California State Water Resources Control Board Hearing Regarding Salton Sea
Testimony of Richard A. Vogl, Principal Hydrogeologist, HydroGeo Consultants

My name is Richard A. Vogl. I am a registered geologist in the states of California, Arizona, and Oregon. I am also a certified hydrogeologist, certified engineering geologist, and registered environmental assessor in the state of California. I currently am a Principal Hydrogeologist, and owner of HydroGeo Consultants, which is an environmental consulting firm specializing in assessment and remediation of contaminated soils and groundwater. I have been performing similar environmental work as a professional consultant for the past 15 years and have both a bachelors degree and masters degree in geology from California State University Los Angeles. I was previously employed by LFR Levine Fricke from 1991 through 2002 as a hydrogeologist and was the lead investigator of the Salton Sea sediment contaminants for a reconnaissance investigation conducted for the Salton Authority in 1998 and 1999. I am a native resident of southern California and have been visiting the Salton Sea regularly since I was approximately three years old, some 36 years ago.

Previous studies on Salton Sea bottom sediments have identified a variety of inorganic and organic chemicals, including organochlorine pesticide residues of banned DDT (1,1,1-trichloro-2,2-bis [p-chlorophenyl]-ethane) at concentrations as high as 82 milligrams per kilogram (mg/kg) (ERM 7 mg/kg) and its derivatives, DDD (1,1-dichloro-2,2-bis [p-chlorophenyl]-ethane) at concentrations as high as 24 mg/kg (ERM 20 mg/kg), DDE (1,1-dichloro-2,2-bis [p-chlorophenyl] ethylene) at concentrations as high as 110 mg/kg (ERM 27 mg/kg), and dieldrin at concentrations as high as 880 mg/kg (ERM 8). Many of these same chemicals, plus some additional ones, have been identified in the riverbeds feeding into the Sea, including DDT, DDD, DDE, dichloromethane, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, pesticides, selenium, and boron (Bechtel, 1997; Eccles, 1979; Hogg, 1973; Setmire [et al.], 1993; and Setmire and Stroud, 1990). Prior to LFR Levine· Fricke's (LFR) study, which I personally conducted, little was known about the current concentrations and distribution of these contaminants within the sediments of the Salton Sea.

LFR conducted a sediment study of Salton Sea for the Salton Sea Authority. This study was one of the first comprehensive studies to evaluate the overall distribution of sediment types and contaminants throughout the Sea and three of its adjoining tributaries. This study was conducted to provide valuable information to the Department of the Interior and Salton Sea Authority for saving this valuable ecosystem.

The Salton Sea is the largest lake in California, with a current size of 56.35 kilometers (km; 35 miles) long and 24.15 km (15 miles) wide and a maximum depth of approximately 15 meters (50 feet). The Sea is a closed drainage system that receives 2.3 inches of rain a year with temperatures reaching 120° Fahrenheit. Agricultural wastewater keeps the Sea alive and carries contaminants such as pesticides, selenium, and other metals, as well as salt leached from the agricultural fields.

An investigation of the physical and chemical characterization of sediments in and around Salton Sea, Imperial and Riverside Counties, California, was undertaken by LFR in the winter of 1998–1999. The study was implemented in two phases. The first phase sampled sediments on December 15 through 22, 1998, and analyzed contaminant concentrations and particle size distribution in the bottom sediment of the Sea plus approximately 1 mile up each of three of its main tributaries: the Whitewater, the Alamo, and the New Rivers. Phase I sediment samples were collected from 42 grab sampling sites and 6 core sampling sites.

Based on results of the first phase of investigation, a second phase of sediment sampling was conducted from January 19 through 22, 1999, to further assess and measure contaminant concentrations and evaluate particle size distribution in the bottom sediment. This second sampling phase focused on the significant areas of interest identified during Phase I and included sediment sampling at 15 grab sites and 10 core sites. The locations of Phase I and Phase II sampling sites are shown below.

