California Department of Fish and Game Incidental Take Permit Application
Commercial Sand Mining within Suisun and Central San Francisco Bays

Prepared by:
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Draft – For Technical Review

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Summary of Findings

1.0 Applicant

The Incidental Take Permit Applicant is:

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2.0 Species Covered

Fish species that are listed for protection under the California Endangered Species Act (CESA) that are addressed in this Incidental Take Permit Application include:

- Winter-run Chinook salmon
- Spring-run Chinook salmon
- Delta smelt
- Longfin smelt

3.0 Project Description

3.1 Description of Sand Mining Equipment and Methods

There are three general methods of hydraulic sand mining (Figure 3-1) – potholing, trolling, and moving potholing. Potholing involves an initial search for an appropriate sand source, followed by "stationary" mining of sand at a site (Figure 3-1a). Potholing operations may involve mining more than one specific location during a mining event, and may involve some movement within a general site. Trolling (Figure 3-1b) involves mining while moving over a site, generally working back and forth along parallel pathways between markers. Moving pothole (Figure 3-1c) involves mining while moving over a site as well as trying to mine in a stationary position when an appropriate sand source is found. Hanson Aggregates uses the moving pothole method of sand mining.

Potholing involves an initial "searching" for sand with appropriate characteristics (e.g., sand particle size, low percentage (e.g., <10%) of fine-grained sediment, etc.) before the mining itself is initiated. For purposes of quality control on commercially harvested sand fine-grained material is defined as having a particle size of 200 microns or less. Although the distribution of sand resources is generally well known by the operators, sands of different qualities may be distributed in patches, and operators will initially test a selected site to determine the quality of sand. Tests include visual observations of the slurry (dark color indicates loose or unconsolidated sand) and readings from vacuum gauges. If, at the onset of a mining event, sand quality is not appropriate, the operator will move to another site, and test again. The exact searching and testing process may vary, depending on equipment, the judgment of the operator, and the market for which the sand is destined (and, therefore, the required size or grade of sand).

The mechanical fundamentals of sand mining involve use of a tugboat to position and maneuver the hopper barge (Figure 3-2). Hopper barges may be partially loaded with water prior to mining; some hold their sand cargo below water line requiring them to use nearly their full draft during the entire dredging event which limits the depth at which they can operate. Hopper barges mining sand within the Central Bay and Bay-Delta estuary use suctions pumps to harvest the sand from the bottom of the bay.

The hydraulic suction system used in sand mining consists of a drag arm equipped with drag head (Figure 3-3a, b), generally mounted on the side of the barge. The drag head is generally fitted with a "grizzly" to screen out oversized material (Figure 3-4). Typical drag heads used in trolling and moving pothole sand mining are shown in Figure 3-5. During a mining event, the drag head is lowered by winches to a depth just above the substrate surface.

The drag head being used may skim across the sediment surface or be buried approximately 12-18 inches beneath the sand surface. During mining using the moving pothole method the drag head may be buried under the substrate surface. During sand mining water is forced under pressure through a series of jets (cutter jets) in the drag head, with the jets directed at the substrate. These jets cut into the substrate, suspending sediment in a sand-water slurry that is then drawn into the drag head and pumped up to the hopper barge. The proportion of sand to water in the slurry may vary, depending on equipment and the quality of sand being mined. As sand is mined, the drag head is lowered and/or moved to maintain its position just above or within the substrate.

Once the sand-water slurry is pumped to the barge, it is discharged into a long loading chute, running lengthwise along the centerline of the barge (Figure 3-6). This chute has hydraulically-controlled screened openings (gates) at intervals along its bottom, and the sand-water slurry flows through these gates into the barge. Some of the slurry, including aggregate larger than the openings in the screens, is discharged overboard. This discharge may contain aggregates, fine sediments, aeration bubbles, and plankton, and a visible plume is sometimes created around the barge. As the sand displaces water in the barge, the water, fine sediments, aeration bubbles, plankton, and other fine material is discharged forming an overflow plume (Figures 3-7, 3-8, and 3-9). Cargo hoppers are also fitted with fine mesh screens along the bottom centerline of the barge where water that has filtered through the sand is also collected and pumped overboard. Based on the equipment and methods used for sand mining within the estuary, commercial sand characteristically ranges in size from approximately 1 mm to 12 mm (1/2 inch), with larger and smaller particles discharged overboard. The volume of sediment discharged overboard during a typical mining event within the estuary has not been quantified.

Hopper barges currently used in sand mining in the Central Bay and Bay-Delta estuary have screened overflow outlets. Water displaced by accumulating sand within the hopper barge, in addition to fine grained sediments and other material, is returned to the receiving waters through either surface discharges and overflow weirs (Figure 3-10) or through subsurface discharges (below the waterline: Figure 3-11). Hopper barges operated by Hanson Aggregates have been modified to include subsurface discharge pipes to release the overflow below the water line (Figure 3-11). Modifications to these barges to include the subsurface discharge of the overflow plume were intended to help reduce the visibility of the overflow plume and increase the rate of turbulent mixing and dissipation of the overflow plume. The effectiveness of these modifications in reducing overflow plume size or increasing the rate of plume dissipation has not, however, been evaluated

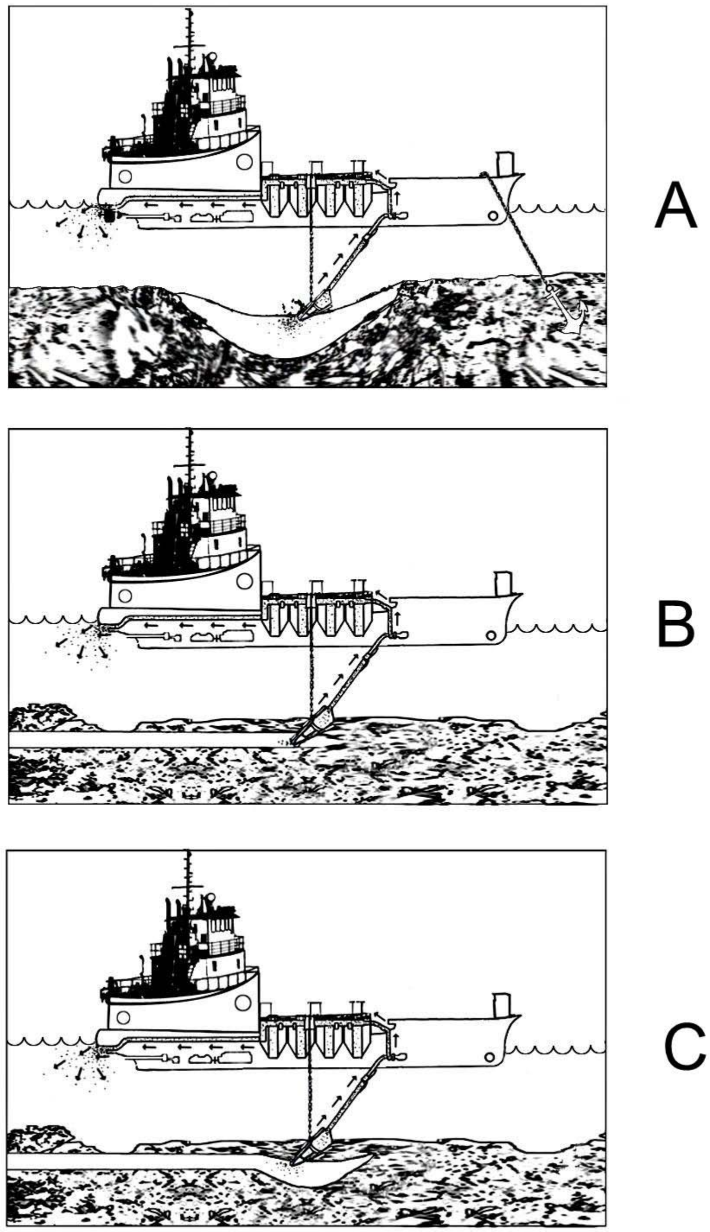


Figure 3-1. Schematic diagram of sand mining methods: (A) stationary pothole, (B) trolling and (C) moving pothole

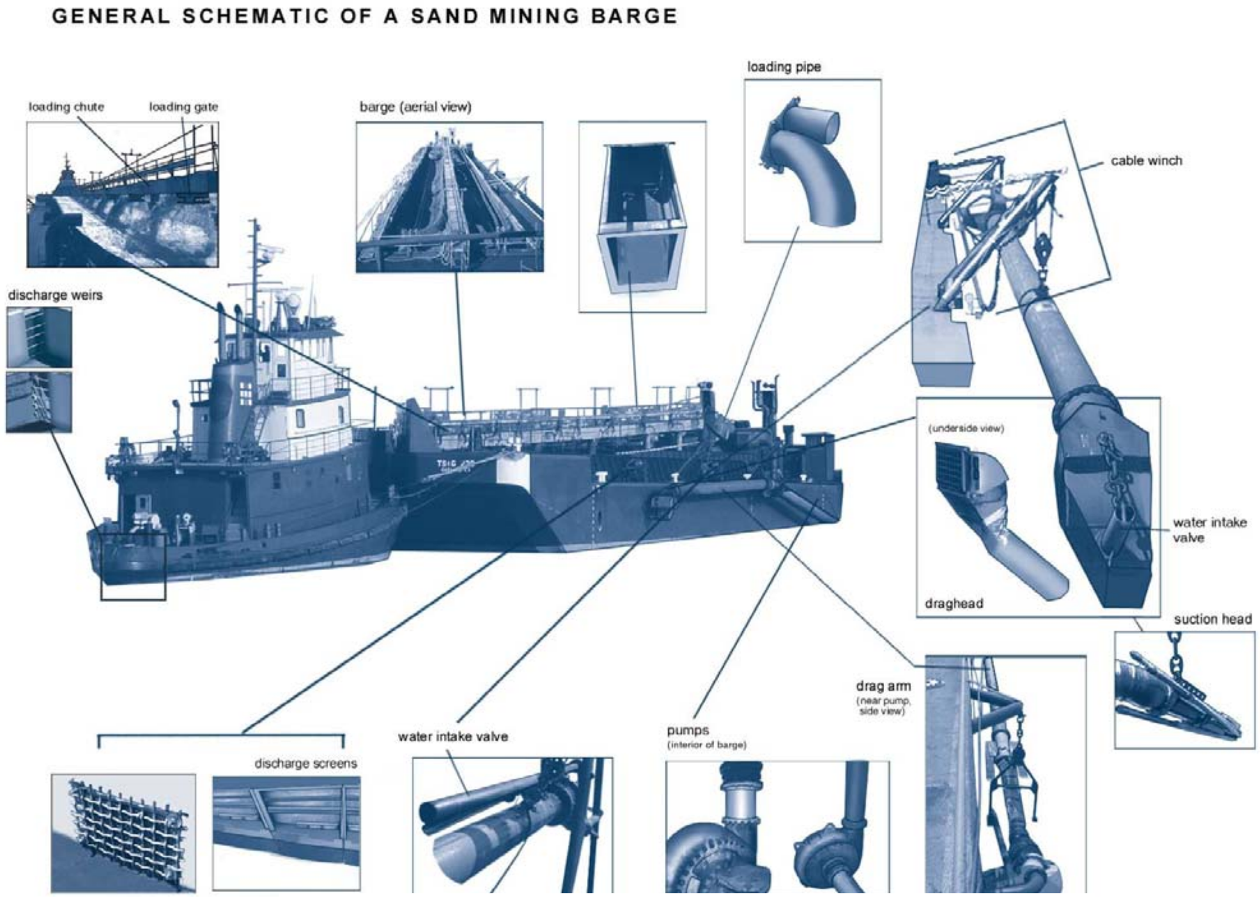


Figure 3-2. Schematic of typical sand mining barge

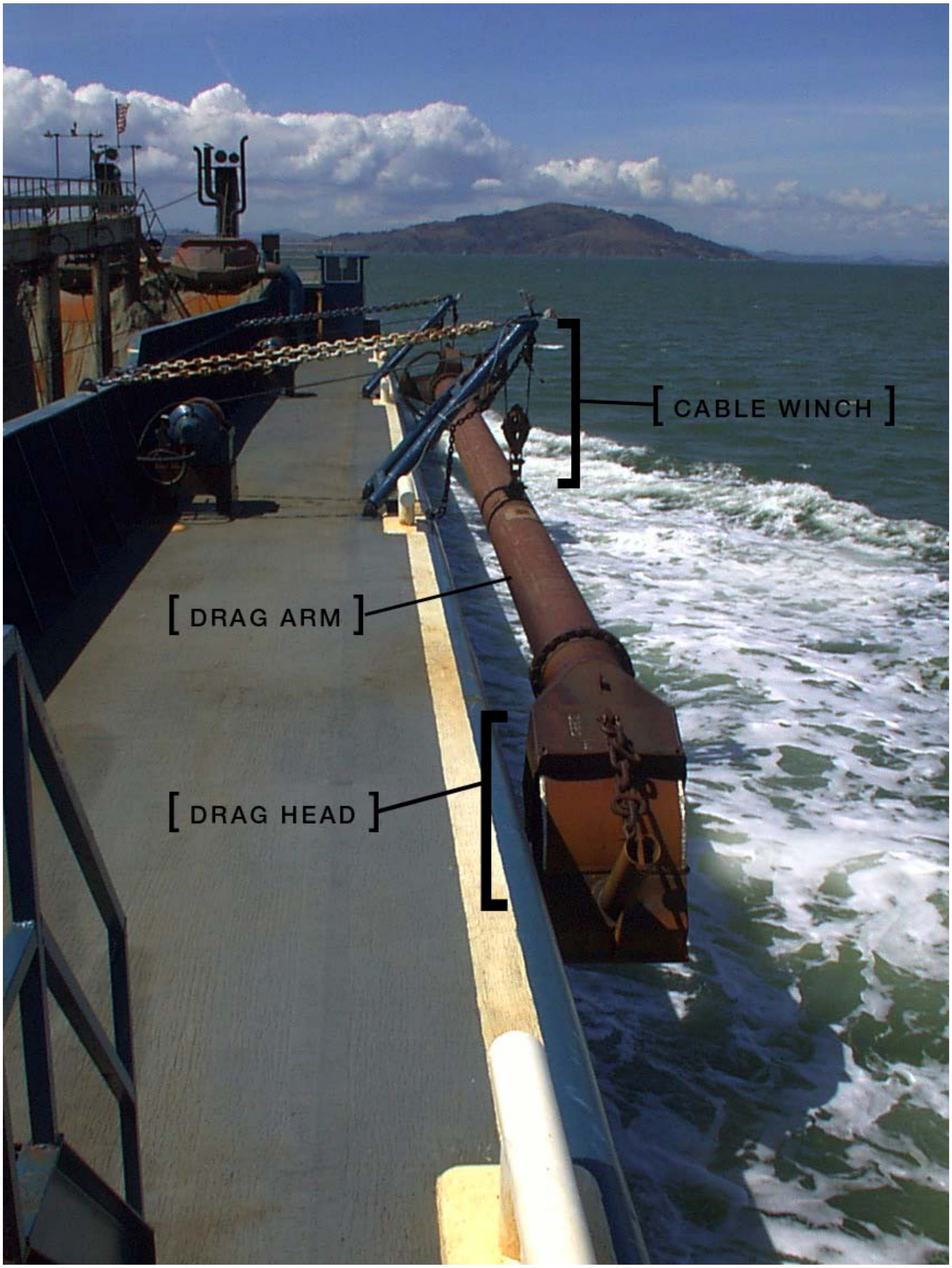


Figure 3-3a. Hydraulic suction drag arm and drag head assembly in the retracted position

Figure 3-3b. Trailing drag arm and hydraulic suction drag head

Figure 3-4. Hydraulic suction drag head showing “grizzly” screen used to exclude large material during sand mining.

Figure 3-5. Hydraulic suction drag head used in moving pothole sand mining.

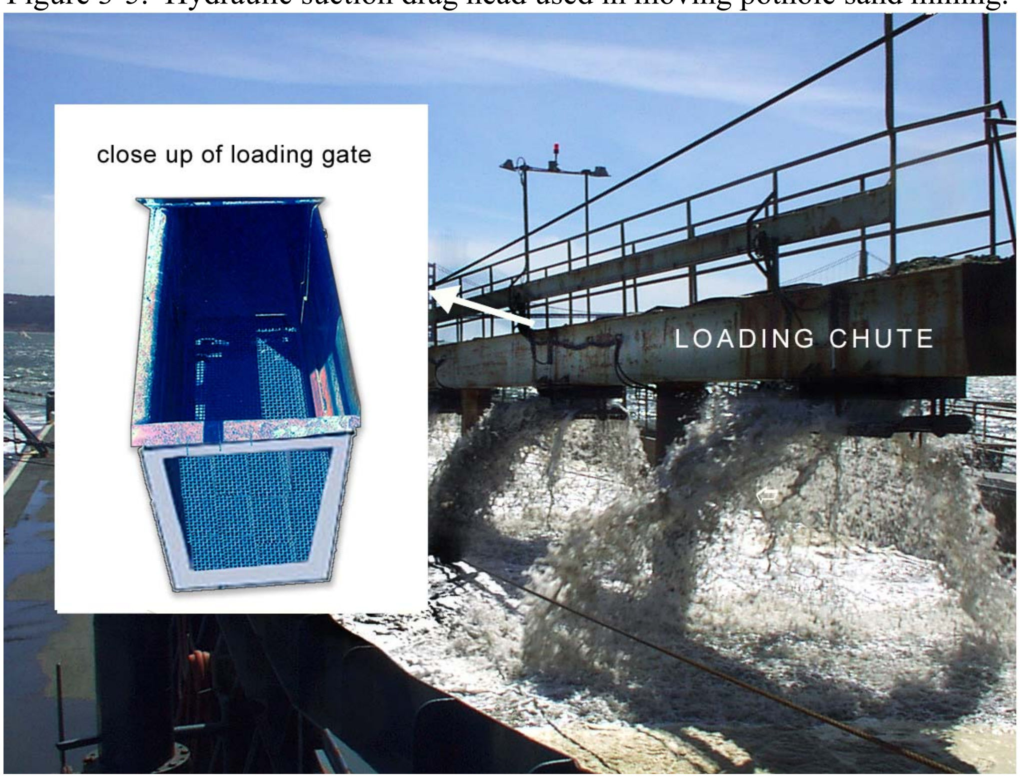


Figure 3-6. Barge loading chute and gate.

Figure 3-7. Sand mining overflow plume within Central Bay showing suspended sediment, entrained air bubbles, and other material

Figure 3-8. Sand mining overflow plume within Suisun Bay and Middle Ground Shoal (note similarity in turbidity between overflow and receiving waters)

Figure 3-9. Sand mining overflow plume and natural turbidity at ebb tide within Central Bay

Figure 3-10a
Surface discharge of sand mining overflow

Figure 3-10b
Surface discharge of sand mining overflow

<u>Figure 3-11</u>

Sand mining barge equipped with submerged overflow discharge. Note that the discharge is submerged below the waterline when the barge is loaded

During sand mining, water is drawn into the drag head by the suction pump from around the sides of the drag head operated by Hanson Aggregates (Figure 3-5). Water entrained into the drag head creates the sand-water slurry that allows the sand to be suspended and pumped into the hopper barge. As a result of the need to create the sand-water slurry, the drag head cannot be completely buried into the sand substrate. Cutter jets (high pressure water jets) are used to loosen and fluidize sand as part of the harvest process. Hanson Aggregates uses a modified drag head equipped with a water intake pipe to help loosen sediments and fluidize sand during moving pothole mining.

During sand mining the bottom of the drag head is typically located just above the sediment surface or buried approximately 12-18 inches into the bottom substrate. This allows the drag head to continually draw water into the drag head while maintaining sufficient suction to mobilize and transport suspended sand. As the sand is withdrawn from an area, the entire drag head assembly is typically lowered to maintain contact with the substrate.

Once mining is completed, the barge is taken to a suitable site for offloading (Figure 3-12). Offloading may be accomplished by creating a sand-water slurry and pumping the slurry into a dewatering pond on shore or by use of a conveyor belt/conveyor boom system to offload "dry" sand to a storage site (Figures 3-13 and 3-14). Slurry pumped into dewatering ponds is allowed to separate (settle) and water is drained over a weir system and subsequently discharged into the estuary. Most sand must be washed using fresh water before delivery to the customer to produce a sand product with chloride content appropriate for concrete, generally 0.006% chloride or less by weight of cement. Offloading and sand distribution sites are relatively small (typically 2-3 acres) and have limited capability to stockpile or store sand for an extended period. Therefore, sand mining within the estuary is conducted in response to short-term demand.

Hanson utilizes one tugboat/barge pair for sand mining (Table 3-1): the *William R* with the *Sand Merchant* (capacity 2400 cy). Mining is conducted using the moving potholing method (Figure 3-1). The *William R*/*Sand Merchant* has equipment for both hydraulic (slurry) and conveyor offloading. The *Sand Merchant* is limited by draft and other practical operating constraints to mining in water a minimum depth of 20 feet.

Sand is loaded into the cargo hopper using a trailing suction dredge “drag arm” (Figure 3-3). The drag arm is comprised of a 20-inch diameter pipe, 120 feet long, mounted on the side of the barge. The “drag head” attached to the end of the suction pipe measures 4 feet by 3 feet by 4 feet and has a 6-inch “grizzly” incorporated into it to screen off oversize material (Figure 3-5). The drag head is lowered to the shoal surface using two cable winches to a minimum depth of 20 feet and a maximum depth of 80 feet. The sand is drawn into the drag arm using a 20-inch centrifugal deck mounted pump capable of 15,000 gpm. While traveling to the mining location, the hopper barge is flooded by filling it approximately 1/3 full with water from the bay as ballast. As sand mining starts, the drag head is lowered to the sand shoal surface and water is mixed with the sand to create a slurry of approximately 17% sand and 83% water for blend and fill sand and 12 % sand and 88% water for coarse sand. The drag head has no vacuum relief valves (i.e. water intake pipes) and hence skims over the sand surface during mining.

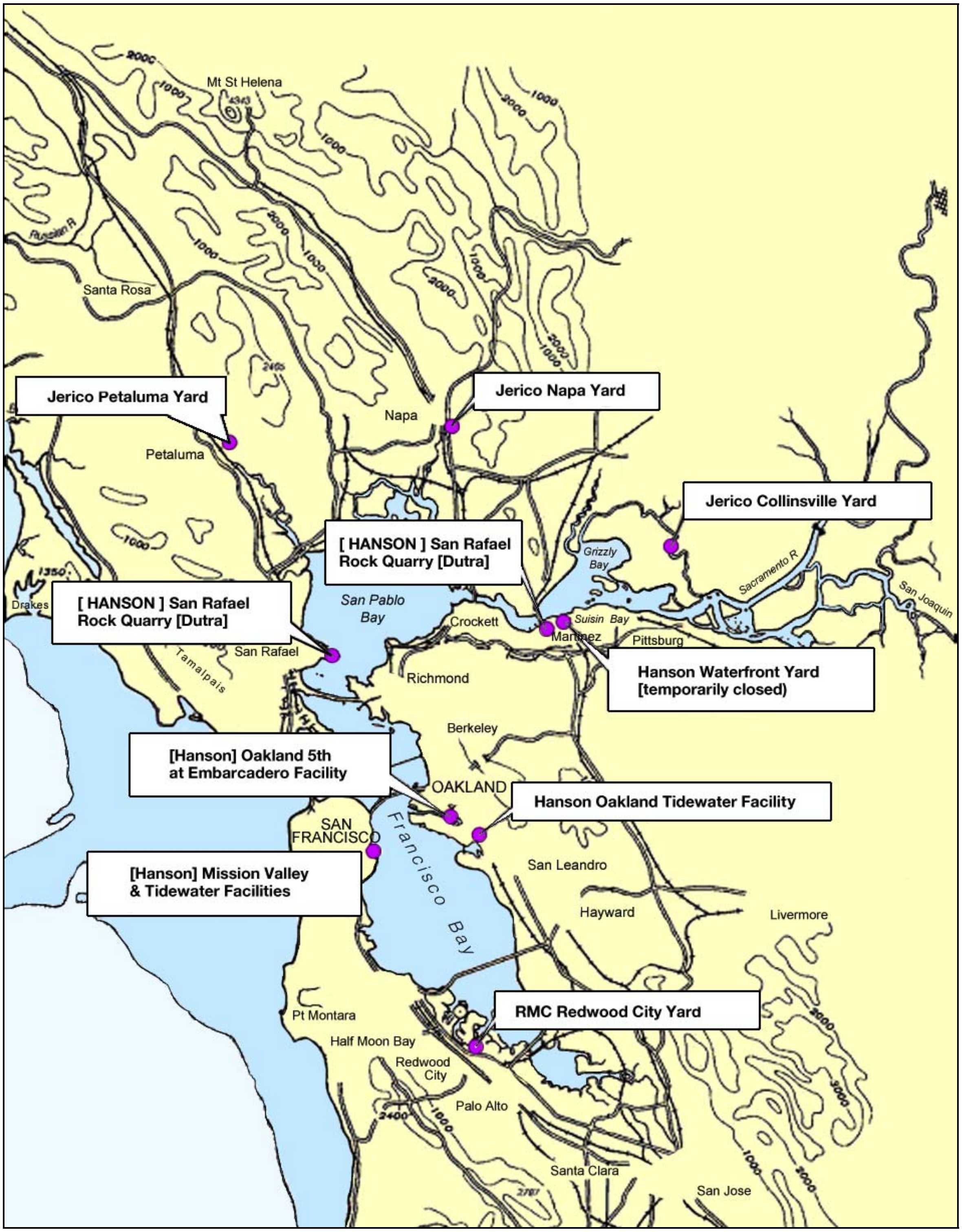


Figure 3-12
Marine sand offload locations within the Bay-Delta estuary

Figure 3-13
Transfer conveyor to boom conveyor

Figure 3-14
On-shore conveyor to stock pile

If the sand is "good" (loose), determined by the dark color of the slurry filing the hopper and vacuum gauge measurements, the operator mines the sand using the traditional potholing method, generally staying in one place allowing the drag head to gradually lower as sand is removed from the mining location (Figure 3-1). If the substrate is hard compacted sand, the operator moves, searching for a looser less compacted sand (moving pothole mining), allowing the drag head to skim along the sand shoal until appropriate substrate is found then the drag head is lowered in the traditional potholing method.

The sand-water slurry is drawn into the drag arm by the suction pump and pumped into the cargo hopper through a loading chute equipped with a series of gates distributed evenly along the bottom of the chute. The gates have a ½-inch screen mesh to exclude over sized material. The gates are hydraulically controlled to distribute the sand evenly to keep the barge level while loading. The oversized material, fine material, and water exit the chute through a discharge pipe located below the water line of the cargo hopper. Throughout the loading process, bay water is displaced by the accumulating volume of sand in the cargo hopper and is drained overboard through two discharge pipes on either side of the cargo hopper back to the bay below the water line (Figure 3-11). Fine sediments, along with aeration bubbles, suspended materials and plankton return to the estuary with the slurry water contributing to an overflow plume. Residual water in the sand has to be pumped from the bottom of the cargo hopper and discharged overboard.

The Sand Merchant is equipped with a pump offload capability as well as a dry offload capability (i.e. use of a conveyor belt system). For pump offloading, the cargo hopper is flooded with water from the estuary, and the sand-water slurry that is created is pumped onshore into a dewatering pond where the sand is allowed to settle and the water is drained through a weir system. The sand is then pushed out into the yard using a bulldozer. For the dry offload process, the hopper barge is equipped with two drag buckets which are pulled along either side (inside the cargo hopper) pulling the sand to the front of the barge feeding a hopper which in turn feeds a transfer conveyer. From the transfer conveyer, the sand is transferred onto the boom conveyer, which extends overboard to the shore side conveyer system stockpiling sand within the yard. The Sand Merchant can be offloaded at Hanson's Oakland Tidewater, Martinez Waterfront, as well as both San Francisco port sites and Dutra's San Rafael facility (Figure 3-12).

