LOUISIANA'S HIGHLY DIVERSIFIED OIL SPILL RESEARCH PROGRAM: 75 PROJECTS AND STILL COUNTING

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ABSTRACT

Immediately following passage of the Oil Pollution Act of 1990, Louisiana lawmaker=s enacted legislation that annually provides $551,300 to support oil spill research. Consequently, since the fall of 1993 the program has granted more than 90 awards in support of 75 projects; $46,925 is the average award. A generic summary of these projects includes: a CD-based GIS; in-situ burning; phytoremediation, remediation and restoration in wetlands and uplands; pipeline analysis and mapping; oil spill risk on the Mississippi River; oceanic and atmospheric conditions off the Mississippi delta; Louisiana seabird colonies; wave-current online information system; estuarine trajectory analysis; boat ramp and launch site inventory and other projects are helping define where the Louisiana Applied and Educational Oil Spill Research and Development Program (OSRADP) is going in the future. All of these efforts focus on a common goal: oil spill prevention and cleanup in a scientifically-based efficient and practical manner using the best techniques available, with approval from the regulatory community to meet the integral demands of an oil spill. The completed projects can be reviewed on the Internet at www.osradp.lsu.edu.

INTRODUCTION

In the beginning of the 20th century, oil entrepreneurs= speculative approach to exploration and development helped establish the United States= energy future. In 1901, W. Scott Heywood drilled Louisiana=s first producing oil wellCin September 2001, the industry celebrated its 100th anniversary. While this well was located near the community of Jennings in south Louisiana, north Louisiana was more promising. In 1904, the search moved to Caddo Lake in the northwest corner of the state. It was around the lake=s perimeter where some of the first primitive water-oriented exploration and development technologies were tried and perfected. By early 1911, the world=s first oil well over inland waters was completed at Caddo Lake. Eventually, piling-supported-platform drilling soon became common from the Great Lakes to Venezuela.

These new exploration methods would henceforth be required to cope with south Louisiana=s swamps, marshes and, eventually, offshore. During the exploration phase, crews often hit high-pressure gas pockets that caused frequent blowouts. These unfortunate events were part of the business as well as part of the many dangers associated with the drilling industry. The technology to prevent these disasters was in its infancy. Therefore, the derricks and machinery were destroyed and the resulting fires often burned for years. It was a hazardous business, with both financial and life-threatening risks. Oil was being exploited rapidly. To those working in the industry, it appeared exploration crews were everywhere. Oil was, in fact, being produced so fast large-earthen impoundments, with a carrying capacity of up to seven million barrels, were often used to store the product.

With the exploration and production successes in north Louisiana, oilmen ignored south Louisiana=s swamps and marshes. This landscape was, at best, difficult to work in and considered by many as worthless and not fit for human habitation. The oil industry changed that perspective quickly. Once seismic crews began to survey the area, they brought attention to the hydrocarbon reserves locked in the subsurface stratigraphic traps that underlie the surface topography.

Wetland exploration, however, required new and different exploration techniques. Boats and barges were essential. Oil companies needed port facilities to aid and support their marine operations; yet, none existed. It was not until the 1930s that the necessary ancillary support facilities were sufficiently developed to make extensive wetland exploration practical. To approach potential drilling sites, suction (or bucket dredges) cut navigable channels through the region=s alluvial wetlands.

The completed canals guaranteed lease access. However, a major problem remained: no one had yet devised an efficient, mobile drilling platform. Companies could move to drilling sites by boat and house their crews on barges, but did not have a cost-effective drilling platform. The industry needed a stable, shallow-draft drilling platform (1). The Texas Company (Texaco), while searching patent records, discovered the plans for a submersible drilling barge. They obtained the rights to the design, built the structure and thus, revolutionized the industry=s approach to wetland exploration and development. The search for marketable hydrocarbons in south Louisiana accelerated as a result of this improved drilling equipment. Quickly, new fields were added to the state=s inventory and oil entrepreneurs began to eye the Gulf of Mexico as a potential site for new Afinds.@

In the 1930s, the industry left the safe confines of land for the harsh and untested aquatic environments of the Gulf of Mexico. This voyage has brought the industry to the edge of the 10,000-foot water depth. The odyssey begins in 1933 when the first attempt was made to drill a well in the Gulf of Mexico. This endeavor from a piling-supported platform was in 12 feet of water about 3,000

feet off Louisiana=s western coastline. It was a dry hole, but essentially gave birth to the offshore industry (2, 3, 4). The following nine years brought a series of steps into deeper water, further and further from the shoreline. It was not until 1947 that a consortium led by Kerr-McGee, at that time an Oklahoma independent, (along with Phillips Petroleum Company and the Stanolind Oil and Gas Company) successfully completed a well out-of-sight of landC10.5 miles from shore (5, 3).

This event completed the land, marsh/swamp, and offshore exploration history of Louisiana's petroleum industry (6, 7). The state became the nation's boiler room. Oil was, without question, Louisiana's economic mainstay. Within seven years after Kerr-McGee=s initial discovery, oil companies extended the offshore frontier to 50 miles and were hitting hydrocarbons on 25% of the exploration wells drilled. More than 40 offshore rigs were in operation by 1955. Consequently, the modern offshore oil industry was born during the 1940s with the industry focusing their efforts from the shore to a depth of 1,500 feet. Today, this area is no longer regarded as an exploration frontier. Even so, this shelf zone has yielded 40 billion barrels of fossil fuel from more than 1,000 fields.

Although production numbers declined in the 1980s and early 1990s, the use of new technologies on and offshore suggest Louisiana was poised for another boomCa forbidden word, loaded with lessons painfully learned in the 1980s (8). A new mantra takes its place: Acautious optimism.@ Regardless, this hydrocarbon province is hardly dead; it is alive and well and the companies involved are operating with a new lean attitude. The 1980s downturn was a powerful learning experience (8). The industry, for nearly a decade, had been in the doldrums; a renaissance occurred with the remarkable resurgence of exploration and production activity in the Gulf of Mexico. The lure of large finds in deepwater (defined by the federal government as 656 feet, with the industry defining the term as water greater than 1,500 feet) coupled with new incentives and improved oil prices, helped generate a record number of bids at the April 1996 Federal auction of leases within the central Gulf of Mexico. There were 1,381 bids on 924 lease blocks (five years earlier producers were interested in only 151 blocks); 442 of the properties were in water deeper than 1,300 feet. The sale resulted in $520.9 million in bids and represented the first sale involving deepwater tracts eligible for consideration under the Federal government=s Deepwater Royalty Relief Act (9). After completion of a two-phase evaluation process, $511 million was added to the Federal treasury. The oil and gas industry promised to pay $825 million to explore for oil and gas on 1,032 tracts in March of 1997. That was the most money garnered from a lease sale since 1985. Between 1943 and 1998, 8,395 leases were issued under federal supervision. These leases involved more than 43 million acres.

Industry leaders were expressing a new optimism that was manifested in the drilling activity in the northern Gulf of Mexico. Drilling is now at a frantic pace, breaking decade-old records, Athe finding rate surpassed all expectations@ (10:36). A new euphoria is affecting the Gulf of Mexico with the discovery of an extraordinary 10 billion barrels of new reserves. Led by a deepwater and ultra-deepwater (water depths greater than 5,000 feet) exploration and production programs pioneered by Shell Offshore, subsalt programs headed by British Petroleum (BP) and Phillips and a shallow water/transition zone program being championed by independents, the Gulf of Mexico is defying all predictions of its demise. Blockbuster discoveries have attracted considerable attention.

It is clear a new oil and gas province is being carved from the deepwater of the Gulf of Mexico. Deepwater is America=s new frontier. Very high rates of production by prolific deepwater wells have convinced operators that this area of the Gulf of Mexico is a sound economical investment. It has been estimated than one in every four wells drilled has found recoverable hydrocarbons. Between 4 and 5 billion barrels of oil have been discovered. Some estimate the full potential of the deepwater Aplay@ may go as high as 25 billion barrels.

The vulnerability of Louisiana=s coast from an oil spill derived from the Outer Continental Shelf (OCS) is of great concern. Of more than 4,000 active production platforms located on the country=s OCS, less than 50 are not in the Gulf of Mexico (11, 12). The vast majority of these structures are located off Louisiana=s coast. Although the spill potential is great, the actual quantity of oil spilled from these operations is relatively small. Oil production from OCS wells was more than 7.1 billion barrels between 1971 and 1991. During this 20-year period, oil spills accounted for 108,000 barrels. This number represents .0015% of what was produced, which is roughly equivalent to spilling one forth of a teaspoon of gasoline from a 20-gal.fuel tank (13, 14). In comparison, Bedinger *et al.* (15) estimated the Mississippi River might add more than 151,000 barrels of oil to the Gulf annually. Regardless, any spill is a concern.