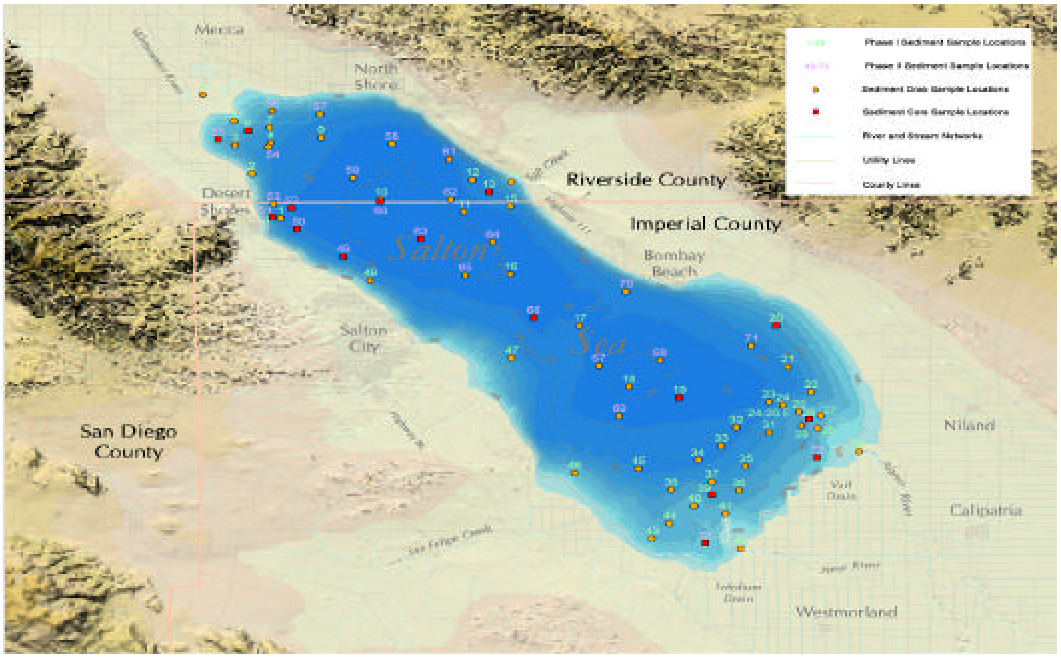

Figure 1: Phase I and II Sampling Locations

A stainless-steel modified Birge-Ekman-style box sediment sampler, 15.24 cm by 15.24 cm by 15.24 cm in size (6 inches by 6 inches by 6 inches), was used to collect samples at the 57 grab sample locations of the 73 sampling sites. For each grab sample, up to 24 ounces of material was retained for inorganic and organic chemical analyses, depending on sample recovery. Sediment samples were transferred directly from the sampling equipment into clean, laboratory-grade glass jars using a stainless-steel trowel.

The core samples were collected using an AMS stainless-steel soft sediment sampler that can produce a 5-cm (6-inch) diameter by 182-cm (6-foot) long square core. The corer can take up to 182 cm of undisturbed samples from soft sediment, provided that rocks or dense materials are not encountered. The AMS soft sediment sampler consists of two stainless steel, 182-cm (6-foot) long, right-angle-shaped sampler halves, each with a pointed lower end, that create a 5.08-cm (6-inch) square when locked together. One half contains a riveted sediment trap that engages when the sampler is pulled from the sediment. Sediment samples obtained using the stainless steel corer were collected from a boring advanced down to a maximum of 182 cm (6 feet) below ground surface (bgs), with samples for laboratory analyses taken at 30-cm (1-foot) intervals. The cores were carefully measured for total length and different layers of sediment without disturbing the sediment-water interface. Cored samples were lithologically described and classified using the Unified Soil Classification System. As with the grab samples, these samples were transferred to clean, laboratory-grade glass jars using a stainless steel trowel that was cleaned between samples.

Each sediment sample was analyzed for particle size, total inorganic metals consisting of the California Code of Regulations 17 metals series (antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc) using EPA Method 7000S, volatile organic compounds using EPA Method 8260, semi-volatile organic compounds using EPA Method 8270, chlorinated pesticides and PCBs using EPA Method 8081, organophosphate and nitrogen pesticides using EPA Method 8141, and chlorinated herbicides using EPA Method 8151. A number of sediment samples were also analyzed for chlorinated pesticides using EPA Method 8270 as a confirmatory measure.

Sediments sampled on the bottom of the Sea consisted of silt, clay, and finer grained sands. The shallow sediment also included abundant barnacle shells and occasional fish bones. The surface sediment composition included a high percentage of sand outside Salton City and extending into the central, deeper parts of the Sea. Sand percentages near the mouths of the New and Alamo rivers were also high, as expected, from deposition of these heavier particles from higher velocity inflows into the Sea. The lower velocity Whitewater River delta, on the other hand, was predominantly silt. Silt was also abundant along the southwest near-shore area and along the shallow water bays near the New and Alamo rivers. A shallow layer of clay blankets the southwestern corner of the Sea and extends toward the center, near the deepest part of the Sea. Clay is also abundant near shore and offshore just north of Desert Shores. The majority of the deeper sediment sampled consisted predominantly of varied amounts of silt and clay, with lesser amounts of fine sand. The distribution of silt, sand, and clay determined from this study are depicted in Figures 2, 3, and 4, respectively.