The number and seasonal timing of mining events is largely dictated by demand for product and weather. Because there is limited storage for sand at offloading facilities, inventories are small and sand is mined in response to demand. The seasonal distribution of sand mining peaks in the summer (Figure 3-15) when construction activity is also at a peak. For purposes of this analysis it has been assumed that sand mining by Hanson Aggregates would occur based on the average monthly seasonal distribution from 2002 to 2007 up to the maximum volumes of sand proposed to be permitted (Section 3.5)

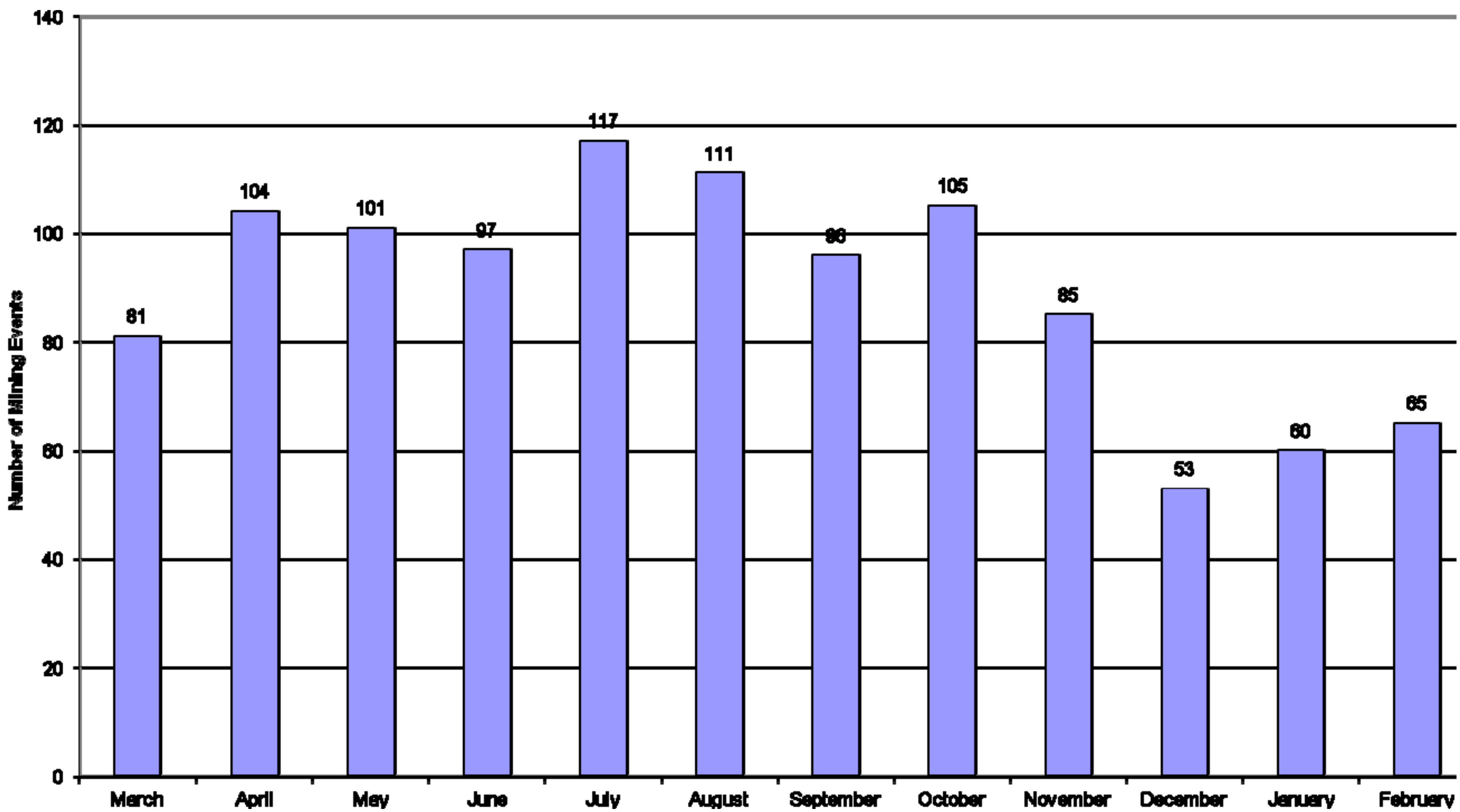


Figure 3-15

Number of mining events for all regions: February 2002 through March 2003 (Hanson et al. 2004)

3.2 Locations of Sand Mining Activity

The locations where sand mining occurs in Central Bay, Middle Ground Shoal, and Suisun Bay are influenced by a number of factors which include State Lands Commission designated lease areas, cable crossing areas, areas having suitable water depths for mining, areas where sand is known from historical observations to accumulate, and areas having moderately high water velocities resulting in frequent sand movement, replenishment, and scour of fines from sand deposits. Lease locations where sand mining by Hanson Aggregates is proposed to be allowed are shown in Figure 3-16 for Central Bay, Figure 3-17 for the private lease area in Middle Ground, and Figure 3-18 for Suisun Bay.

3.3 Mining Duration and Harvest

The duration of individual mining events reflect differences in equipment, equipment malfunctions, weather, availability of sand at the selected mining site, and other factors. Sand mining events generally last from 3 to 5.5 hours.

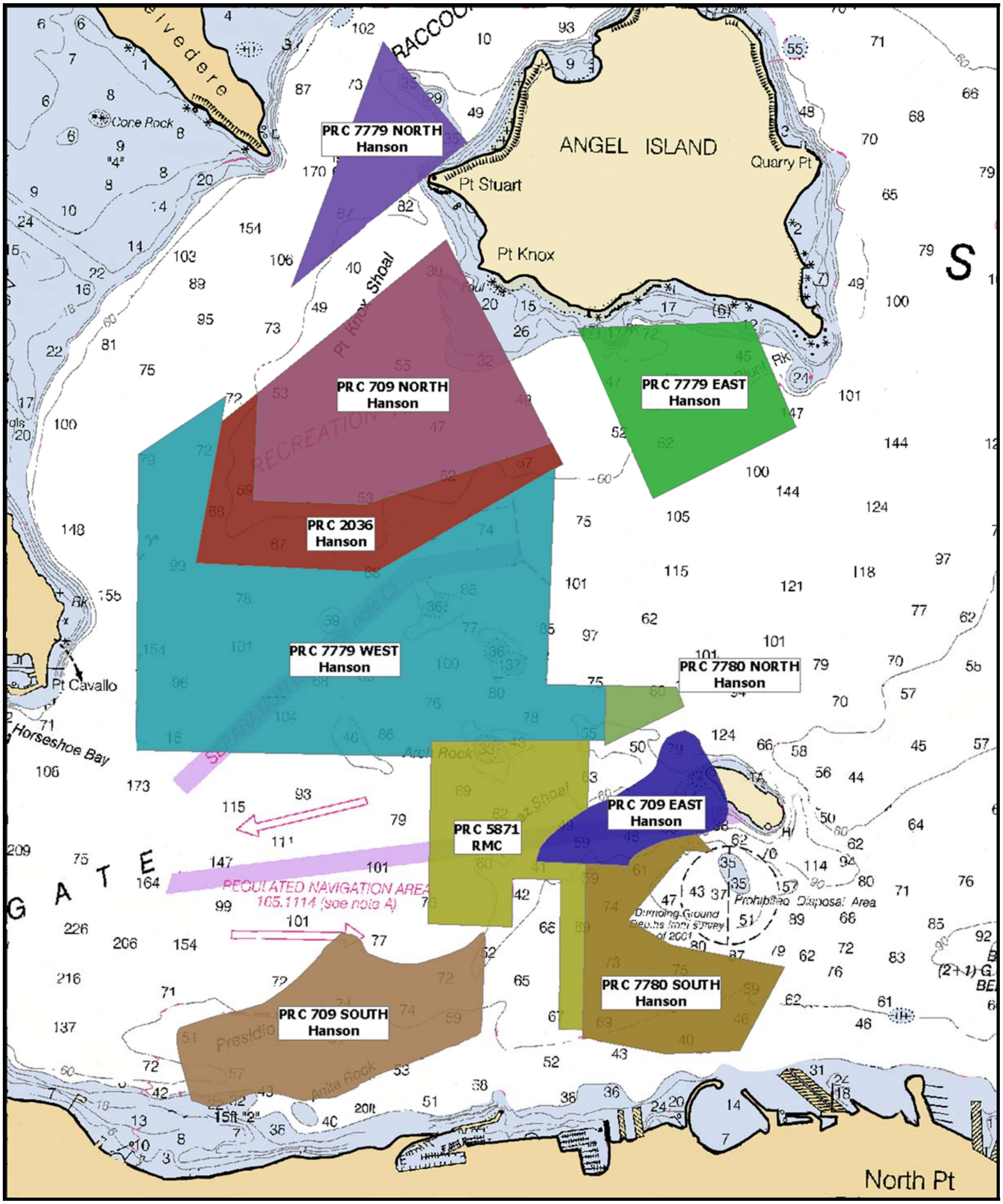
In Central Bay, the mean duration of mining events is relatively consistent from month to month. For Hanson Aggregates mining operations during the period March 2002 through February 2003, mean event duration was from 3.5 to 4.6 hours, with a maximum duration of 9 hours and a minimum duration of 1 hour. Mean yields from Hanson mining operations were also quite consistent, with monthly means of from 1,931 cy per event to 2,149 cy per event (Hanson et al. 2004).

Mining events in the Middle Ground Shoal and Suisun Bay areas show a higher range of event durations, although yield per event was only marginally lower. For Hanson Aggregates mining operations, the monthly mean event duration during the 2004 study ranged from 2 hours to 3.1 hours, and no event lasted longer than 7.5 hours. Monthly mean yield per event ranged from 1,490 cy to 1,768 cy (Hanson et al. 2004).

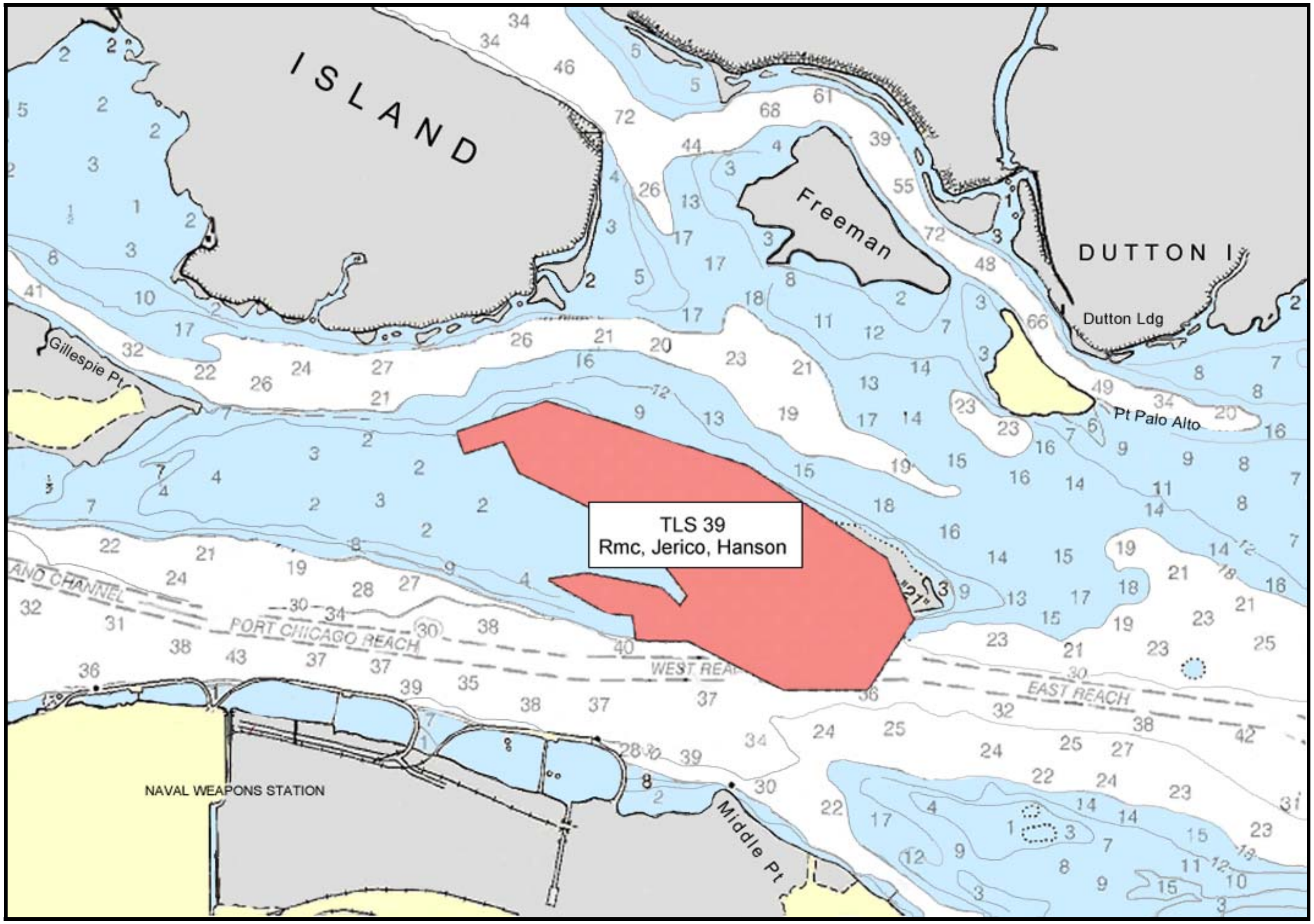
3.4 Water Depth

In Central Bay, sand mining typically occurs in relatively deep water (from 30 to 90 feet deep; Figure 3-19). Within the region of Middle Ground Shoal and Suisun Bay, sand mining typically occurs in waters 20 to 45 feet deep (Figures 3-20 and 3-21). Due to equipment constraints, such as the barge and tug draft and the suction drag head minimum operation depth (due to pipe length and angle during operation), sand mining cannot occur in shallow-water areas. For instance, Hanson Aggregates cannot practically mine in areas with less than 20 feet of water or in areas with depths greater than approximately 80 feet of water (Table 3-1).

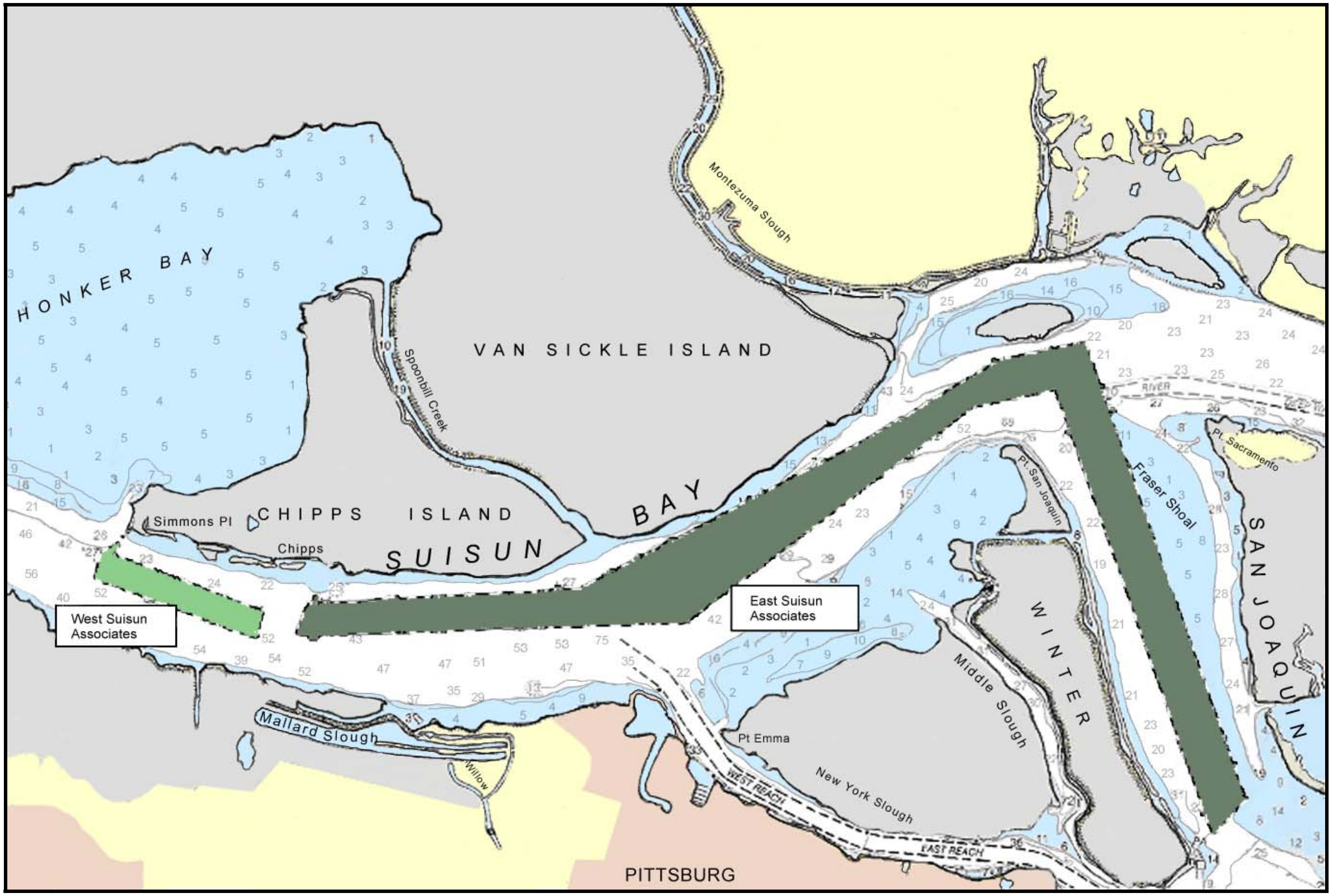
As well as equipment constraints, all recently issued ACOE and BCDC mining permits prohibit sand mining within 200 feet of any shoreline. The permits also prohibit sand mining within 250 feet of any water having a depth of 9 feet or less (MLLW), or 30 feet (MLLW), depending on location within the estuary.



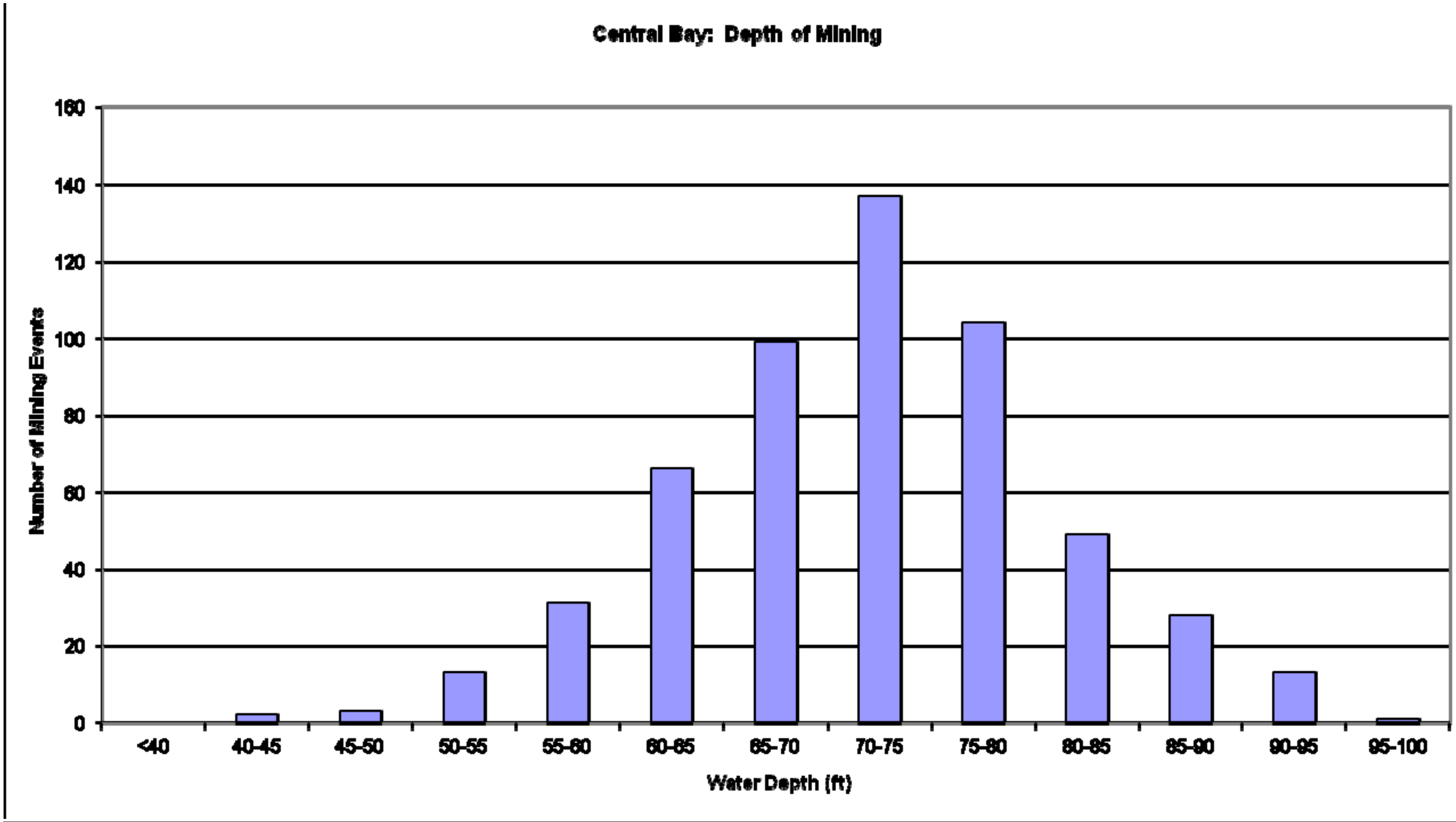
<u>Figure 3-16</u>
Central Bay SLC sand mining lease locations



<u>Figure 3-17</u>
Middle Ground Shoal private lease location



<u>Figure 3-18</u>
Suisun Bay SLC sand mining lease locations



<u>Figure 3-19</u>
Frequency of sand mining at various water depths: Central Bay (Hanson et al. 2004).

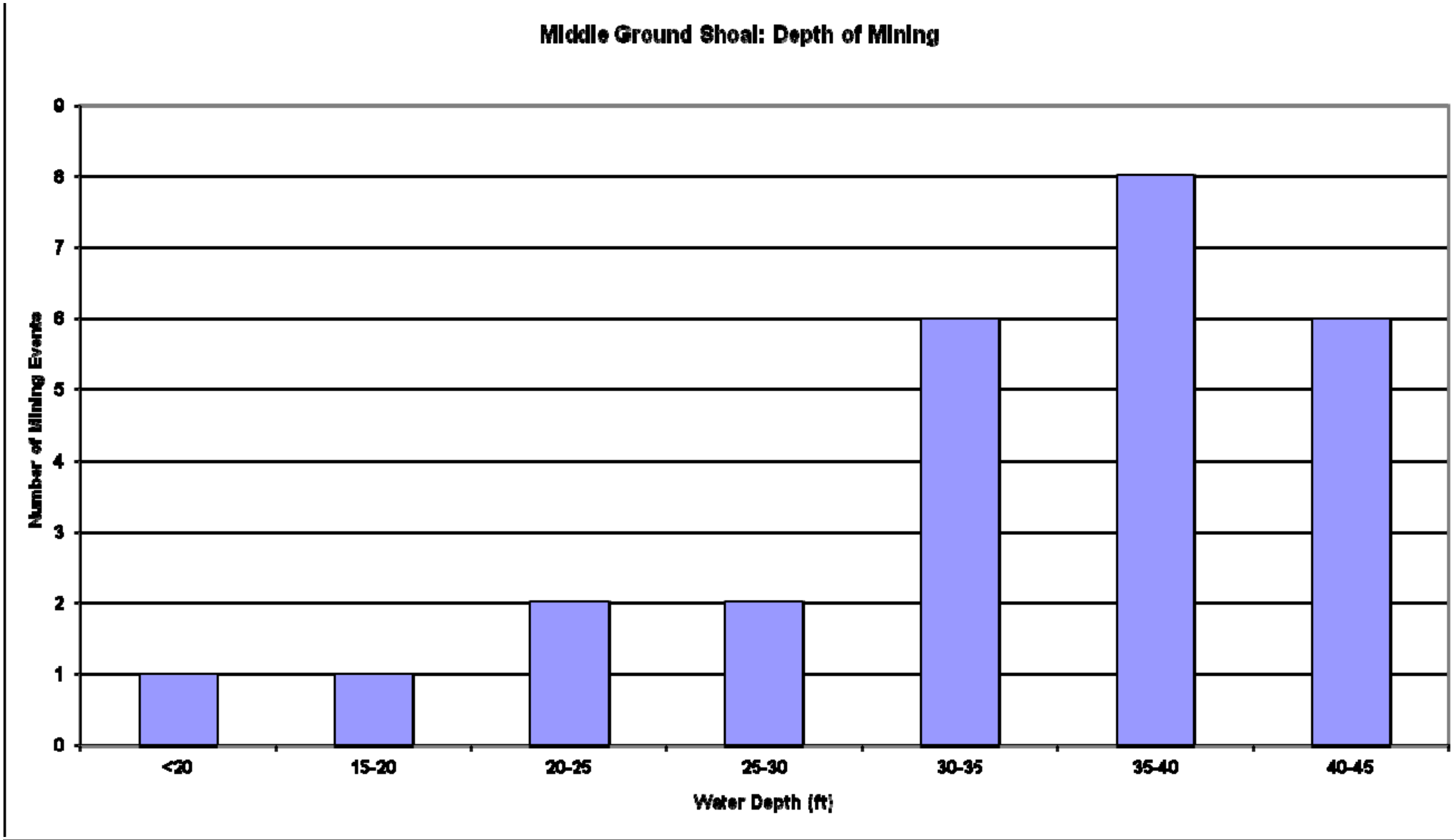


Figure 3-20

Frequency of sand mining at various water depths: Middle Ground Shoal (Hanson et al. 2004).

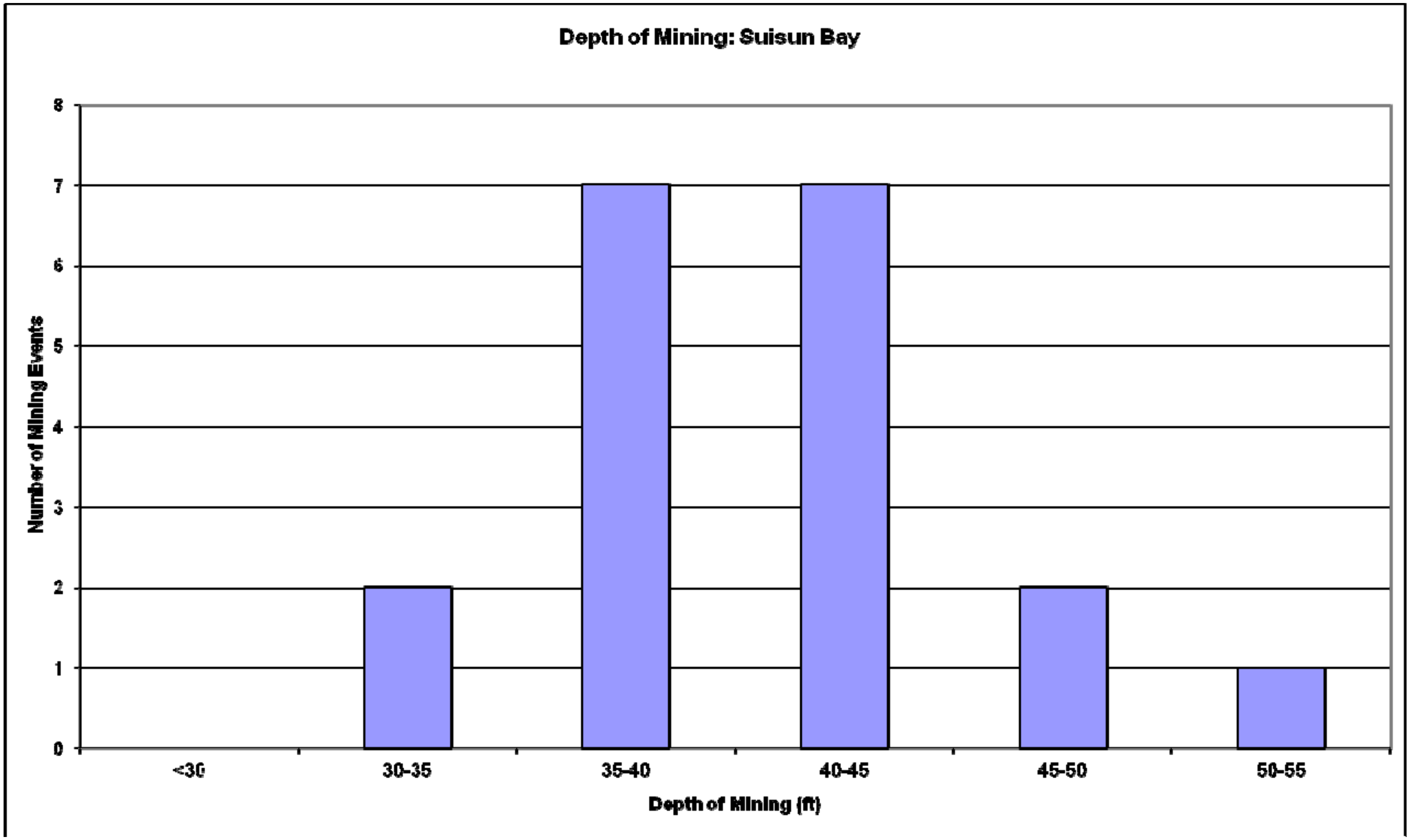


Figure 3-21
Frequency of sand mining at various water depths: Suisun Bay (Hanson et al. 2004).

Table 3-1
Summary of Hanson sand mining operations in the Bay-Delta

Parameter	*William R*/Sand Merchant
Tugboat	
Length (feet)	74.4
Width (feet)	26.26
Draft (feet)	8
Barge	
Type	Hopper
Length (feet)	230
Width (feet	55
Draft, loaded (feet)	14
Capacity (cy)	2400
Loading chute dimensions (L x W x H)	180 feet x 24" x 28 '
Loading chute gates (number)	10
Screen mesh on loading chute gates	½ inch
Drag Arm	
Length (feet)	120
Diameter (inches)	20
Drag Head	
Dimensions in feet (L x W x H)	4 x 3 x 4
Jetted	No
Grizzly	Yes, 6-inch
Offloading System	
Type	Hydraulic (slurry) and Conveyor
Offloading sites (Figure 2-)	Oakland (Tidewater) Martinez (Waterfront) San Francisco (2 sites) San Rafael (Dutra)
Operations	
Minimum operating depth (feet)	20
Maximum Operating depth (feet)	80
Maximum pumping capacity (gallons per minute)	15,000
Type of Operation	Moving Pothole
Typical sand-water slurries (% composition, sand:water using Central Bay data)	17:83 for blend and fill sand 12:88 for coarse

3.5 Sand Volumes Harvested by Area

The volumes of sand that are currently permitted for annual harvest by lease area are summarized in Table 3-2. As part of the permit application for new State Lands Commission leases within Suisun and central Bays Hanson Aggregates has revised the requested annual volumes of sand that can be harvested as shown in Table 3-2. The proposed annual sand harvest volumes were used in preparing the draft Environmental Impact Report (EIR) and have also been used as the basis for the Incidental Take Permit application analyses presented below.

The seasonal distribution of sand mining events varies within and among years in response to factors such as weather and demand. The seasonal distribution of mining by Hanson Aggregates used in this assessment was based on the actual sand mining activity monthly over the period from 2002 through 2007. The average monthly percentage of sand mined is summarized below.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Percentage	6.6	6.8	7.9	8.0	8.0	10.0	8.1	9.2	10.3	9.6	8.1	7.3

The seasonal distribution of sand mining events shown above was used for purposes of analysis. The actual seasonal distribution of mining in any given year in the future may vary.

3.6 State and Federal permits and approvals

Sand mining is regulated in accordance with State Land Commission lease areas located in central Bay and Suisun Bay where sand mining is allowed. Royalty payments are made to the State based on the volume of sand harvested. Permits authorizing sand mining are also issued by the Bay Conservation and Development Commission (BCDC) and the US Army Corp of Engineers (ACOE) that include a number of restrictions on the specific locations (e.g., sand mining cannot take place at locations within 250 feet of locations where water depths are less than 9 feet deep in Suisun Bay and less than 30 feet deep in central Bay, etc.) as well as the annual volumes of sand that can be harvested from each designated sand mining area. The National Marine Fisheries Service (NMFS) has issued a Biological Opinion and incidental take statement under Section 7 of the federal ESA for the take of listed salmonids and green sturgeon as well as potential adverse effects to their critical habitat. US Fish and Wildlife Service (USFWS) determined that sand mining would not adversely affect delta smelt as a result of restrictions on sand mining included in the COE permits and therefore no additional incidental take authorization was required.

