MCEER SPECIAL REPORT SERIES

Engineering and Organizational Issues Before, During and After Hurricane Katrina

HURRICANE KATRINA

Volume Three

HEALTH & ENVIRONMENTAL ISSUES

Public Health and Environmental Infrastructure Implications of Hurricanes Katrina and Rita

James N. Jensen and Pavani Ram

MCEER is a national center of excellence dedicated to establishing disaster-resilient communities through the application of multidisciplinary, multi-hazard research. Headquartered at the University at Buffalo, State University of New York, the Center was originally established by the National Science Foundation (NSF) in 1986, as the National Center for Earthquake Engineering Research (NCEER).

Comprising a consortium of researchers from numerous disciplines and institutions throughout the United States, the Center's mission has expanded from its original focus on earthquake engineering to address a variety of other hazards, both natural and man-made, and their impact on critical infrastructure and facilities. The Center's goal is to reduce losses through research and the application of advanced technologies that improve engineering, pre-event planning and post-event recovery strategies. Toward this end, the Center coordinates a nationwide program of multidisciplinary team research, education and outreach activities.

Funded principally by NSF, the State of New York and the Federal Highway Administration (FHWA), the Center derives additional support from the Department of Homeland Security (DHS)/Federal Emergency Management Agency (FEMA), other state governments, academic institutions, foreign governments and private industry.

MCEER Special Report Series

Engineering and Organizational Issues Before, During and After Hurricane Katrina

Public Health and Environmental Infrastructure Implications of Hurricanes Katrina and Rita

James N. Jensen
Department of Civil, Structural and Environmental Engineering
University at Buffalo,
State University of New York

Pavani Ram
Department of Social and Preventive Medicine
University at Buffalo,
State University of New York

Volume 3

May 17, 2007

MCEER-07-SP02
Red Jacket Quadrangle
Tel: (716) 645-3391; Fax: (716) 645-3399; Email: *mceer@buffalo.edu*
World Wide Web: *http://mceer.buffalo.edu*

Foreword

On August 29, 2005, Hurricane Katrina made landfall with sustained winds estimated at 125 mph, unprecedented storm surges approaching 30 feet and winds extending 125 miles from its center. It resulted in over 1,300 lives lost, and caused major flooding and damage that spanned more than 200 miles along the Gulf Coast of the United States.

The extensive damage to the built environment far exceeded the expected damage for a storm of this size. Based on measured wind speeds and the Saffir-Simpson scale, Hurricane Katrina reached Category 5 strength while in the Gulf of Mexico, but quickly dissipated to a Category 3 storm before landfall. Although the wind speeds were substantially reduced before striking land, the storm surge apparently maintained the momentum associated with a Category 5 storm and is likely responsible for the majority of damage. It should be noted that early estimates ranked Hurricane Katrina as a Category 4 storm at landfall; the National Hurricane Center downgraded this ranking after revising wind speeds in December 2005.

Hurricane Katrina caused significant damage to engineered infrastructure including levees, commercial and public buildings, roads and bridges, utility distribution systems for electric power and water, waste water collection facilities, and vital communication networks. Damage to critical infrastructure such as hospitals and communication systems crippled the affected communities, and more importantly, the response and recovery efforts following the hurricane. In the aftermath of Hurricane Katrina, the important question now is: How can we better prepare ourselves to prevent or minimize the level of damage and the subsequent catastrophe in the next extreme event?

Funded by the National Science Foundation, a multidisciplinary team of investigators from the Multidisciplinary Center for Earthquake Engineering Research (MCEER), headquartered at the University at Buffalo, conducted post-disaster field reconnaissance to examine the impact of Hurricane Katrina on physical engineered systems and the response and recovery efforts that followed. Their objectives were to examine wind, storm surge and debris damage from a multi-hazard perspective. Implications of lessons learned from this reconnaissance effort are being examined to mitigate damage and improve response and recovery efforts not only from future hurricanes, but also from other extreme events such as earthquakes or terrorist attacks. By

collecting this multi-hazard information, MCEER is seeking to develop engineering design strategies and organizational strategies that will make communities more resilient against any extreme event.

The MCEER special report series "Engineering and Organizational Issues Before, During and After Hurricane Katrina" was initiated to present the findings from the field reconnaissance mission. The topics addressed include advanced damage detection using remote sensing, damage to engineered structures, organizational decision making primarily in hospitals, and environmental and public health issues. The reports will contribute to the development of a better understanding of how to cost-effectively enhance the resilience of the nation's infrastructure against future extreme events.

Acknowledgements

The authors offer their humble condolences for hurricane-affected communities throughout the Gulf Coast region and express their sincere gratitude to the many Louisiana residents who talked about their difficult personal experiences with candor and, even humor. We are also grateful to the many governmental and non-governmental colleagues who spared time to interact with us during very busy days. The spirit and dignity of the people of Louisiana will remain with us long after the memories of the devastation fade.

Contents

1.0 Introduction

The public health and environment reconnaissance team visited the Gulf Coast from October 17, 2005 to October 22, 2005. The team comprised Dr. James N. Jensen, professor in the Department of Civil, Structural and Environmental Engineering at the University at Buffalo and Dr. Pavani Ram, research assistant professor in University at Buffalo's Department of Social and Preventive Medicine. The team's efforts extended from New Orleans to the parishes north of Lake Pontchartrain to the Louisiana-Texas border. The primary study areas were Orleans, Jefferson, St. Tammany, Washington, Calcasieu, and Cameron parishes. Details of the facilities visited and contact personnel are given in Table 1-1.

The structure of this report is as follows. Information on the public health aspects of the site visit is given in Section 2. Section 3 reviews the environmental infrastructure observations. The lessons learned from the site visit are discussed in Section 4.