The inorganic and organic chemicals of concern were identified using available comparative values (e.g., maximum "baseline value" for soils of the western United States (Severson et al., 1987; modified from Shacklette and Boerngen, 1984). The NOAA biological effects range low (ERL) and effects range medium (ERM) values (Long et al., 1995) were also used as comparative values on Phase I sample results to identify which contaminants should be the focus of additional sampling efforts in Phase II and any follow-up studies. The ERL and ERM values are guidelines used to evaluate whether sediment chemical concentrations were within ranges that have been reported to be associated with biological effects. These guidelines were generated from a large national sediment database and are currently the most widely used and accepted sediment effects guidelines available. ERMs are the concentrations at which 50 percent of the studies for a particular chemical showed biological effects, and ERLs are the concentrations at which 10 percent of the studies showed biological effects. Since sediment chemical concentrations below ERLs are interpreted as being "rarely" associated with adverse effects, exceedances of ERM values and maximum baseline values were used to identify chemicals of potential concern. However, use of these criteria for evaluating ecological risk was beyond the scope of this assessment. Also, as a result of the Sea's unique ecosystem, whose characteristics (high salinity) put it well outside the database used to determine the ERLs and ERMs, these values may not be applicable for evaluating ecological risk at the Sea. A number of the chemicals of concern (including selenium and molybdenum) do not currently have ERM or ERL values for comparison. For selenium, SFRWQCB guidelines for sediment suitable for cover (0.7 mg/kg) and noncover (1.4 mg/kg) sediment in wetlands creation projects were used for comparisons purposes. For molybdenum, a baseline value of 4.0 mg/kg (Severson et al., 1987; modified from Shacklette and Boerngen, 1984) was used as a comparative value.

Selenium and molybdenum did not have established ERL or ERM values, but did regularly exceed their corresponding screening values (0.7 mg/kg and 1.4 mg/kg, and 4.0 mg/kg, respectively). Selenium, a naturally occurring element in the region's soils and waters, is also known to be leached into Salton Sea as a result of current irrigated agricultural practices. The selenium concentrations found during this investigation appear to be elevated with respect to previously reported background concentrations and Salton Sea data. For example, Shacklette and Boerngen (1984) analyzed 733 samples of undisturbed soil collected throughout the western United States. A comparison of their selenium data with the 118 selenium concentrations measured in this study reveals a 78 percent increase in this element's geometric mean. The Shacklette and Boerngen (1984) data can be used to calculate a "maximum baseline level" of 1.4 mg/kg (based on the geometric mean times the geometric deviation squared). Assuming a log normal distribution of only approximately 5 percent of natural background, selenium values should exceed this level. However, this value was equaled or exceeded by 18 of the 118 (or 15%) collected in this study. The maximum concentration of selenium reported by Shacklette and Boerngen (1984) was 4.3 mg/kg. This value was equaled or exceeded by seven of the 118 samples collected during this study. The highest measured concentration in this study (8.5 mg/kg) is nearly twice the maximum concentration reported by Shacklette and Boerngen and slightly higher than the previous maximum value measured in the Salton Sea of 8.4 mg/kg reported in Bechtel (1984).

The potential for the observed contaminant concentrations to adversely affect benthic organisms can be assessed preliminarily by comparison with available sediment guidelines (ERLs and ERMs) developed by Long et al. (1995). However, as a result of the Sea's unique ecosystem, whose characteristics (especially high salinity) put it well outside the database used to develop the ERLs and ERMs, the relationship of these comparative values to those detected at the Sea for evaluating ecological risks are unknown but suspected to be higher estimates than expected under the stressed conditions of the Sea's environment. The biota of the Salton Sea’s high salinity waters also differ from the organisms found in estuarine areas for which the ERLs and ERMs were developed.

Concentrations of inorganic chemicals in the sediments were found to be higher in the northern part of the Sea. Concentrations were generally higher in the upper 30 cm (1 foot) of sediment. Based on these screening criteria, the following chemicals were determined to be elevated and of potential ecological concern: cadmium, copper, molybdenum, nickel, zinc, and selenium, with the most elevated inorganic constituent being selenium. In addition, the ERL value of lead was exceeded at one sampling location (50 mg/kg). None of these chemicals were detected at concentrations above their respective ERM values. Also, although arsenic concentrations were not above ERL values, concentrations detected were as high as 7.1 mg/kg which do exceed United States Environmental Protection Agency (US EPA), Region 9, preliminary remediation goals (PRGs) for both residential (0.039 mg/kg) and industrial (2.7 mg/kg) areas for arsenic using a cancer endpoint.

