Calcasieu Estuary Remedial Investigation/Feasibility Study (RI/FS): Baseline Ecological Risk Assessment (BERA)

Prepared For:

CDM Federal Programs Corporation
8140 Walnut Hill Lane, Suite 1000
Dallas, Texas 75231

Under Contract To:

Mr. John Meyer, Regional Project Manager
U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, Texas 75202

Prepared – September 2002 – By:

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<td>g/L</td>
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<td>g/m^3</td>
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<td>GC-ECD</td>
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<tr>
<td>GCMS</td>
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<td>GERG</td>
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<td>not toxic</td>
</tr>
<tr>
<td>NTP</td>
<td>National Toxicology Program</td>
</tr>
<tr>
<td>NYSDEC</td>
<td>New York State Department of Environmental Conservation</td>
</tr>
<tr>
<td>OC</td>
<td>organic carbon</td>
</tr>
<tr>
<td>ODEQ</td>
<td>Oregon Department of Environmental Quality</td>
</tr>
<tr>
<td>OH</td>
<td>hydroxide</td>
</tr>
<tr>
<td>O-IOT</td>
<td>observed incidence of toxicity</td>
</tr>
<tr>
<td>O-MOT</td>
<td>observed magnitude of toxicity</td>
</tr>
<tr>
<td>p</td>
<td>level of significance</td>
</tr>
<tr>
<td>P-Avg</td>
<td>average probability</td>
</tr>
<tr>
<td>P-IOT</td>
<td>predicted incidence of toxicity</td>
</tr>
<tr>
<td>P-Max</td>
<td>maximum probability</td>
</tr>
<tr>
<td>P-MOT</td>
<td>predicted magnitude of toxicity</td>
</tr>
<tr>
<td>Pa</td>
<td>pascals (standard international unit for pressure)</td>
</tr>
<tr>
<td>PAH</td>
<td>polycyclic aromatic hydrocarbon</td>
</tr>
<tr>
<td>PARCC</td>
<td>precision, accuracy, representativeness, completeness and comparability</td>
</tr>
<tr>
<td>Pb</td>
<td>lead</td>
</tr>
<tr>
<td>PCA</td>
<td>principal components analysis</td>
</tr>
<tr>
<td>PCB</td>
<td>polychlorinated biphenyl</td>
</tr>
<tr>
<td>PCDD</td>
<td>polychlorinated dibenzo-p-dioxin</td>
</tr>
<tr>
<td>PCDF</td>
<td>polychlorinated dibenzofuran</td>
</tr>
<tr>
<td>PCS</td>
<td>Permit Compliance System</td>
</tr>
<tr>
<td>Pe</td>
<td>penta</td>
</tr>
<tr>
<td>PEC</td>
<td>probable effect concentration</td>
</tr>
<tr>
<td>PEC-Q</td>
<td>probable effect concentration-quotient</td>
</tr>
<tr>
<td>PEL</td>
<td>probable effect level</td>
</tr>
<tr>
<td>PL</td>
<td>Prien Lake and upper old river channel</td>
</tr>
<tr>
<td>ppb</td>
<td>parts per billion</td>
</tr>
<tr>
<td>PPG</td>
<td>Pittsburgh Paint and Glass Industries, Inc.</td>
</tr>
<tr>
<td>PPGC</td>
<td>PPG Canal</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>ppt</td>
<td>parts per thousand</td>
</tr>
<tr>
<td>PW</td>
<td>pore water</td>
</tr>
<tr>
<td>PWC</td>
<td>pore-water chemistry</td>
</tr>
<tr>
<td>QA/QC</td>
<td>quality assurance/quality control</td>
</tr>
<tr>
<td>QAPP</td>
<td>quality assurance project plan</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>QMP</td>
<td>quality monitoring program</td>
</tr>
<tr>
<td>QP</td>
<td>quality procedure</td>
</tr>
<tr>
<td>$r^2$</td>
<td>correlation coefficient</td>
</tr>
<tr>
<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
</tr>
<tr>
<td>REA</td>
<td>reference envelope approach</td>
</tr>
<tr>
<td>RI</td>
<td>remedial investigation</td>
</tr>
<tr>
<td>RNA</td>
<td>ribonucleic acid</td>
</tr>
<tr>
<td>ROI</td>
<td>receptors of interest</td>
</tr>
<tr>
<td>RPD</td>
<td>relative percent difference</td>
</tr>
<tr>
<td>RTECS</td>
<td>Registry of Toxic Effects of Chemical Substances</td>
</tr>
<tr>
<td>S</td>
<td>survival</td>
</tr>
<tr>
<td>S or G</td>
<td>survival or growth</td>
</tr>
<tr>
<td>SAIC</td>
<td>Science Applications International Corporation</td>
</tr>
<tr>
<td>SAP</td>
<td>sampling and analysis plan</td>
</tr>
<tr>
<td>SAS</td>
<td>Statistical Analyses System</td>
</tr>
<tr>
<td>SC</td>
<td>sediment contact</td>
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<tr>
<td>SCV</td>
<td>Secondary Chronic Value</td>
</tr>
<tr>
<td>SD</td>
<td>standard deviation</td>
</tr>
<tr>
<td>SEM</td>
<td>simultaneously extracted metal</td>
</tr>
<tr>
<td>SERA</td>
<td>screening level ecological risk assessment</td>
</tr>
<tr>
<td>SI</td>
<td>sediment ingestion</td>
</tr>
<tr>
<td>SMDP</td>
<td>scientific management decision point</td>
</tr>
<tr>
<td>SO</td>
<td><em>Sciaenops ocellatus</em></td>
</tr>
<tr>
<td>SO$_4^-$</td>
<td>sulfate</td>
</tr>
<tr>
<td>Sp.</td>
<td>Species</td>
</tr>
<tr>
<td>SPF</td>
<td>specific pathogen free</td>
</tr>
<tr>
<td>SPT</td>
<td>solid phase</td>
</tr>
<tr>
<td>SQAL</td>
<td>sediment quality advisory level</td>
</tr>
<tr>
<td>SQG</td>
<td>sediment quality guideline</td>
</tr>
<tr>
<td>SRI</td>
<td>Stanford Research Institute</td>
</tr>
<tr>
<td>STORET</td>
<td>Storage and Retrieval System for water quality data</td>
</tr>
<tr>
<td>SU</td>
<td>standard units</td>
</tr>
<tr>
<td>SV</td>
<td>Standard Value</td>
</tr>
<tr>
<td>SVOCs</td>
<td>semi-volatile organic compounds</td>
</tr>
<tr>
<td>SW</td>
<td>surface water</td>
</tr>
<tr>
<td>SWC</td>
<td>surface-water chemistry</td>
</tr>
<tr>
<td>T</td>
<td>toxic</td>
</tr>
<tr>
<td>$T_{20}$</td>
<td>concentration at which 20% of samples are predicted to be toxic</td>
</tr>
<tr>
<td>$T_{50}$</td>
<td>concentration at which 50% of samples are predicted to be toxic</td>
</tr>
<tr>
<td>TAL</td>
<td>target analyte list</td>
</tr>
<tr>
<td>TCA</td>
<td>trichloroethane</td>
</tr>
<tr>
<td>TCDD</td>
<td>tetrachlorodibenzo-p-dioxin</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>TCL</td>
<td>target compound list</td>
</tr>
<tr>
<td>TCP</td>
<td>tissue chemistry for prey organisms</td>
</tr>
<tr>
<td>TCR</td>
<td>tissue chemistry for receptor under consideration.</td>
</tr>
<tr>
<td>TEC</td>
<td>threshold effect concentrations</td>
</tr>
<tr>
<td>TEF</td>
<td>toxic equivalency factor</td>
</tr>
<tr>
<td>TEQ</td>
<td>toxic equivalents</td>
</tr>
<tr>
<td>TOC</td>
<td>total organic carbon</td>
</tr>
<tr>
<td>TPH</td>
<td>total petroleum hydrocarbons</td>
</tr>
<tr>
<td>TRI</td>
<td>Toxic Release Inventory</td>
</tr>
<tr>
<td>TRV</td>
<td>Tissue reside value</td>
</tr>
<tr>
<td>TRV&lt;sub&gt;H&lt;/sub&gt;</td>
<td>Tissue reside value - high</td>
</tr>
<tr>
<td>TRV&lt;sub&gt;L&lt;/sub&gt;</td>
<td>Tissue reside value - low</td>
</tr>
<tr>
<td>TTC-HA</td>
<td>Toxicity threshold concentration for <em>Hyalella azteca</em> or <em>Leptocheirus plumulosus</em></td>
</tr>
<tr>
<td>TU</td>
<td>toxic units</td>
</tr>
<tr>
<td>U</td>
<td>uncertain</td>
</tr>
<tr>
<td>UBI</td>
<td>Upper Bayou d’Inde</td>
</tr>
<tr>
<td>UCL</td>
<td>upper confidence limit</td>
</tr>
<tr>
<td>UCR</td>
<td>Upper Calcasieu River</td>
</tr>
<tr>
<td>UCR-MS</td>
<td>Upper Calcasieu River - Mainstem</td>
</tr>
<tr>
<td>UF</td>
<td><em>Ulva fasciata</em></td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>U/S</td>
<td>upstream</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>USFWS</td>
<td>United States Fish and Wildlife Service</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator coordinates</td>
</tr>
<tr>
<td>µg/kg</td>
<td>micrograms per kilogram</td>
</tr>
<tr>
<td>µg/L</td>
<td>micrograms per liter</td>
</tr>
<tr>
<td>µmol/g</td>
<td>micromoles per gram</td>
</tr>
<tr>
<td>VF</td>
<td><em>Vibrio fisheri</em></td>
</tr>
<tr>
<td>VOCs</td>
<td>volatile organic compounds</td>
</tr>
<tr>
<td>Vs.</td>
<td>versus</td>
</tr>
<tr>
<td>WC</td>
<td>water contact</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WQC</td>
<td>water quality criteria</td>
</tr>
<tr>
<td>WQS</td>
<td>water quality standards</td>
</tr>
<tr>
<td>WS</td>
<td>whole sediment</td>
</tr>
<tr>
<td>WSC</td>
<td>whole-sediment chemistry</td>
</tr>
<tr>
<td>WST</td>
<td>whole-sediment toxicity</td>
</tr>
<tr>
<td>WW</td>
<td>wet weight</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------</td>
</tr>
<tr>
<td>WWTP</td>
<td>waste water treatment plant</td>
</tr>
<tr>
<td>Zn</td>
<td>zinc</td>
</tr>
</tbody>
</table>
Glossary of Terms

*Acute toxicity threshold* – The concentration of a substance above which adverse effects on an organism are likely to be observed in short-term toxicity tests.

*Acute toxicity* – The immediate or short-term response of an organism to exposure to a stressor (e.g., a chemical substance). Lethality is the response that is most commonly measured in acute toxicity tests.

*Allometric equation* – calculates the relationship between size characteristics of an organism (e.g., body weight) and organism functions (metabolic rate)different species.

*Ambient* – Of or relating to the immediate surroundings.

*Anaerobic* – something that is active or occurs in the absence of air.

*Aquatic organisms* – The species that utilize habitats within aquatic ecosystems (e.g., microorganisms, aquatic plants, invertebrates, fish, amphibians and reptiles).

*Aquatic-dependent species* – Species that are dependent on aquatic organisms and/or aquatic habitats for survival.

*Aquatic-dependent wildlife* – Wildlife species that are dependent on aquatic organisms and/or wildlife habitats for survival, including fish, amphibians, reptiles, birds, and mammals (e.g., egrets, herons, kingfishers, osprey, racoons, mink, otter).

*Aquatic ecosystem* – All the living and nonliving material interacting within an aquatic system (e.g., pond, lake, river, ocean).

*Aquatic invertebrates* – Animals without backbones that utilize habitats in freshwater, estuaries, or marine systems.

*Assimilation efficiency* – proportion energy an organism is able to metabolize from a food item. It is the proportion of gross energy not lost as excretory products.

*Ataxia* – a loss of voluntary muscle movement and coordination.
**Benchmarks** – Guidelines that are intended to define the concentration of a contaminant that is associated with a high or a low probability of observing harmful biological effects.

**Benthic invertebrate community** – The assemblage of aquatic invertebrates that utilize the bottom substrate (e.g., sediment) within an aquatic ecosystem.

**Bioaccumulation** – The net accumulation of a substance by an organism as a result of uptake from all environmental sources.

**Bioaccumulative substances** – The chemicals that tend to accumulate in the tissues of aquatic or terrestrial organisms.

**Bioavailability** – Degree to which a chemical can be absorbed by and/or interact with an organism.

**Bioconcentration** – The accumulation of a chemical in the tissues of an organism as a result of direct exposure to the surrounding medium (i.e., it does not include food web transfer).

**Biological half-life** – The time required for one-half of the total amount of a particular substance in a biological system to be consumed or broken down by biological processes.

**Biomagnification** – The accumulation of a chemical in the tissues of an organism as a result of food web transfer.

**Brackish marsh** – A marsh of low salinity, usually up to 5 parts per thousand during the period of average annual low flow.

**Brood** – The young animals produced during one reproductive cycle.

**Calanoid (copepods)** – Small crustaceans commonly found as part of the free-living zooplankton in freshwater lakes and ponds.

**Carnivorous** – primarily subsists on animal tissue.

**Catabolism** – The phase of metabolism which consists in breaking down of complex substances into simpler substances.

**Chelating agent** – An organic chemical that can bond with a metal and remove it from a solution.
Chemical benchmark – Guidelines for water or sediment quality which define the concentration of contaminants that are associated with high or low probabilities of observing harmful biological effects, depending on the narrative intent.

Chemicals of potential concern – The substances that occur in environmental media at levels that pose potential risks to ecological receptors.

Chronic toxicity – The response of an organism to long-term exposure to a chemical substance. Among others, the responses that are typically measured in chronic toxicity tests include lethality, decreased growth, and impaired reproduction.

Chronic toxicity threshold – The concentration of a substance above which adverse effects on sediment-dwelling organisms are likely to occur in longer-term toxicity tests.

Coefficient of variation – allows one to compare the relative amounts of variation in populations having different means.

Colloids – Very small, finely divided solids that remain dispersed in a liquid (i.e., do not dissolve) for a long time due to their small size and electrical charge.

Confluence – The location where two waterways meet.

Congener – A member of a group of chemicals with similar chemical structures (e.g., PCDDs generally refers to a group of 75 congeners that consist of two benzene rings connected to each other by two oxygen bridges).

Contaminants of concern – The toxic or bioaccumulative substances that occur at concentrations that are sufficient to cause or substantially contribute to adverse effects on microbial, benthic invertebrate, plant, fish, avian or mammalian communities.

Contaminated sediment – Sediment that contains chemical substances at concentrations that could harm microbial, benthic invertebrate, plant, fish, avian or mammalian communities.

Conventional variables – A number of variables that are commonly measured in surface-water, pore-water and/or sediment quality assessments, including ammonia and hydrogen sulfide.
Cracking catalysts – Substances that speed-up petroleum refining processes (used to "crack" crude oil into gasoline, jet fuel, kerosene, diesel fuel, and other petroleum products).

Degradation – A breakdown of a molecule into smaller molecules or atoms.

Demethylated – Removal of a methyl group from a chemical compound.

Diagenesis – The sum of the physical and chemical changes that take place in sediments after its initial deposition (before they become consolidated into rocks, excluding all metamorphic changes).

Dimorphic – Existing in two forms (e.g., male and female individuals in animals).

Dose response curve – relationship that relates exposure to a substance with effects to a receptor.

Ecosystem – All the living (e.g., plants, animals, and humans) and nonliving (rocks, sediments, soil, water, and air) material interacting within a specified location in time and space.

Endpoint – A measured response of a receptor to a stressor. An endpoint can be measured in a toxicity test or a field survey.

Estivate – To pass the summer or dry season in a dormant condition.

Exposure – Co-occurrence of or contact between a stressor (e.g., chemical substance) and an ecological component a receptor (e.g., aquatic organism).

Fumarolic – Describes a vent in or near a volcano from which hot gases, especially steam are emitted.

Gavage – Forced feeding by means of a tube inserted into the stomach through the mouth.

Genotoxic – Describes the toxic effects of a substance which damages DNA.

Gross energy – total energy content (Kcal/kg) of a food type.

Half-life – The length of time required to reduce the concentration of a substance by 50% in a particular medium.
Halogenated aliphatic compound – A chemical compound with a halogen atom (F, Cl, Br, I) associated with an alkane chain.

Hepatomegaly – A condition in which the liver is enlarged beyond its normal size.

Hepatotoxic – Refers to anything that causes adverse effects on the liver.

Hibernate – To pass the winter in a dormant condition, in which metabolism is slowed down.

Histologic – tissue structure or organization.

Homeostasis – The maintenance of metabolic equilibrium within an animal.

Hyperplasia – An abnormal increase in the number of normal cells in a tissue.

Hypertrophy – Enlargement of an organ resulting from an increase in the size of the cells.

in situ – a study performed on a species in its natural environment.

Lethal dose – The amount of a chemical necessary to cause death of an organism.

Lipophilic – a substance that has an affinity for lipids.

Littoral (vegetation) – Pertaining to or along the shore.

Lowest observed adverse effects level – the lowest concentration of a substance that causes adverse effects statistically significantly different from controls.

Marine – Relating to the sea.

Mast – The fruit of forest trees.
Mean PEC-Q – Mean Probable Effects Concentration Quotient, which was calculated using the procedure that was established by USEPA (2000c). Using this method, a PEC-Q was first determined for each metal for which a reliable PEC was available. Then, an average PEC-Q for metals was calculated by summing the PEC-Qs of each metal and dividing by the number of metals that were included in the calculation. PEC-Qs were also calculated for total PAHs and total PCBs. Finally, the mean of the average PEC-Q for metals, the PEC-Q for PAHs, and the PEC-Q for PCBs was determined for each sediment sample (termed the mean PEC-Q).

Microsomal – Describing the membrane-bound vesicles that result from the fragmentation of the endoplasmic reticulum.

Miscible – Capable of being mixed.

Monte Carlo analysis – a modeling technique wherein parameter values are drawn at random from defined input probability distributions, combined according to the model equation, and the process repeated iteratively until a stable distribution of solutions results.

Morphometry (bone) – The quantitative study of the geometry of bone shapes.

Necrosis – The death of plant or animal cells or tissue.

Neoplastic – Refers to abnormal new growth.

Neotenic (salamander) – The retention of juvenile characteristics in the adult individual.

Nephrotoxic – Refers to anything that poisons the kidney.

No observed adverse effects level – the highest concentration of a substance that does not cause statistically significant adverse effects compared to controls.

Omnivorous – primarily subsists on plant and animal tissues.

Order of magnitude – A single exponential value of the number ten.

Organogenesis – The basic mechanisms by which organs and tissues are formed and maintained in an animal or plant.

Osmoregulation – The control of the levels of water and mineral salts in the blood.
Pannes – Bare, exposed, or water-filled depressions in marshes.

Partition coefficient – A variable that is used to describe a chemical’s lipophilic or hydrophobic properties.

Pearson correlation coefficient – measures the association between two variables.

Petechial (hemorrhages) – A minute discolored spot on the surface of the skin or mucous membrane, caused by an underlying ruptured blood vessel.

Photolysis – Chemical decomposition caused by light or other electromagnetic radiation.

Piscivorus – primarily subsists on fish tissue.

Population – An aggregate of individuals of a species within a specified location in time and space.

Pore water – The water that occupies the spaces between sediment particles.

Porphyria – A hereditary disease of body metabolism that is caused by a change in the amount of porphyrins (nitrogen-containing substances) found in the blood.

Probabilistic risk assessment – uses probability distributions to characterize variability or uncertainty in risk estimates. Monte Carlo analysis is the most widely used method of probabilistic risk assessment.

Probability bounds analysis – an exact numerical approach that takes a statistical distribution and rigorously computes bounds on the cumulative distribution function. The spread between the bounds of an input or output distribution corresponds directly to the amount of uncertainty for how to describe the variable.

Pyrolysis – Decomposition of a chemical by extreme heat.

Ranid (frog) – The family of true frogs of the order Anura.

Receiving water – A river, ocean, stream or other watercourse into which wastewater or treated effluent is discharged.

Receptor – A plant or animal that may be exposed to a stressor.
Sediment – Particulate material that usually lies below water.

Sediment chemistry data – Information on the concentrations of chemical substances in whole sediments or pore water.

Sediment quality guideline – Chemical benchmark that is intended to define the concentration of a sediment-associated contaminant that is associated with a high or a low probability of observing harmful biological effects or unacceptable levels of bioaccumulation, depending on its purpose and narrative intent.

Sediment-associated contaminants – Contaminants that are present in sediments, including whole sediments or pore water.

Sediment-dwelling organisms – The organisms that live in, on, or near bottom sediments, including both epibenthic and infaunal species.

Sediment-probing – primarily forages for prey items in sediment.

Seminiferous tubules – The glandular part of testicles that contain the sperm producing cells.

Sorption – The process by which one substance takes up or holds another; adsorption or absorption.

Stressor – Physical, chemical, or biological entities that can induce adverse effects on ecological receptors or human health.

Sublethal dose – The amount, or dosage, of a substance necessary to cause adverse effects, not including death.

Teratogenic – Causing birth defects.

Terrestrial habitats – Habitats associated with the land, as opposed to the sea or air.

Tissue – A group of cells, along with the associated intercellular substances, which perform the same function within a multicellular organism.

Tissue Residue Guideline – Chemical benchmark that is intended to define the concentration of a substance in the tissues of fish or invertebrates that will protect wildlife against effects that are associated with dietary exposure to hazardous substances.
**Trophic level** – A portion of the food web at which groups of animals have similar feeding strategies.

**Volatilization** – To change or cause to change from a solid or liquid to a vapor.

**Wet deposition** – The transfer of an element from the atmosphere to land or water through rain or snow.

**Whole sediment** – Sediment and associated pore water.
Executive Summary

ES1.0 Introduction

The Calcasieu Estuary is located in the vicinity of Lake Charles in Calcasieu Parish, Louisiana (LA; Figure 1-1). The estuary is characterized by a number of distinctive physical features, including Lake Charles, Prien Lake, Moss Lake, and Calcasieu Lake. The Calcasieu River/Calcasieu Ship Channel is joined by several tributaries within the estuary, the most notable being Bayou Verdine, Contraband Bayou, Bayou d’Inde, and Bayou Olsen. The land surrounding the Calcasieu Estuary includes undeveloped, rural, residential, commercial, and heavy industrial properties. Heavy industry dominates the southern reaches of Bayou d’Inde and Bayou Verdine on both sides. Permitted discharge outfalls (as identified in the National Pollution Discharge Elimination System; NPDES), as well as agricultural and industrial drainage ditches (including the Vista West Ditch, the Faubacher Ditch, and the Kansas City Southern Railroad West Ditch), discharge to the estuary (Figure 10-1). Current and historic point source discharges, stormwater runoff, and accidental spills have contributed to the contamination of surface water, sediment, and biota within the estuary and associated concerns regarding human health and ecological effects (Curry et al. 1997).

In response to public concerns regarding environmental contamination, the United States Environmental Protection Agency (USEPA) is conducting a federally-led Remedial Investigation/Feasability Study (RI/FS) to assess risks to human health and ecological receptors and evaluate remedial options for addressing environmental contamination in the Calcasieu Estuary (Figure 10-2). Initially, the available data on the levels of contaminants in environmental media in the estuary were reviewed and evaluated to determine if risks to ecological receptors existed within the estuary (CDM 1999). The results of the screening-level ecological risk assessment (SERA)
indicated that exposure to sediment and surface waters poses potential risks to ecological receptors.

In accordance with USEPA policies and guidance, more comprehensive investigations were initiated following the completion of the SERA, including a human health risk assessment (HHRA) and a baseline ecological risk assessment (BERA). The HHRA (CDM 2002a) was conducted in accordance with the *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual. Part A* (USEPA 1989). Similarly, the BERA (this report) was conducted in accordance with the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (USEPA 1997; Figures 1-3 and 1-4). The Remedial Investigation (RI) also included detailed investigations to identify sources of chemicals of potential concern (COPCs), characterize releases of COPCs, and evaluate the fate of these substances in aquatic ecosystems within the estuary (CDM 2002b).

The portion of the Calcasieu Estuary from the saltwater barrier to Moss Lake has been identified as the area in which environmental contamination posed the greatest potential risks to ecological receptors and, as such, was designated as the primary study area (CDM 1999; Figure 10-3). To facilitate the RI/FS, this study area was divided into four sub-areas (termed Areas of Concern; AOC), including:

- Upper Calcasieu River (UCR) AOC;
- Bayou Verdine (BV) AOC;
- Bayou d’Inde (BI) AOC; and,
- Middle Calcasieu River (MCR) AOC.
Several reference areas were also identified in the lower estuary and in the vicinity of Sabine National Wildlife Refuge to support the interpretation of the data generated during the RI. The AOCs identified in this report are generally consistent with those identified in the HHRA (CDM 2002a) and the RI report (CDM 2002b); however, the names applied to these AOCs differ among the reports.

This report was prepared to evaluate the risks to ecological receptors (i.e., aquatic organisms and aquatic-dependent wildlife) posed by exposure to environmental media (i.e., water, sediment, or biota) in the Calcasieu Estuary (Figure 10-4). More specifically, risks to the microbial community associated with exposure to COPCs in whole sediments were evaluated. In addition, risks to the aquatic plant community associated with exposure to COPCs in surface water or pore water from Calcasieu Estuary sediments were assessed. The risks to the benthic invertebrate community associated with exposure to COPCs in whole sediments and pore water were also evaluated. Furthermore, risks to benthic and pelagic fish associated with exposure to COPCs in surface water, pore water, whole sediments, and prey organisms were assessed. Finally, risks to aquatic-dependent wildlife (i.e., birds and mammals) were evaluated based on their potential exposure to COPCs in prey organisms. The results of the BERA for Bayou Verdine that was conducted for Conoco, Inc. and Condea Vista is presented in a separate document (Entrix 2001).

**ES2.0 Study Objectives**

The goal of this study was to assess the risks to aquatic organisms and aquatic-dependent wildlife exposed to environmental media in the Calcasieu Estuary. The primary objectives of this study were to:
• Determine if adverse effects on ecological receptors are occurring, or are likely to be occurring, within the Calcasieu Estuary;

• Evaluate the nature, severity, and areal extent of any such effects; and,

• Identify the substances that are causing or substantially contributing to effects on aquatic receptors (i.e., contaminants of concern; COCs).

**ES3.0 Study Approach**

A step-wise approach was used to assess the risks to aquatic organisms (i.e., microorganisms, aquatic plants, benthic invertebrates, and/or fish) and aquatic-dependent wildlife associated with exposure to COPCs in the Calcasieu Estuary. The five main steps in this process include:

• Identification of assessment endpoints, risk questions and testable hypotheses, and measurement endpoints;

• Collection, evaluation, and compilation of the relevant information on environmental conditions in the Calcasieu Estuary;

• Assessment of the exposure of aquatic organisms and aquatic-dependent wildlife to COPCs (i.e., exposure assessment; Figure 4-1);

• Assessment of the effects of COPCs on aquatic organisms and aquatic-dependent wildlife (i.e., effects assessment; Figure 4-2); and,

• Characterization of risks to the aquatic organisms and aquatic-dependent wildlife (i.e., risk characterization; Figure 4-3).
The procedures used in this BERA to evaluate the nature, severity, and areal extent of risks to ecological receptors in the Calcasieu Estuary are outlined in Chapter 4 and Appendix C for the microbial community, in Chapter 5 and Appendix D for the aquatic plant community, in Chapter 6 and Appendices E1 to E5 for the benthic invertebrate community, and, in Chapter 7 and Appendices F1 and F2 for the fish community (including benthic and pelagic fish). The methods that were used to evaluate the risks to aquatic-dependent wildlife are described in Chapter 8 and Appendices H1 to H3 for birds (including sediment-probing birds, carnivorous-wading birds, and piscivorous birds) and in Chapter 9 and Appendices I1 and I2 for mammals (including omnivorous mammals, and piscivorous mammals). Each of the above steps in the risk assessment process are briefly described below.

As a first step, assessment endpoints, risk questions and testable hypotheses, and measurement endpoints were identified. In this context, an assessment endpoint was defined as an explicit expression of the environmental value that is to be protected, whereas, a measurement endpoint is defined as a measurable ecological characteristic that is related to the valued characteristic that is selected as the assessment endpoint (USEPA 1997). To facilitate this process, a BERA workshop was convened in Lake Charles, LA in September, 2000. The results of this workshop provided a basis for identifying preliminary assessment endpoints and priority measurement endpoints to support the BERA (MacDonald et al. 2000). Subsequently, additional information on the sources, fate and transport, and ecological effects, of COPCs was compiled in a baseline problem formulation (BPF) report (MacDonald et al. 2001; Appendices A1 and A2 of the BERA). Potential exposure pathways and ecological receptors potentially at risk were also identified in the BPF. Integration of this information in the conceptual model for the site provided a base for linking assessment endpoints to measurement endpoints with a series of risk questions and testable hypotheses (Figure 1-5). The assessment endpoints that were considered in the BERA included:
• Activity of the aquatic microbial community;
• Survival, growth, and reproduction of aquatic plants;
• Survival, growth, and reproduction of benthic invertebrates;
• Survival, growth, and reproduction of benthic and pelagic fish;
• Survival and reproduction of aquatic-dependent birds; and,
• Survival, growth, and reproduction of aquatic-dependent mammals.

In the second step of the process, the relevant information on environmental conditions in the Calcasieu Estuary generated in Phase I and Phase II of the RI was collected, evaluated, and compiled. The data on surface-water quality consisted primarily of information on the levels of conventional variables (e.g., ammonia), metals, and organic substances [e.g., polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OC pesticides)]. The data on sediment quality conditions included whole-sediment chemistry, whole-sediment toxicity, pore-water chemistry, pore-water toxicity, and benthic invertebrate community structure. In addition, data were compiled on the concentrations of COPCs in fish and shellfish from the study area. All of the relevant information was compiled in relational database format (Appendices B1 to B9 of the BERA).

In the third step of the process, the exposure of ecological receptors to COPCs was evaluated. Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter et al. 2000). The exposure assessment was intended to provide an estimate of the magnitude of exposure of receptors to COPCs, over time and space. Exposure of the microbial community to COPCs was evaluated using the data on whole-sediment chemistry. By comparison, data on surface-water and pore-water chemistry were used to assess exposure of aquatic plants to COPCs. For benthic invertebrates, exposure
was evaluated using data on whole-sediment and pore-water chemistry. Exposure of the fish community to COPCs was assessed using data on surface-water, pore-water, whole-sediment, and tissue chemistry. Finally, data on the concentrations of COPCs in the tissues of fish and shellfish were used to assess exposure of aquatic-dependent birds and mammals to COPCs.

In the analysis of effects, risk assessors determine the nature of toxic effects that are associated with exposure to contaminants and their magnitude as a function of exposure (Suter et al. 2000). Information on the effects of environmental contaminants may be acquired from the results of single chemical toxicity tests (e.g., spiked sediment toxicity tests), ambient media toxicity tests (e.g., the results of toxicity tests conducted using sediments collected from the site under investigation), and/or biological surveys (e.g., benthic invertebrate community assessments). In this investigation, the effects of COPCs were evaluated using toxicity thresholds for surface water (i.e., for aquatic plants and fish), toxicity thresholds for whole-sediment chemistry (i.e., for microorganisms, benthic invertebrates, and fish), toxicity thresholds for pore-water chemistry (i.e., for aquatic plants, benthic invertebrates, and fish), and toxicity reference values (i.e., for birds and mammals). The toxicity thresholds for whole sediments were evaluated to determine their relevance for assessing sediment quality conditions in the Calcasieu Estuary (Appendix E1). The results of this evaluation indicated that site-specific concentration-response models were needed to assess the effects on benthic invertebrates associated with exposure to contaminated sediments. The resultant models were used to assess the effects of sediment-associated COPCs on the benthic invertebrate community (Appendix E2).

In the final step of the process, the exposure and effects assessments were integrated to determine if significant effects are occurring or are likely to occur at the site under investigation. In addition, the nature, magnitude, and areal extent of effects on the
selected assessment endpoints were described. The substances that are causing or substantially contributing to such effects (termed COC) were then identified from COPCs. Initially, the results that were obtained for each line of evidence (e.g., whole-sediment chemistry) were compiled and interpreted separately. Subsequently, an evaluation of the uncertainty in the analyses was conducted to determine the level of confidence that could be placed on the results for the individual lines of evidence and for integrating multiple lines of evidence into an overall assessment of risks to a particular receptor group (e.g., benthic invertebrates). Finally, the various lines of evidence were considered together to establish a weight of evidence for assessing risks to the assessment endpoint under consideration. In this latter assessment, the available data were integrated by calculating a final risk score for each location based on multiple lines of evidence. The final risk scores were then used to classify risks at each location into one of three categories including:

- Low (i.e., risks similar to those for reference conditions);
- Indeterminate (i.e., elevated risks relative to reference conditions, decisions on remedial actions should consider multiple factors); and,
- High (i.e., risks substantially elevated relative to reference conditions, remedial actions likely required to mitigate risks).

**ES4.0 Assessment of Risks to Aquatic Receptors**

In this investigation, the risks to four groups of aquatic organisms posed by exposure to COPCs in the Calcasieu Estuary were assessed. The receptors groups that were considered in this evaluation included the microbial community, aquatic plant
community, the benthic invertebrate community, and the fish community. For each receptor group, an assessment was conducted to determine if adverse effects are occurring, or are likely to be occurring, within the Calcasieu Estuary. In addition, the nature, severity, and areal extent of such effects were evaluated. Finally, the substances that are causing or substantially-contributing to such effects (i.e., COCs) were identified.

ES4.0.1 Microbial Community

The risks posed to microbial communities by exposure to whole sediments were assessed in the Calcasieu Estuary. In total, information on two lines of evidence was used to determine if the activity of the aquatic microbial community (i.e., the assessment endpoint) has been adversely affected or is likely to have been adversely affected by exposure to sediments in the estuary relative to reference conditions. The two lines of evidence that were considered in the assessment included whole-sediment chemistry and whole-sediment toxicity. The measurement endpoints for this assessment included the concentrations of COPCs in whole sediments and bioluminescence of the bacterium, *Vibrio fisheri*, in solid phase tests.

The results of this assessment indicated that exposure to whole sediments from the Calcasieu Estuary posed variable risks to microbial communities (i.e., risks were classified as low for 51% and indeterminate for 49% of the 624 sediment samples collected within the three AOCs investigated; Table 4-2). Of the three AOCs considered, the risks to the microbial community were highest in Bayou d’Inde (Figures 10-5 to 10-9). Within this AOC, sediment samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, lower Bayou d’Inde mainstem, and
Lockport Marsh posed the highest risks to the microbial community (Figure 10-6). Although risks to the microbial community were generally lower in the UCR AOC and MCR AOC, sediments posing indeterminate risks were identified in the northern portions of Clooney Island Loop, Clooney Island barge slip, the northern, central, and southern portions of Coon Island Loop, the western shoreline of middle Calcasieu River mainstem from Bayou d’Inde to Moss Lake, Moss Lake, Prien Lake, Indian Wells Lagoon, and portions of the old river channel within the Middle Calcasieu River Mainstem reach (Figures 10-5 to 10-8). Risks to the microbial community are generally low throughout the reference areas with the exception of certain portions of Bayou Choupique (Figure 10-9).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the microbial community. The average EC$_{50}$-bioluminescence was $11.1\pm8.4$ % sediment wet weight/mL (n=84) for the whole-sediment samples that were classified into the low risk category. For the samples that were classified into the indeterminate risk category, a mean EC$_{50}$-bioluminescence of $0.5\pm0.3$ % sediment wet weight/mL (n=5) was calculated. Together, these results demonstrated that the metabolism of microorganisms is impaired in response to exposure to contaminated sediments at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the microbial community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs were considered to include:

- PAHs [1,1-biphenyl, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total low molecular
weight-PAHs (LMW-PAHs), benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total high molecular weight-PAHs (HMW-PAHs), and total PAHs];
• PCBs (total PCBs); and,
• Phthalates [bis(2-ethylhexyl)phthalate; BEHP].

ES4.0.2 Aquatic Plant Community

The risks posed to aquatic plant communities by exposure to surface water and pore water were assessed in the Calcasieu Estuary. In total, information on three lines of evidence was used to determine if the survival, growth, or reproduction of aquatic plants (i.e., assessment endpoints) was being adversely affected or was likely to be adversely affected by exposure to COPCs in the estuary (i.e., relative to reference conditions). The three lines of evidence that were considered in the assessment included surface-water chemistry, pore-water chemistry and pore-water toxicity. The measurement endpoints for this assessment included concentrations of COPCs in surface water, the concentrations of COPCs in pore water, and germination rate of algae zoospores, germling length, and cell number of the macrophyte, Ulva fasciata, in pore-water toxicity tests.

The results of this BERA indicated that exposure to surface water and/or pore water from the Calcasieu Estuary generally posed low risks to aquatic plant communities (i.e., risks were classified as low for 72% of the 130 samples collected within the three AOCs investigated; Table 5-2; Figures 10-5 to 10-9). However, indeterminate and high risks to the aquatic plant community were indicated for 5% (6 of 130) and
24% (31 of 130) of the samples, respectively (Table 5-2). Of the three AOCs considered, the risks to the aquatic plant community were highest in Bayou d’Inde (Figure 10-6). Within this AOC, samples from the upper and lower portions of upper Bayou d’Inde, Maple Fork, PPG Canal, and the central and southeastern portions of Lockport Marsh posed the highest risks. Although risks to the aquatic plant community were generally lower in the UCR AOC and MCR AOC, samples posing high risk are present in the eastern and southwestern portions of Clooney Island Loop, Clooney Island barge slip, the southeastern and southwestern portions of Coon Island Loop, the mouth of Bayou Verdine, old river channel downstream of Prien Lake, west-central portion of Moss Lake, southern side of Contraband Bayou in the vicinity of Charvais Drive, southeastern portion of Lake Charles, and Indian Wells Lagoon (Table 5-2; Figures 10-5 to 10-8). Risks to the aquatic plant community are generally low at the locations sampled in the reference areas, with the exception at lower Bayou Boise Connine and the central portion of Grand Bayou (Figure 10-9).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the aquatic plant community. For example, the germination of algal zoospores was lower in the samples that were designated as indeterminate ($60\pm32\%$; $n=3$) and high ($37\pm20\%$; $n=6$) risk than was the case for the low risk samples ($88\pm7\%$; $n=36$). Likewise, growth rates tended to be highest for the samples that were designated as posing low risks to the aquatic plant communities. These results demonstrate that the survival, growth, and reproduction of aquatic plants are impaired in response to exposure to surface water or pore water at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the aquatic plant community in the
Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs that were considered to include:

- Total ammonia;
- Metals (dissolved copper and total and dissolved nickel); and,
- Benz(a)anthracene.

**ES4.0.3 Benthic Invertebrate Community**

The risks to benthic invertebrate communities posed by exposure to whole sediments and pore water were assessed in the Calcasieu Estuary. In total, information on five lines of evidence was used to determine if the survival, growth, or reproduction of benthic invertebrates (i.e., the assessment endpoints) has been adversely affected or is likely to have been adversely affected by exposure to contaminated sediments in the estuary relative to reference conditions. The five lines of evidence that were considered in the assessment included whole-sediment chemistry, whole-sediment toxicity, pore-water chemistry, pore-water toxicity, and benthic invertebrate community structure. The measurement endpoints in this assessment included: the concentrations of COPCs in whole sediment; the concentrations of COPCs in pore water; the survival and growth of amphipods, *Hyalella azteca*, in whole-sediment toxicity tests; the survival of amphipods, *Ampelisca abdita*, in whole-sediment toxicity tests; gamete fertilization and embryo development in sea urchins, *Arbacia punctulata*, in pore-water toxicity tests; the abundance of pollution sensitive species; the abundance of pollution tolerant species; total abundance of benthic macroinvertebrates; species richness; and, macrobenthic index of biotic integrity.
The results of this assessment indicated that exposure to whole sediment and/or pore water from the Calcasieu Estuary generally posed low risks to benthic invertebrate communities (i.e., risks were classified as low for 68% of the locations sampled (423 of 624) within the three AOCs investigated (Figures 10-5 to 10-9). However, indeterminate and high risks to the benthic invertebrate community were indicated for 9% (58 of 624) and 23% (143 of 624) of the locations sampled, respectively (Table 6-2). Of the three AOCs considered, the risks to the benthic invertebrate community were highest in Bayou d’Inde, based both on the incidence and magnitude of toxicity (i.e., observed and predicted; Figure 10-6). Within this AOC, samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, PPG Canal, and the inner portions of Lockport Marsh posed the highest risks. Although risks to the benthic invertebrate community were generally lower in the UCR AOC and MCR AOC, samples posing a high risk to benthic invertebrates were collected from the northern portions of Clooney Island Loop, the northern portions of Coon Island Loop, the middle Calcasieu River in the vicinity of the Citgo property, and Indian Wells Lagoon (Table 6-2; Figures 10-5 to 10-8). Risks to the benthic invertebrate community are generally low throughout the reference areas (Figure 10-9).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the benthic invertebrate community. For example, the survival and/or growth of freshwater and marine amphipods was lower for the locations that were designated as posing indeterminate and high risks than was the case for the locations that were classified as posing low risk to benthic invertebrates (Table 6-3). Likewise, the fertilization of sea urchin gametes was reduced in the samples from locations that were designated as posing indeterminate or high risks to the benthic community (Table 6-3; Appendix E2). Importantly, the density of pollution indicator (i.e., tolerant) species, the density of pollution sensitive species, species richness, and total abundance of benthic
invertebrates were generally lower for the sampling locations that were classified as posing indeterminate and high risks, as compared to the sampling locations that posed low risks to benthic invertebrates (Table 6-3). Together, these results demonstrate that the survival, growth, and reproduction of benthic invertebrates have been impaired in response to exposure to contaminated sediments in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the benthic invertebrate community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs included:

• Hydrogen sulfide;

• Metals (chromium, copper, lead, mercury, nickel, and zinc);

• PAHs (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs);

• PCBs (total PCBs);

• Chlorinated benzenes [hexachlorobenzene (HCB), hexachloro-1,3-butadiene (HCBD)];

• Phthalates (BEHP);

• OC pesticides (aldrin and dieldrin); and,
• Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans [PCDFs; total 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (total 2,3,7,8-TCDD TEQs)].

**ES4.0.4 Fish Community**

The risks posed to fish communities by exposure to surface water, whole sediments, and pore water, and all exposure routes (i.e., based on tissue chemistry) combined were assessed in the Calcasieu Estuary. In total, information on four lines of evidence was used to determine if the survival, growth, or reproduction of fish was being adversely affected or was likely to be adversely affected by exposure to surface water or sediments in the estuary relative to reference conditions. The four lines of evidence that were considered in the assessment included surface-water chemistry, pore-water chemistry, whole-sediment chemistry, and pore-water toxicity. In addition, tissue chemistry was also used to assess the effects of bioaccumulative COPCs (i.e., total PCBs) that accumulate in fish tissues from all exposure routes. In this assessment, the measurement endpoints included: the concentrations of COPCs in surface water; the concentrations of COPCs in whole sediment; the concentrations of COPCs in pore water; the concentrations of COPCs in the tissues of carnivorous fish; and, the hatching success and survival of redfish, *Sciaenops ocellatus*, eggs and larvae in pore-water toxicity tests.