Figure 1-1. Map of locations visited by the public health and environmental infrastructure reconnaissance team

Table 1-1. List of Sites Visited

Date	Facility	Contacts
10/17/2005	Wellhead/treatment plant, Walker, LA	None
10/17/2005	Red Cross shelter, Denham Springs, LA	Nurse and social worker
10/18/2005	Louisiana State Epidemiologist' Office, Kindred Hospital, New Orleans, LA	LA State Epidemiologist and staff
10/18/2005	East Jefferson Water Works District #1 drinking water treatment facility, New Orleans, LA	Head operator
10/18/2005	Main Red Cross distribution site, Carrollton Avenue, New Orleans, LA	Red Cross personnel
10/18/2005	New Wine Church shelter, Laplace, LA	Shelter personnel
10/19/2005	Region IX Office of Public Health, Mandeville, LA	Regional Epidemiologist; Regional Sanitarian
10/19/2005	American Red Cross Coordinating Site, Covington, LA	Red Cross personnel
10/19/2005	American Red Cross Coordinating Site, Baton Rouge, LA	Red Cross personnel
10/19/2005	Carrollton Drinking Water Treatment Plant, New Orleans, LA	Water Purification Superintendent
10/19/2005	Wastewater Treatment Plant, Slidell, LA	Chief Operator
10/20/2005	Region IX Office of Public Health, Mandeville, LA	St. Tammany Parish Sanitarian
10/20/2005	Willa Villa Trailer Park, Bogalusa, LA	Resident
10/20/2005	Two private residences, Bogalusa, LA	Residents
10/20/2005	Eden Isle area, St. Tammany Parish	None
10/21/2005	Region V Office of Public Health, Lake Charles, LA	Regional Epidemiologist; Two Sanitarians
10/21/2005	City of Cameron, Great Lake, Sweet Lake, and other points along Hwy 27, Cameron Parish, LA	None
10/21/2005	Private home, Lake Charles, LA	Resident

2.0 Public Health

Hurricane Katrina, which made landfall on August 29, 2005, resulted in the loss of more than one thousand lives in New Orleans and surrounding areas in eastern Louisiana. On September 23, Hurricane Rita caused extensive property damage in the western parishes of Louisiana, including Calcasieu, Cameron, and Vermilion. Hundreds of thousands of persons were displaced from their homes, either because of voluntary evacuation before the hurricanes or mandatory evacuation from uninhabitable areas after the hurricanes. For weeks, and occasionally months, many displaced persons stayed in shelters established by government authorities, the American Red Cross, and churches and other community organizations. During the immediate post-hurricane period, extensive media attention was paid to the potential grave public health consequences of the disaster.

In this report, the public health implications of Hurricanes Katrina and Rita among Louisiana residents are reviewed. The information reviewed here is a compilation of information gathered during interviews with primary respondents as well as published material from governmental and non-governmental sources.

The main objectives of the public health portion of the report are to:

1. Provide a general background on the effects of natural disasters on the public health

2. Describe the public health impact of Hurricanes Katrina and Rita among Louisiana residents

3. Interpret the humanitarian response to disasters relative to accepted standards (i.e., the Sphere Project and Sphere Standards)

2.1 Background

The major health effects of natural disasters can be categorized as incident-associated mortality, injuries, communicable disease, and mental health. In the next section, the available post-hurricane data on several of these effects are reported. An immediate concern to many in the post-disaster setting is the possibility of transmission of communicable disease from dead bodies to survivors. A review of the few studies that exist on this issue allays this concern (Morgan et al., 2005). Moreover, contrary to popular belief, the occurrence of catastrophic epidemics of communicable disease following

natural disasters is uncommon (Shultz et al., 2005). When they occur, outbreaks have more often been documented subsequent to disasters in the developing world and less frequently in industrialized nations (Shultz et al., 2005).

An underlying principle is that outbreaks of communicable disease can occur only if the etiologic agent is circulating in the population. For example, to have an outbreak of cholera in a post-disaster setting, the bacterium *Vibrio cholerae* must be circulating in the residents of the community or in their water supplies. Hurricane-affected residents do not suddenly and dramatically acquire *V. cholerae* if the pathogen was not living in the water supply and water bodies in and around the community and infecting the residents of the community prior to the hurricane.

Rather than a direct consequence of the disaster itself, disease transmission is often increased because of living conditions after the disaster. Overcrowding in shelters, insufficient access to potable water and sanitation, and inadequate coverage with routine immunizations such as the measles vaccine, all contribute to increased risk of communicable disease transmission. Surveillance for diseases of epidemic potential is critical in the post-disaster period. Guidelines from the internationally recognized Sphere Project, which provides guidance for humanitarian response to disasters and complex emergencies, are discussed below and consideration is given to the extent to which these guidelines were met in the post-hurricane state (The Sphere Project, 2004).

2.2 Public Health Impacts

As of December 1, 2005, the Louisiana Department of Health and Hospitals (DHH) reported the recovery of a total of 1090 bodies following Hurricane Katrina (*www.dhh.louisiana.gov*). Among the 487 bodies released to families to date, the coroner estimates that 466 (96%) were storm-related deaths. Nearly 75% of these deaths occurred among residents of Orleans, the parish in which New Orleans is located. Officials at the Louisiana Office of Public Health (OPH) Region V, which covers Hurricane Rita-affected parishes of Cameron and Calcasieu, reported that few deaths were documented in that part of the state. Region V officials attributed the dramatically lower death rate in the western parishes to compliance with the mandatory evacuation orders issued prior to Hurricane Rita as a result of fear instilled by the horrific consequences of Hurricane Katrina.