In addition, the CDFG issued a Consistency Determination in April 2006 that indicated that the conclusions of the NMFS Biological Opinion were consistent with the California Endangered Species Act (CESA) with regard to Chinook salmon, and that the mitigation measures identified in the BO will minimize and fully mitigate the impacts of the authorized take on Chinook salmon. Mitigation included the purchase of 0.15 acres of open water habitat at Kimball Island, designated as a habitat mitigation bank.

Table 3-2

Current and proposed sand harvest (cubic yards per year) for Hanson Aggregates.

(The proposed annual harvest volumes have been used in assessing potential take as a result of entrainment.)

Region	Currently Permitted Volume (cy/year)	Proposed Volume (cy/year)
Central Bay		
PRC 709.1: Presidio, Alcatraz, and Pont Knox Shoals	540,000	340,000
PRC 2036.1: Point Knox South	300,000	450,000
PRC 7779.1: Point Knox Shoal	400,000	550,000
PRC 7780.1 Alcatraz South	150,000	200,000
Central Bay Total	1,390,000	1,540,000
Suisun Bay		
PRC 7781.1: Suisun Bay/Western Delta (Suisun Associates)	100,000	150,000[(1)]
Grossi Middle Ground (private lease)	500,000	50,000
Total Suisun Bay	600,000	200,000
Total All Regions	1,690,000	1,740,000

Currently, the California State Lands Commission (SLC) is preparing an Environmental Impact Report (EIR) to comply with CEQA review required for the renewal of sand mining leases issued by SLC to Jerico/MTB and Hanson Marine Operations. The EIR may also be utilized as environmental documentation by other resource agencies issuing permits for sand mining activities.

Although the EIR is being prepared to cover the activities of both Hanson and Jerico/MTB, for purposes of CESA Section 2081, Hanson and Jerico/MTB are seeking individual permits. The companies are coordinating efforts to provide consistent and accurate information.

California State Lands Commission (SLC) Lease Terms

- Each lease limits annual mining volumes (see Table 3-2);
- The leases contain various monitoring and reporting requirements;
- The lessee must implement the mitigation measures contained in the relevant environmental document prepared pursuant to the California Environmental Quality Act;
- The lessee cannot impair waters or interfere with navigation, nor deposit refuse into the water;
- The lessee must prevent waste of or damage to minerals, fisheries, or wildlife on property; operations may be suspended if there is an immediate or serious threat to these resources; and
- The lessee must adhere to the relevant reclamation plan for each lease area prepared pursuant to the State Surface Mining and Reclamation Act.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) Permit Conditions

- Sediment collected must be largely sand;
- Cannot discharge into waters with "beneficial uses" anywhere in San Francisco Bay, where dilution ratio is not at least 10:1, or in any non-tidal water, dead-end slough, or confined water;
- For Middle Ground Shoal, no mining within 200 ft of shoreline and 250 ft of any water 9 ft or less at MLLW
- Cannot degrade water supply or cause a nuisance;
- Cannot operate in areas less than 10 ft MLLW;
- Must minimize wasteful dredging and discharges;

- Must not result in exceeding set limits for dissolved oxygen, dissolved sulfide, pH, or toxic substances in downstream water; and
- Must follow monitoring and reporting requirements and allow for inspections.

Bay Conservation and Development Commission (BCDC) Permit Conditions

- Limits annual mining volumes;
- Must follow monitoring and reporting requirements;
- Prohibits dredging within 200 ft of shoreline or within 250 ft of any water 9 ft MLLW or less for Middle Ground Shoal;
- Priming the pump must occur at no more than 3 ft off the bottom;
- Must mitigate for take of listed species;
- Must complete entrainment study (study was completed in 2006);
- Must allow for inspections;
- Operations may be suspended or limited if there is substantial depletion of sand or significant adverse impacts;
- Must adhere to an approved Reclamation Plan;
- At offloading sites, must minimize muddying of waters, dikes must be waterproof, seepage subject to RWQCB regulations; and
- Must follow monitoring and reporting requirements and allow for inspections.

Army Corps of Engineers (ACOE) Permit Conditions

- Limits annual mining volumes;
- Must not mine within 200 ft of shoreline or within 250 ft of water less than 9 ft MLLW in the Suisun Bay area and prohibits mining in less than 30 ft MLLW in San Francisco Bay;
- Must allow inspections;
- Can suspend operations if there are adverse impacts to aquatic resources;
- Must avoid underground utility lines;
- Must follow monitoring and reporting requirements; and
- Must implement recommendations of 2004 sand mining study.

3.6 Characteristics of the Overflow Plume

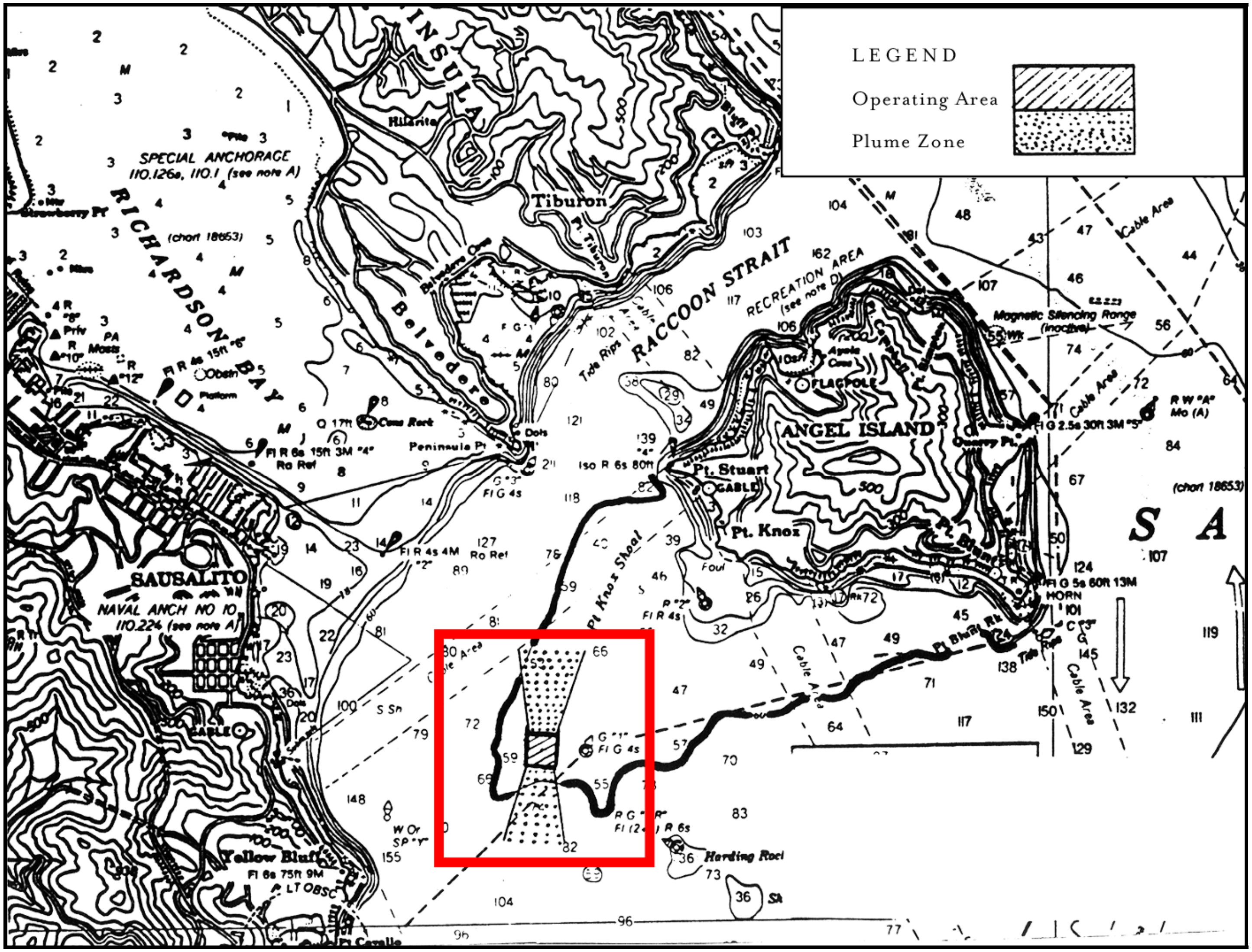
During sand mining operations overflow "plumes" of fine suspended sediment and other material (e.g. entrained air bubbles) are created within the water body adjacent to the barge (Figures 3-7, 3-8, and 3-9). Sediment plumes caused by sand mining can be defined as those particles suspended into the water column during the sand mining operation that do not rapidly settle following discharge back into the estuary. The degree of sediment resuspension, plume size, concentration and duration of the plume depends on many site and operational specific factors. Data presented in the literature on the characteristics of suspended sediment plumes from sand mining and dredging operations similar to those occurring within the estuary are summarized below. Information characterizing the suspended sediment plume will be used to ascertain the effects of plume exposure on fish and macroinvertebrates inhabiting the estuary.

This section discusses the characteristics of the overflow plumes resulting from sand mining. Plume characteristics include the size, location and depth of the plume; suspended sediment concentrations within the overflow plumes, as described from data collected in previous studies; plume composition; and a comparison of overflow plume suspended sediment concentrations with background (ambient) conditions.

Plume Size and Depth

The size and depth of an overflow plume is partly determined by the concentration and grain size (and specific gravity) of sediment particles and other materials discharged as part of the overflow during sand mining. Current velocity and direction also play a large role in determining plume characteristics. MEC and Cheney (1990) conducted a series of studies designed to characterize the overflow plume during sand mining within Central Bay (Figure 3-22). The overflow plume dimensions are characteristically narrow, as determined by tide and current velocity. On ebb and flood tides, the plumes are typically narrow in width and long in length. During slack tides, the plumes extend over a wider area and are less drawn out.

Generally the overflow plume during sand mining is approximately 300 feet or less in width and trails away from the sand mining barge with the prevailing water currents (MEC and Cheney 1990). MEC and Cheney (1990) observed that plumes generally dissipate within approximately 3,000 feet of a sand mining operation. The rate of plume dispersal is related to the settling rate of the particles and turbulent mixing within the receiving waters. Goodwin and Michaelis (1984) observed sediment plumes from dredging operations in Tampa Bay, Florida to be characteristically long and narrow during strong ebb and flood tidal conditions, with wider plumes displaying lower sediment concentration decline rates during slack tides or in areas of low currents, and therefore low mixing.



<u>Figure 3-22</u>

Area on Point Knox Shoal within Central Bay where overflow plume studies were conducted by MEC and Cheney (1990)

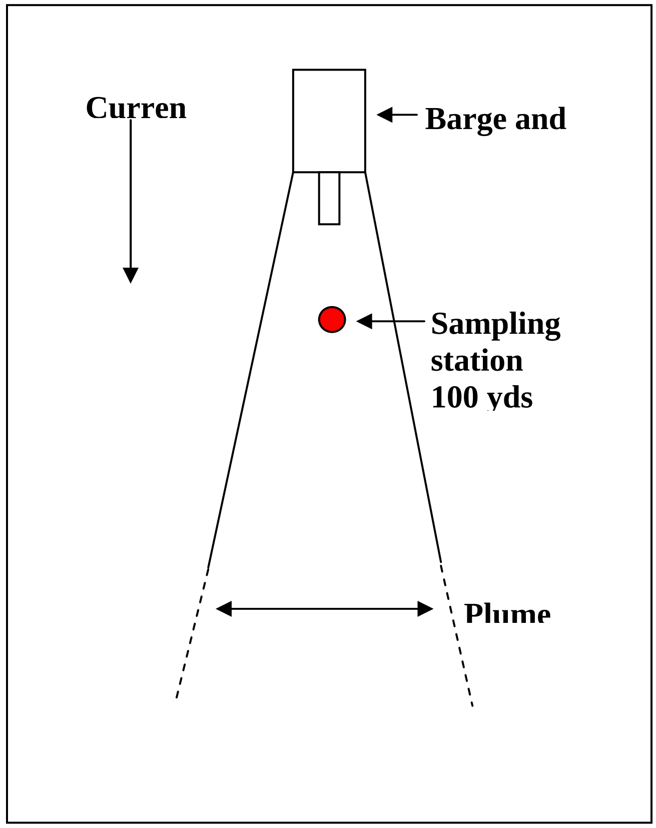
Plume Composition

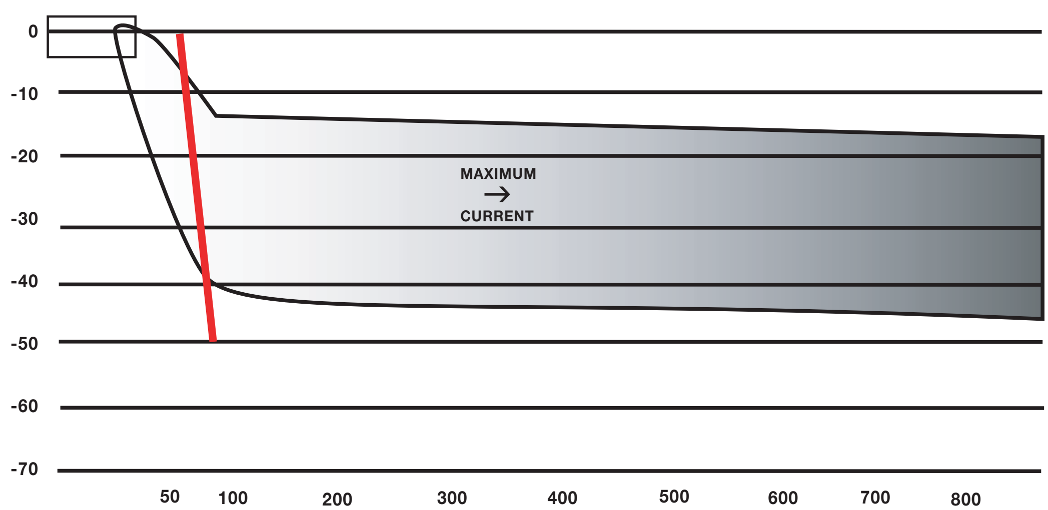
The visible plumes around the sand mining barge created during sand mining operations are composed primarily of fine sediments (silt and clay), aeration bubbles, dissolved materials and plankton. The suspended sediment concentration within the plumes is one of the primary focuses of a biological effects assessment. Overflow plumes typically have an increased suspended sediment concentration and elevated turbidity. The elevated turbidity, however, may not be directly related to increased suspended sediment concentrations, which are measured by weight/volume (mg/l). Increased turbidity associated with the plumes may be formed largely by aeration bubbles and silt/clay particles: there is not necessarily any correlation of turbidity with increased suspended sediment concentration. The material within the overflow plume associated with sand mining originates from the sand substrate. No chemicals or other materials are added to the overflow plume during sand mining.

Sediment Concentrations Within the Plume

As part of the sand mining overflow plume study conducted within Central Bay (Figure 3-22) MEC and Cheney (1990) measured suspended sediment concentrations inside plumes created by overflow during sand mining operations. MEC and Cheney (1990) noted that the overflow from the barge appeared to have elevated levels of fine particulate material when compared to receiving waters, creating a well developed plume in the direction of tidal flow (Figure 3-9). The plume monitoring identified the plume zone both vertically and horizontally within the water column. The water sampling conducted within the plume was divided into three separate procedures to characterize (1) the vertical distribution of the plume within the water column, (2) suspended sediment concentrations within and outside of the plume, and (3) along a longitudinal gradient within the plume. Data related to the characteristics of the plume included:

- Water sampling to determine suspended sediment concentrations immediately astern of the tugboat (Figure 3-23): Water samples were taken at five foot vertical intervals. This test was designed to assess the vertical distribution of the plume to a depth of 50 feet within the water column;
- Secchi disk readings were taken within two of the plumes;
- Literature data on the settling rate of fine sediment was compiled; and
- Data on the composition of mined sediment was compiled.





<u>Figure 3-23</u>

Vertical profile sampling of the overflow plume during sand mining MEC and Cheney (1990)

As part of the sand mining overflow plume study, MEC and Cheney (1990) collected sediment samples from Central Bay Shoal and barge to determine the percentage of fines. Sediment sampling locations are shown in Figure 3-24. Results of these tests (Table 3-3) are consistent with other surveys showing that sand is mined from areas that typically contain less than 10% fine materials (Figure 3-25). The results of these surveys also show the variability in sediments, and the percentage of fines within an area as reflected in the data for Site E. Areas, such as Site E, having a higher percentage of fines (>10%) would not be suitable for commercial sand mining and would be avoided during mining. During a sand mining event operators typically search an area for suitable sand deposits (based on both the quality and quantity of sand at a site).

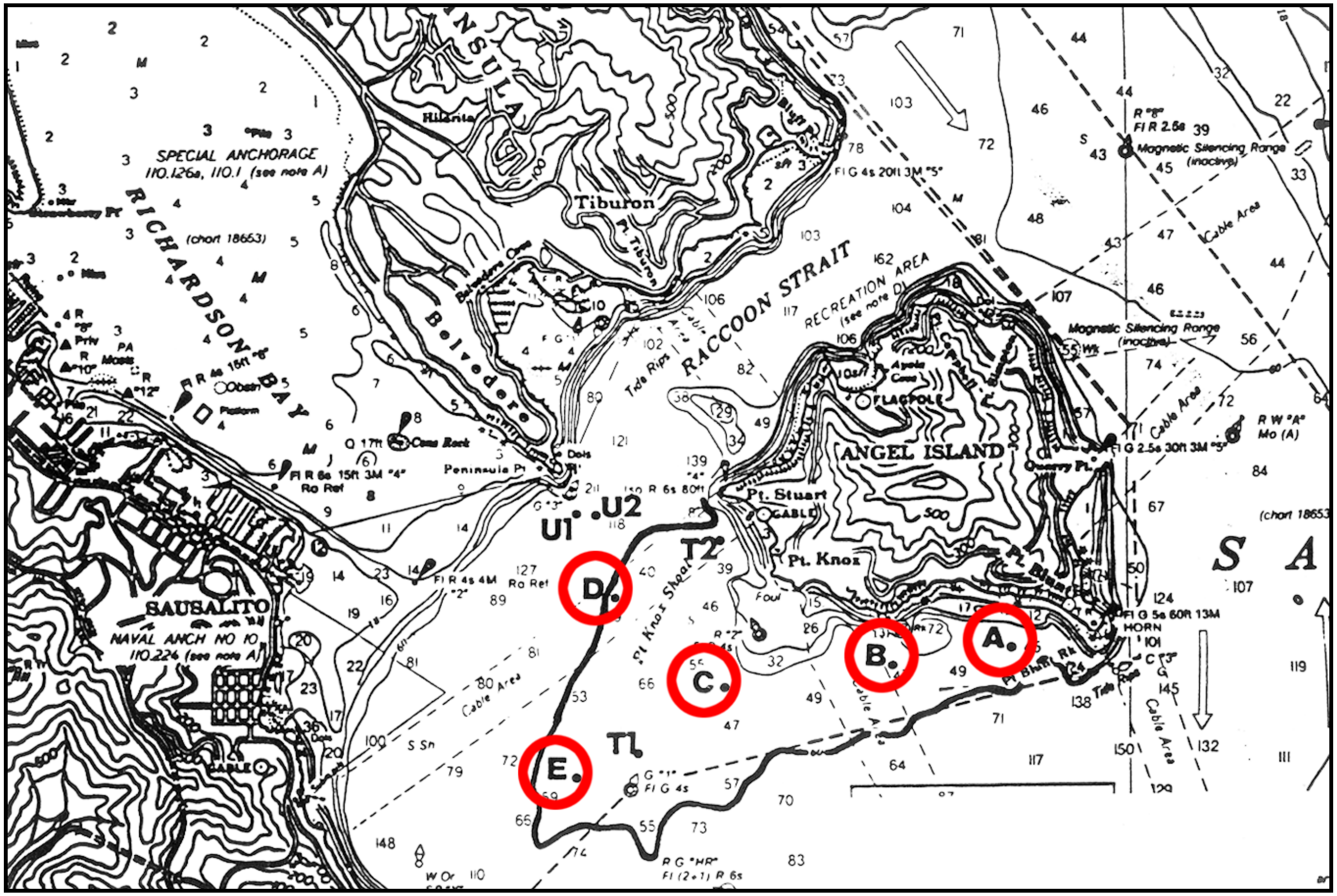
The occurrence of sediments within an area of the estuary is dependent on a variety of factors including current velocity and turbulence. High velocity and turbulence scour fine sediments from an area while providing bedload transport by larger sand and gravel particles. Gradients in water velocity and turbulence result in "sorting" of particles in the sedimentary deposits, resulting in deposits of nearly pure sand in one location (high turbulence and velocity) while other locations may be characterized by sediments rich in silt and clay (low turbulence and velocity). In zones of high velocity and turbulence, only the larger particles (sand in the case of San Francisco Bay) will deposit. In zones of low velocity and turbulence, sand, as well as the smaller particles (silts and clays) will settle to the bottom. As a result of these physical processes, sand mining has historically occurred preferentially in areas of the estuary characterized by moderately high current velocities, typically in deeper channel and depositional areas, while avoiding shallow water low velocity areas where the deposition of fines is greater.

Plumes from sand mining activities increase existing concentrations of suspended sediments before dispersing to background levels. The time required for the concentration to return to background levels is a function of:

- The length of time for the water body affected by a plume to return to an un-impacted condition. This is directly dependent on water body current velocities (flushing time); and

- Time taken for sediment to settle out of suspension. Settlement is dependent, in part, on characteristics such as water depth, salinity and turbulence. Sediment characteristics such as structure, grain size, shape and density will also directly affect settling times.

MEC and Cheney (1990) measured suspended sediment concentrations along a longitudinal transect through the plume (Figure 3-26). Water samples were taken from a set depth of 20 feet starting up current of the barge and at two-minute intervals as the research vessel moved from outside the plume into the plume (MEC and Cheney 1990). This test ran for 24 minutes and the research vessel would typically finish at least 800 yards astern of the barge at the end of the sampling cycle. Sampling was carried out in the mid-line (center) of the plume (Figure 3-26).



<u>Figure 3-24</u>

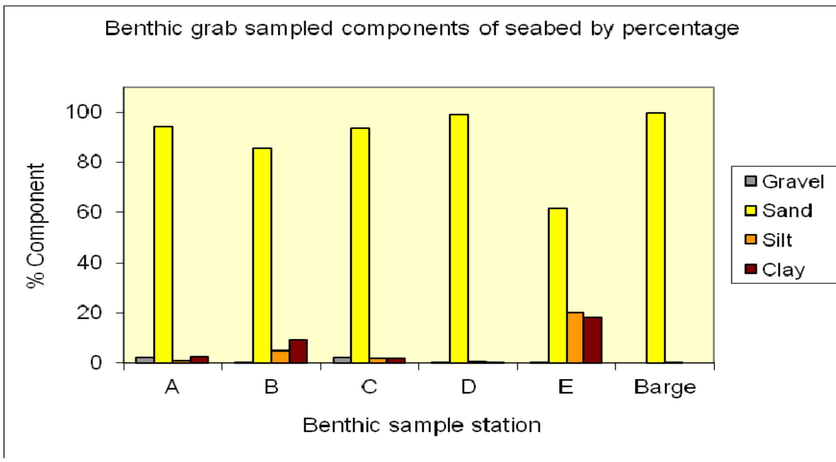
Sampling locations for seabed inorganic composition study MEC and Cheney (1990)

Table 3-3

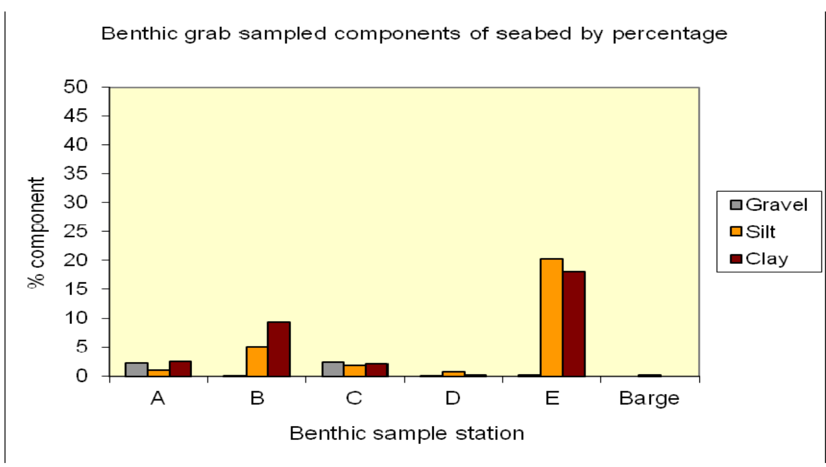
Percentage distribution of seabed inorganic components MEC and Cheney (1990)

%	A	B	C	D	E	Barge
Gravel	2.28	0.007	2.41	0.043	0.199	0
Sand	94.23	85.68	93.52	98.94	61.54	99.77
Silt	0.99	5.07	1.86	0.75	20.17	0.23
Clay	2.49	9.23	2.13	0.27	18.09	0

See Figure 2-32 for sampling locations.



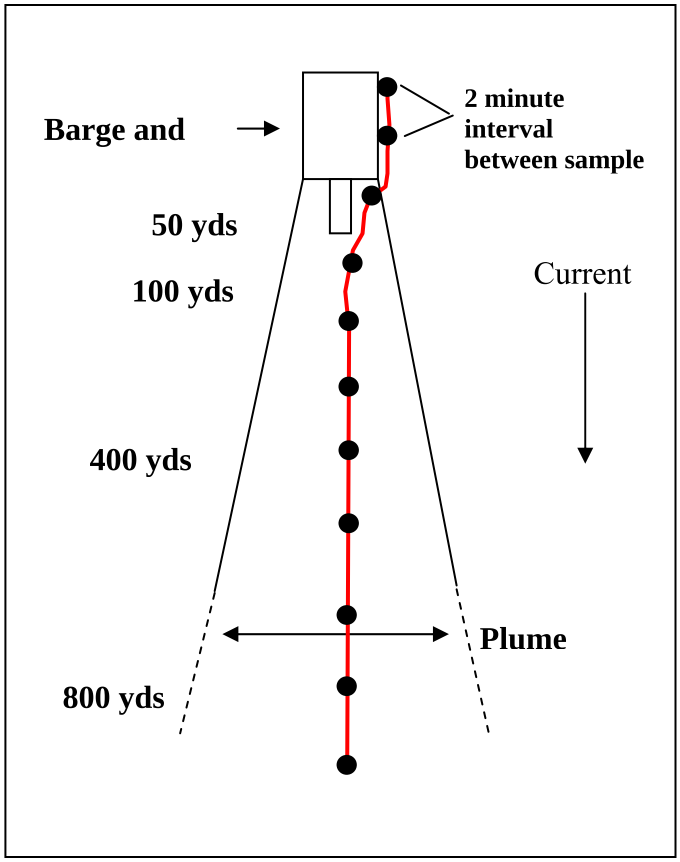
A



B

Figure 3-25

Results of sediment sampling showing the percentage distribution of substrate size with (A) and without (B) sand component MEC and Cheney (1990)



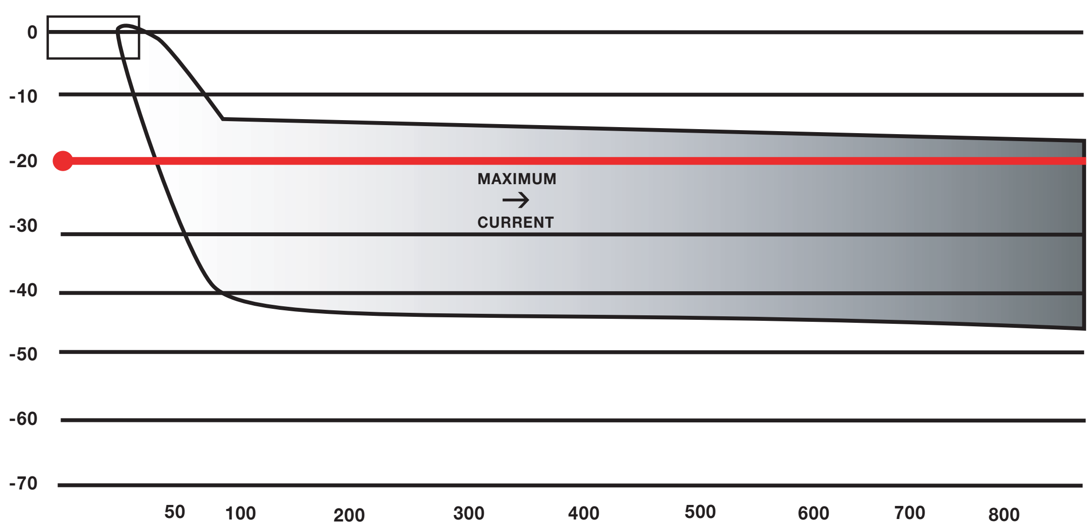


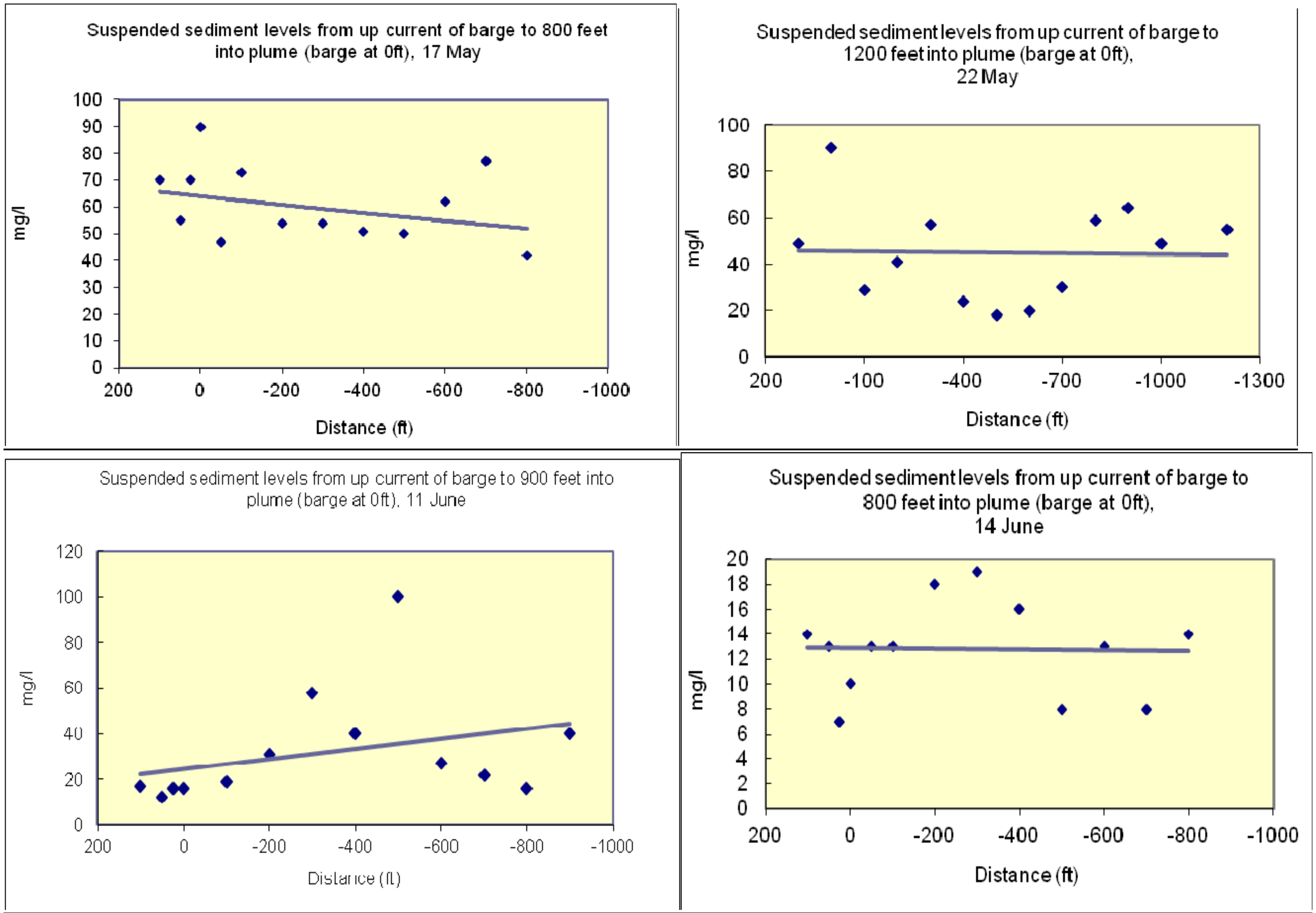
Figure 3-26

Longitudinal analysis of plume sediment concentration MEC and Cheney (1990)

Results of the longitudinal survey conducted by MEC and Cheney (1990) showed no clear pattern or trend in suspended sediment concentrations from the overflow discharge point to 800-1200 feet astern of the barge (Figure 3-27). In two instances (May 17 and May 22) there were increases in suspended sediment concentrations immediately astern of the barge, but in two instances (June 11 and June 14) these increases did not occur and there were actually declines of suspended sediment concentrations measured in the June 14 sampling. Samples taken farther astern of the barge yielded inconsistent results and are characterized by a high degree of variability. The high degree of variability in the MEC and Cheney (1990) results may be a result of the turbulence in the wake of the barge/tugboat. As noted above, the location of sampling sites within the overflow plume were selected based on aerial observations of the plume at the water surface and may or may not represent an accurate location for the plume at a depth of 20 feet. Only the plume measured on June 11 shows a trend upward in suspended sediment concentrations within the plume area, but note the recording of 100 mg/l at mid-point, which may be skewing the data. Table 3-4 gives a summary of the difference in suspended sediment concentrations between sample points moving downstream along the center line within the four plumes. These data on suspended sediment differences between sample points within the plume also show no clear pattern in suspended sediment concentration change from the overflow discharge point to 800-1200 foot astern of the sand mining barge.