In the 1990s, onshore sites B along with the western and central Gulf of Mexico B have become the hottest drilling sites in the nation (9). Three-dimensional seismic geology and improvements in drilling technology dramatically increased the chances of finding oil and/or natural gas. These innovations, coupled with new state incentives, lowered the costs to find hydrocarbon reserves and improved the probability of discovering new reserves. With little to no fanfare, indeed in relative anonymity, the industry has been reborn. With this renewed activity, the chance of an accidental discharge of oil is increased and the state=s valuable estuarine/marine environment is particularly vulnerable. Louisiana=s onshore and offshore production, coupled with the quantity of oil transported through the state=s ports, waterways and pipelines, also contribute to the danger.

Unlike the Agushers@ that characterized the industry=s early history, wild wells are rare today. At the same time, spills do occur. The most frequent spill event today is small and measured in tens of barrels, instead of thousands; nevertheless, they are important. Reactions to oil spills range from major international events, such as the *Nakhodka* and *New Carissa* spills off the coast of Japan and Oregon respectively, to the development of regional contingency plans and strategies. More than 1500 of these plans are in the library of the Louisiana Oil Spill Coordinator.

If a spill occurs, the Louisiana Oil Spill Coordinator and his staff are responsible for oil spill response. In general more than 3,000 oil spills annually are reported to the Louisiana Oil Spill Coordinator=s Office. Most of these spill events are extremely small. Even so, to assist in developing effective oil spill strategies based on the best research and development techniques available in the state, the Oil Spill Coordinator can utilize information derived from the state=s Oil spill Research and Development Program (16).

THE LOUISIANA APPLIED AND EDUCATIONAL OIL SPILL RESEARCH AND DEVELOPMENT PROGRAM (OSRADP)

Various methods are used to combat oil spills. Yet the common lesson learned from most spills is that the best combat strategy is to avoid the spill in the first place. Once sizeable amounts of oil are spilled into the coastal/marine environment, cleanup is difficult and costly. Mechanical spill cleanup, involving containment booms and oil recovery skimmers, is one of the primary oil spill response methods. Although sometimes controversial, dispersants, *in-situ* burning and bioremediation can also be used. Of particular concern is that many of the cleanup techniques and/or activities sometimes can prove more damaging than not cleaning up the spill. This is particularly true in Louisiana=s wetland environments. In some cases, shovels can be used; yet at the same time, this low technology clean up tool may be quite harmful to the environment. Therefore, in order to minimize negative impacts, monitoring the spill rather than trying to clean it up could prove to be most effective;

phytoremediation may be the best clean up technique. In addition to phytoremediation research, more than 40 projects have been funded through the OSRADP to look at less intrusive clean up alternatives. These endeavors are leading to viable options that are cost-effective alternatives to traditional clean up procedures.

The objective of projects funded through the OSRADP is to deal with the broad range of problems associated with oil spills and use this information in the oil spill response, prevention, and training process. These strategies involve understanding the ecological risks posed by particular oil spills, socioeconomic impacts, response training, clean up procedures, and using this information in decision or policy making purposes, as well as educating interested parties. As a result, a dedicated commitment exists to address a wide variety of oil spill issues.

Selecting OSRADP Funded Research Projects

The OSRADP recognized from the beginning it takes time to plan, design, fund and implement targeted major research and development initiatives. A one to two year Astart up@ may seem a long time for some industry stakeholders, but in government this time frame would be equated with a Afast-track@ schedule.

After a highly organized series of meetings and mass mailings, pre-proposals are submitted to the program in October for evaluation by the OSRADP=s Proposal Review Board B a seven member board made up of individuals from the petroleum industry, government, academics and the public-at-large. No projects are funded without being reviewed by the Proposal Review Board as a pre-proposal. Unsolicited proposals are not accepted. Pre-proposals are written in response to the OSRADP=s guidelines for submission, which include the program=s research agenda. A nine member Advisory Panel B made up of individuals representing the petroleum industry, state and federal government, and academics B set the agenda. Although the program does not want to stifle the imagination of the research community, general areas of concern include: dispersants, *in-situ* burning, chemical analysis, physical and chemical cleanup techniques in inland waters, vegetated woodlands, and uplands; information systems, remote sensing and geographic information systems (GIS), and training and public education.

Each submitted pre-proposal undergoes a Ablind@ review B no scientist(s) name or affiliated university can appear on the pre-proposal. After this review, Board members= individual rankings are submitted to the OSRADP Administrator to be tabulated and forwarded to the Oil Spill Coordinator. Once the pre-proposals are ranked, the Board is informed of the rankings to see if further evaluations are necessary. After this evaluation, the Board requests full proposals from those projects that successfully meet the program=s criteria. Pre-proposals are evaluated on: (1) their direct application to Louisiana and its environment; (2) their potential for widespread and demonstrated field application; and (3) their ability to demonstrate an increased, measurable, and enhanced response efficiency. Education-related pre-proposals are assessed based on their general criticality to the program=s goals and objectives versus their likelihood of success. This in-depth review determines the researchers that are asked to submit full proposals.

Full proposals are due in early January from the 19 eligible public colleges and universities. Once all proposals are carefully critiqued, ranked, and tabulated all principal investigators are invited to discuss their projects informally with the Proposal Review Board. This meeting, coupled with the tabulated rankings, determines the projects that are funded. Awards are initiated on May 1st with a completion date of May 31st the following year. This 13-month time line provides for a one-month start up and 12 months of intense research activity. One year after submission of final deliverables, and after a thorough and complete editing, all projects are distributed together on a single CD-ROM.

Selected Abstracts and Bibliography of Oil Spill Research

To help foster the research effort, the OSRADP has compiled an electronic bibliography from a key word list that best fits the goals and objectives of the program. Consequently, some of the words and phrases used may apply only to oil spill issues in Louisiana. Forty-three databases were searched and more than 4,000 citations were downloaded. The *Louisiana Applied and Educational Oil Spill Research and Development Program, Deliverables 1999-2000 and Selected Abstracts and Bibliography of International Oil Spill Research, 2001* CD-Rom is a Aliving@ document. It serves as a conduit to oil spill information and includes citations obtained from a detailed search of articles listed in the *1995 International Oil Spill Conference*: *Proceedings*, Environmental Canada=s publication *Emergencies Science Division, Reference Section, February 1994* and all references in the *Proceedings of the Seventeenth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*. Duplicates were deleted. In this document some citations are accompanied by annotations and/or abstracts. Currently, the OSRADP staff is editing and Acleaning-up@ more than 800 new references obtained from a detailed search of more than 80 databases. These citations will be added to the next edition of the program=s deliverable CD.

FUNDED PROJECTS

The program=s research initiatives are divided into four categories: (1) spill of opportunity; (2) education, training and public awareness; (3) remote sensing and mapping; and (4) spill response cleanup and harmful ecological consequences. Each project=s scientific merit is based on the simple question: Can the results be implemented in a spill event? To be a practical field tool, many of these projects need approval from the regulatory community. In this regard, efforts are underway to increase the collective awareness of the results of these research initiatives.

Spill-of-Opportunity

Spill-of-opportunity funds are used to apply and evaluate new and/or experimental technology to enhance the recovery of spilled oil or to test experimental cleanup techniques in a field situation. The program is not interested in monitoring, although some monitoring may be necessary to prove results. Therefore, the OSRADP has supported projects that can benefit from a field event. Four projects have used these funds:

1. *AApplication of Microtox™ assay to establish and evaluate the efficacy of in-situ burning of oiled marshes@* (Dr. Edward Overton, Phone: 225-578-8634, e-mail: ebovert@lsu.edu, Louisiana State University [LSU]);
2. *AOil spill in Lake Barre: economic and social consequences@* (Dr. Allan Pulsipher, Phone: 225-578-4550, e-mail: agpul@lsu.edu, LSU);
3. *APotential for enhanced anaerobic BTEX degradation at the Blind River spill@* (Dr. John Pardue, Phone: 225-578-8661, e-mail: jpardue@lsu.edu, LSU); and
4. *AFollow-up surveys of inland sites where in-situ burning was used as a cleanup method,@* (Dr. Edward Overton).

An oil spill at Louisiana=s Rockefeller Refuge presented a rare opportunity to investigate *in-situ* burning as a mitigation technique in a coastal marsh environment. To augment standard monitoring techniques at this site, scientists integrated the MicrotoxJ system as a screening tool for residual oil toxicity. The research effort focused on the appropriateness of the MicrotoxJ assay to establish and evaluate the efficacy of oil spill cleanup and response activities, and specifically, *in-situ* burning in a marsh environment. The ability of the MicrotoxJ system to quantify change related directly to the presence of residual oil pollution was limited by a lack of assay sensitivity relative to analytical chemistry. In addition, the presence of background toxicity derived from other anthropogenic and

natural biogenic sources and storage effects on sample integrity were also critical. Consequently, the MicrotoxJ assay of solvent-extracted marsh sediment samples provided very little data to assess efficacy or recovery after the prescribed *in-situ* burn.