A syndromic surveillance system to capture injuries and other illnesses, including infectious and non-infectious diseases, was implemented by the

DHH and the Centers for Disease Control and Prevention (CDC) in health facilities serving persons living or working in Jefferson, Orleans, Plaquemines, St. Bernard Parishes (Center for Disease Control, 2005a). Prospective surveillance was conducted beginning on September 9, 2005. Retrospective data was collected as far back as August 27, two days before Hurricane Katrina made landfall. A total of 7,508 health events were reported to the surveillance system, with injuries causing about 27% of events for which patients sought care at the participating facilities. Falls represented the single most frequent cause of injury, among residents and relief workers alike. Intentional injuries, i.e., injuries deliberately inflicted by one person against another or against oneself, resulted in only 2% of all injury and exposure-related events. Infectious diseases accounted for 37% of illnesses recorded in the prospective surveillance system. Skin or wound infections were diagnosed in 40% and acute respiratory infections (ARI) were diagnosed in 32% of the infectious disease encounters.

A cluster of methicillin-resistant *Staphylococcus aureus* (MRSA) infections was reported among evacuees from New Orleans housed in a Dallas, Texas facility (Figure 2-1). Transmission of the drug-resistant *S. aureus* is enhanced in close-contact situations and when hygiene is inadequate. Insufficient access to soap and water predisposes to poor skin hygiene.

Photo courtesy of Public Health Image Library, CDC

Figure 2-1. Wound infection caused by methicillin-resistant ***Staphylococcus aureus***

The *Vibrionaceae* family of bacteria includes *V. cholerae,* the causative organism of cholera, and several non-choleragenic species. Non-choleragenic *Vibrio* species can cause wound infections, gastrointestinal illness, or life-threatening systemic infections. Individuals with chronic medical problems such as liver disease or immunosuppression are at increased risk for wound infections with non-cholera *Vibrios. Vibrio* infections are typically acquired from the environment and are not transmitted from person-to-person. Gulf Coast states contribute about 35% of the annual burden of 400 non-choleragenic *Vibrio* cases documented in the United States each year. A total of 22 illnesses and 5 deaths caused by non-cholera *Vibrio* were detected among Gulf Coast residents between August 29, 2005 and September 11, 2005 (Center for Disease Control, 2005b). Of these, 18 were wound-associated and most of the wound infections were caused by the species *V. vulnificus* (Figure 2-2). The cluster of *Vibrio* infections may be explained by the fact that the Gulf Coast is endemic for these pathogens and there was large-scale exposure of people to *Vibrio*-contaminated floodwaters in the aftermath of the hurricane. Wounds that come into contact with brackish or sea water should be washed thoroughly with soap to reduce the risk of *Vibrio* infections.

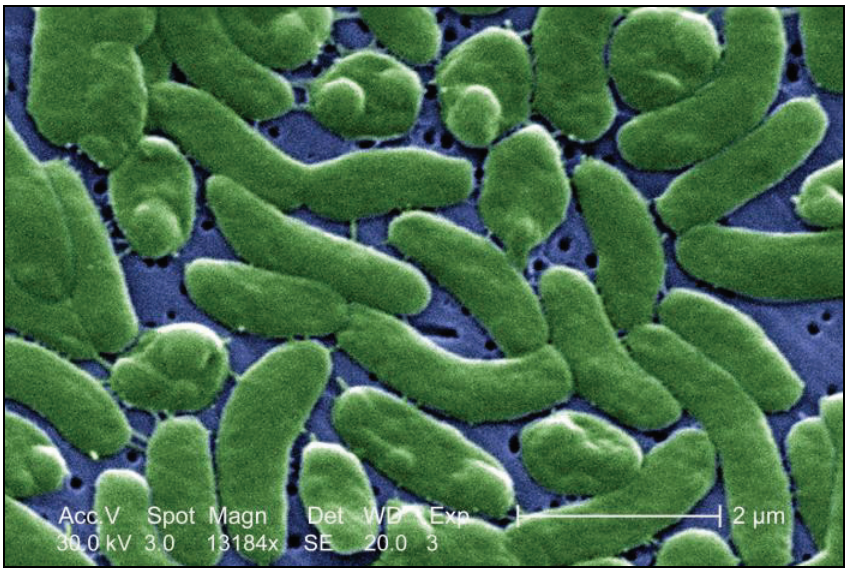

Photo courtesy of Public Health Image Library, CDC

Figure 2-2. Scanning electron micrograph of ***Vibrio vulnificus***

During the three weeks following Hurricane Katrina, diarrheal disease was common with about 1000 cases reported from several Gulf Coast states (Center for Disease Control, 2005c). About 1150 (5%) of the 24,000 evacuees sheltered at the Reliant Park complex in Houston, Texas suffered gastrointestinal illness between September 2, 2005 and September 12, 2005. Norovirus infection was confirmed by the laboratory in 22 stool specimens. Norovirus is the most common cause of gastrointestinal illness in the United States and is highly contagious. The pathogen can be spread by contaminated food or water, by fomites, or from person to person. Fomite or person-to-person transmission is enhanced in crowded situations such as might be experienced in evacuation shelters. Handwashing with soap plays a critical role in halting norovirus transmission. The risk of diarrheal disease is greatly increased when drinking water is contaminated with microorganisms, as occurred in many hurricane-affected communities (see Section 3.1.5).

Guidance for screening for mental health issues was provided by federal agencies including the CDC and the Substance Abuse and Mental Health Services Administration. At the time of this writing, no published results of mental health screening were available.

2.3 Interpretation

2.3.1 Introduction to the Sphere Project

Although exact figures are not available, about one million people were estimated to have evacuated from Louisiana as a result of Hurricane Katrina. Large-scale evacuations occurred for Hurricane Rita as well. In the early days following the hurricane, tens of thousands of people sought shelter at the Superdome and Convention Center in New Orleans. Many evacuees ultimately stayed in hotel rooms or with friends and family in other parts of the state and country. Vast numbers were evacuated to shelters operated by non-governmental organizations, churches, and generous communities.