A subsequent study was conducted by MEC in 1993 recording overflow plume sediment concentrations at two locations, Pt Knox and Presidio Shoals, on three occasions over three months. These plumes were measured at four points:

- Upstream of the plume representative of ambient conditions;
- 30 m downstream of the point of discharge, within the "head" of the plume;
- Mid-point in the plume; and
- Downstream location outside the plume representing ambient conditions.



<u>Figure 3-27</u>

Results of longitudinal analysis of plume suspended sediment concentration decline with distance from barge (MEC and Cheney 1990)

Table 3-4

Summary of difference in suspended sediment concentrations (mg/l) between sample points moving downstream through centerline of plume (MEC 1993)

Date: 5/17			**Date: 5/22**	
Tide: Ebb			**Tide: Ebb**	
Distance (m)	**TSS difference (mg/l)**		**Distance (m)**	**TSS difference (mg/l)**
0	25		0	41
-50	-18		-100	-20
-100	8		-200	-8
-200	-11		-300	8
-300	-11		-400	-25
-400	-14		-500	-31
-500	-15		-600	-29
-600	-3		-700	-19
-700	12		-800	10
-800	-23		-900	15
			-1000	0
			-1200	6
Date: 6/11			**Date: 6/14**	
Tide: Flood			**Tide: Ebb**	
Distance (m)	**TSS difference (mg/l)**		**Distance (m)**	**TSS difference (mg/l)**
0	1		0	-1
-100	4		-50	2
-200	16		-100	2
-300	43		-200	7
-400	25		-300	8
-500	85		-400	5
-600	12		-500	-3
-700	7		-600	2
-800	1		-700	-3
-900	25		-800	3

Note: Differences in suspended sediment concentrations were calculated as the difference between the ambient or background concentration measured upstream out of the influence of the overflow plume minus the concentration at each point along the centerline of the plume. Positive values of the TSS difference indicate that the suspended sediment concentration in the plume is less than the background concentration and negative differences indicate that the concentration in the plume is greater than background upstream and downstream (ambient) of the plume and within the overflow plume near the surface and near the bottom (vertical differences in suspended sediment contents

Table 3-5
Concentrations of total suspended solids (TSS) in mg/l (ppm) in receiving waters (MEC 1993)

		STATION	
Location	**Depth**	**Presidio Shoal**	**Point Knox Shoal**
Survey 1 (June 2)			
Upstream (Ambient)	Surface Bottom	29 29	12 12
30 m Downstream (Plume)	Surface Bottom	24 29	10 7
Midpoint (Plume)	Surface Bottom	9 72	6 10
Downstream (Ambient)	Surface Bottom	7 38	9 8
Survey 2 (June 30-July 1)			
Upstream (Ambient)	Surface Bottom	34 78	9 13
30 m Downstream (Plume)	Surface Bottom	17 28	12 19
Midpoint (Plume)	Surface Bottom	34 67	16 18
Downstream (Ambient)	Surface Bottom	38 70	8 14
Survey 3 (August 18-19)			
Upstream (Ambient)	Surface Bottom	8 36	8 12
30 m Downstream (Plume)	Surface Bottom	18 39	5 12
Midpoint (Plume)	Surface Bottom	12 38	12 14
Downstream (Ambient)	Surface Bottom	6 17	ND 16

EPA Method: 160.2
MRL (Method Reporting Limit): 5
ND = None Detected at or above the Method Reporting Limit

The three plumes studied, on June 2nd, June 30th – July 1st and August 19th-20th, were sampled both at the surface and at the bottom to give an understanding of sediment concentration differences at varying depths in the water column, both in and out of the overflow plume (Table 3-5). The MEC (1993) study shows a clear pattern of higher surface suspended sediment concentration levels in the area immediately astern of the tugboat/barge (Figure 3-27), a general trend towards decreasing surface suspended sediment concentration in the mid-point of the plume, and an increase in suspended sediment concentration immediately above the bottom at the mid-point of the plume. Results of the MEC (1993) study help explain the inconsistent results of the MEC and Cheney 1990 study, in which sediment sampling was conducted at only one depth. The single-depth study, characterized by inconsistent patterns of suspended sediment concentrations at a 20-foot depth (Figure 3-27), may be reflecting slightly varying settlement rates as a result of currents and turbulence and would not record the rapid deposition of sediments on the substrate shown in the MEC (1993) data. Again, however, there are instances in the 1993 data that are not entirely consistent with the general trend, suggesting that currents or turbulence contributed to the observed variability in results of those plume studies. As noted earlier, recent advances in suspended sediment monitoring and mapping technologies are available and can be used to provide more detailed information on overflow plume dynamics, sediment concentrations, areal extent, and dissipation following completion of a mining event. In the absence of more refined plume data, the environmental analysis presented in this report relies on the best data available and worst-case assumptions regarding plume exposure.

In the studies reviewed, suspended sediment levels increased immediately behind the mining craft, but the overflow plume suspended sediments were observed to settle and disperse rapidly down current. A visible plume of increased turbidity may persist beyond the point at which suspended sediment concentrations have returned to baseline levels. This “slick” (far field plume) may be composed of dissolved and colloidal clay particles, entrained aeration bubbles, and organic particles. The plume generated by discharge of fines from the barge appears to be relatively narrow in response to river and tidal currents. These data suggest that the overflow plume and the area of re-deposition of sediments may be limited to an area of approximately 500-1000 meters in length and 100 meters in width, depending to some extent on current velocity.

Results of the MEC (1990, 1993) studies of sand mining within Central Bay showed an incremental increase in suspended sediment concentrations within the overflow plume ranging from approximately 5 to 30 mg/l. The highest suspended sediment concentrations observed were approximately 100 mg/l. Similar data is not available for sand mining in Middle Ground Shoal or Suisun Bay.

The overflow plume resulting from sand mining is present for the duration of active mining and for a period of time after a mining event has been completed and the residual overflow plume dissipates. Results of field studies indicate that the overflow plume typically dissipates within 3-4 hours. For purposes of this assessment the analyses of biological effects was based on maximum worst-case conditions. The worst-case condition assumes that typical mining events occur over a 3-5.5 hour period with a 3-4 hour dissipation period. Therefore, the maximum expected duration of exposure to an overflow plume would be 6 to 9.5 hours.[1]

4.0 Background and Environmental Setting

4.1 Background

Hanson *et al.* (2004) conducted an assessment to evaluate the potential for commercial sand mining activity to adversely affect fishery resources (1) directly through mechanisms such as exposure to elevated suspended sediment concentrations and turbidity associated with the overflow plume, entrainment into the suction head, or physical disturbance of benthic organisms during mining or (2) indirectly as a result of such mechanisms as depletion of bottom sediments contributing to increased water depths and change in the composition of the substrate. Despite the long history of commercial sand mining activity within the Bay-Delta estuary, a relatively small body of San Francisco-specific scientific information has been developed specifically to evaluate the potential for adverse impacts on fishery resources and their habitat from sand mining. However, there exists a large body of scientific information based on results of numerous investigations conducted on sand mining, marine aggregate harvest, and channel maintenance dredging within other regions of the United States and internationally. Channel maintenance dredging that has occurred within the Bay-Delta estuary over a number of decades also has been the subject of environmental review and scientific investigation. The process, equipment and methods, and potential biological effects of channel maintenance dredging (the type that uses using suction dredges and hopper barges) are similar to sand mining, and the potential biological effects of this type of channel maintenance dredging are similar in many respects to those that may result from sand mining.

The technical assessment prepared by Hanson *et al.* (2004) synthesized information from the available scientific literature to identify specific issues and areas of concern regarding potential impacts of future sand mining activity on fishery resources and their habitat. The synthesis also serves as a basis to:

- Identify areas and issues where sufficient scientific information exists for use in evaluating and analyzing potential adverse impacts;
- Provide a synthesis of available information for use by resource and regulatory agencies and the marine aggregate industry to evaluate existing terms and conditions and authorizations for sand mining activity; and
- Develop environmental documentation and analyses for use in analyzing the potential for adverse impacts associated with the expansion of sand mining activity on the fish and macroinvertebrate communities within the estuary.

Specific objectives of the assessment included:

[1] Note: The exposure duration was established based on the observed distribution of reported mining durations and around the mean duration for actual mining events documented by Hanson *et al.* (2004).

- Research the potential impact of current and projected future sand mining activity on San Francisco Bay and Delta aquatic resources, including fish and macroinvertebrate populations, habitat quality and availability and related resources;
- Compile and analyze currently available information on the potential effects of sand mining on aquatic resources; and
- Identify additional monitoring, experimental field investigations, or analyses that may be needed or useful to assess current and/or future effects of sand mining on aquatic resources.

The scope of the 2004 investigation was primarily limited to a review and analysis of existing scientific information, available information from the peer-reviewed scientific literature, technical reports, and other sources of available information. As part of this study, extensive information was compiled for the first time on the specific locations and methods used in sand mining, in addition to field observations on sand mined from various locations within the estuary and geologic characteristics of potential sand sources. This investigation did not, however, include field studies or other scientific investigations, but rather was designed to provide a scientific foundation for characterizing and understanding specific sand mining methods, synthesizing of currently available information, identifying potential impacts to fishery resources and subtidal habitat within the estuary. Information on characteristics and effects of sand mining within the Bay-Delta developed by Hanson *et al.* (2004) provides much of the technical and scientific foundation used in this incidental take permit application.

In response to the need to develop new lease agreements for SLC mining areas within Suisun Bay and central Bay a draft EIR was prepared that analyzed potential environmental impacts associated with the proposed level of sand mining. The EIR analysis addressed a number of potential impacts including the potential for incidental take of listed fish species. The draft EIR identified the potential take of longfin smelt as a result of entrainment into the suction head while sand mining as a significant environmental impact. Technical analyses of potential impacts are currently being reconsidered based on comments received on the draft EIR. The analysis of potential incidental take of CESA listed fish presented below is based on the proposed locations and volumes of sand that could be harvested each year as outlined in the EIR project description. Results of this analysis and any associated regulatory restrictions or mitigation measures identified through these ITP application analyses will serve to reduce potential adverse impacts to listed fish to a level of less than significant within the revised EIR.

4.2 Environmental Setting

The San Francisco Central Bay, Suisun Bay, and the western Delta are habitat to a diverse assemblage of marine and estuarine organisms. The biological environment is a complex community of plants and animals inhabiting the saltwater, estuarine (brackish-water), and freshwater habitats within the Bay-Delta estuary. The Bay-Delta is a complex estuarine ecosystem, a transition zone between inland sources of freshwater and saltwater from the ocean. Along the salinity gradient extending from the Golden Gate upstream into the Delta, the species composition of the aquatic community changes dramatically, although the basic functional relationships among organisms (e.g., predator-prey, etc) remain similar throughout the system.

In the following sections, the major components of the Bay-Delta aquatic community are briefly discussed, including aquatic plants, phytoplankton, zooplankton, benthic macroinvertebrates, fish, shrimp, and crabs.

Fish species may utilize the estuary for any or all of their life history stages. They may have planktonic, epibenthic (demersal) and pelagic (open water) life histories. The majority of fish species inhabiting the estuary have planktonic larval stages; as plankton they feed on zooplankton and in some cases phytoplankton. Many of these species forage on plankton during the larval and early juvenile lifestages, and then as juveniles and adults become more selective predators and feed on large invertebrates and fish. Demersal fish such as sturgeon, flatfish, gobies, sculpin, and croaker, are planktivorous as larvae but begin to feed on epibenthic invertebrates as juveniles. Many smaller fish including smelt, silversides, northern anchovy and Pacific herring are planktivorous throughout their lives.

Some estuarine fish do not rely on plankton as a major food source at any lifestage. The live-bearing surfperch, for example, predominantly feed on epibenthic invertebrates, such as mollusks, crustaceans, and polychaetes throughout their life. Sharks and some skates and rays feed on benthic and epibenthic invertebrates by shoveling through the substrate, and also feed on fish and large invertebrates in the water column. Many freshwater fish prey primarily on benthic and drifting insect larvae and crustaceans, because zooplankton abundance is low in the swifter flowing freshwater sloughs and rivers.

The abundance and species composition of fish inhabiting the estuary vary in response to salinity gradients (Baxter *et al.* 1999). The most abundant taxa inhabiting the high-salinity areas of Central Bay include the schooling pelagic forage fish such as northern anchovy, Pacific herring, topsmelt, jacksmelt, and true smelt (whitebait, surf smelt, and night smelt). Other members of Central Bay fish community include flatfish, rockfish, surfperch, gobies, and sharks. In the low-salinity areas of Suisun Bay and the western Delta the most abundant taxa include striped bass, prickly sculpin, Pacific staghorn sculpin, threadfin shad, yellowfin goby, and starry flounder. Anadromous fish species such as Chinook salmon, steelhead, American shad, striped bass, and sturgeon utilize the entire estuarine system as a migration corridor and foraging habitat.

Factors affecting the abundance and geographic distribution of fish within the estuary include water velocities, substrate, salinity gradients, water temperature, and food availability. Many of the fish that inhabit the estuary reside in coastal marine waters, entering the estuary on a seasonal basis for foraging or reproduction. The seasonal cycles of fish abundance vary in response to migration patterns, reproductive cycles, foraging patterns, and environmental conditions occurring both within the estuary and coastal marine waters.

The fish community inhabiting the estuary is diverse and dynamic. Abundance of the species may fluctuate substantially within and among years (Baxter *et al.* 1999) in response to both population dynamics and environmental conditions. Life-history strategies and habitat requirements also vary substantially among species within the fish community. The following sections briefly describe the species composition of the fish community inhabiting various regions of the estuary where sand mining activity occurs. The primary source of information used to describe species composition and seasonal patterns in abundance and geographic distribution for various fish species was the extensive fishery monitoring program conducted by the California Department of Fish and Game (CDFG) (Baxter *et al.* 1999). Information is also presented below on habitat types that occur within the regions of the estuary, and habitat functions that affect species composition and habitat use. Information on habitat functions and analysis of the available fishery information will be used to assess the potential adverse impacts of sand mining activity on the estuarine fish community and their habitat.

Sand mining by Hanson Aggregates currently occurs and is proposed to occur in the future within Suisun Bay and Central San Francisco Bay (Section 3.2). Aquatic habitats within these mining areas extend from freshwater/brackish estuarine habitat in Suisun Bay to marine (saltwater) in Central Bay. General habitat characteristics are briefly described below.

Estuarine/Riverine

Estuarine/Riverine habitats encompass the entire portion of aquatic habitat in the Suisun Bay region. Sand mining occurs in an area of Suisun Bay, which has variable salinity levels that are dependent upon tide and freshwater flow input. This area supports several types of aquatic habitats, including sloughs and cuts, shallow channel and shoal areas, and the main river channels. Together, these habitats support a large and diverse aquatic community (Baxter *et al.* 1999), which includes several commercially and recreationally important species of fish and waterfowl.

Sloughs and Cuts

There are many sloughs and cuts within the Delta and Suisun Bay. Numerous man-made inlets have been excavated as harbors and marinas for commercial and recreational boats. Siltation and reduced water depth in many of these areas have adversely affected navigation and require periodic maintenance dredging. Stands of emergent vegetation, particularly cattails and tules, border many of these cuts and sloughs. Sand mining is not permitted to occur within Sloughs and Cuts.

Common invertebrates that inhabit sloughs and cuts include amphipods, bay shrimp, polychaetes (e.g., marine worms), and small bivalves (e.g., clams). Fish commonly found in the area include threadfin shad, striped bass, Sacramento splittail (*Pogonichthys macrolepidotus*), delta smelt, tule perch (*Hysterocarpus traskii*), Sacramento pikeminnow (*Pytchocheilus grandis*), white catfish (*Ameiurus catus*), yellowfin goby (*Acanthogobius flavimanus*), common carp (*Cyprinus carpio*), and Sacramento blackfish (*Orthodon microlepidotus*). In addition, the calm waters and shelter afforded by many of the cuts and sloughs attract early life stages of many fish species.

Shallow Channel and Shoal Areas

The area between the shore and deepwater ship channels is characterized by water depth less than 20 feet, a mud or mud-sand bottom, and reduced tidal and river currents. The smaller channels are characterized by water depths less than 6 feet with slit and mud substrate. Many areas adjacent to the shoals and channels are bordered by tules. Large numbers of small crustaceans, particularly *mysid* shrimp, bay shrimp, and amphipods inhabit the area and serve as an important food supply for young-of-the-year striped bass, juvenile Chinook salmon, green sturgeon, and other young fish. The shallow shoal area serves as a foraging and rearing area for juvenile striped bass and Chinook salmon in addition to a variety of other resident and migratory species. Other fish found inhabiting shallow channel and shoal areas include threespine stickleback, tule perch, Sacramento pikeminnow, gobies, inland silversides, largemouth bass, Sacramento splittail, delta smelt, carp, and white catfish. Sand mining is not permitted to occur within shallow channel and shoal areas.

Deep River Channels

The deep channel areas within Suisun Bay are characterized by depths of more than 20 feet and strong tidal and river currents, typically 30-40 cm/sec (1.1-1.5 ft/sec) or more. These channels extend to within approximately 150 feet of the shoreline. The deep water navigation channel in Suisun Bay extends through the Delta upstream to the Ports of Sacramento and Stockton. The river bottom in the navigation channels where water velocities are high is generally composed of sand. Finer silt and other sediments occur in areas adjacent to the main channel in areas where water velocities are reduced. Invertebrates, which inhabit the main channels, include bottom-dwelling polychaetes, amphipods, bivalves, and bay shrimp (bay shrimp include *Palaemon macrodactylus* and *Crangon* spp.). These two bay shrimp are harvested commercially as part of a local bait fishery. Sand mining is permitted in the deeper channel areas within Suisun Bay.

Open Water

The open waters of Suisun Bay and Central San Francisco Bay in the general vicinity of Alcatraz and Angel islands serve as migratory routes for several species of anadromous fish whose adults migrate to the freshwater reaches of the tributary rivers to spawn and whose juveniles migrate downstream to return to the ocean. These fish include steelhead, Chinook salmon, white and green sturgeon, and striped bass. In addition, the open water areas support populations of resident species including delta and longfin smelt. Sand mining is permitted in open water areas within Suisun Bay and Central San Francisco Bay

Aquatic Habitat Function and Use

Fish, shrimp, and crabs use habitats within the Bay-Delta estuary for a number of functions including, but not limited to:

- Adult and juvenile foraging;
- Spawning;
- Egg incubation and larval development;
- Juvenile nursery areas; and
- Migratory corridors.

Species use of aquatic habitats for any of these functions may vary in response to a suite of factors, and many of these factors may vary daily, seasonally, and annually. Primary factors affecting species composition, geographic distribution, and use of habitat within the estuary are varied but include:

- Salinity gradients;
- Variation in water temperature;
- Variation in water depth;
- Variation in water velocity;
- Substrate; and
- Availability of foraging and cover habitat (e.g., pilings, rock outcroppings, submerged aquatic vegetation, and riprap).

The Bay-Delta environment is dynamic, varying in response to factors such as the magnitude of freshwater inflow from the Sacramento and San Joaquin river systems and other tributaries, wind and tidally driven current patterns, seasonal variation in water temperatures, and a variety of other physical and biological processes. The habitat use and functions of areas within the Bay-Delta vary in response to these physical factors as well as to differences in life history characteristics and habitat requirements for the wide variety of fish and macroinvertebrates. In short, at any given site, the conditions which may affect habitat use by a species may vary and use of habitats at the site by a species, at any particular life history stage may vary. It may therefore be possible to generally predict whether a species is likely to utilize a site, and to generally predict what that use might be under a given set of circumstances. But in an ecosystem where conditions such as freshwater flow may change rapidly and somewhat unpredictably, it may be difficult to predict the distribution and abundance of aquatic species with precision. The CDFG and USFWS provide some general insight into how many aquatic species may respond to some of the varying habitat and environmental conditions.

Baxter *et al.* (1999) categorized the fish, shrimp, and crabs inhabiting the Bay-Delta estuary based on three different life history strategies, including the following:

- Species that reside in the estuary year-round;
- Species that seasonally inhabit the estuary, typically as foraging, spawning, or juvenile nursery habitat; and
- Anadromous or migratory species that move through the estuary during passage to or from freshwater and coastal marine habitats. The vast majority of anadromous fish species, including Chinook salmon, steelhead, striped bass, American shad, and sturgeon, migrate through the northern portion of San Francisco Bay (e.g., Central Bay, San Pablo Bay, and Suisun Bay) during their upstream and downstream migrations into the Sacramento and San Joaquin river systems. A substantially smaller proportion of anadromous fish populations migrate into the South Bay.

Among the seasonal inhabitants, many species use the Bay-Delta estuary as a spawning area and/or juvenile nursery habitat on either an obligatory or nonobligatory basis (Baxter *et al.* 1999). For obligate species, reproduction and rearing of juveniles occurs almost exclusively within a bay or estuarine environment**.** Non-obligate species may or may not inhabit the estuary during any given year. The occurrence of non-obligate species varies substantially from one year to the next within the Bay-Delta estuary. These species are typically found in the more marine areas of the estuary and are generally not abundant upstream within Suisun Bay or the marsh. Opportunistic species use the Bay-Delta estuary as an extension of their habitat based on the suitability of environmental conditions. Many species that inhabit coastal marine waters, such as northern anchovy, may opportunistically move into the estuary when conditions are favorable for reproduction, juvenile rearing, and foraging. Baxter *et al.* (1999) notes that several freshwater or low-saline species, such as white catfish *(Ictalurus catus)* and threadfin shad *(Dorosoma petenese),* may opportunistically use habitats within Suisun Bay, San Pablo Bay or Central Bay during periods of high freshwater outflow from the river systems that result in lower salinity and more suitable habitat conditions for these species further downstream within the system.

Anadromous species such as Chinook salmon and steelhead spawn within freshwater portions of rivers and creeks tributary to the Bay-Delta estuary. Juvenile rearing habitat for these species is also primarily within the freshwater or low-saline portions of the system. Juvenile Chinook salmon and steelhead emigrate from freshwater habitat and move downstream through the estuary, which is used primarily as a migratory corridor and short-term foraging habitat, as they move into coastal waters for rearing. Adult Chinook salmon and steelhead subsequently migrate back upstream to spawn, again using the Bay–Delta estuary as a migratory corridor. Delta smelt inhabit the freshwater and brackish waters of the Delta and Suisun Bay throughout their lifecycles. Longfin smelt spawn in the freshwater reach of the lower Sacramento River but juveniles and adults inhabit more saline areas of western Suisun Bay, San Pablo Bay, San Francisco Bay, and near-shore coastal waters.

4.3 Life History and Occurrence of Listed Fish Species

Winter-run Chinook salmon

Status

Winter-run Chinook salmon are listed as an endangered species under both the CESA and FESA.

Winter-run Chinook salmon historically migrated into the upper tributaries of the Sacramento River for spawning and juvenile rearing. With the construction of Shasta and Keswick dams winter-run salmon no longer had access to historic spawning habitat within the upper watersheds. As a result of migration blockage spawning and juvenile rearing habitat for winter-run Chinook is limited to the main stem Sacramento River downstream of Keswick Dam. During the mid-1960s adult winter-run Chinook salmon returns to the Sacramento River were relatively high (approximately 80,000 returning adults). However, the population declined substantially during the 1970s and 1980s. The population decline continued until 1991 when the adult winter-run Chinook salmon population returning to the Sacramento River was estimated to be less than 200 fish. As a result of the substantial decline in abundance the species was listed as endangered under both the CESA and FESA. During the mid- and late 1990s the numbers of adult winter-run salmon returning to the Sacramento River gradually increased. Approximately 8200 adult winter-run salmon returned to the river to spawn in 2001. Approximately 7,400 adult winter-run Chinook salmon returned in 2002, 8,200 returned in 2003, 7,900 returned in 2004, 15,900 returned in 2005, 17,300 returned in 2006, 2,500 returned in 2007, 2,800 returned in 2008, and 4,700 returned in 2009. As with other Chinook salmon stocks, CDFG and NMFS are continuing to evaluate the status of the winter-run Chinook salmon population and the effectiveness of various management actions implemented within the Sacramento River, Delta, and ocean to provide improved protection and reduced mortality for winter-run salmon, in addition to providing enhanced habitat quality and availability for spawning in and juvenile rearing. NMFS has prepared a draft recovery plan for winter-run Chinook salmon.

Life History

Winter-run Chinook salmon are an anadromous species spending 1-3 years within the ocean before migrating upstream into the Sacramento River to spawn. The majority of adult winter-run Chinook salmon returning to spawn are generally three-year-olds; however, the adult population also includes two-year-old and four-year-old Chinook salmon. Adult winter-run salmon migrate upstream through San Francisco Bay, Suisun Bay, and the Delta during the winter and early spring months with peak migration occurring during March (Moyle, 2002). Adult winter-run Chinook salmon migrate upstream within the Sacramento River with the majority of adults spawning in the reach upstream of Red Bluff. Winter-run Chinook salmon spawn within the mainstem of the Sacramento River in areas where gravel substrate, water temperatures, and water velocities are suitable. Spawning occurs during the spring and summer (mid-April through August; Moyle, 2002). Egg incubation continues through the fall months. Juvenile winter-run Chinook salmon rear within the Sacramento River throughout the year feeding primarily on aquatic insects. Juvenile winter-run salmon (smolts) migrate downstream through the lower reaches of the Sacramento River, Delta, Suisun Bay, and San Francisco Bay during the winter and early spring (December through May) as they migrate from the freshwater spawning and juvenile rearing areas into the coastal marine waters of the Pacific Ocean. The Sacramento River mainstem is the primary upstream and downstream migration corridor for winter-run Chinook salmon. The migration timing of juvenile winter-run Chinook salmon varies within and among years in response to a variety of factors including increases in river flow and turbidity resulting from winter storms.