The socio-economic study of the Lake Barre incident concluded that the spill=s short-term social and economic consequences were modest when measured with the available data on numbers of people employed or as reflected in the interviews conducted with businesses, public officials, and area residents. There are concerns about negative economic and social consequences in the long term, particularly if fishing, shrimping or oystering were to suffer or were to be perceived as having suffered as a result of this spill. However, no persuasive evidence exists at this time to support or refute such concerns.

In the Blind River gasoline incident of June 1996, the research team determined that sediments from this swamp site appeared to have a relatively low ability to naturally attenuate gasoline, especially the BTEX (benzene, toluene, ethyl benzene and xylene) components. Further, the natural attenuation of gas components of these sediments is limited with only toluene exhibiting degradation. Sulfate amendments were successful in promoting faster degradation rates and promoted degradation over a broader spectrum of compounds. Limited success was observed with nitrate amendments and none with iron. Sulfur reduction, in fact, appears to be the primary oxidation pathway under which the BTEX and other gas components degrade. The findings indicate further studies are necessary to fully develop the use of sulfate to promote gasoline degradation in fresh-water habitats.

In 1998, Research Planning Incorporated (RPI) conducted a literature compilation and review of data on the environmental effects of *in-situ* burning of inland and upland oil spills for the American Petroleum Institute (API). There are relatively few documented case histories (only 31 were found) on the medium- and long-term recovery rates of habitats where *in-situ* burning was used. LSU=s Institute for Environmental Studies, in collaboration with the API-funded RPI project, is in the process of conducting chemical characterization studies of up to 30 sediment samples collected from five sites determined by RPI to be relevant. This is an on-going project that will not be completed until mid-2002.

Education, Training, and Public Awareness

Education, training, and public awareness have evolved into important components in the OSRADP=s mission. Public perception often far exceeds reality. Originally, the program focused on educating middle and senior high school students about earth sciences and the oil and gas industry through the *AOil spill awareness through geoscience education (OSAGE)@* CD-ROM and *AOil spill awareness through geoscience education (OSAGE): an overview of its development, implementation, and impact@* (Dr. Gary Stringer, Phone: 318-342-1893, e-mail: gestringer@alpha.nlu.edu, University of Louisiana at Monroe). The curriculum associated with the CD is based on national science reform efforts and consists of four major concepts: (1) What is oil, and why is it important? (2) Why and how is oil transported? (3) What are the methods for the clean up of oil spills? And (4) What are the environmental and economic ramifications of oil spills? The CD evolved from an original project that focused on concepts, activities and resources into a multimedia-oriented educational tool. Nearly 10,000 copies of the CD have been systematically distributed to appropriate science educators throughout the state. The CD has the endorsement of the State Department of Education and the Louisiana Science Teachers Association. Both are encouraging classroom instructors to incorporate the CD into their earth science classes. As part of Louisiana=s Oil Centennial, the oil and gas industry is underwriting production of at least 5,000 additional copies of this CD.

Like OSAGE, the program=s Proposal Review Board felt that the *Louisiana GIS CD* (see Remote Sensing and Mapping section for a discussion of this product) needed to be formatted as an educational tool. Consequently, we are in the process of finalizing our efforts to put the *Louisiana Oil Spill Contingency Plan Map CD* in all of the state=s middle and senior high schools. This is an exciting project and one that has the potential of familiarizing students with some of the newest computer technology. To our knowledge, this project is a first in the nation. Dr. Debra Dardis (Phone: 504-549-3851, e-mail: ddardis@selu.edu, Southeastern Louisiana University [SLU]) developed an *AInterdisciplinary exploration of Louisiana using the OSRADP=s satellite imagery.@* This multi-disciplinary curriculum involves mathematics, science, social studies and language arts. The curriculum and satellite tour is being reviewed by a number of curriculum specialists and will be introduced into the state=s public schools by the end of 2001.

In order to guarantee widespread utilization of this product several members of the Louisiana Science Teachers Association are involved in the project. In addition, through the generous donations of more than a dozen agencies, private foundations, and oil and gas companies 10,000 copies of the two CD-ROM sets have been incorporated into 1,000 binders. Each school will receive 10 copies of the CD. More importantly, this effort has shown how industry, working in tandem with the academic community, can produce a product that meets their immediate needs. By modifying this oil-spill product, the curriculum team has added a significant element to the state=s middle and senior high schools environmental curriculum.

In addition, the Oil Spill Coordinator=s office has developed a web-accessible database that includes 72 data bundles. Using Internet Explorer, go to http://atlas.lsu.edu, which will bring up the Louisiana statewide GIS. Along with more than 60 overlays, there are 3,211 aerial photographs available on this site at a resolution of one meter. About 90% of the entire state is now covered by digital ortho-quarter-quadrangles. These are available through the atlas web site. If help is required accessing this material, the atlas home page (http://atlas.lsu.edu) has detailed instructions on what one needs to download, unzip, and how to view the compressed map image.

With a state that has five of the nation=s ten top fishing ports, the diesel and gasoline-powered fishing fleet exceeds 6,000 vessels. With each vessel representing a potential oil spill, used oil disposal has become a major concern. *APotential impact of used oil recycling in Louisiana=s coastal fishing communities@* (Rodney Adams, Phone: 225-578-6343, e-mail: radams@lsu.edu, LSU) collected information on the quantity of used oil generated annually by coastal fishermen. Current disposal practices and attitudes toward recycling waste engine oil were also assessed. The study revealed approximately 250,000 gallons of waste oil is generated by the commercial fishing industry annually. This large figure represents more than 50,000 disposal events. On a parish (county) basis, survey respondents indicated a recycling rate that varied from 50% to 100%. Based on environmental stewardship concerns, more than 95% expressed a positive attitude toward recycling. Three percent felt recycling was important only because of penalties involved; only 1.5% felt recycling was not important. To call attention to the positive benefits of recycling, a poster *Small Spills Add Up: Recycle used Engine Oil Protect Your Fisheries Resources*, was distributed to more than 1,000 entities, including more than 750 schools.

Since the Mississippi River is a major transportation corridor for the movement of a wide array of petroleum or petroleum-based products, a series of projects involving the river were funded:

1. *AModeling the Mississippi: oil spill risk on Louisiana=s largest river@* (Dr. Craig Forsyth, Phone: 337-482-5372, e-mail: cjf5714@louisiana.edu, University of Louisiana at Lafayette [ULL]);

2. *AModeling the Mississippi: transportation risks on the nation=s busiest waterway@* (Dr. Robert Gramling, Phone: 337-482-5375, e-mail: gramling@louisiana.edu, ULL);
3. *AA test and refinement of a risk model for vessel traffic on the lower Mississippi River A* (Dr. Robert Gramling);
4. *AA risk model for vessel traffic on the lower Mississippi River@* (Dr. Robert Gramling); and
5. *AOil resource atlas for Louisiana: creating and maintaining a focused baseline for oil spill response@* (Dr. Robert Gramling).

In these projects, tankers (1994) and barges (1995) were tracked utilizing maritime experts, previous research, and existing databases to evaluate and assess risk factors on the Mississippi. Vessel traffic data and geographic risk location information were combined to produce relative risk scores for each mile (km) along the river. The analysis extends from the mouth of Southwest Pass to the termination of shipping at the U.S. 190 Bridge in Baton Rouge, Louisiana.

Many river pilots consider the most dangerous river situation to be a blind turn, which leads into an anchorage. Other combinations (e.g. a floating anchorage near rafts, barges, dangerous currents, or narrow channels) also affect the risk associated with particular portions of the river. It is important, therefore, to assess accident risk for various locations along the lower Mississippi River in order to aid in the development of realistic risk reduction, contingency, and response plans. Since this is the first systematic model of river traffic to assess accident risks, training is crucial. Awareness of potential risk sites can considerably reduce accidents and thereby reduce insurance costs.

In order to complete this analysis the University of Louisiana at Lafayette (ULL) team=s final deliverable will be a database of oil spills on and off the coast of Louisiana between 1992 and 1999. When combined with information that the Oil Spill Coordinator=s office has been collecting since 2000, this database will provide a continuously updated coverage of oil spills from 1992. For each spill, a variety of information will be included, such as the latitude and longitude coordinates, the size of the spill, the substance spilled (e.g. crude oil, diesel fuel, etc.), the cause of the spill, and a description of the physical location. This information will be available on the *2002 Deliverable CD-Rom*. This ULL team currently has a project: *AHistorical analysis of oil spills in Louisiana@* (Dr. George Wooddell, Phone: 337-482-6044, e-mail: gpw4993@louisiana.edu, ULL) that will provide, when completed in 2002, an analysis of the distribution and frequency of oil spills that have been recently reported to official sources in the State of Louisiana. The database that contains the reported spills and an historical analysis of major oil spills during the latter half of the 20th century will be included in this study. When completed, the state will have a powerful planning tool for oil spill prevention and response. To our knowledge, no other state has such a comprehensive analysis of spill patterns that will be integrated into a GIS.