The Sphere Project is an international initiative to provide guidance for the achievement of minimum standards for care of populations affected by disasters and complex emergencies (The Sphere Project, 2004). The Sphere Project rests on two fundamental principles:

- "All possible steps should be taken to alleviate human suffering arising out of calamity and conflict"
- "Those affected by disaster have a right to life with dignity and therefore a right to assistance"

Guidelines are provided for minimum standards in health services, food security, shelter, and water supply, sanitation, and hygiene promotion. They are intended to be used in various emergency settings and in developing and developed countries alike. Acceptable time for achievement of the standards is not specified since innumerable factors play a role in their implementation. As noted in Section 2.2, several of the clusters of illness detected after Hurricane Katrina could have been mitigated with improved water and hygiene practices. Therefore, the discussion below focuses on the Sphere standards as they apply to water, sanitation, and hygiene and the extent to which these standards were met in the post-hurricane context. Features relevant to these standards were reviewed during the assessment team's visit to Louisiana during the week of October 17. The team visited an American Red Cross shelter housing 53 persons in Denham Springs, LA and a church-based shelter for 48 in a church sanctuary in LaPlace, LA (Figure 2-3).

Figure 2-3. Church-based shelter in LaPlace, LA, October 2005

2.3.2 Sphere Standards for Water

The Sphere standards for water address supply, quality, and water use and goods. The standards are:

- Average water use for drinking, cooking and personal hygiene in any household is at least 15 liters per person per day.
- Water sources and systems are maintained such that appropriate quantities of water are available consistently or on a regular basis.
- People drink water from a protected or treated source in preference to other readily available water sources.
- No negative health effect is detected due to short-term use of water contaminated by chemical (including carry-over of treatment chemicals) or radiological sources, and assessment shows no significant probability of such an effect.

The Sphere standards for water can be applied to the post-hurricane relief efforts as follows. The usual source of drinking water, the local municipal water supply system, was unavailable in communities hit by Hurricanes Katrina and Rita for days to weeks after the respective disaster. As noted in Section 3.1.2, boil water notices were posted for communities in all hurricane-affected parishes. Local public health officials in Hurricane Katrina- and Rita-affected regions of Louisiana discussed the tremendous challenge of disseminating information regarding the importance of boiling water given the widespread disruptions in electricity and telephone service, which hampered the usual means of communication such as television and radio. Thus, public health officials could not be sure that people were adequately notified of the need to boil water; consumption of contaminated water without disinfection through boiling or other techniques could have placed people at risk for waterborne diseases such as diarrhea.

The assessment team visited Louisiana in mid-October, about six weeks after the hurricane. Although the team could not confirm directly, innumerable media reports described water, sanitation, and hygiene conditions in emergency shelters set up at the New Orleans Superdome and Convention Center. On September 1, 2005, the *Seattle Times* reported that two nine-ounce bottles of water were being distributed per person per day at the Superdome. Even if water was reliably available in the restroom facilities for handwashing and other hygiene needs, this volume of bottled water was likely insufficient to meet Sphere guidelines for water quantity in the shelter.

By mid-October, the assessment team found that bottled water was being distributed extensively by relief agencies (Figure 2-4) at shelters and distribution centers. However, evacuees who were residing in their own homes or other non-shelter locations had to locate and transport themselves to distribution sites where they could obtain bottled water. Since public transportation was largely non-functional and many private cars were rendered inoperable by the hurricane, those living far from a distribution center had decreased access to bottled water and other distributed goods.

Figure 2-4. Distribution of bottled water at an American Red Cross distribution site, New Orleans, Louisiana, October 2005

Hygiene issues were complicated by the presence of abundant floodwater. The microbiological quality of the floodwater was poor and similar to stormwater (Pardue et al., 2005). The Environmental Protection Agency and the Centers for Disease Control and Prevention recommended avoidance of body contact with floodwater.

2.3.3 Sphere Standards for Sanitation

Sphere sanitation standards applicable to the post-hurricane situation include:

- A maximum of 20 people use each toilet.
- Use of toilets is arranged by household(s) and/or segregated by sex.
- Shared or public toilets are cleaned and maintained in such a way that they are used by all intended users.
- People are provided with tools and materials for constructing, maintaining and cleaning their own toilets if appropriate.

The Sphere standards for sanitation can be applied to the post-hurricane relief efforts as follows. Media reports suggested that sanitation facilities during the several days following the Hurricane were far below minimum standards recommended by the Sphere Project. One evacuee at the Superdome was quoted by the *Seattle Times* on September 1, 2005: "We pee on the floor. We are like animals." Fox News reported on September 2, 2005 that "Bathrooms had no lights, making people afraid to enter, and the stench from backed-up toilets inside killed any inclination toward bravery."

Sanitation conditions at the shelters visited by the assessment team were much improved from the descriptions of the Superdome during the week after Hurricane Katrina. Both shelters visited had a sufficient number of toilets with the toilet:person ratio at 1:8 in one shelter and 1:13 in the second shelter, and the toilets were segregated by sex. Residents were noted to have taken personal responsibility for assuring the cleanliness of the toilets.

2.3.4 Sphere Standards for Hygiene

Hygiene-related Sphere standards relevant to the post-hurricane situation include:

- There is at least 250 g of soap available for personal hygiene per person per month.
- People wash their hands after defecation and before eating and food preparation.
- Where communal bathing facilities are necessary, there are sufficient bathing cubicles available, with separate cubicles for males and females, and they are used appropriately and equitably.

Handwashing with soap or use of alcohol-based hand sanitizers have been shown to reduce the risk of diarrheal and acute respiratory diseases by about 50%. The Sphere Project recommends that soap be made available for each

disaster-affected individual. Soap was made available in restrooms at the two shelters visited for handwashing after defecation. Shelter and community residents alike reported that alcohol-based hand sanitizers were distributed extensively by relief agencies (Figure 2-5). In one of the shelters, both soap and alcohol-based hand sanitizer were available at the sink. Alcohol-based hand sanitizer should be allowed to dry and not rinsed off. Shelter staff reported that, sometimes, residents used both soap and the alcohol-based hand sanitizer and then rinsed. Improved signage could have clarified appropriate use of these hygiene tools.