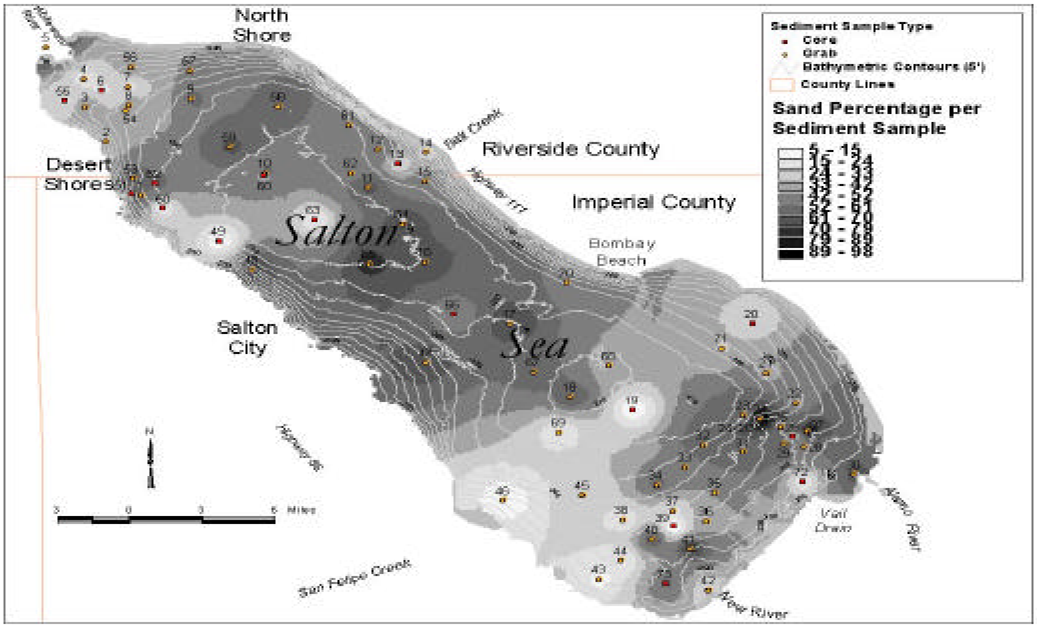

Figure 2: Sand Percentage per Sediment Sample

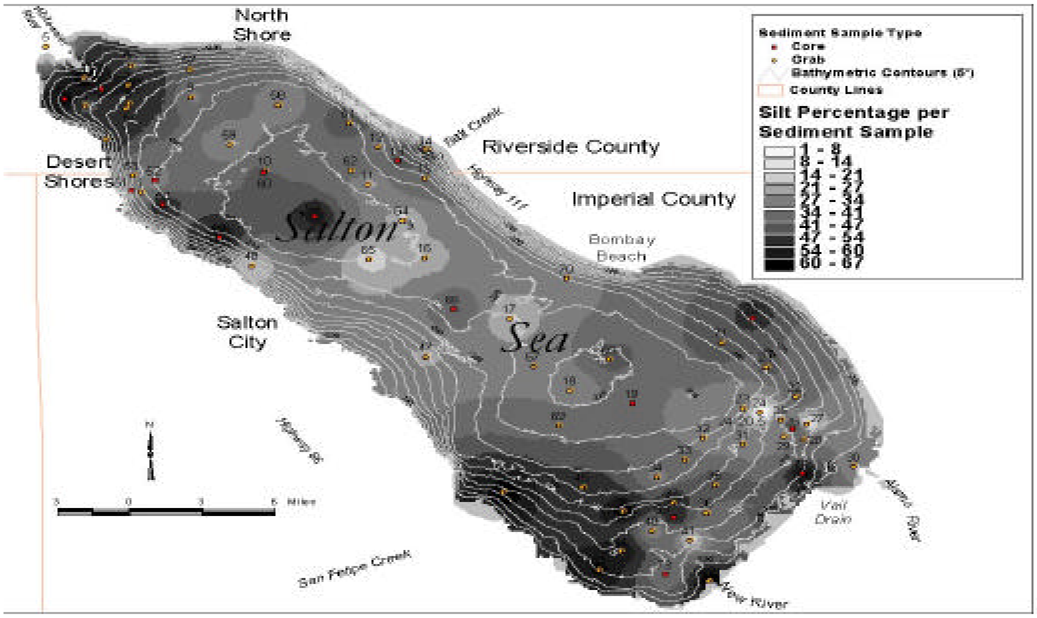

Figure 3: Silt Percentage per Sediment Sample

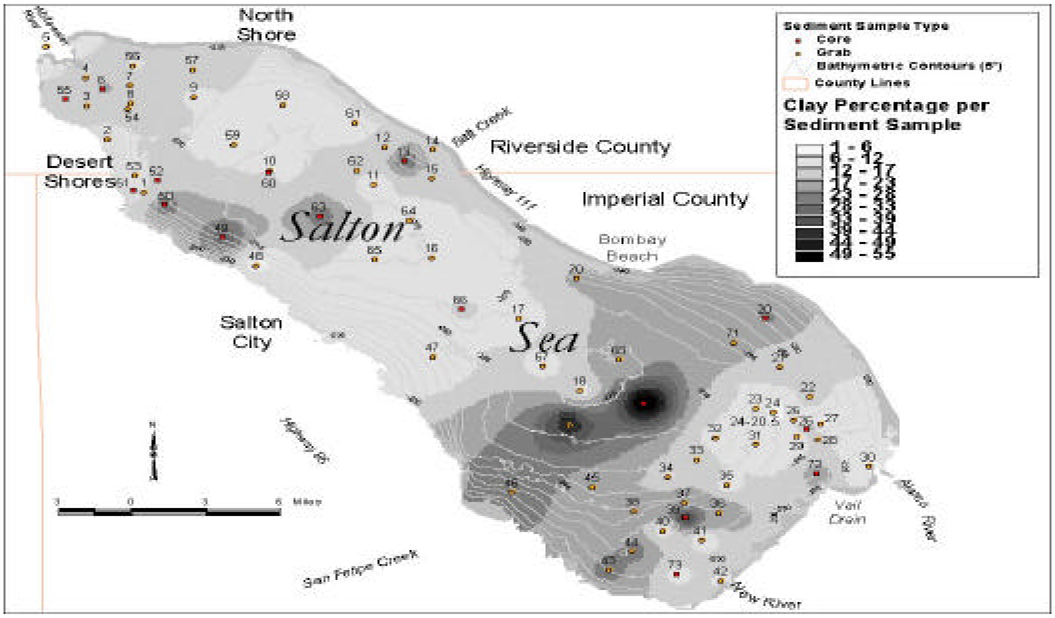

Figure 4: Clay Percentage per Sediment Sample

Concentrations of cadmium ranged from 0.67 to 5.8 mg/kg. The highest reported concentrations of cadmium were found in the north-central part of the Sea. Concentrations of copper ranged from 8.1 to 53 mg/kg. The highest concentrations were found near the mouth of the Whitewater River. Concentrations of molybdenum detected in the north and central part of the Sea ranged from approximately 11 to 194 mg/kg. The range of reported concentrations for nickel was from 3.3 to 33 mg/kg. The highest concentrations of nickel were detected at the mouth of the Whitewater River and in the deeper portion of the Sea. The range of concentrations for zinc was from 5.4 to 190 mg/kg. The highest concentrations of zinc were found at the mouths of the Whitewater River and Salt Creek. Concentrations of selenium detected at the Sea ranged from 0.086 to 8.5 mg/kg. The highest concentrations of selenium were found just offshore of Desert Shores. In general, inorganic and organic chemical concentrations were elevated over much of the northern half of the Sea. The distribution of detected concentrations of cadmium, molybdenum, nickel, and selenium are depicted in Figures 5, 6, 7, and 8, respectively.

Elevated concentrations of organic chemicals were detected in sediment predominately in the northern part of the Sea. Of the 118 sediment samples analyzed for volatile organic compounds, 114 samples contained detectable concentration of acetone, carbon disulfide, and/or 2-butanone. These three detected chemicals are believed to be present as a result of natural biological processes occurring within Salton Sea sediment. Acetone concentrations ranged from 32 to 840 µg/kg. The highest concentrations of acetone were located near the mouth of the New River. Carbon disulfide concentrations ranged from 15 to 1,800 µg/kg. The highest concentrations of carbon disulfide were near the mouth of the Whitewater River. Concentrations of 2-butanone ranged from 11 to 150 µg/kg. The highest concentration of 2-butanone was located in the northern portion of the Sea, offshore from Salton Sea State Park.

