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

Executive Summary

Prepared For:

CDM Federal Programs Corporation
600 North Pearl Street, Suite 2170
Dallas, Texas 75201

Under Contract To:

U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, Texas 75202

Prepared – September 2002 – By:

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In Association With:

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Executive Summary

1.0 Introduction

The Calcasieu Estuary is located in the vicinity of Lake Charles in Calcasieu Parish, Louisiana (LA; Figure ES-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 ES-2). 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 ES-3). 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 ES-4 and ES-5). 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 ES-6). 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 ES-7). 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).

2.0 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).

3.0 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 ES-8);
- Assessment of the effects of COPCs on aquatic organisms and aquatic-dependent wildlife (i.e., effects assessment; Figure ES-9); and,
- Characterization of risks to the aquatic organisms and aquatic-dependent wildlife (i.e., risk characterization; Figure ES-10).

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, carnivores 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 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 ES-11). 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).

4.0 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.

4.1 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 baterium, *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 ES-1). Of the three AOCs considered, the risks to the microbial community were highest in Bayou d'Inde (Figures ES-12 to ES-16). 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 ES-13). 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 ES-12 to ES-15). Risks to the microbial community are generally low throughout the reference areas with the exception of certain portions of Bayou Choupique (Figure ES-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$\pm$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].

4.2 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 ES-2; Figures ES-12 to ES-16). 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 ES-2). Of the three AOCs considered, the risks to the aquatic plant community were highest in Bayou d'Inde (Figure ES-13). 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 ES-2; Figures ES-12 to ES-15). 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 ES-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 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.

4.3 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 ES-12 to ES-16). 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 ES-3). 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 ES-13). 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 ES-3; Figures ES-12 to ES-15). Risks to the benthic invertebrate community are generally low throughout the reference areas (Figure ES-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 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 ES-4). 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 ES-4; 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 ES-4). 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)].

4.4 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 ES-12 to ES-16). 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 ES-5). 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 ES-5; Figures ES-12 to ES-15). Risks to the fish community are generally low throughout the reference areas (Figure ES-16).

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).

4.5 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 ES-17 to ES-21 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 ES-6). 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 ES-6). Among the three AOCs, the highest risks to aquatic receptors were evident in Bayou d'Inde (Table ES-6). 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 ES-5) to 72% of the locations sampled for aquatic plants (Table ES-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 ES-12 to ES-16. 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 ES-6). 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 ES-6). 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 ES-17).

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 ES-6). 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 ES-6). 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 ES-18).

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 ES-6). 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 ES-6). 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 ES-19 and ES-20).

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 ES-6). All of the locations sampled were classified as posing low risks to aquatic receptors (Figure ES-21).

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 ES-7). 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-methlynaphthalene; 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.

5.0 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).

5.1 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 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 behaviours 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 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, carnivorous wading, and piscivorus birds exposed to lead and 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, carnivorous wading, and piscivorus birds, except for Bayou d'Inde where it poses indeterminate risks to small piscivorus birds. Accordingly, selenium, lead, mercury, and TCDD-TEQs were identified as COCs in the Calcasieu Estuary for aquatic-dependent birds.

5.2 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 behaviours 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.

6.0 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, 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.

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