minimal explosive material. Multiple drill rigs running on tracks on multiple barges would speed the placement of holes. A bubble curtain would surround the blasts to confine the effects to the rock and not the surrounding animal life and structures. A number of Corps Districts use this technique. New York And New England District were also consulted for their experiences. New England District uses a "fish horn" to keep fish and marine mammals away during blasting.

2) Expansive <u>Grout.</u> This type of grout was used to fracture and break off rock and concrete. It is very effective for approximately a foot back from an open face. It would be extremely difficult to use to demolish the large rock masses involved in this study.

3) Mechanical <u>Breakers, Crushers, Pulverizers.</u> This equipment can be mounted on the end of a backhoe. There is one in the bay mounted on a barge with a 70-foot reach. This type of equipment works on a relatively small area at a time. It would be extremely difficult to demolish the large rock masses involved in this study.

4) Rock <u>Abrasion or Grinding.</u> The small units could be mounted as **3** above with the same problems. Large units used to cut massive 30-foot diameter shafts would be extremely difficult to use for grinding the large rock masses involved in this study. They would create a large quantity of fines, which would spread in the currents.

5) Large <u>Rock Coring.</u> Equipment exits to cut up to 20-foot diameter rock cores. The cores would be difficult to remove and handle. It would be extremely difficult to remove the large rock masses involved in this study.

6) Rock <u>Dredge.</u> There is no rock dredge, which could remove rock of the hardness of the greywacke rock involved with this project. They might be able clean the debris area after blasting is complete.