The results of this BERA indicated that exposure to surface water, whole sediments, or pore water from the Calcasieu Estuary generally poses low risks to fish communities. Risks to fish were classified as low for 58% of the sediment samples (i.e., 367 of 634) collected within the three AOCs investigated; Figures 10-5 to 10-9). However, indeterminate and high risks to the fish community were indicated for 5%
(33 of 634) and 37% (234 of 634) of the samples, respectively (Table 7-2). Of the three AOCs considered, the risks to the fish community were highest in Bayou d’Inde. Within this AOC, samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, the central portions of Lockport Marsh, and lower Bayou d’Inde mainstem posed the highest risks. Although risks to the fish community were generally lower in the UCR AOC and MCR AOC, sediments posing high risk are present in portions of Clooney Island Loop, portions of Coon Island Loop, the middle Calcasieu River in the vicinity of the Citgo and WR Grace properties, Indian Wells Lagoon, Moss Lake and west-central portion of Prien Lake (Table 7-2; Figures 10-5 to 10-8). Risks to the fish community are generally low throughout the reference areas (Figure 10-9).

Of the exposure routes examined, exposure to COPCs in whole sediments and pore water represents the most important routes for benthic and pelagic fish. Accordingly, the fish that are closely associated with sediments, such as flounder (i.e., benthic species), are the most likely to be adversely affected by COPCs in the Calcasieu Estuary. As risks to carnivorous fish associated with the accumulation of PCBs in their tissues are considered to be low, dietary exposure to COPCs may be of lesser importance.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the fish community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs were considered to include:

- Hydrogen sulfide;
- Metals (chromium, copper, lead, mercury, nickel, and zinc);
• PAHs (2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, total HMW-PAHs, and total PAHs);

• PCBs (total PCBs);

• OC pesticides (dieldrin); and,

• PCDDs and PCDFs (total 2,3,7,8-TCDD TEQs).

ES4.0.5 Integrated Risks to Aquatic Receptors

The results of this investigation indicated that exposure to COPCs is adversely affecting a variety of ecological receptors in the Calcasieu Estuary. More specifically, activity of the microbial community has been impaired in portions of the Calcasieu Estuary due to exposure to sediment-associated COPCs. In addition, the survival, growth, and/or reproduction of aquatic plants have also been adversely affected in portions of the estuary through exposure to COPCs in surface water and pore water. Furthermore, exposure to whole sediments or pore water have been adversely affected the survival, growth, and/or reproduction of benthic invertebrates. Finally, the survival, growth, and/or reproduction of benthic fish have been impaired due to exposure to COPCs in whole sediments and/or pore water (Figures 10-10 to 10-14 summarize the risks to each receptor group throughout the Calcasieu Estuary).

For each of the four aquatic receptor groups, the information for various measurement endpoints and lines of evidence were integrated by calculating a final risk score for each location sampled. Subsequently, the final risk scores that were calculated for the various receptor groups for each location were averaged to obtain an overall risk score
for the four receptor groups for each location. Then, risks to microorganisms, plants, benthic invertebrates, and fish were classified into three categories for each location, based on the overall risk score that was calculated. Locations with overall risk scores of <2, 2 to 3, and >3 were classified as posing low, indeterminate, and high risks to aquatic receptors, respectively. In this way, it was possible to integrate information on the risks posed to multiple aquatic receptors by exposure to COPCs in the Calcasieu Estuary.

The results of this assessment indicated that risks to aquatic receptors are generally low throughout the Calcasieu Estuary. Of the 634 locations that were sampled within the three AOCs, 377 (59%) were classified as posing low risks to microorganisms, aquatic plants, benthic invertebrates, and/or fish (Table 10-1). By comparison, 11% (69 of 634) and 30% (188 of 634) of the locations sampled were classified as posing indeterminate and high risks, respectively (Table 10-1). Among the three AOCs, the highest risks to aquatic receptors were evident in Bayou d’Inde (Table 10-1). Risks to aquatic receptors were classified as low throughout the reference areas.

In general, there was good correspondence among the risk classifications for the four groups of aquatic receptors. For example, risks were classified as low within the three AOCs for 58% of the locations sampled for fish (Table 7-2) to 72% of the locations sampled for aquatic plants (Table 5-2). With the exception of microorganisms, the frequency of classification of indeterminate risks was generally low (i.e., 5 to 9%) for the various receptor groups. Similarly, the frequency of classification of high risks was comparable for three of the four aquatic receptor groups (i.e., 23 to 37%, with microorganisms being the exception). Risks to the microbial community were generally classified as being lower than those for the other three aquatic receptor groups because confidence in the information on the selected measurement endpoints tended to be lower for microorganisms. The degree of correspondence among the risk
classifications for the various receptor groups is illustrated in Figures 10-5 to 10-9. These figures also show that correspondence was lower in certain locations, particularly within the more contaminated areas within the estuary (e.g., Clooney Island barge slip, Lockport Marsh).

**Upper Calcasieu River AOC** – In general, risks to aquatic receptors were low throughout the UCR AOC, as indicated by the average overall risk score of 0.81 that was calculated for this AOC. Of the 155 locations that were sampled within this AOC, 131 (85%) were classified as posing a low risk to microorganisms, aquatic plants, benthic invertebrates, and/or fish (Table 10-1). Nevertheless, 15% (i.e., 24 of 155) of the locations within this AOC were classified as posing indeterminate (5%; 7 of 155) or high (11%; 17 of 155) risks to aquatic receptors (Table 10-1). All of the locations that posed a high risk to aquatic receptors were encountered in the Clooney Island Loop (n=7) or the Coon Island Loop (n=10). The locations that posed the highest risk to aquatic receptors included the Clooney Island barge slip, the northern and north eastern portions of Clooney Island Loop, the northern and central portions of Coon Island Loop, and the mouth of Bayou Verdine (Figure 10-10).

**Bayou d’Inde AOC** – Risks to aquatic receptors were generally as high within the BI AOC. The average overall risk score that was calculated for this reach was 2.4 (n=316). Forty-nine percent of the locations sampled within the BI AOC (i.e., 156 of 316) were classified as posing a high risk to microorganisms, aquatic plants, benthic invertebrates, and/or fish (Table 10-1). By comparison, 33% (i.e., 104 of 316) and 18% (i.e., 56 of 316) of the locations sampled were classified as posing low or indeterminate risks to aquatic receptors, respectively (Table 10-1).
The locations that posed the highest risk to aquatic receptors (i.e., overall risk score >3) were collected in the lower portion of upper Bayou d’Inde (i.e., between the CitCon facility and the Highway 108 bridge), the mainstem and wetland areas within middle Bayou d’Inde, throughout Lockport Marsh, the lower and middle portion of PPG Canal, and lower Bayou d’Inde mainstem in the vicinity of the confluence with PPG Canal and throughout the mainstem (Figure 10-11).

**Middle Calcasieu River AOC** – Risks to aquatic receptors were generally classified as low with the MCR AOC. An average overall risk score of 0.73 was calculated for this portion of the study area. Based on the results that were obtained for microorganisms, aquatic plants, benthic invertebrates, and/or fish, 87% of the locations sampled (i.e., 142 of 163) within this AOC were classified as posing a low risk to aquatic receptors (Table 10-1). Nevertheless, 13% (i.e., 21 of 163) samples from this AOC were classified as posing indeterminate (4%; 6 of 163) or high (9%; 15 of 163) risks to aquatic receptors (Table 10-1). The samples that posed the highest risk to aquatic receptors were collected along the western shoreline of the middle Calcasieu River in the vicinity of the Citgo property, in Indian Wells Lagoon, Prien Lake and the central portions of Moss Lake (Figures 10-12 and 10-13).

**Reference Areas** – Risks to aquatic receptors were classified as low for all of the locations sampled within the reference areas. An average overall risk score of 0.55 was calculated for this portion of the study area (Table 10-1). All of the locations sampled were classified as posing low risks to aquatic receptors (Figure 10-14).
Contaminants of Concern – In this report, the COPCs that were considered to be causing or substantially contributing to adverse effects on aquatic receptors were termed COCs. The results of this assessment indicated that there are a number of substances that are adversely affecting microorganisms, aquatic plants, benthic invertebrate and/or fish (Table 10-2). In surface water, ammonia, dissolved copper, and total and dissolved nickel are considered to be COCs. In whole sediments, the COCs are considered to include: metals (chromium, copper, lead, mercury, nickel, and zinc); 18 individual PAHs; total LMW-PAHs; total HMW-PAHs; total PAHs; total PCBs; aldrin; dieldrin; BEHP; HCB; HCBD; and, TCDD TEQs. The pore-water COCs are considered to include: hydrogen sulfide; total nickel; total zinc; 1-methynaphthalene; benz(a)anthracene; and, benzo(a)pyrene.

All of these substances occurred in whole-sediment, surface-water, and/or pore-water samples from the Calcasieu Estuary at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. In addition, the concentrations in the effects distribution (i.e., toxic samples) were generally higher than the concentrations in the no effects distribution (i.e., non-toxic samples) for one or more of the measurement endpoints (e.g., survival of Ampelisca abdita in 10-d toxicity tests). This latter evaluation was conducted to assess concordance between the chemistry and biological effects data. Many of these substances or groups of substances also accumulated in the tissues of polychaetes (Nereis virens) in 28-d bioaccumulation tests and were shown to be associated with toxicity to amphipods (Ampelisca abdita) in toxicity identification evaluations.
ES5.0 Assessment of Risks to Aquatic-Dependent Wildlife

The risks to five groups of aquatic-dependent wildlife posed by exposure to COPCs in the Calcasieu Estuary were assessed. The receptor groups included: sediment-probing birds, carnivorous-wading birds, piscivorus birds, piscivorus mammals, and omnivorous mammals. For each receptor group, an assessment was conducted to determine if adverse effects are occurring, or are likely to be occurring, in the Calcasieu Estuary. To the extent possible, the nature, severity and areal extent of such effects were evaluated and the COPCs contributing to such effects were identified (i.e., COCs).

ES5.0.1 Avian Community

The risks to sediment-probing, carnivorous-wading, and piscivorus birds from exposure to contaminated aquatic prey were assessed for the Calcasieu Estuary. A conservative, deterministic screening ecological risk assessment (ERA) identified AOCs and COCs in the Calcasieu Estuary (Appendix G). The COCs identified in the deterministic assessment for birds included selenium, TCDD-TEQs, mercury, total PCBs, and lead.

For each group of aquatic-dependent birds, local receptors of concern were identified. The life history and foraging behaviors of these receptors of concern were blended to create hypothetical receptors possessing the qualities characteristic of each bird group. For example, the hypothetical receptor for piscivorus birds was based on the characteristics of the belted kingfisher, osprey, brown pelican, and Caspian, least and Forster’s terns, all of which occur in the Calcasieu Estuary area. In addition to the
average-sized hypothetical receptor, a small hypothetical receptor was created to account for the higher metabolic rate, and therefore, higher exposure of smaller birds.

The probabilistic risk assessment was carried out in four steps: (1) collection, evaluation, and compilation of data; (2) exposure assessment; (3) effects assessment; and, (4) risk characterization. In the first step, relevant data on COC concentrations in prey items and sediments from the Calcasieu Estuary were collected, evaluated, and compiled. These data were then incorporated into a probabilistic exposure model calculating total daily intake of COCs for each group of aquatic-dependent birds. Monte Carlo analysis was applied to this model to account for the distribution of possible exposures. The effects characterization began with a review of the literature on effects of COCs on the survival, growth, and reproduction of aquatic-dependent birds. An appropriate effects metric was selected for each COC to be used with the results of the exposure assessment to estimate risks. The effects metrics in this assessment were expressed as a threshold range spanning sensitive and tolerant species. This range is likely to include the threshold for the receptor groups of interest. In the risk characterization step, the results of the exposure and effects characterizations were integrated to estimate the risks of each COC to each aquatic-dependent bird group in each AOC. High, indeterminate, and low risk categories were used to express the level of risk to each group of aquatic-dependent birds.

The results of the assessment for aquatic-dependent birds indicated that no areas in the Calcasieu Estuary had COCs at levels representing a high risk to the survival, growth, or reproduction of aquatic-dependent birds. Selenium poses indeterminate risks to average-sized and small sediment-probing birds in the MCR AOC, as well as small sediment-probing birds in the UCR AOC. Small piscivorus birds in Bayou d’Inde and the reference areas also face indeterminate risks from exposure to selenium. TCDD-TEQs pose indeterminate risks to small piscivorus birds in the
AOCs and reference areas. Mercury and total PCBs pose indeterminate risks to small piscivorous birds in Bayou d’Inde. Lead poses indeterminate risks to average-sized and small sediment-probing birds in the AOCs and reference areas. The risk of aquatic-dependent birds experiencing adverse effects from COCs is low for the remaining scenarios. Accordingly, selenium, TCDD-TEQs, mercury, total PCBs, and lead were identified as COCs in the Calcasieu Estuary for aquatic-dependent birds.

**ES5.0.2 Mammalian Community**

The risks to piscivorus and omnivorous mammals from exposure to contaminated aquatic prey were assessed for the Calcasieu Estuary. A conservative, deterministic screening ERA identified AOCs and COCs in the Calcasieu Estuary (Appendix G). The COCs identified in the deterministic assessment for mammals included TCDD-TEQs, selenium, mercury, and PCBs.

For each group of aquatic-dependent mammals, local receptors of concern were identified. The life history and foraging behaviors of these receptors of concern were blended to create hypothetical receptors possessing the qualities characteristic of each mammal group. For example, the hypothetical receptor for omnivorous mammals was based on the characteristics of the raccoon, marsh rice rat and muskrat, all of which occur in the Calcasieu Estuary area. In addition to the average-sized hypothetical receptor, a small hypothetical receptor was created to account for the higher metabolic rate, and therefore, higher exposure of smaller mammals.

The probabilistic risk assessment was carried out in four steps: (1) collection, evaluation, and compilation of data; (2) exposure assessment; (3) effects assessment; and, (4) risk characterization. In the first step, relevant data on COC concentrations
in prey items from the Calcasieu Estuary were collected, evaluated, and compiled. These data were then incorporated into a probabilistic exposure model calculating total daily intake of COCs for each group of aquatic-dependent mammals. Monte Carlo analysis was applied to this model to account for the distribution of possible exposures. The effects characterization began with a review of the literature on effects of COCs on the survival, growth, and reproduction of aquatic-dependent mammals. An appropriate effects metric was selected for each COC to be used with the results of the exposure assessment to estimate risks. The effects metrics in this assessment were expressed as benchmarks and as dose-response curves. In the risk characterization step, the results of the exposure and effects characterizations were integrated to estimate the risks of each COC to each aquatic-dependent mammal group in each AOC. High, indeterminate, and low risk categories were used to express the level of risk to each group of aquatic-dependent mammals.

The risk characterization results showed that there is a low probability that exposure to methylmercury, TCDD-TEQs and selenium will cause adverse effects to piscivorous and omnivorous mammals foraging in the Calcasieu Estuary. There is also a low probability of adverse effects to omnivorous mammals exposed to total PCBs. However, there is a high risk that total PCBs are causing adverse effects to average-sized and small piscivorus mammals inhabiting the Bayou d’Inde AOC of the Calcasieu Estuary. Based on the deterministic ecological risk assessment, total PCBs pose low risks to piscivorus mammals in other parts of the estuary. Accordingly, total PCBs were identified as COCs in the Calcasieu Estuary for aquatic-dependent mammals.
ES6.0 Conclusions

In accordance with USEPA (1997) guidance, the BERA of the Calcasieu Estuary was conducted following an eight-step process (see Appendix A1). The first two of these steps (i.e., the SERA) were completed in 1999 (CDM 1999). The results of the final six steps of the process are described in this document and the RI report (CDM 2002b). A companion document describes the risks to human health associated with exposure to COPCs in the Calcasieu Estuary (CDM 2002a).

The results of this assessment indicated that the presence of COCs in surface water, whole sediments, pore water, and/or the tissues of aquatic organisms poses a risk to ecological receptors. Exposure to contaminated sediment and pore water pose risks to microorganisms, aquatic plants, benthic invertebrates, and/or fish throughout portions of the Calcasieu Estuary. Consumption of contaminated fish and shellfish also poses risks to aquatic-dependent wildlife, including sediment-probing birds, carnivorous-wading birds, piscivorous birds, omnivorous mammals, and/or piscivorous mammals. Collectively, the information compiled, evaluated, and analyzed to support the BERA provides a weight-of-evidence that clearly demonstrates that the presence of ammonia; hydrogen sulfide; metals (chromium, copper, lead, mercury, nickel, and zinc); PAHs (1,1-biphenyl, 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs); PCBs (total PCBs), chlorinated benzenes (HCB and HCBD); phthalates (BEHP); OC pesticides (aldrin and dieldrin) and PCDDs and, PCDFs (total 2,3,7,8-TCDD TEQs) in environmental
media poses unacceptable risks to ecological receptors. The information contained in this BERA and companion documents (i.e., CDM 2002a; 2002b) is intended to support decisions regarding the need for remedial actions within the Calcasieu Estuary.
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Chapter 1. Introduction

1.0 Background

The Calcasieu Estuary is located in the vicinity of Lake Charles in Calcasieu Parish, Louisiana (LA; Figure 1-1). The Calcasieu River flows some 255 kilometers from its headwaters to the Gulf of Mexico. The estuarine portion of the watershed extends from the saltwater barrier, north of Lake Charles, to the gulf. The Calcasieu Estuary is characterized by a number of distinctive physical features, including Lake Charles, Prien Lake, Moss Lake, and Lake Calcasieu. The Calcasieu River/Calcasieu Ship Channel is joined by several tributaries within the estuary, the most notable being Bayou Verdine, Contraband Bayou, Bayou d’Inde, and Bayou Olsen. The Intracoastal Waterway connects the Calcasieu Estuary with the Sabine Lake system to the west, and Grand Lake to the east.

The land surrounding the Calcasieu Estuary includes undeveloped, rural, residential, commercial, and heavy industrial properties. Heavy industry dominates the southern reaches of Bayou d’Inde and Bayou Verdine on both sides. Permitted discharge outfalls (as identified in the National Pollution Discharge Elimination System; NPDES), as well as agricultural and industrial drainage ditches (including the Vista West Ditch, the Faubacher Ditch, and the Kansas City Southern Railroad West Ditch), discharge to the estuary (Curry et al. 1997). Current and historic point source discharges, stormwater runoff, and accidental spills have contributed to the contamination of surface water, sediment, and biota within the estuary (Curry et al. 1997). CDM (1999) reviewed and evaluated the available data on the levels of
contaminants in environmental media in the estuary and concluded that exposure to sediment and surface waters pose potential risks to ecological receptors.

In addition to chemical contamination, the Calcasieu Estuary has also been affected by a number of physical alterations. Construction of the Calcasieu Ship Channel (completed in 1941) has altered the salinity regime of the Calcasieu Estuary and impacted marsh areas to the west of Calcasieu Lake. Water control structures were installed thereafter by the United States Fish and Wildlife Service (USFWS) to reduce these impacts; monitoring is currently being conducted by the USFWS to evaluate the effectiveness of these structures. In addition, much of the Calcasieu River and portions of the various bayous contained within the study area were dredged or rerouted during the 1950s. For example, the southernmost 1,100 meters of the Bayou Verdine was rerouted to the west when Olin Corporation (Olin) built the West Pond over the original bayou (PRC 1994). Periodic navigational dredging is conducted in portions of the basin to facilitate access by ocean-going vessels and/or barge traffic. These physical alterations have most certainly contributed to the stresses on this system.

The estuary currently supports a recreational fishery primarily targeted on sea trout, redfish, black drum, and flounder. In addition, commercial fisheries for shrimp and crab exist in the southern portions of the estuary, primarily in the ship channel. However, fish consumption advisories have been issued in portions of the estuary to protect human health from adverse effects associated with the ingestion of contaminated fish (LDEQ 1998). Although the estuary is not used as a drinking water source, the surface waters have been designated by the Louisiana Department of Environmental Quality (LDEQ) as supporting primary contact recreation, secondary contact recreation, and fish and wildlife propagation (PRC 1994). While the
Calcasieu Estuary Cooperative Site has not been proposed for inclusion on the National Priorities List (NPL; i.e., sites that require investigation to assess risks to human health and the environment), it has been the subject of numerous environmental studies dating back to the early 1970's.

1.1 Remedial Investigation and Feasability Study

In response to concerns regarding environmental contamination, the United States Environmental Protection Agency (USEPA) is conducting a federally-led remedial investigation/feasibility study (RI/FS) in the Calcasieu Estuary. A portion of this study has been designed and implemented to support an ERA of the Calcasieu Estuary. This ERA is being conducted in accordance with the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment (USEPA 1997a). The United States Environmental Protection Agency (USEPA) guidance document describes an eight-step process for conducting an ERA, including (Figure 1-2):

Step 1: Screening-Level Preliminary Problem Formulation and Ecological Effects Evaluation;

Step 2: Screening-Level Preliminary Exposure Estimate and Risk Calculation Scientific Management Decision Point (SMDP);

Step 3: Baseline Risk Assessment Problem Formulation SMDP;

Step 4: Study Design and Data Quality Objectives SMDP;

Step 5: Field Verification of Sampling Design SMDP;
Step 6: Site Investigation and Analysis of Exposure and Effects SMDP;

Step 7: Risk Characterization; and,

Step 8: Risk Management SMDP.

In accordance with the USEPA guidance, the Calcasieu Estuary RI/FS is being conducted using this stepwise approach. The objectives of this ERA are:

- To estimate the risks posed by environmental contamination to ecological receptors in the Calcasieu Estuary; and,

- To provide the information needed by risk managers to make decisions regarding the need for remedial actions.

CDM Federal Programs Corporation (CDM) is the primary contractor for USEPA and has completed the initial steps of the investigation (i.e., steps 1 and 2). Specifically, the screening-level ecological risk assessment (SERA) has been completed, including the initial problem formulation, effects evaluation, exposures estimate, and risk calculation. The results of that assessment indicate that there is potential for risk to ecological receptors from exposure to environmental media in the Calcasieu Estuary, including surface water and sediment (CDM 1999). As such, the need to conduct a baseline ecological risk assessment (BERA) of the Calcasieu Estuary was identified (USEPA 1997a). The results of the BERA, including those associated with steps 3 to 8 of the ERA process, are described in the subsequent chapters of this report and associated appendices. The results of the BERA of the Bayou Verdine area of concern (AOC) are described in Entrix (2001).
To support the RI/FS, detailed information was needed on environmental conditions within the estuary. Such data are usually collected in two stages, a Phase I sampling program to support the SERA and a Phase II sampling program to support the BERA. The Phase I sampling program was completed in 2000, providing detailed information on the nature and extent of contamination in the estuary. While the results of the Phase I sampling program provide important data for assessing the risks to aquatic and aquatic-dependent receptors associated with environmental contamination, additional information was needed to support the BERA.

To identify information needs and associated monitoring strategies for the Phase II sampling program, the USEPA - Region VI convened a BERA workshop in Lake Charles, LA on September 6 and 7, 2000. The workshop participants included representatives of the USEPA, National Oceanic and Atmospheric Administration (NOAA), LDEQ, USFWS, United States Geological Survey (USGS), CDM, the Cadmus Group, and MacDonald Environmental Sciences Ltd. (MESL). The workshop was designed to enable participants to articulate the management goals and objectives for the ecosystem (i.e., based on the input that had been provided by the community in a series of public meetings), to assess the status of the knowledge base, to clearly define key issues and concerns, and to identify the chemicals of potential concern (COPCs) and areas of interest in the study area. Workshop participants also refined the preliminary assessment endpoints and selected priority measurement endpoints to support the BERA (MacDonald et al. 2000a). Collectively, the results of the workshop provided a basis for designing a Phase II sampling program to provide further information on the nature, severity and areal extent of contamination, to assess the bioavailability of environmental contaminants, to evaluate the effects on ecological receptors associated with exposure to COPCs, and to fill outstanding data gaps. Detailed information on the Phase II sampling program is provided in the
Sampling and Analysis Plan (SAP; CDM 2000a) and the associated Quality Assurance Project Plan (QAPP; SFF 2000). Collectively, the data generated in the Phase I and Phase II sampling programs provide the information that was used to assess baseline ecological risks in the Calcasieu Estuary.

### 1.2 Purpose of this Report

Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors (USEPA 1998). The process is used to systematically evaluate and organize data, information, assumptions, and uncertainties in order to help understand and predict the relationships between stressors and ecological effects in a way that is useful for environmental decision-making (USEPA 1998). An assessment may involve one or more chemical, physical, or biological stressors.

The ecological risk assessment process consists of three phases, problem formulation, analysis, and risk characterization (Figures 1-3 and 1-4). The problem formulation phase is a systematic planning process that identifies the factors to be addressed in a BERA and consists of five major activities (USEPA 1997a). First, preliminary list of contaminants of ecological concern (which are termed COPCs in this report) at the site is refined. Next, the potential ecological effects of the COPCs at the site are further characterized. In addition, the available information on the fate and transport of COPCs, on potential exposure pathways, and on the receptors potentially at risk is reviewed and evaluated. Together, this information provides a basis for selecting the assessment and measurement endpoints that will be used in the risk assessment.
Finally, a conceptual model, with testable hypotheses (or risk questions) that the site investigation will address, is developed in a manner that links the assessment and measurement endpoints (Figure 1-5). At the conclusion of the problem formulation, there is a scientific/management decision point, which consists of agreement on four items: the assessment endpoints, the exposure pathways, the risk questions, and the conceptual model that integrates these components (Figure 1-2).

The analysis phase of the process, which is driven by the problem formulation, consists of two main elements, exposure characterization and effects characterization (USEPA 1998). Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter et al. 2000). The exposure assessment is intended to provide an estimate of the magnitude of exposure to stressors, over time and space. In the analysis of effects, the nature of the effects that are associated with exposure to one or more stressors is evaluated, along with their magnitude as a function of exposure. Collectively, the information compiled during this phase of the process supports characterization of the nature of potential or actual exposure and the ecological responses under the circumstances defined in the conceptual model (USEPA 1998). The two main products of analysis phase, the exposure profile and the stressor-response profile, provide a basis for the final phase of the process, risk characterization. At the conclusion of the analysis phase, a scientific/management decision point is required if new information becomes available that necessitates alteration of measurement endpoints, testable hypotheses, and/or sampling design (Figure 1-2).

During the risk characterization, the exposure and stressor-response profiles are integrated through the risk estimation process (USEPA 1998). Risk characterization is undertaken to determine if significant effects are occurring or are likely to be
occurring at the site under investigation. In addition, the nature, magnitude, and areal extent of effects on the selected assessment endpoints are determined. Finally, the stressors that are causing or substantially contributing to such effects are identified. Risk characterization includes a summary of assumptions, scientific uncertainties, and the strengths and weaknesses of the analyses (i.e., an uncertainty analysis).

This document was prepared to present the results of the BERA for the Calcasieu Estuary. More specifically, the BERA report is intended to present the results of the problem formulation process, describe the conceptual model for the site, and identify the assessment endpoints that were selected. The exposure profiles and stressor-response profiles that were developed are also presented, along with descriptions of the major data sources and analytical procedures used. Furthermore, the risks to the selected assessment endpoints are described. Finally, the major areas of uncertainty in the assessment, along with the approaches that were used to address them, are reviewed and summarized in this report.

1.3 Organization of this Report

This report is organized into a number of sections to facilitate access to the information associated with the BERA of the Calcasieu Estuary, including:

- Introduction (Chapter 1);
- Geographic Scope of Study Area (Chapter 2);
- Problem Formulation (Chapter 3);
• Assessment of Risks to the Microbial Community (Chapter 4);
• Assessment of Risks to Aquatic Plant Microbial Community (Chapter 5);
• Assessment of Risks to Benthic Invertebrate Communities (Chapter 6);
• Assessment of Risks to Fish Communities (Chapter 7);
• Assessment of Risks to Avian Communities (Chapter 8);
• Assessment of Risks to Mammalian Communities (Chapter 9);
• Summary and Conclusions (Chapter 10); and,
• References (Chapter 11).

A series of technical appendices are included to provide more detailed information on the Calcasieu Estuary problem formulation (Appendix A), the underlying data that were used in the BERA (Appendix B1 to B10), and the assessments of risks to ecological receptors associated with exposure to contaminated environmental media in the Calcasieu Estuary, including microbial (Appendix C), aquatic plant (Appendix D), benthic invertebrate (Appendices E1 and E2), fish (Appendices F1 and F2), avian (Appendices G, H1, H2, and H3) and mammalian (Appendices G, I-1, and I-2) communities. Finally, a glossary of terms and a list of acronyms are provided at the beginning of this report to define the various scientific terms that are used throughout this document.
Chapter 2. Geographic Scope of the Study Area

2.0 Introduction

The Calcasieu River is one of the largest river systems in southwest Louisiana. From its headwaters in the vicinity of Kisatchie National Forest (in Vernon Parish), the Calcasieu River flows some 255 kilometers to the Gulf of Mexico near Cameron, LA. While much of the Calcasieu River system is relatively uncontaminated, the portion of the watershed from the saltwater barrier near Lake Charles, LA to the Intracoastal Waterway has undergone extensive industrial development over the past five decades. These developmental activities have resulted in widespread contamination in the estuarine portion of the watershed, particularly in the bayous within the upper portion of the estuary (Curry et al. 1997).

In response to public concerns, United States Environmental Protection Agency (USEPA) is conducting a federally-led remedial investigation/feasibility study (RI/FS) to assess risks to human health and ecological receptors and evaluate remedial options for addressing environmental contamination in the Calcasieu Estuary. The portion of the Calcasieu Estuary from the saltwater barrier to Moss Lake has been identified as the area in which environmental contamination posed the greatest potential risks to ecological receptors and, as such, was designated as the primary study area (CDM 1999). To facilitate the RI/FS, this study area was divided into four sub-areas or areas of concern (AOCs), including:

- Upper Calcasieu River (UCR) AOC;
- Bayou Verdine (BV) AOC;
• Bayou d’Inde (BI) AOC; and,

• Middle Calcasieu River (MCR) AOC.

Several reference areas were also identified in the lower estuary and in the vicinity of Sabine Lake to support the interpretation of the data generated during the RI. A baseline ecological risk assessment (BERA) for the BV AOC was completed previously (Entrix 2001); each of the remaining areas are described in the following sections. The AOCs identified in this report are generally consistent with those identified in the human health risk assessment (HHRA; CDM 2002a) and the RI report (CDM 2002b); however, the names applied to these AOCs differ among the three reports.

2.1 Upper Calcasieu River

The upper Calcasieu River includes the portion of the watershed from the saltwater barrier to the Highway 210 bridge, a distance of roughly 12 kilometers (or 15 kilometers, including the loop of the river located south of the saltwater barrier). This portion of the river system consists of several readily identifiable water bodies, including the Upper Calcasieu River Mainstem from the saltwater barrier to Lake Charles, Lake Charles, Calcasieu Ship Channel from Lake Charles to the Highway 210 bridge, Clooney Island Loop, Contraband Bayou, Coon Island Loop, and Bayou Verdine (Figure 2-1).
2.2 Bayou d’Inde

Bayou d’Inde is one of the major tributaries to the Calcasieu River (Figure 2-2). From its headwaters near Sulphur, Louisiana, Bayou d’Inde flows in a southeasterly direction some 16 kilometers to its confluence with the Calcasieu Ship Channel (or roughly 11 kilometers from the I-10 bridge to the mouth). Over that distance, Bayou d’Inde is joined by several tributaries, the largest of which is Maple Fork. The lower portions of the bayou are characterized by hydraulic connections (i.e., channels that connect the wetlands to the bayou) with a great deal of off-channel wetland habitat, the largest of which is the Lockport Marsh.

2.3 Middle Calcasieu River

The middle Calcasieu River comprises the portion of the watershed from the Highway 210 bridge to the outlet of Moss Lake (a distance of roughly 12 kilometers), excluding Bayou d’Inde (Figure 2-3). The primary physiographic features in this portion of the study area include the Calcasieu Ship Channel, Prien Lake, the original Calcasieu River channel (termed the old river channel in this report), and Moss Lake. For the purposes of this assessment, the Indian Wells Lagoon and Bayou Olsen were also included in the middle Calcasieu River study area.
2.4 Reference Areas

A total of five areas were selected to represent reference conditions within the Calcasieu River watershed and surrounding environments (Figure 2-4). These areas included Bayou Choupique, Grand Bayou, Bayou Bois Connine, Willow Bayou, and Johnson Bayou. Choupique Bayou is located southwest of Moss Lake and flows roughly 8 kilometers miles from its headwaters to its confluence with the Intracoastal Waterway northwest of Ellender, LA. Grand Bayou and Bayou Bois Connine are tributaries to Calcasieu Lake, both of which empty into the lake along its eastern shore. Willow Bayou and Johnson Bayou are tributaries to Sabine Lake, discharging into the lake along its southeastern shoreline. All five of these reference areas have been virtually unaffected by point source discharges from industrial activities (Ramelow et al. 1987).
Chapter 3. Problem Formulation

3.0 Introduction

The process of defining the questions that will be addressed during the baseline ecological risk assessment (BERA) is termed problem formulation. Problem formulation is a systematic planning process that identifies the factors to be addressed in a BERA and consists of five major activities (USEPA 1997a), including:

- Refinement of the preliminary list of chemicals of potential concern (COPCs) at the site (i.e., those that were identified during the screening-level ecological risk assessment; SERA; Section 3.1);
- Further characterization of the potential ecological effects of the COPCs at the site (Section 3.2);
- Review and refinement of the information on the fate and transport of COPCs, on potential exposure pathways, and on the biota potentially at risk (Sections 3.3 and 3.4);
- Development of a conceptual model with testable hypotheses (or risk questions) that the site investigation will address (Section 3.5); and,
- Selection of assessment and measurement endpoints (Section 3.6).

At the conclusion of the problem formulation, there is a scientific/management decision point, which consists of agreement on four items: the assessment endpoints, the exposure pathways, the risk questions, and the conceptual model that integrates
these components (USEPA 1997a). This chapter provides a summary of baseline problem formulation (BPF) for the BERA of the Calcasieu Estuary, which is presented in detail in Appendix A of this document.

### 3.1 Chemicals of Potential Concern and Areas of Interest in the Calcasieu Estuary

The identification of COPCs and areas of interest represents an essential element of the problem formulation process (USEPA 1998). To initiate this process, CDM Federal Programs Corp (CDM) conducted a SERA of the Calcasieu Estuary in 1999 to assess the potential for adverse biological effects on ecological receptors associated with either direct or indirect exposure to contaminated environmental media in the Calcasieu Estuary (CDM 1999). To support this assessment, historical data on the levels of environmental contaminants in surface water, sediment, and biota were collated and compiled (CDM 1999). Subsequently, the maximum measured concentration of each substance in each media type was compared to the lowest ecological screening value for that substance to facilitate the determination of maximum hazard quotients. These maximum hazard quotients provided a basis for identifying the substances in Calcasieu Estuary surface water, sediment, and biota that occurred at levels sufficient to potentially adversely affect one or more ecological receptors. These substances were termed COPCs in the Calcasieu Estuary and included: metals; polycyclic aromatic hydrocarbons (PAHs); polychlorinated biphenyls (PCBs); organochlorine and other pesticides; chlorophenols; chlorinated benzenes; chlorinated ethanes; phthalates; cyanide; and acetone (see Tables A1-3 to A1-6 of the BPF).
Because the preliminary list of COPCs that emerged from the SERA contained over 100 substances (CDM 1999), it was determined that it required further refinement to assure that it included only those substances with a relatively high probability of adversely affecting ecological receptors. As one of the first steps in the BERA process, a scoping meeting was convened in Denver, Colorado (CO) in July, 2000 to develop a more focused list of COPCs. The scoping meeting was attended by risk assessors, risk managers, and the United States Environmental Protection Agency (USEPA) Region VI Ecological Technical Assistance Group (ETAG). Rather than relying on historical data (as was done in the SERA), the participants at this scoping meeting used the results of the Phase I sampling program of the remedial investigation (RI) to identify the COPCs in the Calcasieu Estuary (Goldberg 2001). For water-borne contaminants, the substances that occurred in unfiltered water samples at concentrations in excess of the ambient water quality criteria (i.e., final chronic values, which are termed criteria continuous concentrations, or CCCs; USEPA 1999a; 1999b) were deemed to be COPCs. For sediment-associated constituents, the substances that occurred in whole sediments at concentrations in excess of the effects range median values (ERMs; Long et al. 1995) or comparable sediment quality benchmarks (i.e., probable effect levels PEL; MacDonald et al. 1996; CCME 1999a) were considered to be COPCs. Based on the results of these evaluations, the scoping meeting participants agreed that the following substances were the primary COPCs in the Calcasieu Estuary:

**Water-Borne COPCs**

- Metals (copper and mercury);
- 1,2-dichloroethane (DCE); and,
- Trichloroethane (TCA).
Sediment-Associated COPCs

- Metals (copper, chromium, lead, mercury, nickel, and zinc);
- PAHs [acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene, phenanthrene, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene, total PAHs, and other PAHs];
- PCBs;
- Polychlorinated dibenzo-\(p\)-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs);
- Chlorinated benzenes [(hexachlorobenzene (HCB), hexachlorobutadiene (HCB), and degradation products];
- Phthalates [bis(2-ethylhexyl)phthalate (BEHP)];
- Carbon disulfide;
- Unionized ammonia;
- Hydrogen sulfide;
- Acetone; and,
- Organochlorine pesticides (aldrin and dieldrin).

The substances of greatest concern to aquatic-dependent wildlife are those that are persistent and bioaccumulative. The COPCs identified for water and sediment included all of the persistent and bioaccumulative substances (e.g., PCBs, PCDDs, PCDFs, HCB, HCBD, organochlorine pesticides) that had been regularly detected in monitoring studies of the Calcasieu Estuary.
The areas of interest with respect to environmental contamination were identified using an approach that was similar to the one that was used to identify the COPCs. Specifically, the areas in which concentrations of one or more sediment-associated substances exceeded the ERM (Long et al. 1995; Long and Morgan 1991) or a comparable benchmark were considered to be areas of greatest interest. The areas of interest that were identified by workshop participants included (see Figure A1-7 of the BPF):

- Lower Bayou Verdine (i.e., downstream of the west ditch; COPCs included chromium, copper, zinc, PAHs, and DCE);
- Upper Bayou Verdine (i.e., upstream of the west ditch; COPCs included PAHs);
- Clooney Island Loop (COPCs included PAHs);
- Clooney Island Loop barge slip (COPCs included chromium, zinc, and PCBs);
- Coon Island Loop Northeast (COPCs included PAHs and PCBs);
- Coon Island Loop Southwest (COPCs included PAHs);
- Lower Bayou d’Inde (i.e., mouth to the first bridge over the bayou, including the PPG canal; COPCs included copper, chromium, lead, mercury, nickel, zinc, PAHs, PCBs, PCDDs/PCDFs, HCB, HCBD, acetone, aldrin, and dieldrin);
- Middle Bayou d’Inde (COPCs included nickel, lead, and PCBs);
- South Prien Lake (COPCs included BEHP); and,
Indian Wells Lagoon Outflow (COPCs included copper, lead, mercury, PAHs, and PCBs).

Although these areas were of greatest interest relative to assessing risks to aquatic receptors, the BERA for microorganisms, aquatic plants, benthic invertebrates, and fish was not confined to these areas of interest. Likewise, the exposure and risk analyses for wildlife species were not confined only to these areas of interest because many aquatic-dependent wildlife species have broad foraging ranges or they prey upon highly mobile species (e.g., fish). Nevertheless, identification of the areas of interest helped to focus the BERA.

### 3.2 Potential Ecological Effects of Chemicals of Potential Concern in the Calcasieu Estuary

A stressor is any physical, chemical, or biological entity that has the potential to cause a change in the ecological condition of the environment (USEPA 2000a). Accurate identification of the stressor or stressors that are causing or substantially contributing to biological impairments in aquatic ecosystems is important because it provides a basis for developing strategies that are likely to improve the quality of aquatic resources (USEPA 2000a). In this way, limited human and financial resources can be directed at the challenges that are most likely to maintain or restore beneficial uses.

The RI of the Calcasieu Estuary Cooperative Site was focused on the identification of the chemical stressors that are posing a potential risk to ecological receptors. Many
physical (e.g., water temperature, salinity, dissolved oxygen, erosion and sedimentation, habitat degradation, and pH) and biological (e.g., introduced species, recreational and commercial fishing, disease) factors also have the potential to adversely affect aquatic organisms and aquatic-dependent wildlife species. However, quantification of the effects of these factors on key ecological receptors is outside the scope of the BERA. The strategy for addressing this apparent limitation of the BERA involves assessing risks to ecological receptors in the study areas relative to the comparable risks to those receptors in reference areas. In this way, the incremental risks (i.e., or additional risks, which is often referred to as risk) posed by COPCs above those posed by physical and biological stressors in the systems can be estimated. In addition, any unaccounted effects of such factors on the measurement endpoints can be addressed in the associated uncertainty analysis.

The available information on the identity, fate and transport, toxicity, and bioaccumulation of the COPCs that were identified in the SERA (CDM 1999) and subsequent analytical activities (Goldberg 2001) are summarized in the BPF. The reader is directed to Chapter 4 of the BPF (Appendix A1) and associated Appendices A2 to A17 for more detailed information on the environmental fate and effects of the COPCs that are considered in the Calcasieu Estuary BERA.

3.3 Ecological Receptors Potentially at Risk

A critical element of the problem formulation process is the identification of the receptors at risk that occur within the study area. USEPA guidance is available to help identify receptors at risk (USEPA 1989; 1992; 1997a). The guidance states that
receptors at risk include: (1) resident species or communities exposed to the highest chemical concentrations in sediments and surface water; (2) species or functional groups that are essential to, or indicative of, the normal functioning of the affected habitat; and, (3) federal or state threatened or endangered species.

In the Calcasieu Estuary, the ecological receptors potentially at risk include the plants and animals that utilize aquatic, wetland, and terrestrial habitats within the watershed. Based on the results of the SERA (CDM 1999), the ecological receptors that are potentially at risk due to historic and ongoing discharges of contaminants into surface waters are those species that utilize habitats within aquatic and wetland ecosystems. These groups of organisms include microorganisms, aquatic plants, benthic macroinvertebrates, zooplankton, fish, reptiles and amphibians, and aquatic-dependent birds and mammals. While other groups of ecological receptors are known to occur within this ecosystem (e.g., terrestrial insects, terrestrial plants), they are considered to be of secondary importance from an aquatic risk assessment perspective due to the low potential for exposure to water-borne or sediment-associated contaminants. The highest priority receptor groups for assessing ecological risks included the microbial community, aquatic plant communities, benthic invertebrate communities, benthic and pelagic fish, sediment-probing birds, carnivorous-wading birds, piscivorus birds, omnivorous mammals, and piscivorus mammals.
3.4 Key Exposure Pathways for Ecological Receptors in the Calcasieu Estuary

Evaluation of the risks posed by COPCs in the estuary requires a detailed understanding of the pathways through which ecological receptors are exposed to these substances. In turn, the identification of key exposure pathways requires an understanding of the sources and releases of environmental contaminants and the environmental fate of these substances.