A variety of environmental and biological factors have been identified that affect the abundance, mortality, and population dynamics of winter-run Chinook salmon. One of the primary factors that has affected population abundance of winter-run Chinook salmon has been the loss of access to historic spawning and juvenile rearing habitat within the upper reaches of the Sacramento River and its tributaries as a result of the migration barrier caused by Shasta and Keswick dams. Operation of the Red Bluff Diversion Dam, which impeded adult upstream migration and increased vulnerability of juvenile winter-run Chinook salmon to predation mortality in the past, has been identified as a factor affecting mortality within the river. In recent years, changes to Red Bluff Diversion Dam gate operations and construction of a new water diversion and fish screen have been made to provide improved access for upstream and downstream migrating winter-run Chinook salmon. Water temperatures within the main stem Sacramento River have also been identified as a factor affecting incubating eggs, holding adults, and growth and survival of juvenile winter-run Chinook salmon rearing in the upper Sacramento River. Modifications to Shasta

Reservoir storage and operations and water temperature management have been implemented in recent years to improve water temperature conditions within the upper reaches of the Sacramento River. Juvenile winter-run Chinook salmon are also vulnerable to entrainment at a large number of unscreened water diversions located along the Sacramento River and within the Delta in addition to entrainment and salvage mortality at the SWP and CVP export facilities. Changes in habitat quality and availability for spawning and juvenile rearing, exposure to contaminants and acid mine drainage, predation mortality by Sacramento pikeminnow, striped bass, and other predators, and competition and interactions with hatchery-produced Chinook salmon have all been identified as factors affecting winter-run Chinook salmon abundance. In addition, subadult and adult winter-run Chinook salmon are vulnerable to recreational and commercial fishing, ocean survival is affected by climatic and oceanographic conditions, and adults are vulnerable to predation mortality by marine mammals.

In recent years a number of changes have been made to improve the survival and habitat conditions for winter-run Chinook salmon. Modifications have been made to reservoir operations for instream flow and temperature management, modifications been made to Red Bluff diversion gate operations, and several large previously unscreened water diversions have been equipped with positive barrier fish screens. Changes to ocean salmon fishing regulations have also been made to improve the survival of adult winter-run Chinook salmon. Modifications to SWP and CVP export operations have also been made to improve the survival of juvenile winter-run Chinook salmon. These changes in management actions, in combination with favorable hydrologic and oceanographic conditions in recent years, are thought to have contributed to the trend of increasing abundance of adult winter-run Chinook salmon returning to the upper Sacramento River to spawn since the mid-1990s.

Presence in the Action Area and Vicinity

The occurrence of adult winter-run Chinook salmon within San Francisco and Suisun bays would be limited to the winter and early spring period of adult upstream migration. The majority of adult winter run salmon are thought to migrate upstream through the Bay-Delta during the period from about December to March or early April. Winter-run salmon do not spawn in areas where sand mining is permitted to occur. Juvenile winter-run salmon migrate through the Delta and bays during the winter and early spring months.

Central Valley Spring-run Chinook Salmon

Status

Spring-run Chinook salmon are listed as a threatened species under both the CESA and FESA.

Spring-run Chinook salmon were historically widely distributed and abundant within the Sacramento and San Joaquin river systems (Yoshiyama *et al.* 1998). Spring-run Chinook salmon historically migrated upstream into the upper reaches of the mainstem rivers and tributaries for spawning and juvenile rearing. Construction of major dams and reservoirs on these river systems eliminated access to the upper reaches for spawning and juvenile rearing and completely eliminated the spring-run salmon population from the San Joaquin River system. Spring-run Chinook salmon abundance has declined substantially and the geographic distribution of the species within the Central Valley has also declined substantially. Spring-run spawning and juvenile rearing currently occurs on a consistent basis within only a small fraction of their previous geographic distribution, including populations inhabiting Deer, Mill, and Butte creeks, the mainstem Sacramento River, several other local tributaries on and intermittent basis, and the lower Feather River. Recent genetics studies have shown that spring-run like Chinook salmon returning to lower Feather River are genetically similar to fall-run Chinook salmon. Hybridization between spring-run and fall-run Chinook salmon, particularly on the Feather River where both stocks are produced within the Feather River hatchery, is a factor affecting the status of the spring-run salmon population. NMFS is in the process of developing a recovery plan for Central Valley spring-run Chinook salmon.

Life History

Spring-run Chinook salmon are an anadromous species, spawning in freshwater and spending a portion of their life cycle within the Pacific Ocean. Adult spring-run Chinook salmon migrate upstream into the Sacramento River system during the spring months, but are sexually immature. Adult spring-run Chinook salmon hold in deep cold pools within the rivers and tributaries over the summer months prior to spawning. Spawning occurs during the late summer and early fall (late August through October) in areas characterized by suitable spawning gravels, water temperatures, and water velocities. Eggs incubate within the gravel nests (redds) emerging as fry during the late fall and winter. A portion of fry appear to migrate downstream soon after emerging where they rear within the lower river channels, and potentially within the Delta estuary, during winter and spring months. After emergence a portion of the spring-run Chinook salmon fry remain as residents in the creeks and rear for a period of approximately one year. The juvenile spring-run Chinook salmon that remain in the creeks migrate downstream as yearlings primarily during the late fall, winter and early spring with a peak yearling migration occurring in November (Hill and Weber 1999). The downstream migration of both spring-run Chinook salmon fry and yearlings during the late fall and winter typically coincides with increased flow and turbidity associated with winter stormwater runoff.

A variety of environmental and biological factors have been identified that affect the abundance, mortality, and population dynamics of spring-run Chinook salmon. One of the primary factors that has affected population abundance of spring-run Chinook salmon has been the loss of access to historic spawning and juvenile rearing habitat within the upper reaches of the Sacramento River and its tributaries and San Joaquin River as a result of the migration barriers caused by construction of major dams and reservoirs. Operation of the Red Bluff Diversion Dam, which impeded adult upstream migration and increased the vulnerability of juvenile spring-run Chinook salmon to predation mortality in the past, has been identified as a factor affecting mortality within the river. Water temperatures within the rivers and creeks have also been identified as a factor affecting incubating eggs, holding adults, and growth and survival of juvenile spring-run Chinook salmon. Juvenile spring-run Chinook salmon are also vulnerable to entrainment at a large number of unscreened water diversions located along the Sacramento River and within the

Delta in addition to entrainment and salvage mortality at the SWP and CVP export facilities. Changes in habitat quality and availability for spawning and juvenile rearing, exposure to contaminants, predation mortality by Sacramento pikeminnow, striped bass, and other predators, and competition and interactions with hatchery-produced Chinook salmon have all been identified as factors affecting spring-run Chinook salmon abundance. In addition, subadult and adult spring-run Chinook salmon are vulnerable to recreational and commercial fishing, ocean survival is affected by climatic and oceanographic conditions, and adults are vulnerable to predation mortality by marine mammals.

In recent years a number of changes have been made to improve the survival and habitat conditions for spring-run Chinook salmon. Several large previously unscreened water diversions have been equipped with positive barrier fish screens. Changes to ocean salmon fishing regulations have been made to improve the survival of adult spring-run Chinook salmon. Modifications to SWP and CVP export operations have also been made to improve the survival of juvenile spring-run Chinook salmon. Improvements in fish passage facilities have also been made to improve migration and access to Butte Creek. These changes and management actions, in combination with favorable hydrologic and oceanographic conditions in recent years, are thought to have contributed to the trend of increasing abundance of adult spring-run Chinook salmon returning to spawn in Butte Creek and other habitats within the upper Sacramento River system in recent years.

Presence in the Action Area and Vicinity

The occurrence of adult spring-run Chinook salmon within the Bay-Delta would be limited to the late winter and spring period (primarily March-May) of adult upstream migration. Juvenile spring-run Chinook salmon may migrate from the Sacramento River, including its tributaries, into the Bay-Delta during their downstream migration and also use the Bay-Delta as a foraging area and migration pathway during the winter and early spring migration period. The occurrence of juvenile spring-run Chinook salmon in Suisun and Central Bay would be expected during late fall through spring (October-June). Spring-run salmon do not spawn in areas where sand mining is permitted to occur.

Delta Smelt

Status

Delta smelt are listed as an endangered species under CESA and a threatened species under FESA. On December 19, 1994, USFWS designated critical habitat for delta smelt within the Sacramento-San Joaquin River system (USFWS, 1994). The designation of delta smelt critical habitat extends throughout the Delta and encompasses the areas of Suisun Bay where sand mining is allowed.

Life History

Delta smelt are endemic to the Sacramento–San Joaquin Delta estuary and inhabit the freshwater portions of the Delta, lower reaches of the Sacramento and San Joaquin rivers, and the low-salinity portions of Suisun Bay. They occur in the Delta primarily below Mossdale on the San Joaquin River and Isleton on the Sacramento River, although they may occur as far upstream as the Feather River confluence (USFWS 2008). Delta smelt used to be one of the most common pelagic fish (i.e., living in open water away from the bottom) in the upper Sacramento-San Joaquin Estuary. Currently however, the delta smelt population has been reduced due to several factors which include, but are not limited to:

- Changes in the seasonal timing and magnitude of freshwater inflow to the Delta and outflow from the Delta;
- Entrainment of larval, juvenile, and adult delta smelt into a large number of unscreened water diversions (primary agricultural) located throughout the Delta (Center for Biological Diversity *et al.* 2006);
- Entrainment and salvage mortality at the CVP and SWP water export facilities;
- Predation by striped bass, largemouth bass, and a number of other fish species inhabiting the estuary has also been identified as a source of mortality for delta smelt;
- Exposure to toxic substances resulting in direct or indirect affects;
- Variation in the quality and availability of low-salinity habitat within the Delta and Suisun Bay, in response to seasonal and interannual variability in hydrologic conditions within the Delta; and
- Reduced food (prey) availability thought to be the result of reduced primary production due, in part, to a reduction in seasonally-inundated wetlands, competition for food resources with non-native fish and macroinvertebrates (e.g., filter feeding by the non-native Asian overbite clam *Corbula*), and competition among native and non-native zooplankton species.

Delta smelt are a relatively small (2 to 3 inches long) species with an annual lifecycle, although some individuals may live two years. Prior to spawning, adult delta smelt may migrate upstream into the lower reaches of the Sacramento and San Joaquin rivers, and lower eastside streams, where spawning occurs from approximately February through June, with the greatest spawning activity occurring in April and May in the Sacramento River basin. Delta smelt also spawn in Suisun Marsh, Suisun Bay, and the lower Napa River. Females deposit adhesive eggs on substrates such as gravel, rock, and submerged vegetation. Eggs hatch, releasing planktonic larvae which are passively dispersed downstream by river flow. Larval and juvenile delta smelt rear within the estuarine portions of Suisun Bay and the Delta for a period of approximately 6 to 9 months before beginning their upstream spawning movement.

Delta smelt were once one of the most common pelagic fish in the upper Sacramento/San Joaquin Estuary. Delta smelt have experienced a general decline in population abundance over the past several decades leading to their listing under FESA and CESA. The causes of decline are multiple and synergistic, including reduction in flows; entrainment losses to water diversions; high outflows; changes in food organisms; toxic substances; disease, competition, and predation; and loss of genetic integrity (SWRCB, 1999, Baxter *et al.* 2008). The Interagency Ecological Program (IEP) continues to evaluate the available scientific information regarding the status of delta smelt and the performance of various management actions designed to improve protection, reduce mortality, and enhances habitat quality and availability for delta smelt within the estuary.

Presence in the Action Area and Vicinity

Delta smelt larvae, juveniles, and adults are all know to occur seasonally within Suisun Bay. Delta smelt have adhesive eggs that are attached to various substrates during incubation and hence are not vulnerable to entrainment into water diversions. The later life stages of delta smelt are pelagic, living in the open waters of Suisun Bay and the Delta. Delta smelt larvae, which are planktonic and passively drift with water currents, are present in the Suisun Bay during the late spring and early summer (e.g., late March through June). The juvenile delta smelt typically inhabit cooler areas of the estuary, such as Suisun Bay, during the summer months when water temperatures in the central and southern Delta are generally unsuitable for delta smelt. Pre-spawning adult delta smelt migrate upstream into the central Delta and lower Sacramento River during the fall and winter months when water temperatures have seasonally declined to a suitable range for adult smelt. Later during the winter the adult delta smelt typically migrate further upstream, primarily in the lower Sacramento River in the vicinity of Cache Slough, the Sacramento Deep Water Ship Channel, and the mainstem Sacramento River upstream of Rio Vista where they spawn in the late winter and spring months. The majority of delta smelt die after spawning, although a small number of two year old delta smelt are known to inhabit the estuary.

Longfin Smelt

Status

*L*ongfin smelt have been listed as a threatened species under CESA. USFWS is currently evaluating a petition to list longfin smelt under FESA, however no listing decision has been made.

Lift History

The longfin smelt is a small, slender-bodied fish that measures about 3 inches in length as an adult. The species generally lives for 2 years although some individuals may live to spawn at age 3. Populations of longfin smelt occur along the Pacific Coast of North America, from Hinchinbrook Island, Prince William Sound, Alaska to the San Francisco estuary (Lee *et al.* 1983). Although individual longfin smelt have been caught in Monterey Bay (Moyle 2002), there is no evidence of a spawning population south of the Golden Gate. The Bay-Delta population is the southernmost, and also the largest, spawning population in California. Small and perhaps ephemeral longfin smelt spawning populations have been documented or suspected to exist in Humboldt Bay, the Eel River estuary, the Klamath River estuary, and the Russian River (Moyle 2002, Pinnix *et al.* 2004).

Longfin smelt have a life history that is similar to the delta smelt. Pre-spawning adult longfin smelt migrate upstream into the lower reaches of the rivers during the late fall and winter.

Longfin smelt have adhesive eggs which are deposited on sand, gravel, rocks, submerged aquatic vegetation, and other hard substrates during spawning. Spawning occurs during the late winter and early spring. Longfin smelt have planktonic larvae that are transported downstream into the western Delta and Suisun Bay during the late winter and spring where juveniles rear. Longfin smelt have a two year lifecycle. Longfin smelt reside as juveniles and pre-spawning adults in more saline habitat within San Pablo and San Francisco Bays during a majority of their life. Movement patterns based on catches in CDFG fishery sampling suggest that longfin smelt actively avoid water temperatures greater than 22° C (72° F). These conditions occur within the Delta during the summer and early fall, when longfin smelt inhabit more marine waters further downstream in the bays and are not present within the Delta.

Juvenile and subadult longfin smelt predominantly inhabit brackish water areas of the San Francisco Bay estuary (San Pablo and San Francisco Bays) and nearshore coastal marine waters outside of the Golden Gate (Baxter *et al.* 1999, Rosenfield and Baxter 2007). Adult longfin smelt return to spawn in the freshwater regions of the lower Sacramento River, near or downstream of Rio Vista, and the lower San Joaquin River downstream of Medford Island. Historically, spawning longfin smelt were also common in Suisun Marsh; in recent years, very few adult, spawning-age longfin smelt have been collected in Suisun Marsh (UCD, unpubl. data). Collection of small longfin smelt larvae in the 20 mm surveys suggests spawning also occurs in the Napa River. During January and February pre-spawning adult longfin smelt are migrating upstream and staging in the lower reaches of the Sacramento and San Joaquin Rivers. During the winter months the female continues to develop eggs in preparation for spawning. Spawning begins to take place in mid- to late February. The actual seasonal timing of spawning appears to vary among years in response to factors such as seasonal water temperatures. Water temperature is also expected to have an influence on the duration of egg incubation and subsequent timing of hatching and larval growth.

Upon hatching from adhesive eggs (primarily February-April), buoyant longfin smelt larvae rise toward the surface and are transported downstream by surface currents resulting from both river flow and tidal mixing of fresh and marine waters. Flow rates are positively related to downstream transport of the planktonic larvae (Hieb and Baxter 1993, Baxter *et al.* 1999, Dege and Brown 2004). Larval longfin smelt remain in the upper part of the water column until they reach 10-15 mm, after which they move to the middle and bottom parts of the water column (Hieb and Baxter 1993, Bennett *et al.* 2002, Moyle 2002). Based on results of CDFG larval smelt and 20mm fishery sampling larval longfin smelt less than 10-15 mm in length inhabit the Delta, lower river reaches, and Suisun Bay during the period from approximately late February through March depending on factors such as seasonal water temperatures that affect the timing of spawning and rate of egg incubation and larval growth. Based on the results of larval smelt and 20mm surveys, which start in early March each year, it is expected that larval smelt are absent or rare during January and that eggs begin to hatch in late February with early larvae (approximately 5-10 mm in length) are present in greater numbers starting in March and continuing through the spring months.

Larval and early juvenile longfin smelt typically inhabit areas within the lower Sacramento River (e.g., Cache Slough region), the central and western Delta, and Suisun Bay. Larval longfin smelt are typically collected in the region of the estuary extending from the western Delta into San

Pablo Bay, but their distribution shifts upstream or downstream in response to Delta outflow (Baxter *et al.* 1999; Dege and Brown 2004). In years when winter-spring Delta outflow is low, fewer larvae are transported to San Pablo Bay. After absorbing the yolk-sac the larvae begin to forage on small zooplankton. Based on results of 20 mm fishery surveys the larval longfin smelt appear to be distributed within the lower Sacramento River (including Cache Slough), the western Delta, Suisun Bay, and in higher flow years San Pablo Bay. In years when winter-spring Delta outflow is high, few larvae remain in the western Delta, but are abundant in San Pablo Bay and may reach northern San Francisco Bay (Baxter *et al.* 1999; Dege and Brown 2004). Although the early larval lifestage of longfin smelt is thought to successfully forage and rear over a range of habitats within the estuary, correlations between Delta outflow during the late winter and spring (February-May) when longfin smelt larvae are transported and dispersed into downstream rearing areas have shown higher population abundance in the fall during those years when winter and spring outflow was higher. Although the causal mechanism underlying the correlation between winter-spring Delta outflow and longfin smelt abundance is unknown, it has been hypothesized that higher flows contribute to more rapid downstream transport of planktonic larvae (moving larvae into areas of the estuary where zooplankton densities are greater and therefore better rearing conditions) as well as transporting more phytoplankton and nutrients downstream into the low and moderate salinity regions of the estuary in Suisun and San Pablo Bays. During the period starting in approximately early March longfin smelt larvae are distributed within open water estuarine habitats. The initial distribution of young juveniles correlates positively with that of larvae, both vertically within the water column and geographically.

During their first year, juvenile longfin smelt disperse downstream into brackish and marine regions of the estuary, eventually inhabiting Suisun, San Pablo, and Central and South San Francisco bays and moving into nearshore coastal marine habitats in most years (Baxter *et al.* 1999; Dege and Brown 2004; Hieb and Baxter 1993; Moyle 2002). Late larval and juvenile longfin smelt migrate downstream from the Suisun Bay rearing habitat into the more saline regions of the estuary in late spring. Collections of larval and juvenile longfin smelt less than 50 mm fork length (FL) within the Bay-Delta showed that 90% of the individuals inhabited areas with salinities ≤18 parts per thousand (ppt; Baxter *et al.* 1999). Salinities of 18 ppt are typical of conditions occurring in San Pablo Bay in most years. Salinity in Suisun Bay during the spring in most years is generally within the range from 1 to 5 ppt. Healthy individuals 20 mm FL and larger have been captured in salinities of 32 ppt (marine water) and along the open coast, demonstrating the high salinity tolerance of longfin smelt. The affect of turbidity (i.e., low water clarity and visibility) on longfin smelt geographic distribution or habitat preferences is unknown. However, longfin smelt larvae hatch coincident with annual peak Delta outflows, which typically coincide with high turbidity. Also, larval and older lifestages of longfin smelt possess a well developed olfactory system, which suggests its use in food acquisition (Scott Foott, pers. comm.).

A variety of factors are thought to influence the abundance and year class strength of longfin smelt. These factors include seasonal hydrologic conditions (Delta outflow) during the late winter and spring, colonization of Suisun Bay and the western Delta by the Asian overbite clam (*Corbula amurensis*) in the mid-1980s, exposure to toxics, predation and competition with non-native species, and sources of direct mortality such as entrainment into the many (estimated to be over

1,800) unscreened water diversions located within the Delta. One of the causal mechanisms potentially contributing to the decline in longfin smelt and other pelagic species inhabiting the estuary is reduced food supplies (i.e., reductions in the abundance of suitable zooplankton), which are caused by foraging of zooplankton by non-native species, such as the overbite clam, and reductions in phytoplankton abundance due to increased concentrations of ammonia or other factors in the Delta. Longfin smelt abundance has also been potentially impacted by changes in coastal upwelling (i.e., cold ocean water with high nutrients mixing with surface waters) and production of phytoplankton and zooplankton in coastal marine waters. Statistical analyses (State Contractors and SLDMWA 2008) show strong and statistically significant correlations between indices of longfin smelt abundance, based on results of the fall midwater trawl surveys, and (a) the magnitude of freshwater flowing into and out of the Delta during the late winter and spring which, in turn, influences the location of the low salinity region within the estuary (referred to as the X2 location in km upstream from the Golden Gate Bridge), (b) winter-spring (February-April) air temperature at Davis, and (c) ammonia concentrations observed in the Sacramento River at Hood/Greens Landing during March and September of the previous year. It is also notable that increased Delta outflow is not always a strong indicator of longfin smelt abundance. As just one example, although Delta outflow conditions improved (i.e., outflow increased) in 2003, longfin smelt abundance did not increase (as would be expected based on the outflow-abundance relationship). This finding suggests that an additional factor or factors besides freshwater outflow, such as air temperature or ammonia concentration, may now be limiting the Bay-Delta population abundance of longfin.

Results of fishery sampling conducted by CDFG, such as the fall midwater trawl surveys show that longfin smelt indices of abundance are typically greater than the corresponding indices for delta smelt abundance. Both delta smelt and longfin smelt are considered to be "pelagic" species – meaning they inhabit the open water areas of the Bay-Delta estuary where they forage on zooplankton throughout their juvenile and adult life stages. Results of fishery surveys have documented a substantial decline in the abundance of a variety of pelagic species, including both longfin and delta smelt, since 2000, which circumstance is referred to as the pelagic organism decline (POD). The causes of decline are likely multiple and synergistic (Armor *et al.* 2005), including:

- Reduction in Delta outflows during the late winter and spring;
- Entrainment losses to water diversions;
- Reduced spawning and rearing habitat;
- Reduced food (prey) availability thought to be the result of reduced primary production due, in part, to a reduction in seasonally-inundated wetlands, competition for food resources with non-native fish and macroinvertebrates (e.g., filter feeding by the non-native Asian overbite clam *Corbula*), and competition among native and non-native zooplankton species;
- Climatic variation;
- Exposure to toxic substances, however there is no known direct link between chemical concentration and larval mortality; and
- Predation, and introduced species.

A number of investigations are currently underway to provide information on the factors that contribute to the POD (Armor *et al.* 2005).

Presence in the Action Area and Vicinity

Larval and early juvenile longfin smelt are present in Suisun Bay during the late winter and spring. Larval and early juvenile longfin smelt do not inhabit Central San Francisco Bay. Juvenile and adult longfin smelt inhabit Suisun Bay and Central San Francisco Bay year-round. Longfin smelt spawn adhesive eggs in shallow areas adjacent to the lower Sacramento River and the San Joaquin River during the late winter and early spring and may also spawn in shallow areas adjacent to Suisun Bay.

5.0 Impact Analysis/Incidental Take Assessment

5.1 Introduction

Subtidal habitats within the San Francisco Bay-Delta estuary serve important functions for fish species protected under the California Endangered Species Act (CESA), which use subtidal sand habitat in Central Bay and Suisun Bay for foraging, larval development (longfin and delta smelt), juvenile nursery areas, and as migratory corridors. Spring-run and winter-run Chinook salmon do not use Suisun Bay or central San Francisco Bay as spawning or for egg incubation and therefore there is no potential for take of eggs. Delta smelt and longfin smelt may spawn in shallow habitat adjacent to Suisun Bay. Factors affecting the habitat functions of these areas are varied but include salinity gradients, temperature gradients, water depth, substrate, and availability of foraging and cover habitat (e.g., pilings, submerged aquatic vegetation, riprap, etc.). The functional use of these habitats varies among species and lifestages.

Sand mining has the potential to alter or modify subtidal habitats by changing water depth, substrate characteristics, water currents, or water quality (including suspended sediment concentrations (TSS) resulting in temporary behavioral avoidance by sensitive species of previously available habitat. These physical changes could affect the quality and availability of suitable habitat and habitat functions for protected fish species. Information on species habitat requirements, changes associated with sand mining activity, habitat types and functions in the sand mining areas, and the biological response of various species can be used to assess potential effects of sand mining on protected fish species in the estuary. A number of investigations have been performed throughout the world on the environmental effects of dredging and sand mining activities, and specifically on habitat quality and function for fish populations (see Hanson *et al.* 2004 for review). Results of these investigations provide a foundation for use in assessing potential effects of sand mining on subtidal habitats and the protected fish species inhabiting the Bay-Delta estuary.

This incidental take permit application reviews information from investigations involving dredging and sand mining in estuarine environments, together with information on the species composition; and seasonal occurrence, lifestage, habitat usage, and habitat functions of protected fish species including winter-run and spring-run Chinook salmon, delta smelt, and longfin smelt. Based on this information, various factors associated with sand mining that might affect these protected fish species in the area of the estuary where sand mining occurs were identified and then analyzed. Based on information available from the scientific literature, in combination with information on the methods and processes involved in sand mining (Section 3), two conceptual models (Figures 5-1 and 5-2) were developed regarding the potential adverse effects of sand mining on fish, and their habitat, within the Bay-Delta estuary. The conceptual models were used as a framework for identifying various factors associated with sand mining activity that could adversely affect habitat conditions and protected fish within various regions of Suisun Bay and Central San Francisco Bay where sand mining by Hanson Aggregates currently occurs and where sand mining is proposed to occur in the future.

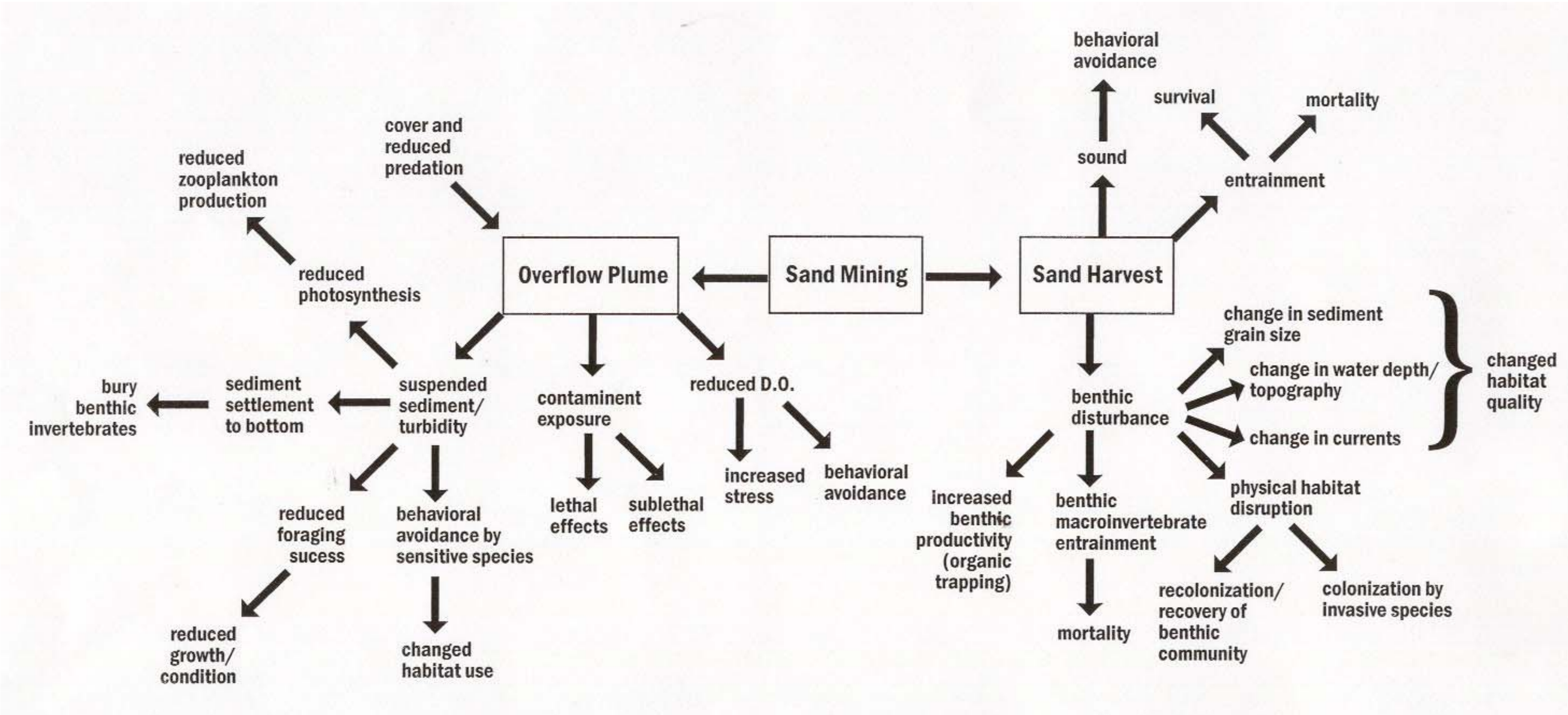


Figure 5-1. Conceptual model of the potential effects of sand mining on fish and macroinvertebrates.