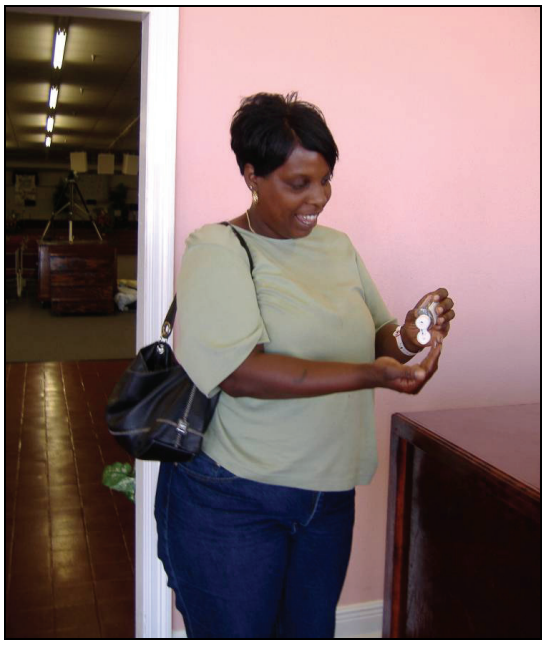

Figure 2-5. Resident at Louisiana shelter using alcohol-based hand sanitizer, LaPlace, LA, October 2005

2.4 Conclusions: Public Health

Based on the information collected during in-person interviews and a review of the public health literature on the effects of Hurricane Katrina, the following conclusions can be drawn:

- As expected, Hurricanes Katrina and Rita did not result in large, deadly epidemics of infectious diseases.

- Clusters of diarrheal disease and bacterial infections, such as non-cholera *Vibrio* and antimicrobial-resistant *S. aureus*, were evident.

- Many cases of diarrheal disease, respiratory illness, and skin infections could have been prevented with stricter attention to improved hand and skin hygiene, specifically washing with soap or the use of waterless hand sanitizers.

- Relative to the standards developed in the Sphere Project, better planning for the humanitarian care of the US population immediately after a disaster may be required. Such planning should take into account adequate provision of potable water, sufficient sanitation facilities, and appropriate communication messages and tools for maintaining adequate hand and body hygiene.

3.0 Environmental Infrastructure

One aspect of public health is the availability of potable water and the removal of wastewater. The environmental infrastructure required to support public health comprised six elements. Three elements are associated with drinking water (raw water supply, drinking water treatment, and drinking water distribution) and three elements are associated with wastewater (wastewater collection, wastewater treatment, and discharge of treated wastewater to the environment). Hurricanes Katrina and Rita inflicted significant damage to all six elements of the environmental infrastructure. The impact of the hurricanes varied significantly across the southern portion of Louisiana due to geographical factors.

In this report, the impact of Hurricanes Katrina and Rita on the environmental infrastructure of Louisiana is reviewed. The information reviewed here is a compilation of data gathered during interviews with water, wastewater, and public health personnel and published material from governmental sources.

The objectives of the environmental infrastructure portion of the report are to:

1. Describe the effects of the hurricanes on the drinking water infrastructure

2. Describe the effects of the hurricanes on the wastewater infrastructure

3.1 Drinking Water

3.1.1 Overview

Hurricanes Katrina and Rita impacted the vast majority of drinking water treatment plants in a 600 km swath across the Gulf Coast. As shown in Table 3-1, over 4,000 drinking water treatment plants in four states were adversely affected. Collectively, the plants serve over 13 million people.

The remainder of this report will focus on Louisiana, which serves the largest portion of the population of the Gulf Coast. To assess the number of drinking water utilities and people in Louisiana affected by the hurricanes, it is useful to examine the history of boil water orders. Orders for the public to boil tap water are issued in Louisiana until the utility has:

- Uninterrupted treatment capable of producing water meeting microbiological standards

- Backup electrical service in place
- Capacity to receive and store treatment chemicals, and
- Capability to maintain adequate pressure in an uninterrupted fashion

Table 3-1: Drinking Water Facilities Affected by Hurricanes Katrina and Rita

State	No. of Facilities	No. of People Served
Louisiana	1,591	5 million
Mississippi	1,367	3.1 million
Alabama	72	961,000
Texas	1,054	4 million
Total	*4,084*	*13.1 million*

Source: *www.epa.gov*

Boil water orders for the state are shown over time in Figure 3-1. (Boil water orders are broken down by parish in Appendix A.) Note that the number of boil water orders increased to about 500 after Hurricane Katrina made landfall on August 29, 2005 and increased to over 700 after Hurricane Rita made landfall on September 23, 2005. Some facilities on the boil water order list no longer exist as a result of massive hurricane-related damage. On December 9, 2005, the DHH lifted the boil water order for all of eastern New Orleans except lower Ninth Ward and ZIP Code 70117 east of the Industrial Canal (New Orleans Times-Picayune, 2005).