There are a number of sources of toxic and bioaccumulative substances in the Calcasieu Estuary. Natural sources of such substances include weathering and erosion of terrestrial soils, bacterial decomposition of vegetation and animal matter, and long-range transport of substances originating from forest fires or other natural combustion sources. Anthropogenic sources of environmental contaminants in the estuary include industrial wastewater discharges, municipal wastewater treatment plant discharges, surface water recharge by contaminated groundwater, non-point source discharges, and/or deposition of substances that have been released into the atmosphere. An overview of the sources of environmental contaminants that have been released into the Calcasieu Estuary is provided in Chapter 3 of the BPF.

Upon release into aquatic ecosystems, these COPCs partition into environmental media (i.e., water, sediment, and/or biota) in accordance with their physical and chemical properties and the characteristics of the receiving water body (see Chapter 4 and Appendices A2 to A17 of the BPF for descriptions of the environmental fate of the COPCs in the estuary). As a result of such partitioning, COPCs can occur at elevated levels in surface water, bottom sediments, and/or the tissues of aquatic organisms. To facilitate the development of conceptual models that link stressors to
receptors, the COPCs can be classified into three groups based on their fate and effects in the aquatic ecosystem, including bioaccumulative substances, toxic substances that partition into sediments, and toxic substances that partition into water (including the surface microlayer; see Table A1-7 of the BPF).

Once released to the environment, there are three pathways through which ecological receptors can be exposed to COPCs. These routes of exposure include direct contact with contaminated environmental media, ingestion of contaminated environmental media, and inhalation of contaminated air. The exposures routes that apply to each of the categories of COPCs are described below.

**Bioaccumulative Substances** – Aquatic organisms and aquatic-dependent wildlife species can be exposed to bioaccumulative substances via several pathways. First, direct contact with contaminated water or sediment can result in the uptake of bioaccumulative substances through the gills or through the skin of aquatic organisms (see Table A1-8 of the BPF). This route of exposure is particularly important for sediment-dwelling organisms because most of the bioaccumulative COPCs tend to accumulate in sediments upon release into the environment. Ingestion of contaminated sediments and/or prey species also represents an important route of exposure to bioaccumulative substances for aquatic organisms, particularly for sediment-dwelling organisms, carnivorous fish, amphibians, and reptiles (see Table A1-9 of the BPF).

For aquatic-dependent wildlife species, ingestion of contaminated prey species represents the principal route of exposure to bioaccumulative substances (see Table A1-8 of the BPF). The groups of wildlife species that are likely to be exposed to bioaccumulative substances through this pathway include
insectivorous birds, sediment-probing birds, carnivorous-wading birds, piscivorus birds, and omnivorous and piscivorus mammals (see Table A1-9 of the BPF).

**Toxic Substances that Partition into Sediments** – Aquatic organisms and aquatic-dependent wildlife species can be exposed to toxic substances that partition into sediments through several pathways. For aquatic organisms, such as microbiota, aquatic plants, sediment-dwelling organisms, benthic fish, and amphibians, direct contact with contaminated sediment and/or contaminated pore water represents the most important route of exposure to toxic substances that partition into sediments (see Tables A1-8 and A1-9 of the BPF). However, ingestion of contaminated sediments can also represent an important exposure pathway for certain species (e.g., polychaetes that process sediments to obtain food). Direct contact with contaminated sediments also represents a potential exposure pathway for reptiles; however, it is less important for reptiles than for other aquatic organisms.

For aquatic-dependent wildlife species, ingestion of contaminated sediments represents the principal route of exposure to toxic substances that partition into sediments. Of the wildlife species that occur in the Calcasieu Estuary, sediment-probing birds are the most likely to be exposed through this pathway (see Table A1-9 of the BPF).

**Toxic Substances that Partition into Surface Water** – Aquatic organisms and aquatic-dependent wildlife species can be exposed to toxic substances that partition into surface water through several pathways. For aquatic organisms, such as microbiota, aquatic plants, aquatic invertebrates, fish, and amphibians, direct contact with contaminated water represents the most important route of
exposure to toxic substances that partition into surface water (see Tables A1-8 and A1-9 of the BPF). This exposure route involves uptake through the gills and/or through the skin.

For aquatic-dependent wildlife species, ingestion of contaminated water represents the principal route of exposure to toxic substances that partition into surface water. While virtually all aquatic-dependent wildlife species are exposed to toxic substances that partition into surface water, this pathway is likely to account for a minor proportion of the total exposure for most of these species (see Tables A1-8 and A1-9 of the BPF).

**Toxic Substances that Partition into the Surface Microlayer** — Aquatic organisms and aquatic-dependent wildlife species can be exposed to toxic substances that partition into surface water through several pathways. For aquatic organisms, such as aquatic invertebrates and pelagic fish, direct contact with the contaminated surface microlayer (i.e., the layer of water that is present at the water-air interface) represents the most important route of exposure to such toxic substances (see Tables A1-8 and A1-9 of the BPF). This exposure route involves uptake through the gills and/or through the skin of aquatic organisms.

For aquatic-dependent wildlife species (birds and mammals), inhalation of substances that volatilize from the surface microlayer represents the principal route of exposure to toxic substances that partition into this environmental medium. However, this route of exposure is likely to be of relatively minor importance under most circumstances. This pathway could become important during and following accidental spills, when such substances are present as slicks on the water surface.
3.5 Conceptual Model for the Calcasieu Estuary BERA

In accordance with USEPA guidance, the problem formulation for a BERA is intended to provide three main products, including: assessment endpoints, conceptual models, and a risk analysis plan (USEPA 1997a; 1998). The conceptual model represents a particularly important component of the problem formulation because it enhances the level of understanding regarding the relationships between human activities and ecological receptors at the site under consideration. Specifically, the conceptual model describes key relationships between stressors and assessment endpoints. In so doing, the conceptual model provides a framework for predicting effects on ecological receptors and a template for generating risk questions and testable hypotheses (USEPA 1997a; 1998). The conceptual model also provides a means of highlighting what is known and what is not known about a site. In this way, the conceptual model provides a basis for identifying data gaps and designing monitoring programs to acquire the information necessary to complete the assessment.

Conceptual models consist of two main elements, including: a set of hypotheses that describe predicted relationships between stressors, exposures, and assessment endpoint responses (along with a rationale for their selection); and, diagrams that illustrate the relationships presented in the risk hypotheses. The sources and releases of COPCs, the fate and transport of these substances, the pathways by which ecological receptors are exposed to the COPCs, and the potential effects of these substances on the ecological receptors that occur in the Calcasieu Estuary are described in the BPF. Similarly, the hypotheses that provide predictions regarding how ecological receptors will be exposed to and respond to the COPCs is presented in Chapter 7 of the BPF. The diagrams that illustrate food web dynamics in the Calcasieu Estuary are presented in Figures A1-8 and A1-9 of the BPF. In addition,
conceptual model diagrams that illustrate exposure pathways and potential effects for bioaccumulative substances, toxic substances that partition into sediments, toxic substances that partition into overlying water, toxic substances that partition into the surface microlayer, and all categories of COPCs are presented in Figures A1-10 to A1-14 of the BPF, respectively.

### 3.6 Selection of Assessment and Measurement Endpoints

In the environment, a variety of plant and animal species can be exposed to COPCs (these species are referred to as receptors at risk). Each of these receptors may be exposed to a chemical through different exposure routes and have the potential to exhibit different types and severities of effects. While information on the effects of each chemical on each component of the ecosystem would provide comprehensive information for evaluating ecological risks, it is neither practical nor feasible to directly evaluate risks to all of the individual components of the ecosystem that could be adversely affected by environmental contamination at a site (USEPA 1997a). For this reason, risk assessment activities must be focused on the receptors that represent valued ecosystem components (e.g., sportfish species) and on the receptors that support valued ecosystem functions (e.g., carbon processing by the microbial community, which is needed to support healthy fish populations). Of particular interest are those receptors that are most likely to be adversely affected by the presence of environmental contaminants at the site (USEPA 1998).

An assessment endpoint is an ‘explicit expression of the environmental value that is to be protected’ (USEPA 1997a). The selection of assessment endpoints is an
essential element of the overall ERA process because it provides a means of focusing assessment activities on the key environmental values (e.g., reproduction of sediment-probing birds) that could be adversely affected by exposure to environmental contaminants. Assessment endpoints must be selected based on the ecosystems, communities, and species that occur, have historically occurred, or could potentially occur at the site (USEPA 1997a). The following factors need to be considered during the selection of assessment endpoints (USEPA 1997a):

- The COPCs that occur in environmental media and their concentrations;
- The mechanisms of toxicity of the COPCs to various groups of organisms;
- The ecologically-relevant receptor groups that are potentially sensitive or highly exposed to the contaminant, based upon their natural history attributes; and,
- The presence of potentially complete exposure pathways.

Thus, the fate, transport, and mechanisms of ecotoxicity for each contaminant or group of contaminants must be considered to determine which receptors are likely to be most at risk. This information must include an understanding of how the adverse effects of the contaminant could be expressed (e.g., eggshell thinning in birds) and how the form of the chemical in the environment could influence its bioavailability and toxicity.

The primary COPCs in the study area were identified in Chapter 3 of the BPF. Brief overviews of the environmental fate and ecological effects of each of these COPCs were also provided in the BPF (Chapter 4) to describe what happens to each chemical when it is released into the environment and how adverse effects could be expressed.
on various ecological receptors. Importantly, the information on fate and transport of these COPCs facilitated identification of the environmental media in which each chemical is most likely to be found at elevated concentrations (i.e., in water, sediment, or biota; see Chapter 4 of the BPF). A review of the available toxicological data provided a basis for identifying which groups of ecological receptors are most sensitive to the effects of each substance is also presented in the BPF (Chapter 4). Chapter 5 of the BPF provides more detailed descriptions of the various exposure pathways, while the ecological receptors that occur within the study area were identified in Chapter 6 of the BPF. Integration of this information provides a means of developing a conceptual model of the site that clearly identifies linkages between contaminant discharges and effects on key ecological receptors (see Chapter 7 of the BPF). The resultant conceptual site model and associated information provide the basis for selecting the assessment endpoints that are most relevant for the Calcasieu Estuary BERA. The assessment endpoints that were selected for consideration in the BERA include:

- Activity of the microbial community;
- Survival, growth, and reproduction of aquatic plants;
- Survival, growth, and reproduction of benthic invertebrates;
- Survival, growth, and reproduction of benthic and pelagic fish;
- Survival and reproduction of aquatic-dependent bird species; and,
- Survival, growth, and reproduction of aquatic-dependent mammalian species.
The measurement endpoints that were selected to evaluate the status of each of the selected assessment endpoints are described in Chapters 4 through 9 of this document.
Chapter 4. Assessment of Risks to the Microbial Community in the Calcasieu Estuary using a Weight of Evidence Approach

Summary: This chapter summarizes the components of the baseline ecological risk assessment (BERA) that evaluate the risks posed to the microbial community associated with exposure to chemicals of potential concern (COPCs) in the Calcasieu Estuary (Appendix C). More specifically, the data on whole-sediment chemistry and whole-sediment toxicity (i.e., the results of solid-phase sediment toxicity tests with the bacterium, *Vibrio fisheri*; Microtox™) were evaluated to determine if significant effects on the activity of the microbial community are occurring or are likely to be occurring in the Calcasieu Estuary. The information on these two lines of evidence were also used to evaluate the nature, magnitude, and areal extent of effects on the selected assessment endpoint. Furthermore, these data were used to identify the substances that are causing or substantially contributing to such effects in the Calcasieu Estuary (i.e., the contaminants of concern; COCs). Finally, these data were further evaluated to support an integrated assessment of risks to the microbial community associated with exposure to COPCs in the Calcasieu Estuary.

The results of the integrated assessment were used to classify environmental conditions at specific sampling locations into three risk categories. Ecological risks were classified as low if the frequency (i.e., percent toxic samples) and/or magnitude of effects (i.e., median effective concentration; EC$_{50}$) that were observed or predicted to occur were similar to those for selected reference areas. By comparison, ecological risks were classified as indeterminate if the frequency and/or magnitude of effects that were observed or predicted to occur were moderately higher than those for selected reference areas. The term, indeterminate, was used to describe this classification because decisions regarding remedial actions at such locations
should consider a variety of factors in addition to ecological risks (e.g., costs and effects of remedial actions, potential for natural recovery, etc.). Finally, ecological risks were classified as high if the frequency and/or magnitude of effects that were observed or predicted to occur were substantially higher than those for selected reference areas. Reaches or areas of concern (AOCs) so designated represent the highest priority for remedial action planning.

The results of the integrated assessment indicate that exposure to whole sediments poses low to indeterminate risks to microbial communities in the Calcasieu Estuary. Risks were classified as low for 51% (316 of 624) of the sampling locations from the three AOCs. However, indeterminate risks to the microbial community (i.e., incremental risks compared to those associated with exposure to conditions in reference areas), were indicated for 49% of the sampling locations (i.e., 308 of 624) within the three AOCs in the estuary. None of the sampling locations within the three AOCs were classified as posing high risks to the microbial community, primarily due to the results of the uncertainty analysis and associated moderate weighting of the results. Nevertheless, conditions posing incremental risks to the microbial community (i.e., relative to reference areas) were frequently observed in the Calcasieu Estuary.

The risks to microbial communities posed by exposure to COPCs were evaluated for three AOCs in the estuary, including the Upper Calcasieu River AOC (UCR AOC), the Bayou d’Inde AOC (BI AOC), and the Middle Calcasieu River AOC (MCR AOC). The risks to the microbial community were also evaluated in selected reference areas within the estuary. Of the three AOCs considered, the risks to the microbial community were highest in Bayou d’Inde (BI). Within this AOC, sediment samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, lower Bayou d’Inde mainstem, and the inner portions of Lockport Marsh posed the highest risks. Although risks to the microbial community were generally lower in the UCR AOC and in the MCR AOC, sediments posing indeterminate risks to microorganisms were frequently identified in the northern portions of Clooney Island Loop, Clooney Island barge slip, portions of Lake Charles,
portions of the Coon Island Loop, the western shore of Middle Calcasieu River Mainstem, Prien Lake, Moss Lake, and Indian Wells Lagoon. Risks to the microbial community were classified as low throughout the reference areas that were selected to represent contemporary background sediment conditions in the estuary.

The results of the biological investigations conducted during the Remedial Investigation (RI) indicate that the magnitude of effects tends to increase with increasing risk to the microbial community. The average EC$_{50}$-bioluminescence was $11.1 \pm 8.4$ (n=84) for the whole-sediment samples that were classified into the low risk category. For the samples that were classified into the indeterminate risk category, a mean EC$_{50}$-bioluminescence of $0.50 \pm 0.32$ (n=5) was calculated. Together, these results demonstrate that the metabolism of microorganisms has been impaired in response to exposure to contaminated sediments at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the microbial community in the Calcasieu Estuary (i.e., COCs). More specifically, the COCs in the estuary were considered to include:

- PAHs [1,1-biphenyl, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs];
- PCBs (total PCBs); and,
- Phthalates (BEHP).

All of these substances occurred in whole-sediment samples from the Calcasieu Estuary at concentrations in excess of those observed in samples...
from reference areas and in excess of the selected benchmarks. In addition, the concentrations of these substances in the effects distribution were generally higher than they were in the no-effects distribution for the selected measurement endpoint (i.e., bioluminescence of the bacterium, *Vibrio fisheri*). A detailed assessment of the risks to the microbial community associated with exposure to contaminated sediments in the Calcasieu Estuary is provided in Appendix C.

### 4.0 Introduction

Microbial communities, which consist of bacteria, protozoans, and fungi, play several essential roles in estuarine ecosystems. First, microbial communities transform the energy from aquatic organisms into forms that can be used directly by primary consumers, such as crabs, worms, shellfish, and snails (e.g., by degrading and transforming detrital organic matter, Apple *et al.* 2001). Microbial communities also play a key role in the cycling and transformation of nutrients in sediments and the water column. For example, the microbial community is an essential element of the nitrogen cycle, in which atmospheric nitrogen is converted through a series of steps into nitrates, nitrites, and ammonia. These forms of nitrogen represent essential plant nutrients and are the basic building blocks for protein synthesis. The sulfur cycle in aquatic environments, in which hydrogen sulfide is converted to sulfate (which is incorporated into plant and animal tissues), is also mediated by the microbial community (Odum 1975). The microbial community supports primary productivity by transforming phosphorus into forms that can be readily used by aquatic plants (i.e., phosphate). Finally, carbon cycling (i.e., between the dissolved and particulate forms) in aquatic ecosystems is dependent on the microbial community.
As the microbial community supports a number of critical ecosystem functions (see above), it is important to evaluate the effects of environmental contaminants on this group of ecological receptors. Aquatic microorganisms, including bacteria, protozoans, and fungi, can be exposed to environmental contaminants through contact with contaminated surface water, contaminated sediments, and contaminated pore water. Because contact with whole sediment is likely to represent the most important and direct route of exposure for the microbial community, other possible exposure pathways (e.g., surface water or pore water) were not evaluated relative to the potential for adverse effects on the microbial communities in the estuary. In addition to the assessment of risks to the microbial community, risk assessments were also conducted to evaluate the potential effects of COPCs in the estuary on aquatic plant communities (Chapter 5), benthic invertebrate communities (Chapter 6), fish communities (Chapter 7), avian communities (Chapter 8), and mammalian communities (Chapter 9).

4.1 Methods

A step-wise approach was used to assess the risks to the microbial community posed by the COPCs in the Calcasieu Estuary (see Appendix C for details). The five main steps in this process included: (1) identification of assessment endpoints, measurement endpoints, risk questions and testable hypotheses; (2) collection, evaluation, and compilation of the relevant information on sediment quality conditions in the Calcasieu Estuary; (3) assessment of the exposure of the microbial community to COPCs (i.e., exposure assessment; Figure 4-1); (4) assessment of the effects of COPCs on the microbial community (i.e., effects assessment; Figure 4-2);
and, (5) characterization of risks to the microbial community (i.e., risk characterization; Figures 4-3 to 4-8).

Assessment Endpoints, Measurement Endpoints, and Risk Questions – As the microbial community supports a number of critical ecosystem functions (see above), it is important to evaluate the effects of environmental contaminants on this group of ecological receptors. Aquatic microorganisms, including bacteria, protozoans, and fungi, can be exposed to environmental contaminants through contact with contaminated surface water, contaminated sediments, and contaminated pore water. Of these, exposure to contaminated sediments probably represents the primary route of exposure for epibenthic and infaunal microbial species. For this reason, it is important to evaluate the effects of exposure to contaminated sediments on the activity of the microbial community (i.e., the rate at which microorganisms perform essential ecosystem functions, such as processing organic carbon). As the goal of this assessment is to determine if contaminated sediments are likely to adversely affect the key functions that are provided by the microbial community, the activity of the aquatic microbial community was identified as the assessment endpoint for this component of the BERA.

To provide a valid basis for assessing ecological effects, the assessment endpoints are linked to the measurement endpoints by a series of risk questions and/or testable hypotheses. In this study, the investigations to assess the effects of environmental contaminants on the microbial community were designed to answer the following risk questions:
• Are the levels of COPCs in whole sediment from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in whole sediment from reference areas and greater than the sediment quality benchmarks for the protection of microorganisms that utilize benthic habitats (i.e., the activity of the microbial community)?

• Is the metabolic rate of bacteria (i.e., the activity of aquatic microbiota, as indicated by the bioluminescence of the bacterium, *Vibrio fisheri*) exposed to sediments from the Calcasieu Estuary AOCs outside the normal range (i.e., 95% Confidence interval) for bacteria exposed to reference sediments?

It is difficult to measure the status of the assessment endpoint directly in the Calcasieu Estuary. For this reason, a suite of measurement endpoints were selected to provide the information needed to determine if the activity of the microbial community is being adversely affected due to exposure to COPCs. First, sediment chemistry data were used to determine if the concentrations of COPCs in Calcasieu Estuary sediments are sufficient to cause or substantially contribute to sediment toxicity. In addition, the results of solid-phase sediment toxicity tests with the bacterium, *Vibrio fisheri* [i.e., Microtox™; using the methods described in Johnson (1998) and in Johnson and Long (1998)] were used to evaluate the effects of contaminated sediments on the activity of the microbial community. More specifically, bioluminescence in the bacterium, *Vibrio fisheri*, was used as an indicator of microbial metabolic rate and, hence, the ability of the microbial community to perform key functions (such as carbon processing). Although *Vibrio fisheri* is a marine species, it has been used as a surrogate species for evaluating the effects of contaminants in surface water, pore water,

**Data Collection, Evaluation, and Compilation** – The information that was used in the Calcasieu Estuary BERA was collected as part of the Phase I and Phase II RI. Whole-sediment samples were collected in the three AOCs and in reference areas using a stratified-random sampling design. Samples were shipped to multiple laboratories to support chemical and toxicological characterization. The results of chemical analyses were available for 641 whole-sediment samples from the estuary. Whole-sediment toxicity tests were conducted on all 100 of the Phase II samples. Of the 100 whole-sediment samples that were collected during Phase II of the RI, 75 were obtained from the three principal AOCs (i.e., UCR AOC, BI AOC, and MCR AOC), 10 were obtained from Bayou Verdine, and 15 were obtained from reference areas. All of the resultant data were evaluated against the project data quality objectives (DQOs) upon receipt from the laboratories and incorporated into the project database. The results of data validation and data auditing indicated that the information used in the BERA generally met the project DQOs.

**Exposure Assessment** – Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter et al. 2000). The exposure assessment is intended to provide an estimate of the magnitude of exposure of receptors (i.e., the microbial community) to COPCs, over time and space. In this assessment, information on the concentrations of COPCs in whole sediment was used to evaluate exposure of the microbial community to COPCs (Figure 4-1). Summary
statistics (i.e., measures of central tendency and distributions) were calculated for each reach and each AOC in the Calcasieu Estuary. The substances that could pose incremental risks to the microbial community were identified by comparing the concentrations of COPCs in each AOC to the upper limit of background concentrations (i.e., 95% upper confidence limit; UCL) for the reference areas. Substances that occurred within a reach or an AOC at concentrations that were a factor of two or more higher than the 95% UCL for reference areas were considered to have the potential to pose incremental risks to the microbial community.

**Effects Assessment** – In the analysis of effects, risk assessors determine the nature of toxic effects that are associated with exposure to contaminants and the magnitude of the toxic effects as a function of exposure (Suter *et al.* 2000). In this assessment, exposure of the microbial community was evaluated using information on the concentrations of COPCs in whole sediments. As such, it was necessary to compile information on the effects on microbial communities associated with exposure to COPCs in whole sediment (Figure 4-2). The Microtox apparent effects threshold (AETs) from Washington State were selected as the toxicity benchmarks for whole sediments for this assessment (Barrick *et al.* 1988). Because the Microtox AETs represent the concentrations of sediment-associated contaminants above which adverse effects are always observed on the toxicity test organism (i.e., the bacterium, *Vibrio fisheri*), COPCs were considered to pose a significant risk to the microbial community at concentrations in excess of the Microtox AETs. That is, whole-sediment samples with concentrations of one or more COPCs above the Microtox AETs were predicted to be toxic to the microbial community.
**Risk Characterization** – The purpose of risk characterization is to determine if significant effects are occurring or are likely to occur at the site under investigation. In addition, this step of the process is intended to provide the information needed to describe the nature, magnitude, and areal extent of effects on the selected assessment endpoints. Finally, the substances that are causing or substantially contributing to adverse effects on the survival, growth, or reproduction of the microbial community (i.e., COCs) are identified from the preliminary list of COPCs. Two lines of evidence were examined to determine if sediments in the Calcasieu Estuary pose significant risks to the microbial community: whole-sediment chemistry and whole-sediment toxicity (Figures 4-3 to 4-8).

In this assessment, both lines of evidence were used to determine if exposure to COPCs in whole sediment poses incremental risks to the microbial community in the Calcasieu Estuary (i.e., relative to the risks that are associated with exposure to whole sediment from reference areas in the estuary). The nature of the effects associated with exposure to sediment-associated COPCs was also evaluated using both of these lines of evidence. Subsequent to evaluating the nature of effects, the magnitude of the effects on the microbial community exposed to contaminated sediments was evaluated using whole-sediment toxicity data. A preliminary assessment of the areal extent of adverse effects on microbial communities in the Calcasieu Estuary was conducted using the whole-sediment chemistry data that were collected in the Phase I and II RI. Finally, the COCs were identified by comparing the concentrations of COPCs in whole sediments to the concentrations of those substances in reference sediments and by comparing the concentrations of COPCs to the selected benchmarks for those
substances. Concordance between the sediment chemistry and the toxicity data was also used to identify the COCs from the longer list of COPCs.

Risks to the microbial community were evaluated using the Microtox™ Solid-Phase Toxicity (SPT) test. This SPT test was conducted on 100 whole-sediment samples collected during the Phase II sampling program (i.e., including 10 samples from BV AOC). In the SPT test, bioluminescent bacteria (*Vibrio fisheri*) were exposed directly to sediment suspended in solution for a period of 20 minutes at 15°C in a temperature controlled water-bath. A log-linear model was used to calculate EC$_{50}$ values (expressed as percentage of sediment wet weight/mL) and 95% confidence intervals for each sediment tested.

Sediment samples were designated as toxic or not toxic using a reference envelope approach. In this approach, the statistical distribution of the EC$_{50}$ values for the samples from the reference areas was first determined. These values were found to be lognormally distributed. Next, the normal range of the EC$_{50}$ values for the reference samples (i.e., 95% prediction limits) was determined by calculating the 2.5$^{th}$ and 97.5$^{th}$ percentile values. Samples were designated as toxic if the calculated EC$_{50}$ values were lower than the lower limit of the normal range of EC$_{50}$ values (i.e., the 2.5$^{th}$ percentile value; that is, if the EC$_{50}$ was less than 1.4% sediment ww/mL). All other samples were designated as not toxic.

The risks to the microbial community associated with exposure to COPCs in environmental media were classified into three categories, based on the results that were obtained for the various measurement endpoints. More specifically, risks to the microbial community were classified as low, indeterminate, or high.
based on the observed and predicted incidence of toxicity (IOT; i.e., <20%, 20-50%, and >50% increase in the proportion of toxic samples relative to reference, respectively) and on the observed magnitude of toxicity (MOT; i.e., <10%, 10-20%, and >20% increase in mortality relative to reference, respectively; Appendix C).

An integrated assessment of the risks posed to the microbial community by exposure to COPCs in whole sediments was conducted following the assessment of the nature, magnitude, and areal extent of risks. In this assessment, the available data were integrated by calculating a final risk score for each sampling location based on the results for up to two lines of evidence (as described in Appendix C). The final risk score is intended to provide an integrated measure of the risks that contaminated sediments pose to microbial communities in the Calcasieu Estuary. More specifically, the final risk score integrates the results of whole-sediment toxicity tests and whole-sediment chemical analyses into a single parameter (Section 5.0 of Appendix C). The final risk scores were used to evaluate the areal extent of risk to on the microbial community in the Calcasieu Estuary, with scores of <2 designated as low risk, 2 to 3 designated as indeterminate risk, and >3 designated as high risk. Because microorganisms tend to have very limited ranges, this evaluation was conducted on a sampling location by sampling location (i.e., area averaging was not considered to be appropriate for assessing risks to locally-exposed sub-populations of microorganisms).
4.2 Results and Discussion

Two lines of evidence were used to determine if exposure to whole sediments was likely to adversely affect microbial communities in the Calcasieu Estuary. Evaluation of the whole-sediment chemistry data collected during the Phase I and Phase II RI using the selected toxicity thresholds for whole sediment indicates that roughly 54% (337 of 624) of the sediment samples from the three AOCs have concentrations of one or more COPCs that are sufficient to cause or substantially contribute to sediment toxicity to marine bacteria. By comparison, 15% of the whole-sediment samples (11 of 75 samples) collected from the three AOCs were found to be acutely toxic to marine bacteria (endpoint: EC\textsubscript{50}-bioluminescence). When considered together, these two lines of evidence indicate that exposure to contaminated sediments is adversely affecting the metabolic rate of microorganisms in the Calcasieu Estuary and, hence, the activity of the microbial community.

**Nature of Effects** – The results of the investigations that were conducted during the RI indicate that adverse effects on microorganisms are associated with exposure to COPCs in whole sediment from the Calcasieu Estuary. More specifically, evaluation of the whole-sediment chemistry data indicates that the concentrations of COPCs are sufficient to adversely affect the microbial community (i.e., as indicated by exceedances of the Microtox AETs). Additionally, the results of toxicity tests with the Microtox\textsuperscript{TM} SPT indicate that the metabolic rate of the bacterium (*Vibrio fisheri*) has been adversely affected by exposure to whole-sediment samples from the Calcasieu Estuary. Therefore, it is concluded that the activity of the microbial community is being adversely affected by exposure to contaminated sediments at certain locations in the
Calcasieu Estuary, based on the evaluations of the whole-sediment chemistry and whole-sediment toxicity data.

**Magnitude of Effects** – The magnitude of the effects on the microbial community exposed to contaminated sediments was evaluated using one line of evidence: whole-sediment toxicity. Based on the results of SPTs with the bacterium, *Vibrio fisheri*, it is apparent that exposure to whole sediments poses risks to the microbial community that range from low to indeterminate in the Calcasieu Estuary. Of the 75 whole-sediment samples that were collected from the three AOCs, 64 (85%) were classified as posing a low risk to the microbial community (i.e., observed EC$_{50}$-bioluminescence was <10% lower than the 95% LCL for reference samples). The balance of the samples 11 (15%) were classified as posing high risks to the microbial community (i.e., observed EC$_{50}$-bioluminescence was >20% lower than the 95% LCL for reference samples). Therefore, the information on the magnitude of the effects indicates that whole-sediment samples posing high risks to the microbial community were commonly encountered in the Calcasieu Estuary.

**Preliminary Assessment of the Areal Extent of Effects** – The areal extent of adverse effects on microbial communities in the Calcasieu Estuary was initially assessed using the whole-sediment chemistry data that were collected in the Phase I and II Remedial Investigations. To support this evaluation of the spatial distribution of chemical contamination, each sediment sample (n=641) was classified into one of two categories (i.e., low or high) based on the risk that it posed to microorganisms (i.e., samples were classified as low if there were no
exceedances of the Microtox AETs and high if the concentrations of one or more COPCs exceeded the Microtox AETs; Appendix C). Then, these data were compiled on a reach by reach basis and mapped using ArcView/Spatial Analyst software.

The results of the preliminary evaluation of the areal extent of effects indicate that sediment quality conditions within the Calcasieu Estuary are generally of sufficient quality to support the normal activity of the microbial community (i.e., the metabolic rate of microorganisms in the three AOCs is likely to be generally consistent with that for reference areas). However, the concentrations of COPCs were sufficient to adversely affect the microbial community in numerous whole-sediment samples from each of the three AOCs. A number of hot spots with respect to sediment contamination were identified within the UCR AOC, with the highest risks to the microbial community occurring in the Clooney Island barge slip, the northern and eastern portions of Clooney Island Loop, the mouth of Bayou Ver dine, Coon Island Loop northwest and northeast, and the southern portions of Coon Island Loop. Within the BI AOC, the highest risks to the microbial community were evident in portions of upper Bayou d’Inde, throughout middle Bayou d’Inde, PPG Canal, the lower Bayou d’Inde mainstem, and Lockport Marsh. The hot spots in the MCR AOC with respect to sediment contamination were largely associated with the western shore of the Middle Calcasieu River Mainstem, Prien Lake, Moss Lake, and the Indian Wells Lagoon. The integrated assessment of risks to the microbial communities, which is presented below, provides a basis for further identifying the locations that pose low and indeterminate risks to the microbial community.
**Contaminants of Concern** – The substances that occurred in whole-sediment samples at concentrations above those in reference areas, above the selected benchmarks, and showed concordance with the biological response data, represent the COCs relative to effects on the microbial community. In the UCR AOC, the COCs include: various individual PAHs; total LMW-PAHs; total PCBs; and, BEHP. The COCs in the BI AOC include: various individual PAHs; total PCBs; and, BEHP. In the MCR AOC, the COCs include: numerous individual PAHs; total LMW-PAHs; total HMW-PAHs; total PAHs; total PCBs; and, BEHP. The results of whole-sediment toxicity tests indicate that one or more of these substances are biologically-available in Calcasieu Estuary sediments. Hence, the COCs identified above should be considered to be the highest priority for developing preliminary remediation goals for the Calcasieu Estuary.

**Uncertainty Assessment** – There are a number of sources of uncertainty in assessments of risk to the microbial community, including uncertainties in the conceptual model, in the exposure assessment, and in the effects assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and influence of such uncertainties.

A total of 10 criteria were used to evaluate the level of confidence that can be placed in the various measurement endpoints that were used to assess risks to the microbial community. For each of these criteria, the degree of uncertainty in the measurement endpoint was scored from 1 (higher uncertainty) to 3 (lower uncertainty). These results were then used to determine the level of uncertainty...
that was associated with the conceptual model, the exposure assessment, and the effects assessment. In turn, these results provided a basis for weighting each measurement endpoint (i.e., using the total evaluation score) used in the integrated assessment of risks to the microbial community (Table 4-1). The resultant total evaluation scores reflect the potential for confounding factors to influence the results of the assessment and, in so doing, affect the potential for obtaining false positive results (i.e., samples designated as indeterminate or high risk that actually pose low risks to the microbial community) or false negative results (i.e., samples designated as low risk that actually pose indeterminate or high risks to the microbial community). The results of the uncertainty analysis that was conducted as part of the BERA are presented in Appendix C.

**Integrated Assessment of Risks** – Information on two lines of evidence was considered in the integrated assessment of risks to the microbial community. Consideration of multiple lines of evidence in an integrated assessment of risks is desirable because it provides a basis for utilizing all of the available data for assessing risks, explicitly considers the uncertainty associated with each line of evidence, and, in so doing, reduces the uncertainty associated with the overall assessment of risks. The final risk scores that were calculated using information on the two measurement endpoints and the associated uncertainty in each measurement endpoint were used to provide an integrated measure of the risks posed to the microbial community associated with exposure to COPCs in whole sediment.

**Upper Calcasieu River AOC** – A total of 146 sediment samples were collected within the UCR AOC to support an assessment of the risks posed to
the microbial community associated with exposure to sediment-associated COPCs. The results of this assessment indicated that exposure to whole sediments in the UCR AOC generally posed a low risk to microorganisms (i.e., average of the final risk scores of 0.727; n=146). Seventy-eight percent of the sediment samples (i.e., 114 of 146) from this AOC had low final risk scores (i.e., < 2; Table 4-2). However, indeterminate risks to microorganisms were indicated for 22% of the sediment samples (32 of 146) of the sediment samples from the UCR AOC. Consistent with the results of the previous analyses, the locations where contaminated sediments posed the highest risks (i.e., relative to the activity of the microbial community) included the Calcasieu River downstream of the salt water barrier, portions of Lake Charles, the Calcasieu River downstream of Lake Charles, the Clooney Island barge slip, the northern and northeastern portions of Clooney Island Loop, and, the northern, central, and southern portions of the Coon Island Loop (Figures 4-9 and 4-10).

**Bayou d’Inde AOC** – A total of 315 sediment samples were collected within the BI AOC to support an assessment of the risks posed to the microbial community associated with exposure to sediment-associated COPCs. The results of this assessment indicated that exposure to whole sediments in the BI AOC generally posed an indeterminate risk to microorganisms (i.e., average of the final risk scores of 2.32; n=315). Roughly 26% of the sediment samples (i.e., 83 of 315) from this AOC had low final risk scores (i.e., < 2; Table 4-2). By comparison indeterminate risks to microorganisms were indicated for 74% (232 of 315) of the sediment samples from the BI AOC. Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where contaminated sediments posed the highest risks (i.e., relative to the
activity of the microbial community) included upper Bayou d’Inde from roughly 0.5 km upstream of the CitCon property to the Highway 108 bridge, the mainstem and off-channel wetland areas throughout middle Bayou d’Inde, PPG Canal, Lockport Marsh, the wetland areas located east of lower Bayou d’Inde mainstem, and lower Bayou d’Inde mainstem (Figures 4-11 and 4-12).

**Middle Calcasieu River AOC** – A total of 163 sediment samples were collected within the MCR AOC to support an assessment of the risks posed to the microbial community associated with exposure to sediment-associated COPCs. The results of this assessment indicated that exposure to whole sediments in the MCR AOC generally posed a low risk to microorganisms (i.e., average of the final risk scores of 0.845; n=163). Seventy-three percent of the sediment samples (i.e., 119 of 163) from this AOC had low final risk scores (i.e., <2; Table 4-2). Nevertheless, indeterminate risks to the microbial community were indicated for 27% (44 of 163) of the sediment samples from the MCR AOC. Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where contaminated sediments posed the highest risks (i.e., relative to the activity of the microbial community) included the western shoreline of Middle Calcasieu River Mainstem from Bayou d’Inde to Moss Lake, portions of Prien Lake, portions of Moss Lake, Indian Wells Lagoon, and portions of the old river channel within the Middle Calcasieu River Mainstem reach (Figures 4-13, 4-14, and 4-15).
4.3 Summary and Conclusions

The risks to microbial communities posed by exposure to whole sediments were assessed in the Calcasieu Estuary. In total, information on two lines of evidence was used to determine if the activity of the aquatic microbial community has been adversely affected or is likely to have been adversely affected by exposure to sediments in the estuary relative to reference conditions. The two lines of evidence that were considered in the assessment included whole-sediment chemistry and whole-sediment toxicity.

The results of this assessment indicated that exposure to whole sediments from the Calcasieu Estuary posed variable risks to microbial communities (i.e., risks were classified as low for 51% and indeterminate for 49% of the 624 sediment samples collected within the three AOCs investigated; Table 4-2). Of the three AOCs considered, the risks to the microbial community were highest in Bayou d’Inde. Within this AOC, sediment samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, lower Bayou d’Inde mainstem, and Lockport Marsh posed the highest risks to the microbial community (Figures 4-11 and 4-12). Although risks to the microbial community were generally lower in the UCR AOC and MCR AOC, sediments posing indeterminate risks were identified in the northern portions of Clooney Island Loop, Clooney Island barge slip, the northern, central, and southern portions of Coon Island Loop, the western shoreline of Middle Calcasieu River Mainstem from Bayou d’Inde to Moss Lake, Moss Lake, Prien Lake, Indian Wells Lagoon, and portions of the old river channel within the Middle Calcasieu River Mainstem reach (Figures 4-9, 4-10, 4-13, 4-14, and 4-15). Risks to the microbial community are generally low throughout the reference areas with the exception of certain portions of Bayou Choupique (Figure 4-16).
The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the microbial community. The average EC$_{50}$-bioluminescence was 11.1±8.4 % sediment wet weight/mL (n=84) for the whole-sediment samples that were classified into the low risk category (Table 4-3). For the samples that were classified into the indeterminate risk category, a mean EC$_{50}$-bioluminescence of 0.5±0.3 % sediment wet weight/mL (n=5) was calculated. Together, these results demonstrate that the metabolism of microorganisms has been impaired in response to exposure to contaminated sediments at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the microbial community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs in the estuary were considered to include:

- PAHs (1,1-biphenyl, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-COCs, and total PAHs);
- PCBs (total PCBs); and,
- Phthalates (BEHP).

All of these substances occurred in whole-sediment samples at concentrations in excess of those observed in samples from reference areas and in excess of the selected
benchmarks. In addition, the concentrations in the effects distribution were generally higher than the concentrations in the no effects distribution for the selected measurement endpoint (i.e., bioluminescence of the bacterium, *Vibrio fisheri*). Hence, the COCs identified above should be considered to be the highest priority for developing preliminary remediation goals.
Chapter 5  Assessment of Risks to the Aquatic Plant Communities in the Calcasieu Estuary using a Weight of Evidence Approach

Summary: This chapter summarizes the components of the baseline ecological risk assessment (BERA) that evaluate the risks posed to the aquatic plant communities associated with exposure to chemicals of potential concern (COPCs) in the Calcasieu Estuary (Appendix C). More specifically, the data on surface-water chemistry, pore-water chemistry, and pore-water toxicity (i.e., the results of pore-water toxicity tests with the macrophyte, *Ulva fasciata*) were evaluated to determine if significant effects on the survival, growth, or reproduction of aquatic plants are occurring or are likely to be occurring in the Calcasieu Estuary. The information on these three lines of evidence were also used to evaluate the nature, magnitude, and/or areal extent of effects on the selected assessment endpoint. Furthermore, these data were used to identify the substances that are causing or substantially contributing to such effects in the Calcasieu Estuary (i.e., the contaminants of concern; COCs). Finally, these data were further evaluated to support an integrated assessment of risks to aquatic plant communities associated with exposure to COPCs in the Calcasieu Estuary.

The results of the integrated assessment were used to classify environmental conditions at specific sampling locations into three risk categories. Ecological risks were classified as low if the frequency (i.e., percent toxic samples) and/or magnitude of effects (i.e., percent germination of algal zoospores) that were observed or predicted to occur were similar to those for selected reference areas. By comparison, ecological risks were classified as indeterminate if the frequency and/or magnitude of effects that were observed or predicted to occur were moderately higher than those for selected reference areas. The term, indeterminate, was used to describe this classification because decisions regarding remedial actions at such locations
should consider a variety of factors in addition to ecological risk (e.g., costs and effects of remedial actions, potential for natural recovery, etc.). Finally, ecological risks were classified as high if the frequency and/or magnitude of effects that were observed or predicted to occur were substantially higher than those for selected reference areas. Reaches or areas of concern (AOCs) so designated represent the highest priority for remedial action planning.

The results of the integrated assessment indicate that exposure to surface water or pore water from the Calcasieu Estuary generally poses low risks to aquatic plant communities. Risks to aquatic plants were classified as low for 72% of the samples (i.e., 93 of 130) collected within the three AOCs investigated. However, indeterminate and high risks to the aquatic plant community were indicated for 5% (6 of 130) and 24% (31 of 130) of the samples, respectively. Therefore, conditions posing incremental risks to aquatic plant communities (i.e., relative to reference areas) were frequently encountered in the Calcasieu Estuary.