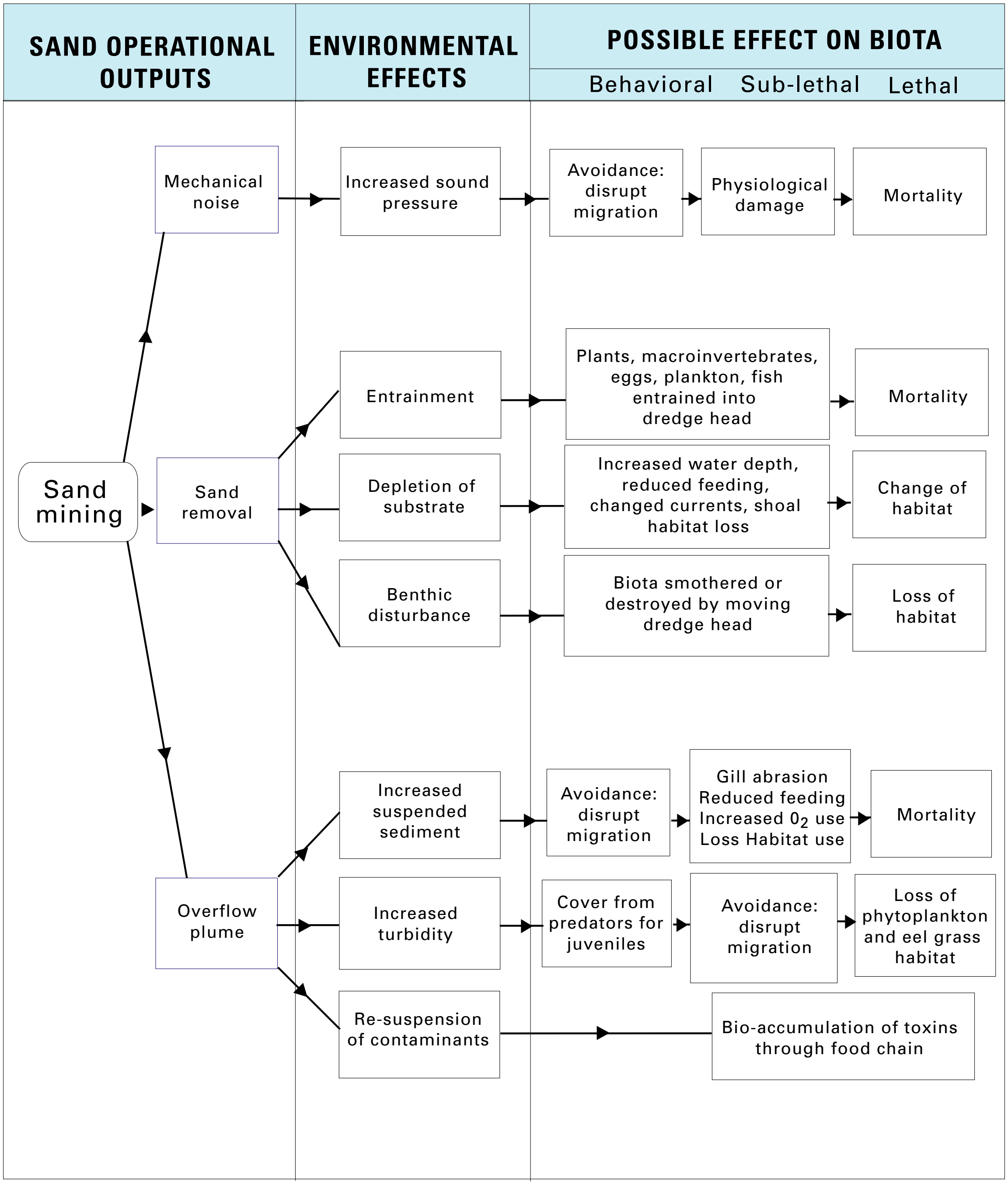


Figure 5-2. Possible effects of sand mining on fish and macroinvertebrates and their subtidal habitats.

Factors considered were:

- Spread of invasive species;
- Exposure to increased suspended sediment concentrations and turbidity;
- Exposure to contaminants;
- Changes in fish movement or migration patterns;
- Entrainment of protected fish species;
- Short-term acoustic and/or noise effects; and
- Habitat use and potential impacts.

These factors and the resulting responses of the protected fish species inhabiting the subtidal areas within the Bay-Delta estuary that would constitute take under CESA are complex. Biological responses could include three general categories of adverse effects:

- Lethal effects (effects that result in mortality of individuals, cause population reductions, or damage the capacity and function of habitats to support various species and lifestages);
- Sublethal effects (effects that result in reduced growth rates, physiological stress, histological damage, moderate habitat degradation, reduced health or condition of individuals, etc.); and
- Behavioral effects (impaired homing or migration, reduction in feeding rates, avoidance response, abandonment of otherwise suitable habitat, etc.).

Lethal, sublethal, and behavioral effects of sand mining and/or dredging on fish have been extensively studied for a wide range of species and lifestages (Newcombe and MacDonald 1991; Newcombe and Jensen 1996; O'Connor 1991; Peddicord 1976; Peddicord and McFarland 1978; Sherk 1971; Sigler *et. al.* 1984; Stern and Stickle 1978; Peddicord and McFarland 1976; Muncy *et. al.* 1979; Bisson and Bilby 1982; Servizi and Martens 1991; O'Connor *et. al.* 1976; Whitman *et. al.* 1982; Reine and Clarke 1998; Buell 1992; McGraw *et. al.* 1988; and Wainwright *et. al.* 1992). Behavioral responses such as avoidance and changes in foraging vary among species exposed to elevated suspended sediments (O'Connor *et. al.* 1976; Sherk 1971; Bisson and Bilby 1982). The concentration of suspended sediment and the duration of exposure (Newcombe and MacDonald 1991; Newcombe and Jensen 1996; Wilber and Clark 2001), in addition to sediment particle size, water current velocities, and other biotic and abiotic factors (Sherk 1971; O'Connor 1991; Peddicord and McFarland 1978; Peddicord 1976), influence the behavioral and stress response of various fish species to suspended sediments and habitat disruption resulting from sand mining. In addition, sand mining methods have the potential to entrain protected fish into the suction head during a mining event. These mechanisms could result in direct take of a protected fish species.

In addition, many protected fish species use subtidal habitat areas within the estuary for different portions of the lifecycle, including larval and juvenile rearing, foraging, and migration. The response of these species and lifestages to habitat disturbance affecting the quality or availability of subtidal habitat as a result of sand mining could alter how various species use aquatic habitats in the Bay-Delta estuary. These potential effects could result in take of protected fish species through modifications to their habitat.

An extensive body of scientific information describes the species composition, seasonal and interannual variation in abundance, and habitat usage patterns by fish and macroinvertebrates inhabiting various regions of the estuary (Baxter *et. al.* 1999). CDFG has conducted fishery surveys in areas of Central Bay and Suisun Bay where sand mining occurs at approximately monthly intervals since 1980. Since sand mining would potentially affect protected fish species in the lower portion of the water column near the channel bottom, results of CDFG otter trawling which samples fish near the bottom are most valuable for use in this assessment. The CDFG fishery sampling within subtidal areas provides a useful long-term record on the regional occurrence of various species in the areas where sand mining occurs and interannual variability in their abundance. Additional CDFG fishery sampling surveys have been implemented in recent years that provide useful information on the seasonal and geographic distribution of larval delta and longfin smelt densities (CDFG 20mm surveys) that have also been used in this assessment.

For purposes of evaluating potential take of protected fish species as a result of sand mining by Hanson Aggregates in Suisun Bay and central San Francisco Bay information from the CDFG Bay Fish Study (otter trawl) and 20mm smelt surveys were integrated into the environmental assessment in addition to information on the proposed magnitude and locations of sand mining activity. These and other surveys of the fishery and aquatic resources of the estuary (Baxter *et. al.* 1999; Skinner 1962; Aplin 1967; USFWS 1970; Newcombe and Mason 1972; CDFG 1968; and others) provide a scientific foundation for identifying and assessing the potential for adverse effects (incidental take) as a result of Hanson Aggregate sand mining activity. The assessment of potential adverse changes in habitat quality and availability and the potential for take of protected fish species was based on knowledge of the species seasonal and geographic distribution for each lifestage, habitat usage patterns, and habitat quality and availability within the subtidal areas where sand mining occurs. Data from these surveys were used to develop qualitative and quantitative indices of potential take of protected fish species resulting from (1) indirect effects associated with changes in the availability or quality of subtidal physical habitat and (2) direct take or impacts to a protected species (e.g., entrainment into the suction head) resulting from sand mining activity.

The objectives of the following sections are to summarize and synthesize available information on the potential effects and take of protected fish species resulting from sand mining by Hanson Aggregates within the estuary. Specific objectives include:

- Review and analyze scientific information in order to evaluate the potential stresses and effects of sand mining on aquatic organisms in the Bay-Delta estuary from exposure to increased suspended sediment concentrations and turbidity, contaminants, noise and acoustic effects, and other effects resulting from sand mining;
- Assess the potential for sand mining activity to directly take protected fish (e.g., entrainment), adversely modify habitat availability, quality, or habitat function for various lifestages; and
- Assess the potential lethal, sublethal, and behavioral effects (take) of sand mining on protected fish and their habitats within the Bay-Delta estuary.

Results of the synthesis of available information and assessment of potential take of CESA listed fish species are summarized below.

5.2 Spread of Invasive Species

The Bay-Delta estuary has been colonized by a large number of introduced exotic species. Some species introductions, such as striped bass and American shad, have been made through conscious action while a majority of other species introductions have resulted from the inadvertent transport and release of species into the estuary. Many of the inadvertent species introductions have occurred as a result of ballast water discharges, associated with importation of oysters, as part of fouling communities on ship hulls, and through a variety of other mechanisms. It has been hypothesized that sand mining would potentially affect the spread of invasive species of fish or macroinvertebrates within the Bay-Delta estuary through two potential mechanisms, which include (1) the transport and introduction of invasive species into the estuary from other water bodies and (2) benthic disturbance or other changes to subtidal habitat that would favor colonization by invasive species when compared to native species of fish and/or macroinvertebrates.

Sand mining equipment utilized by Hanson Aggregates within the Bay-Delta estuary is consistently moored and operated exclusively within the estuary, and therefore there is no potential for sand mining to introduce new invasive species to the area. Tugs and barges utilized in sand mining activity within the Bay-Delta estuary are not used for mining or other purposes outside of the estuary and therefore would not contribute to the transport or movement of invasive species.

Sand mining occurs within higher velocity subtidal areas, including the Suisun Bay navigation channel, the navigational channel adjacent to Middle Ground Shoal, and areas within Central Bay that are characterized by high velocity water currents and frequent naturally-occurring benthic disturbance as evidenced by sand waves and other transient bedforms within many of the areas where sand mining activity occurs. Many of the macroinvertebrate species that have invaded the Bay-Delta estuary have high reproductive rates, dispersal lifestages, and the ability to rapidly colonize available habitat following disturbance. Many of the benthic macroinvertebrates colonizing areas within the estuary where sand mining activity occurs, and many areas where sand mining activity does not occur, are non-native invasive species. Sand mining results in localized benthic disturbance that could provide suitable habitat for colonization by invasive species. Frequent benthic disturbance resulting from sand mining activity and/or natural processes would generally tend to favor many of the invasive species (e.g., weedy colonizers) when compared to many of the native species which could require a longer period of time for succession and development of an equilibrium benthic community.

Sand mining would not be expected to have any effects on the abundance or distribution of introduced predatory fish species such as striped bass or to result in a direct or indirect increase in the vulnerability of protected fish to predation mortality. The protected fish species are characterized as occupying pelagic habitats (upper portions of the water column) and do not forage extensively on benthic macroinvertebrates that colonize deep subtidal habitats. Sand mining is prohibited from occurring near shallow water areas or adjacent to shorelines where many of the protected fish such as juvenile Chinook salmon forage during rearing and migration through the estuarine portion of the Bay-Delta system. Delta smelt and longfin smelt forage on planktonic zooplankton which would not be expected to be affected by sand mining benthic disturbance. Based on these factors it was concluded that sand mining would not result in an increased risk of adverse effects associated with non-native species interactions with protected fish species. No take of protected fish is expected to occur as a result of sand mining effects on non-native species inhabiting the estuary.

5.3 Exposure of Fish to Suspended Solids

The overflow plume produced by sand mining results in localized increases in suspended sediment concentrations (SSCs) and turbidity which typically disperses after 3-4 hours following completion of a mining event. There is concern that this sediment plume could adversely affect the health and behavior of adult and juvenile fish exposed to the elevated suspended sediment concentrations. This section discusses the possible effects of suspended sediments from sand mining on protected fish species. Current literature was reviewed in the context of the overflow plume, characterized in Section 3. Consideration is also given to specific species and lifestages of protected fish inhabiting Central Bay and Suisun Bay where sand mining occurs, where available from the literature. Although specific data are not available for all of the protected fish species occurring within Central Bay and Suisun Bay, the data available from the scientific literature, including tests and studies done on species from the Bay-Delta estuary, have shown that species and lifestages vary substantially in sensitivity to suspended sediment exposure.

This section presents a general literature review on the effects of suspended sediment concentrations on behavior and health of various fish species, with special reference given to protected fish species found in the Bay-Delta estuary. Because data on Bay-Delta species are limited, studies relevant to this issue were reviewed regardless of whether the species studied occurs in the estuary. This approach was taken in an effort to fully define the range of potential effects from sand mining (Hanson et al. 2004). Information on the response of various species to suspended sediment exposure, including extrapolations from species similar to those inhabiting the estuary, form part of the foundation for this assessment.

Exposure to excessive suspended sediment concentrations could lead to physiological stresses such as clogged gills, eroded gill and epithelial tissues, impaired foraging activity and feeding success, and altered movement and migration patterns of juvenile and adult fish (Clarke and Wilber 2000; Davis and Hidu 1969; Grant and Thorpe 1991; Minello *et. al.* 1987; Newcombe and Jensen 1996; Newcombe and MacDonald 1991). Exposure of fish to elevated SSCs could result in behavioral avoidance and exclusion from otherwise suitable habitat; disrupt movement and migration patterns; reduce feeding rates and growth; result in sublethal and lethal physiological stress, habitat degradation, or delayed hatching; and, under severe circumstances, could result in mortality (see Newcombe and Jensen 1996; Clarke and Wilber 2000). The response of fish to suspended sediments varies among species and lifestages as a function of suspended particle size, particle shape (angularity), water velocities, SSCs, water temperature, depressed dissolved oxygen concentrations, contaminants, and exposure duration (O'Connor 1991; Sherk 1971; Newcombe and Jensen 1996). Results of these and other investigations were used in assessing the effects of suspended sediment concentrations on the behavior and physiology of various protected fish species inhabiting San Francisco Bay.

Results of the literature review are summarized in Hanson *et al.* (2004) and used to assess potential lethal and/or sublethal effects on fish protected under CESA. For purposes of this assessment exposure to the overflow plume is assumed to have a worst-case maximum duration of 9.5 hours and maximum suspended sediment concentration of 100 mg/l (Section 3). The worst-case duration of exposure assumed that active mining occurred over a 3-5.5-hour period and dissipation of the overflow plume after completing a mining event would last 3-4 hours. The maximum duration of exposure under these assumptions would range from 6 to 9.5 hours. The parameters of a 9.5 hour sand mining plume duration at 100 mg/l concentration of suspended solids was chosen as a "worst case" scenario for fish species at various lifestages for effects from exposure. Since suspended sediments will settle exponentially from the water column, suspended sediment concentrations within the overflow plume will decline rapidly, and an organisms would not be expected to remain in the plume for the full duration of mining and plume dissipation, the worst-case exposure duration assumed in these analyses is considered to be extremely conservation (e.g., unrealistically long duration of exposure and sediment concentrations). This concentration-duration exposure regime was used, however, as a benchmark against which to measure effects of increased suspended sediment from a sand mining overflow plume against those reported in the literature on protected fish species at various lifestages. Specific objectives of the review and analysis included:

- Review scientific information to evaluate the potential stresses and effects of sand mining on aquatic organisms from exposure to increased suspended sediment concentrations and turbidity;
- Assess the potential for sand mining activity to adversely affect protected fish, habitat availability or quality, or habitat function for various lifestages; and
- Review and discuss biological effects of suspended sediment exposure and turbidity including:

  (1) Lethal effects: result in mortality of individuals, cause population reductions, or damage the capacity and function of habitats to support various species and lifestages;

  (2) Sub-lethal effects: result in reduced growth rate, physiological stress, reduced health or condition of individuals, gill abrasion; and

  (3) Behavioral effects: create a barrier or impediment to migration, reduction in feeding rates, avoidance response, abandonment of otherwise suitable habitat, and alter predator-prey relationships.

Five ways in which high concentrations of suspended sediment that could adversely affect fish have been identified from the literature (Wood and Armitage 1997):

- Reduced rates of growth and reduced tolerance to disease or resulting in mortality. Lethal concentrations of suspended sediments primarily kill by clogging gill rakers and gill filaments (identified in Wood Armitage (1997) (from Burton 1985);
- Reductions in the suitability of spawning habitat and affecting the development of eggs, larvae and juveniles; these stages typically are the most susceptible to suspended sediment, much more so than adult fish (identified from Chapman 1988, Moring 1982);
- Modification of migration patterns of fish (identified from Alabaster and Lloyd 1982);
- Reduction in the abundance of food available to fish due to a reduction in light penetration and prey capture (feeding activity), reduced primary production, and a reduction of habitat available to insectivore prey items (identified from Burton 1985; Doeg and Koehn 1994; Gray and Ward 1982); and
- Effects on the efficiency of prey detection and foraging success, particularly in the case of visual feeders (Burton 1985).

Investigations conducted to evaluate the effects of suspended sediments on various species and lifestages of fish are summarized in Hanson *et al.* (2004) and include:

- Reviews of the effects of suspended sediment on fish inhabiting San Francisco Bay (O'Connor 1991; USFWS 1970) and more comprehensive reviews by Peddicord and McFarland (1978), Peddicord (1976), Sherk (1971), O'Connor *et al.* (1976), Newcombe and MacDonald (1991), Muncy *et al.* (1979), Newcombe and Jensen (1996), Wilber and Clarke (2001); and
- Individual laboratory investigations of various responses of fish to increased suspended sediment concentration. These include studies by Breitburg (1988) on the effects of increased suspended sediment concentration on prey consumption by striped bass larvae, Bisson and Bilby (1982) on the avoidance of suspended sediments by juvenile coho salmon, Wildish *et al.* (1977) on avoidance of suspended sediments by adult Pacific herring, and Whitman *et al.* (1982) on the influence of suspended sediments on the homing behavior of adult Chinook salmon.

Although the behavioral avoidance response of fish is expected to substantially reduce or eliminate the risk of lethal exposure, short-duration exposure to elevated suspended sediment concentration associated with the sand mining overflow plume could result in sublethal effects. Although these sublethal effects have been documented in various scientific investigations, no information is available from the scientific literature on the biological importance of these sublethal responses on the overall health, condition, or survival of fish that experience short-duration (minutes or hours) exposure to suspended sediment concentration within the ranges occurring within the sand mining plume. The biological response of protected fish species inhabiting the Bay-Delta estuary to suspended sediment plume exposure is further complicated by the variability in biological response associated with factors such as suspended sediment particle shape (angularity), water quality conditions that could contribute to additive or synergistic effects, the occurrence of chemical contaminants within the suspended sediment plume, the condition of the fish prior to exposure (e.g., physiological stress associated with reproductive activity, etc.) and a variety of other factors.

The dose response of fish to increased suspended sediment concentrations has been discussed within the literature. The principle of the dose response is that there is a relationship between a biological reaction and response, whether lethal or sublethal (the response) and the concentration of sediment the organism is exposed to over a given time period (the dose). An important assumption in this relationship is that there is a dose below which no response occurs or can be measured. Figure 5-3 shows the relationship between increasing dose and increasing response. In the case of exposure of fish to raised suspended sediment levels, the maximum effect range is 100% mortality of test group.

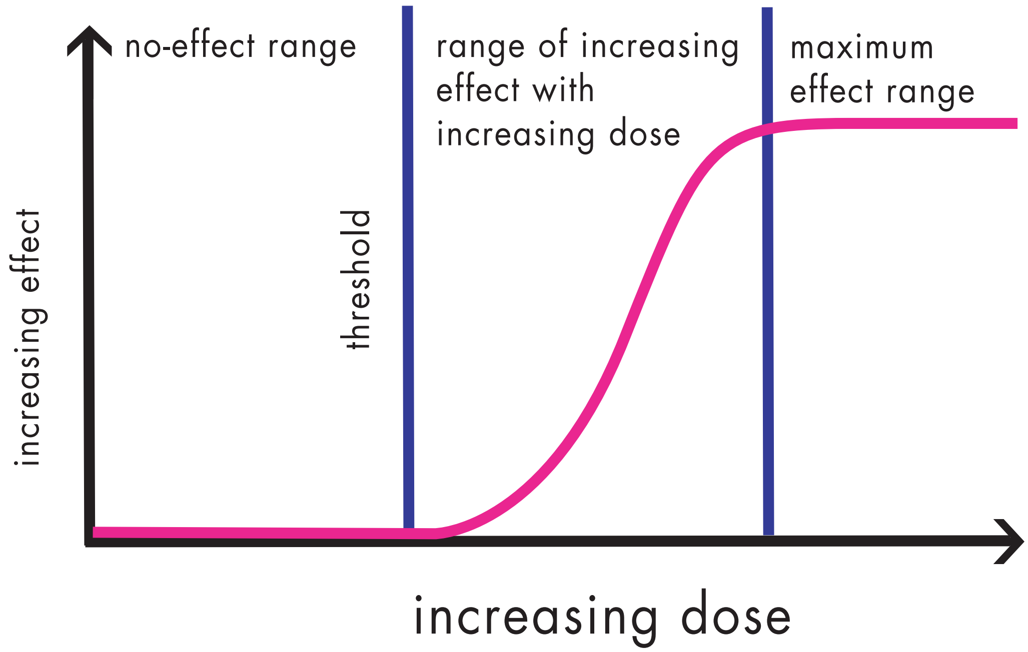


Figure 5-3. Relationship between dose response and effect.

Results of investigations on the effects of suspended sediment exposure are available for many species and lifestages inhabiting the Bay-Delta estuary including striped bass, Pacific herring, Chinook salmon, shiner perch, Pacific tomcod, rubberlip sea perch, and brown rockfish (USFWS 1970; Kiorboe *et. al.* 1981; Peddicord 1976, Newcombe and Jensen 1996; and Peddicord and McFarland 1976). This information was specifically reviewed to establish threshold concentrations for adverse effects on varying species of protected fish inhabiting the estuary and potentially exposed to the sand mining overflow plume. Data for delta and longfin smelt indicate a behavioral preference for areas where turbidity is increased, however, there is no specific data available on the dose-response for either species.

A limited number of laboratory studies have been conducted to evaluate the potential effects of suspended sediment exposure on larval fish (Muncy *et. al.* 1979; Wilber and Clarke 2001). Breitburg (1988) conducted laboratory studies to evaluate the effects of turbidity and suspended sediment concentrations on prey consumption by larval striped bass. Larval striped bass feeding rates in short-term (25-minute) feeding trials were found to be significantly reduced (40 percent fewer prey) when suspended sediment concentrations ranged from 200-500 mg/l, compared with feeding trials conducted at suspended sediment concentrations ranging from 0-75 mg/l. Prey used in these laboratory studies was a natural assemblage of zooplankton, primarily copepods. In the second set of feeding trials, in which *Daphnia pulex* was used as prey, no change in larval striped bass feeding rates was detected as a function of suspended sediment concentrations. Conflicting results on the effects of suspended sediment concentrations on larval fish foraging were also apparent in studies conducted by Johnson and Wildish (1982), which demonstrated a significant reduction in prey capture by Atlantic herring larvae when exposed to suspended sediment concentrations of 20 mg/l, compared with a control (0 mg/l). In contrast, Boehlert and Morgan (1985) found that Pacific herring larvae increased feeding success and prey capture at suspended sediment concentrations of 500-1,000 mg/l. Other studies cited by Newcombe and Jensen (1996) that examined the effects of suspended sediment concentrations on fish eggs and larvae showed decreased feeding rates and other adverse effects. These included various levels of physiological stress and, at higher suspended sediment concentrations; evidence of reduced growth rates, reduced or delayed hatching, and under severe conditions, increased mortality. The effects of suspended sediment on fish eggs and larvae thus appear to vary among species, lifestages, suspended sediment concentrations, and duration of exposure.

Responses to suspended sediments have been studied in depth for salmonid fishes (Wilber and Clarke 2001). These studies include subtle reactions that could be indications of physiological stress such as increased cough reflexes, reduced swimming activity, gill flaring and territoriality. Short term pulses of suspended sediments that involve a sharp increase within an hour can disrupt the feeding behavior and dominance hierarchies of juvenile coho salmon. These increases can also cause an alarm reaction that can lead to fish relocating to undisturbed areas. Alarm reactions disrupt schooling behavior.

The potential effects of the overflow plume on Chinook salmon, delta smelt, and longfin smelt foraging were evaluated, specifically whether any increase in turbidity or suspended sediment associated with the sand mining overflow plume could temporarily reduce the foraging opportunities of juvenile and adult fish that occupy the area immediately adjacent to the mining operations. As discussed above, the areal extent of the overflow plume is reduced by mixing and is dispersed by tidal flow and river currents. Turbidity as well as suspended sediment concentration levels return to ambient levels following completion of each mining operation. Any reduction in the opportunities for juvenile and adult fish to forage on macroinvertebrates (e.g., zooplankton or amphipods) within the water column would be expected to be limited to a small area immediately adjacent to the sand mining operation and of short duration (hours or less). However, as discussed earlier, the area in which sand mining occurs is offshore in relatively deep water (approximately 20-35 feet or more). This relatively deep water within central Bay, Suisun Bay and Middle Ground Shoal is characterized by high turbidity and suspended sediment concentrations (ambient background conditions) throughout the year. Juvenile winter-run and spring-run Chinook salmon typically emigrate through the Bay-Delta estuary during the winter and spring months coincident with storm activity, storm water runoff, and increased levels of turbidity within the Sacramento River, Delta, and San Francisco Bay. During these months, ambient turbidity conditions are elevated to levels similar to, or greater than, those occurring within the overflow plume. Therefore, the likelihood of significant impacts on juvenile and adult fish from exposure to the overflow plume is low.

Newcombe and Jensen (1996) synthesized a large body of scientific information on the effects of suspended sediment concentrations on various fish species for use as a quantitative framework for assessing potential risk of adverse effects resulting from suspended sediment exposure. The analysis included consideration of a variety of biological responses including behavioral effects such as alarm reaction, abandonment of cover, or avoidance response; sublethal effects such as short-term reductions in feeding rates, minor physiological stress, and impaired homing; and more severe effects such as reduced growth rates, delayed hatching, and mortality. Wilber and Clarke (2001) subsequently updated and refined the synthesis and analysis of information on the effects of suspended sediments on fish and macroinvertebrate species inhabiting estuaries. The results of these revised analyses also showed the importance of the relationship between suspended sediment concentrations and the duration of exposure as factors affecting the response of fish to suspended sediment concentrations. Results of the analyses presented by Newcombe and Jensen (1996) and Wilber and Clarke (2001) showed that the threshold for behavioral response (e.g., avoidance) is less than the concentrations resulting in either sublethal or more significant adverse effects. The synthesis of data by Wilber and Clarke (2001) for a variety of estuarine species and lifestages, including fish eggs and larvae and juvenile and adult fish shows that the threshold for sublethal effects to sensitive species occurs at a concentration of approximately 100 mg/l for an exposure duration of approximately 24 hours.

Detailed studies have not been performed on the behavioral response of juvenile or adult delta smelt or longfin smelt when encountering areas of increased turbidity. However, the high suspended sediment loads that have historically occurred and continue to occur within the Sacramento River and Delta within the areas inhabited by both delta smelt and longfin smelt suggest that exposure to suspended sediment loads has not contributed to mechanical abrasion or reduced health (increased susceptibility to fungal infections, etc.). It is also expected that given the relatively small area within the water column, both horizontally and vertically where increases in suspended sediment load occur as a consequence of sand mining activities, delta smelt and longfin smelt would actively avoid exposure to elevated suspended sediment concentrations. This conclusion is plausible in the light of some data about delta smelt behavior. Because both delta smelt and longfin smelt have historically utilized the high turbidity environments of the Bay-Delta estuary, there is no reason to assume that short-term increases in either suspended sediment concentrations levels or visual turbidity would affect these species adversely.

Research has shown that juvenile Chinook salmon, although experiencing some sublethal effects from raised sediment levels, can actually benefit from and seek out areas of increased turbidity as protection from predation (Burton 1985). Areas of raised turbidity can offer cover and increase survival (Burton 1985). Suspended sediments can inhibit light penetration into the water column and offers possibilities for increased turbidity to provide a form of cover from predators.

Behavioral effects associated with exposure to the sand mining overflow plume would include avoidance and exclusion of sensitive estuarine fish species from the suspended sediment plume area and behavioral responses that would temporarily affect movement and migration of fish. As previously discussed, elevated suspended sediment concentrations could result in avoidance behavior and/or delays in the migration of juvenile and adult salmon and steelhead, as well as in local movements of other fish within the Bay-Delta estuary. Whitman *et al.* (1982) evaluated the effects of suspended sediments (volcanic ash) on homing and upstream migration of adult Chinook salmon. Adult Chinook salmon exposed to suspended sediment concentrations of 650 mg/l for 7 days showed homing and return rates comparable to controls; however, adult salmon showed a preference for the control (low suspended sediment concentrations water). Whitman *et al.* (1982) found evidence that adult Chinook salmon, when given a choice, preferred a control water supply when compared to waters with an elevated (650 mg/l) suspended sediment concentration. No tests were conducted to determine the behavioral response of adult Chinook salmon to lower suspended sediment concentrations. The behavioral response of juvenile coho salmon to sublethal concentrations of suspended sediments was also tested (Servizi and Martens 1991), and less than a 5 percent avoidance response to suspended sediment concentrations up to 2,550 mg/l was observed, although a more definite avoidance response was observed (25 percent) when suspended sediment concentrations increased to 7,000 mg/l.

Chinook salmon upstream-migrating adults and downstream-migrating juveniles pass through the Bay-Delta estuary as part of their migration route. Although the number of Chinook salmon migrating and their migration pathways are unknown, these fish would potentially be exposed to elevated suspended sediment concentrations resulting from sand mining over flow plumes. Chinook salmon encountering a turbidity plume resulting from sand mining could modify their migration route to avoid elevated suspended sediment concentrations.

Downstream juvenile salmonids migrate through the estuary from January through June, encountering a wide range of water conditions. There is no conclusive evidence that they emigrate through Suisun Bay to the ocean more effectively during high flow or low flow events (which would be associated with different levels of suspended sediment concentrations and visual turbidity). Juveniles could spend some time foraging in the estuary, but migration is triggered by physiological adaptation to saline conditions, and passage through the western Delta and Bay could be rapid once the juvenile smolts enters the western portion of the estuary (Kjelson personal communication; McFarland personal communication). McFarland reported that emigrating juveniles also lose condition and gain length as they cross through Suisun Bay to the Golden Gate, suggesting that they are not foraging extensively during the emigration. In the estuary, juvenile emigration behavior does not appear to be sensitive to events associated with elevated suspended sediment concentrations levels. In contrast, evidence suggests that juvenile salmon migration is frequently greater in response to increased flows and turbidity. In addition, data from survival studies conducted using juvenile Chinook salmon released into the Sacramento and San Joaquin rivers have not detected a relationship between migration duration and survival (USFWS unpublished data; SJRG 2001), or migration distance and survival (Bailey and Monroe 2001). Finally, sand mining events could have only short-term effects on emigrating juvenile salmonids. On a flood tide, juveniles would encounter a plume of elevated suspended sediment concentrations or elevated visual turbidity for only a short period (hours) as the current carried it past them upstream. On an ebb tide, the plume of sediments settling to the substrate would drop out of suspension within 1,000 yards; a juvenile would pass through this plume in a matter of 10-15 minutes, even if only drifting with the outgoing tide.