Following the spill of potentially toxic materials into a river, rapid decisions must be made in order to protect human health and natural resources. For example, municipal and industrial water intakes must often be shut down; water storage for drinking and fire protection may also be limited. In addition, water control structures may need to be operated and other protective measures taken to minimize damage to infrastructure and ecosystems. In order to support this decision making process, knowledge of the arrival and passage times of waterborne contaminants is vital. Consequently, a river time-of-travel model has been developed for the Mississippi River. *AR-TOT river time-of-travel model: computer program extension, enhancement, distribution, and training@* and *AEmergency management river oil spill models@* (Dr. Ehab Meselhe, Phone: 337-482-5802, e-mail: meselhe@louisiana.edu, ULL) are tools that can predict a spill=s time of arrival and duration of passage. Additionally, if the quantity of material spilled is known, or estimated, the model predicts

peak concentrations at any downstream location and is sufficiently accurate for most spill monitoring and risk management requirements. Further, it is computationally simple enough to be applied in actual spill management events. This model has been used for spill contingency planning; moreover, seminars and short courses are available. These sessions are designed to allow those that work in the petrochemical plants within the Mississippi River=s industrial corridor to learn how to use and apply this model in their various management plans.

The lower Mississippi River port is one of the largest port complexes in the world. Approximately, 7,000 deep-sea merchant vessels enter the river each year - 19 a day. In addition, the world=s highest concentration of oil and gas drilling rigs is found on the continental shelf and slope off Louisiana=s coast. As a consequence, the delta and adjacent coastal areas are at risk from the transport or production of oil. The *APredictability of oceanic and atmospheric conditions off the Mississippi delta: a field manual@* (Dr. Nan Walker, Phone: 225-578-5331, e-mail: nwalke1@lsu.edu, LSU) project synthesized oceanographic and atmospheric information into a manual. Using the advanced very-high-resolution radiometer (AVHRR) satellite information (available at LSU) a model was created that can assist decision makers in predicting oil spill movement near the Mississippi River delta.

Predicting spilled oil movements is a difficult task, particularly near river outflows where currents are often variable and complex. Circulation patterns around the Mississippi delta are complicated further by the land=s protrusion into the Gulf of Mexico and the area=s proximity to deep ocean currents. This report summarizes information on frontal location, frontal configuration and circulation patterns under various scenarios of river discharge and wind history. The data presented, therefore, demonstrates that surface circulation in the Mississippi delta region is complex and that surface currents are relatively strong. Even so, if a spill occurs, conceptual models of surface circulation and probable areas at risk from oiling under various wind conditions are presented to assist decision makers to assist in the problem solving process.

AA legal guide of Louisiana=s oil spill prevention and response act, regulations and associated laws@ (Erinn Neyrey, Phone: 225-578-5932, e-mail: eneyrey@lsu.edu, LSU) was completed in May 2001. A limited number of copies are available of this two-volume document. This guide has been written for a broad audience, encompassing professionals in the field, as well as others that may be affected by the laws and accompanying regulation. The guide reviews the statutes, case law, regulations, and natural resource damage assessment requirements, associated restoration programs, and identify the numerous agencies and agency programs that may be involved in an oil spill event. It is designed to be a timesaving resource and reference book that is user-friendly and up-to-date, by compiling existing program information and materials, as well as reviewing any new legislation, case law and regulatory provisions recently enacted. It is hoped that all interested parties can incorporate this material by late 2002 into a CD-ROM to facilitate its easy use.

In addition to these educational endeavors, Louisiana=s Oil Spill Coordinator (LOSCO) sponsors the Oil Spill Response Management Training Program. Students from the public and private sectors are taught the basics of response management in two-day classes. Individuals under contract to LOSCO teach these once a month at various locations in Louisiana. An interactive format is used to demonstrate principles that strengthen the Louisiana=s response capability. By interconnecting public as well as private sectors, the class serves as a model for the possibilities of response during an actual spill event. All individuals within the state can be affected by a spill, thus all should be involved and included in the response process.

Remote Sensing and Mapping

Oil and/or gas are produced in every parish in Louisiana involving at least 230,000 well (approximately 30,000 are in production). Each well, along with their ancillary support services, represents a potential spill sites. Through seminars, and other meetings with oil industry officials, it was clear the industry needed an up-to-date map. To fill this void, the Oil Spill Coordinator contracted research scientists at LSU to produce the *Louisiana Oil Spill Contingency Plan Map*. This product is designed to provide a document for oil spill planning and response. The map was developed using satellite imagery to provide a complete view of environmental and land-cover conditions. Since Louisiana has experienced significant land change in the past 40 years, most available maps are obsolete, especially those of coastal areas where maximum land loss is measured at more than 64.7 km^2/yr (25 mi^2/yr).

The *Contingency Plan Map* is a multi-color lithograph at a scale of 1:500,000. In addition, it is digitally maintained in a GIS at the resolution of the source data. To improve the map=s distribution, it is available on a CD-ROM with appropriate GIS overlays on the Internet. Consequently, for strategic planning, any area in the state can be printed at larger scales. The original product is a seamless satellite image at a resolution of 30 m (115.8 ft). A new version was released in 1999 that runs on Windows 95 ™ and NT ™. This new product is based on Landsat Thematic Mapper (TM) ™ imagery for background color, overlaid with SPOT ™ data to provide a false-color composite at 10 m (32.8 ft) resolution. This version is available for training purposes. *ATraining selected groups in the utilization of the merged SPOT-TM data CD-ROM with associated spatial data sets of Louisiana@* (DeWitt Braud, Phone: 225-578-6177, e-mail: dbraud1@lsu.edu, LSU); *ASatellite and GIS database of Louisiana: a continuation of training@* (Dr. Anthony Lewis, Phone: 225-578-6199, e-mail: galewi@lsu.edu, LSU) and *ALA GIS CD v. 2: continuation of demonstrations@* (DeWitt Braud) are projects that were initiated in 1998. The purpose of all of these efforts was to explain how to use the Louisiana GIS two CD-ROM set - one of north Louisiana and the other of south Louisiana. This set is an innovative map of Louisiana containing more than 40 spatial data layers, a satellite image of Louisiana, and GIS software and tutorials. The CD has been widely distributed to environmental, oil-spill response and oil industry organizations. The development team is currently funded to conduct demonstrations of the CD using application scenarios programmed for the audience. Experience has shown the user community immediately began using the two CD set after these demonstrations. The CD has been used in a number of oil-spill related incidences.

Rapid response to oil spills is critical for effective clean up and remediation, especially for spills on water or in wetlands. To assist with this challenge, two groups have surveyed and described waterway access points throughout south Louisiana=s lower tier of parishes. A*Boat ramp and launch site inventory, southwest Louisiana coast zone@* (Dr. Greg Hartman, Phone: 318-475-5672, e-mail: ghartman@acc.mcneese.edu, McNeese State University) and *AOil and hazardous spill access point inventory for southeast Louisiana@* (Dr. Russell Bender, Phone: 985-448-4502, e-mail: rockdoc@cajun.net, Nicholls State University). These data are currently being checked and will be added to the state=s GIS. In conducting this survey, access points were divided into three categories: (1) public boat ramps and lifts that are free and maintained by a government agency; (2) semi-private ramps or lifts available for public use, usually for a fee; and (3) private boat ramps or lifts owned by industry or private individuals and not available to the public. Field survey data taken included: coordinates in latitude and longitude; highway directions to the site; ramp=s construction material; ramp measurements B length, width, water depth at end of ramp, water depth 10 and 20 feet beyond the end of ramp; lift capacity; size of parking area; ownership status; description of any on-site store; availability of fuel, electricity and water; and digital photographs of the site. When completed, it is estimated the teams will have surveyed nearly 1,000 access points. Dr. Bender=s project *AOil and hazardous waste access point inventory of river parishes and northern Lake Pontchartrain@* will

continue this work. The endeavor will be completed by May 2001. Industry response personnel and clean-up organizations will have available, for the first time, a complete inventory of boat launch facilities.

Louisiana=s coastal zone is widely recognized for its ecological and economic importance. The risk of damaging this fragile ecosystem due to an oil spill is of some concern. As a result, a number of studies address, directly or indirectly, this near sea-level environment. In order to optimize deployment of oil spill cleanup equipment, an accurate delineation of Louisiana=s coastline is imperative. The dynamic, fragile, complex and constantly changing nature of Louisiana=s coast prohibits the use of traditional surveying and photogrammetric techniques for updating coastal maps. The availability of Landsat Thematic Mapper (TM)^{TM} and airborne X-band synthetic aperture radar, in concert with recent advances in computer hardware and software, has made it possible to generate accurate and up-to-date maps. This product is suitable for use by field personnel in preparation for, during, and following an oil spill. Although spills are inevitable, by using this digital map product environmental impacts can be easily assessed. *AMerging Landsat Thematic Mapper (TM)*^{TM} *satellite imagery and airborne synthetic aperture radar to facilitate coastline delineation@* (Dr. Anthony Lewis) provides a helpful tool in the mitigation process.