The risks to aquatic plant communities posed by exposure to COPCs were evaluated for three areas of concern (AOCs) in the estuary, including the Upper Calcasieu River AOC (UCR AOC), the Bayou d’Inde AOC (BI AOC), and the Middle Calcasieu River AOC (MCR AOC). The risks to aquatic plant communities were also evaluated in selected reference areas within the estuary. Of the three AOCs considered, the risks to the aquatic plant community were highest in Bayou d’Inde (BI). Within this AOC, conditions posing a high risk to aquatic plant communities were frequently encountered in the upper and lower portions of upper Bayou d’Inde, Maple Fork, PPG Canal, and the central and southeastern portions of Lockport Marsh posed the highest risks to aquatic plants. Although risks to the aquatic plant community were generally lower in the Upper Calcasieu River (UCR) AOC and Middle Calcasieu River (MCR) AOC, conditions posing high risk to aquatic plants were encountered in the eastern and southwestern and southwestern portions of Clooney Island Loop, Clooney Island barge slip, the southeastern and southwestern portions of Coon Island Loop, the mouth of Bayou Verdiene, Contraband Bayou, southeastern portion of Lake Charles,
and Indian Wells Lagoon. Risks to the aquatic plant community are generally low at the locations sampled in the reference areas, with the exception at lower Bayou Bois Connine and the central portion of Grand Bayou.

The results of the biological investigations conducted during the Remedial Investigation (RI) indicate that the magnitude of effects tends to increase with increasing risk to the aquatic plant community. For example, the germination of algal zoospores was lower in the samples that were designated as indeterminate and high risk than was the case for the low risk samples. Likewise, growth rates tended to be highest for the samples that were designated as posing low risks to the aquatic plant communities. These results demonstrate that the survival, growth, and reproduction of aquatic plants have been impaired in response to exposure to surface water or pore water in portions of the Calcasieu Estuary.

The results of this assessment indicate that a number of substances are causing or substantially contributing to adverse effects on the aquatic plant community in the Calcasieu Estuary. More specifically, the COCs that were considered to include:

- Total ammonia;
- Metals (dissolved copper, and total and dissolved nickel); and,
- PAHs (benz(a)anthracene).

All of these substances occurred in surface-water and/or pore-water samples from the Calcasieu Estuary at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. In addition, the concentrations in the effects distribution were generally higher than those in the no-effects distribution for one or more of the measurement endpoints for the pore-water toxicity tests. A detailed assessment of the risks to aquatic plant communities associated with exposure to surface water or pore water in the Calcasieu Estuary is provided in Appendix D.
5.0 Introduction

The aquatic plant communities in freshwater and estuarine ecosystems consist of phytoplankton, periphyton, aquatic macrophytes, and riparian vegetation. Phytoplankton, the small non-vascular aquatic plants that are suspended in the water column, are comprised of several types of algae. While periphyton are also non-vascular aquatic plants, they tend to be larger than the planktonic forms of algae and grow on other aquatic plants or on the bottom of the watercourse. Aquatic macrophytes is the general term applied to large vascular or non-vascular aquatic plants that grow in freshwater, estuarine, and marine systems (including both submergent and emergent aquatic plants). Riparian vegetation is the term that is applied to the plants that grow along the waters edge.

As primary producers, aquatic plants transform the energy of the sun into organic matter. Aquatic plants represent a primary food source for many plant-eating aquatic invertebrates (i.e., herbivores, which are also known as primary consumers). In addition, aquatic plants provide habitats for a wide variety of species, including aquatic invertebrates. Furthermore, submergent and emergent aquatic plants provide critical spawning and rearing habitats for many estuarine fish species. Aquatic-dependent wildlife species, such as ducks and geese, also rely on habitats created by aquatic vegetation for reproduction and other life history stages. Hence, aquatic plants represent essential components of aquatic ecosystems.

Aquatic plants can be exposed to COPCs via several exposure routes, including direct contact with surface water (i.e., all three groups of plants identified above), through contact with sediments (i.e., periphyton and macrophytes), and, through contact with pore water (i.e., periphyton and macrophytes). Although it would be useful to
evaluate the effects of COPCs on all three groups of aquatic plants through the various exposure routes, focusing on surface water and pore water provides a means of evaluating the exposure scenarios that are most likely to adversely affect aquatic plants. If adverse effects are not observed as a result of exposure to surface water or pore water from Calcasieu Estuary sediments, then it is unlikely that aquatic plants would be adversely affected through other exposure routes. Accordingly, these two exposure pathways were evaluated relative to the potential for adverse effects on aquatic plant communities in the estuary. In addition to the assessment of risks to aquatic plant communities, risk assessments were also conducted to evaluate the potential effects of COPCs in the estuary on microbial communities (Chapter 4), benthic invertebrate communities (Chapter 6), fish communities (Chapter 7), avian communities (Chapter 8), and mammalian communities (Chapter 9).

5.1 Methods

A step-wise approach was used to assess the risks to the aquatic plant community posed by the COPCs in the Calcasieu Estuary (see Appendix D for details). The five main steps in this process included: (1) identification of assessment endpoints, measurement endpoints, risk questions and testable hypotheses; (2) collection, evaluation, and compilation of the relevant information on surface-water and pore-water quality conditions in the Calcasieu Estuary; (3) assessment of the exposure of aquatic plants to COPCs (i.e., exposure assessment; Figure 4-1); (4) assessment of the effects of COPCs on aquatic plants (i.e., effects assessment; Figure 4-2); and, (5) characterization of risks to the aquatic plant community (i.e., risk characterization; Figures 4-3 to 4-8).
Assessment Endpoints, Measurement Endpoints, and Risk Questions – As primary producers, aquatic plants transform the energy of the sun into organic matter. Aquatic plants represent a primary food source for a variety of plant-eating invertebrates. In addition, aquatic plants provide habitats for a wide variety of species, including aquatic invertebrates, fish, and many aquatic-dependent wildlife species. Hence, aquatic plants represent essential components of aquatic ecosystems. As the goal of this assessment is to determine if surface-water or pore-water conditions are likely to adversely affect the key functions that are provided by aquatic plant communities, the survival, growth, and reproduction of aquatic plants were identified as the assessment endpoints for this component of the BERA.

To provide a valid basis for assessing ecological effects, the assessment endpoints are linked to the measurement endpoints by a series of risk questions and/or testable hypotheses. In this study, the investigations to assess the effects of environmental contaminants on the aquatic plant community were designed to answer the following risk questions:

- Are the concentrations of COPCs in surface water from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in surface water from reference areas and greater that the chronic toxicity thresholds for the survival, growth, or reproduction of aquatic plants?
- Are the concentrations of COPCs in pore water from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in pore water from reference areas and greater that the chronic toxicity
thresholds for the survival, growth, or reproduction of aquatic plants?

- Is the survival, growth, or reproduction of aquatic plants (as indicated by germination rate, germling length, and cell number of the algae, *Ulva fasciata*) exposed to pore water from Calcasieu Estuary sediments outside the normal range (i.e., 95% confidence interval) for aquatic plants exposed to pore water from reference sediments?

A suite of measurement endpoints was selected to provide the information needed to determine if the aquatic plant community is being or is likely to be adversely affected due to exposure to COPCs. First, surface-water chemistry and pore-water chemistry data were used to determine if these media were sufficiently contaminated to adversely affect the survival, growth, or reproduction of aquatic plants in the Calcasieu Estuary. In addition, the results of pore-water toxicity tests with the aquatic macrophyte, *Ulva fasciata*, were used to evaluate the effects on aquatic plant communities associated with exposure to pore water from Calcasieu Estuary sediments. Germination rate, germling length, and cell number, which were used as surrogates for survival, growth, and reproduction of aquatic plants, were evaluated using the methods described by Hooten and Carr (1998) and Carr et al. (2001). Although *U. fasciata* is primarily a marine species, it is considered to be an appropriate surrogate for freshwater and estuarine aquatic plant species (Hooten and Carr 1998).
Data Collection, Evaluation, and Compilation – The information that was used in the Calcasieu Estuary BERA was collected as part of the Phase I and Phase II RI. Surface-water and pore-water samples were collected in the three AOCs and in reference areas using a stratified-random sampling design. Samples were shipped to multiple laboratories to support chemical and/or toxicological characterization. The results of chemical analyses were available for 16 to 56 surface-water samples (i.e., n=56 for metals and organics; n=16 for conventional variables, such as ammonia) and 45 to 89 pore-water samples (i.e., n=45 for metals and organics; n=89 for conventional variables, such as hydrogen sulfide and ammonia). Pore-water toxicity tests were conducted on 45 pore-water samples. Of the 45 pore-water samples that were collected during Phase II of the RI, 38 were obtained from the three principal AOCs (i.e., UCR AOC, BI AOC, and MCR AOC) and 7 were obtained from reference areas. All of the resultant data were evaluated against the project data quality objectives (DQOs) upon receipt from the laboratories and incorporated into the project database. The results of data validation and data auditing indicated that the information used in the BERA generally met the project DQOs.

Exposure Assessment – Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter et al. 2000). The exposure assessment is intended to provide an estimate of the magnitude of exposure of receptors (i.e., aquatic plants) to COPCs, over time and space. In this assessment, information on the concentrations of COPCs in surface water and in pore water were used to evaluate exposure of aquatic plant communities to COPCs (Figure 4-1). Summary statistics (i.e., measures of central tendency and distributions) were calculated for each reach and each AOC in the Calcasieu Estuary. The
substances that could pose incremental risks to aquatic plants were identified by comparing the concentrations of COPCs in each AOC to the upper limit of background concentrations (i.e., 95% upper confidence limit; UCL) for the reference areas. Substances that occurred within a reach or an AOC at concentrations that were a factor of two or more higher than the 95% UCL for reference areas were considered to have the potential to pose incremental risks to plants.

**Effects Assessment** – In the analysis of effects, risk assessors determine the nature of toxic effects that are associated with exposure to contaminants and the magnitude of the toxic effects as a function of exposure (Suter *et al.* 2000). In this assessment, exposure of aquatic plant communities was evaluated using information on the concentrations of COPCs in surface water and in pore water. As such, it was necessary to compile information on the effects on aquatic plant communities associated with exposure to COPCs in surface water and in pore water (Figure 4-2).

Exposure to surface water or pore water has the potential to adversely affect aquatic plants. In this assessment, published chronic toxicity threshold values for plants were selected preferentially as toxicity thresholds for surface water and pore water for assessing the effects of COPCs on aquatic plant communities (i.e., Suter and Tsao 1996; see Table D-2 in Appendix D). If a chronic toxicity threshold value for aquatic plants was not available in Suter and Tsao (1996) for a particular COPC, then chronic water quality criteria (CCCs) or equivalent values (NHDES 1996; NYSDEC 1998; USEPA 1999a; 1999b; LDEQ 2000) were used to estimate chronic toxicity thresholds for plants. The Ecotox thresholds that were developed by USEPA (1996) were used when such water
quality criteria were unavailable. Application of chronic water quality criteria or Ecotox thresholds for assessing the potential effects of COPCs in surface water or pore water on aquatic plants is premised on the assumption that aquatic plants would exhibit a similar range of sensitivities to COPCs as the species represented in the underlying toxicological data that was used to generate these various thresholds. The comparisons of the levels of COPCs in surface water or pore water to the selected benchmarks were undertaken separately for conventional variables, metals, and organic substances.

**Risk Characterization** – The purpose of risk characterization is to determine if significant effects are occurring or are likely to occur at the site under investigation. In addition, this step of the process is intended to provide the information needed to describe the nature, magnitude, and areal extent of effects on the selected assessment endpoints. Finally, the substances that are causing or substantially contributing to adverse effects on the survival, growth, or reproduction of aquatic plants (i.e., COCs) are identified from the preliminary list of COPCs. The following three lines of evidence were examined to determine if sediments in the Calcasieu Estuary pose significant risks to aquatic plant communities: surface-water chemistry, pore-water chemistry, and pore-water toxicity.

In this assessment, all three lines of evidence were used to determine if exposure to COPCs in surface water or in pore water poses incremental risks to plants in the Calcasieu Estuary (i.e., relative to the risks that are associated with exposure to surface water or to pore water from reference areas in the estuary). The nature of the effects associated with exposure to surface-water- or pore-water-associated COPCs was also evaluated using these three lines of evidence. Subsequent to
evaluating the nature of effects, the magnitude of the effects on plants exposed to contaminated sediments was evaluated using the results of pore-water toxicity tests. A preliminary evaluation of the areal extent of effects on aquatic plant communities in the Calcasieu Estuary was also conducted using the pore-water toxicity data that were collected during the RI. Finally, the COCs were identified by comparing the concentrations of COPCs in surface water or in pore water to the concentrations of those substances in surface-water or pore-water samples from reference areas and to the selected benchmarks for those substances. Concordance between the pore-water chemistry and the pore-water toxicity data was also used to identify the COCs from the longer list of COPCs.

The results of toxicity tests were used to assess risks to aquatic plants exposed to COPCs in pore water from the Calcasieu Estuary. More specifically, risks to aquatic plants were evaluated using the results of 96-h pore-water toxicity tests with the macrophyte, *Ulva fasciata* (endpoint: zoospore germination and germling growth). A reference envelope approach was used to identify in pore-water samples in the estuary that posed incremental risks to aquatic plants. More specifically, pore-water samples were identified as toxic when survival, growth, or reproduction of the test organisms was lower than the lower limit of the normal range (i.e., 95% LCL) of responses for test organisms exposed to samples from the reference areas. Risks to aquatic plants were characterized as low, indeterminate, or high, based the observed or predicted incidence of toxicity (IOT; i.e., <20%, 20-50%, and >50% increase in the proportion of toxic samples relative to reference, respectively) and on the observed magnitude of toxicity (MOT; i.e., <10%, 10-20%, and >20% based on percent germination of algal zoospores in pore-water toxicity tests relative to reference, respectively; Appendix D).
An integrated assessment of the risks posed to aquatic plant communities by exposure to COPCs in surface water and/or pore water was conducted following the assessment of the nature, magnitude, and areal extent of risks. In this assessment, the available data were integrated by calculating a final risk score for each sampling location based on the results for up to three lines of evidence (as described in Appendix D). The final risk score is intended to provide an integrated measure of the risks that contaminated surface water or pore water pose to the survival, growth, or reproduction of aquatic plant communities in the Calcasieu Estuary. More specifically, the final risk score integrates the results of pore-water chemical analyses, pore-water toxicity tests, and surface-water chemical analyses into a single parameter (Section 5.0 of Appendix D). The final risk scores were used to evaluate the areal extent of risk to aquatic plants in the Calcasieu Estuary, with scores of <2 designated as low risk, 2 to 3 designated as indeterminate risk, and >3 designated as high risk. Because aquatic plant communities occupy small home ranges, this evaluation was conducted on a sampling location by sampling location (i.e., area averaging was not considered to be appropriate for assessing risks to locally-exposed sub-populations of aquatic plants).

5.2 Results and Discussion

Three lines of evidence were examined to determine if exposure to environmental media in the Calcasieu Estuary poses significant risks to the aquatic plant community, including surface-water chemistry, pore-water chemistry and pore-water toxicity. Evaluation of the surface-water chemistry data collected during the Phase I RI using
the chronic toxicity thresholds indicated that the predicted incidence of toxicity to aquatic plants in the three AOCs was similar to the predicted incidence of toxicity for the reference areas. For pore water, the concentrations of hydrogen sulfide or ammonia were sufficient to cause chronic toxicity to aquatic plants in 69% (52 of 75) of the pore-water samples collected from the three AOCs. Based on the results of 96-h toxicity tests with the alga, *Ulva fasciata* (endpoint: germination or growth), the incidence of toxicity to aquatic plants within the three AOCs was similar to that for reference areas [i.e., 21% (8 of 38) and 14% (1 of 7), respectively]. When considered together, these three lines of evidence indicate that exposure to surface water or pore water may be adversely affecting the survival, growth, and reproduction of aquatic plants in the Calcasieu Estuary. Accordingly, each of the three AOCs were examined in greater detail to assess the nature, magnitude, and areal extent of risks to aquatic plant communities.

**Nature of Effects** – The results of the investigations that were conducted during the RI indicate that a variety of adverse effects on aquatic plants are associated with exposure to COPCs in surface water or pore water from the Calcasieu Estuary. While adverse effects on aquatic plants are not anticipated in response to exposure to surface water in the three AOCs, evaluation of the pore-water chemistry data indicated that the concentrations of certain COPCs are sufficient to adversely affect aquatic plants. More specifically, elevated levels of hydrogen sulfide in pore water has the potential to adversely affect the survival, growth, or reproduction of aquatic plants. Although short-term exposure (i.e., 96-h) to pore-water samples from the Calcasieu Estuary did not adversely affect the germination of alga zoospores or the growth of germlings, it is likely that manipulation of these samples prior to testing (i.e., freezing) substantially
reduced the concentrations of hydrogen sulfide in pore water and, hence, the toxicity of the pore-water samples. As the levels of hydrogen sulfide in pore water were higher in the three AOCs (i.e., average concentrations ranged from 2.4 : g/L in the MCR AOC to 4.9 : g/L in the UCR AOC) than they were in reference areas (i.e., averaging 1.5 : g/L), it is possible that COPC-related effects on the microbial community resulted in accumulations of this substance in pore water. Overall, it is concluded that the survival, growth, and reproduction of aquatic plants in the Calcasieu Estuary could, potentially, be adversely affected by exposure to pore water. Accordingly, each of the three AOCs were examined in greater detail to assess the magnitude and areal extent of risks to aquatic plant communities.

Magnitude of Effects – The magnitude of the effects on aquatic plants in the three AOCs was evaluated using one line of evidence: pore-water toxicity. Based on the results of 96-h pore-water toxicity tests with the macrophyte Ulva fasciata (i.e., observed magnitude of toxicity), it is apparent that exposure to pore water from sediments collected from the three AOC generally does not adversely affect the germination of algal zoospores relative to reference conditions. Of the 38 pore-water samples that were collected from the three AOCs, a 12 of 15 (80%) from the UCR AOC, 11 of 15 (73%) from the BI AOC, and 7 of 8 (88%) from the MCR AOC were found to pose a low risk to algae (i.e., germination rates of Ulva fasciata were similar to those observed for samples from reference areas). By comparison, 7 of 7 samples (100%) from the reference areas were found to pose a low risk to algae in pore-water toxicity tests. Hence, the information on the observed magnitude of toxicity to Ulva fasciata indicates that exposure to pore water collected from the three AOCs generally poses a low risk to the
aquatic plant community in the Calcasieu estuary. However, incremental risks to aquatic plants were observed at certain locations within the estuary.

**Preliminary Assessment of the Areal Extent of Effects** – The areal extent of adverse effects on aquatic plant communities in the UCR AOC was assessed using the pore-water toxicity data that were collected in the Phase II RI. To support this evaluation of the spatial distribution of effects on aquatic plants, each sample was classified into one of three categories (i.e., low, indeterminate, or high), based on the risk that it posed to aquatic plants (as indicated by the results of 96-h pore-water toxicity tests with the macrophyte, *Ulva fasciata*). Then, these data were compiled on a reach by reach basis and mapped using ArcView/Spatial Analyst software.

The results of the preliminary evaluation of the areal extent of effects indicate that pore-water quality conditions within the Calcasieu Estuary are generally of sufficient quality to support the normal survival, growth, and reproduction of aquatic plants. Nevertheless, samples of concern with respect to effects on aquatic plants were obtained from several locations in the UCR AOC, including the eastern portion of Lake Charles, Contraband Bayou roughly 1 km from the mouth, and the southeastern portion of the Coon Island Loop. Within the BI AOC, samples of concern with respect to effects on aquatic plants were obtained from the upper portion of upper Bayou d’Inde near the I-10 bridge, Maple Fork, and Lockport Marsh. Within the MCR AOC, one sample of concern was identified from the northern portion of the Indian Wells Lagoon reach. The integrated assessments of risks to aquatic plants, which is presented below,
provides a basis for further identifying the locations that pose low, indeterminate, and high risks to aquatic plants.

**Contaminants of Concern** – The substances that occur in surface-water or pore-water samples at concentrations above those in reference areas, above the selected benchmarks, and show concordance with the biological response data, represent the COCs relative to effects on aquatic plants. The results of this evaluation indicated that total and dissolved nickel represent the surface-water COCs relative to the aquatic plant community in the UCR AOC and in the MCR AOC. In the BI AOC, ammonia, dissolved copper, and total and dissolved nickel represent the surface-water COCs relative to the aquatic plant community. No toxicity tests were conducted on surface waters from Calcasieu Estuary; therefore, it was not possible to evaluate the degree of concordance between COPC concentrations and biological effects. Insufficient information was available to determine if many other substances represent surface-water COCs, including hydrogen sulfide, total sulfide, methyl mercury, various individual polycyclic aromatic hydrocarbons (PAHs), various polychlorinated biphenyl (PCB) mixtures and total PCBs, hexachlorobutadiene (HCBD), bis(2-ethylhexyl)phthalate (BEHP), various chlorinated benzenes, and carbon disulfide.

Data on the concentrations of COPCs in pore-water samples also provide important information for identifying COCs. Comparison of the measured concentrations of COPCs in pore water to the concentrations in pore water from reference sediments, comparison to the toxicity thresholds for pore water, and evaluation of the effects and no effects distributions (based on the results of the *Ulva fasciata* toxicity test indicates that benz(a)anthracene should be considered
to be a COC in pore water (Table D-30). However, insufficient data were available to determine if the following substances represent COCs in pore-water: chromium; mercury; methyl mercury; 1-methylnaphthalene; polychlorinated biphenyl (PCB) 77/110; bis(2-ethylhexyl) phthalate (BEHP); various chlorinated benzenes; chlorinated ethanes; acetone; and, carbon disulfide.

**Uncertainty Assessment** – There are a number of sources of uncertainty in assessments of risk to aquatic plant communities, including uncertainties in the conceptual model, in the exposure assessment, and in the effects assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and influence of such uncertainties.

A total of 10 criteria were used to evaluate the level of confidence that can be placed in the various measurement endpoints that were used to assess risks to aquatic plants. For each of these criteria, the degree of uncertainty in the measurement endpoint was scored from 1 (higher uncertainty) to 3 (lower uncertainty; Table 5-1). These results were then used to determine the level of uncertainty that was associated with the conceptual model, the exposure assessment, and the effects assessment. In turn, these results provided a basis for weighting each measurement endpoint (i.e., using total evaluation score) in the integrated assessment of risks to aquatic plant communities (Table 5-2). The resultant total evaluation scores reflect the potential for confounding factors to influence the results of the assessment and, in so doing, affect the potential for obtaining false positive results (i.e., samples designated as indeterminate or high risk that actually pose low risks to aquatic plant communities) or false negative
results (i.e., samples designated as low risk that actually pose indeterminate or high risks to aquatic plant communities). The detailed results of the uncertainty analysis that was conducted as part of the BERA are presented in Appendix D.

**Integrated Assessment of Risks** – Information on three lines of evidence was considered in the integrated assessment of risks to aquatic plant communities. Consideration of multiple lines of evidence in an integrated assessment of risks is desirable because it provides a basis for utilizing all of the available data for assessing risks, explicitly considers the uncertainty associated with each line of evidence, and, in so doing, reduces the uncertainty associated with the overall assessment of risks. Importantly, calibration of key lines of evidence (e.g., pore-water chemistry) against other lines of evidence (e.g., pore-water toxicity) increases confidence that designations of risk based on a single line of evidence are likely to be consistent with those based on multiple lines of evidence (see Appendix D for additional information; Ingersoll and MacDonald 2002; Menzie *et al.* 1996; Johnston *et al.* 2002). The final risk scores that were calculated using information on the various measurement endpoints and the associated uncertainty in each measurement endpoint were used to provide an integrated measure of the risks posed to aquatic plant communities associated with exposure to COPCs in surface water and/or in pore water.

**Upper Calcasieu River AOC** – Samples were collected from a total of 41 locations to support an assessment of the risks posed to the aquatic plant community associated with exposure to COPCs in surface water or pore water in the UCR AOC (Table 5-2). The results of this assessment indicate that
exposure to surface water and/or pore water in the UCR AOC generally posed a low risk to aquatic plants (i.e., average of the final risk scores of 1.27; n=41). Seventy-six percent of the locations (i.e., 31 of 41) within this AOC had low final risk scores (i.e., < 2; Table 5-2). Nevertheless, indeterminate (2%; 1 of 41) or high (22%; 9 of 41) risks to aquatic plants were indicated for 24% of the locations (i.e., 10 of 41) from the UCR AOC (Table 5-2). Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where exposure to surface water or pore water posed the highest risks (i.e., relative to the survival, growth, or reproduction of aquatic plants) included the eastern and southwestern portions of the Clooney Island Loop, Clooney Island barge slip, the mouth of Bayou Verdine, the southeastern and southwestern portions of Coon Island Loop, the southern side of Contraband Bayou in the vicinity of Charvais Drive, and the southeastern portion of Lake Charles (Figure 5-1). Indeterminate risks to the aquatic plant community exist in the eastern portion of Lake Charles (Figure 5-1).

**Bayou d’Inde AOC** – Samples were collected from a total of 52 locations to support an assessment of the risks posed to the aquatic plant community associated with exposure to COPCs in surface water and pore water in the BI AOC. The results of this assessment indicate that exposure to surface water and/or pore water in the BI AOC generally posed a low risk to aquatic plants (i.e., average of the final risk scores of 1.85; n=52). Roughly 60% of the locations (i.e., 31 of 52) within this AOC had low final risk scores (i.e., < 2; Table 5-2). However, indeterminate (6%; 3 of 52) or high (35%; 18 of 52) risks to aquatic plants were indicated for 40% of the locations (i.e., 21 of 52) from the BI AOC. Consistent with the results of the preliminary analysis of
the areal extent of effects, the locations where exposure to surface water or pore water posed the highest risks (i.e., relative to the survival, growth, or reproduction of aquatic plants) included upper Bayou d’Inde downstream of the I-10 bridge and at the Highway 108 bridge, middle Bayou d’Inde immediately downstream of the Highway 108 bridge and in Maple Fork, PPG Canal, and the central, northwestern, and southeastern portions of Lockport Marsh (Figure 5-2). Indeterminate risks to the aquatic plant community exist at stations located in the central portion of middle Bayou d’Inde, in the southern portion of Lockport Marsh, and in the lower Bayou d’Inde mainstem (Figure 5-2).

**Middle Calcasieu River AOC** – Samples were collected from a total of 37 locations to support an assessment of the risks posed to the aquatic plant community associated with exposure to COPCs in surface water or pore water in the MCR AOC. The results of this assessment indicate that exposure to surface water and/or pore water in the MCR AOC generally posed low risks to aquatic plants (i.e., average of the final risk scores of 0.69; n=37). Eighty-four percent of the locations (i.e., 31 of 37) within this AOC had low final risk scores (i.e., <2; Table 5-2). Nevertheless, indeterminate (5%; 2 of 37) or high (11%; 4 of 37) risks to aquatic plants were indicated for 16% of the samples (i.e., 6 of 37) from the MCR AOC. Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where contaminated surface water or pore water posed the highest risks (i.e., relative to the survival, growth, or reproduction of aquatic plants) included the old river channel downstream of Prien Lake, Indian Wells Lagoon, and the west central portion of Moss Lake (Figure 5-3 and 5-4). Indeterminate risks to the
aquatic plant community exist in the middle Calcasieu River upstream of Moss Lake and near the mouth of Bayou Olsen (Figure 5-4).

5.3 Summary and Conclusions

The risks to aquatic plant communities posed by exposure to surface water and pore water were assessed in the Calcasieu Estuary. In total, information on three lines of evidence was used to determine if the survival, growth, or reproduction of aquatic plants was being adversely affected or was likely to be adversely affected by exposure to COPCs in the estuary (i.e., relative to reference conditions). The three lines of evidence that were considered in the assessment included surface-water chemistry, pore-water chemistry and pore-water toxicity.

The results of this BERA indicated that exposure to surface water and/or pore water from the Calcasieu Estuary generally posed low risks to aquatic plant communities (i.e., risks were classified as low for 72% of the 130 samples collected within the three AOCs investigated; Table 5-2). However, indeterminate and high risks to the aquatic plant community were indicated for 5% (6 of 130) and 24% (31 of 130) of the samples, respectively (Table 5-2). Of the three AOCs considered, the risks to the aquatic plant community were highest in Bayou d’Inde. Within this AOC, samples from the upper and lower portions of upper Bayou d’Inde, Maple Fork, PPG Canal, and the central and southeastern portions of Lockport Marsh posed the highest risks. Although risks to the aquatic plant community were generally lower in the UCR AOC and MCR AOC, samples posing high risk are present in the eastern and southwestern portions of Clooney Island Loop, Clooney Island barge slip, the southeastern and
southwestern portions of Coon Island Loop, the mouth of Bayou Verdine, old river channel downstream of Prien Lake, west-central portion of Moss Lake, southern side of Contraband Bayou in the vicinity of Charvais Drive, southeastern portion of Lake Charles, and Indian Wells Lagoon (Table 5-2). Risks to the aquatic plant community are generally low at the locations sampled in the reference areas, with the exception at lower Bayou Bois Connine and the central portion of Grand Bayou (Figure 5-5).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the aquatic plant community. For example, the germination of algal zoospores was lower in the samples that were designated as indeterminate (60±32%; n=3) and high (37±20%; n=6) risk than was the case for the low risk samples (88±7%; n=36; Table 5-3). Likewise, growth rates tended to be highest for the samples that were designated as posing low risks to the aquatic plant communities (Table 5-3). These results demonstrate that the survival, growth, and reproduction of aquatic plants are impaired in response to exposure to pore water at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the aquatic plant community in the Calcasieu Estuary. More specifically, the COCs that were considered to include:

- Total ammonia;
- Metals (dissolved copper and total and dissolved nickel); and,
- Benz(a)anthracene.
All of these substances occurred in surface-water and/or pore-water samples at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. In addition, the concentrations in the effects distribution were generally higher than the concentrations in the no effects distribution for one or more of the measurement endpoints in pore-water toxicity tests (e.g., germination of algal zoospores in 96-h toxicity tests). Furthermore, the results of toxicity identification evaluations conducted on pore-water samples from Calcasieu Estuary sediment samples indicate that non-polar organics and metals substantially contributed to acute toxicity to marine amphipods, *Ampelisca abdita*, in 96-h toxicity tests (SAIC 2002). Hence, the COCs identified above should be considered to be high priority for developing preliminary remediation goals.
Chapter 6. Assessment of Risks to the Benthic Invertebrate Community in the Calcasieu Estuary using a Weight of Evidence Approach

Summary: This chapter summarizes the components of the baseline ecological risk assessment (BERA) that evaluate the risks posed to benthic invertebrates associated with exposure to chemicals of potential concern (COPCs) in the Calcasieu Estuary (Appendix E2). More specifically, data on whole-sediment chemistry, pore-water chemistry, whole-sediment toxicity, pore-water toxicity, and benthic invertebrate community structure were evaluated to determine if significant effects on survival, growth, or reproduction of benthic invertebrates are occurring or are likely to be occurring in the Calcasieu Estuary. The information on these five lines of evidence were also used to evaluate the nature, magnitude, and areal extent of effects on the selected assessment endpoints. Furthermore, these data were used to identify the substances that are causing or substantially contributing to such effects in the Calcasieu Estuary (i.e., the contaminants of concern; COCs). Finally, these data were further evaluated to support an integrated assessment of risks to the benthic invertebrate community associated with exposure to COPCs in the Calcasieu Estuary.

The results of the integrated assessment were used to classify environmental conditions at specific sampling locations into three risk categories. Ecological risks were classified as low if the frequency and/or magnitude of effects that were observed or predicted to occur were similar to those for selected reference areas. By comparison, ecological risks were classified as indeterminate if the frequency and/or magnitude of effects that were observed or predicted to occur were moderately higher than those for selected reference areas. The term, indeterminate, was used to describe this
classification because decisions regarding remedial actions at such locations should consider a variety of factors in addition to ecological risks (e.g., costs and effects of remedial actions, potential for natural recovery, etc.). Finally, ecological risks were classified as high if the frequency and/or magnitude of effects that were observed or predicted to occur were substantially higher than those for selected reference areas. Reaches or areas of concern (AOCs) so designated represent the highest priority for remedial action planning.

The results of the integrated assessment indicate that exposure to whole sediments and/or pore water from the Calcasieu Estuary generally poses low risks to benthic invertebrate communities. Risks were classified as low for 68% (423 of 624) of the sampling locations within the three AOCs. However, incremental risks to the benthic invertebrate community, compared to those associated with exposure to conditions in reference areas, were indicated for 32% (201 of 643) of the sampling locations within the three AOCs in the estuary [i.e., 9% (58 of 624) of the sampling locations were classified as posing indeterminate risks and 23% (143 of 624) of the sampling locations were classified as posing high risks to the benthic community]. Therefore, conditions posing incremental risks to benthic invertebrate communities (i.e., relative to reference areas) were frequently observed in the Calcasieu Estuary.

The risks to benthic invertebrate communities posed by exposure to COPCs were evaluated for three AOCs in the estuary, including the Upper Calcasieu River AOC (UCR AOC), the Bayou d’Inde AOC (BI AOC), and the Middle Calcasieu River AOC (MCR AOC). The risks to benthic invertebrates were also evaluated in selected reference areas within the estuary. Of the three AOCs considered, the risks to the benthic invertebrate community were highest in BI AOC. Within this AOC, conditions in the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, PPG Canal, the inner portions of Lockport Marsh, and lower Bayou d’Inde mainstem posed the highest risks to the benthic invertebrate community. Although risks to the benthic invertebrate community were generally lower in the UCR AOC and MCR AOC, conditions posing high risks to benthic invertebrates were identified
in the northern portions of Clooney Island Loop, the northern portions of Coon Island Loop, middle Calcasieu River in the vicinity of the Citgo property, and Indian Wells Lagoon. Risks to the benthic invertebrate community were generally classified as low throughout the reference areas that were selected to represent contemporary background sediment conditions in the estuary.

The results of the biological investigations conducted during the Remedial Investigation (RI) indicate that the integrated assessment provides a reliable basis for classifying sediment samples from the Calcasieu Estuary in terms of the risks that they pose to the benthic invertebrate community. For example, the survival and/or growth of freshwater and marine amphipods were lower in the samples that were designated as posing indeterminate and high risks than was the case for the low risk samples. Likewise, the fertilization of sea urchin gametes (an indicator of reproductive success) was reduced in the samples that were designated as posing indeterminate or high risks to the benthic community. Importantly, the density of pollution indicator (i.e., tolerant) species, the density of pollution sensitive species, species richness, and total abundance of benthic invertebrates were generally lower at the locations at which risks were classified as indeterminate and high (i.e., as compared to those that were classified as posing low risks). Together, these results demonstrate that the survival, growth, and reproduction of benthic invertebrates have been impaired in response to exposure to contaminated sediment and/or pore water in the Calcasieu Estuary.

The results of this assessment indicate that a number of substances are causing or substantially contributing to adverse effects on the benthic invertebrate community in the Calcasieu Estuary (i.e., COCs). More specifically, the COCs in the estuary were considered to include:

- Metals (chromium, copper, lead, mercury, nickel, and zinc);
• PAHs (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(a)fluoranthen, benzo(g,h,i)perylene, benzo(b)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs);

• PCBs (total PCBs);

• Chlorinated benzenes (HCB and HCBD);

• Phthalates (BEHP);

• Organochlorine pesticides (aldrin and dieldrin); and,

• PCDDs and PCDFs (total 2,3,7,8-TCDD TEQs).

All of these substances occurred in whole-sediment and/or pore-water samples from the Calcasieu Estuary at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. In addition, the concentrations of these substances in the effects distribution were generally higher than the concentrations in the no effects distribution for one or more of the measurement endpoints (e.g., survival of *Ampelisca abdita* in 10-d toxicity tests). Many of these substances or groups of substances also accumulated in the tissues of polychaetes (*Nereis virens*) in 28-d bioaccumulation tests and were shown to be associated with acute toxicity to amphipods (*Ampelisca abdita*) in toxicity identification evaluations using pore water from Calcasieu Estuary sediment samples. A detailed assessment of the risks to the benthic invertebrate community associated with exposure to contaminated sediments in the Calcasieu Estuary is provided in Appendix E2.
6.0 Introduction

Benthic invertebrate communities inhabiting sediments are extremely diverse and are represented by nearly all taxonomic groups from protozoa to large invertebrates. The groups of organisms that are commonly associated with benthic communities include protozoa, sponges (i.e., Porifera), coelenterates (e.g., *Hydra* sp.), flatworms (i.e., Platyhelminthes), bryozoans, aquatic worms (i.e., oligochaetes), crustaceans (e.g., mysids, decapods, and amphipods), mollusks (e.g., oysters and clams), and aquatic insects (e.g., dragonflies, mayflies, true flies, and aquatic beetles). Because benthic invertebrate communities are difficult to study in a comprehensive manner, benthic ecologists often focus on the relatively large members of benthic invertebrate communities, which are known as benthic macroinvertebrates. These organisms are often defined as those that are retained on a 0.5 mm sieve. Benthic invertebrates represent key elements of aquatic food webs because they consume aquatic plants (i.e., such as algae and aquatic macrophytes) and detritus. In this way, these organisms facilitate the break down of detritus in sediment and the transfer of energy and nutrients to fish, birds, and other organisms that consume benthic invertebrates.

Because these animals live in and on the sediments (and, hence, have a high potential for exposure to sediment-associated COPCs) and because these animals represent essential components of freshwater and estuarine ecosystems, benthic invertebrates were selected to be included in the ecological risk assessment of the Calcasieu Estuary. Benthic invertebrate communities are likely to be exposed to various COPCs that occur in whole sediments and pore water in the estuary (MacDonald *et al.* 2001). Because whole sediment and pore water are likely to represent the most important and direct routes of exposure for the benthic invertebrate community, other possible exposure pathways (e.g., surface water) were not evaluated relative to the potential...
for adverse effects on the benthic invertebrate communities in the estuary. In addition to the assessment of risks to the benthic invertebrate community, risk assessments were also conducted to evaluate the potential effects of COPCs in the estuary on microbial communities (Chapter 4), aquatic plant communities (Chapter 5), fish communities (Chapter 7), avian communities (Chapter 8), and mammalian communities (Chapter 9).

### 6.1 Methods

A step-wise approach was used to assess the risks to the benthic invertebrate community posed by the COPCs in the Calcasieu Estuary (see Appendix E2 for details). The five main steps in this process included: (1) identification of assessment endpoints, measurement endpoints, risk questions and testable hypotheses; (2) collection, evaluation, and compilation of the relevant information on sediment quality conditions in the Calcasieu Estuary; (3) assessment of the exposure of benthic invertebrates to COPCs (i.e., exposure assessment; Figure 4-1); (4) assessment of the effects of COPCs on benthic invertebrates (i.e., effects assessment; Figure 4-2); and, (5) characterization of risks to the benthic invertebrate community (i.e., risk characterization; Figures 4-3 to 4-8).

**Assessment Endpoints, Measurement Endpoints, and Risk Questions** – Benthic invertebrates represent key elements of aquatic food webs because they consume aquatic plants (i.e., such as algae and aquatic macrophytes) and detritus (i.e., decaying plants and animals). In this way, these organisms facilitate the transfer of nutrients and energy to fish, birds, and other organisms that consume aquatic...
invertebrates. As the goal of this assessment is to determine if contaminated sediments are likely to adversely affect the key functions that are provided by the benthic invertebrate community, the survival, growth, and reproduction of benthic invertebrates were identified as the assessment endpoints for this component of the BERA.

To provide a valid basis for assessing ecological effects, the assessment endpoints are linked to the measurement endpoints by a series of risk questions and/or testable hypotheses. In this study, the investigations to assess the effects of environmental contaminants on the benthic invertebrate community were designed to answer the following risk questions:

- Are the levels of COPCs in whole sediments from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in whole sediments from reference areas and greater than sediment quality benchmarks for the survival, growth, or reproduction of benthic invertebrates?
- Are the levels of COPCs in pore water from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in pore water from reference areas and greater than the chronic toxicity thresholds for survival, growth, or reproduction of benthic invertebrates?
- Is the survival of benthic invertebrates (as indicated by the survival of the amphipods, *Hyalella azteca* and *Ampelisca abdita*) exposed to whole sediments from the Calcasieu Estuary outside the normal range [95% confidence intervals; i.e., <2.5th percentile] for amphipods exposed to reference sediments?
• Is the growth of benthic invertebrates (as indicated by the growth of the amphipod, *Hyalella azteca*) exposed to whole sediments from the Calcasieu Estuary outside the normal range (i.e., 95% confidence interval) for amphipods exposed to reference sediments?

• Is the reproductive success of benthic invertebrates (as indicated by fertilization and embryo development in the sea urchin, *Arbacia punctulata*) exposed to pore water from Calcasieu Estuary sediments outside the normal range (i.e., 95% confidence interval) for benthic invertebrates exposed to pore water from reference sediments?

• Is the incidence of impairment benthic macroinvertebrate community structure (as indicated by the results of cluster analyses of data on the density of pollution indicator species, density of pollution sensitive species, richness, total abundance of benthic invertebrates, and a normalized macroinvertebrate index of biotic integrity) in Calcasieu Estuary sediments elevated relative to the incidence of impairment for reference sediments?

A suite of measurement endpoints was selected to provide the information needed to determine if the benthic invertebrate community is being or is likely to be adversely affected due to exposure to COPCs. First, whole-sediment and pore-water chemistry data were used to determine if the concentrations of COPCs in Calcasieu Estuary sediments are sufficient to adversely affect the survival, growth, or reproduction of benthic invertebrates in the Calcasieu Estuary. In addition, the results of whole-sediment toxicity tests with the amphipods, *Hyalella azteca* and *Ampelisca abdita*, pore-water toxicity tests with sea urchins, *Arbacia punctulata*.
Arbacia punctulata, and benthic invertebrate community assessments were used to directly evaluate the effects of contaminated sediments on the benthic invertebrate community. More specifically, survival in the A. abdita test, survival or growth in the Hyalella azteca test, and fertilization or development in the sea urchin test were used as indicators of the ability of the benthic invertebrates to survive, grow, and reproduce. As amphipods often represent important components of benthic invertebrate communities (i.e., in terms of energy transfer to fish) and tend to be among the most sensitive benthic organisms (Swartz et al. 1985; 1994), measurement of the survival and growth of amphipods was considered to provide relevant information for assessing effects on the survival and growth of benthic invertebrates. Likewise, the fertilization and development of sea urchin gametes and embryos, respectively, was considered to provided relevant information for evaluating effects on the reproduction of benthic invertebrates, particularly for those species that are likely to be exposed to pore water during early life history stages. By comparison, benthic invertebrate community structure was used as a direct measure of effects on benthic invertebrates inhabiting the estuary.

**Data Collection, Evaluation, and Compilation** – The information that was used in the Calcasieu Estuary BERA was collected as part of the Phase I and Phase II RI. Whole-sediment and pore-water samples were collected in the three AOCs and in reference areas using a stratified-random sampling design. Samples were shipped to multiple laboratories to support chemical, biological, and toxicological characterization. The results of chemical analyses were available for 641 whole-sediment samples and 45 to 89 pore-water samples (i.e., n=45 for metals and organics; n=89 for conventional variables, such as hydrogen sulfide and
ammonia). Whole-sediment toxicity tests were conducted on 90 Phase II samples collected from the three AOCs and reference areas, while pore-water toxicity tests were conducted on a sub-set (45) of these samples. Benthic invertebrate community structure analysis was conducted on the same 90 whole-sediment samples that were evaluated using whole-sediment toxicity tests. Of the 90 whole-sediment samples that were collected from the three AOCs during Phase II of the RI, 75 were obtained from the three principal AOCs (i.e., UCR AOC, BI AOC, and MCR AOC) and 15 were obtained from reference areas. All of the resultant data were evaluated against the project data quality objectives (DQOs) upon receipt from the laboratories and incorporated into the project database. The results of data validation and data auditing indicated that the information used in the BERA generally met the project DQOs.