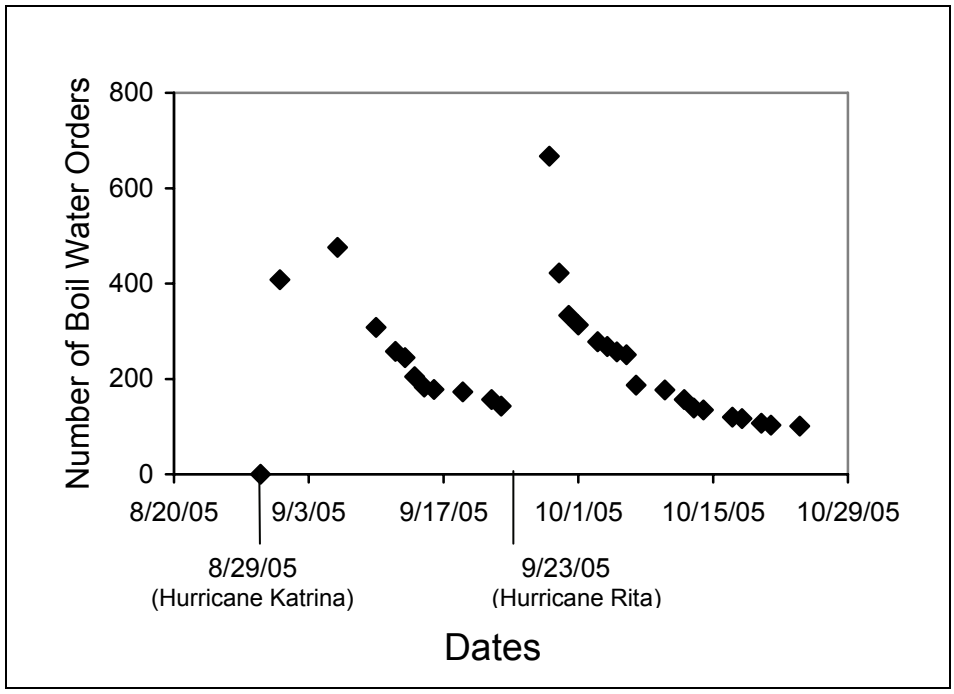

Figure 3-1. Boil water orders in Louisiana

3.1.2 Drinking Water Supply

To assess the impact of the hurricanes on the drinking water supply, it is necessary to understand the sources of drinking water in Louisiana. Surface water (primarily, the Mississippi River) serves as the source water for only 5% of Louisiana's 1,215 permitted water supplies. However, surface water is used by 42% of the state's residence. Of the people in Louisiana drinking treated surface water, over half (53%) are in the metropolitan New Orleans area (Jefferson and Orleans Parish).

In general, Hurricanes Katrina and Rita had little effect on the quality of surface water sources. In particular, the quality of the Mississippi River as a water source was not affected by the hurricanes.

The quality of the groundwater sources was affected by the hurricanes. In the areas using groundwater visited by the reconnaissance team (St. Tammany and Washington Parishes north of Lake Pontchartrain and Calcasieu and Cameron Parishes in the Lake Charles area), municipal wells supplying community water systems typically are deep, but private wells may be quite shallow. For example, the municipal supply for the City of Slidell in St.

Tammany Parish comprises deep wells (about 2,000 ft deep). Significant numbers of people in Louisiana are served by private wells. For example, Washington Parish has a population of about 44,000. About 24,000 people are on public water supplies (all groundwater sources) and about 20,000 are on private wells.

Possible well contamination led to the issuance of boil water orders. For example, DHH officials issued boil water orders in OPH Region V (Lake Charles area) if:

- the well was flooded (primary reason)
- the well casing was compromised, or
- the pump was reprimed with poor quality water

In general, boil water orders in the Lake Charles area were issued for community systems that lost pressure. Loss of pressure may have occurred when power was lost or when emergency generators ran out of fuel. Power was restored to some of the region within three days, although other parts of the region were still without power. In general, the community water systems immediately went to backup generators. Non-community systems typically did not have generators.

The effects of the boil water orders on community systems were minimized in the Lake Charles area because Calcasieu and Cameron Parishes were under mandatory evacuation. Residents were not allowed in to Calcasieu Parish until power and potable water service was restored.

In OPH Region V, all community and non-community water systems were declared to be under a boil water order after Hurricane Katrina. This decision was much different than with previous hurricanes, where boil water orders were made selectively. The blanket order was needed because of the length of time that power was out to the region.

In some cases, drinking water wells were completely destroyed. The municipal well for the Eden Isles Water Supply in Slidell was sheared off during Hurricane Katrina. Water poured out of the wellhead. The boil water order for the Eden Isles Water Supply was lifted on October 6, 2005. All six wellhead facilities in Cameron Parish were destroyed during Hurricane Rita.

3.1.3 Drinking Water Treatment

The utilities employing groundwater typically do not treat the water other than to add chlorine. Therefore, treatment issues are more important with the impacted facilities using surface waters.

Two examples are given of the challenges affecting drinking water treatment after the hurricanes. The first example is the Carrolton Water Works in Orleans Parish. This is the main drinking water treatment facility for the City of New Orleans. The plant treats 122 million gallons per day (mgd) and serves 440,000 people. The source water is the Mississippi River. The boil water order was issued on August 31, 2005. It was lifted for about 269,000 people on October 6, 2005. The boil water order for the remaining customers was lifted on October 7, 2005. The facility was visited by the reconnaissance team on October 18, 2005. At the time of the visit, the facility was operating with a highly reduced staff.

After power was restored to the treatment plant, water was produced quickly. Initially, raw water was coagulated but not disinfected. In general, chemical addition processes (coagulation and disinfection) were not affected significantly. However, filtration was impacted severely. The pipe galleries were flooded, rendering filter controllers and instrumentation inoperative. Filters were operated manually until controller operation was reestablished. Once treatment was reestablished, the plant maintained about 1 mg/L free chlorine (no ammonia added). As a result, the plant has switched from chloramination to chlorination. Staff expressed concerned that chlorine residuals may dissipate more rapidly than in the past.

The second example is the East Jefferson Water Works District #1 drinking water treatment facility in Jefferson Parish. This is the main drinking water treatment facility for the Jefferson Parish. The plant serves 308,000 people. The source water is the Mississippi River. The boil water order was issued on August 31, 2005 and lifted on September 12, 2005.

This facility never shut down during the storm. Five plant personnel stayed in the facility during Hurricane Katrina and maintained operations. The Jefferson plant also served as a water source for Orleans Parish during the time that the boil water order was imposed on the Carrollton Water Works. Tanker trucks were filled at the plant for use in institutions such as hospitals.