Even with this tool, current maps of coastal Louisiana are out-of-date and a recent digital shoreline of the coast did not exist. What was missing was a computer-aided product that would automatically measure shoreline features and attributes, depict and analyze spatial characteristics, allow proximity analysis and other spatial functions. A digital vector land/water interface in a GIS system was required. The *ASemi-automated construction of the Louisiana coastline digital land/water boundary using Landsat Thematic Mapper*^{TM} *satellite imagery@* (DeWitt Braud) solved this problem. The completed system is designed to assist oil spill planning and response activities by creating models of oil spill currents or projected dispersion vectors. In addition, the system gives the responsible party=s contractor a clear understanding of the land/water boundary to accurately place boom and other clean up and response equipment during a spill event.

All land/water interface boundaries are important to spill planners, as they change quickly in coastal Louisiana. *ADigital access to aerial videotape survey data@* (Karen Westphal, Phone: 225-578-5382, e-mail: westph@lsu.edu, LSU) is a project whose mission is to digitize and index a vast amount of analog video to create a system for efficient accessing of aerial videotape survey information on a CD-ROM or through a web site. During the summer of 2001, oblique aerial videotape imagery of the Louisiana outer shoreline was acquired. In the bottom of the video image, real-time navigation data from a global positioning system (GPS) are be presented so that each image is referenced with latitude, longitude, and compass heading of the aircraft, date and time. Imagery was taken by helicopter at an altitude of approximately 200 feet at a speed of 40-60 knots. Once completed, a user will be able to click on an image of the Louisiana coastline and bring up subdirectories for that area. Clicking further will display the latitude/longitude and initiate digital playback of imagery of a specific spot, which is important for spill planning, as any spot on the coast can be analyzed during a spill event.

Since Louisiana=s alluvial wetlands are an integral part of the North American Flyway, the migratory bird population could be severely impacted by an oil spill. In order to learn more about the nesting habits of the bird population a *ASurvey of Louisiana seabird colonies to enhance oil spill response: a digital survey and inventory@* (Dr. Jenneke Visser, Phone: 225-578-6377, e-mail: comvss@lsu.edu, LSU) was funded. Due to their location and ground nesting habits, seabird colonies are extremely vulnerable to oil spills during the nesting period. Knowing these sites can help lower potential clean up costs by alerting clean up crews to the areas where there are nests.

Therefore, these sites can be protected during the cleanup process. The nesting sites were surveyed and are incorporated as a data layer on the new Oil Spill Contingency Plan Map CD. This digital record provides an up-to-date map of nesting sites that can be protected in the case of an oil spill and easily downloaded from the Map CD.

With nearly 100 years of oil and gas development in Louisiana, the state=s oil and gas pipeline network is highly complex and routes are often not well documented. Recognizing this complication as a potential clean up problem, a two-year *AResearch, compilation, and digitization of undocumented and abandoned Louisiana pipelines for the statewide pipeline digital database@* (Robert Pausell, Phone: 225-578-8655, e-mail: rpaulsell@lsu.edu, LSU) generated data on the state=s intricate pipeline network. This digital map will eventually provide a much better understanding of the rights-of-way, river crossings, pipeline corridors and pipeline agglomerations throughout Louisiana. Of particular note are the pipeline routes in the state=s swamps and marshes. This is an ongoing project and is only beginning to yield information that can be properly mapped; however, a preliminary map is available. Further, the Proposal Review Board approved funding two additional pipeline projects: *AResearch and development of a GIS for oil and gas transmission pipelines in Baton Rouge@* (Robert Paulsell) and *AField investigation and digital mapping of pipeline crossings of the Red River in Louisiana@* (John Snead, Phone: 225-5783454, e-mail: snead@lsu.edu, LSU). These will be completed in 2002.

Recent highly publicized pipelines accidents involving injuries and death has heightened awareness of potential pipeline problems. With this as the backdrop, Mr. Paulsell will develop a GIS of crude oil, natural gas and petrochemical transmission pipelines used in the movement of butane, propane and other produces within the city limits of Baton Rouge. These data will be developed by collecting pertinent source documentation (maps) then compiling the GPS data on transmission lines and performing a GIS analysis. Special attention will be paid to locating undocumented and abandoned pipelines and to assess the spatial accuracy of existing digital data.

Continuing with this theme, Mr. Snead will investigate and digitally map the pipeline crossings of the Red River. Routine waterway incidents such as dragging anchor, dredging accidents or shipwreck pose a threat. In addition, the potential for floodwaters to rupture and destroy pipeline crossings has been documented in recent floods on the Red River in Minnesota and the Trinity River in east Texas. Therefore, accurate and up-to date digital pipeline information is of fundamental importance to the oil spill community. A high-resolution pipeline crossing GIS of these streams offers previously unavailable information and will enable increased response efficiency by allowing responders to quickly access the size, product carried, and operator of specific pipelines. Such a database will augment the capabilities of oil spill planners and emergency responders as well as being a basic tool for oil spill researchers studying risk management and environmental impact.

To better understand movement of a potential spill on the Calcasieu River - a route used by tankers moving imported product into the refining centers of the greater Lake Charles area - two projects were funded. Dr. Ehab Meselhe completed a study entitled: *ATrajectory analysis planner program for the Calcasieu estuary."* After completion of this work it was apparent that the model was not complete until the Sabine River was added. In this regard, Dr. Meselhe will complete by May of 2002 the first phase of a *ATrajectory analysis planner for Sabine Lake."* To help mitigate some of the environmental risks associated with an oil spill. A trajectory analysis planner (TAP) computer model was developed for the Calcasieu system and will also be developed for the Sabine. It is believed this model will help oil spill contingency planners and managers investigate how spills travel and spread within the two systems.

The model can identify sites within the estuarine environments that will be most vulnerable to a specified oil spill. Furthermore, the model can estimate the time available for mitigation and remedial actions before the specified spill impacts sensitive areas. The modeling system (TAP) was developed at the Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration (NOAA) in Seattle, Washington. The first step in setting up a TAP model is to represent the hydrodynamic characteristics of the estuarine system. Hydrodynamics in the Calcasieu system are affected by: (1) estuarine processes, (2) lake dynamics, and (3) the development of high velocity currents in near-shore shallow regions. A robust, flexible, and efficient numerical model was required to incorporate all of these processes in one operational program. A three-dimensional hydrodynamic model was used to simulate the hydrodynamic characteristics of the Calcasieu system. The results illustrate the ability of the model to accurately simulate flow patterns and can be used to perform reliable spill trajectory analysis. It is expected this model will be enhanced with the addition of Sabine hydrodynamic characteristics and thus complete the analysis between these two interrelated systems.

Although theoretically not a mapping project, the *AWave-current online information system for oil spill contingency planning@* (Dr. Gregory Stone, Phone: 225-578-2395, e-mail: gagreg@lsu.edu, LSU) is a three-year project partially funded by the OSRADP. This online oceanographic and meteorological observing system is designed to support Louisiana=s ability to anticipate and prepare for emergencies offshore (oil spills, hurricanes, winter storms, shipping accidents, etc) and assist numerical modeling efforts during storm events by measuring important data sets and making them available in real time, or, after archiving, as a time series. WAVCIS (Wave Current Information System) provides water information including wave height, period, and direction of propagation, water level, surge, water column velocity profiles, and meteorological conditions on a near real time basis. At present, four stations are online. The WAVCIS system is being coordinated with the Texas automated Buoy system (TABS) to enhance the program=s geographic coverage. The system can be reviewed and accessed at: www.wavics.csi.lsu.edu.

Spill Response, Cleanup and Harmful Ecological Consequences

At best, responding to a wetland spill is difficult. The cleanup activity often does more damage than the actual spill. Consequently, a series of studies involving *in-situ* burning have been initiated. These studies include:

1. "Environmental effects and effectiveness of in-situ burning in wetlands: considerations for oil-spill cleanup@ (Dr. Irv Mendelssohn, Phone: 225-578-6425, e-mail: imendel@lsu.edu, LSU);
2. "*Evaluation of habitat responses to in-situ burning as a method of oil removal phase II - sagittaria lancifolia [bull tongue] salt marsh field study@* (Dr. Charles Lindau, Phone: 225-578-8766, e-mail: clinda1@lsu.edu, LSU);
3. *AEvaluation of habitat response to in-situ burning as a method of oil removal phase III - sagittaria lancifolia [bull tongue] fresh marsh field study@* (Dr. Charles Lindau);
4. *AIn-situ burning studies for onshore oil spills@* (Dr. Maureen McCurdy, Phone: 318-257-3165, e-mail: hillard@latech.edu, Louisiana Tech University [La Tech]); and
5. *ASalt marsh recovery after in-situ burning for oil remediation: effects of water depth and burn duration@* (Dr. Irv Mendelssohn).

After extensive laboratory and field trials, the scientists agree the best method to clean up a wetland spill, provided there is a thin layer of water on the marsh surface and with the agreement of all trustees and interested parties, are to burn off the residual oil. This is a cost-effective technique that, under the right conditions, does little damage to the plants. Since fire culture has been a part of

wetland inhabitants annual use cycle for more than 100 years, burning the marsh is not a new or novel practice.