Exposure Assessment – Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter et al. 2000). The exposure assessment is intended to provide an estimate of the magnitude of exposure of receptors (i.e., benthic invertebrates) to COPCs, over time and space. In this assessment, information on the concentrations of COPCs in whole sediment and pore water was used to evaluate exposure of the benthic invertebrate community to COPCs (Figure 4-1). Summary statistics (i.e., measures of central tendency and distributions) were calculated for each reach and each AOC in the Calcasieu Estuary. The substances that could pose incremental risks to benthic invertebrates were identified by comparing the concentrations of COPCs in each AOC to the upper limit of background concentrations (i.e., 95% UCL) for the reference areas. Substances that occurred within a reach or an AOC at concentrations that were a factor of two or more higher than the 95% UCL for
reference areas were considered to have the potential to pose incremental risks to benthic invertebrates.

*Effects Assessment* – In the analysis of effects, risk assessors determine the nature of toxic effects that are associated with exposure to contaminants and the magnitude of the toxic effects as a function of exposure (Suter *et al.* 2000). In this assessment, exposure of the benthic invertebrate community was evaluated using information on the concentrations of COPCs in whole sediments and pore water (Figure 4-2). As such, it was necessary to compile information on the effects on benthic invertebrate communities associated with exposure to COPCs in whole sediment and pore water.

Exposure to whole sediment has the potential to adversely affect the survival, growth, and reproduction of benthic invertebrates. Numerical sediment quality guidelines provide a basis for assessing the effects on benthic invertebrates associated with exposure to sediment-associated COPCs. In this assessment, the concentrations of COPCs that correspond to a 50% probability of observing toxicity to marine amphipods (i.e., $T_{50}$ values; Field *et al.* 2002), based on the results of logistic regression modeling of matching sediment chemistry and sediment toxicity data, were selected preferentially as toxicity benchmarks for whole sediments. Alternate, but functionally equivalent, toxicity benchmarks were identified if $T_{50}$ values were not available for a COPC (see Table E2-3 of Appendix E2). Simple, estuary-specific chemical mixture models were then developed to facilitate the characterization of risks to benthic invertebrates in sediment samples containing complex mixtures of COPCs [i.e., mean probable effect concentration-quotients (PEC-Qs); see Appendix E1 and E2].
Exposure to pore water also has the potential to adversely affect benthic invertebrate communities. In this assessment, the chronic marine water quality standards for the state of Louisiana were selected preferentially as toxicity thresholds for pore water (LDEQ 2000). Alternate, but functionally equivalent, toxicity thresholds for pore water were selected if such chronic marine water quality standards were not available for a COPC (see Table E2-4a and E2-4b of Appendix E2).

**Risk Characterization** – The purpose of risk characterization is to determine if significant effects are occurring or are likely to be occurring at the site under investigation. In addition, this step of the process is intended to provide the information needed to describe the nature, magnitude, and areal extent of effects on the selected assessment endpoints. Finally, the substances that are causing or substantially contributing to adverse effects on the survival, growth, or reproduction of benthic invertebrates (i.e., COCs) are identified from the preliminary list of COPCs. The following five lines of evidence were examined to determine if sediments in the Calcasieu Estuary pose significant risks to the benthic invertebrate community: whole-sediment chemistry; pore-water chemistry; whole-sediment toxicity; pore-water toxicity; and, benthic invertebrate community structure.

In this assessment, all five lines of evidence were used to determine if exposure to COPCs in whole sediment or pore water poses incremental risks to benthic invertebrates in the Calcasieu Estuary (i.e., relative to the risks that are associated with exposure to whole sediment and pore water from reference areas in the estuary; Figures 4-3 to 4-8). The nature of the effects associated with exposure
to sediment- or pore-water-associated COPCs was also evaluated using all five of these lines of evidence. Subsequent to evaluating the nature of effects, the magnitude of the effects on benthic invertebrates exposed to contaminated sediments was evaluated using two primary lines of evidence: whole-sediment toxicity; and, whole-sediment chemistry. These two lines of evidence were selected to assess the magnitude of effects on benthic invertebrates because they provided the most reliable basis for linking COPC concentrations to the magnitude of responses for the estuary-specific data set. A preliminary assessment of the areal extent of adverse effects on benthic invertebrate communities in the Calcasieu Estuary was conducted using the whole-sediment chemistry data that were collected in the Phase I and II RI. Finally, the COCs were identified by comparing the concentrations of COPCs in whole sediments or pore water to the concentrations of those substances in reference sediments and by comparing the concentrations of COPCs to the selected benchmarks for those substances. Concordance between the whole-sediment or pore-water chemistry and the biological response data was also used to identify the COCs from the longer list of COPCs.

Information on a variety of toxicity tests and biological surveys was used to assess risks to benthic invertebrates exposed to COPCs in whole sediment and pore water from the Calcasieu Estuary. More specifically, risks to the benthic invertebrate community were evaluated using the results of 10-d and 28-d toxicity tests with the amphipod, *Hyalella azteca* (endpoint: survival and growth), 10-d toxicity tests with the amphipod, *Ampelisca abdita* (endpoint: survival), 60-min or 48-h toxicity tests with the sea urchin, *Arbacia punctulata* (endpoint: gamete fertilization or embryo development), and assessments of benthic invertebrate community structure. The results of such ambient media toxicity tests and
biological surveys were considered to be relevant for evaluating effects on local-exposed sub-populations of benthic invertebrates (i.e., organisms that have limited mobility and small home ranges).

A reference envelope approach was used to identify whole-sediment and pore-water samples in the estuary that posed incremental risks to benthic invertebrates. More specifically, whole-sediment or pore-water samples were identified as toxic when survival, growth, or reproduction of the test organisms was lower than the lower limit of the normal range (i.e., 95% LCL) of responses for test organisms exposed to samples from the reference areas. The results of these tests (i.e., for which toxicity designations were made using the reference envelope approach) were used in the development of the estuary-specific concentration-response models. The results of cluster analyses were used to designate whole-sediment samples as impacted or not impacted relative to benthic invertebrate community structure. Risks to the benthic invertebrate community were classified as low, indeterminate, or high based on the observed and predicted incidence of toxicity (IOT; i.e., <20%, 20-50%, and >50% increase in the proportion of toxic samples relative to reference, respectively) and on the observed and predicted magnitude of toxicity (MOT; i.e., <10%, 10-20%, and >20% decrease in survival relative to reference, respectively; Appendix E2).

An integrated assessment of the risks posed to the benthic invertebrate community by exposure to COPCs in whole sediments and/or pore water was conducted following the assessment of the nature, magnitude, and areal extent of risks. In this assessment, the available data were integrated by calculating a final risk score for each sampling location based on the results for up to five lines of evidence and the associated level of uncertainty (as described in Appendix E2;
Menzie et al. 1996; Johnston et al. 2002). The final risk score is intended to provide an integrated measure of the risks that contaminated sediments pose to the survival, growth, or reproduction of benthic invertebrates in the Calcasieu Estuary. More specifically, the final risk score integrates the results of whole-sediment toxicity tests, pore-water toxicity tests, whole-sediment chemical analyses, pore-water chemical analyses, and benthic invertebrate community analyses, and their associated uncertainties, into a single parameter (Section 5.0 of Appendix E2). The final risk scores were used to evaluate the areal extent of risks to benthic invertebrates in the Calcasieu Estuary, with scores of <2 designated as low risk, 2 to 3 designated as indeterminate risk, and >3 designated as high risk. Because benthic invertebrates tend to have small home ranges, this evaluation was conducted on a sampling location by sampling location basis (i.e., area averaging was not considered to be appropriate for assessing risks to locally-exposed sub-populations of benthic invertebrates).

6.2 Results and Discussion

Five lines of evidence were used to determine if exposure to whole sediments or pore water was likely to adversely affect benthic invertebrates in the Calcasieu Estuary. Evaluation of the whole-sediment chemistry data collected during the Phase I and Phase II RI using the estuary-specific concentration-response models (Appendix E2) indicates that 62% (389 of 624) and 36% (225 of 624) of the whole-sediment samples from the three AOCs have concentrations of metals, polycyclic aromatic hydrocarbons (PAHs), and/or polychlorinated biphenyls (PCBs) that are sufficient to cause or substantially contribute to adverse effects in marine amphipods and freshwater
amphipods, respectively. By comparison, 69% of the whole-sediment samples (52 of 75 samples) collected from the three AOCs were found to be acutely toxic to marine amphipods (endpoint: survival), while 37% (28 of 75 samples) were found to be chronically toxic to freshwater amphipods (endpoints: survival or growth). The concentrations of many analytes in pore water were similar to those that were measured in reference areas; however, the concentrations of hydrogen sulfide and/or ammonia were sufficient to cause chronic toxicity to sediment-dwelling organisms in 69% (52 of 75 samples) of the pore-water samples collected from Calcasieu Estuary sediments. The incidence of toxicity within the three AOCs was 13% (i.e., 5 of 38 samples) when the results of pore-water toxicity tests with sea urchins (endpoint: fertilization or development) were considered. Finally, the structure of benthic invertebrate communities was impacted in 63% of the sediment samples (47 of 75 samples) collected in the three AOCs, based on the results of the cluster analysis. When considered together, these five lines of evidence indicate that contaminated sediments are adversely affecting the survival, growth, and/or reproduction of benthic invertebrates in the Calcasieu Estuary.

**Nature of Effects** – The results of the investigations that were conducted during the RI indicate that a variety of adverse effects are associated with exposure to COPCs in whole sediment and pore water from the Calcasieu Estuary. More specifically, evaluation of the whole-sediment and pore-water chemistry data indicates that the concentrations of COPCs are sufficient to adversely affect sediment-dwelling organisms. Additionally, the results of toxicity tests indicate that amphipod (*Ampelisca abdita* and *Hyalella azteca*) survival, amphipod (*Hyalella azteca*) growth, and/or sea urchin (*Arbacia punctulata*) fertilization or development have been adversely affected by exposure to whole-sediment and/or
pore-water samples from the Calcasieu Estuary. Furthermore, unspecified effects leading to alterations in benthic invertebrate community structure are also occurring in the Calcasieu Estuary. Therefore, it is concluded that the survival, growth, and reproduction of benthic invertebrates are being adversely affected by exposure to contaminated sediments and/or pore water, based on the evaluations of the whole-sediment chemistry, pore-water chemistry, whole-sediment toxicity, pore-water toxicity, and benthic invertebrate community structure data.

**Magnitude of Effects** – Overall, the information on the magnitude of toxicity to freshwater and marine amphipods indicates that exposure to whole sediments poses risks to the benthic invertebrate community that range from low to high in the Calcasieu Estuary. The concentrations of COPCs are sufficient to pose low, indeterminate, and high risks (i.e., predicted MOT <10%, 10 to 20% and >20% higher than predicted MOT for reference areas, respectively) to freshwater amphipods in 78% (489 of 624), 13% (83 of 624), and 8% (52 of 624) of the whole-sediment samples collected from the estuary, respectively. By comparison, the results of whole-sediment toxicity tests with the amphipod, *Hyalella azteca* indicate that 75% (56 of 75) of the samples were classified as posing low risk, 7% (5 of 75) of the samples were classified as posing indeterminate risk, and 19% (14 of 75) of the samples were classified as posing high risk to the benthic invertebrate community (i.e., observed MOT <10%, 10 to 20% and >20% higher than predicted MOT for reference areas).

For marine amphipods, the concentrations of COPCs are sufficient to pose low, indeterminate, and high risks in 63% (391 of 624), 8% (51 of 624), and 29% (182 of 624) of the whole-sediment samples collected from the estuary, respectively.
By comparison, the results of whole-sediment toxicity tests with the amphipod, *A. abdita* indicate that 36% (27 of 75), 19% (14 of 75), and 45% (34 of 75) of the whole-sediment samples tested from this estuary can be classified as posing low, indeterminate, and high risks relative to reference conditions. The fertilization of sea urchin gametes was reduced by <10%, 10 to 20% and >20%, relative to reference, in 87% (33 of 38), 3% (1 of 38), and 11%(4 of 38) of the pore-water samples from the three AOCs. Therefore, the information on the magnitude of the effects indicates that whole-sediment or pore-water samples posing indeterminate and high risks to the benthic invertebrate community were frequently encountered in the Calcasieu Estuary.

**Preliminary Assessment of the Areal Extent of Effects** – The areal extent of adverse effects on benthic invertebrate communities in the Calcasieu Estuary was initially assessed using the whole-sediment chemistry data that were collected in the Phase I and II RIs. To support this evaluation of the spatial distribution of chemical contamination, mean PEC-Qs were calculated for each of the sediment samples (n=641) that were obtained from the estuary. The use of mean PEC-Qs to evaluate the areal extent of effects on the benthic invertebrate community was based on the relationships between mean PEC-Qs and sediment toxicity that were established with the estuary-specific concentration-response models described in Appendix E2. Each sediment sample was classified into one of three categories using the mean PEC-Qs: low; indeterminate; or, high (based on the risk that it posed to marine amphipods and freshwater amphipods). Then, these data were compiled on a reach by reach basis and mapped using ArcView/Spatial Analyst software.
Sediments within the Calcasieu Estuary are generally of sufficient quality to support the normal survival, growth, and reproduction of benthic invertebrates. However, the concentrations of metals, PAHs, and/or PCBs were sufficient to adversely affect benthic invertebrates in numerous whole-sediment samples from each of the three AOCs. A number of hot spots with respect to sediment contamination were identified within the UCR AOC, with the highest risks to benthic invertebrates occurring in the Clooney Island barge slip, the northeastern and southwestern portions of Clooney Island Loop, the mouth of Bayou Verdine, Coon Island Loop northwest, and various other locations in the Coon Island Loop. Within the BI AOC, the highest risks to benthic invertebrates were evident in portions of upper Bayou d’Inde, in the vicinity of the Hwy 108 bridge, Maple Fork, PPG Canal, the lower Bayou d’Inde mainstem, and Lockport Marsh. The hot spots in the MCR AOC with respect to sediment contamination are largely associated with the Middle Calcasieu River Mainstem and the Indian Wells Lagoon reaches. The integrated assessment of risks to benthic invertebrate communities, which is presented below, provides a basis for further identifying the locations that pose low, indeterminate, and high risks to benthic invertebrates.

**Contaminants of Concern** – The substances that occur in whole-sediment or pore-water samples at concentrations above those in reference areas, above the selected benchmarks, and show concordance with the biological response data, represent the COCs relative to effects on benthic invertebrates. In the UCR AOC, the COCs include: chromium; copper; lead; mercury; zinc; numerous individual PAHs; total low molecular weight-PAHs (LMW-PAHs); total high molecular weight-PAHs (HMW-PAHs); total PCBs; bis(2-ethylhexyl)phthalate (BEHP); and, tetrachlorodibenzo-\(p\)-dioxins equivalents (TCDD-TEQs). The
COCs in the BI AOC include: chromium; copper; lead; mercury; nickel; zinc; various individual PAHs; total PCBs; aldrin; dieldrin; BEHP; hexachlorobenzene (HCB); hexachlorobutadiene (HCBD); and, TCDD-TEQs. In the MCR AOC, the COCs include: chromium; copper; lead; mercury; zinc; numerous individual PAHs; total LMW-PAHs; total HMW-PAHs; total PAHs; total PCBs; aldrin; BEHP; HCB; and, TCDD-TEQs.

The results of whole-sediment bioaccumulation and/or toxicity tests indicate that one or more of the COCs identified are biologically-available in Calcasieu Estuary sediments. The results of 28-d bioaccumulation tests with the polychaete, *Nereis virens*, confirm that the following substances have accumulated to elevated levels in the tissues of benthic invertebrates (i.e., mean concentrations are factor of two or more higher than those in reference areas) and, hence, are bioavailable in Calcasieu Estuary sediments: chromium; nickel; chrysene; various PCB congeners; HCB; BEHP; diethylphthalate; and, certain PCDDs and PCDFs. These results also indicate that these substances would be available for food web transfer to organisms that feed on polychaetes. Furthermore, the results of toxicity identification evaluations conducted on pore water from Calcasieu Estuary sediment samples indicate that non-polar organics and metals contributed to acute toxicity to marine amphipods, *Ampelisca abdita*, in 96-h toxicity tests (SAIC 2002). Hence, the COCs identified above should be considered to be the highest priority for developing preliminary remediation goals for the Calcasieu Estuary.

*Uncertainty Assessment* – There are a number of sources of uncertainty in assessments of risk to the benthic invertebrate community, including uncertainties
in the conceptual model, in the exposure assessment, and in the effects assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and influence of such uncertainties.

A total of 10 criteria were used to evaluate the level of confidence that can be placed in the various measurement endpoints that were used to assess risks to benthic invertebrates. For each of these criteria, the degree of uncertainty in the measurement endpoint was scored from 1 (higher uncertainty) to 3 (lower uncertainty; Table 6-1). These results were then used to determine the level of uncertainty that was associated with the conceptual model, the exposure assessment, and the effects assessment. In turn, these results provided a basis for weighting each measurement endpoint (i.e., total evaluation score) used in the integrated assessment of risks to the benthic invertebrate community (Table 6-1). The resultant total evaluation scores reflect the potential for confounding factors to influence the results of the assessment and, in so doing, affect the potential for obtaining false positive results (i.e., samples designated as indeterminate or high risk that actually pose low risks to the benthic community) or false negative results (i.e., samples designated as low risk that actually pose indeterminate or high risks to the benthic community). The detailed results of the uncertainty analysis that was conducted as part of the BERA are presented in Appendix E2.

**Integrated Assessment of Risks** – Information on five lines of evidence was considered in the integrated assessment of risks to the benthic invertebrate community. Consideration of multiple lines of evidence in an integrated assessment of risks is desirable because it provides a basis for utilizing all of the
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available data for assessing risks, explicitly considers the uncertainty associated with each line of evidence, and, in so doing, reduces the uncertainty associated with the overall assessment of risks. Importantly, calibration of key lines of evidence (e.g., whole-sediment chemistry) against other lines of evidence (e.g., sediment toxicity; i.e., through the development of estuary-specific concentration-response relationships) increases confidence that designations of risk based on a single line of evidence are likely to be consistent with those based on multiple lines of evidence (see Appendix E2 for additional information; Ingersoll and MacDonald 2002; Menzie et al. 1996; Johnston et al. 2002). The final risk scores that were calculated using information on the various measurement endpoints and the associated uncertainty in each measurement endpoint were used to provide an integrated measure of the risks posed to the benthic invertebrate community associated with exposure to COPCs in whole sediment and/or pore water.

Upper Calcasieu River AOC – Samples were collected from a total of 146 locations to support an assessment of the risks posed to the benthic invertebrate community associated with exposure to sediment and pore water within the UCR AOC. The results of this assessment indicate that exposure to whole sediments and/or pore water in the UCR AOC generally posed a low risk to benthic invertebrates (i.e., average of the final risk scores of 0.838; n=146). Low final risk scores (i.e., < 2) were calculated for 86% of the locations (i.e., 126 of 146) sampled within this AOC (Table 6-2). Nevertheless, indeterminate (4%; 6 of 146) or high (10%; 14 of 146) risks to benthic invertebrates were indicated for 14% of the locations that were sampled (i.e., 20 of 146) in the UCR AOC (Table 6-2). Consistent with the results of the analyses of the information on individual lines of evidence, the
locations where contaminated sediments posed the highest risks (i.e., relative to the survival, growth, or reproduction of benthic invertebrates) included the eastern portion of Lake Charles, the Clooney Island barge slip, the northeastern and southwestern portions of the Clooney Island Loop, the mouth of Bayou Verdine, and the northern, northwestern, and central portions of Coon Island Loop (Figures 6-1 and 6-2). Indeterminate risks to the benthic invertebrate community exist in the eastern portion of Lake Charles, in the Calcasieu River downstream of Lake Charles, the eastern portion of Clooney Island Loop, in Contraband Bayou in the vicinity of the Port of Lake Charles, and the central and southern portions of Coon Island Loop (Figures 6-1 and 6-2).

**Bayou d’Inde AOC** – Samples were collected from a total of 315 locations to support an assessment of the risks posed to the benthic invertebrate community associated with exposure to sediment and pore water within the BI AOC. The results of this assessment indicate that exposure to whole sediments and/or pore water in the BI AOC posed risks to benthic invertebrates ranging from low to high (i.e., average of the final risk scores of 2.20; n=315). Roughly 49% of the locations that were sampled (i.e., 153 of 315) in this AOC had low final risk scores (i.e., < 2; Table 6-2). However, indeterminate (14%; 44 of 315) or high (37%; 118 of 315) risks to benthic invertebrates were indicated for 51% of the locations (i.e., 162 of 315) in the BI AOC (Table 6-2). Consistent with the results of the analyses of the individual lines of evidence presented in Appendix E2, the locations where contaminated sediments posed the highest risks (i.e., relative to the survival, growth, or reproduction of benthic invertebrates) included upper Bayou d’Inde from the CitCon property to the Highway 108 bridge, the off-channel wetland and mainstem areas
throughout middle Bayou d’Inde, PPG Canal, the portions of Lockport Marsh closest to PPG Canal, the central portion of the wetland areas located east of lower Bayou d’Inde, and lower Bayou d’Inde mainstem (Figures 6-3 and 6-4). Indeterminate risks to the benthic invertebrate community exist in upper Bayou d’Inde downstream of the I-10 bridge and from the CitCon property to the Highway 108 bridge, the mainstem and off-channel wetland areas throughout middle Bayou d’Inde, PPG Canal, the central portions of Lockport Marsh and the wetland area located southeast of lower Bayou d’Inde, and the lower Bayou d’Inde mainstem (Figures 6-3 and 6-4).

Middle Calcasieu River AOC – Samples were collected from a total of 163 locations to support an assessment of the risks posed to the benthic invertebrate community associated with exposure to sediment and pore water within the MCR AOC. The results of this assessment indicate that exposure to whole sediments and/or pore water in the MCR AOC generally posed a low risk to benthic invertebrates (i.e., average of the final risk scores of 0.674; n=163). Eighty-eight percent of the locations that were sampled (i.e., 144 of 163) in this AOC had low final risk scores (i.e., < 2; Table 6-2). Nevertheless, indeterminate (5%; 8 of 163) or high (7%; 11 of 163) risks to benthic invertebrates were indicated for 12% of the locations (i.e., 19 of 163) in the MCR AOC (Table 6-2). Consistent with the results of the analyses of the individual lines of evidence presented in Appendix E2, the locations where contaminated sediments posed the highest risks (i.e., relative to the survival, growth, or reproduction of benthic invertebrates) included the middle Calcasieu River adjacent to the Citgo property and Indian Wells Lagoon (Figures 6-5, 6-6, and 6-7). Indeterminate risks to the benthic invertebrate
community exist in portions of Prien Lake and the old river channel, in the middle Calcasieu River in the vicinity of the Citgo property and the WR Grace property, and the central portion of Moss Lake (Figures 6-5, 6-6, and 6-7).

6.3 Summary and Conclusions

The risks to benthic invertebrate communities posed by exposure to whole sediments and pore water were assessed in the Calcasieu Estuary. In total, information on five lines of evidence was used to determine if the survival, growth, and/or reproduction of benthic invertebrates have been adversely affected or is likely to have been adversely affected by exposure to contaminated sediments in the estuary relative to reference conditions. The five lines of evidence that were considered in the assessment included whole-sediment chemistry, whole-sediment toxicity, pore-water chemistry, pore-water toxicity, and benthic invertebrate community structure.

The results of this assessment indicated that exposure to whole sediment and/or pore water from the Calcasieu Estuary generally posed low risks to benthic invertebrate communities (i.e., risks were classified as low for 68% of the locations sampled (423 of 624) within the three AOCs investigated. However, indeterminate and high risks to the benthic invertebrate community were indicated for 9% (58 of 624) and 23% (143 of 624) of the locations sampled, respectively (Table 6-2). Of the three AOCs considered, the risks to the benthic invertebrate community were highest in Bayou d’Inde, based both on the incidence and magnitude of toxicity (i.e., observed and predicted). Within this AOC, samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, PPG Canal, and the inner portions of Lockport Marsh posed the
highest risks. Although risks to the benthic invertebrate community were generally lower in the UCR AOC and MCR AOC, samples posing a high risk to benthic invertebrates were collected from the northern portions of Clooney Island Loop, the northern portions of Coon Island Loop, the middle Calcasieu River in the vicinity of the Citgo property, and Indian Wells Lagoon (Table 6-2). Risks to the benthic invertebrate community are generally low throughout the reference areas (Figure 6-8).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the benthic invertebrate community. For example, the survival and/or growth of freshwater and marine amphipods were lower for the locations that were designated as posing indeterminate and high risks than was the case for the locations that were classified as posing low risks to benthic invertebrates (Table 6-3). Likewise, the fertilization of sea urchin gametes was reduced in the samples from locations that were designated as posing indeterminate or high risks to the benthic community (Table 6-3; Appendix E2). Importantly, the density of pollution indicator (i.e., tolerant) species, the density of pollution sensitive species, species richness, and total abundance of benthic invertebrates were generally lower for the sampling locations that were classified as posing indeterminate and high risks, as compared to the sampling locations that posed low risks to benthic invertebrates (Table 6-3). Together, these results demonstrate that the survival, growth, and/or reproduction of benthic invertebrates have been impaired in response to exposure to contaminated sediments in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the benthic invertebrate community in the Calcasieu Estuary. More specifically, the COCs included:
• Hydrogen sulfide;

• Metals (chromium, copper, lead, mercury, nickel, and zinc);

• PAHs (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs);

• PCBs (total PCBs);

• Chlorinated benzenes (HCB and HCBD);

• Phthalates (BEHP);

• Organochlorine pesticides (aldrin and dieldrin); and,

• PCDDs and PCDFs (total 2,3,7,8-TCDD TEQs).

All of these substances occurred in whole-sediment and/or pore-water samples from the Calcasieu Estuary at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. In addition, the concentrations in the effects distribution were generally higher than the concentrations in the no effects distribution for one or more of the measurement endpoints (e.g., survival of *Ampelisca abdita* in 10-d toxicity tests). Many of these substances or groups of substances also accumulated in the tissues of polychaetes (*Nereis virens*) in 28-d bioaccumulation tests and were shown to be associated with toxicity to amphipods (*Ampelisca abdita*) in toxicity identification evaluations.
Chapter 7. Assessment of Risks to Fish Communities in the Calcasieu Estuary using a Weight of Evidence Approach

Summary: This chapter summarizes the components of the baseline ecological risk assessment (BERA) that evaluate the risks posed to benthic and pelagic fish (Appendix F1) associated with exposure to chemicals of potential concern (COPCs) in the Calcasieu Estuary. The risks to carnivorous fish, which represent a subset of the pelagic and benthic fish communities, were also evaluated in the BERA (Appendix F2). More specifically, the data on surface-water chemistry, whole-sediment chemistry, pore-water chemistry, and pore-water toxicity were evaluated to determine if significant effects on survival, growth, or reproduction of benthic or pelagic fish are occurring or are likely to be occurring in the Calcasieu Estuary. The information on these four lines of evidence was also used to evaluate the nature, magnitude, and areal extent of effects on benthic and pelagic fish. Furthermore, these data were used to identify the substances that are causing or substantially contributing to such effects in the Calcasieu Estuary (i.e., the contaminants of concern; COCs). Finally, these data were further evaluated to support an integrated assessment of risks to benthic and pelagic fish associated with exposure to COPCs in the Calcasieu Estuary (Appendix F1). In a companion assessment, the tissue residue data collected during the Remedial Investigation (RI) were used to evaluate the risks to carnivorous fish posed by the accumulation of COPCs in fish tissues (i.e., whole body burdens; Appendix F2). This chapter of the BERA provides a summary of the information presented in Appendix F1 and F2, with a focus on the integrated assessment of risks to fish communities based on multiple lines of evidence.

The results of the integrated assessment of risks to benthic and pelagic fish were used to classify environmental conditions at specific sampling locations
into three risk categories. Ecological risks were classified as low if the frequency and/or magnitude of effects that were observed or predicted to occur were similar to those for selected reference areas. By comparison, ecological risks were classified as indeterminate if the frequency and/or magnitude of effects that were observed or predicted to occur were moderately higher than those for selected reference areas. The term, indeterminate, was used to describe this classification because decisions regarding remedial actions at such locations should consider a variety of factors in addition to ecological risk (e.g., costs and effects of remedial actions, potential for natural recovery, etc.). Finally, ecological risks were classified as high if the frequency and/or magnitude of effects that were observed or predicted to occur were substantially higher than those for selected reference areas. Reaches or areas of concern (AOCs) so designated represent the highest priority for remedial action planning.

The results of this BERA indicated that exposure to COPCs in surface water, whole sediment, and/or pore water from the Calcasieu Estuary generally poses low risks to fish communities. Risks were classified as low for 58% (i.e., 367 of 634) of the sampling locations investigated within the three AOCs. However, indeterminate and high risks to fish communities were indicated for 5% (33 of 634) and 37% (234 of 634) of the sampling locations, respectively. Therefore, conditions posing incremental risks to fish communities (i.e., relative to reference areas) were frequently observed in the Calcasieu Estuary.

The risks to fish communities posed by exposure to COPCs were evaluated for three AOCs in the estuary, including the Upper Calcasieu River AOC (UCR AOC), the Bayou d’Inde AOC (BI AOC), and the Middle Calcasieu River AOC (MCR AOC). The risks to benthic and pelagic fish were also evaluated in selected reference areas within the estuary. Of the three AOCs considered, the risks to fish communities were highest in the BI AOC. Within this AOC, conditions posing a high risk to fish communities were frequently encountered in the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, the lower Bayou d’Inde mainstem, and the inner portions of
Lockport Marsh. Although risks to fish communities were generally lower in the UCR AOC and MCR AOC, sampling locations classified as posing high risks to fish were identified in portions of Clooney Island Loop, portions of Coon Island Loop, the middle Calcasieu River in the vicinity of the Citgo and W.R. Grace properties, Indian Wells Lagoon, west central portion of Prien Lake, and Moss Lake. Risks to fish communities were classified as low throughout the reference areas that were selected to represent contemporary background conditions in the estuary.

The potential for adverse effects on fish associated with exposure to COPCs was evaluated for four routes of exposure, including contact with surface water, contact with whole sediments, contact with pore water, and all exposure routes combined (i.e., using data on whole body burdens for fish). Of the exposure routes examined, exposure to COPCs in whole sediments and pore water posed the greatest risks to fish communities. Accordingly, fish that are closely associated with sediments, such as flounder (i.e., benthic species), are the most likely to be adversely affected by COPCs in the Calcasieu Estuary. Biota accumulation of polychlorinated biphenyls (PCBs) in their tissues was not considered to pose significant risks to carnivorous fish utilizing benthic or pelagic habitats in the three AOCs; insufficient data were available to determine if the accumulation of PCBs or polychlorinated dibenzo-\textit{p}-dioxins/polychlorinated dibenzofurans (PCDDs/PCDFs) in their tissues posed a significant risk to carnivorous fish in the estuary (Appendix G).

The results of this assessment indicate that a number of substances are causing or substantially contributing to adverse effects on fish communities in the Calcasieu Estuary (i.e., COCs). More specifically, the COCs were considered to include:

- Hydrogen sulfide;
- Metals (chromium, copper, lead, mercury, nickel, and zinc);
• PAHs (2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene, total HMW-PAHs, and total PAHs);
• PCBs (total PCBs);
• Organochlorine pesticides (dieldrin); and,
• PCDDs and PCDFs (total 2,3,7,8-TCDD TEQs).

All of these substances occurred in surface-water, whole-sediment, or pore-water samples at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. A detailed assessment of the risks to fish communities associated with exposure to contaminated surface water, sediment, and pore water in the Calcasieu Estuary is provided in Appendix F1. Appendix F2 provides an assessment of the risks to carnivorous fish that are posed by the accumulation of COPCs in their tissues.

7.0 Introduction

Fish are key elements of freshwater, estuarine, and marine ecosystems for a number of reasons. As one of the most diverse groups of vertebrates, fish are able to occupy a wide range of ecological niches and habitats (Hoese and Moore 1998). Accordingly, fish represent important components of aquatic food webs by processing energy and nutrients from aquatic plants (i.e., primary producers), zooplankton and benthic macroinvertebrate species (i.e., primary consumers), or detritivores. Importantly, fish also represent essential prey species for piscivorus (fish-eating) wildlife, including reptiles, birds, and mammals.
The fish that occur in the Calcasieu Estuary can be classified into two general categories according to their habitat preferences. Pelagic fish species, such as spotted gar (Lepisosteus oculatus) and spotted seatrout (Cynoscion nebulosus), are widely distributed in the water column and are likely to be exposed to COPCs in surface water and in their diets. By comparison, benthic fish species, such as black drum (Pogonias cromis), channel catfish (Ictalurus punctatus), and southern flounder (Paralichthys lethostigma), tend to be associated with the substrate at the bottom of lakes and bayous, and are likely to be exposed to COPCs in surface water, sediments (including pore water), and in their diet (MacDonald et al. 2001). Dietary exposure to COPCs can represent a particularly important exposure route for carnivorous fish species (i.e., those species that prey upon other fish, such as spotted seatrout, red drum, black drum, and southern flounder), utilizing benthic or pelagic habitats. Accordingly, all of these exposure pathways were evaluated relative to the potential for adverse effects on benthic and pelagic fish communities in the estuary. In addition to the assessment of risks to fish communities, risk assessments were also conducted to evaluate the potential effects on microbial communities (Chapter 4), aquatic plant communities (Chapter 5), benthic invertebrate communities (Chapter 6), avian communities (Chapter 8), and mammalian communities (Chapter 9) associated with exposure to COPCs in the estuary.

7.1 Methods

A step-wise approach was used to assess the risks to fish communities posed by exposure to COPCs in the Calcasieu Estuary (see Appendix D for details). The five main steps in this process including: (1) identification of assessment endpoints, risk questions and testable hypotheses, and measurement endpoints; (2) collection,
evaluation, and compilation of the relevant information on environmental conditions in the Calcasieu Estuary; (3) assessment of the exposure of fish to COPCs (i.e., exposure assessment; Figure 4-1); (4) assessment of the effects of COPCs on fish (i.e., effects assessment; Figure 4-2); and, (5) characterization of risks to fish communities (i.e., risk characterization; Figures 4-3 to 4-8).

Assessment Endpoints, Measurement Endpoints, and Risk Questions – Fish communities represent essential components of aquatic food webs because they provide important sources of food for many species of reptiles, birds, and mammals. Herbivorous, planktivorous, and omnivorous fish at lower trophic levels in aquatic food webs (i.e., those species that consume aquatic plants, planktonic invertebrates, and/or benthic invertebrates) also represent important prey species for carnivorous fish species, including both benthic and pelagic fish species. As the goal of this assessment is to evaluate the effects of environmental contaminants on these groups of ecological receptors, the survival, growth, and reproduction of benthic and pelagic fish were identified as the assessment endpoints for this component of the BERA.

To provide a valid basis for assessing ecological effects, the assessment endpoints need to be linked to the measurement endpoints by a series of risk questions and testable hypotheses. In this study, the investigations to assess the effects of environmental contaminants on fish communities were designed to answer the following risk questions:

- Are the concentrations of COPCs in surface water from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in surface water from reference areas and greater than the chronic toxicity
thresholds for the survival, growth, and reproduction of benthic and pelagic fish?

• Are the concentrations of COPCs in whole sediment from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in whole sediment from reference areas and greater than the sediment quality benchmarks for the survival, growth, and reproduction of benthic fish?

• Are the concentrations of COPCs in pore water from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in pore water from reference areas and greater than the chronic toxicity thresholds for the survival, growth, and reproduction of benthic fish?

• Are the concentrations of COPCs in fish tissues from the AOCs in the Calcasieu Estuary greater than the levels of COPCs in fish tissues from reference areas and greater than the toxicity thresholds for the survival, growth, and reproduction of carnivorous fish?

• Is the survival of fish (as indicated by larval survival in the red drum, *Sciaenops ocellatus*) exposed to pore water from Calcasieu Estuary sediments outside the normal range (i.e., 95% confidence interval) of survival for fish exposed to pore water from reference sediments?

• Is the reproductive success of fish (as indicated by egg hatching success in the red drum, *Sciaenops ocellatus*) exposed to pore water from Calcasieu Estuary sediments outside the normal range (i.e., 95% confidence interval) of reproductive success of fish exposed to pore water from reference sediments?
A suite of measurement endpoints was selected to provide the information needed to determine if the fish community is being adversely affected due to exposure to COPCs. First, data on the concentrations of COPCs in surface water, whole sediments, pore water, and fish tissues (i.e., whole body burden) were used to determine if these media were sufficiently contaminated to adversely affect the survival, growth, or reproduction of fish in the Calcasieu Estuary. The results of toxicity tests with red drum were also used to evaluate the effects on the fish community associated with exposure to pore water from Calcasieu Estuary sediments. More specifically, adverse effects on fish survival and reproduction were evaluated using the results of pore-water toxicity tests with the red drum in which egg hatching success and larval survival were measured.

_data collection, evaluation, and compilation_ – the information that was used in the Calcasieu Estuary BERA was collected as part of the Phase I and Phase II RI. Surface-water, whole-sediment, pore-water, and fish tissue samples were collected in the three AOCs and in reference areas using a stratified-random sampling design. Samples were shipped to multiple laboratories to support chemical, biological, and/or toxicological characterization. The results of chemical analyses were available for 13 to 56 surface-water samples (i.e., n=13 for conventional variables and n=56 for metals and organics), 647 whole-sediment samples, 45 to 89 pore-water samples (i.e., n=45 for metals and organics; n=89 for conventional variables, such as hydrogen sulfide and ammonia), and 96 fish tissue samples (i.e., whole body). Pore-water toxicity tests were conducted on a sub-set (n=45) of these samples. Of the 45 pore-water samples that were collected during Phase II of the RI, 38 were obtained from the three principal AOCs (i.e., UCR AOC, BI AOC, and MCR AOC) and 7 were obtained from reference areas. All of the resultant data were evaluated against
the project data quality objectives (DQOs) upon receipt from the laboratories and incorporated into the project database. The results of data validation and data auditing indicated that the information used in the BERA generally met the project DQOs.

**Exposure Assessment** – Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter *et al.* 2000). The exposure assessment is intended to provide an estimate of the magnitude of exposure of receptors (i.e., benthic and pelagic fish) to COPCs, over time and space. In this assessment, information on the concentrations of COPCs in surface water, whole sediment, pore water, and fish tissues was used to evaluate exposure of fish communities to COPCs (Figure 4-1). In the carnivorous fish assessment four focal species were selected, red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), spotted seatrout (*Cynoscion nebulosus*), and southern flounder (*Paralichthys lethostigma*) as representative carnivorous fish species found in the Calcasieu Estuary. Summary statistics (i.e., measures of central tendency and distributions) were calculated for each reach and each AOC in the Calcasieu Estuary. The substances that could pose incremental risks to benthic or pelagic fish were identified by comparing the concentrations of COPCs in each AOC to the upper limit of background concentrations (i.e., 95% upper confidence limit; UCL) for the reference areas. Substances that occurred within a reach or an AOC at concentrations that were a factor of two or more higher than the 95% UCL for reference areas were considered to have the potential to pose incremental risks to fish communities.


**Effects Assessment** – In the analysis of effects, risk assessors determine the nature of toxic effects that are associated with exposure to contaminants and the magnitude of the toxic effects as a function of exposure (Suter *et al.* 2000). In this assessment, exposure of fish communities was evaluated using information on the concentrations of COPCs in surface water, whole sediments, pore water, and fish tissues (Figure 4-2). As such, it was necessary to compile information on the effects on fish associated with exposure to COPCs in these environmental media (Appendices F1 and F2).

Exposure to whole sediment has the potential to adversely affect benthic fish. While numerical sediment quality guidelines (SQGs) for the protection of fish have not been established in North America or elsewhere, two sets of empirically-derived SQGs included data on the effects on fish associated with exposure to contaminated sediments, including the effects range low (ERLs)/effect range median (ERMs; Long *et al.* 1995) and the threshold effect levels/probable effect levels (TELs/PELs; MacDonald *et al.* 1996). Additionally, the sediment quality advisory levels (SQALs) that were reported by USEPA (1997b) were based on chronic water quality criteria, which consider the effects of COPCs on fish. Accordingly, the ERMs that were established by Long and Morgan (1990) and Long *et al.* (1995) were selected as the whole-sediment chemistry benchmarks for assessing the risks to the fish community posed by exposure to COPCs in whole sediments in the Calcasieu Estuary. If ERMs were not available for a COPC, then PELs (CCME 1999a), or SQALs (USEPA 1997b) were used establish the whole-sediment chemistry benchmarks (i.e., toxicity thresholds) for assessing the risks to the fish community associated with exposure to sediment-associated COPCs.
Exposure to surface water or pore water also has the potential to adversely affect benthic or pelagic fish. In this assessment, the water quality standards that have been established by the state of Louisiana were used preferentially for estimating chronic toxicity thresholds for fish exposed to surface water or pore water (LDEQ 2000). Nationally-recommended marine water quality criteria or Ecotox thresholds were selected when such water quality standards were not available (USEPA 1996; 1999a; 1999b). Alternatively, marine water quality criteria from other jurisdictions were adopted for use if nationally-recommended water quality criteria were not available (NHDES 1996; NYSDEC 1998). Finally, Tier II secondary chronic values or the lowest chronic values for fish were selected for those COPCs for which no other benchmarks were available (Suter and Tsao 1996).

Effects data can be characterized and summarized in a variety of ways ranging from benchmarks designed to be protective of most or all species to dose-response curves for the receptor group of interest. For carnivorous fish, whole body burdens that were found to have adverse effects on growth, reproduction, or survival were used to derive benchmarks for comparison to Calcasieu Estuary carnivorous fish body burdens. The appropriate toxicological studies were isolated and reviewed for quality (e.g., appropriate controls, statistics, methods). Jarvinen and Ankley (1999) developed a comprehensive database of studies that examined the link between tissue residue values and effects in fish from exposure to inorganic and organic chemicals. This review document was used as a starting point to identify the appropriate effects literature. Numerous additional studies and reviews were located during an extensive literature search and these studies formed the basis for developing appropriate benchmarks for tissue chemistry.
Risk Characterization – The purpose of risk characterization is to determine if significant effects are occurring or are likely to be occurring at the site under investigation. In addition, this step of the process is intended to provide the information needed to describe the nature, magnitude, and areal extent of effects on the selected assessment endpoints. Finally, the substances that are causing or substantially contributing to adverse effects on the survival, growth, or reproduction of benthic and pelagic fish (i.e., COCs) are identified from the preliminary list of COPCs. The following five lines of evidence were examined to determine if exposure to surface water, exposure to sediment (including pore water), and/or consumption of prey items in the Calcasieu Estuary pose significant risks to fish communities: surface-water chemistry, whole-sediment chemistry; pore-water chemistry; pore-water toxicity; and, fish tissue chemistry.