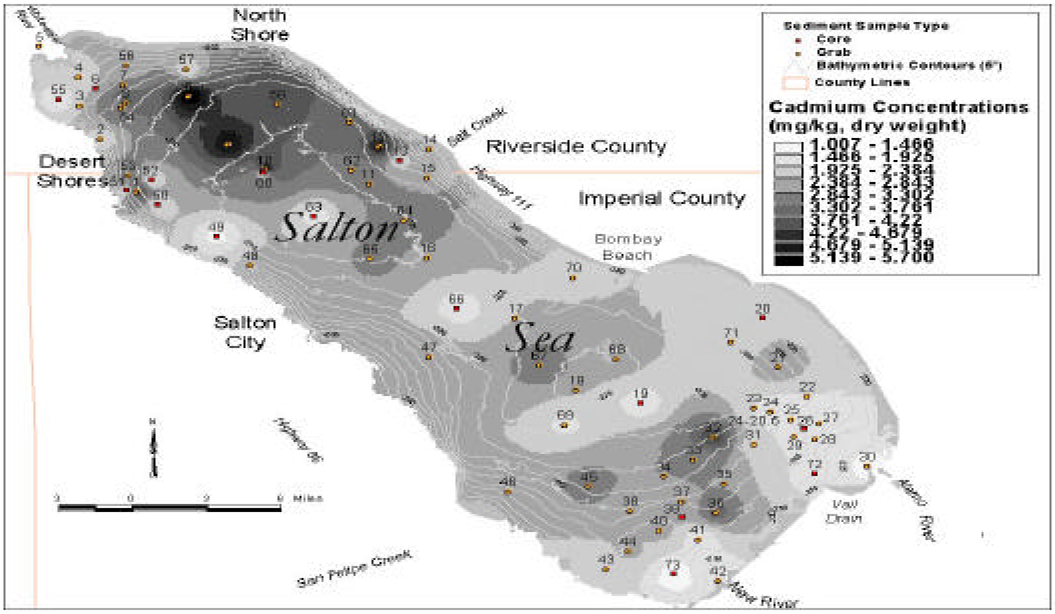

Figure 5: Cadmium Concentrations

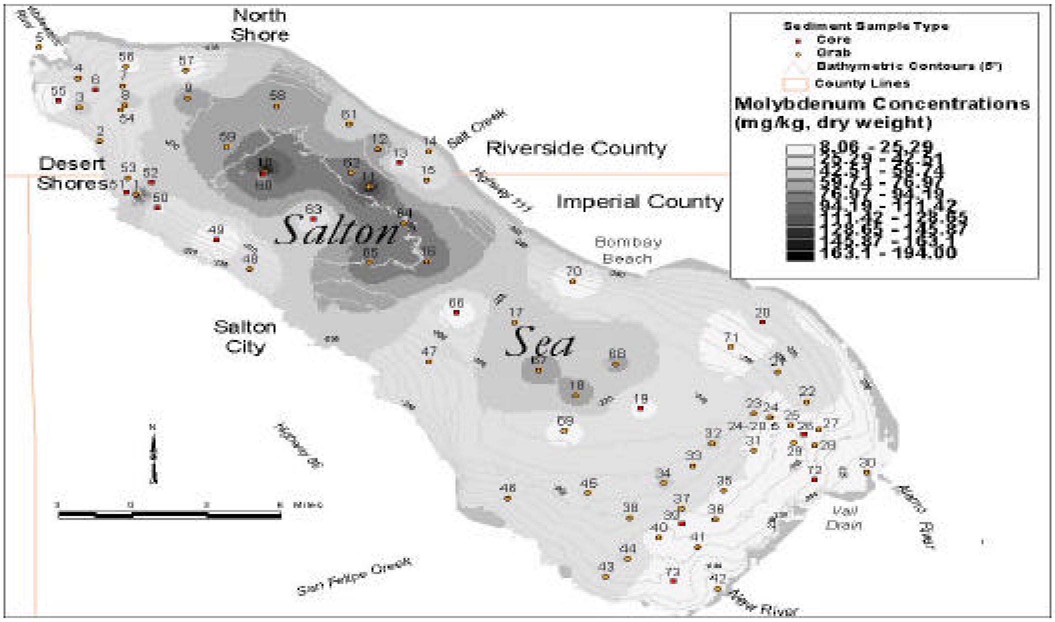

Figure 6: Molybdenum Concentrations

Only two other sediment samples contained other detectable concentrations of volatile organic compounds, including o-xylenes, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, naphthalene, and n-propylbenzene. These chemicals appeared to be very localized and non-pervasive.

Although concentrations of organochlorine pesticides were not detected in LFR's study because of elevated reporting detection limits, a number of previously detected concentrations for these pesticides were reported by others at concentrations below the laboratory detection limits for this study and at higher concentrations. The detection limit problem resulted from the characteristics of Salton Sea sediments, which contain very high levels of organic carbon and sulfur. For each analysis, the laboratory attempted to achieve the lowest detection limit possible based on the available sample size and matrix sampled.