It has been shown that burning is an effective cleanup technique, burn intensity and duration may influence the response of wetlands to the burn. A mesocosm-scale investigation was conducted to study the effects of water depth, burn duration, and oil application on relationships between recovery of marsh vegetation, soil temperature, and oil remediation. In the mesocosm, *Spartina alterniflora* (smooth cord grass or oyster grass) containers were instrumented with thermocouples and assigned three treatments: (1) oil exposure - unweathered diesel versus no diesel, (2) burn duration - five minutes versus 20 minutes, and (3) water depth - 10, 2 and 0 cm over the mash surface and 10 cm below the marsh surface. With primary support from the National Institute of Standards and Technology, the team has shown that water depth over the soil surface during the burn event was a major factor in recovery. Ten centimeters of water overlying the soil surface was sufficient to protect the marsh soil from burn impacts. However, because the lethal temperature of 60 degrees centigrade was not observed, two centimeters of water overlying the sod=s surface appears to be sufficient for a successful burn. The water protected the plants from the burn impact. *Sagittaria* (bull tongue*)* and *Spartina alterniflora* (smooth cord grass or oyster grass) were impacted, but the brackish marsh plants, *S. patens* (wiregrass) and *D. spicata* (salt grass) were not impacted.

Dr. Gary Breitenbeck (Phone: 225-578-1362, e-mail: gbreite@lsu.edu, LSU) investigated floating wicks in the study *ADevices to support in-situ burning of oil on water.@* Using these wicks, slicks of thin oils such as diesel and bunker fuel can be burned as readily as slicks of weather crude and heavier oils. When slicks are greater than 1.5 mm, use of these devices results in rapid ignition of the entire oil surface. Slicks as thin as 0.15 mm are also easily ignited and burned. Even emulsified oils can be ignited. These devices were designed to be biodegradable, non-toxic, water-resistant, lightweight, and easily deployed from fixed-wing aircraft. The most effective wicks were ellipsoid-shaped disks approximately 3 inches in diameter and comprised of kenaf, a fiber crop, bonded and coated with a hydrophobic copolymer. Because the thickness of most oil slicks is not sufficient to maintain combustion without the addition of a wick, these devices allow controlled burns of large and small spills even in close proximity to ships or other objects.

Although i*n-situ* burning is an effective and efficient clean up procedure, phytoremediation is also being investigated. With the aid of fertilizers, this technique allows the habitat to recover naturally. Even though phytoremediation is not a proven or generally accepted practice, it holds considerable potential. The two year study *ABaseline experimental studies for onshore oil spills@* and *AUnassisted and enhanced remediation studies for onshore oil spills: concept development@* (Dr. Maureen McCurdy) assessed the minimum baseline requirement for Louisiana=s upland plants to recover naturally from oil spill damage. This experiment involved four objectives: (1) to establish that oil spills can be considered reproducible events that can be studied using traditional, scientific techniques; (2) to establish research protocols that can be used to obtain scientifically defensible data about oil spill remediation; (3) to provide a quantitative assessment of how small, onshore oil spills remediate naturally over time; and (4) to provide a quantitative assessment of how small onshore oil spills effect the mortality of vegetation. Although minimal revegetation occurred within the oiled plots during the first post-spill growing season, vegetative recovery increased during the second growing season.

In keeping with the OSRADP=s concern about uplands, as well as wetland spill events. The program funded a two-year project led by Dr. Wayne Hudnall (Phone: 225-578-1344, e-mail: whudnall@agctr.lsu.edu, LSU) entitled: *ARemediation and restoration of an oil contaminated wetland and pine forest site.@* The premise behind this effort is that accidental spills, leaks, or

discharges can expose a wide variety of sensitive habitats to petroleum and brine contamination. The goal of this project was to introduce a successful remediation and restoration plan for a contaminated wetland and pine forest site impacted by an oil well blowout simultaneously.

The research site, located in Kisatchie National Forest, was polluted by an oil and brine spill (13,000 barrels of oil and 600,000 barrels of brine). The release resulted in oil and brine contamination of a 4.3-acre freshwater wetland. Aerial spray of oil, brine, and gas from the blowout also killed or severely stressed numerous loblolly and longleaf pine trees in the vicinity of the well. Remediation and restoration of the wetland and pine forest required both a field and a greenhouse study. The field study examined the effectiveness of ammoniated bagasse (ABG) at enhancing bioremediation.

Burning was the most effective, ecologically sound, and economical method for removing the oil from the wetland. Once the area was burned, a combination of ABG, lime, and topsoil was applied *in situ* to 20 research plots. The results of the study showed that the bagasse reduced the total petroleum hydrocarbons (TPH) over 300% in the top 10 cm of the soil. Further, greenhouse studies investigated the effect of foliar and soil applications of oil and brine on one-year-old loblolly pine tree seedlings. Foliar application of oil has no effect on the trees (i.e. death, signs of stress). However, when 100% of the surface area of five trees was covered with oil, the new shoot growth on these trees died; other areas of the trees showed no signs of stress. When oil was applied to the soil at a rate of 400 ml/tree, the trees died or showed signs of severe stress within one week. Consequently, concentrations of oil and brine in the soil were not significant to cause death of the trees. Foliar brine had little or no effect on the trees. Results from this work suggest that foliar oil contamination was the cause of the death of the loblolly pine trees at the blowout site.

ABioremediation protocol for small-scale oil spills in Louisiana=s marshes@ (Dr. Gary Childers, Phone: 504-549-3740, SLU) was a two-year project involving development of a mesocosm to emulate marsh conditions. Four fresh marsh plants B *Alternanthera philoxeroides* (alligator weed), *Sagittaria lancifolia* (bull tongue), *Panicum hemitomon* (maiden cane or paille fine), and *Phragmites phragmites* (roseau cane) B were oiled. An unplanted control was also part of the experiment. Nutrient augmentation increased overall biomass production, especially for maiden cane and bull tongue. The short-term response of bull tongue was one of resilience, whereas maiden cane had the highest biomass production and photosynthetic rates by the end of the experiment. Both species were judged excellent candidates for transplanting in an oiled marsh. It appears they can be used to naturally bioremediate an oiled fresh-water marsh. Alligator weed was the least tolerant species, followed by Roseau cane. As a result, neither should be considered as oil spill bioremediation agents.

Three years of work were involved in the following projects: *APhytoremediation for oil spill cleanup and habitat restoration in Louisiana=s coastal marshes: effects of marsh plant species and fertilizer,@ APhytoremediation for oil spill cleanup: biostimulant and species effects,@ AEffects of fresh marsh species and inundation environment on phytoremediation of oil,@* and *APhytoremediation of oil by brackish marsh species: effects of inundation regimes and soil texture@* (Dr. Qianxin Lin, Phone: 225-578-8889, e-mail: comlin@lsu.edu, LSU). The objectives of these endeavors were: (1) to determine the potential of phytoremediation for habitat restoration, (2) to compare oil phytoremediation=s effectiveness on dominant marsh plants, and (3) to determine the role of fertilizer in enhancing phytoremediation induced oil degradation. Preliminary results suggest phytoremediation can be used as a successful means of restoring oil-contaminated habitats and accelerating a reduction in residual oil concentration. This study is the first intensive investigation in Louisiana of phytoremediation as a means for oil spill cleanup in wetlands. These investigators are currently investigating the *AEffects of inundation environment on phytoremediation by fresh and brackish marsh plants for oil spill cleanup@* (Dr. Qianxin Lin) and thereby completing the

investigation of all plant salinity regimes in coastal Louisiana. This works demonstrates that phytoremediation can accelerate oil degradation and site restoration in a wide range of common coastal environments.

The Louisiana Tech group that developed the baseline information for north Louisiana=s uplands is now involved in a study on *AIn-situ burning and phytoremediation for onshore oil spills@* (Dr. Jeff Hillard, Phone: 318-257-3165, e-mail: hillard@latech.edu, La Tech). A detailed literature review indicates this project is one of only a few to investigate these two issues in an upland environment. Although *in-situ* burning was considered, the initial focus is on phytoremediation. More than 40 different species of native plants were observed growing in oil-contaminated oil at existing upland spill sites in northern Louisiana. These observations indicated that a variety of plants might be able to persist in crude oil contaminated soil. Over the course of a 300-day greenhouse study, the team=s analysis suggests that the application of nitrogen, phosphorous and potassium fertilizer may be an effective means of in-situ remediation. In addition, re-introduction of vegetation into oiled upland sites is also desirable to prevent soil erosion, improve habitat and may actually accelerate the natural attenuation of crude oil. Because of problems with some of the GC/FID samples the study *ARe-evaluation of soil from in-situ and phytoremediation studies for onshore oil spills@* (Dr. Ed Overton) is designed to re-sample and evaluate samples for accuracy. This project will be completed in May of 2001.