In this assessment, all five lines of evidence were used to determine if the presence of COPCs in surface water, whole sediment, pore water, or fish tissues posed incremental risks to benthic or pelagic fish in the Calcasieu Estuary (i.e., relative to the risks that are associated with exposure to COPCs in environmental media in reference areas in the estuary; Figures 4-3 to 4-8). The nature of the effects associated with exposure to COPCs in surface water, sediment or pore water was evaluated using four of the five lines of evidence (i.e., excluding tissue chemistry). Subsequent to evaluating the nature of effects, the magnitude of the effects on benthic fish exposed to contaminated sediments was then evaluated using one line of evidence: pore-water toxicity. A preliminary assessment of the areal extent of adverse effects on fish communities in the Calcasieu Estuary was conducted using the whole-sediment chemistry data that were collected in Phase I and II of the RI. Finally, the COCs were identified by comparing the concentrations of COPCs in surface water, whole sediments, pore water, or fish
tissues to the concentrations of those substances in reference areas and by comparing the concentrations of COPCs to the selected benchmarks for those substances. Concordance between the pore-water chemistry and the biological response data was also used, when possible, to identify the COCs from the longer list of COPCs.

The results of toxicity tests were used to assess risks to fish exposed to COPCs in pore water from the Calcasieu Estuary. More specifically, risks to benthic fish were evaluated using the results of 24- or 48-h toxicity tests with the redfish, *Sciaenops ocellatus* (endpoint: egg hatching success or larval survival). A reference envelope approach was used to identify pore-water samples in the estuary that posed incremental risks to fish. More specifically, pore-water samples were identified as toxic when hatching success or survival of the test organisms was lower than the lower limit of the normal range (i.e., 95% lower confidence limit; LCL) of responses for test organisms exposed to samples from the reference areas.

The risks to fish associated with exposure to COPCs in environmental media were classified into three categories, based on the results that were obtained for individual measurement endpoints. More specifically, risks to fish communities were classified as low, indeterminate, or high based on the observed and predicted incidence of toxicity (IOT; i.e., <20%, 20-50%, and >50% increase in the proportion of toxic samples relative to reference, respectively) and on the observed and predicted magnitude of toxicity (MOT; i.e., <10%, 10-20%, and >20% increase in mortality relative to reference, respectively; Appendix F1).
An integrated assessment of the risks posed to fish communities by exposure to COPCs in surface water, whole sediments, and/or pore water was conducted following the assessment of the nature, magnitude, and areal extent of risks. In this assessment, the available data were integrated by calculating a final risk score for each sampling location based on the results for up to four lines of evidence (as described in Appendix F1). The final risk score is intended to provide an integrated measure of the risks posed to the survival, growth, or reproduction of fish communities in the Calcasieu Estuary by exposure to surface water and/or sediment (including pore water). More specifically, the final risk score integrates the results of pore-water toxicity tests, surface-water chemical analyses, whole-sediment chemical analyses, and pore-water chemical analyses, and their associated uncertainties, into a single parameter (Appendix F1). The final risk scores were used to evaluate the areal extent of risks to fish in the Calcasieu Estuary, with scores of <2 designated as low risk, 2 to 3 designated as indeterminate risk, and >3 designated as high risk.

For carnivorous fish (Appendix F2), the entire effects range for growth, reproduction, and survival was considered and a threshold range (i.e., tissue residue value; TRV range) based on the lowest reasonable no effects value (most sensitive) and highest no effects value (least sensitive) was determined for total PCBs. The results of the exposure assessment (i.e., reverse cumulative distribution functions) and effects assessment (i.e., TRV range) were integrated to estimate the probabilities of exceeding the lower and upper bounds of the TRV range for black drum, red drum, spotted seatrout, and southern flounder in each AOC. The lowest no effect value selected was from the study by Mac and Seelye (1981) using lake trout fry. Both survival and growth were examined and no effect was observed in the range of 2–4 mg/kg in the tissue of the fry. The 4
mg/kg value was used as the low effects tissue residue value (TRV_L). The highest no effect value selected was from the study by Nestel and Budd (1975) where rainbow trout were exposed to PCBs in the diet for 330 days. The study reported a no-effects concentration of 81 mg/kg in tissue for survival and growth, and is considered to be the high tissue residue value (TRV_H). Slight changes in behavior and pigmentation were observed in the fish at this tissue concentration. This effects range encompasses a wide range of no effects and effects data from a number of early life stage studies (e.g., Hansen et al. 1971; Freeman and Idler 1975; Mayer et al. 1977; Mauck et al. 1978; USACOE 1988). Ideally, a risk characterization would involve three major lines of evidence: comparison of modeled exposure to lab-derived effects metrics, in situ or whole-media toxicity tests, and biological surveys. For carnivorous fish, the latter two lines of evidence were not available. We therefore relied upon the comparison of measured tissue levels to laboratory derived effects metrics.

7.2 Results and Discussion

Four lines of evidence were used to determine if exposure to surface water, whole sediment, and pore water was likely to adversely affect benthic or pelagic fish in the Calcasieu Estuary. Evaluation of the surface-water chemistry data collected during the Phase I RI using the chronic toxicity thresholds indicated that the predicted incidence of toxicity to fish in the three AOCs was similar to the predicted incidence of toxicity for the reference areas. However, comparison of the whole-sediment chemistry data to the selected chemical benchmarks indicated that roughly 42% (266 of 630) of the sediment samples from the three AOCs have concentrations of COPCs.
that were sufficient to cause or substantially contribute to sediment toxicity [compared to 6% (1 of 17) for reference areas]. While the concentrations of many analytes in pore water were similar to those that were measured in reference areas; the concentrations of hydrogen sulfide and/or ammonia were sufficient to cause chronic toxicity to fish in 69% (52 of 75 samples) of the pore-water samples collected from Calcasieu Estuary sediments (i.e., compared to 21% for reference samples; 3 of 14). The incidence of toxicity within the three AOCs was low (i.e., 0 of 38 samples; 0%) when the results of pore-water toxicity tests with redfish, *Sciaenops ocellatus*; endpoint: hatching success or survival) were considered. When considered together, these four lines of evidence indicate that exposure to surface water, sediments or pore water are adversely affecting the survival, growth, and reproduction of fish in portions of the Calcasieu Estuary. Of the exposure routes examined, exposure to whole sediments and pore water poses the highest risks to fish. Therefore, benthic fish species are most likely to be adversely affected by exposure to COPCs in the Calcasieu Estuary.

**Nature of Effects** – The results of the investigations that were conducted during the RI indicate that a variety of adverse effects are associated with exposure to COPCs in surface water, whole sediment, or pore water from the Calcasieu Estuary. While adverse effects on fish are not anticipated in response to exposure to surface water in the three AOCs, evaluation of the whole-sediment chemistry data indicates that the concentrations of various COPCs are sufficient to adversely affect fish. More specifically, exposure to sediment-associated certain COPCs is associated with a variety of adverse effects on fish, including reduced survival, increased incidence of idiopathic lesions, and increased frequency of neoplasms (MacDonald et al. 1994). Exposure to certain COPCs (i.e., hydrogen
sulfide) in pore water is known to adversely affect the survival, growth, and/or reproduction of a variety of fish species. Although short-term exposure (i.e., 24-h or 48-h) to pore-water samples from the Calcasieu Estuary did not adversely affect the hatching success or larval survival of redfish, it is likely that manipulation of these samples prior to testing (i.e., freezing and thawing) substantially reduced the concentrations of hydrogen sulfide in the pore water and, hence, the toxicity of the samples. As the levels of hydrogen sulfide in pore water were higher in the three AOCs (i.e., average concentrations ranged from $2.4 \pm \text{g/L}$ in the MCR AOC to $4.9 \pm \text{g/L}$ in the UCR AOC) than they were in reference areas (i.e., averaging $1.6 \pm \text{g/L}$), it is possible that COPC-related effects on the microbial community resulted in accumulations of this substance in pore water. Overall, it is concluded that the survival, growth, and reproduction of benthic fish are being adversely affected by exposure to contaminated sediments and/or pore water, based on the evaluations of the surface-water chemistry, whole-sediment chemistry, pore-water chemistry, and/or pore-water toxicity data.

**Magnitude of Effects** – The magnitude of the effects on fish exposed to contaminated sediments was evaluated using one line of evidence: pore-water toxicity. Based on the results of acute toxicity tests (i.e., observed magnitude of toxicity), it is apparent that exposure to pore water from Calcasieu Estuary sediments does not pose incremental risks to fish relative to those that are associated with exposure to pore water from reference sediments. The average survival of redfish eggs and larvae was 3% for the pore-water samples from the three AOCs. By comparison, the results of 48-h toxicity tests with redfish showed that average survival was 0% for eggs and larvae exposed to pore water from reference sediments. Overall, the information on the observed magnitude
of toxicity to redfish indicates that exposure to pore water from Calcasieu Estuary sediments generally poses a low risk to fish communities. It should be noted, however that the pore-water toxicity tests on fish were conducted using pore water that had been frozen and thawed prior to testing. Therefore, hydrogen sulfide levels were probably much lower than would have been the case for pore water collected directly from whole sediments. Therefore, the magnitude of effects on fish exposed to pore water was probably higher than was estimated using the results of pore-water toxicity tests.

**Preliminary Assessment of the Areal Extent of Effects** – The areal extent of adverse effects on fish communities in the Calcasieu Estuary was initially assessed using the whole-sediment chemistry data that were collected in the Phase I and II of the RI. To support this preliminary evaluation of the spatial distribution of effects on fish communities, the concentrations of COPCs in each whole-sediment sample were compared to the corresponding chemical benchmark. Samples for which one or more COPCs exceeded the corresponding benchmark were predicted to be toxic to fish. Long *et al.* (1995) reported that the incidence of effects on aquatic organisms ranged from 50% to 100% for 26 of the 28 substances for which ERMs were derived (i.e., for samples in which at least one ERM was exceeded). As the sensitivities of sediment-dwelling species to COPCs has been shown to be similar to those of water-column species (i.e., fish; Di Toro *et al.* 1991), it is not unreasonable to conclude that COPCs that occur at levels in excess of one or more ERMs would adversely affect fish that are exposed to contaminated sediments. Each sediment sample was classified into one of two categories (i.e., low or high), based on the risk that it posed to fish (i.e., high for samples with one or more exceedances of the ERMs). Then, these
data were compiled on a reach by reach basis and mapped using ArcView/Spatial Analyst software.

The results of the preliminary evaluation of the areal extent of effects indicate that sediment quality conditions within the Calcasieu Estuary are generally of sufficient quality to support the normal survival, growth, and reproduction of benthic fish. However, the concentrations of COPCs were sufficient to adversely affect benthic fish in numerous whole-sediment samples from each of the three AOCs. A number of hot spots with respect to sediment contamination were identified within the UCR AOC, with the highest risks to fish occurring in the Clooney Island barge slip, the northern and eastern portions of Clooney Island Loop, the mouth of Bayou Verdine, and elsewhere in the Coon Island Loop. Within the BI AOC, the highest risks to fish were evident in the lower portion of upper Bayou d’Inde, middle Bayou d’Inde, PPG Canal, lower Bayou d’Inde mainstem, and Lockport Marsh. The hot spots in the MCR AOC with respect to sediment contamination are largely associated with the middle Calcasieu River (i.e., western shoreline), portions of Moss Lake, portions of Prien Lake, and the Indian Wells Lagoon. The integrated assessment of risks to fish invertebrate communities, which is presented below, provides a basis for further identifying the locations that pose low, indeterminate, and high risks to fish.

Contaminants of Concern – The substances that occur in surface-water, whole-sediment, or pore-water samples at concentrations above those in reference areas and above the selected benchmarks represent the COCs relative to effects on fish. For pore water, concordance between chemical concentrations and biological effects was also evaluated to support the identification of COCs. Insufficient
information was available to conduct this evaluation for surface water or whole sediment, however. In the UCR AOC, the COCs included: lead; mercury; nickel; zinc; numerous individual polycyclic aromatic hydrocarbons (PAHs); total low molecular weight-PAHs (LMW-PAH); total high molecular weight-PAHs (HMW-PAHs); total PCBs; and, tetrachlorodibenzo-\(p\)-dioxins equivalents (TCDD-TEQs). The COCs in the BI AOC included: hydrogen sulfide; chromium; copper; lead; mercury; nickel; zinc; numerous individual PAHs; total PCBs; dieldrin; and, TCDD-TEQs. Although concordance between the concentrations of hydrogen sulfide and the hatching success or larval survival of redfish was not observed for pore-water samples from Bayou d’Inde, this substance was still identified as a COC because the pore water used in the toxicity tests was substantially manipulated (i.e., frozen and thawed) prior to testing. In the MCR AOC, the COCs included: copper; lead; mercury; nickel; numerous individual PAHs; total LMW-PAHs; total HMW-PAHs; total PAHs; total PCBs; and, TCDD-TEQs. Hence, the COCs identified above should be considered to be the highest priority for developing preliminary remediation goals for the Calcasieu Estuary.

**Uncertainty Assessment** – There are a number of sources of uncertainty in assessment of risks to fish communities, including uncertainties in the conceptual model, in the exposure assessment, and in the effects assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and influence of such uncertainties.
A total of 10 criteria were used to evaluate the level of confidence that can be placed in the various measurement endpoints that were used to assess risks to benthic and pelagic fish. For each of these criteria, the degree of uncertainty in the measurement endpoint was scored from 1 (higher uncertainty) to 3 (lower uncertainty; Table 7-1). These results were then used to determine the level of uncertainty that was associated with the conceptual model, the exposure assessment, and the effects assessment. In turn, these results provided a basis for weighting each measurement endpoint (i.e., using the total evaluation score) used in the integrated assessment of risks to fish communities. The resultant total evaluation scores reflect the potential for confounding factors to influence the results of the assessment and, in so doing, affect the potential for obtaining false positive results (i.e., locations designated as indeterminate or high risk that actually pose low risks to fish communities) or false negative results (i.e., locations designated as low risk that actually pose indeterminate or high risks to fish communities).

There are a number of sources of uncertainty in the assessment of risk to carnivorous fish (Appendix F2). In the conceptual model, the identification of appropriate ecological effects likely represents the primary source of uncertainty. To minimize the effect of selecting one very sensitive effect concentration (i.e., a benchmark) with which to compare exposure, lower and upper bound thresholds were used. The receptors chosen as representative of carnivorous fish in the Calcasieu Estuary are likely to be the dominant high trophic level fish found in the estuary. Nevertheless, it is possible that other high trophic level carnivorous fish are much more sensitive to PCBs than the four fish species selected. In the exposure assessment, there are a number of potential sources of uncertainty including analytical errors, extrapolation errors, and data gaps. The
The greatest source of uncertainty in the effects assessment for carnivorous fish are the few appropriate effects studies available where tissue residues were considered. Furthermore, there were no studies that examined the effects of PCBs on the focal species selected. Therefore, surrogate effects data on a mix of freshwater and marine fish species were used to compare to the body burdens in the focal species. It seems likely that the PCB thresholds for the focal species are between the TRV bounds selected for this assessment. However, there is no way to verify this assumption without further studies being performed with the focal species. The detailed results of the uncertainty analyses that were conducted as part of the BERA are presented in Appendix F1 and F2.

**Integrated Assessment of Risks** – Information on four lines of evidence was considered in the integrated assessment of risks to fish communities. Consideration of multiple lines of evidence in an integrated assessment of risks is desirable because it provides a basis for utilizing all of the available data for assessing risks, explicitly considers the uncertainty associated with each line of evidence, and, in so doing, reduces the uncertainty associated with the overall assessment of risks. The final risk scores that were calculated using information on the various measurement endpoints and the associated uncertainty in each measurement endpoint were used to provide an integrated measure of the risks posed to fish communities associated with exposure to COPCs in surface water, whole sediment, and/or pore water.

**Upper Calcasieu River AOC** – Samples were collected from a total of 155 locations to support an assessment of the risks posed to fish communities associated with exposure to water-borne and sediment-associated COPCs.
within the UCR AOC (Table 7-2). The results of this assessment indicate that exposure to surface water, whole sediments, or pore water in the UCR AOC generally posed a low risk to benthic and pelagic fish (i.e., average of the final risk scores of 0.85; n=155). Eighty-two percent (127 of 155) of the sediment samples from this AOC had low final risk scores (i.e., < 2; Table 7-2). Nevertheless, indeterminate (5%; 7 of 155) or high (14%; 21 of 155) risks to fish were indicated for 18% of the sediment samples (i.e., 28 of 155) from the UCR AOC. Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where exposure to surface water or surficial sediments (including pore water) posed the highest risks (i.e., relative to the survival, growth, or reproduction of fish) included the Calcasieu River downstream of Lake Charles, the Clooney Island barge slip, the northern and eastern portion of the Clooney Island Loop, and the northern and central portions of Coon Island Loop (Figure 7-1). Although few data were available to conduct the assessment, it appears that the highest risks to fish (i.e., if deeper sediments were exposed) exist in the northern and west-central portions of the Coon Island Loop (Figure 7-2).

**Bayou d’Inde AOC** – Samples were collected from a total of 316 locations to support an assessment of the risks posed to fish communities associated with exposure to water-borne and sediment-associated COPCs within the BI AOC. The results of this assessment indicate that exposure to surface water, whole sediments, or pore water in the BI AOC generally posed a high risk to fish (i.e., average of the final risk scores of 2.79; n=316). Roughly 32% (101 of 316) of the sediment samples from this AOC had low final risk scores (i.e., < 2; Table 7-2). However, indeterminate (7%; 21 of 316) or high (61%; 194 of 316) risks to fish were indicated for 68% of the sediment samples (i.e., 215
of 316) from the BI AOC. Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where exposure to surface water or surficial sediments (including pore water) posed the highest risks (i.e., relative to the survival, growth, or reproduction of fish) included upper Bayou d’Inde from the CitCon property to the Highway 108 bridge, the off-channel wetland areas and mainstem of throughout middle Bayou d’Inde, the central portions of Lockport Marsh, the northern portion of the wetland areas located east of lower Bayou d’Inde, and lower Bayou d’Inde mainstem (Figure 7-3). Although few data were available to conduct the assessment, it appears that the highest risks to fish (i.e., if deeper sediments were exposed) exist immediately downstream of the CitCon property, Maple Fork, the lower portion of middle Bayou d’Inde, and lower Bayou d’Inde mainstem (Figure 7-4).

**Middle Calcasieu River AOC** – Samples were collected at a total of 163 locations to support an assessment of the risks posed to the fish community associated with exposure to water-borne and sediment-associated COPCs within the MCR AOC. The results of this assessment indicate that exposure to surface water, whole sediments, or pore water in the MCR AOC generally posed a low risk to fish (i.e., average of the final risk scores of 0.70; n=163). Eighty-five percent of the sediment samples (139 of 163) from this AOC had low final risk scores (i.e., < 2; Table 7-2). Nevertheless, indeterminate (3%; 5 of 163) or high (12%; 19 of 163) risks to fish were indicated for 15% of the sediment samples (i.e., 24 of 163) from the MCR AOC. Consistent with the results of the preliminary analysis of the areal extent of effects, the locations where exposure to surface water or surficial sediments (including pore water) posed the highest risks (i.e., relative to the survival, growth, or reproduction of fish) included the middle Calcasieu River adjacent to the Citgo and W.R.
Grace properties, Indian Wells Lagoon, western portion of Prien Lake, and the central and southern portions of Moss Lake (Figures 7-5 and 7-6). Although few data were available to conduct the assessment, it appears that the highest risks to fish (i.e., if deeper sediments were exposed) exist in Indian Wells Lagoon (Figure 7-7). The risks to fish associated with exposure to surface water, whole sediment, or pore water were classified as low throughout the reference areas (Table 7-2; Figure 7-8).

The results of a companion assessment indicates that the accumulation of total PCBs in fish tissues (i.e., whole body burden; a measure of all exposure pathways) is unlikely adversely affect the survival, growth, or reproduction of carnivorous fish in the UCR AOC (Figure 7-9), the BI AOC (Figure 7-10), or the MCR AOC (Figure 7-11). Therefore, exposure to total PCBs is considered to pose low risks to carnivorous fish in the Calcasieu Estuary. Insufficient information was available for any of the three AOCs to assess the risks posed to carnivorous fish associated with the accumulation of PCDDs, PCDFs, and dioxin-like PCBs in their tissues (Appendix F2).

### 7.3 Summary and Conclusions

The risks to fish communities posed by exposure to surface water, whole sediments, and pore water, and all exposure routes combined were assessed in the Calcasieu Estuary. In total, information on four lines of evidence was used to determine if the survival, growth, or reproduction of fish was being adversely affected or was likely to be adversely affected by exposure to COPCs in surface water or sediments in the
The Calcasieu Estuary relative to reference conditions. The four lines of evidence that were considered in the assessment included surface-water chemistry, pore-water chemistry, whole-sediment chemistry, and pore-water toxicity. In addition, tissue chemistry (i.e., whole body burdens) was also used to assess the effects of bioaccumulative COPCs (i.e., total PCBs) that accumulate in fish tissues from all exposure routes.

The results of this BERA indicated that exposure to surface water, whole sediments, or pore water from the Calcasieu Estuary generally poses low risks to fish communities (i.e., risks were classified as low for 58% of the 634 locations sampled within the three AOCs investigated). However, indeterminate and high risks to the fish community were indicated for 5% (33 of 634) and 37% (234 of 634) of these locations, respectively (Table 7-2). Of the three AOCs considered, the risks to the fish community were highest in Bayou d’Inde. Within this AOC, conditions in the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, the central portions of Lockport Marsh, and lower Bayou d’Inde mainstem posed the highest risks. Although risks to the fish community were generally lower in the UCR AOC and MCR AOC, conditions posing high risk were present in portions of Clooney Island Loop, portions of Coon Island Loop, the middle Calcasieu River in the vicinity of the Citgo and W.R. Grace properties, Indian Wells Lagoon, Prien Lake, and Moss Lake (Table 7-2; Figures 7-1 to 7-7). Risks to the fish community are generally low throughout the reference areas (Figure 7-8). The survival of larval redfish was similar among the locations that were classified as posing low or indeterminate risks (Table 7-3).

Of the exposure routes examined, exposure to COPCs in whole sediments and pore water represents the most important routes for benthic and pelagic fish. Accordingly, the fish that are closely associated with sediments, such as flounder (i.e., benthic species), are the most likely to be adversely affected by COPCs in the Calcasieu Estuary BERA.
Estuary. As risks to carnivorous fish associated with the accumulation of total PCBs in their tissues are considered to be low, dietary exposure to certain COPCs may be of lesser importance.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the fish community in the Calcasieu Estuary. More specifically, the COCs that were considered to include:

- Hydrogen sulfide;
- Metals (chromium, copper, lead, mercury, nickel, and zinc);
- PAHs (2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, pyrene, total HMW-PAHs, and total PAHs);
- PCBs (total PCBs);
- Organochlorine pesticides (dieldrin); and,
- PCDDs and PCDFs (total 2,3,7,8-TCDD TEQs).

All of these substances occurred in surface-water, whole-sediment, or pore-water samples at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. The results of toxicity identification evaluations conducted with pore water from Calcasieu Estuary sediment samples indicate that non-polar organics and metals substantially contributed to acute toxicity to marine amphipods, *Ampelisca abdita*, in 96-h toxicity tests (SAIC 2002). Therefore, these groups substances are bioavailable in the Calcasieu Estuary. Hence,
the COCs identified above should be considered to be the highest priority for developing preliminary remediation goals.
Chapter 8. Assessment of Risks to Aquatic-Dependent Avian Communities in the Calcasieu Estuary

Summary: This chapter provides a summary of the information presented in Appendices H1 to H3. It integrates the assessment of risks posed by substances in the Calcasieu Estuary to sediment-probing birds, carnivorous-wading birds, and piscivorus birds. Prior to completing this assessment, a conservative, deterministic screening ecological risk assessment (ERA) identified areas of concern (AOCs) and contaminants of concern (COCs) in the Calcasieu Estuary (Appendix G). The COCs identified in the deterministic assessment for birds included tetrachlorodibenzo-\(p\)-dioxin and equivalents (TCDD-TEQs), selenium, mercury, total polychlorinated biphenyls (PCBs), and lead.

Receptors of concern are identified for each group of aquatic-dependent birds. The life history and foraging behaviors of the receptors of concern are blended, creating hypothetical receptors possessing qualities characteristic of each bird group (e.g., sediment-probing birds, carnivorous-wading birds, and piscivorus birds). In addition to the average-sized hypothetical receptor, a small hypothetical receptor is created to account for the higher metabolic rate, and therefore, higher exposure of smaller birds. Information on life history of the hypothetical receptors, AOCs, and COCs is used to create a conceptual model. This model illustrates the relationship between the sources of COCs, their fate and transport, and the pathways through which they come into contact with aquatic-dependent birds.

Assessment endpoints are selected to focus the assessment of risks posed by COCs to aquatic-dependent birds on specific processes of environmental value. The assessment endpoint for this ERA is the survival, growth, and reproduction of aquatic-dependent birds. Measurement endpoints are chosen to provide measurable ecological characteristics for the assessment endpoint. The potential for adverse effects to aquatic-dependent birds are evaluated by comparing COC levels in prey-tissue and sediment to the results of
laboratory toxicity studies. Once the assessment and measurement endpoints, and the conceptual model are determined, a risk hypothesis is created to identify the key stressor-effect relationships to be evaluated in the probabilistic risk assessment. The risk hypothesis evaluated in this chapter is that concentrations of COCs in the Calcasieu Estuary will cause adverse effects to aquatic-dependent birds. To test this hypothesis the following risk questions must be answered: (1) are the levels of COCs in the tissues of prey species of aquatic-dependent birds in the Calcasieu Estuary sufficiently high that the effects benchmark values for survival, growth, reproduction are exceeded; and, (2) if yes, what are the probabilities of effects of differing magnitude for survival, growth, and/or reproduction of aquatic-dependent birds?

The probabilistic risk assessment is carried out in four steps: (1) collection, evaluation, and compilation of data; (2) exposure assessment; (3) effects assessment; and, (4) risk characterization. In the first step, relevant data on COC concentrations in prey items and sediments from the Calcasieu Estuary are collected, evaluated, and compiled. These data are then incorporated into an exposure model calculating total daily intake of COCs for each group of aquatic-dependent birds. Monte Carlo analysis is applied to this model to account for the range of possible exposures. The effects characterization provides a review of the literature on effects of COCs on the survival, growth, and reproduction of aquatic-dependent birds. An appropriate effects metric is selected for each COC to be used with the results of the exposure assessment to estimate risks. The effects metrics in this assessment are expressed as a threshold range spanning sensitive and tolerant species. This range is likely to include the threshold for the receptor groups of interest. Finally, risk characterization integrates the results of the exposure and effects characterizations to estimate risks of each COC to each aquatic-dependent bird group in each AOC.

Ideally, risk characterization would use three lines of evidence to estimate risks: comparison of modeled exposure to lab-derived effects metrics, in situ or whole-media toxicity tests, and biological surveys. In this assessment, the
latter two lines of evidence are not available. High, indeterminate, and low risk categories are used to express the level of risk to each group of aquatic-dependent birds. The risks for each AOC and COC are discussed in the results section.

The results of the assessment for aquatic-dependent birds indicate that there is a high risk that small hypothetical sediment-probing birds will be adversely affected by exposure to selenium in the Middle Calcasieu River. The risk of adverse effects are indeterminate for average-sized and small sediment-probing birds, carnivorous-wading birds, and piscivorus birds exposed to, lead, TCDD-TEQs in all AOCs, and selenium in AOCs other than the Middle Calcasieu River. Mercury poses a low risk to average-sized and small sediment-probing birds, carnivorous-wading birds, and piscivorus birds, except for Bayou d’Inde where it poses indeterminate risks to small piscivorus birds.

8.0 Introduction

There are concerns that chemical levels in the Calcasieu Estuary are adversely affecting aquatic-dependent bird species inhabiting and foraging in the area. These species can be classified, based on their feeding habits, into three main groups: sediment-probing birds (i.e., species that eat benthic macroinvertebrates), carnivorous-wading birds (i.e., species that eat various types of aquatic organisms, including invertebrates, small fish, reptiles, and amphibians), and piscivorus birds (i.e., species that eat fish). These groups of aquatic-dependent birds have been included in the ERA of the Calcasieu Estuary.
The current section summarizes the results of the conservative, deterministic ERA, including a description of the AOCs and COCs described in detail in Appendix G. Other methods discussed here include the creation of hypothetical receptors for each group of aquatic-dependent birds, the creation of a conceptual model, the selection of assessment and measurement endpoints, and the establishment of a risk hypothesis and risk questions. Section 8.1 describes the probabilistic risk assessment methods used to estimate risks of COCs to sediment-probing birds, carnivorous-wading birds, and piscivorous birds in the Calcasieu Estuary AOCs. Section 8.2 discusses the results of the probabilistic risk assessment. Section 8.3 identifies the sources of uncertainty and the influence they may have on estimates of risk to aquatic-dependent birds. Finally, Section 8.4 summarizes the risks that COCs pose to sediment-probing birds, carnivorous-wading birds, and piscivorous birds in the Calcasieu Estuary.

8.0.1 Deterministic Ecological Risk Assessment

The methods and results of the deterministic ERA are presented in detail in Appendix G. In summary, the deterministic assessment used a conservative approach to estimate risks to sediment-probing birds, carnivorous-wading birds, and piscivorous birds posed by COCs in the Upper Calcasieu River AOC (UCR AOC), Bayou d’Inde AOC (BI AOC), and Middle Calcasieu River AOCs (MCR AOC) of the Calcasieu Estuary system. Several reference areas, including Bayou Connine Bois and Choupique Bayou, were also included in the deterministic assessment to provide a basis for comparison of risks. The deterministic assessment compared potentially attainable high exposures with conservative adverse effects benchmarks to provide a means of identifying which substances are a potential concern to aquatic-dependent birds and in which areas of the Calcasieu Estuary system. A risk quotient (total daily
intake/effects benchmark) for sediment-probing birds, carnivorous-wading birds, and piscivorous birds greater than one, and greater than 1.2 times the risk quotient for the reference areas, for any COC in any of the Calcasieu areas, resulted in the COC being screened through to the probabilistic ERA (i.e., being identified as a COC). Tetrachlorodibenzo-p-dioxin and equivalents (TCDD-TEQs), selenium, mercury, and lead screened through to the probabilistic risk assessment for sediment-probing birds. TCDD-TEQs and mercury screened through to the probabilistic risk assessment for carnivorous-wading birds. TCDD-TEQs, selenium, mercury, and total PCBs screened through to the probabilistic risk assessment for piscivorus birds. The COCs that were identified for each AOC are presented in Table 8-1. The reference areas were also included in the probabilistic risk assessment so that risks in the AOCs could be compared to background risks.

8.0.2 Contaminants of Concern

TCDD-TEQs represent a group of aromatic compounds with similar properties (WHO 1989a). The term equivalents refers to a specific group of polychlorinated dibenzo-p-dioxins (PCDDs) congeners, polychlorinated dibenzofurans (PCDFs) congeners, and PCB congeners with similar chemical structures. The majority of these congeners have low solubility, low vapor pressure, and high resistance to chemical breakdown, and are, therefore, highly persistent in the environment. They are also highly lipophilic with a high propensity to bind to organic and particulate matter. Predatory organisms can be exposed to TCDD-TEQs through trophic transfer. PCDDs, PCDFs, and PCB congeners are highly bioaccumulative substances that increase in concentration as they transfer up the food chain (i.e., through biomagnification).
Elemental selenium is insoluble in water and will remain inert when released in the environment under anaerobic conditions. Heavy metal selenides and selenium sulfides predominate in acidic soils and soils with high organic matter, and will remain insoluble and immobile in this form (NAS 1976). Selenites and selenates are water soluble and are, therefore, more bioavailable in surface water and groundwater contained in soils (Eisler 2000a; ATSDR 1996; Robberecht and Van Grieken 1982). Selenium bioconcentrates and biomagnifies in aquatic food chains from invertebrates to birds (Ohlendorf et al. 1986a; 1986b; Lemly 1985; Saiki and Lowe 1987; Saiki et al. 1993). Lemly (1985) reported bioconcentration factors ranging from 1,500 to 1,850 and bioaccumulation factors from 1,746 to 3,975 for selenium in freshwater species. Thus, selenium has the potential to biomagnify in aquatic-dependent birds.

Mercury is typically reported as either total mercury or methylmercury. This assessment focuses on methylmercury, because it is the most toxic form. Methylmercury is highly soluble in water, extremely mobile, and thus, readily enters the aquatic food web (USEPA 1997c). Because methylation is higher under anaerobic conditions, benthic organisms in the anaerobic zones of sediment may be exposed to high methylmercury concentrations. These organisms are consumed by a variety of species, including aquatic-dependent birds, leading to biomagnification up the food chain. The accumulation of methylmercury in aquatic organisms has been well documented, with concentrations in carnivorous fish being 10,000 to more than 1,000,000 times the concentrations found in ambient waters (Stein et al. 1996). Gilmour and Henry (1991) showed that fish from contaminated systems may continue to contain high levels of methylmercury long after inputs to the systems have ceased. Also, the efficient assimilation of the lipophilic methylmercury in fat and muscle and
the lack of elimination results in increasing methylmercury concentrations with the age and size of fish and wildlife predators.

Total PCBs is the generic term applied to a mixture of 209 chlorinated organic compounds (congeners) that have similar molecular structures and properties. PCB congeners generally have low solubilities, low vapor pressure, and high resistance to chemical breakdown. PCBs are persistent and highly lipophilic substances with low water solubility and a high propensity to bind to organic and particulate matter. PCBs are highly bioaccumulative and increase in concentration as they transfer up the food chain. In consequence, sediment-probing birds, carnivorous-wading birds, and piscivorus birds that reside, or partially reside, within the Calcasieu Estuary are exposed to PCBs principally through diet and trophic transfer, and may accumulate high levels of PCBs.

Lead and its salts are generally poorly soluble in water and tend to partition into sediment as organic complexes (WHO 1989a). As such, lead bioavailability in natural systems is limited and almost all of the lead is tightly bound to sediment. Consumers may take up large quantities of lead via their food, but the ingested metal might not be fully bioavailable and, therefore, exposure will be low. In aquatic systems, lead is taken up by primary producers and consumers at a rate strongly controlled by the bioavailability of lead. Uptake by aquatic organisms is also controlled by temperature, salinity, pH, humic acid levels, and alginic acid concentrations (WHO 1989a). This assessment focuses on the risks posed by lead to sediment-probing birds, because lead can be toxic when large quantities in sediment are directly ingested.
8.0.3 Receptors of Concern

**Sediment-Probing Birds**
The exposure assessment for sediment-probing birds will be based on a hypothetical receptor that incorporates the characteristics typical of this receptor group. The hypothetical receptor is based on three species of aquatic-dependent birds potentially found in the Calcasieu Estuary: willets, black-necked stilts, and spotted sandpipers.

**Carnivorous-Wading Birds**
The exposure assessment for carnivorous-wading birds will be based on a hypothetical receptor that incorporates the characteristics typical of this receptor group. The hypothetical receptor is based on four species of aquatic-dependent birds potentially found in the Calcasieu Estuary: great blue herons, great egrets, white ibis, and roseate spoonbills.

**Piscivorus Birds**
The exposure assessment for piscivorus birds will be based on a hypothetical receptor that incorporates the characteristics typical of this receptor group. The hypothetical receptor is based on six species of aquatic-dependent birds potentially found in the Calcasieu Estuary: Brown pelicans, belted kingfishers, osprey, least terns, Forster’s terns, and Caspian terns.

The hypothetical receptors for each group of aquatic-dependent birds possess the following qualities:
• The average-sized receptor’s weight is derived from the average of the focal species in the respective group. A 15% coefficient of variation (CV) for body weight is assumed. This value is a typical coefficient of variation found in wild birds. A “what if” scenario is also considered, where the body weight is set to that of the smallest receptor in each group (e.g., spotted sandpiper, white ibis, least tern). These species are considered to have the greatest potential for exposure, because of their higher metabolic and food ingestion rates;

• The hypothetical receptors are assumed to have a foraging range within either UCR AOC, BI AOC, MCR AOC, or;

• The hypothetical receptors are year-round inhabitants in each of the Calcasieu Estuary areas and the temporal scale of the assessment is long term, because: (1) chemical levels are likely to exhibit low temporal variability, because of their high persistence; and, (2) chronic toxicity typically occurs at much lower levels than acute toxicity; and,

• The diet of the hypothetical sediment-probing bird is assumed to consist entirely of small invertebrates. It is assumed that the hypothetical carnivorous and piscivorous birds forage entirely on fish.

8.0.4 Conceptual Model

The conceptual model provides a visual representation of the relationships between sources of COCs, their fate and transport, and the pathways through which COCs reach aquatic-dependent birds. This model improves one’s understanding of the
relationship between human activities and ecological receptors in the Calcasieu Estuary.

Aquatic-dependent birds are exposed to a number of COCs in the Calcasieu Estuary system. The deterministic assessment (Appendix G) identified those that pose potential risks to these animals. Specifically, sediment-probing birds are at risk from TCDD-TEQs, selenium, lead, and mercury; carnivorous-wading birds are at risk from TCDD-TEQs and mercury; and piscivorus birds are at risk from TCDD-TEQs, selenium, mercury, and total PCBs. These substances are persistent and bioaccumulative and are primarily available for uptake through the food chain. The Phase II sampling program provided data identifying substantial tissue residues of these substances in invertebrates and fish, which are the prey item for aquatic-dependent birds. Other routes of exposure, including inhalation, water consumption, and sediment ingestion have been excluded from the assessment of carnivorous-wading and piscivorus birds as their contribution to overall exposure is likely negligible. Sediment concentrations of COCs are considered in the assessment of sediment-probing birds.

### 8.0.5 Assessment Endpoint

An assessment endpoint is an ‘explicit expression of the environmental value that is to be protected’ (USEPA 1997c). Aquatic-dependent bird species are integrally linked to aquatic ecosystems as a result of their reliance on aquatic organisms for food. Therefore, it is important to evaluate the effects of environmental substances on this group of ecological receptors. COCs bioaccumulate in prey items and biomagnify up the food chain. Aquatic-dependent birds are exposed to these COCs
through the consumption of contaminated prey items, and as a result, are at risk of high exposures and toxicity to adverse effects from these substances. The assessment endpoint for this ERA is the **survival, growth, and reproduction of aquatic-dependent birds**.

### 8.0.6 Measurement Endpoints

A measurement endpoint is defined as ‘a measurable ecological characteristic that is related to the valued characteristic selected as the assessment endpoint’ and is a measure of biological effects (e.g., mortality, reproduction, growth; USEPA 1997c). Measurement endpoints are chosen based on linkages between exposure media and receptors within the Calcasieu Estuary. This information is used to identify candidate measurement endpoints that could be used to evaluate the status of each assessment endpoint. The potential for adverse effects on sediment-probing birds was evaluated using prey-tissue and sediment residue data. Risks to carnivorous-wading and piscivorus birds were evaluated using fish tissue data. These data were compiled by geographic area within the Calcasieu Estuary, incorporated into the daily intake exposure model, and compared to appropriate toxicity values for survival, growth, and reproduction for avian species.

### 8.0.7 Risk Hypothesis and Questions

The following risk hypothesis was developed to identify the key stressor-effect relationships that will be evaluated in the probabilistic risk assessment:
Based on the physical-chemical properties (e.g., $K_{ow}$s) of the bioaccumulative contaminants of concern, the nature of the food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, TCDD-TEQs, selenium, mercury, total PCBs, and lead released into surface waters will accumulate in the tissues of aquatic organisms to levels that adversely affect the survival, growth, and/or reproduction of aquatic-dependent birds.

The key risk questions for aquatic-dependent bird species include:

• Are the levels of contaminants in the tissues of prey species of aquatic-dependent birds in the Calcasieu Estuary higher than the tissue residue benchmark values for survival, growth, or reproduction?

• If yes, what are the probabilities of effects of differing magnitude for survival, growth, and/or reproduction of aquatic-dependent birds?

The risk questions assume that aquatic-dependent birds are primarily exposed to COCs through the consumption of prey items.

### 8.1 Methods

A step-wise approach was used to assess the risks posed by COCs to aquatic-dependent birds in the Calcasieu Estuary. The steps in this process were:
• Collection, evaluation, and compilation of relevant data on the concentrations of COCs in prey items and sediment in the Calcasieu Estuary;

• Assessment of exposure of aquatic-dependent birds to COCs (Figure 8-1);

• Assessment of the effects of COCs on aquatic-dependent birds (Figure 8-2); and,

• Characterization of risks to the aquatic-dependent avian community (Figure 8-3).

8.1.1 Collection, Evaluation, and Compilation of Data

Information on substance levels in sediment and tissues of prey of aquatic-dependent bird species were collected in two phases, termed the Phase I and Phase II sampling programs. The Phase I program results indicated that the detection limits for many of the COCs in tissues were orders of magnitude above corresponding benchmarks. Therefore, the Phase I results for tissues were not considered in this assessment.

Five hundred sediment samples were collected in Phase I and 100 in Phase II. More than 600 tissue samples were collected during Phase II sampling from the three AOCs (Upper Calcasieu River, Bayou d’Inde, Middle Calcasieu River) as well as reference areas (Bayou Connine Bois, Calcasieu Lake, Choupique Bayou, Grand Bayou, and Grand Bayou and Wetlands).

Chemical analyses were conducted at various contract laboratory program (CLP) and subcontract (non-CLP) analytical laboratories. All tissue samples were analyzed for
total target analyte list (TAL) metals, target compound list (TCL) semi-volatile organic compounds (SVOCs) and TCL pesticides. All of the data sets generated during the course of the study were critically reviewed to determine their applicability to the assessment of risks to the biotic community in the Calcasieu Estuary. To support the compilation and subsequent analysis of the information on biota and sediment quality conditions in the Calcasieu Estuary, a relational project database was developed in MS Access format.

Historical data sets on total PCBs in fish tissue were examined and compared with the Phase II sampling fish tissue data to evaluate trends in risk over time. Less than one order of magnitude difference was found between ten years of historical data and data collected in the Phase II sampling program.

8.1.2 Exposure Assessment

Exposure of sediment-probing birds, carnivorous-wading birds, and piscivorus birds to TCDD-TEQs, selenium, mercury, total PCBs, and lead was estimated using a total daily intake model. The exposure model calculates the total daily intake of COCs associated with the ingestion of food, and sediments for sediment-probing birds. Aquatic-dependent birds are unlikely to use the saline waters of the estuary as a source of drinking water and the inhalation route of exposure has been shown to be an insignificant source of hydrophobic substances in previous assessments of the risks of these substances to aquatic-dependent wildlife (e.g., Moore et al. 1999).