A copy of LFR's Report of "Environmental Reconnaissance of The Salton Sea Sediment Contaminants" which summarizes this investigation and other pertinent past investigations is submitted as Exhibit A to further support this testimony.

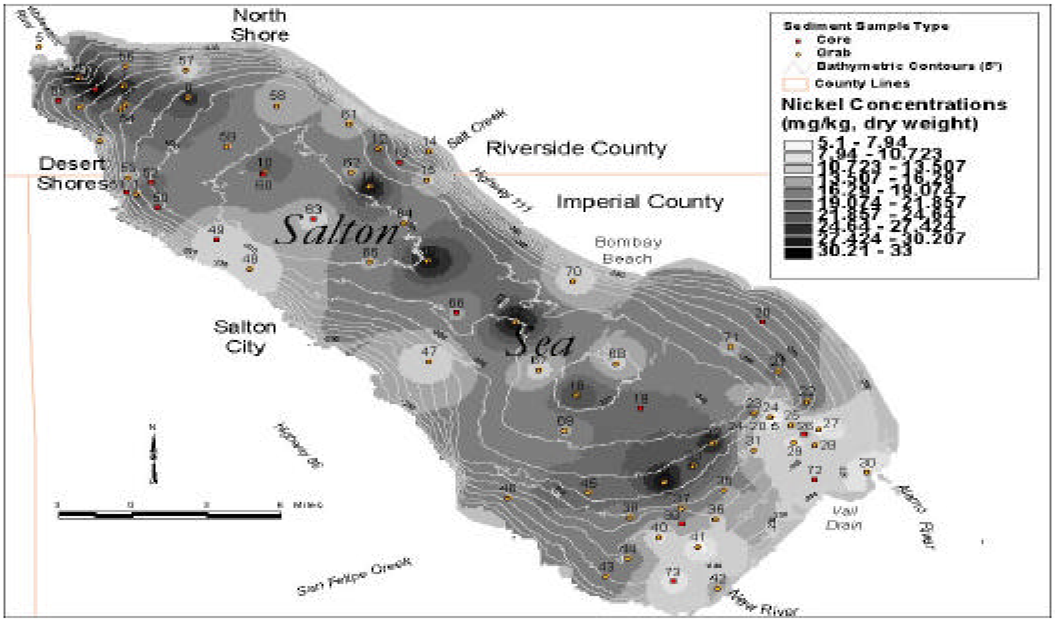

Figure 7: Nickel Concentrations

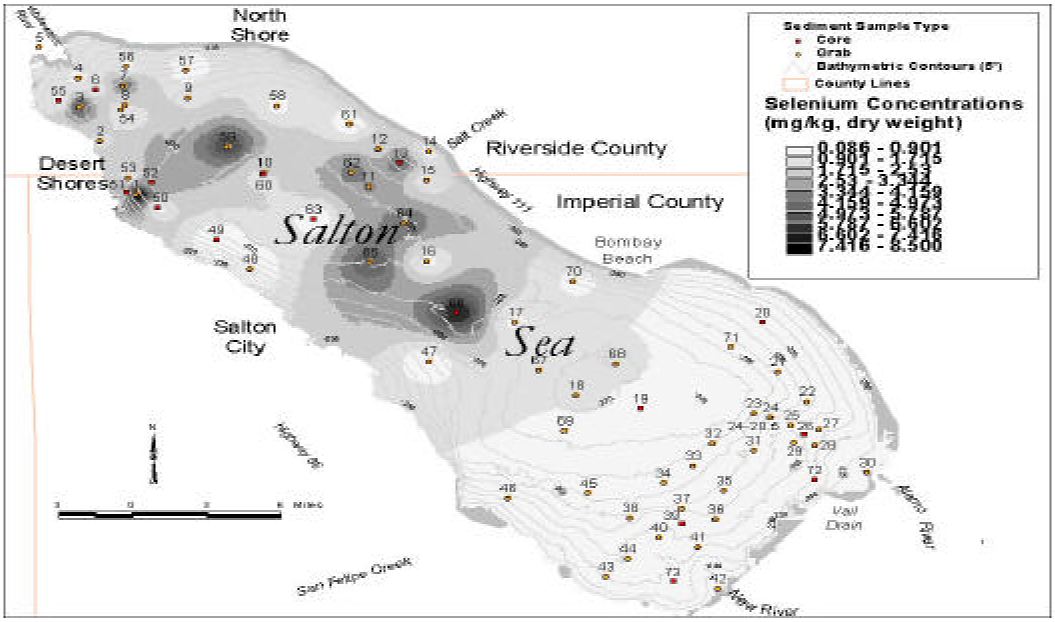

Figure 8: Selenium Concentrations

Based on the results of this study conducted by myself and LFR, I believe that the concentrations of inorganic chemicals including arsenic, cadmium, copper, lead, molybdenum, nickel, selenium, and zinc along with organic chemicals such as acetone, 2-butanone, and carbon disulfide, could have a negative impact on human health and the surrounding biota of the Salton Sea Basin if the water level of the Sea is not maintained at its current level. This would also be true for the concentrations of pesticides reported by others for the area such as DDT, DDD, DDE, and dieldrin. The lowering of the Sea would allow these sediments with elevated concentrations to become exposed. This exposure can result in a number of different potential scenarios which could greatly increase the bioavailability of these identified contaminants. These scenarios include fine grained sediment with elevated contaminant concentrations becoming airborne and inhaled and possibly ingested by humans and fauna of the area; increased bioavailability of contaminants from sediments with elevated concentrations of contaminants that were previously submerged and had more limited bioavailability; and increased bioavailability of contaminant as a result of leaching from exposed sediment as a result of changing submerged sediments from a reduced state to a more oxidized state where the metals and metalloids may become more soluble.

As demonstrated during LFR's field investigation, many of the sediments encountered within the Sea, especially the upper most layers of sediments consist of very fine grained sediments comprised of high percentages of silt and clay sized particles. If elevated wind conditions occur, the sediment could become air borne and travel great distances. Exposure to these sediments would not only become a health issue as a result of PM-10 values but also as a result of exposure to the organic and inorganic contaminants that have been accumulating in the Salton Sea sediments from agricultural runoff. Increased exposure from inhalation may occur with respect to arsenic, cadmium, copper, lead, molybdenum, nickel, selenium, zinc, DDT, DDD, DDE, and dieldrin. In addition, typically some of these particulates containing these constituents will not be inhaled directly into the lungs of those exposed but may fall out in the air passage and be later ingested with mucus. In addition, the maximum arsenic concentrations observed at the Sea if airborne at PM-10 levels of grater than 150 micrograms per cubic meter could result in ambient concentrations