In addition, three other studies are in progress that concentrate on plants and their ability to survive in an oiled environment: *ADevelopment of a sensitivity index for plant response to applied oil@* (Dr. William Campbell, Phone: 318-257-4573, e-mail: campbell@.latech.edu, La Tech); *ADevelopment of a germination index of sensitivity to applied oil@* (Dr. Milan Vavrek, Phone: 318-257-4573, e-mail: mvavrek@latech.edu, La Tech); and *AUse of donor seed banks in terrestrial vegetation recovery after an oil spill@* (Dr. Milan Vavrek). These projects involve the survivability of plants in an oiled environment and the accessibility of seed banks that can be used to reseed the environment.

It has been shown that recovering plant communities may become re-established through regrowth of belowground plant parts, by germination of seeds immigrating into the site, by germination of dormant seeds in the soil bank, or by restoration efforts (e.g., planting of nursery stock). Ideally, a plant community that includes the original species in the same relative proportions, in the same structure, as well as restored primary productivity would characterize complete recovery. Preliminary results suggest seed banks are an effective component of vegetation recovery after a spill. In the case of severe spills, however, the *in-situ* seed bank may not promote complete recovery. Active restoration, including planting nursery stock or sowing seeds, may also be necessary. Alternatively, donor seed banks may be applied, particularly after degradation of oil has occurred.

The literature indicates that plants accelerate degradation of oil after a spill. Presumably, plants contribute limiting resources to soil microbes and improve the soil microbial environment. By identifying specific plant traits that are responsible for the stimulated microbial growth and metabolism, plant species selection for remediation can be simplified (i.e. species native to the spill site can be chosen on the basis of their characteristics). To test the effectiveness of particular traits, Dr. Milan Vavrek=s two-year study: *APhytoremediation of petroleum: identification of plant traits that enhance degradation@* selected plants on the basis of growth rate, root morphology, water use efficiency, photosynthetic pathway, and nitrogen fixation. These varieties were grown in the greenhouse in sterilized soil and after about 20 weeks, total petroleum hydrocarbons in the soils indicated that plants and microbes contributed little to bioremediation. In contrast, a bioassay (germination) indicated a significant reduction in soil toxicity. The difference between these two

analyses may be a function of soil sampling, transformation of petroleum constituents, and the binding of petroleum components to humus. Three species, *Panicum virgatum* (switch grass), *Festuca arundinacea* (tall fescue), and *Cajanus cajan* (pigeonpea) possessed some tolerance to oil and enhanced microbial degradation. All three species are perennial and tolerate drought and moderate to high temperatures. Drought tolerance may be advantageous because of the hydrophobic nature of oil-contaminated soils. Thus, water use efficiency may be an important trait for tolerance to oil. Additional studies are necessary to further identify plant traits that are effective in remediation. In this regard Dr. Vavrek=s study is continuing this work in the project: *AThe role of plant-bacterial-fungal interaction in remediation of oak-hickory-pine systems.@* Preliminary results suggest that by facilitating the interactions of plants, bacteria, and fungi oil degradation can be accelerated. These organisms potentially improve each other=s performance and act on oil directly. However, any restoration plan may require monitoring of soil nutrients, repeated applications of fertilizer and consideration of interactions among biological components.

"Engineered application of bioremediation to oil spills in coastal wetlands: a field trial" (Dr. Donald Adrian, Phone: 225-578-8636, e-mail: dadrian@lsu.edu, LSU) investigated the effect of nutrient amendments on the kinetics of crude oil degradation using laboratory and field experiments. It was determined that nutrient additions are plausible strategies for improving oil degradation in salt marshes. Respectively, the overall effectiveness of nutrient addition may be limited by oxygen availability and costs associated with the appropriate additive.

AAssessment of the role of anaerobic biodegradation of crude oil on natural recovery@ (Dr. John Pardue) is currently being finished. Dr. Pardue is investigating several applied questions. Does biodegradation of spilled oils in marshes occur when oxygen is absent? What range of oil components will degrade under these conditions? Does an anaerobic Asignature@ of crude oils develop following anaerobic biodegradation and what are its characteristics? Does the ability of salt marshes to anaerobically degrade have a significant lag time after a spill? This project addressed these questions and the results suggest that anaerobic degradation of crude oil is an important natural recovery process. Salt marshes in particular may recover from a combination of anaerobic and aerobic microbial processes.

The results of a study involving the *AEffects of oil and chemical responses on fresh marsh function and oil degradation: response implications@* (Dr. John Nyman, Phone: 225-578-4220, e-mail: jnyman@lsu.edu, LSU) indicates the use of chemical cleaners, dispersants, or fertilizers has no long-term effects on a fresh marsh. Use of these techniques for the purpose of short-term gain, such as reducing vegetation or wildlife mortality, is not prohibited by the long-term soil microbial response. More information is needed before response strategies can actually be clarified, but initial results are positive. Currently, this research is being augmented by a study on the *AEffects of crude oil and spill-response-options on microbial functions and oil disappearance in salt marsh soils@* (Dr. John Nyman). When finished, Dr. Nyman will have completed investigations in fresh and salt marsh habitats. Further, a two-year study on *AThe interaction between oil spills, chemical responses, and fresh marsh types in determining toxicity to indigenous aquatic animals and the detail of hydrocarbon analysis required to predict this toxicity@* (Dr. Paul Klerks, Phone: 337-482-6356, e-mail: klerks@louisiana.edu, ULL) investigated how oil spills affect aquatic animals in fresh marshes. Specifically, the research investigated the toxicity and temporal changes in toxicity of fouling by south Louisiana crude and diesel fuel and two chemical responses options to this problem (the cleaner Corexit 9580™ and the dispersant Corexit 9500™). Toxicity was investigated for soil/sediment (using sediment dwelling invertebrate species) and the water column (using an invertebrate and a fish species). The experiments were conducted in laboratory microcosms under static conditions and without water change. Results from this research are especially relevant for oil spills in freshwater

systems having very little water exchange. The research was also aimed at determining what level of hydrocarbon analysis (ranging from simple gravimetric analyses to complex gas chromatography with mass spectrometry detection B GC/MS) is optimal for predicting toxicity.

The research employed 288 individual laboratory microcosms composed of soil collected from two Louisiana marshes. Toxicity data were obtained for days 1, 7, 31 and 186 following the addition of the oil and/or chemical treatment to the microcosms. Results were consistent among the two marsh soils. Overall, toxicity was much higher for the sediment dwelling chironomids (midge) than for the two water column species, and higher for the diesel fuel than for the south Louisiana cure. The cleaner and especially the dispersant had toxic effects by themselves and enhanced toxicity when added to oiled microcosms. This enhancement of oil toxicity was observed for all time points, thus no beneficial effects were observed for the cleaner and dispersant.

Overall toxicities showed a gradual decline with time. The various analyses of total petroleum hydrocarbon levels and the analysis of total aromatic hydrocarbons all showed a substantial decline over the 186-day period. The researchers could not detect any effect of the chemical treatments on hydrocarbon levels. In order to predict toxicity a relationship between the chemical data and survival in the bioassays were developed. In all cases, there was a significant relationship between the hydrocarbon measurement and survival. It was determined that the relationships were poorly suited for accurately ranking toxicity of samples, even when correlations were significant. The detailed and expensive hydrocarbon analyses (such as CG/MS) did not fare any better in this respect than the simple and much cheaper gravimetric analysis.

Vendors have available a number of cleaners and dispersants that can be used in a spill event. In Louisiana=s marshes there was interest in determining whether a shoreline cleaner could be used to clean vegetation in a cost-effective manner. The projects A*Evaluation of habitat sensitivity to oiling: use of cleaners for removing oil from vegetation@* and A*Evaluation of habitat sensitivity to oiling: effectiveness and impact of cleaner in removing oil from fresh water habitat, Sagittaria lancifolia L [bull tongue] (field study)@* (Dr. Ronald DeLaune, Phone: 225-578-8810, e-mail: rdelaun@lsu.edu, LSU) involved initially extensive greenhouse studies using intact cores of marsh vegetation. The object was to determine the potential of a shoreline cleaner (Corexit 9580^{TM}) in removing oil from the plant canopy. Because of the positive results obtained in the greenhouse experiment, a permit to conduct a full-scale field test was obtained from Louisiana=s regulatory agencies in June of 1995. Field tests began in August of 1995, and substantial recovery was noted in plants that were cleaned two days after oiling. By day 45, oiled and cleaned plants had regained their stomatal function and had rates comparable to that of the control plants. After the second year, the oil plus cleaner and control plants appeared to be nearly equal in their biomass make up. The cleaner worked, but cost and availability may be its limiting factor.