The exposure model, adapted from USEPA (1993), is:
EQUATION #1

\[
TDI = \frac{FMR \times \left( C_i + \left( C_s \times P_s \right) \right)}{AE_i \times GE_i}
\]

where:

- \( TDI \) = total daily intake of COC (mg/kg BW/day);
- \( FMR \) = normalized free metabolic rate (Kcal/kg BW/day);
- \( C_i \) = concentration of COC in prey (mg/kg);
- \( GE_i \) = gross energy of prey (Kcal/kg prey);
- \( AE_i \) = assimilation efficiency of prey (unitless);
- \( C_s \) = concentration of COC in sediments (for sediment-probing birds only, mg/kg); and,
- \( P_s \) = proportion of sediments ingested relative to diet (for sediment-probing birds only, unitless).

This model considers the food energy needs of the receptors, the caloric values of the food items, the receptors’ ability to digest these items, the concentrations of COCs in the food items, and the proportion of the diet accounted for by that food item. The distribution of possible exposures of aquatic-dependent birds to COCs in the Calcasieu Estuary was estimated using Monte Carlo analysis. With this statistical technique, each of the input variables (e.g., COC concentrations in food) is represented as a distribution rather than a point estimate. This approach recognizes the fact that the variables in Equation 1 are subject to natural variability and that different aquatic-dependent birds have varying daily intakes. For example, birds that consume prey with varying concentrations of substances will be exposed to varying doses. The results of the Monte Carlo analysis can be used to estimate the probability of exposure exceeding an effects threshold or levels that cause adverse effects of differing magnitudes. Details on the distributions and parameters used in the exposure models for aquatic-dependent bird are presented in Tables H1-2, H2-2, and...
H3-2 of Appendices H1 to H3. A probability bounds analysis was also conducted to determine how uncertainty regarding the distributions of the input variables influenced the estimated exposure distribution.

### 8.1.3 Effects Assessment

The purpose of this section is to: (1) review the literature on the effects of TCDD-TEQs, selenium, mercury, total PCBs, and lead to aquatic-dependent birds; and, (2) select the appropriate effects metric for each COC to be used with the results of the exposure assessment to estimate risk. The characterization focuses on ecologically relevant effects endpoints such as survival, growth, and reproduction. Because the toxicological information is limited for most aquatic-dependent bird species, data from other bird studies are discussed where appropriate. This section briefly describes the characteristics and effects associated with each COC. Complete effects characterizations are provided in Appendices H1 to H3. Additional information on the toxicity of these COCs to wildlife is also found in Appendices 5 and 10 of the problem formulation document (MacDonald et al. 2001).

Effects data can be characterized and summarized in a variety of ways ranging from benchmarks designed to be protective of most or all species to dose-response curves for the receptor group of interest (e.g., piscivorus birds). In this assessment, effects characterization preferentially relies on dose-response curves, but defaults to benchmarks or other estimates of effect [e.g., no observed adverse effect level (NOAEL), lowest observed adverse effect level (LOAEL)] when insufficient data are available to derive dose-response curves or when assessing risk in a screening-level deterministic risk assessment.
Tetrachlorodibenzo-\(p\)-dioxin and Equivalents

The common characteristic of TCDD-TEQs is their ability to bind to the aryl-hydrocarbon (Ah) receptor, eliciting an Ah receptor-mediated biochemical and toxic response. The TCDD-TEQs approach relates the toxicity of specific PCB, PCDD, and PCDF congeners to that of 2,3,7,8-TCDD, the most toxic congener. Adverse effects caused by exposure to TCDD-TEQs include loss of body weight, impaired growth, and death (Tillitt et al. 1996; Heaton et al. 1995). Effects to reproduction also occur due to, for example, reductions in egg production and embryo mortality. The effects metric for this group of substances is represented by a threshold range. The lower and upper toxicity thresholds for aquatic-dependent birds are the fecundity of ring-necked pheasants (Nosek et al. 1992) and American kestrels (Hoffman et al. 1996a).

Selenium

Selenium is an element required by birds and wildlife for good health. However, the range in concentration from healthy to toxic levels is very narrow (Heinz 1996). In nature, birds are exposed to different forms of selenium, each with varying degrees of accumulation and toxicity. Inorganic forms of selenium, such as selenite and selenate, are toxic to birds, but not to the same extent as organic selenides. Of these, selenomethionine is considered to be the most toxic and the most likely to harm birds (Heinz 1996). Symptoms of selenium toxicity (selenosis) include decreased body weight and emaciation, hepatotoxicity, histologic lesions, and reproductive effects (Heinz 1996; Eisler 2000a). The toxicity of different forms of selenium to birds has received little attention in laboratory studies and there is still much to be learned about its toxicity. The effects metric for this substance is represented by a threshold range. The lower
toxicity threshold for aquatic-dependent birds is the fecundity of mallard ducks (Heinz et al. 1989). The upper toxicity threshold is the fecundity of black-crowned night herons and eastern screech owls (Wiemeyer and Hoffman 1996; Smith et al. 1988).

Methylmercury
Methylmercury is a strong nervous system toxicant. Its ability to cross the blood brain barrier results in brain lesions, damage to the central nervous system, and spinal cord degeneration (Wolfe et al. 1998). Methylmercury (MeHg) is absorbed into the bloodstream and transported to tissues and organs throughout the body (USEPA 1997c). As a result, neurological disorders, damage to organs, and effects on growth and development are the characteristic effects of MeHg poisoning. Clinical symptoms of acute poisoning include ataxia, tremors, weakness in legs and wings, muscular incoordination, paralysis, recumbency, and convulsions (USEPA 1997c; Wolfe et al. 1998; Eisler 2000a). Adverse effects also occur from chronic exposure to low concentrations of MeHg. The effects metric for this substance is represented by a threshold range. The lower and upper toxicity thresholds for aquatic-dependent birds are the fecundity of mallard ducks (Heinz 1974; 1979; Heinz and Locke1975) and the survival of red-tailed hawks (Fimreite and Karstad 1971).

Total Polychlorinated Biphenyls
Commercial PCB mixtures elicit a variety of toxic effects, but some specific coplanar PCB congeners cause toxic responses through the induction of mixed function oxidase enzymes, such as aryl hydrocarbon hydroxylase (AHH) and 7-
ethoxyresorufin-O-deethylase (EROD; Powell et al. 1997; Metcalfe and Haffner 1995). The effects range from decreased body weight to reproductive impairment and mortality (CCME 1999b). Aquatic-dependent birds are exposed to PCBs primarily through the consumption of prey that have accumulated these substances. Birds have been shown to efficiently absorb PCBs from feed (Drouillard and Norstrom 2000; Drouillard and Norstrom 2001; Drouillard et al. 2001) and PCBs are transferred from adult females to eggs at predictable rates (Bargar et al. 2001). Froese et al. (1998) and Secord et al. (1999) studied the accumulation of PCBs in tree swallow eggs and nestlings from prey. Custer et al. (1997; 1999) and Larson et al. (1996) reported chemical concentrations in cormorant eggs and embryos. These studies and others (e.g., Environment Canada 1998; Hoffman et al. 1996b, Eisler and Belisle 1996) have shown that PCBs accumulate in a variety of avian species to concentrations that may cause adverse effects. The effects metric for this group of substances is represented by a threshold range. The lower and upper toxicity thresholds for aquatic-dependent birds are the fecundity of white leghorn chickens (Lillie et al. 1974) and American kestrels (Fernie et al. 2001).

**Lead**

Inorganic lead is toxic to a broad range of organs and tissues due to its activity as a metabolic poison (Kendall et al. 1996). Lead alters the biological function of various enzymes (lead displaces essential metals from enzyme proteins) and this has the effect of producing severe degeneration in the central nervous system, blood production (inhibits iron activity), and kidney activity (Kendall et al. 1996). Lead also exhibits adverse effects on reproduction including premature abortions and mortality of neonates. Effects on the immune system include increased
susceptibility of exposed animals to bacterial and viral infections (Kendall et al. 1996). Chronic exposure to lead is often associated with loss of body weight, behavioral changes, and partial paralysis (Sanderson and Belrose 1986; Heitmeyer et al. 1993).

Metallic lead is toxic to birds when administered as a powder or as lead shot. Lead shot is retained in the gizzard where it is quickly ground down to lead powder. The rate of pellet erosion is very rapid. As much as 70% of the lead contained in pellets is lost within the first five days in the gizzard. Pellets disappear completely within 35 days (Cook and Trainer 1966). Some birds are sensitive and one ingested pellet is sufficient to cause mortality (WHO 1989a).

8.1.4 Risk Characterization

In the risk characterization phase of the probabilistic risk assessment (PRA), the results of the exposure assessment (i.e., reverse cumulative distribution functions) and effects measures are integrated to develop risk estimates for each COC and AOC. Ideally, risk characterization involves three major lines of evidence: comparison of modeled exposure to lab-derived effects metrics, in situ or whole-media toxicity tests, and biological surveys. For aquatic-dependent birds, however, the latter two lines of evidence were not available. Therefore, estimates of risk were generated from the comparison of modeled exposure to effects thresholds derived from laboratory studies.
For the AOCs of the Calcasieu Estuary, a low, indeterminate, and high category of risk was determined for birds. These categories of risk were derived using the following guidance:

- If the probability of exceeding the lower toxicity threshold is less than 20%, the risk to aquatic-dependent birds is considered low;
- If the probability of exceeding the upper toxicity threshold is greater than 20%, the risk to aquatic-dependent birds is considered high; and,
- All other probabilities are considered to have indeterminate risk.

Tables 8-2, 8-3, and 8-4 illustrate the results discussed below. The results of the probability bounds analyses are not discussed here. For information on these results, refer to Appendices H1 to H3.

### 8.2 Results and Discussion

#### 8.2.1 Sediment-Probing Birds

There is a 49% probability of exceeding the lower toxicity threshold for small sediment-probing birds exposed to selenium in the MCR AOC and a 0% probability of exceeding the upper toxicity threshold. As a result, selenium poses indeterminate risks to small sediment-probing birds in the MCR AOC. In comparison, there is a 23% probability of exceeding the lower toxicity threshold for average-sized sediment-probing birds exposed to selenium in the MCR AOC and a 0% likelihood of
exceeding the upper toxicity threshold. Therefore, selenium poses indeterminate risks to average-sized sediment-probing birds in the MCR AOC. Figures 8-4 and 8-5 show the estimates of risk and upper and lower toxicity threshold exceedance probabilities for small and average-sized sediment-probing birds in the MCR AOC. The risks from exposure to selenium for average-sized sediment-probing birds are low in UCR AOC, BI AOC and the reference areas. The risks from exposure to selenium for small sediment-probing birds are indeterminate in the UCR AOC and low in BI AOC and the reference areas.

TCDD-TEQs pose low risks to average-sized and small sediment-probing birds in BI AOC, UCR AOC, and the reference areas. Both average-sized and small sediment-probing birds are at low risk of mercury toxicity in all AOCs and reference areas. Risks from exposure to lead are indeterminate for average-sized and small sediment-probing birds in all AOCs and reference areas (Table 8-2).

### 8.2.2 Carnivorous-Wading Birds

There is a low risk that average-sized and small carnivorous-wading birds foraging in BI AOC and the reference areas will be adversely effected by TCDD-TEQs. The risk of adverse effects from mercury appear low in all AOCs for both average-sized and small carnivorous-wading birds (Table 8-3).

### 8.2.3 Piscivorus Birds

There is an indeterminate risk for average-sized piscivorus birds exposed to TCDD-TEQs in BI AOC; the risk of TCDD-TEQs is low in the MCR AOC and reference
areas. The risks are indeterminate for small piscivorus birds exposed to TCDD-TEQs in BI AOC, MCR AOC, and the reference areas.

There is a low risk that average-sized piscivorus birds will be adversely affected by selenium toxicity in either BI AOC or the reference areas. The risk of selenium toxicity to small piscivorus birds inhabiting these areas is indeterminate.

Average-sized piscivorus birds inhabiting UCR AOC, BI AOC, MCR AOC, and the reference areas are at low risk of adverse effects from mercury toxicity. Small piscivorus birds are at indeterminate risk to mercury toxicity in BI AOC and low risk in UCR AOC, MCR AOC, and the reference areas.

Total PCBs pose a low risk to average-sized piscivorus birds in BI AOC and the reference areas. Risks to small piscivorus birds are indeterminate in BI AOC and low in the reference areas.

**8.3 Sources of Uncertainty**

There are a number of sources of uncertainty in the assessment of risk to aquatic-dependent birds. They include uncertainties in the conceptual model as well as in the exposure, effects, and risk assessments. As each of these sources of uncertainty can influence the estimates of risk, it is important to describe and, when possible, quantify the magnitude and the direction of these uncertainties. In this way, it is possible to evaluate the level of confidence that can be placed in the assessments conducted. The major sources of uncertainty are as follows.
According to the Monte Carlo sensitivity analyses, the FMR slope and power terms were among the most influential variables driving the predicted intake rates. Unfortunately, a precise estimate of the FMR was not possible, as measured metabolic rates for piscivorus birds used in this assessment were not available in the literature. Instead, the FMR for piscivorus birds was estimated using allometric equations. This introduced some degree of uncertainty into the exposure estimates because the allometric relationships were not only associated with some fitting error, but also were based on many bird species, some of which were very different from those represented here. However, given the lack of empirical data on species specific to the current assessment, it is difficult to judge the magnitude of the uncertainty introduced by the use of the allometric model rather than empirical data.

Other sensitive variables that influenced the exposure estimates included the gross energy of food and the food assimilation efficiency. These variables were also somewhat uncertain because no feeding studies were specifically performed in the Calcasieu Estuary on the species of interest. Rather, diet compositions were matched to those reported in the literature from birds raised in a laboratory or collected from other geographical locations. In consequence, the quantification of food gross energy and assimilation efficiency was limited to the fish food group, without considering specific fish species. Some of the COC concentrations from the AOCs were derived from small sample sizes. This was a major source of uncertainty in the exposure assessment.

The Monte Carlo analysis also identified the concentrations of substances in prey species as one of the sensitive variables. However, the level of uncertainty associated with this parameter is relatively low because Calcasieu-specific fish and invertebrate species were used in our exposure analysis and chemical levels were detected using
acceptable analytical techniques. It is unlikely that further sampling would substantially reduce the associated uncertainty, which is likely attributable to natural variability.

The effects analyses had several key sources of uncertainty. Insufficient data were available to create dose-response relationships for key species. As a result, toxicity thresholds were developed. This method tends to be conservative, as well as variable in nature due to the varying laboratory conditions and experimental designs. This variability was often expressed as somewhat wide intervals between the lower and upper toxicity thresholds encountered in many of the effects metrics.

Toxicity data were lacking for species specific to the assessment, so toxicity data for surrogate species were used instead. This added another degree of uncertainty because it is not known whether laboratory raised and tested birds have the same sensitivity as birds living in the wild.

The combined sources of uncertainty in the exposure and effect assessments had the ultimate effect of causing somewhat wide risk prediction intervals in the probability bounds analyses (see Appendix H1 to H3). For additional details on sources of uncertainty, the reader is referred to Appendices H1 to H3.

### 8.4 Conclusions

None of the AOCs had COC levels that pose a high risk to average-sized or small sediment-probing birds. Indeterminate risks were found for average-sized sediment-
probing birds exposed to selenium in MCR AOC. Low risks were found for average-sized sediment-probing birds exposed to selenium in UCR AOC, BI AOC, and the reference areas. Indeterminate risks were found for small sediment-probing birds exposed to selenium in UCR AOC and MCR AOC; low risks were reported in BI AOC and the reference areas. Indeterminate risks were found for average-sized and small sediment-probing birds exposed to lead in the AOCs. Both mercury and TCDD-TEQs pose low risks to average-sized and small sediment-probing birds in the AOCs.

None of the AOCs had COC levels that pose a high risk to average-sized or small carnivorous-wading birds. Both mercury and TCDD-TEQs pose low risks to average-sized and small carnivorous-wading birds in all AOCs.

No areas within the Calcasieu Estuary contain COCs at levels representing a high risk to the survival or reproduction of piscivorus birds. TCDD-TEQs pose indeterminate risk to average-sized piscivorus birds in BI AOC and small piscivorus birds in BI AOC, MCR AOC, and the reference areas. Selenium concentrations in BI AOC and the reference areas pose indeterminate risks to small piscivorus birds and low risks to average-sized piscivorus birds. Concentrations of mercury and total PCBs in BI AOC pose indeterminate risks to small piscivorus birds. The risk of adverse effects from exposure to total PCBs and mercury is considered low for average-sized and small piscivorus birds in all other areas of the Calcasieu Estuary.

Accordingly, selenium, TCDD-TEQs, mercury, total PCBs, and lead were identified as COCs in the Calcasieu Estuary for aquatic-dependent birds.
Chapter 9. Assessment of Risks to Mammalian Communities in the Calcasieu Estuary

Summary: This chapter provides a summary of the information presented in Appendices I1 and I2. The purpose of the chapter is to summarize the assessment of risks posed by substances in the Calcasieu Estuary to piscivorus and omnivorous mammals. A conservative, deterministic ecological risk assessment (ERA) identified areas of concern (AOCs) and contaminants of concern (COCs) in the Calcasieu Estuary. The COCs identified in the deterministic assessment included tetrachlorodibenzo-p-dioxin and equivalents (TCDD-TEQs), selenium, mercury, and total polychlorinated biphenyls (PCBs).

Receptors of concern are identified for each group of aquatic-dependent mammals. The life history and foraging behaviors of the receptors of concern are blended, creating hypothetical receptors possessing qualities characteristic of each aquatic-dependent mammal group (e.g., piscivorus and omnivorous mammals). In addition to an average-sized hypothetical receptor, a small hypothetical receptor is created to account for the higher metabolic rate, and therefore higher exposure, of smaller mammals. Information on the life history of hypothetical receptors, AOCs, and COCs is used to create a conceptual model. This model illustrates the relationship between the sources of COCs, their fate and transport, and the pathways through which they come into contact with aquatic-dependent mammals.

Assessment endpoints are selected to focus the assessment of risks posed by COCs to aquatic-dependent mammals. The assessment endpoint for this ERA is the survival, growth, and reproduction of aquatic-dependent mammals. Measurement endpoints are then chosen to provide measurable ecological characteristics (e.g., mortality, growth, reproduction) for the assessment endpoint. The potential for adverse effects on these mammals...
are evaluated by comparing COC levels in prey-tissue data to the results of laboratory toxicity studies. Once the assessment and measurement endpoints, and the conceptual model are determined, a risk hypothesis is created to identify the key stressor-effect relationships to be evaluated in the probabilistic risk assessment. The risk hypothesis states whether concentrations of COCs in the Calcasieu Estuary are such that they will cause adverse effects to aquatic-dependent mammals. To test this hypothesis the following risk questions must be answered: (1) are the levels of COCs in the tissues of prey species of aquatic-dependent mammals in the Calcasieu Estuary sufficient to cause the effects benchmarks for survival, growth, reproduction to be exceeded; and, (2) if yes, what are the probabilities of effects of differing magnitude for survival, growth, and/or reproduction of aquatic-dependent mammals?

The probabilistic risk assessment is carried out in four steps: (1) collection, evaluation, and compilation of data; (2) exposure assessment; (3) effects assessment; and, (4) risk characterization. In the first step, relevant data on COC concentrations in prey items from the Calcasieu Estuary are collected, evaluated, and compiled. These data are then incorporated into an exposure model that calculates total daily intake of COCs for each group of aquatic-dependent mammals. Monte Carlo analysis is applied to this model to account for the distribution of possible exposures. The effects characterization reviews the literature on effects of COCs on the survival, growth, and reproduction of aquatic-dependent mammals. An appropriate effects metric is selected for each COC to be used with the results of the exposure assessment to estimate risks. The effects metrics in this assessment are expressed as effects curves for the most sensitive species and endpoint. Finally, risk characterization integrates the results of the exposure and effects assessments to estimate risks to each aquatic-dependent mammal group for each COC and AOC.

Ideally, the risk characterization uses three lines of evidence to estimate risks: comparison of modeled exposure to lab-derived effects metrics; *in situ* or whole-media toxicity tests; and biological surveys. In this assessment the
latter two lines of evidence are not available. High, indeterminate, and low risk categories are used to express the level of risk to each group of aquatic-dependent mammals. The risks for each AOC and COC are discussed in the results section.

In conclusion, the risk characterization results showed that there is a low probability that exposure to methylmercury, TCDD-TEQs and selenium will cause adverse effects to piscivorous and omnivorous mammals foraging in the Calcasieu Estuary. There is also a low probability of adverse effects to omnivorous mammals exposed to total PCBs. However, there is a high risk that total PCBs are causing adverse effects to average-sized and small piscivorous mammals inhabiting the Bayou d’Inde AOC (BI AOC) of the Calcasieu Estuary. Based on the deterministic ERA, total PCBs pose lesser risks to piscivorous mammals in other parts of the estuary.

**9.0 Introduction**

The habitat provided by the Calcasieu Estuary system is suitable for a number of aquatic-dependant mammalian species, such as mink and raccoon. Raccoons are commonly observed in the study area, and while mink have not been observed in the study area, they may be present. This is because mink are secretive and visually hard to spot (Gottschang 1981). These mammals feed on a number of aquatic organisms that accumulate substances, such as PCBs and methylmercury. Exposure to bioaccumulative substances in their diet places aquatic dependant mammals at a potential risk of adverse toxic effects.

Aquatic-dependant mammals were included in the ERA of the Calcasieu Estuary because they consume prey items that have accumulated substances and because they
represent essential components of the Calcasieu Estuary system. The purpose of this chapter is to summarize the results of the probabilistic ERA conducted for piscivorous and omnivorous mammals exposed to substances in the Calcasieu Estuary system.

This chapter is organized as follows. This section provides a brief overview of the results of the conservative, deterministic ERA for wildlife described in detail in Appendix G. The AOCs and COCs that screened through the conservative, deterministic assessment for piscivorous and omnivorous mammals are described in this section. Section 9.0 includes a description of the conceptual model for piscivorous and omnivorous mammals in the Calcasieu Estuary. Section 9.1 describes the probabilistic risk assessment methods used to estimate risks of COCs to piscivorous and omnivorous mammals in the Calcasieu AOCs. Section 9.2 describes the probabilistic risk assessment results and Section 9.3 identifies the sources of uncertainty that could influence the estimated risks for piscivorous and omnivorous mammals. The final section of this appendix, Section 9.4, contains the conclusions regarding risks of COCs to piscivorous and omnivorous mammals in the Calcasieu Estuary.

9.0.1 Deterministic Ecological Risk Assessment

The methods and results of the deterministic ERA are presented in detail in Appendix G. In summary, the deterministic assessment used a conservative approach to estimate potential risk to piscivorous and omnivorous mammals from COCs in the Upper Calcasieu River (UCR), Bayou d’Inde (BI), and Middle Calcasieu River (MCR) AOCs. Several reference sites, such as Bayou Connine and Choupique Bayou, were also included in the deterministic assessment to provide a basis of
comparison of risks. The deterministic assessment compared potentially attainable high exposures with conservative adverse effects benchmarks to identify which substances are a potential concern to piscivorus and omnivorous mammals and in which areas of the Calcasieu Estuary. A risk quotient (total daily intake/effect dose) for piscivorus and omnivorous mammals greater than one, and greater than 1.2 times the risk quotient for the reference areas, for any COC, in any of the Calcasieu areas, resulted in the substance being screened through to the probabilistic ERA. Selenium, 2,3,7,8-TCDD and equivalents (TEQs), total PCBs, and mercury were screened through to the probabilistic risk assessment phase in various AOCs. The reference areas were also screened through to the probabilistic risk assessment so that risks in the AOCs could be compared to background risks. Results of the deterministic risk assessment are presented in Table 9-1a for piscivorus mammals and Table 9-1b for omnivorous mammals.

9.0.2 Contaminants of Concern

Mercury is typically reported as either total mercury or methylmercury. This assessment focused on methylmercury because it is the most toxic form. Methylmercury is highly soluble in water, extremely mobile, and readily enters the aquatic food web. Because methylation is higher under anaerobic conditions, benthic organisms in the anaerobic zones of sediment may be exposed to high methylmercury concentrations. These organisms are consumed by a variety of species, including piscivorus and omnivorous mammals, leading to biomagnification up the food chain. The accumulation of methylmercury in aquatic organisms has been well documented, with concentrations in carnivorous fish being 10,000 to more than 1,000,000 times the concentrations found in ambient waters (Stein et al. 1996). Gilmour and Henry
(1991) showed that fish from contaminated systems may continue to contain high levels of methylmercury long after inputs to the systems have ceased. Also, the efficient assimilation of the lipophilic methylmercury in fat and muscle and the lack of elimination results in increasing methylmercury concentrations with the age and size of fish and wildlife predators.

TCDD-TEQs represent a group of aromatic compounds with similar properties (WHO 1989b). These terms refer to a specific group of polychlorinated dibenzo-\(p\)-dioxin (PCDDs) congeners, polychlorinated dibenzofurans (PCDFs) congeners and co-planar PCB congeners. Organisms may be exposed to TCDD-TEQs through trophic transfer. PCDDs, PCDFs and co-planar PCB congeners are highly bioaccumulative substances that increase in concentration as they are transferred up the food chain (i.e., through biomagnification).

Selenium bioconcentrates and biomagnifies in aquatic food chains from invertebrates to birds (Ohlendorf et al. 1986a; 1986b; Lemly 1985; Saiki and Lowe 1987; Saiki et al. 1993). Lemly (1985) reported bioconcentration factors of 1,500-1,850 and bioaccumulation factors of 1,746-3,975 for selenium in freshwater species. Concentrations of selenium in river otter and raccoon have been measured (wet weight) in various organs ranging from 0.2 to 2.8 mg Se/kg (Wren 1984). These studies demonstrate that selenium has the potential to biomagnify up the food chain and accumulate in piscivorous and omnivorous mammals.

Polychlorinated biphenyls is the generic term applied to a group of 209 chlorinated organic substances that have similar molecular structures and properties. PCBs are persistent and highly lipophilic substances. Piscivorous and omnivorous mammals in the estuary are exposed to PCBs principally through the diet and trophic transfer.
PCBs are highly bioaccumulative substances that increase in concentration as they are transferred up the food chain (Eisler and Belisle 1996; Hoffman et al. 1996).

This assessment focuses on the risks posed by mercury, selenium, total PCBs, and TCDD-TEQs to piscivorus and omnivorous mammals because these substances are readily bioaccumulated and potentially toxic to wildlife. Previous assessments of the risks of these COCs to wildlife have shown that species higher in the aquatic food chain are at particular risk of experiencing adverse effects, including reduced reproduction, impaired growth and development, and death (MacIntosh et al. 1994; USEPA 1997c; Moore et al. 1999). Piscivorus and omnivorous mammals are high in the food chain and are potentially at high risk of exposure to COCs because they consume invertebrates, fish, waterfowl eggs, and other aquatic dependant organisms (Environment Canada 2000; NSRL 2002) found in the Calcasieu Estuary system.

9.0.3 Receptors of Concern

Piscivorus Mammals
The exposure assessment for piscivorus mammals will be based on a hypothetical receptor that incorporates the characteristics typical of this receptor group. The hypothetical receptor is based on two species of aquatic-dependent piscivorus mammals potentially found in the Calcasieu Estuary: mink and river otter. These piscivores consume aquatic invertebrates and fish as parts of their diets.

Omnivorous mammals
The exposure assessment for omnivorous mammals will be based on a hypothetical receptor that incorporates the characteristics typical of this receptor
group. This hypothetical receptor is based upon characteristics of three aquatic-dependant omnivorous mammals commonly found in the Calcasieu Estuary: raccoons; muskrats; and, marsh rice rats. These omnivores consume aquatic invertebrates and fish as parts of their diets.

The hypothetical piscivorus mammal and the hypothetical omnivorous mammal have the following characteristics:

- The average-sized receptor’s weight is derived from the average of the focal species in the respective groups. An 11% and 13% coefficient of variation (CV) for body weight is assumed for piscivorus mammals and omnivorous mammals, respectively. This variation is a typical coefficient of variation found in wild mammals. A “what if” scenario was conducted to estimate risk to small piscivorus and omnivorous mammals. A 10% and 13% coefficient of variation (CV) for body weight is assumed for small piscivorus mammals and small omnivorous mammals, respectively. These species are considered to have the greatest potential for exposure because of their higher metabolic and food ingestion rates;

- The hypothetical receptors are assumed to have a relatively small foraging range with high site fidelity and no territoriality. The Upper Calcasieu River, Bayou d’Inde, and Middle Calcasieu River were identified as AOCs for piscivorus and omnivorous mammals in the deterministic risk assessment. It is assumed that receptors will forage exclusively within each of these areas;
• For piscivores, the diet is assumed to consist of almost entirely of fish. However, invertebrates were also part of the diet;

• For omnivores, the diet is assumed to consist of equal parts animal and vegetable matter. The animal portion is assumed to be equally divided among fish, aquatic invertebrates and terrestrial invertebrates;

• Piscivorous and omnivorous mammals in the area are opportunistic in terms of habitat as well as diet. For this assessment, we assume that hypothetical receptors will be found in most habitats in the AOCs; and,

• The hypothetical receptor is assumed to be resident year-round in the Calcasieu area.

9.0.4 Conceptual Model

The conceptual model illustrates the relationships between sources and releases of COCs, their fate and transport, and the pathways through which COCs reach piscivorous and omnivorous mammals and exert potential adverse effects. Piscivorous and omnivorous mammals are exposed to a number of COCs in the Calcasieu Estuary system and the deterministic risk assessment (Appendix G) identified those that pose potential risks to these animals. Specifically, piscivorous and omnivorous mammals are at greatest risk from mercury, selenium, total PCBs, and TCDD-TEQs in the Calcasieu Estuary. These substances are persistent and bioaccumulative and are available for uptake by mammals, primarily through the food chain. The Phase II sampling program provided data identifying substantial tissue residues of these substances in fish and aquatic invertebrates, which are prey items of many piscivorous and omnivorous mammals. Other routes of exposure, including inhalation, water
consumption and sediment ingestion have been excluded from this assessment as their contribution to overall exposure is likely negligible (Moore et al. 1997; 1999).

9.0.5 Assessment Endpoint

An assessment endpoint is an ‘explicit expression of the environmental value that is to be protected’ (USEPA 1997a). A number of aquatic-dependent mammals are present, or potentially present, in the Calcasieu Estuary and are linked to this aquatic ecosystem due to their reliance on aquatic organisms for food. These prey items accumulate persistent and bioaccumulative COCs in their tissues from their diet and the surrounding environment. Aquatic-dependant mammals are subsequently exposed through the consumption of contaminated prey items. Therefore, the assessment endpoint for this section of the ERA of the Calcasieu Estuary is the survival, growth, and reproduction of piscivorus and omnivorous mammals.

9.0.6 Measurement Endpoints

A measurement endpoint is defined as ‘a measurable ecological characteristic that is related to the valued characteristic selected as the assessment endpoint’ and it is a measure of biological effects (e.g., mortality, reproduction, growth; USEPA 1997a). A single measurement endpoint will be used to evaluate the risks to piscivorus and omnivorous mammals. The potential for adverse effects on these mammals will be evaluated by comparing estimated total daily intake to the results of laboratory toxicity studies. The prey-tissue data were compiled by geographic area within the estuary (based on the diet and foraging range of the hypothetical mammalian species),
incorporated into a daily intake exposure model, and compared to appropriate toxicity values for survival, growth and reproduction of piscivorous and omnivorous mammals.

9.0.7 Risk Hypothesis and Questions

The following risk hypothesis was developed to identify the key stressor-effect relationships that will be evaluated in the ERA:

Based on the physical-chemical properties (e.g., $K_{ow}$) of the bioaccumulative substances of concern, the nature of the food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, mercury, selenium, total PCBs, and TCDD-TEQs released into surface waters will accumulate in the tissues of aquatic organisms to levels that adversely affect the survival, growth, and/or reproduction of piscivorous and omnivorous mammals.

To assess ecological risks, the assessment endpoint is linked to the measurement endpoint by risk questions. In this study, the investigation to assess the risks of COCs to mammals was designed to answer the following risk questions:

- Are the levels of substances in the tissues of prey species of piscivorous and/or omnivorous mammals in the Calcasieu Estuary higher than the tissue residue benchmark values for survival, growth, or reproduction?
- If yes, what are the probabilities of effects of differing magnitude for survival, growth, and/or reproduction of piscivorous and/or omnivorous mammals?
The linkages between the assessment endpoint and the measurement endpoints are articulated in greater detail in Table 9-5 of the Baseline Problem Formulation (MacDonald et al. 2001).

9.1 Methods

A step-wise approach was used to assess the risks to the mammalian community posed by the COCs in the Calcasieu Estuary. The four main steps in this process included:

- Collection, evaluation, and compilation of the relevant data on the concentrations of COCs in prey items and sediment in the Calcasieu Estuary;
- Assessment of exposure of mammals to COCs (Figure 9-1);
- Assessment of the effects of COCs on mammals (Figure 9-2); and,
- Characterization of risks to the mammalian community (Figure 9-3).

9.1.1 Collection, Evaluation, and Compilation of Data

More than 600 tissue samples were collected at sites located throughout the estuary between October, 2000 and November, 2000. Biota tissue samples were collected in three AOCs in the estuary (UCR AOC, BI AOC, MCR AOC) and in the reference
areas (Bayou Bois Connine, Calcasieu Lake, Bayou Choupique, Grand Bayou and Grand Bayou and Wetlands; CH2M HILL 2000). Briefly, fish and invertebrate species were collected by hook and line, hand collection and netting. Minnows and other small bait species were collected using legal cast nets, minnow traps, dip nets and bait seines in accordance with the Louisiana Department of Wildlife and Fisheries. In addition, samples of fiddler crabs and *Rangia* were also collected in October 2001.

All tissue samples were analyzed for total target analyte list (TAL) metals, target compound list (TCL) semi-volatile organic compounds (SVOCs) and TCL pesticides. Twenty percent of the tissue samples were analyzed for PCB congeners and dioxins/furans. All of the data sets generated during the course of the study were critically reviewed to determine their applicability to the assessment of risks to the biotic community in the Calcasieu Estuary. Following translation of these data into database format, the validated data were then further evaluated to ensure the quality of the data used in the risk assessment.

Historical data sets on total PCBs in fish tissue were examined and compared with the Phase II sampling fish tissue data to evaluate trends in risk over time. Less than one order of magnitude difference was found between ten years of historical data and data collected in the Phase II sampling program.

### 9.1.2 Exposure Assessment

The exposure assessment is intended to provide an estimate of the magnitude of exposure of receptors (i.e., piscivorous and omnivorous mammals) to COCs, over time.
and space. We estimated exposure of piscivorous and omnivorous mammals to methylmercury, selenium, total PCBs and TCDD-TEQs via a daily intake model that considered the dietary ingestion route of exposure. Piscivorous and omnivorous mammals are unlikely to use the saline waters of Bayou d’Inde as a source of drinking water and the inhalation route of exposure has been shown to be an insignificant source of hydrophobic substances in previous assessments of the risks of these substances to aquatic-dependent wildlife (e.g., Moore et al. 1997; 1999). Sediment ingestion was also considered as a possible route of exposure, however, analysis indicated that the contribution of sediment intake to overall exposure of COCs was insignificant. Therefore, the exposure model used in this assessment only includes the ingestion of food items as an exposure route.

The exposure model is adapted from USEPA (1993) and is represented in Equation 1:

**EQUATION #1**

\[
TDI = FMR \times \sum_{i=1}^{n} \frac{C_i \times P_i}{AE_i \times GE_i}
\]

where:

- \( TDI \) = total daily intake of COC (mg/kg BW/day);
- \( FMR \) = normalized free metabolic rate (Kcal/kg BW/day);
- \( i \) = 1 = fish, 2 = invertebrates;
- \( C_i \) = concentration of COC in prey (mg/kg ww prey);
- \( P_i \) = proportion of prey in the diet (unitless);
- \( GE_i \) = gross energy of prey (Kcal/kg ww prey); and,
- \( AE_i \) = assimilation efficiency of prey (unitless).
This model considers the food energy needs of the receptors, the caloric values of the food items, the receptors’ ability to digest these items, the concentrations of COCs in the food items, and the proportion of the diet accounted for by that food item. The range of possible exposures of mammals to COCs in the Calcasieu Estuary is estimated using Monte Carlo analysis. With this statistical technique, each of the input variables (e.g., COC concentrations in food) is represented as a distribution in which the values may fall. This approach recognizes the fact that the variables in Equation 1 are subject to natural variability, and that different mammals will have varying daily intakes. For example, mammals that consume prey with varying concentrations of substances will be exposed to varying doses. The results of the Monte Carlo analysis can be used to estimate the probability of exposure exceeding an effects threshold or levels that cause adverse effects of differing magnitudes. A probability bounds analysis was also conducted to determine how uncertainty regarding the distributions of the input variables influenced the estimated exposure distribution. The results of this analysis are discussed in detail in Appendices I1 and I2.

9.1.3 Effects Assessment

The purpose of this section is to: (1) briefly review the scientific literature on the effects of dietary methylmercury, selenium, total PCBs, and TCDD-TEQs to piscivorous and omnivorous mammals; and, (2) develop a dose-response relationship or select a daily dose for each COC that represents a threshold beyond which toxic effects may appear in piscivorous and omnivorous mammals. These outputs are known as effects metrics, and are used with the results of the exposure assessment to estimate
risk. We will focus on ecologically relevant effects endpoints such as survival, growth, and reproduction of piscivorous and omnivorous mammals.

**Methylmercury**

Mercury has no known physiological use to mammals, but can cause teratogenic, mutagenic, carcinogenic, and other effects (Eisler 2000a). Mercury most commonly exists as methylmercury (MeHg) in higher trophic level species (Wolfe et al. 1998). MeHg attacks the central nervous system, affecting coordination, site, hearing, and sensory functions (Eisler 2000a). Acute effects of MeHg include muscular incoordination, falling, slowness, calmness, and hyperactivity (USEPA 1997c). Chronic exposure may lead to liver or kidney damage, neurobehavioral effects, reduced food consumption, weight loss, impaired growth, effects to reproduction, and death (USEPA 1997c). The effects metrics for this substance were based on mortality of female mink and fecundity of female mice for piscivorous and omnivorous mammals, respectively.

**Tetrachlorodibenzo-p-dioxin and Equivalents**

Coplanar PCDDs, PCDFs, and PCBs act by the same mode of toxic action, which is initiated by binding to the aryl hydrocarbon receptor protein (Bosveld and van den Berg 1994). The response of organisms can range from enzyme induction (Aulerich et al. 1985) to mortality (Safe 1994; Eisler and Belisle 1996; Tillitt et al. 1996). The most toxic PCDD and PCDF congeners tend to be those chlorinated in the 2,3,7, and 8 positions, such as 2,3,7,8-TCDD, as these seem to best fit the receptor site. The toxic response to this group of chemicals is therefore related to the three-dimensional structure of the substance, including the degree of chlorination and positions of the chlorine on the aromatic frame. Substances that are more structurally similar to TCDD will elicit a toxic response
closer to that of TCDD. The toxicity of PCBs, PCDDs, and PCDFs may therefore be expressed in terms of 2,3,7,8-TCDD Toxic Equivalents (TEQs), as described by van den Berg et al. (1998), where the toxicity of the members of this chemical class are all expressed relative to TCDD for fish, birds, and mammals. The effects metric for this group of substances was fecundity of female rat for piscivorus and omnivorous mammals.

**Selenium**

Selenium is an essential element in human and animal nutrition and is efficiently concentrated in living tissues. Absorption of oral radioselenite by rats is as high as 95 to 100% (Eisler 1985). Marine fish have tissue residues of approximately 2 mg/kg ww, a concentration 50,000 times that of the surrounding seawater (Wilber 1980). Though essential to life and naturally accumulated, excess selenium exposure has been associated with lethality, neurological, developmental, and reproductive effects (ATSDR 1996). The selenium compounds shown to be the most toxic to mammals by ingestion appear to be sodium selenite and sodium selenate (Olson 1986). Selenium poisoning is a hazard to livestock in areas naturally rich in selenium (ATSDR 1996; Wilbur 1980; Rosenfeld and Beath 1964). “Blind staggers” and “alkali disease” are two conditions seen in livestock exposed to excess selenium. The effects metric for this substance was mortality of female rat for piscivorus and omnivorous mammals.

**Total Polychlorinated Biphenyls**

PCBs have been shown to be toxic in all organisms tested, with adverse effects including hepatotoxicity, immunotoxicity, neurotoxicity, numerous reproductive effects and other effects. PCBs have also been associated with adverse effects
in mammals due to their ability to mimic female hormones. Mink are one of the most sensitive animals to PCB toxicity (Eisler 2000b). Studies have shown that PCBs are not particularly toxic during short exposures but that chronic exposure may result in effects at low levels (Coulston and Kolbye 1994; Aulerich et al. 1985; Bleavins et al. 1980). The effects metrics for this group of substances were fecundity of female mink and fecundity of female rats for piscivorous and omnivorous mammals, respectively.

9.1.4  Risk Characterization

In the risk characterization phase of the probabilistic ERA, the results of the probabilistic exposure assessment and effects characterization were integrated to develop risk estimates for each COC in each AOC. Ideally, risk characterization involves three major lines of evidence: comparison of modeled exposure to laboratory-derived effects metrics (as described in Sections 9.1.2 and 9.1.3), in situ or whole-media toxicity tests, and biological surveys. For piscivorous and omnivorous mammals, however, the latter two lines of evidence are not available. We, therefore, rely on the risk estimates generated from the comparison of modeled exposures to laboratory-derived effects metrics.

For the AOCs of the Calcasieu Estuary, a low, indeterminate or high category of risk was determined for mammals. These categories of risk were derived using the following guidance:

- If the probability of 10% or greater effect is less than 20%, then the risk to mammals is low;
• If the probability of 20% or greater effect is greater than 50%, then the risk to mammals is high; and,

• Other outcomes are considered to have an indeterminate risk.

9.2 Results

9.2.1 Piscivorus Mammals

The risk assessment indicates that methylmercury, TCDD-TEQs and selenium have a low probability of causing adverse effects to average-sized and small piscivorus mammals foraging in the Calcasieu Estuary (Table 9-2a).

The assessment indicates that piscivorus mammals of any size are at high risk from total PCBs exposure in BI AOC. Presented below is a summary of the probabilities of effects derived from the comparison of exposure with the effects metrics and the conservative deterministic benchmark used for the screening assessment (Appendix G).

According to the Monte Carlo analysis, there is a 100%, 50% and 10% probability that the predicted total daily intake of total PCBs in BI AOC will induce a 10%, 25% and 38% or greater effect to reproductive success of average-sized piscivorus mammals. Figure 9-4 shows the estimated probabilities of effects of differing magnitude for average-sized piscivorus mammals in BI AOC. The Monte Carlo analysis indicates that average-sized piscivorus mammals have a 100% probability of total daily total PCBs intake exceeding the benchmark from the conservative deterministic assessment of 0.00272 mg/kg BW/day.
According to the Monte Carlo analysis, there is a 100%, 50% and 10% probability that the predicted total daily intake of PCBs in BI AOC will induce a 10%, 32% and 45% or greater effect to reproductive success of small piscivorus mammals. Figure 9-5 shows the estimated probabilities of effects of differing magnitude for small piscivorus mammals in BI AOC. The Monte Carlo analysis indicates that small piscivorus mammals have a 100% probability of total daily total PCBs intake exceeding the benchmark from the conservative deterministic assessment of 0.00272 mg/kg BW/day.