The overflow plumes are not expected to result in a complete blockage of migration for either adult or juvenile Chinook salmon. Results of the limited data available on the relationship between juvenile Chinook salmon survival and migration duration suggest that migration delays in the range of hours would not be expected to result in a significant incremental increase in juvenile mortality rates. Many juvenile salmonids, in fact, appear to preferentially emigrate during periods of storm water runoff and increased river and delta outflow (times of high turbidity and suspended sediment concentrations, which have been hypothesized to contribute to reduced predation mortality.). Although the behavioral response of Chinook salmon, delta and longfin smelt to sand mining turbidity plumes may affect localized behavior and contribute to delays in migration, the incremental effect of these changes on survival are not expected to be sufficient to result in broad regional reductions in population abundance of these species.

The overflow plumes have been characterized as being approximately 300 feet or less in width, trailing away from the sand mining barge with the prevailing water currents (Section 3). Within Suisun Bay where sand mining occurs, the channel width is approximately 1,000 to 4,000 feet. As a result of the intermittent nature of sand mining activity the overflow plume does not create an impassable barrier to salmonid migration. After completion of each sand mining event, the overflow plume rapidly dissipates as a result of tidal flow (Section 3). During the time period that the plume is present, it will extend across 7.5% to 30% of the channel cross section area. The small area affected by the overflow plume, combined with the short time and intermittent nature of the plume, provide juvenile salmonids, delta and longfin smelt the opportunity to actively avoid exposure to the plume. There is therefore little risk that the overflow plume will create a barrier to fish migration or result in the incidental take of winter-run or spring-run Chinook salmon, delta or longfin smelt.

5.4 Dissolved Oxygen

Sand mining results in the disruption of benthic sediment deposits and resuspension of fine-grained sediments into the water column as part of the overflow plume (Section 3). If bottom sediments contained a high percentage of organic material, which through decomposition, resulted in anoxic conditions resuspension of these sediments would potentially result in a localized reduction in dissolved oxygen concentrations. Reductions in dissolved oxygen concentrations, typically below a level of 6 ppm, would potentially result in adverse impacts to protected fish exposed to depressed dissolved oxygen levels. Concern has been expressed regarding dissolved oxygen depression associated with dredge material disposal, which is characterized by a high percentage of silt, clay, and mud and decomposing organic material. Sand mining, in contrast, does not involve disposal of dredge material and the mining itself within the Bay-Delta estuary occurs in areas characterized by sand deposits having a low percentage of fine sediments and organic material, which limit the potential for dissolved oxygen depression within the overflow plume in relation to the potential for such depression from dredge material disposal.

Isaac (1965) and Burdick (1976) summarize reported biological oxygen demand rates for a wide range of sediment conditions. Much of this work with biological oxygen demand has been related to the degree of chemical contamination of sediment. When anaerobic conditions occur within sediment deposits and/or chemical contaminants occur, at a significant level, sediments resuspended in the water column can result in depressed dissolved oxygen concentrations. It was shown that within the overflow plume, chemical contamination of the sediments harvested by sand mining was not significantly higher than surrounding waters. Oxygen demand has also been shown to be a function of the suspended sediment concentration (Isaac 1965; Berg 1970; Reynolds *et. al.* 1973; cited in Lunz and La Salle 1986). It is clear from these studies that oxygen demand is directly related to a number of parameters, such as biological oxygen demand, temperature, degree of resuspension and level of contamination as well as fine grained sediment concentrations (Lunz and La Salle 1986). From studies of the sand mining overflow plumes (Section 3) it was shown that suspended sediment concentrations within the plume are typically within the range of the natural variation of the Bay-Delta estuary. The suspended sediment concentrations of the overflow plumes have generally been measured at concentrations of approximately 100 mg/l or less within 400 ft of the barge and further decays to ambient levels within 3-4 hours (Section 3). Therefore, using the hypothetical dissolved oxygen concentration reductions outlined by Lunz and LaSalle (1986) dissolved oxygen reductions could be in the range of 0.04 mg/l and 0.12 mg/l before dispersion of the plume.

MEC and Cheney (1990) conducted a series of field studies to determine whether or not the overflow plume resulting from sand mining operations within Central Bay contributed to short-term localized reductions in dissolved oxygen concentrations. Results (MEC and Cheney 1990) showed that a reduction in dissolved oxygen concentrations associated with the overflow plume would be small, localized and of short duration. These findings can be seen to be largely in line with the hypothetical values discussed by Lunz and LaSalle (1986) for sediment concentrations typical of the sand mining overflow plume.

MEC and Cheney (1990) conducted a limited sampling of dissolved oxygen concentrations inside and outside of the overflow plume at various distances from an actual sand mining operation in Central Bay at Point Knox Shoal. Dissolved oxygen concentrations measured within and outside of the overflow plume at a depth of 20 feet are shown in Figure 5-4 during both ebb and flood tidal stages. These results show oxygen concentrations varying both within and outside of the sand mining plume, and no pattern of higher or lower concentrations inside of the plume when compared to outside of the plume. Dissolved oxygen concentrations were higher outside of the plume 5 times out of 12 and lower outside of the plume 6 times out of 12. Oxygen levels inside and outside of the plume never dropped below 6 mg/l.

There is no obvious mechanism by which sand mining would result in significantly lower dissolved oxygen levels. In clean sand, BOD in the discharge from the barge would be low, and the process of discharging fine grained sediments into the water column results in turbulent mixing, introducing oxygen into the water. Results of these field studies provide no evidence to suggest that sand mining activity within the Bay-Delta estuary would result in depressed dissolved oxygen concentrations within the plume or contribute to incidental take of winter-run or spring-run Chinook salmon, delta or longfin smelt inhabiting the area.

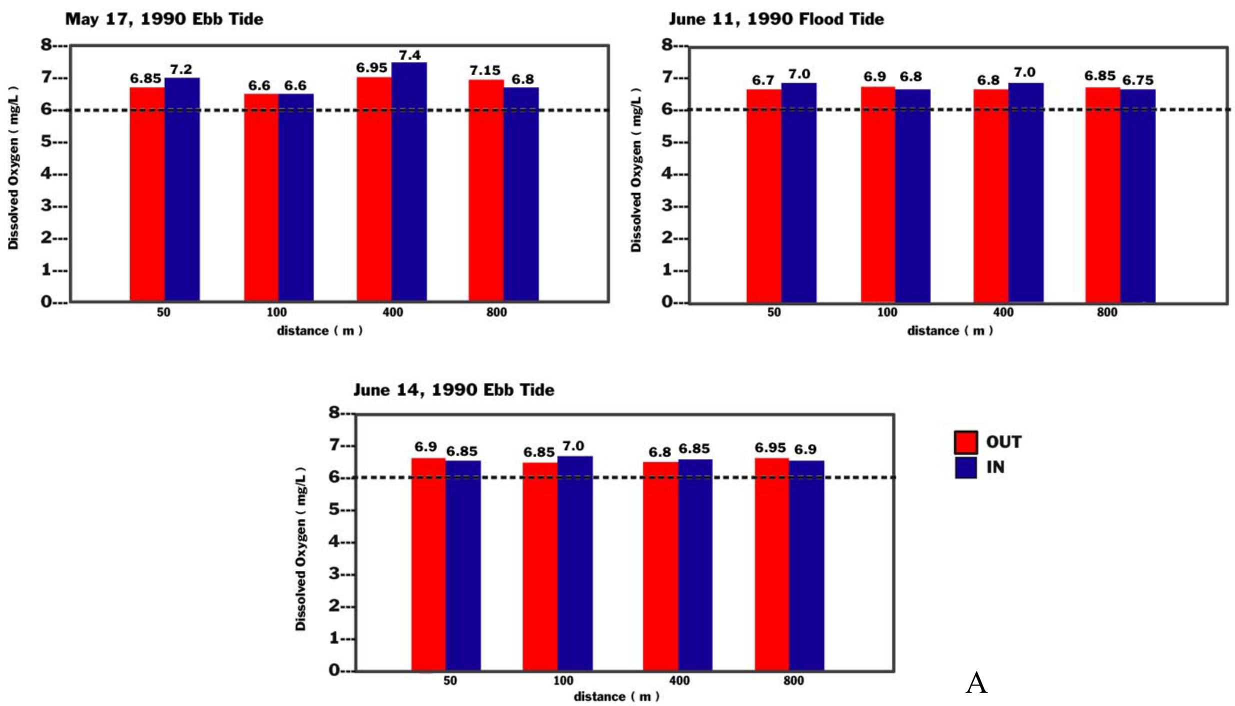


Figure 5-4. **Dissolved oxygen concentration at 20-foot depth inside and outside of an overflow plume during sand mining in Central Bay (MEC and Cheney 1990).**

5.5 Contaminants And Toxicity Within The Overflow Plume

Sand mining creates an overflow plume that typically disperses after 3-4 hours (Section 3). There is concern that exposure to contaminants within the overflow plume could affect the health of adult and juvenile fish due to increased levels of contaminants resuspended with the fine sediments contained in the overflow effluent. This section discusses the measured levels of contaminants within the overflow plume as well as the possible effects of contaminants on fish species listed for protection under CESA.

An extensive body of scientific information is available on the effects of exposure for various species and lifestages of protected fish and other aquatic species to contaminant concentrations. Although specific data are not available for all of the protected fish species occurring within Central Bay and Suisun Bay, the data available from monitoring programs of toxicity within the sand mining plumes and bioassays performed using undiluted plume effluent, provide no evidence of a threat of increased toxicity within the plume from contaminant resuspension with fine materials (silts and clays).

As discussed in Section 3, sand mining occurs in areas that typically are comprised of sediments with a fines content of less than 10%. Sand mined from Central Bay and Suisun Bay would not be expected to contain significant concentrations of chemical contaminants. Sand particles do not adsorb, absorb, or bind pollutants. As discussed in Section 3 the percentage of fine sediment in sand deposits that would be mined (and therefore could contain contaminants) is low.

The California Regional Water Quality Control Board (RWQCB), San Francisco Bay Region, has issued a general permit (Permit No. 95-177) for existing and proposed surface water discharges to the San Francisco Bay Region from sand mining operations. The RWQCB has determined that sand mining effluent discharged into the Bay-Delta Estuary is acceptable under normal sand mining conditions based on MEC (1993) data on toxicity and contaminants within the overflow plume. The water quality data presented by MEC Analytical Systems (1993) provided the technical basis for the RWQCB to issue a general permit for sand mining operations and resulting water quality of the overflow plume. The main factor for the issuing of a general Waste Discharge Requirement permit was the fact that sediment collected during sand mining is largely sand, which is recognized as an unlikely repository of pollutants. The basis of the permit is that sand mining will not cause degradation of surface waters within the estuary.

Water samples for chemical analysis were collected from a sand mining overflow plume within Central Bay on a monthly basis for three months (MEC 1993). Water samples were also collected from outside the plume for comparison of contaminant levels. The sampling took place during sand mining events at Presidio Shoal and Point Knox Shoal. At each station samples representative of ambient conditions were collected from upstream of the overflow plume and downstream of the plume away from the influence of discharge. Samples were also taken 30 m downstream of the discharge point within the overflow plume and at the midpoint of the plume.

Discrete water samples for chemical analysis were collected at two depths. Samples were collected 1 meter below the water surface (surface) and 2 meters above the bottom (bottom) for all surveys. Water samples were analyzed for:

- Metals;
- Arsenic;
- Total Organic Carbon; and
- Ammonia.

Water depths where samples were collected at ranged from 50 to 80 feet at Presidio Shoal and Point Knox Shoal. Temperatures were monitored and found to be slightly higher at the surface (13.9 to 17.5 C) compared to the temperatures of bottom waters (12.4 to 17.2 C). Temperatures during the water quality sampling program were found to be similar at the two locations and at the four sampling points (within and outside the plume). Salinity values also showed slight variation between surface waters and bottom waters, typically being slightly lower at the surface, but consistent both inside and outside the overflow plume during sampling.

Dissolved oxygen was found to be variable at all station locations. In general, surface values were slightly higher than bottom values. No effects from the plume discharge were found and in all cases dissolved oxygen concentrations were greater than 6.0 mg/l.

These results are consistent with earlier studies in showing no substantial reduction in dissolved oxygen concentrations within the overflow plume during sand mining. Values for pH were stable throughout the water column at all sampling points and no effects of the overflow plume were detected.

Results of the water quality chemical analysis found that most ammonia concentrations were slightly higher in surface waters compared to bottom waters. Ammonia concentrations were found to be similar at the two locations and between the four sampling points, showing no significant increase within the overflow plume. Total organic carbon concentrations were found to be variable between surveys, but were similar among the four sampling points inside and outside the plume.

Water samples were collected by MEC (1993) at Presidio Shoal and Point Knox Shoal upstream of the sand mining overflow plume in ambient waters, 30 m downstream of the effluent discharge point within the plume to obtain levels of relatively undiluted sample, at the plume mid-point and downstream of the plume in ambient waters. Samples were analyzed for concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Concentrations were found to vary only slightly between the two locations and among the four sampling points outside and inside the overflow plume. Samples were also analyzed for concentrations of mercury, selenium and silver and were found to contain only very low concentrations or were not detected at all. No plume related differences were found for metal concentration variations within the water column.

Table 5-1 shows the observed water quality values from the MEC (1993) study for samples collected from the overflow plume compared to water quality standards set by EPA as numeric criteria for priority toxic pollutants for the State of California (EPA 2000). The EPA water quality guidelines are included for freshwater as well as saltwater standards for reference to allowable levels of discharge in Suisun Bay as well as in Central Bay. The levels of measured pollutants reported in Table 5-1 are the concentrations measured within the overflow plume 30 m from the discharge point on the barge. This sample point was chosen to represent the highest concentration of pollutants and the least dilution of discharged sediment. Also, the data from the sample program has been averaged for the three surveys across the two locations (Point Knox Shoal and Presidio Shoal) for the samples taken at the surface and the bottom. In this way the worst case scenario (highest observed concentrations) is presented for toxicity concentration in terms of any sample point within the overflow plume.

In all cases the measured concentrations within the overflow plume are below EPA guidelines for allowable maximum discharge of toxic pollutants into salt and freshwater. This is also the case for the maximum observed values measured for the three surveys at surface and bottom. For mercury, only one detectable level occurred in one sample, 0.05 µg/l. This was measured from a single point on the bottom and is not representative of the rest of the sample group where no detectable amount was found for all other samples.

As is shown by the data on contaminants within the overflow plume and within upstream and downstream ambient water there is no consistent pattern of the overflow plume contributing contaminants to the water column. It is also clear from the plume contaminant level data that the sand mining overflow plume does not at any point exceed EPA saltwater or freshwater contaminant discharge criteria for water quality standards. This is true both for averaged discharged contaminant component 30 m from the discharge point as well as for maximum measured contaminant concentrations during the sampling period.

As shown by the sampling program and analyses discussed above, there is no evidence that sand mined from Suisun Bay and Central Bay contains significant concentrations of chemical contaminants. Sand particles do not adsorb, absorb, or bind pollutants. An analysis of the chemical characteristics of the overflow plume effluent from sand mining operations was conducted for samples collected at Presidio Shoal and at Pt. Knox Shoal in July, August and September 1993 (MEC 1993). Both filtered and unfiltered samples were analyzed for heavy metals, polycyclic aromatic hydrocarbons (PAH's), total organic carbon (TOC), total suspended solids (TSS), total sulfides, and ammonia. Based upon results of these chemical analyses of the overboard effluent produced during sand mining operations, it appears that particulate bound metals can be found in the effluent discharge. However, there appears to be little solubilization of metals from the particulates into a dissolved state where they would be potentially toxic to aquatic organisms. Concentrations of PAH's found were at the detection limit or below and due to their solubility in water, it would not be expected that there would be a significant potential for the release of these organics or a potential for toxicity. The levels of ammonia, sulfides, and total organic carbon are variable, but do not appear to have a significant potential to affect background toxicity within the receiving waters.

Table 5-1. EPA standards for toxic pollutants to California State waters compared to measured concentrations of pollutants within the overflow plume during Central Bay sand mining (MEC 1993; USEPA 2000).

Metal	EPA criteria Fresh Water (µg/l)	EPA criteria Salt Water (µg/l)	MEC Averaged Samples at 30m From Discharge (µg/l)	Max Discharge Observed (µg/l)
Arsenic	340	69	1.63	1.9
Cadmium	4.3	42	0.09	0.17
Chromium	16	1100	0.88	2
Copper	13	4.8	1.49	2.4
Lead	65	210	2.69	16.7
Mercury	-	-	0.04	0.05
Nickel	470	74	1.30	2.3
Selenium	-	290	0.12	0.05
Silver	3.4	1.9	0.00	0
Zinc	120	90	23.08	87

Although no toxicity studies have been performed on sand mining overflow effluents within Suisun Bay and the western Delta, results of sediment analyses from the navigational shipping channel where maintenance dredging is performed have shown a low risk of toxic effects (ACOE unpublished data). Similarly, results of water quality analyses for sand and the overflow plume from mining operations within Central Bay (MEC 1993) showed a low risk of toxic effects.

Contaminants have been found to be primarily bound to fine silt and clay particles, and have not been found to be absorbed or adsorbed to sand particles. Since sand mining within Central Bay and Suisun Bay is conducted in areas characterized by relatively high water velocity and dynamic substrate movement, the sand deposits characteristically have a very low percentage of silts and clays (Section 3). Results of grab samples and sediment analyses have consistently shown that within the areas where sand mining occurs, the percentage fines have consistently been less than 10% (Section 3). Based upon these results, and similar information from earlier sampling, including water chemistry analyses (MEC 1993), no evidence suggests that sand mining activity would result in an increased exposure and risk of adverse impacts or incidental take of protected fish as a result of contaminant resuspension during sand mining activity.

Toxicity studies previously required by the Regional Water Quality Control Board (MEC 1993) conclude that no adverse chemical effects would occur within the water column from the return of sand particles to Central and/or Suisun bays from the overflow plume during sand mining operations. The RWQCB, through issuing a general Waste Discharge Requirement permit, has determined that the overflow plume from sand mining does not cause waters of the State to exceed the following quality limits downstream of the zone of discharge:

- Dissolved Oxygen: 5.0 mg/l minimum;
- Dissolved Sulfide: 0.1 mg/l maximum; and
- Toxic or other deleterious substances: None are present in concentrations or quantities that could cause deleterious effects on aquatic biota, wildlife or waterfowl, or which render any of these unfit for human consumption either at levels created in the receiving waters or as a result of biological concentrations.

Therefore, the sand mining overflow plume does not represent an increased risk of toxicity and no evidence was found that levels of pollutants within the overflow plume are significantly different from ambient background conditions. Based on results of these analyses it was concluded that there is no evidence that sand mining will result in the incidental take of winter-run or spring-run Chinook salmon, delta or longfin smelt as a result of contaminant exposure within the overflow plume.

5.6 Entrainment

The process of sand mining involves suction heads creating a sand/water slurry at the seabed which is then pumped aboard the sand mining barge (Section 3). Sand mining involving hydraulic suction dredges, such as those used in the Bay-Delta estuary, results in potential entrainment mortality of fish listed for protection under CESA. The suction current created to pump the sand slurry on board the barge could be too strong for some organisms and age classes to escape being entrained. Entrainment is defined as the direct uptake of aquatic organisms by the suction field generated at the draghead.

No data on actual entrainment by sand mining are available, so hypothetical entrainment estimates were developed based upon available information and statistical calculations. In order to develop a hypothetical estimate of protected fish entrained by the process of sand mining, the amount of water, which could potentially include larval, juvenile, and adult lifestages, pumped per mining event must be determined. By using the barge pump capacity, in gallons per minute, and the time of each mining event, in minutes, the total amount of slurry (mixture of sand and water) is determined. Then, taking into account the sand:water efficiency by barge (Hanson et al. 2004), the total amount of slurry pumped is multiplied by the average percent water that was determined by region by barge by sand type by operator to calculate the amount of water pumped. Based on barge capacity, an additional 1/3 of the barge capacity was added to the amount of water pumped by Hanson Aggregates for mining events using the Sand Merchant because they load the barge about 1/3 of the way full with water prior to a sand mining event (Section 3). This total amount of water pumped was then converted from gallons to cubic meters.

The process of developing hypothetical entrainment estimates used CDFG fish catch data for each representative regional station and lifestage (e.g., 20mm survey data was used for smelt larvae and early juveniles, Bay Study otter trawl data was used for juvenile and adult smelt). On the basis of these data, the average density (no/10,000 m^3) was calculated for delta and longfin smelt for each region by month by lifestage. Hypothetical entrainment estimates for delta and longfin smelt were developed based on the average monthly density calculated from the CDFG fishery surveys conducted in various regions of the estuary. A hypothetical monthly number of the species entrained was then calculated as the product of the density of the species and lifestage (number per 10,000 m^3) and volume of water estimated to be entrained (in 10,000 m^3) during the month. For example, assuming that the density of a species was 1 fish per 10,000 m^3 and sand mining within the region during the month entrained 100,000 m^3 of water a hypothetical estimate of the number of fish entrained during the month would equal 10 fish. The monthly estimates of hypothetical entrainment losses for each species and lifestage was then summed over 12 months to develop an annual average entrainment loss estimate. As a result of the geographic distribution of both protected fish and sand mining activity within the estuary, entrainment loss estimates were derived separately for each regions of the estuary to take into account site-specific differences in mining activity and the geographic distribution and density of various fish species included in these analyses.

Analyzing the potential adverse effects of entrainment by sand mining operations on aquatic organisms poses severe technical challenges. Previous studies demonstrate the difficulties in determining precise estimates of absolute entrainment rates and have seldom been able to determine population level consequences with any degree of accuracy or confidence. The vulnerability of each protected fish species and lifestage to entrainment during sand mining varies substantially by region, season, and year. Based on a consideration of the life history and habitat use for various species it was concluded that the planktonic larvae and early juvenile stages for protected fish occurring seasonally in Suisun Bay and/or Central Bay would be susceptible to entrainment. Larger juvenile and adult fish with good swimming performance and pelagic fish species such as delta and longfin smelt and Chinook salmon that inhabit the mid- and upper portions of the water column are expected to have lower vulnerability to entrainment into a suction head operating on or in the bottom substrate. Results of studies conducted in other estuaries (Larson and Moehl 1990) have concluded that juvenile salmonids (Chinook salmon and steelhead) have a low risk of entrainment. The California ESA, however, prohibits incidental take of listed species in the absence of take authorization.

Delta and longfin smelt inhabiting Suisun Bay and the Middle Ground Shoal have planktonic early lifestages (e.g., larvae) that would be susceptible to entrainment during sand mining. Many of the other species, including Chinook salmon, delta smelt, and longfin smelt utilize the Suisun Bay complex as juvenile rearing habitat and could also be vulnerable to entrainment during sand mining. No investigations have been conducted to quantify entrainment risk for species such as delta and longfin smelt specifically for the methods and equipment utilized in commercial sand harvest. Information available from CDFG fishery surveys of Chinook salmon, delta smelt and longfin smelt within areas where sand mining occurs within the Suisun Bay, Middle Ground Shoal, and Central Bay have been used to assess the potential risk of take of these protected fish species as a direct result of entrainment into the suction head during mining. Results of entrainment risk calculations presented in this assessment are based on a combination of information available on the frequency and duration of sand mining activity within the area and densities of various fish species potentially vulnerable to entrainment.

Assessment of the potential risk of incidental take of fish species protected under CESA as a result of entrainment during sand mining by Hanson Aggregates was based on the following assumptions (Hanson et al. 2004):

- Pump volume on the Sand Merchant is 15,000 gpm (3,407 m^3/hour)
- Each mining event lasts 4 hours
- Ballast added to the barge prior to mining is assumed to be 833 yd^3 (637 m^3) of water pumped from a depth of not greater than 3 feet above the bottom
- The sand:water slurry is 83% water and 17% sand
- 75% of the slurry water originates in sand substrate and 25% is entrained through the water supply opening in the top of the suction head and sides of the head (no fish are

expected to be present in interstitial water within the sand substrate)

- Sand mining would occur at the maximum permitted volumes each year from each of the designated mining areas and would include:
  - Suisun Bay – 150,000 yd^3 (half of the proposed volume for Suisun Associates)
  - Middle Ground Shoal – 50,000 yd^3
  - Central Bay – 1,540,000 yd^3
- Sand mining would occur in accordance with the monthly average harvest as presented in Section 3.5 (seasonal variation in mining is expected with greatest demand for sand during the summer months, however, the actual volume and seasonal pattern of mining is unknown)
- Sand mining using the Sand Merchant would harvest 2,500 yd^3 per event
- Average monthly densities (2000-2010) of each of the protected fish species recorded in the CDFG fishery surveys within each designated mining area are representative of the densities of fish potentially at risk of entrainment during a sand mining event
- Fish would be vulnerable to entrainment in direct proportion to their local density and the volume of water entrained into the suction head (although behavioral avoidance of the disturbance and noise created during sand mining is expected to result in a reduction in entrainment as a result of avoidance of the suction head, no data were available to factor behavioral avoidance into the risk calculations).

Winter-run and Spring-run Chinook Salmon Eggs

Winter-run and spring-run Chinook salmon spawn and eggs incubate in tributary habitats upstream of the Delta. The larval salmon remain buried in gravel nests (redds) until the young salmon develop and emerge into the surface waters as fry. The fry stage (approximately 30 to 50mm in length) of both spring-run and winter-run Chinook rear in the upstream habitats and therefore would not be vulnerable to potential entrainment as a result of sand mining in either Suisun Bay or central San Francisco Bay. There is no risk of take of these early lifestages of either winter-run or spring-run Chinook salmon.

Based on their life histories it was concluded that eggs and larvae of the protected fish species would not be vulnerable to entrainment during sand mining. Winter-run and spring-run Chinook salmon do not spawn in the subtidal areas where sand mining occurs. In addition, neither winter-run nor spring-run Chinook salmon have planktonic eggs or larvae. As a result of these factors there is no risk of take of eggs or larvae of winter-run or spring-run Chinook salmon as a result of sand mining in either Suisun Bay or central San Francisco Bay.

Juveniles

Juvenile winter-run and spring-run Chinook salmon (>50mm in length) migrate downstream through Suisun Bay and central San Francisco Bay during the late winter and spring months. Although juvenile salmon typically migrate predominantly in the upper portions of the water column, there is a potential risk of juvenile salmon entrainment as a result of sand mining. Methods were developed in consultation with NMFS (2006) that have been used to assess the potential for juvenile salmon entrainment within both Suisun Bay and central San Francisco Bay. The analytical methods and assumptions developed and used in the NMFS juvenile salmonid entrainment analysis have been used in the CESA assessment based on the assumption that sand mining would occur at the maximum volume permitted for each of the designated mining areas. The analysis includes consideration of the diameter of the zone of potential entrainment risk (based on approach velocities greater than 0.33 ft/sec), the channel cross-sectional area, the total duration of mining within the Suisun Bay area between January 1 and May 31 period of juvenile salmon migration. Estimates of the number of juvenile winter-run and spring-run Chinook salmon migrating through the estuary each year were derived based on adult escapement estimates presented in GranTab and the relationship between adult escapement and juvenile production for winter-run derived by NMFS. The resulting juvenile abundance estimates were obtained from fishery analysis performed as part of the Bay Delta Conservation Plan (BDCP) effects analysis and assume that 1,000,000 juvenile winter-run and 1,500,000 juvenile spring-run Chinook salmon migrate through the estuary each year (the actual juvenile production varies among years in response to variation in factors such as adult escapement, juvenile rearing habitat conditions, other sources of juvenile mortality, etc.). The analysis assumed that juvenile Chinook salmon exhibit a diel vertical distribution within the water column with 12.5% of the fish in the lower third of the water column during the day and 33.3% occur in the lower third of the water column at night. For purposes of estimating the risk of incidental take it was assumed that mining occurs equally during the day and at night. NMFS (2006) concluded that since mining in central Day occurs in depths ranging from approximately 43 to 96 feet (Hanson et al. 2004) and that juvenile migrating salmon are not constrained to a small channel cross section that the risk of incidental take of juvenile winter-run and spring-run salmon during mining in central Bay is de minimis and was not included in the incidental take estimates. NMFS (2006) estimated that mining in the Suisun Bay region, where water depths are relatively shallow (typically less than 30 feet) and the channel cross-section confines juvenile salmon in the general area where mining occurs that a total mining time 1,173.4 hours (maximum mining by three companies combined) would result in a take of 0.0042% of the juvenile salmon migrating through Suisun Bay. These relationships were subsequently modified to account for the maximum volume proposed by Hanson Aggregates for mining within the Suisun Bay region.

Assuming that Hanson Aggregates mines 200,000 yd^3 of sand from the Suisun Bay region each year (83,335 yd^3 during the January-May period) it was estimated that the mining duration during the migration period would total 133.3 hours. Based on these assumed relationships it was estimated that incidental take of juvenile winter-run Chinook salmon would be 5 fish. Incidental take of juvenile spring-run Chinook salmon was estimated to be 9 fish.

The low risk of juvenile salmon entrainment during sand mining based on the methods and assumptions outlined above are consistent with results of an experimental entrainment study conducted within Suisun Bay. During the study sand mining equipment was used to assess the entrainment risk of juvenile salmon and other fish species. The suction head during these tests was not buried into the substrate as would occur during actual mining but rather was suspended immediately above the bottom while water was pumped onto the barge and screened to observe any fish that may have been entrained. No juvenile salmon or smelt were observed in tests conducted using sand mining equipment operated by Hanson Aggregates or Jerico/MTB (Hanson 2006). Juvenile salmon were collected in the tests using a stationary pothole suction pipe (RMC) that is no longer in use for sand mining in the estuary. The risk of entrainment in these studies would have been further reduced by submerging the suction head into sand deposits and mining using conventional methods. During the operation of sand mining equipment there is noise (Section 5.7) and benthic disturbance that would also be expected to result in behavioral avoidance of the suction head and thereby further reduce the risk of entrainment.