of arsenic of 0.001065 micrograms per cubic meter which are well in excess of the US EPA Region 9 PRGs for arsenic in ambient air of 0.00045 micro grams per cubic meter. During LFR field investigation during the winter of 1989-1990, which was conducted during two separate weeks, high winds were encounter during both weeks, that lasted for a 24-hour period that had gusts typically in the 35 mile per hour, and as high as 50 miles per hour. These high winds were from the north, and from personnel observations, are a regular occurrence during the winter months within this area. According to the testimony of Theodore D. Schade, Great Basin Air Pollution Control District, these winds would be more than adequate to entrain exposed sediments surrounding the Sea, especially during the winter months when puffy, unstable crusts on the newly exposed sediments may be present.

If the water level in the sea is reduced as a result of the proposed water transfer, it could greatly increase bioavailability of contaminants from sediments with elevated concentrations that were previously submerged and had more limited bioavailability. Previously these sediments had limited bioavailability to terrestrial fauna and waterfowl as a result of the lack of emergent aquatic vegetation and limited surface exposure. The main exposure pathway is currently from eating fish and pile worms from the Sea. The surface area containing elevated contaminant concentrations would greatly increase with a reduction in Sea level and size of the Sea, which could cause increased exposure of terrestrial creatures using this are to forage. Furthermore, concentrations within the reduced surface water body would greatly increase and cause further magnification of these chemicals in the food chain using this water body.

If the water levels are lowered as a result of the proposed water transfer thus exposing former Sea bottom sediments, it could greatly increase the bioavailability of contaminant as a result of leaching from exposed sediment. Many of the metals and metals that are present in the submerged sediments were precipitated as non soluble minerals under reduced or anaerobic conditions. When these sediments are exposed to the atmosphere and rainfall, they can become oxidized and will likely become more soluble. Runoff from these sediments may also contain soluble forms of the various metals and metalloids that are more toxic to flora and fauna. These contaminants will be leached from the sediments, now in greatly concentrated levels, similarly to how they are leached from the surrounding agricultural fields where many of them originated. This would greatly concentrate these contaminants into runoff from these sediments and into the remaining Sea water body in soluble forms that are much easier for flora and fauna to uptake greatly magnifying the exposure to these contaminants.

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