Remediation of coastal wetland ecosystems contaminated with spilled crude oil is complicated because these heavily vegetated areas typically offer limited access to cleanup equipment and personnel. Laboratory and field experiments were performed in the studies: A*Assessment of ammoniated organic wastes for remediation of wetland soils contaminated with crude oil@* and A*Use of ammoniated cellulotic materials for remediation of oil-contaminated wetlands@* (Dr. Gary Breitenbeck). This project investigated the value of naturally occurring, nitrogen-rich absorbents, as well as other commercially available absorbents for *in-situ* remediation of wetlands contaminated with Louisiana sweet crude oil. The commercially available absorbents tested were ground sphagnum peat, kenaf, wool pads, and polypropylene pads. Tests were performed on two products not on the approved list: ammoniated bagasse (a waste by-product of the sugar industry) and ground chicken feathers. In the final analysis, ammoniated bagasse was the most effective material tested for

retaining spilled oil and promoting *in-situ* disappearance. The ammoniated bagasse is in the process of being commercialized.

Since absorbent pads are an important tool in the cleanup business, a study on the *AEvaluation and characterization of sorbents in removal of oil spills@* (Ali Ghalambor, Phone: 337-482-5948, e-mail: alig@Louisiana.edu, ULL) was funded. This project examined, evaluated, and characterized several commercially available oil spill sorbents. Kenaf, wool, and polypropylene were analyzed and appraised. Kenaf has absorption capacity almost equivalent to polypropylene and slightly less than wool, but with much higher retaining capacity than the other two. Although not commercially available, kenaf appears to be one of the cheapest and most efficient sorbents tested. Many sorbents are manufactured from organic material and are therefore naturally biodegradable. Once used, Adisposal@ becomes an issue since they are classified as hazardous material. To reduce disposal cost associated with used pads, a project involving *AComposting technology for practical and safe remediation of oil spill residuals@* (Dr. Donald Adrian) and *AComposting technology for practical and safe remediation of oil spill residuals@* (Dr. Ali Ghalambor) were initiated in 1996. Preliminary results suggest that several organic sorbents will degrade effectively when properly composted. The decomposition of some spent sorbents benefits from the addition of supplemental nitrogen in the ratios of 60:1 to 120:1. These ratios appear to provide optimal support for oil disappearance under composting conditions. One member of this research group investigated the *AEffectiveness of solidifiers for combating oil spills@* (Dr. Ali Ghalambor), but because of industry work in this area, this two-year project was terminated after only a year.

Wastes associated with petroleum production can have harmful ecological consequences when released into wetland and coastal marine ecosystems. There is however, little understanding of petroleum=s changes and biotransformation products in this environment. For treatment and impact assessment strategies to be successful, it is important to understand degradation pathways of chemicals associated with petroleum and produced waters. *ABiodegradation of toxic chemicals from petroleum and produced waters, brackish marsh sediments: pathway studies and degradation rates using deuterated standards@* (Dr. James Catallo, Phone: 225-578-8518, e-mail: jcatallo@mail.vetmed.lsu.edu, LSU) investigated these issues. In this study most of the target compounds were found to be only partially degraded under anaerobic and reducing conditions typically found in Louisiana=s brackish and salt marsh sediments. Stirring and increasing the redox potential of the sediments increased the rates of transformation of many of the target compounds. This suggests that physicochemical modifications may be able to promote compound transformation from affected sediments. As tilling and mixing frequently accompany the introduction of bioremediation agents, this may have a positive affect on the degradation process.

When a spill occurs two questions are often asked: (1) How clean is clean? and (2) Should we clean a site? To help answer these queries, Dr. Howard Hunt=s (Phone: 318-257-4141, e-mail: hhunt@latech.edu, La Tech) study *AArthropod indicators of onshore oil spill severity@* indicates arthropods might have potential as indicators of the severity and degree of recovery from oil spill events. Dr. Hunt=s two-year study used pit-traps to capture arthropods in 1 m blocks of habitat exposed to different intensities of waste oil within a fenced enclosure. By using broad arthropod groupings the team reduced species-specific variability between samples and made broad-scale community changes easier to quantify. Preliminary results suggests that the use of arthropods may indicate spill sites requiring little or no clean up, thereby saving the cost of expensive and unnecessary soil remediation treatments.

Because of the extensive oil activity in Louisiana, large number of un-vegetated oil pits resulting from routine petroleum operations may contaminate their surroundings and greatly reduce the

ecological functions of wetlands and uplands. Dr. Qianxin Lin=s project *AThe use of phytoremediation, biostimulation and aeration for the restoration and cleanup of non-hazardous oil pits and related NOW sites@* investigated this issue. Results from this study are being reviewed and will be published in 2002.

Currently, three studies have been funded that will be published in 2003. *ADetecting the chronic effects of oil development in Caddo Lake@* (Dr. Charles Ramcharan, Phone: 225-578-1745, e-mail: cramcha@lsu.edu, LSU) will look at the acute effects of oil development in a freshwater lake, since these environments preserve a history of their past physical, chemical, biological, and even climatological environments in their sediments. Using a variety of sensitive and sophisticated techniques for chemical analyses, the residues of these past environments can be detected in sediment cores. This project will attempt to determine the chronic effects of oil development in the food web of Caddo Lake. Dr. Ramcharan believes the study will provide a better understanding of the impacts of oil development and the data collected may also aid in monitoring oil spill remediation efforts.

ARevegetation of oil brine spills sites@ (Dr. Milan Vavrek) has often been unsuccessful. This project involves a compound approach to address revegetation in the multi-stress environment of an oil brine spill. The approach involves a detailed literature review and experimental components. The objectives are to: (1) identify plant species capable of growing in contaminated sites by cross-referencing species tolerance to oil, saline, and sodic soils and by reviewing successful restoration techniques; (2) quantify survival, growth, and fecundity of identified species when grown in saline, oil, and oil brine-contaminated soils to test whether these species are candidates for restoration schemes; (3) quantify the benefits of a calcium amendment to plant and fungal growth; (4) quantify the benefits of amending arbuscular-mycorrhizal fungi to re-establishment of plant species; and (5) quantify the salinity, sodium, oil land structure of vegetated and unvegetated oil brine-contaminated soils to test whether plants and fungi contribute to reduction of oil and salt.

In order to assist in reducing the loss of living resources in a spill event, Dr. Jenneke Visser=s project *ADevelopment of a rapid survey technique for living resources in Louisiana=s fresh marshes@* is designed to develop an ecologically, economically, and statistically sound rapid assessment plan for living resources of Louisiana=s freshwater marshes in order to provide useful information to resource managers in the absence of adequate baseline data. Development of this rapid assessment plan will consist of four steps: (1) a review of existing rapid assessment methods; (2) an inventory of all existing data on living resources in the Louisiana fresh marshes of resident and migratory species; (3) development of a list of species of special concern; and (4) development of a sampling design. The end product will be a standard operating procedure of national resource damage assessment of living resources within freshwater marshes.

SUMMARY

The impact of an oil spill and the success of cleanup efforts depend on the characteristics of the water, nearby land and weather conditions. In some cases, luck B good and bad B plays the prominent role in determining the severity of a spill. The greatest damage to bottom organisms will occur in shallow water. High winds and ocean currents can spread oil faster and impede cleanup efforts. Tidal mud flats, shallow grass beds, marshes, and swamps are especially difficult to clean. The time of day a spill occurs also can be important, as initial responses can only benefit from adequate sunlight and good visibility. The key to an effective response plan is that Athe level of pre-existing environmental and ecological information is extensive, current and easily extracted from a comprehensive data base@ (17:76). One of the best tools in understanding the pre-existing

environmental conditions is a map, preferably in a digital format. Louisiana=s Oil Spill Contingency Plan Map is a key element in mobilizing clean up teams to minimize the environmental consequences associated with an oil spill. This product is less than two years old and has been widely distributed and used. The CD-ROM has been particularly well received.

In five years, more than 30 projects have been funded to investigate a number of oil spill related issues in Louisiana. These projects are directly related to the applied mandate of Louisiana=s oil spill research and development effort. The process works because of the interchange of ideas and knowledge between industry oil spill representatives and the university communities to ensure the research efforts are applicable. Such an arrangement/partnership minimizes duplication and guarantees that the Aapplied@ aspect of the research/education project is relevant to oil spill related concerns in Louisiana. The process works and has been quite successful. Louisiana is better prepared because of the coordinated efforts of the state=s Oil Spill Coordinator, the OSRADP, the university research community, and industry. The partnership is focused on a common goal: oil spills prevention and clean up in a scientifically based, efficient, and practical manner.

It is critical the science developed with OSRADP support is incorporated into the oil industry=s planning and response strategies. These projects are only useful when they are implemented. We are convinced the goals and objectives of the OSRADP are compatible with industry. We must work together to see these research efforts, and others are approved and utilized by all parties involved in an oil spill cleanup operation. On the shelf, the research initiatives are not meeting the program=s applied mandate. If not approved, they will have at least been assessed. Regardless, questions will be answered. Rejection is not necessarily bad, if that rejection leads to better science. Acceptance by the regulatory community can lead to better response in the future. Expectations are kept, therefore, within the context of the research, so the best efforts are used to limit an oil spill=s environmental impacts.

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