Results of this analysis are also consistent with estimates of the risk of juvenile winter-run and spring-run Chinook salmon entrainment during sand mining in Suisun and central Bay that were derived using the volumetric approach (see smelt methods and assumptions) and salmon densities from the CDFG otter trawl catches. Based on estimates of sand mining between January 1 and May 31 the expected level of incidental take resulting from mining by Hanson Aggregates was less than 1 salmon in both Suisun Bay and central Bay.

Adults

As a result of their large size and swimming performance in relationship to the size of the sand mining suction head it has been assumed that there would be no take of adult winter-run or spring-run Chinook salmon as a result of sand mining in either Suisun Bay or central San Francisco Bay. This finding is consistent with observations during sand mining by captains and crew that no adult salmon have been observed to be entrained during sand mining operations in the Bay-Delta estuary.

Longfin and Delta Smelt

Adult delta and longfin smelt migrate upstream to spawn primarily in the Sacramento River, Cache Slough, and Sacramento Deep Water Ship Channel. The adults of both species lay adhesive eggs on firm substrate. After incubation the larval smelt hatch and begin passively drifting downstream as planktonic larvae. The planktonic larvae of longfin smelt are present in the Delta and Suisun Bay during the late winter and early spring and the larvae of delta smelt are present in the spring months. Delta smelt inhabit Suisun Bay and the Delta throughout their life. Longfin smelt spawn and the larvae disperse within the Delta and Suisun Bay during the late winter and spring, however, a substantial proportion of the juvenile and adult longfin smelt inhabit more marine waters within San Pablo and central Bay. CDFG has implemented fishery surveys for larval and early juvenile smelt (20mm surveys starting in 1995) which provide data on the seasonal and geographic distribution of delta and longfin smelt densities within the Delta and Suisun Bay. Data on larval and juvenile smelt densities from the CDFG surveys have been used as part of the technical foundation for this assessment of potential entrainment risk. Larval smelt surveys have been conducted by CDFG during the winter and early spring over the past several years (starting in January 2009), however, these survey data have not been used in this analysis as a result of high variability and short survey duration. Data on the densities of juvenile and adult smelt are available, and have been used, from the CDFG Bay Study otter trawl surveys that began in 1980.

Eggs

Based on their life histories it was concluded that adhesive eggs of delta and longfin smelt, which are thought to be laid in shallow channel margin habitat, would not be vulnerable to entrainment during sand mining. Delta and longfin smelt are not known to spawn in the deeper subtidal areas where sand mining occurs. Neither delta or longfin smelt are known to spawn in habitats within central Bay. As a result of these factors there is no risk of take of eggs of delta or longfin smelt eggs as a result of sand mining in either Suisun Bay or central San Francisco Bay.

Larvae

Delta and longfin smelt inhabiting Suisun Bay and the Middle Ground Shoal have planktonic early lifestages (e.g., larvae) that would potentially be susceptible to entrainment during sand mining. To estimate the number of larval and early juvenile delta and longfin smelt that could be entrained during sand mining, the amount of water pumped was multiplied by the density of each plankton stage by region by month by mining event. Data on the seasonal and geographic distribution of larval and early juvenile smelt densities was derived from CDFG 20mm surveys that began in 1995. Smelt densities for the Suisun Bay mining area were based on average monthly densities (no./10,000 m^3) at Stations 804, 508, and 504 over the period from 2000-2010. Smelt densities for the Middle Ground Shoal mining area were based on survey results for Station 411.

Results of the analysis of potential take of delta and longfin smelt larvae and early juveniles as a result of proposed sand mining by Hanson Aggregates in Suisun Bay and Middle Ground Shoal are summarized in Tables 5-2 and 5-3. Based on the assumptions used in these analyses and average monthly delta and longfin smelt densities it was estimated that the potential incidental take would be 1,966 larval longfin smelt and 55 larval delta smelt in Suisun Bay. The estimated level of incidental take would be 619 larval longfin smelt and 5 larval delta smelt in Middle Ground Shoal. No larval Delta or longfin smelt are expected to be entrained by sand mining in Central Bay.

Juveniles and Adults

Juvenile and adult delta smelt inhabit Suisun Bay and would potentially be vulnerable to entrainment during sand mining in Suisun Bay and Middle Ground Shoal. Juvenile and adult longfin smelt inhabit central San Francisco Bay where they would also potentially be vulnerable to entrainment during sand mining. Data on the densities and distribution of longfin and delta smelt used in the analysis was based on results of CDFG Bay Study otter trawling. CDFG has collected fish samples that have been used to estimate fish densities at sampling stations located in both Suisun Bay and central San Francisco Bay. Densities of longfin smelt collected in the Bay-Study otter trawl were based on young-of-year (age 0) and yearling (age 1) smelt. Data on delta and longfin smelt densities from CDFG sampling at Station 214 were used to represent central Bay, Station 433 to represent Middle Ground Shoal, and Station 535 to represent Suisun Bay. Average monthly densities were calculated over the period from 2000 to 2010 and assuming a mouth opening of the otter trawl is 1 m high to calculate smelt densities (no./10,000 m^3). Data on smelt densities from the otter trawl sampling were used in the analysis since the suction head used in sand mining is operational only when in close proximity to the channel bottom. As discussed above, the estimates were based on the proposed maximum annual sand harvest volume (Section 3) and number of mining events for each region and lease area, an assumed distribution of mining events each month of the year, and the corresponding average monthly density of juvenile and adult delta and longfin smelt within each region of the estuary. The estimates of entrainment were based on the sand:water ratio in the slurry. Monthly estimates of entrainment based on these data and assumptions were then summed over the year to develop an estimated annual incidental take for both delta and longfin smelt.

Results of the analysis of potential incidental take of longfin and delta smelt as a result of entrainment are summarized in Table 5-4 for sand mining by Hanson Aggregates in the Suisun Bay region, Table 5-5 for Middle Ground Shoal, and Table 5-6 for central Bay. The estimated level of incidental take of juvenile and adult longfin and delta smelt in Suisun Bay (Table 5-4) was 107 and 13 fish, respectively. The level of incidental take associated with sand mining in Middle Ground Shoal was 26 longfin smelt and 1 delta smelt (Table 5-5). The level of incidental take associated with sand mining in central Bay was 2,254 longfin smelt and 0 delta smelt (Table 5-6). As noted for salmon, the risk of incidental take of juvenile and adult delta and longfin smelt may be reduced as a result of behavioral avoidance response to noise and benthic disturbance associated with sand mining.

Table 5-2. Hanson sand mining in Suisun Bay 20 mm densities (2000-2010).

				Longfin Smelt		Delta Smelt	
Total Mined	**Cubic Yards/Year (150,000 yd^3)**	**Number of Events**	**Volume per month (10,000 m^3)**	**Density**	**Loss(1)**	**Density**	**Loss(1)**
January	9,900	4.0	1.1	0.0	0	0.0	0
February	10,200	4.1	1.2	0.0	0	0.0	0
March	11,850	4.7	1.3	726.2	973	2.1	3
April	12,000	4.8	1.4	517.0	702	2.6	4
May	12,000	4.8	1.4	167.1	227	12.3	17
June	15,000	6.0	1.7	34.6	59	15.7	27
July	12,150	4.9	1.4	4.0	6	4.2	6
August	13,800	5.5	1.6	0.0	0	0.0	0
September	15,450	6.2	1.7	0.0	0	0.0	0
October	14,400	5.8	1.6	0.0	0	0.0	0
November	12,150	4.9	1.4	0.0	0	0.0	0
December	10,950	4.4	1.2	0.0	0	0.0	0
				Total	**1,966(2)**		**55(2)**

(1)Assuming 83:17 ratio of water:sand and 75% of water is from interstitial sources.

(2)Totals may not match due to rounding.

Table 5-3. Hanson sand mining in Middle Ground Shoal 20mm densities (2000-2010).

				Longfin Smelt		Delta Smelt	
Total Mined	**Cubic Yards/Year (50,000 yd^3)**	**Number of Events**	**Volume per month (10,000 m^3)**	**Density**	**Loss[(1)]**	**Density**	**Loss[(1)]**
January	3,300	1.3	0.4	0.0	0	0.0	0
February	3,400	1.4	0.4	0.0	0	0.0	0
March	3,950	1.6	0.4	556.2	249	0.0	0
April	4,000	1.6	0.5	562.3	254	0.3	0
May	4,000	1.6	0.5	234.7	106	4.3	2
June	5,000	2.0	0.6	14.7	8	4.8	3
July	4,050	1.6	0.5	2.5	1	1.5	1
August	4,600	1.8	0.5	0.0	0	0.0	0
September	5,150	2.1	0.6	0.0	0	0.0	0
October	4,800	1.9	0.5	0.0	0	0.0	0
November	4,050	1.6	0.5	0.0	0	0.0	0
December	3,650	1.5	0.4	0.0	0	0.0	0
				Total	**619[(2)]**		**5[(2)]**

[(1)]Assuming 83:17 ratio of water:sand and 75% of water is from interstitial sources.

[(2)]Totals may not match due to rounding.

Table 5-4. Hanson sand mining in Suisun Bay – Bay study densities (2000-2010).

				Longfin Smelt		Delta Smelt	
Total Mined	**Cubic Yards/Year (150,000 yd^3)**	**Number of Events**	**Volume per month (10,000 m^3)**	**Density**	**Loss(1)**	**Density**	**Loss(1)**
January	9,900	4.0	1.1	18.8	21	0.0	0
February	10,200	4.1	1.2	15.0	17	0.0	0
March	11,850	4.7	1.3	11.5	15	0.0	0
April	12,000	4.8	1.4	1.8	2	0.0	0
May	12,000	4.8	1.4	1.7	2	0.0	0
June	15,000	6.0	1.7	0.0	0	0.0	0
July	12,150	4.9	1.4	2.4	3	0.0	0
August	13,800	5.5	1.6	0.9	1	1.6	2
September	15,450	6.2	1.7	1.0	2	2.9	5
October	14,400	5.8	1.6	1.0	2	2.2	4
November	12,150	4.9	1.4	24.8	34	1.2	2
December	10,950	4.4	1.2	5.3	7	0.0	0
				Total	**107(2)**		**13(2)**

(1)Assuming 83:17 ratio of water:sand and 75% of water is from interstitial sources.

(2)Totals may not match due to rounding.

Table 5-5. Hanson sand mining in Middle Ground-Bay study densities (2000-2010).

				Longfin Smelt		Delta Smelt	
Total Mined	**Cubic Yards/Year (50,000 yd^3)**	**Number of Events**	**Volume per month (10,000 m^3)**	**Density**	**Loss[(1)]**	**Density**	**Loss[(1)]**
January	3,300	1.3	0.4	11.6	4	0.0	0
February	3,400	1.4	0.4	7.9	3	0.0	0
March	3,950	1.6	0.4	7.2	3	0.0	0
April	4,000	1.6	0.5	0.0	0	0.0	0
May	4,000	1.6	0.5	7.3	3	0.0	0
June	5,000	2.0	0.6	0.0	0	0.0	0
July	4,050	1.6	0.5	5.8	3	1.2	1
August	4,600	1.8	0.5	0.0	0	0.0	0
September	5,150	2.1	0.6	1.3	1	0.0	0
October	4,800	1.9	0.5	6.1	3	0.0	0
November	4,050	1.6	0.5	5.2	2	0.0	0
December	3,650	1.5	0.4	8.3	3	0.0	0
				Total	**26[(2)]**		**1[(2)]**

[(1)]Assuming 83:17 ratio of water:sand and 75% of water is from interstitial sources.

[(2)]Totals may not match due to rounding.

Table 5-6. Hanson sand mining in Central Bay - Bay study densities (2000-2010).

				Longfin Smelt		Delta Smelt	
Total Mined	**Cubic Yards/Year (1,540,000 yd^3)**	**Number of Events**	**Volume per month (10,000 m^3)**	**Density**	**Loss[1]**	**Density**	**Loss[1]**
January	101,640	41	11.5	14.0	161	0.0	0
February	104,720	42	11.8	4.1	49	0.0	0
March	121,660	49	13.8	4.4	61	0.0	0
April	123,200	49	13.9	2.5	35	0.0	0
May	123,200	49	13.9	1.1	15	0.0	0
June	154,000	62	17.4	20.9	364	0.0	0
July	124,740	50	14.1	7.0	99	0.0	0
August	141,680	57	16.0	32.2	516	0.0	0
September	158,620	63	17.9	20.2	362	0.0	0
October	147,840	59	16.7	12.0	201	0.0	0
November	124,740	50	14.1	17.8	251	0.0	0
December	112.420	45	12.7	11.1	141	0.0	0
				Total	**2,254[2]**		**0[2]**

[1]Assuming 83:17 ratio of water:sand and 75% of water is from interstitial sources.

[2]Totals may not match due to rounding.

Summary of Incidental Take

Based on the assumptions and methods outlined above estimates were derived on the potential risk of incidental take of winter-run and spring-run Chinook salmon and delta and longfin smelt as a result of entrainment into the suction head during sand mining. Based on results of these analyses the level of potential incidental take of CESA listed fish associated with the maximum proposed level of sand mining by Hanson Aggregates is summarized in Table 5-7.

Table 5-7. Summary of potential incidental take associated with entrainment during sand mining.

Winter-run Chinook Salmon	Egg	Larvae	Juvenile	Adult
Suisun Bay	0	0	5	0
Middle Ground	0	0	(a)	0
Central Bay	NA	NA	NA	0
Total	0	0	5	0
Spring-run Chinook Salmon				
Suisun Bay	0	0	9	0
Middle Ground	0	0	(a)	0
Central Bay	NA	NA	NA	0
Total	0	0	9	0
Delta Smelt				
Suisun Bay	0	55	13	(b)
Middle Ground	0	5	1	(b)
Central Bay	NA	NA	0	(b)
Total	0	60	14	(b)
Longfin Smelt				
Suisun Bay	0	1966	107	(b)
Middle Ground	0	619	26	(b)
Central Bay	NA	NA	2254	(b)
Total	0	2585	2387	(b)

(a)Estimates for Suisun Bay and Middle Ground were combined
(b)Estimates for juvenile and adult lifestages were combined

5.7 Effects of Sound Pressure (Noise)

Sand mining operations within the San Francisco Bay-Delta estuary use hydraulic dredges to mine sand for construction aggregates. As a result of sand mining activity, underwater noise is produced from the tug engines, propeller turbulence, operation of the hydraulic centrifugal pump and hydraulic drag head (Section 3).

In recent years concerns have been raised regarding underwater sounds of anthropogenic origin and their potential impacts on aquatic organisms (Division of Energy Research 2001, Popper 2003). Though the majority of research has been focused on marine mammals, there is also potential for underwater sounds to affect protected fish, since many species use sound to find prey, avoid predators, and for social interactions (Popper 2003). Also, the sensory receptors for sound detection are similar to those of marine and terrestrial mammals, and therefore it is possible that sounds affecting marine mammals may also affect fish. It has also been shown that all fishes are able the detect sound within the frequency range of the most widely occurring anthropogenic sounds (Popper 2003).

Anthropogenic sound may have no effect on fish, or may result in various behavioral or physiological responses depending on the lifestage and species of the animal and the intensity and duration of the sound. Behavioral responses may involve the fish swimming away, thereby decreasing the potential physiological effect. Behavioral alterations however, could result in fish leaving a feeding ground or an area associated with reproductive activity. Such behavioral responses that result in longer term behavioral change may subsequently affect survival and reproduction. Direct physiological effects are also possible for various fish species and lifestages resulting in temporary to permanent hearing loss, damage to internal organs and even mortality for sound sources at certain intensities.

Sound is produced during sand mining operations from tug engines, propeller rotation, the action of waves against the hull of the barge and tug, centrifugal pumps, and dredge head suction. All combine to produce underwater sound. This mix of sound persists in a single locale (a pothole area or a trawl line) for the duration of the mining event, typically 3 to 5.5 hours; the tug/barge also generates noise during the journey to and from the mining site (Section 3).

Most underwater sound from suction dredges are at low frequencies, primarily between 20 to 1000 Hz, but typically found to be around the 400 Hz frequency (Greene 1987: cited in Richardson *et. al.* 1990). Dredges remain stationary for prolonged periods, and in the case of mining in the Bay-Delta estuary, sand mining operates within small areas, resulting in a continuous noise from a single point source over a period of several hours (Section 3). Sound pressure levels decrease exponentially underwater with increasing distance (Richardson *et. al.* 1990).

Richardson *et al.* (1990) conducted a study to assess distances and received sound for industrial sounds carrying through a water body. For this study, controlled experiments were carried out in which suction dredge operations were assessed for underwater sound levels and range. Dredge noise levels were recorded to establish noise levels and radius at various distances. Dredge sounds were recorded at a depth of 13 m from a suction dredge similar to suction dredges used for sand mining in the Bay-Delta estuary. Recording of noise levels from dredge operations were carried out at distances of 0.2 to 15 km. At 1.2 km, Richardson *et al.* (1990) found the noise level generated by the dredge was 120 dB, or 22 dB above the ambient measured noise level of 98 dB. At a distance of 2-4 km, the same suction dredge and support vessels produced a measured sound level of 112 dB. This is generally consistent with results from Greene (1987) who measured noise from hopper dredges and a hopper barge, and found the noise level was 115-117 dB in the 20-1000 Hz range at 13 km distance from the operation. Based on these measurements, received broad band noise levels (Hz) are expected to equal the average ambient noise level (98 dB) 10 km to 20 km from dredge (Richardson *et. al.* 1990). Received broad band noise levels (Hz) are expected to equal the average ambient noise level (98 dB) 15 km from dredge. Ambient noise level is often 10 dB above or below the median measured by Richardson *et al.* (1990). Based on these results dredge noise is expected to be 115 dB 4.6 km from dredge operations. Different levels of noise measured would occur within similar radii if water depths were greater or less than the 13-15 m of dredge operations.

A critical aspect of underwater acoustics is that low frequency sound propagates very poorly in shallow waters such as rivers and streams. This is due to the wavelength being larger than the water depth (Rogers and Cox 1988 cited in Popper and Carlson 1998). Low frequency sounds attenuate far more rapidly with distance from the source in shallow water than in deep water. As water depth increases, lower frequency sound waves are able to carry further. Over a rocky bottom, the lowest frequency that can be propagated in water 1 m deep is 300 Hz (Rogers and Cox 1988), whereas if the water is 10 m deep, frequencies around 30 Hz can be propagated (Rogers and Cox 1988). Substrate also affects attenuation rates, and for a given depth, lower frequencies can be propagated over soft bottoms than over hard bottoms.

Vessel size, hull construction, speed, and mode of operation influence sound levels generated by boats and ships. Large vessels generally produce more sound than smaller vessels. Fully loaded or towing/pushing ships produce more sound then partially full or empty ships. Sound pressure levels could range from 150-160 dB for outboard engine types and other small vessels, where as supertankers and large container ships could range from 185-205 dB. Large ships could create a constant level of potentially disturbing noise for many kilometers around the vessel, however large ships have been found to produce a lower frequency noise. Outboard engines from small craft tend to produce a high frequency sound, and although the pressure levels are typically lower, the high frequencies generated have been found to cause a startle response in fish.

From the studies reviewed above, sand mining sound pressure levels are expected to be around 130-140 dB at frequencies ranging around 300-400 Hz at a depth of approximately 30-40 feet. At approximately 1 km from a sand mining operation sound pressure levels are expected to have decayed to 120 dB and a further drop in sound pressure level to 112 dB by approximately 3 km. These levels are expected to decay to ambient background levels by 15 km from the point of operation. Water depth and substrate, among other factors, will affect the time and distance taken for sound levels to reach ambient background levels. No actual sound pressure measurements are available for sand mining within the Bay-Delta estuary for use in validating these predictions.

Results of studies available in the scientific literature show the awareness thresholds of many species of fish, including Chinook salmon, steelhead trout, American shad, delta smelt, inland silversides, sturgeon, catfish, golden shiner and species of macroinvertebrates at various lifestages as well as Pacific herring eggs are not adversely impacted by sound pressure levels of up to 160 dB at frequencies of 300-400 Hz (San Luis and Delta Mendota Water Authority and Hanson 1996) as well as sound pressure levels of 166 dB at 100 Hz (Loeffelman *et al. 1*991). These sound pressure thresholds are levels at which the tested fish species have been found to significantly display behavioral avoidance. These tests resulting in behavioral avoidance have not resulted in sublethal effects or mortality. Some levels of stress or startle reaction have been observed at the described levels when sensitive fish species have been contained in a tank and exposed to the described levels. Normal behavior is resumed however when fish are released and are able to naturally avoid the sound source.

From the data described above it can be concluded that protected fish exposed to sand mining sound pressure levels of 130-140 dB at frequencies of 300-400 Hz in depths of sand mining operational parameters will not suffer lethal or sublethal effects. The levels of sound generated from the sand mining operations are typically around the threshold of fish awareness. It is probable that fish will behaviorally avoid sound pressure levels from sand mining if within the species hearing capacity. Based on these considerations it was concluded that underwater sound generated during sand mining is not expected to result in incidental take of winter-run or spring-run Chinook salmon, delta or longfin smelt.

5.8 Migration and Habitat and Use

The Bay-Delta estuary provides habitat supporting a diverse assemblage of fish and macroinvertebrate species. Subtidal habitats within Suisun Bay and Central Bay support larval dispersal and rearing (delta and longfin smelt), juvenile rearing of both salmon and smelt, migratory pathways, and subadult and adult holding and foraging habitat for the protected fish species. The fish and macroinvertebrate assemblage inhabiting Central Bay is characteristic of marine coastal waters, and species having a higher tolerance to salinity. Habitats within Suisun Bay also support diverse populations of fish and macroinvertebrates. The species assemblage within the Suisun Bay area is typical of low-salinity estuarine habitat conditions. Central Bay and Suisun Bay areas serve as important migratory corridors for both juvenile and adult lifestages of anadromous fish including Chinook salmon. Habitats within the Bay-Delta estuary have been identified by National Marine Fisheries Service as Essential Fish Habitat for managed species such as Pacific salmon and have also been identified as critical habitat under the Federal Endangered Species Act for spring-run and winter-run Chinook salmon (including both Suisun and Central Bay) and for delta smelt (Suisun Bay and the western delta). As part of the assessment of potential impacts of sand mining activity on these protected fish species, and their associated habitat, data were compiled on the geographic distribution of habitat conditions supporting protected fish species and the corresponding locations where sand mining activity occurs. Information on the seasonal and geographic distribution of protected fish within the estuary, in combination with the distribution of sand mining activity, provided a basis of assessing potential adverse effects on various species and their habitat. Results of these analyses are briefly summarized below.

Juvenile and adult Chinook salmon utilize Central Bay and Suisun Bay primarily as a migratory corridor between upstream freshwater river spawning and juvenile rearing habitat and nearshore marine coastal waters. Juvenile Chinook salmon migrating downstream through Central Bay and Suisun Bay forage on amphipods and other aquatic organisms. Adult Chinook salmon also migrate through Central Bay and Suisun Bay on their upstream migration to spawning areas within the Sacramento River and tributaries. The distribution of sand mining activity within Central Bay occurs within the areas utilized as a migratory pathway by both juvenile and adult Chinook salmon. A similar circumstance exists further upstream within Middle Ground Shoal and Suisun Bay where both adult and juvenile Chinook salmon migration occur within the deeper navigational channel coinciding with the locations where sand mining activity occurs. Juvenile Chinook salmon migrate downstream, predominantly in the mid- and upper portions of the water column and/or along the shallower shoals and channel margins and would not be expected to be vulnerable to substantial mortality resulting from entrainment into a hydraulic suction head.

Juvenile Chinook salmon could, however, be exposed to elevated suspended sediment concentrations associated with the overflow plume during sand mining. Results of laboratory investigations have shown that juvenile Chinook salmon are tolerant to elevated suspended sediment concentrations given the expected concentration and duration of exposure resulting from sand mining operations. Juvenile Chinook salmon migrants could experience a reduced ability to forage on macroinvertebrates and small fish during passage through an overflow plume, representing a localized and temporary effect, expected to have duration of several hours or less. Studies conducted by Gregory and Levings (1996) suggest that juvenile Chinook use increased turbidity and suspended sediments as cover during downstream migration which is thought to reduce their vulnerability to predation by fish, birds, and marine mammals. Given the geographic distribution of the overflow plumes resulting from sand mining within Central Bay and the navigation channel within Suisun Bay, it is not expected that the overflow plume would result in a barrier to juvenile Chinook salmon migration.

Adult Chinook salmon migrate upstream within the lower portion of the water column; however, as a result of the size of adult salmon and their swimming performance capability it is not expected that they would be vulnerable to entrainment into the hydraulic suction dredge. Adult Chinook salmon also have a high tolerance to suspended sediment concentrations (Whitman *et al.,* 1982), and therefore it would not be expected that sand mining operations resulting in elevated suspended sediment concentrations associated with either benthic disturbance or the overflow plume would result in a barrier to adult upstream Chinook salmon migration. Some adult Chinook salmon migrate upstream in close proximity to bottom bedforms, bedform disturbance, if severe, would have the potential to temporarily affect localized migration behavior. Given the topographic variability in bedforms within the estuary, including sand waves, and the shallow and temporary changes in local bathymetry following sand mining (particularly with moving pothole mining methods), it is considered to be unlikely that sand mining would result in bedform changes of a sufficient magnitude and duration to adversely affect adult salmon migration behavior.

The low-salinity areas within Suisun Bay, extending downstream to Middle Ground Shoal and Carquinez Strait, provide important habitat for a variety of resident and migratory fish and macroinvertebrates. In addition, these areas of the estuary serve as a migratory corridor for anadromous fish species including Chinook salmon, as well as rearing habitat for delta and longfin smelt. The occurrence of delta and longfin smelt throughout the year, and over a range of lifestages, including planktonic larvae, juveniles, and adults, in addition to the seasonal migratory patterns of juvenile and adult anadromous Chinook salmon and delta and longfin smelt, contributes to their potential vulnerability to adverse effects resulting from sand mining. Since sand mining within the Suisun Bay complex is limited to the deeper water channel areas, sand mining would not be expected to have any direct adverse impact on the quality or availability of shallow-water (e.g., water depths of 9 feet or less MLLW) within the area. These findings are consistent with the general results of a comparison of bathymetric contours within the Suisun Bay and Middle Ground Shoal areas between 1975 and 2001 (Hanson *et al.* 2004). Sand mining within the main navigation channel within Suisun Bay and Middle Ground Shoal occurs in a relatively high velocity, channelized portion of the estuary which, based upon available data, appears to be an area characterized by sediment accretions which would further reduce the potential risk of adverse affects of sand mining on habitat conditions for delta and longfin smelt as well as juvenile and adult Chinook salmon within these areas.

Protected fish inhabiting Suisun Bay, Middle Ground Shoal, and Central Bay could periodically be exposed to elevated suspended sediment concentrations associated with the overflow plume generated during sand mining activity. The estimated concentrations of suspended sediments within the overflow plume, however, appear to be within the general range of naturally occurring suspended sediment concentrations within the Suisun Bay complex, which is characterized by high suspended sediment concentrations seasonally as a result of increased freshwater inflow from the Sacramento and San Joaquin river systems and/or resuspension of fine sediments from shallow-water areas within the Suisun Bay complex as a result wind-driven and tidal currents and turbulence. The channel areas where sand mining activity occurs are characterized by relatively high water velocities that affect the distribution of overflow plume suspended sediments within the water body. Although resident (delta and longfin smelt) and migratory (Chinook salmon) fish species could be exposed to elevated suspended sediment concentrations within the overflow plume, the orientation of the plume offers opportunities for fish to behaviorally avoid the plume by moving laterally within the channel and therefore, overflow plume exposure is not expected to result in a barrier to fish movement or migration within the area. Exposure to the overflow plume, although not a barrier to fish migration and movement could contribute to short-duration delays (impediment) and a localized change in the distribution of sensitive fish within the channel and water column.

Increased suspended sediment concentrations could also result in temporary, localized, reductions in foraging success by larval and juvenile fish feeding on zooplankton. Exposure to elevated suspended sediment concentrations associated with the overflow plume is anticipated to be relatively short duration (e.g., minutes or hours) and therefore, reductions in prey capture ability as result of sand mining activity would not be expected to result in detectable changes in growth rates, condition, or survival of protected fish inhabiting the estuary. Further, studies on feeding behavior and geographic distribution of delta smelt suggest a behavioral preference for higher turbidities.

Information on the geographic distribution and habitat use by protected fish species has shown that many of the species occupy subtidal habitats where sand mining activity occurs within Central Bay, Middle Ground Shoal, and Suisun Bay channels. For Chinook salmon, delta smelt, and longfin smelt sand mining within various regions of the estuary occurs within areas utilized by these species and hence their vulnerability to direct and indirect take resulting from sand mining could be increased. Potential impacts of sand mining on these species and their habitat would include entrainment into the suction head, and exposure of sensitive species or lifestages to temporary, localized, increases in suspended sediment concentrations as results of both benthic disturbance and exposure to the overflow plume. Direct impacts of sand mining on subtidal habitats, such as rock outcrops and other hard substrate, are not expected to occur as a result of the active avoidance by sand miners of shallow habitat areas (e.g., less than 30 feet within Central Bay and 9 feet within the Suisun Bay complex), and rock outcrops and other structures that could damage mining equipment.

Entrainment as a result of sand mining has been identified as an incremental source of mortality to planktonic larvae of delta and longfin smelt occurring seasonally within Suisun Bay. The risk of entrainment is considered to be reduced for larger juvenile and adult fish with good swimming performance such as juvenile Chinook salmon and for those pelagic species such as juvenile and adult delta and longfin smelt that primarily inhabit the mid- and upper parts of the water column, and hence are less susceptible to entrainment into a drag head located on or in the bottom substrate.

Chinook salmon, delta and longfin smelt are tolerant of highly variable environmental conditions, including exposure to elevated suspended sediment concentrations and other habitat disturbances, and therefore would not be expected to be adversely affected by sand mining activity. Potential adverse effects of sand mining activity would primarily focus on the early lifestages of species that could be vulnerable to entrainment into the suction head during sand harvest and/or exposure to localized temporary increases in suspended sediment concentrations.