3.1.4 Drinking Water Distribution

In general, drinking water distribution systems were extremely affected by the hurricanes. An example is provided by the distribution system of the

Carrolton Water Works in New Orleans. To assist in the reestablishment of service, the distribution system was valved off in a controlled fashion. Service was restored slowly. Large pipe breaks were repaired quickly. Distribution system problems came from numerous small breaks (perhaps hundreds) at service points, e.g., hydrants sheared of by storm-propelled vehicles and broken plumbing from homes moved in the storm. The six pipe crossings over the Industrial Canal were positively valved off to isolate the contiguous portions of the city.

While treated drinking water was flowing to most of Greater New Orleans quickly (see Appendix A), portions of the area were without water for months. Water distribution was not reestablished to the northern portion of the Lower Ninth Ward until October 2006, fourteen months after Hurricane Katrina (Krupa 2006).

The smaller distribution systems were affected to a smaller degree. For example, the distribution systems in Hackberry and Grand Lake (Cameron Parish) were not affected.

3.1.5 Other Drinking Water Issues

Three other factors played important roles in the recovery of drinking water service: monitoring, communication, and bottled water.

Monitoring. A great deal of effort was expended by treatment plant and public health professions to insure that drinking water in community and non-community systems was safe to drink. At the Carrolton Water Works in New Orleans, plant personnel collected 300-400 samples in exploratory sampling and three days of compliance sampling. Most samples were collected at hydrants. Only 11 samples tested positive for coliforms (only one fecal coliform-positive sample).

In the Lake Charles area, testing of water from private wells began two weeks after Hurricane Rita. A U.S. Environmental Protection Agency (EPA) mobile lab stationed in Kinder, LA performed presence/absence tests. Calcasieu Parish generated about five samples per day from private wells and about 5-7 samples per day from public water supplies. The parish has few private wells, most of which are located in South Lake Charles and most of which were not flooded. Vermillion Parish, which has more private wells, generated about 100-110 samples per day.

In the parishes north of Lake Pontchartrain (OPH Region IX), groundwater is the primary water source. Plants went back online fairly quickly. Facilities

dosed high levels of chlorine until microbiological analyses (sampled at Safe Drinking Water Act sites) were negative. A large proportion of the population relies on private wells for drinking water supply. The EPA put mobile laboratories in place soon after Hurricane Katrina but these were removed before Hurricane Rita struck the area. Testing resumed two weeks after Hurricane Rita and ended in mid-October. Families were requested to bring a drinking water sample in thiosulfate-containing sterile containers. They were notified of samples found to have total coliforms and/or *E. coli*. All families were given instructions on the disinfection of private wells.

The State of Louisiana has established a web page to distribute the results of testing of private wells. Approximately 1,200 test results were posted from September 11, 2005 to December 15, 2005.

Communication. There were severe problems in communicating the boil water orders to the community (see also Section 2.4.2). There was no landline or cell phone service. Television was out. Communication through radio was possible, although radio broadcasts by the United Radio Broadcasters (the New Orleans consortium formed after Hurricane Katrina) focused on New Orleans news. In addition, travel was difficult because of downed trees and the need of residents to conserve fuel. The primary mode of communicating boil water orders in Slidell (St. Tammany Parish) was sandwich board signs placed at major intersections. Problems occurred when signage indicating "Water OK" were posted (Figure 3-2), since residents often did not know which water system they were on.

Bottled water. As discussed in Section 2.4.2, many people relied on bottled water during the time period when boil water orders were in effect. *Every* person interviewed in this study stated that bottled water was available. It is interesting to note that public confidence in the public water supplies appeared low even after boil water orders were lifted. For example, the main Red Cross distribution center in New Orleans ran out of bottled water by mid-afternoon even seven weeks after Hurricane Katrina (Figure 2-4).

Figure 3-2. Communication of the state of the environmental infrastructure: Eden Isles, LA

3.2 Wastewater

3.2.1 Overview

Hurricanes Katrina and Rita also impacted a large number of wastewater treatment plants across the Gulf Coast. As shown in Table 3-2, 800 wastewater treatment plants in four states were adversely affected.

The story of wastewater in southern Louisiana is a tale of two regions. In Greater New Orleans, conventional wastewater collection and treatment systems are employed. In southeastern Louisiana, private wastewater treatment systems are more prevalent. In fact, over 20,000 onsite treatment systems were licensed in Louisiana in 2005. Onsite systems treat about 125 mgd in the state. Onsite treatment systems include septic systems/absorption fields, oxidation ponds, mechanical systems (including aerobic treatment unit or ATUs), and sand filters. Septic systems, while common in New York State, are rare because of the low porosity of the soil.

Table 3-2: Wastewater Facilities Affected by Hurricanes Katrina and Rita

State	No. of Facilities
Louisiana	317
Mississippi	329
Alabama	84
Texas	70
Total	*800*

Source: *www.epa.gov*

3.2.2 Wastewater Collection

In general, wastewater is collected by gravity. In flat areas, such as the Gulf Coast region of Louisiana, pump stations are needed to transmit the wastewater from the point of generation to the treatment plant. Pump stations (also called lift stations) require power. The primary impact of the hurricanes on wastewater collection was the loss of power to the pump stations.

As an example, the city of Slidell employs 90 pump stations in its distribution system. This is a very large number of pump stations for a 6 mgd facility. Flow to the plant was delayed because power was not available to the lift stations in the collection system. As a result, wastewater began entering the facility five days after the storm, at which time the plant was restarted.

Regardless of how wastewater is collected, wastewater will build up in the collection system if not treated. This can cause significant problems. For example, some areas in Metarie (a 146,000-person suburb of New Orleans in Jefferson Parish) experienced sewage backup into the home as a result of the inability to process wastewater. Sewage backup problems were rampant in Orleans Parish.