### 9.2.2 Omnivorous Mammals

The risk assessment indicates that methylmercury, TCDD-TEQs, selenium, and total PCBs have a low probability of causing adverse effects to average-sized and small omnivorous mammals foraging in the Calcasieu Estuary (Table 9-2b).

### 9.3 Sources of Uncertainty

There are a number of sources of uncertainty in the assessments of risk to aquatic-dependent mammals. They include uncertainties in the conceptual model as well as in the exposure, effects, and risk assessments. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and direction of such uncertainties. In this way, it is possible to evaluate the level of confidence that can be placed in the assessments conducted. The major sources of uncertainty are as follows.
According to the Monte Carlo sensitivity analyses, the slope and power terms in the free metabolic rate equation were among the most influential variables driving the predicted intake rates in the exposure analysis. Unfortunately, no corresponding measurements of free metabolic rate were available for aquatic-dependent mammals. Therefore, free metabolic rates were estimated using allometric equations. The use of allometric equations introduced some degree of uncertainty into the exposure estimates because they are associated with some fitting error and are based on some mammalian species that are different from the aquatic-dependent mammals of interest. The potential magnitude and direction of the uncertainty associated with lack of information on metabolic rate are unknown.

Another sensitive variable that influence the exposure estimates included the gross energy of food and the food assimilation efficiency. Uncertainty is associated with these variables because no feeding studies were specifically performed on the aquatic-dependent mammals residing in the Calcasieu Estuary. Rather, diet compositions were matched to those reported in the literature for mammals raised in a laboratory or collected from other geographical locations. In consequence, the quantification of food gross energy and assimilation efficiency was limited to general food groups such as mammals or invertebrates rather than specific Calcasieu Estuary prey species.

The Monte Carlo analysis also identified the concentrations of substances in prey species as one of the sensitive variables. However, the level of uncertainty associated with this parameter is relatively low because Calcasieu-specific mammal and invertebrate species were used in the exposure analysis and substance levels were measured using acceptable analytical techniques. It is unlikely that further sampling would substantially reduce the associated uncertainty, which is likely attributable to natural variability.
Because toxicity data for aquatic-dependent mammals were not always available, toxicity data on surrogate mammals were used in the effects assessment. This added another degree of uncertainty because it is not known whether laboratory raised and tested mammals have the same sensitivity as mammals living in the wild. Differing environmental conditions between the laboratory and the field also introduces uncertainty to the estimation of effects doses.

The combined sources of uncertainty in the exposure and effect assessments had the ultimate effect of causing somewhat wide risk prediction intervals in the probability bounds analyses (see Appendices I1 and I2). For additional details on sources of uncertainty, the reader is referred to Appendices I1 and I2.

### 9.4 Summary and Conclusions

The risk characterization results indicate that there is a low probability that exposure to methylmercury, TCDD-TEQs and selenium will cause adverse effects to piscivorous and omnivorous mammals foraging in the Calcasieu Estuary. There is also a low probability of adverse effects to omnivorous mammals exposed to total PCBs. However, the results showed that there is a high probability of total PCBs causing adverse effects to average-sized and small piscivorous mammals in the BI AOC, even when sources of uncertainty are considered. Based on the deterministic ERA, total PCBs pose lesser risks to piscivorous mammals in other parts of the estuary.

Biological surveys and ambient toxicity testing are two other lines of evidence for which we had no data. While the evidence presented certainly cannot be used to rule
out the possibility that COCs are causing adverse effects to piscivorus mammals in the Calcasieu Estuary, it does seem unlikely that COCs are causing widespread impacts, except for total PCBs in the BI AOC.
Chapter 10. Summary and Conclusions

10.0 Introduction

The Calcasieu Estuary is located in the vicinity of Lake Charles in Calcasieu Parish, Louisiana (LA; Figure 1-1). The estuary is characterized by a number of distinctive physical features, including Lake Charles, Prien Lake, Moss Lake, and Calcasieu Lake. The Calcasieu River/Calcasieu Ship Channel is joined by several tributaries within the estuary, the most notable being Bayou Verdine, Contraband Bayou, Bayou d’Inde, and Bayou Olsen. The land surrounding the Calcasieu Estuary includes undeveloped, rural, residential, commercial, and heavy industrial properties. Heavy industry dominates the southern reaches of Bayou d’Inde and Bayou Verdine on both sides. Permitted discharge outfalls (as identified in the National Pollution Discharge Elimination System; NPDES), as well as agricultural and industrial drainage ditches (including the Vista West Ditch, the Faubacher Ditch, and the Kansas City Southern Railroad West Ditch), discharge to the estuary (Figure 10-1). Current and historic point source discharges, stormwater runoff, and accidental spills have contributed to the contamination of surface water, sediment, and biota within the estuary and associated concerns regarding human health and ecological effects (Curry et al. 1997).

In response to public concerns regarding environmental contamination, the United States Environmental Protection Agency (USEPA) is conducting a federally-led Remedial Investigation/Feasibility Study (RI/FS) to assess risks to human health and ecological receptors and evaluate remedial options for addressing environmental contamination in the Calcasieu Estuary (Figure 10-2). Initially, the available data on the levels of contaminants in environmental media in the estuary were reviewed and evaluated to determine if risks to ecological receptors existed within the estuary.
The results of the screening-level ecological risk assessment (SERA) indicated that exposure to sediment and surface waters poses potential risks to ecological receptors.

In accordance with USEPA policies and guidance, more comprehensive investigations were initiated following the completion of the SERA, including a human health risk assessment (HHRA) and a baseline ecological risk assessment (BERA). The HHRA (CDM 2002a) was conducted in accordance with the *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual. Part A* (USEPA 1989). Similarly, the BERA (this report) was conducted in accordance with the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (USEPA 1997a; Figures 1-3 and 1-4). The Remedial Investigation (RI) also included detailed investigations to identify sources of chemicals of potential concern (COPCs), characterize releases of COPCs, and evaluate the fate of these substances in aquatic ecosystems within the estuary (CDM 2002b).

The portion of the Calcasieu Estuary from the saltwater barrier to Moss Lake has been identified as the area in which environmental contamination posed the greatest potential risks to ecological receptors and, as such, was designated as the primary study area (CDM 1999; Figure 10-3). To facilitate the RI/FS, this study area was divided into four sub-areas (termed Areas of Concern; AOC), including:

- Upper Calcasieu River (UCR) AOC;
- Bayou Verdine (BV) AOC;
- Bayou d’Inde (BI) AOC; and,
- Middle Calcasieu River (MCR) AOC.
Several reference areas were also identified in the lower estuary and in the vicinity of Sabine National Wildlife Refuge to support the interpretation of the data generated during the RI. The AOCs identified in this report are generally consistent with those identified in the HHRA (CDM 2002a) and the RI report (CDM 2002b); however, the names applied to these AOCs differ among the reports.

This report was prepared to evaluate the risks to ecological receptors (i.e., aquatic organisms and aquatic-dependent wildlife) posed by exposure to environmental media (i.e., water, sediment, or biota) in the Calcasieu Estuary (Figure 10-4). More specifically, risks to the microbial community associated with exposure to COPCs in whole sediments were evaluated. In addition, risks to the aquatic plant community associated with exposure to COPCs in surface water or pore water from Calcasieu Estuary sediments were assessed. The risks to the benthic invertebrate community associated with exposure to COPCs in whole sediments and pore water were also evaluated. Furthermore, risks to benthic and pelagic fish associated with exposure to COPCs in surface water, pore water, whole sediments, and prey organisms were assessed. Finally, risks to aquatic-dependent wildlife (i.e., birds and mammals) were evaluated based on their potential exposure to COPCs in prey organisms. The results of the BERA for Bayou Verdine that was conducted for Conoco, Inc. and Condea Vista is presented in a separate document (Entrix 2001).
10.1 Study Objectives

The goal of this study was to assess the risks to aquatic organisms and aquatic-dependent wildlife exposed to environmental media in the Calcasieu Estuary. The primary objectives of this study were to:

- Determine if adverse effects on ecological receptors are occurring, or are likely to be occurring, within the Calcasieu Estuary;
- Evaluate the nature, severity, and areal extent of any such effects; and,
- Identify the substances that are causing or substantially contributing to effects on aquatic receptors (i.e., contaminants of concern; COCs).

10.2 Study Approach

A step-wise approach was used to assess the risks to aquatic organisms (i.e., microorganisms, aquatic plants, benthic invertebrates, and/or fish) and aquatic-dependent wildlife associated with exposure to COPCs in the Calcasieu Estuary. The five main steps in this process include:

- Identification of assessment endpoints, risk questions and testable hypotheses, and measurement endpoints;
- Collection, evaluation, and compilation of the relevant information on environmental conditions in the Calcasieu Estuary;
• Assessment of the exposure of aquatic organisms and aquatic-dependent wildlife to COPCs (i.e., exposure assessment; Figure 4-1);

• Assessment of the effects of COPCs on aquatic organisms and aquatic-dependent wildlife (i.e., effects assessment; Figure 4-2); and,

• Characterization of risks to the aquatic organisms and aquatic-dependent wildlife (i.e., risk characterization; Figure 4-3).

The procedures used in this BERA to evaluate the nature, severity, and areal extent of risks to ecological receptors in the Calcasieu Estuary are outlined in Chapter 4 and Appendix C for the microbial community, in Chapter 5 and Appendix D for the aquatic plant community, in Chapter 6 and Appendices E1 to E5 for the benthic invertebrate community, and, in Chapter 7 and Appendices F1 and F2 for the fish community (including benthic and pelagic fish). The methods that were used to evaluate the risks to aquatic-dependent wildlife are described in Chapter 8 and Appendices H1 to H3 for birds (including sediment-probing birds, carnivorous-wading birds, and piscivorus birds) and in Chapter 9 and Appendices I1 and I2 for mammals (including omnivorous mammals, and piscivorus mammals). Each of the above steps in the risk assessment process are briefly described below.

As a first step, assessment endpoints, risk questions and testable hypotheses, and measurement endpoints were identified. In this context, an assessment endpoint was defined as an explicit expression of the environmental value that is to be protected, whereas, a measurement endpoint is defined as a measurable ecological characteristic that is related to the valued characteristic that is selected as the assessment endpoint (USEPA 1997a). To facilitate this process, a BERA workshop was convened in Lake Charles, LA in September, 2000. The results of this workshop provided a basis for
identifying preliminary assessment endpoints and priority measurement endpoints to support the BERA (MacDonald et al. 2000). Subsequently, additional information on the sources, fate and transport, and ecological effects, of COPCs was compiled in a baseline problem formulation (BPF) report (MacDonald et al. 2001; Appendices A1 and A2 of the BERA). Potential exposure pathways and ecological receptors potentially at risk were also identified in the BPF. Integration of this information in the conceptual model for the site provided a base for linking assessment endpoints to measurement endpoints with a series of risk questions and testable hypotheses (Figure 1-5). The assessment endpoints that were considered in the BERA included:

- Activity of the aquatic microbial community;
- Survival, growth, and reproduction of aquatic plants;
- Survival, growth, and reproduction of benthic invertebrates;
- Survival, growth, and reproduction of benthic and pelagic fish;
- Survival and reproduction of aquatic-dependent birds; and,
- Survival, growth, and reproduction of aquatic-dependent mammals.

In the second step of the process, the relevant information on environmental conditions in the Calcasieu Estuary generated in Phase I and Phase II of the RI was collected, evaluated, and compiled. The data on surface-water quality consisted primarily of information on the levels of conventional variables (e.g., ammonia), metals, and organic substances [e.g., polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OC pesticides)]. The data on sediment quality conditions included whole-sediment chemistry, whole-sediment toxicity, pore-water chemistry, pore-water toxicity, and benthic invertebrate
community structure. In addition, data were compiled on the concentrations of COPCs in fish and shellfish from the study area. All of the relevant information was compiled in relational database format (Appendices B1 to B9 of the BERA).

In the third step of the process, the exposure of ecological receptors to COPCs was evaluated. Exposure is the contact or co-occurrence of a contaminant and a receptor (Suter et al. 2000). The exposure assessment was intended to provide an estimate of the magnitude of exposure of receptors to COPCs, over time and space. Exposure of the microbial community to COPCs was evaluated using the data on whole-sediment chemistry. By comparison, data on surface-water and pore-water chemistry were used to assess exposure of aquatic plants to COPCs. For benthic invertebrates, exposure was evaluated using data on whole-sediment and pore-water chemistry. Exposure of the fish community to COPCs was assessed using data on surface-water, pore-water, whole-sediment, and tissue chemistry. Finally, data on the concentrations of COPCs in the tissues of fish and shellfish were used to assess exposure of aquatic-dependent birds and mammals to COPCs.

In the analysis of effects, risk assessors determine the nature of toxic effects that are associated with exposure to contaminants and their magnitude as a function of exposure (Suter et al. 2000). Information on the effects of environmental contaminants may be acquired from the results of single chemical toxicity tests (e.g., spiked sediment toxicity tests), ambient media toxicity tests (e.g., the results of toxicity tests conducted using sediments collected from the site under investigation), and/or biological surveys (e.g., benthic invertebrate community assessments). In this investigation, the effects of COPCs were evaluated using toxicity thresholds for surface water (i.e., for aquatic plants and fish), toxicity thresholds for whole-sediment chemistry (i.e., for microorganisms, benthic invertebrates, and fish), toxicity
thresholds for pore-water chemistry (i.e., for aquatic plants, benthic invertebrates, and fish), and toxicity reference values (i.e., for birds and mammals). The toxicity thresholds for whole sediments were evaluated to determine their relevance for assessing sediment quality conditions in the Calcasieu Estuary (Appendix E1). The results of this evaluation indicated that site-specific concentration-response models were needed to assess the effects on benthic invertebrates associated with exposure to contaminated sediments. The resultant models were used to assess the effects of sediment-associated COPCs on the benthic invertebrate community (Appendix E2).

In the final step of the process, the exposure and effects assessments were integrated to determine if significant effects are occurring or are likely to occur at the site under investigation. In addition, the nature, magnitude, and areal extent of effects on the selected assessment endpoints were described. The substances that are causing or substantially contributing to such effects (termed COC) were then identified from COPCs. Initially, the results that were obtained for each line of evidence (e.g., whole-sediment chemistry) were compiled and interpreted separately. Subsequently, an evaluation of the uncertainty in the analyses was conducted to determine the level of confidence that could be placed on the results for the individual lines of evidence and for integrating multiple lines of evidence into an overall assessment of risks to a particular receptor group (e.g., benthic invertebrates). Finally, the various lines of evidence were considered together to establish a weight of evidence for assessing risks to the assessment endpoint under consideration. In this latter assessment, the available data were integrated by calculating a final risk score for each location based on multiple lines of evidence. The final risk scores were then used to classify risks at each location into one of three categories including:

- Low (i.e., risks similar to those for reference conditions);
• Indeterminate (i.e., elevated risks relative to reference conditions, decisions on remedial actions should consider multiple factors); and,

• High (i.e., risks substantially elevated relative to reference conditions, remedial actions likely required to mitigate risks).

10.3 Assessment of Risks to Aquatic Receptors

In this investigation, the risks to four groups of aquatic organisms posed by exposure to COPCs in the Calcasieu Estuary were assessed. The receptors groups that were considered in this evaluation included the microbial community, aquatic plant community, the benthic invertebrate community, and the fish community. For each receptor group, an assessment was conducted to determine if adverse effects are occurring, or are likely to be occurring, within the Calcasieu Estuary. In addition, the nature, severity, and areal extent of such effects were evaluated. Finally, the substances that are causing or substantially-contributing to such effects (i.e., COCs) were identified.

10.3.1 Microbial Community

The risks posed to microbial communities by exposure to whole sediments were assessed in the Calcasieu Estuary. In total, information on two lines of evidence was used to determine if the activity of the aquatic microbial community (i.e., the assessment endpoint) has been adversely affected or is likely to have been adversely affected by exposure to sediments in the estuary relative to reference conditions. The
two lines of evidence that were considered in the assessment included whole-sediment chemistry and whole-sediment toxicity. The measurement endpoints for this assessment included the concentrations of COPCs in whole sediments and bioluminescence of the bacterium, *Vibrio fisheri*, in solid phase tests.

The results of this assessment indicated that exposure to whole sediments from the Calcasieu Estuary posed variable risks to microbial communities (i.e., risks were classified as low for 51% and indeterminate for 49% of the 624 sediment samples collected within the three AOCs investigated; Table 4-2). Of the three AOCs considered, the risks to the microbial community were highest in Bayou d’Inde (Figures 10-5 to 10-9). Within this AOC, sediment samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, lower Bayou d’Inde mainstem, and Lockport Marsh posed the highest risks to the microbial community (Figure 10-6). Although risks to the microbial community were generally lower in the UCR AOC and MCR AOC, sediments posing indeterminate risks were identified in the northern portions of Clooney Island Loop, Clooney Island barge slip, the northern, central, and southern portions of Coon Island Loop, the western shoreline of Middle Calcasieu River Mainstem from Bayou d’Inde to Moss Lake, Moss Lake, Prien Lake, Indian Wells Lagoon, and portions of the old river channel within the Middle Calcasieu River Mainstem reach (Figures 10-5 to 10-8). Risks to the microbial community are generally low throughout the reference areas with the exception of certain portions of Bayou Choupique (Figure 10-9).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the microbial community. The average EC$_{50}$-bioluminescence was 11.1±8.4 % sediment wet weight/mL (n=84) for the whole-sediment samples that were classified into the low
risk category. For the samples that were classified into the indeterminate risk category, a mean EC$_{50}$-bioluminescence of 0.5±0.3 % sediment wet weight/mL (n=5) was calculated. Together, these results demonstrated that the metabolism of microorganisms is impaired in response to exposure to contaminated sediments at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the microbial community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs were considered to include:

- PAHs [1,1-biphenyl, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total low molecular weight-PAHs (LMW-PAHs), benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total high molecular weight-PAHs (HMW-PAHs), and total PAHs];
- PCBs (total PCBs); and,
- Phthalates [bis(2-ethylhexyl)phthalate; BEHP].

### 10.3.2 Aquatic Plant Community

The risks posed to aquatic plant communities by exposure to surface water and pore water were assessed in the Calcasieu Estuary. In total, information on three lines of
evidence was used to determine if the survival, growth, or reproduction of aquatic plants (i.e., assessment endpoints) was being adversely affected or was likely to be adversely affected by exposure to COPCs in the estuary (i.e., relative to reference conditions). The three lines of evidence that were considered in the assessment included surface-water chemistry, pore-water chemistry and pore-water toxicity. The measurement endpoints for this assessment included concentrations of COPCs in surface water, the concentrations of COPCs in pore water, and germination rate of algae zoospores, germling length, and cell number of the macrophyte, *Ulva fasciata*, in pore-water toxicity tests.

The results of this BERA indicated that exposure to surface water and/or pore water from the Calcasieu Estuary generally posed low risks to aquatic plant communities (i.e., risks were classified as low for 72% of the 130 samples collected within the three AOCs investigated; Table 5-2; Figures 10-5 to 10-9). However, indeterminate and high risks to the aquatic plant community were indicated for 5% (6 of 130) and 24% (31 of 130) of the samples, respectively (Table 5-2). Of the three AOCs considered, the risks to the aquatic plant community were highest in Bayou d’Inde (Figure 10-6). Within this AOC, samples from the upper and lower portions of upper Bayou d’Inde, Maple Fork, PPG Canal, and the central and southeastern portions of Lockport Marsh posed the highest risks. Although risks to the aquatic plant community were generally lower in the UCR AOC and MCR AOC, samples posing high risk are present in the eastern and southwestern portions of Clooney Island Loop, Clooney Island barge slip, the southeastern and southwestern portions of Coon Island Loop, the mouth of Bayou Verdine, old river channel downstream of Prien Lake, west-central portion of Moss Lake, southern side of Contraband Bayou in the vicinity of Charvais Drive, southeastern portion of Lake Charles, and Indian Wells Lagoon (Table 5-2; Figures 10-5 to 10-8). Risks to the aquatic plant community are generally
low at the locations sampled in the reference areas, with the exception at lower Bayou Boise Connine and the central portion of Grand Bayou (Figure 10-9).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the aquatic plant community. For example, the germination of algal zoospores was lower in the samples that were designated as indeterminate (60±32%; n=3) and high (37±20%; n=6) risk than was the case for the low risk samples (88±7%; n=36). Likewise, growth rates tended to be highest for the samples that were designated as posing low risks to the aquatic plant communities. These results demonstrate that the survival, growth, and reproduction of aquatic plants are impaired in response to exposure to surface water or pore water at certain locations in the Calcasieu Estuary.

The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the aquatic plant community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs that were considered to include:

- Total ammonia;
- Metals (dissolved copper and total and dissolved nickel); and,
- Benz(a)anthracene.
10.3.3 Benthic Invertebrate Community

The risks to benthic invertebrate communities posed by exposure to whole sediments and pore water were assessed in the Calcasieu Estuary. In total, information on five lines of evidence was used to determine if the survival, growth, or reproduction of benthic invertebrates (i.e., the assessment endpoints) has been adversely affected or is likely to have been adversely affected by exposure to contaminated sediments in the estuary relative to reference conditions. The five lines of evidence that were considered in the assessment included whole-sediment chemistry, whole-sediment toxicity, pore-water chemistry, pore-water toxicity, and benthic invertebrate community structure. The measurement endpoints in this assessment included: the concentrations of COPCs in whole sediment; the concentrations of COPCs in pore water; the survival and growth of amphipods, *Hyalella azteca*, in whole-sediment toxicity tests; the survival of amphipods, *Ampelisca abdita*, in whole-sediment toxicity tests; gamete fertilization and embryo development in sea urchins, *Arbacia punctulata*, in pore-water toxicity tests; the abundance of pollution sensitive species; the abundance of pollution tolerant species; total abundance of benthic macroinvertebrates; species richness; and, macrobenthic index of biotic integrity.

The results of this assessment indicated that exposure to whole sediment and/or pore water from the Calcasieu Estuary generally posed low risks to benthic invertebrate communities (i.e., risks were classified as low for 68% of the locations sampled (423 of 624) within the three AOCs investigated (Figures 10-5 to 10-9). However, indeterminate and high risks to the benthic invertebrate community were indicated for 9% (58 of 624) and 23% (143 of 624) of the locations sampled, respectively (Table 6-2). Of the three AOCs considered, the risks to the benthic invertebrate community were highest in Bayou d’Inde, based both on the incidence and magnitude of toxicity.
Within this AOC, samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, PPG Canal, and the inner portions of Lockport Marsh posed the highest risks. Although risks to the benthic invertebrate community were generally lower in the UCR AOC and MCR AOC, samples posing a high risk to benthic invertebrates were collected from the northern portions of Clooney Island Loop, the northern portions of Coon Island Loop, the middle Calcasieu River in the vicinity of the Citgo property, and Indian Wells Lagoon (Table 6-2; Figures 10-5 to 10-8). Risks to the benthic invertebrate community are generally low throughout the reference areas (Figure 10-9).

The results of the biological investigations conducted during the RI indicate that the magnitude of effects tends to increase with increasing risk to the benthic invertebrate community. For example, the survival and/or growth of freshwater and marine amphipods was lower for the locations that were designated as posing indeterminate and high risks than was the case for the locations that were classified as posing low risk to benthic invertebrates (Table 6-3). Likewise, the fertilization of sea urchin gametes was reduced in the samples from locations that were designated as posing indeterminate or high risks to the benthic community (Table 6-3; Appendix E2). Importantly, the density of pollution indicator (i.e., tolerant) species, the density of pollution sensitive species, species richness, and total abundance of benthic invertebrates were generally lower for the sampling locations that were classified as posing indeterminate and high risks, as compared to the sampling locations that posed low risks to benthic invertebrates (Table 6-3). Together, these results demonstrate that the survival, growth, and reproduction of benthic invertebrates have been impaired in response to exposure to contaminated sediments in the Calcasieu Estuary.
The results of this assessment indicated that a number of substances are causing or substantially contributing to adverse effects on the benthic invertebrate community in the Calcasieu Estuary (i.e., relative to reference conditions). More specifically, the COCs included:

- Hydrogen sulfide;
- Metals (chromium, copper, lead, mercury, nickel, and zinc);
- PAHs (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene, total LMW-PAHs, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs);
- PCBs (total PCBs);
- Chlorinated benzenes [hexachlorobenzene (HCB), hexachloro-1,3-butadiene (HCBD)];
- Phthalates (BEHP);
- OC pesticides (aldrin and dieldrin); and,
- Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) [(total 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (total 2,3,7,8-TCDD TEQs)].
10.3.4 Fish Community

The risks posed to fish communities by exposure to surface water, whole sediments, and pore water, and all exposure routes (i.e., based on tissue chemistry) combined were assessed in the Calcasieu Estuary. In total, information on four lines of evidence was used to determine if the survival, growth, or reproduction of fish was being adversely affected or was likely to be adversely affected by exposure to surface water or sediments in the estuary relative to reference conditions. The four lines of evidence that were considered in the assessment included surface-water chemistry, pore-water chemistry, whole-sediment chemistry, and pore-water toxicity. In addition, tissue chemistry was also used to assess the effects of bioaccumulative COPCs (i.e., total PCBs) that accumulate in fish tissues from all exposure routes. In this assessment, the measurement endpoints included: the concentrations of COPCs in surface water; the concentrations of COPCs in whole sediment; the concentrations of COPCs in pore water; the concentrations of COPCs in the tissues of carnivorous fish; and, the hatching success and survival of redfish, *Sciaenops ocellatus*, eggs and larvae in pore-water toxicity tests.

The results of this BERA indicated that exposure to surface water, whole sediments, or pore water from the Calcasieu Estuary generally poses low risks to fish communities. Risks to fish were classified as low for 58% of the sediment samples (i.e., 367 of 634) collected within the three AOCs investigated; Figures 10-5 to 10-9). However, indeterminate and high risks to the fish community were indicated for 5% (33 of 634) and 37% (234 of 634) of the samples, respectively (Table 7-2). Of the three AOCs considered, the risks to the fish community were highest in Bayou d’Inde. Within this AOC, samples from the lower portions of upper Bayou d’Inde, middle Bayou d’Inde, the central portions of Lockport Marsh, and lower Bayou d’Inde
mainstem posed the highest risks. Although risks to the fish community were
generally lower in the UCR AOC and MCR AOC, sediments posing high risk are
present in portions of Clooney Island Loop, portions of Coon Island Loop, the middle
Calcasieu River in the vicinity of the Citgo and WR Grace properties, Indian Wells
Lagoon, Moss Lake and west-central portion of Prien Lake (Table 7-2; Figures 10-5
to 10-8). Risks to the fish community are generally low throughout the reference
areas (Figure 10-9).

Of the exposure routes examined, exposure to COPCs in whole sediments and pore
water represents the most important routes for benthic and pelagic fish. Accordingly,
the fish that are closely associated with sediments, such as flounder (i.e., benthic
species), are the most likely to be adversely affected by COPCs in the Calcasieu
Estuary. As risks to carnivorous fish associated with the accumulation of PCBs in
their tissues are considered to be low, dietary exposure to COPCs may be of lesser
importance.

The results of this assessment indicated that a number of substances are causing or
substantially contributing to adverse effects on the fish community in the Calcasieu
Estuary (i.e., relative to reference conditions). More specifically, the COCs were
considered to include:

- Hydrogen sulfide;
- Metals (chromium, copper, lead, mercury, nickel, and zinc);
- PAHs (2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene,
  fluorene, naphthalene, phenanthrene, total LMW-PAHs,
benz(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, total HMW-PAHs, and total PAHs);

• PCBs (total PCBs);

• OC pesticides (dieldrin); and,

• PCDDs and PCDFs (total 2,3,7,8-TCDD TEQs).

10.3.5 Integrated Risks to Aquatic Receptors

The results of this investigation indicated that exposure to COPCs is adversely affecting a variety of ecological receptors in the Calcasieu Estuary. More specifically, activity of the microbial community has been impaired in portions of the Calcasieu Estuary due to exposure to sediment-associated COPCs. In addition, the survival, growth, and/or reproduction of aquatic plants have also been adversely affected in portions of the estuary through exposure to COPCs in surface water and pore water. Furthermore, exposure to whole sediments or pore water have been adversely affected the survival, growth, and/or reproduction of benthic invertebrates. Finally, the survival, growth, and/or reproduction of benthic fish have been impaired due to exposure to COPCs in whole sediments and/or pore water (Figures 10-10 to 10-14 summarize the risks to each receptor group throughout the Calcasieu Estuary).

For each of the four aquatic receptor groups, the information for various measurement endpoints and lines of evidence were integrated by calculating a final risk score for each location sampled. Subsequently, the final risk scores that were calculated for the various receptor groups for each location were averaged to obtain an overall risk score for the four receptor groups for each location. Then, risks to microorganisms, plants,
benthic invertebrates, and fish were classified into three categories for each location, based on the overall risk score that was calculated. Locations with overall risk scores of <2, 2 to 3, and >3 were classified as posing low, indeterminate, and high risks to aquatic receptors, respectively. In this way, it was possible to integrate information on the risks posed to multiple aquatic receptors by exposure to COPCs in the Calcasieu Estuary.

The results of this assessment indicated that risks to aquatic receptors are generally low throughout the Calcasieu Estuary. Of the 634 locations that were sampled within the three AOCs, 377 (59%) were classified as posing low risks to microorganisms, aquatic plants, benthic invertebrates, and/or fish (Table 10-1). By comparison, 11% (69 of 634) and 30% (188 of 634) of the locations sampled were classified as posing indeterminate and high risks, respectively (Table 10-1). Among the three AOCs, the highest risks to aquatic receptors were evident in Bayou d’Inde (Table 10-1). Risks to aquatic receptors were classified as low throughout the reference areas.

In general, there was good correspondence among the risk classifications for the four groups of aquatic receptors. For example, risks were classified as low within the three AOCs for 58% of the locations sampled for fish (Table 7-2) to 72% of the locations sampled for aquatic plants (Table 5-2). With the exception of microorganisms, the frequency of classification of indeterminate risks was generally low (i.e., 5 to 9%) for the various receptor groups. Similarly, the frequency of classification of high risks was comparable for three of the four aquatic receptor groups (i.e., 23 to 37%, with microorganisms being the exception). Risks to the microbial community were generally classified as being lower than those for the other three aquatic receptor groups because confidence in the information on the selected measurement endpoints tended to be lower for microorganisms. The degree of correspondence among the risk
classifications for the various receptor groups is illustrated in Figures 10-5 to 10-9. These figures also show that correspondence was lower in certain locations, particularly within the more contaminated areas within the estuary (e.g., Clooney Island barge slip, Lockport Marsh).

**Upper Calcasieu River AOC** – In general, risks to aquatic receptors were low throughout the UCR AOC, as indicated by the average overall risk score of 0.81 that was calculated for this AOC. Of the 155 locations that were sampled within this AOC, 131 (85%) were classified as posing a low risk to microorganisms, aquatic plants, benthic invertebrates, and/or fish (Table 10-1). Nevertheless, 15% (i.e., 24 of 155) of the locations within this AOC were classified as posing indeterminate (5%; 7 of 155) or high (11%; 17 of 155) risks to aquatic receptors (Table 10-1). All of the locations that posed a high risk to aquatic receptors were encountered in the Clooney Island Loop (n=7) or the Coon Island Loop (n=10). The locations that posed the highest risk to aquatic receptors included the Clooney Island barge slip, the northern and north eastern portions of Clooney Island Loop, the northern and central portions of Coon Island Loop, and the mouth of Bayou Verdine (Figure 10-10).

**Bayou d’Inde AOC** – Risks to aquatic receptors were generally as high within the BI AOC. The average overall risk score that was calculated for this reach was 2.4 (n= 316). Forty-nine percent of the locations sampled within the BI AOC (i.e., 156 of 316) were classified as posing a high risk to microorganisms, aquatic plants, benthic invertebrates, and/or fish (Table 10-1). By comparison, 33% (i.e., 104 of 316) and 18% (i.e., 56 of 316) of the locations sampled were
classified as posing low or indeterminate risks to aquatic receptors, respectively (Table 10-1). The locations that posed the highest risk to aquatic receptors (i.e., overall risk score >3) were collected in the lower portion of upper Bayou d’Inde (i.e., between the CitCon facility and the Highway 108 bridge), the mainstem and wetland areas within middle Bayou d’Inde, throughout Lockport Marsh, the lower and middle portion of PPG Canal, and lower Bayou d’Inde mainstem in the vicinity of the confluence with PPG Canal and throughout the mainstem (Figure 10-11).

Middle Calcasieu River AOC – Risks to aquatic receptors were generally classified as low with the MCR AOC. An average overall risk score of 0.73 was calculated for this portion of the study area. Based on the results that were obtained for microorganisms, aquatic plants, benthic invertebrates, and/or fish, 87% of the locations sampled (i.e., 142 of 163) within this AOC were classified as posing a low risk to aquatic receptors (Table 10-1). Nevertheless, 13% (i.e., 21 of 163) samples from this AOC were classified as posing indeterminate (4%; 6 of 163) or high (9%; 15 of 163) risks to aquatic receptors (Table 10-1). The samples that posed the highest risk to aquatic receptors were collected along the western shoreline of the middle Calcasieu River in the vicinity of the Citgo property, in Indian Wells Lagoon, Prien Lake and the central portions of Moss Lake (Figures 10-12 and 10-13).

Reference Areas – Risks to aquatic receptors were classified as low for all of the locations sampled within the reference areas. An average overall risk score of 0.55 was calculated for this portion of the study area (Table 10-1). All of the
locations sampled were classified as posing low risks to aquatic receptors (Figure 10-14).

**Contaminants of Concern** – In this report, the COPCs that were considered to be causing or substantially contributing to adverse effects on aquatic receptors were termed COCs. The results of this assessment indicated that there are a number of substances that are adversely affecting microorganisms, aquatic plants, benthic invertebrate and/or fish (Table 10-2). In surface water, ammonia, dissolved copper, and total and dissolved nickel are considered to be COCs. In whole sediments, the COCs are considered to include: metals (chromium, copper, lead, mercury, nickel, and zinc); 18 individual PAHs; total LMW-PAHs; total HMW-PAHs; total PAHs; total PCBs; aldrin; dieldrin; BEHP; HCB; HCBD; and, TCDD TEQs. The pore-water COCs are considered to include: hydrogen sulfide; total nickel; total zinc; 1-methynaphthalene; benz(a)anthracene; and, benzo(a)pyrene.

All of these substances occurred in whole-sediment, surface-water, and/or pore-water samples from the Calcasieu Estuary at concentrations in excess of those observed in samples from reference areas and in excess of the selected benchmarks. In addition, the concentrations in the effects distribution (i.e., toxic samples) were generally higher than the concentrations in the no effects distribution (i.e., non-toxic samples) for one or more of the measurement endpoints (e.g., survival of *Ampelisca abdita* in 10-d toxicity tests). This latter evaluation was conducted to assess concordance between the chemistry and biological effects data. Many of these substances or groups of substances also accumulated in the tissues of polychaetes (*Nereis virens*) in 28-d
bioaccumulation tests and were shown to be associated with toxicity to amphipods (*Ampelisca abdita*) in toxicity identification evaluations.

### 10.4 Assessment of Risks to Aquatic-Dependent Wildlife

The risks to five groups of aquatic-dependent wildlife posed by exposure to COPCs in the Calcasieu Estuary were assessed. The receptor groups included: sediment-probing birds, carnivorous-wading birds, piscivorus birds, piscivorus mammals, and omnivorous mammals. For each receptor group, an assessment was conducted to determine if adverse effects are occurring, or are likely to be occurring, in the Calcasieu Estuary. To the extent possible, the nature, severity and areal extent of such effects were evaluated and the COPCs contributing to such effects were identified (i.e., COCs).

#### 10.4.1 Avian Community

The risks to sediment-probing birds, carnivorous-wading birds, and piscivorus birds from exposure to contaminated aquatic prey were assessed for the Calcasieu Estuary. A conservative, deterministic screening ecological risk assessment (ERA) identified AOCs and COCs in the Calcasieu Estuary (Appendix G). The COCs identified in the deterministic assessment for birds included TCDD-TEQs, selenium, mercury, total PCBs, and lead.

For each group of aquatic-dependent birds, local receptors of concern were identified. The life history and foraging behaviors of these receptors of concern were blended to
create hypothetical receptors possessing the qualities characteristic of each bird group. For example, the hypothetical receptor for piscivorus birds was based on the characteristics of the belted kingfisher, osprey, brown pelican, and Caspian, least and Forster’s terns, all of which occur in the Calcasieu Estuary area. In addition to the average-sized hypothetical receptor, a small hypothetical receptor was created to account for the higher metabolic rate, and therefore, higher exposure of smaller birds.

The probabilistic risk assessment was carried out in four steps: (1) collection, evaluation, and compilation of data; (2) exposure assessment; (3) effects assessment; and, (4) risk characterization. In the first step, relevant data on COC concentrations in prey items and sediments from the Calcasieu Estuary were collected, evaluated, and compiled. These data were then incorporated into a probabilistic exposure model calculating total daily intake of COCs for each group of aquatic-dependent birds. Monte Carlo analysis was applied to this model to account for the distribution of possible exposures. The effects characterization began with a review of the literature on effects of COCs on the survival, growth, and reproduction of aquatic-dependent birds. An appropriate effects metric was selected for each COC to be used with the results of the exposure assessment to estimate risks. The effects metrics in this assessment were expressed as a threshold range spanning sensitive and tolerant species. This range is likely to include the threshold for the receptor groups of interest. In the risk characterization step, the results of the exposure and effects characterizations were integrated to estimate the risks of each COC to each aquatic-dependent bird group in each AOC. High, indeterminate, and low risk categories were used to express the level of risk to each group of aquatic-dependent birds.

The results of the assessment for aquatic-dependent birds indicated that no areas in the Calcasieu Estuary had COCs at levels representing a high risk to the survival,
growth, or reproduction of aquatic-dependent birds. Selenium poses indeterminate risks to average-sized and small sediment-probing birds in the MCR AOC, as well as small sediment-probing birds in the UCR AOC. Small piscivorous birds in BI AOC and the reference areas also face indeterminate risks from exposure to selenium. TCDD-TEQs pose indeterminate risks to small piscivorous birds in the AOCs and reference areas. Mercury and total PCBs pose indeterminate risks to small piscivorous birds in BI AOC. Lead poses indeterminate risks to average-sized and small sediment-probing birds in the AOCs and reference areas. The risk of aquatic-dependent birds experiencing adverse effects from COCs is low for the remaining scenarios. Accordingly, selenium, TCDD-TEQs, mercury, total PCBs, and lead were identified as COCs in the Calcasieu Estuary for aquatic-dependent birds.

### 10.4.2 Mammalian Community

The risks to piscivorous and omnivorous mammals from exposure to contaminated aquatic prey were assessed for the Calcasieu Estuary. A conservative, deterministic screening ERA identified AOCs and COCs in the Calcasieu Estuary (Appendix G). The COCs identified in the deterministic assessment for mammals included TCDD-TEQs, selenium, mercury, and PCBs.

For each group of aquatic-dependent mammals, local receptors of concern were identified. The life history and foraging behaviors of these receptors of concern were blended to create hypothetical receptors possessing the qualities characteristic of each mammal group. For example, the hypothetical receptor for omnivorous mammals was based on the characteristics of the raccoon, marsh rice rat and muskrat, all of which occur in the Calcasieu Estuary area. In addition to the average-sized hypothetical
receptor, a small hypothetical receptor was created to account for the higher metabolic rate, and therefore, higher exposure of smaller mammals.

The probabilistic risk assessment was carried out in four steps: (1) collection, evaluation, and compilation of data; (2) exposure assessment; (3) effects assessment; and, (4) risk characterization. In the first step, relevant data on COC concentrations in prey items from the Calcasieu Estuary were collected, evaluated, and compiled. These data were then incorporated into a probabilistic exposure model calculating total daily intake of COCs for each group of aquatic-dependent mammals. Monte Carlo analysis was applied to this model to account for the distribution of possible exposures. The effects characterization began with a review of the literature on effects of COCs on the survival, growth, and reproduction of aquatic-dependent mammals. An appropriate effects metric was selected for each COC to be used with the results of the exposure assessment to estimate risks. The effects metrics in this assessment were expressed as benchmarks and as dose-response curves. In the risk characterization step, the results of the exposure and effects characterizations were integrated to estimate the risks of each COC to each aquatic-dependent mammal group in each AOC. High, indeterminate, and low risk categories were used to express the level of risk to each group of aquatic-dependent mammals.

The risk characterization results showed that there is a low probability that exposure to methylmercury, TCDD-TEQs and selenium will cause adverse effects to piscivorus and omnivorous mammals foraging in the Calcasieu Estuary. There is also a low probability of adverse effects to omnivorous mammals exposed to total PCBs. However, there is a high risk that total PCBs are causing adverse effects to average-sized and small piscivorus mammals inhabiting the Bayou d’Inde AOC of the Calcasieu Estuary. Based on the deterministic ecological risk assessment, total PCBs
pose low risks to piscivorus mammals in other parts of the estuary. Accordingly, total PCBs were identified as COCs in the Calcasieu Estuary for aquatic-dependent mammals.

10.5 Conclusions

In accordance with USEPA (1997a) guidance, the BERA of the Calcasieu Estuary was conducted following an eight-step process (see Appendix A1). The first two of these steps (i.e., the SERA) were completed in 1999 (CDM 1999). The results of the final six steps of the process are described in this document and the RI report (CDM 2002b). A companion document describes the risks to human health associated with exposure to COPCs in the Calcasieu Estuary (CDM 2002a).

The results of this assessment indicated that the presence of COCs in surface water, whole sediments, pore water, and/or the tissues of aquatic organisms poses a risk to ecological receptors. Exposure to contaminated sediment and pore water pose risks to microorganisms, aquatic plants, benthic invertebrates, and/or fish throughout portions of the Calcasieu Estuary. Consumption of contaminated fish and shellfish also poses risks to aquatic-dependent wildlife, including sediment-probing birds, carnivorous-wading birds, piscivorus birds, omnivorous mammals, and/or piscivorus mammals. Collectively, the information compiled, evaluated, and analyzed to support the BERA provides a weight-of-evidence that clearly demonstrates that the presence of ammonia; hydrogen sulfide; metals (chromium, copper, lead, mercury, nickel, and zinc); PAHs (1,1-biphenyl, 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, total LMW-PAHs,
benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total HMW-PAHs, and total PAHs); PCBs (total PCBs), chlorinated benzenes (HCB and HCBD); phthalates (BEHP); OC pesticides (aldrin and dieldrin) and PCDDs and, PCDFs (total 2,3,7,8-TCDD TEQs) in environmental media poses unacceptable risks to ecological receptors. The information contained in this BERA and companion documents (i.e., CDM 2002a; 2002b) is intended to support decisions regarding the need for remedial actions within the Calcasieu Estuary.
Chapter 11. References


Olson, O.E. 1986. Selenium toxicity in animals with emphasis on man. American College of Toxicology 5:45-69.