Wastewater collection system problems in Greater New Orleans were exacerbated by the geographic extent of the system. The Sewerage and Water Board of New Orleans operates a sewage collection system with a service area of about 86 square miles and a service population of about 497,000. The collection system has 83 pump stations and over 100 miles of force mains (pipes conveying pumped wastewater).

3.2.3 Wastewater Treatment

Hurricanes Katrina and Rita severely impacted wastewater treatment. The two wastewater treatment plants in New Orleans are the East Bank Wastewater Treatment Plant (a 122 mgd activated sludge plant serving the East Bank of Orleans Parish) and the West Bank Sewage Treatment Plant (a 20 mgd trickling filter plant serving the West Bank of Orleans Parish). Immediately following Hurricane Katrina, treatment was disrupted completely and raw wastewater was pumped into the Mississippi River. By October 23, 2005, at least primary treatment had been reestablished to all of Greater New Orleans, except New Orleans East and the Lower Ninth Ward.

Many wastewater treatment plants were overwhelmed by flooding. As an example, the East Bank Wastewater Treatment Plant has an eight-foot flood wall. The estimated maximum floodwater depth near the facility was 13 feet (data found at *http://www.cctechnol.com*). Debris damage at some wastewater facilities was extensive (EPA 2006).

An example of the impacts of the hurricanes on wastewater treatment plants is provided by the Slidell Wastewater Treatment Plant. The Slidell facility is a 6 mgd high-rate activated sludge plant. It discharges to the W14 Canal, which feeds the Salt Bayou and ultimately Lake Pontchartrain. According to a rain gauge at the plant, the facility received 15 inches of rain from Hurricane Katrina, resulting in 4 feet of water on-site and 30 inches of water inside the buildings. Plant staff waded into the plant the day after Hurricane Katrina struck. A generator had tripped off early in the morning of the Hurricane Katrina strike. This likely protected the generator. The plant used the generator for a week until power was restored. Several motors and other pieces of small equipment were destroyed. The staff believes that the biomass was killed off by insufficient oxygen. After restart, water quality (BOD and TSS) have been good. Compounding the challenges, the plant has had to treat high strength wastewater from portable toilets and trailers. In addition, low rainfall (approximately ¾ inch since the storms) has affected settleability.

The treatment staff faces continuing problems. The staff anticipates that some corrosion may occur because of brackish water deposited on site (although Mississippi received much more brackish water, as evidenced by the death of plant life in the affected areas). In addition, staffing issues may play a role. At the time of the reconnaissance team's visit (October 18, 2005), the City of Slidell had lost about 25 people (out of a workforce of about 330) due to attrition after Hurricanes Katrina and Rita. Also, electrical contractors were in short supply.

Wastewater treatment challenges were different away from New Orleans. For example, the only municipal systems in Washington Parish are in Bogalusa and Franklinton. Many residents of the parish are on private wastewater systems, including septic systems/absorption fields, oxidation ponds, mechanical systems, and sand filters. Septic systems are not possible in all areas because of the low porosity of the soil. The situation is similar in St. Tammany Parish, except that oxidation ponds and sand filters are no longer allowed there. Private water systems also are common in OPH Region IX. In OPH Region IX, private wastewater systems frequently were flooded. This apparently led to sewer odor problems in the City of Lake Charles.

3.2.4 Discharge of Treated Wastewater

Wastewater processing requires a water body to discharge treated wastewater. It is fortunate that the City of New Orleans can discharge untreated wastewater to the Mississippi River. Although discharge of untreated sewage may have long-term environmental effects, the city could not be repopulated without a receiving water body.

3.3 Conclusions: Environmental Infrastructure

Based on the information collected during the site visits, the following conclusions can be drawn:

- Hurricanes Katrina and Rita caused the disruption of drinking water service to 5 million people in Louisiana. Bottled water (Section 2.4.2) was the main source of drinking water while service was interrupted.

- Drinking water treatment typically was restored soon after electric power was available, although systems with compromised wells remained under boil water orders.

- Drinking water distribution systems suffered large numbers of small breaks, leading to pressure loss and difficulties in reestablishing service.

- Wastewater collection systems were affected by the lack of electric power for pump stations.

- The availability of the Mississippi River as a receiving water body has allowed for partial repopulation of New Orleans.

4.0 Lessons Learned

There is no doubt that the courage, dedication, and heroism of public health and environmental professionals minimized the impacts of two large storms on the Louisiana Gulf Coast. During extreme events, professionals are called upon to make public health systems and water and wastewater facilities operational. A stellar example was set by the public health and environmental professionals in the Gulf Coast.

Regarding public health, planning is the key to providing humanitarian care after extreme events. Clusters of diarrheal disease and bacterial infections were observed. Many cases of diarrheal disease, respiratory illness, and skin infections could have been prevented by washing with soap or the use of waterless hand sanitizers.

Regarding wastewater, backup electric power and the availability of a receiving stream were key issues. Wastewater collection systems were affected by the lack of electric power for pump stations. Fortunately, the availability of the Mississippi River as a receiving water body has allowed for partial repopulation of New Orleans.

Regarding drinking water, Hurricanes Katrina and Rita caused the disruption of drinking water service to 5 million people in Louisiana. Bottled water was the main source of drinking water while service was interrupted (and after). Thus, access to transportation systems to distribute bottled water is of importance if water service is unavailable. Drinking water treatment typically was restored soon after electric power was available, although systems with compromised wells remained under boil water orders. Drinking water distribution systems suffered large numbers of small breaks, leading to pressure loss and difficulties in reestablishing service.

5.0 References

Centers for Disease Control and Prevention, 2005. "Surveillance for illness and injury after hurricane Katrina--New Orleans, Louisiana," September 8-25, 2005. [erratum appears in *MMWR Morb Mortal Wkly Rep*. 2005 Oct 21;54(41):1057]. *MMWR - Morbidity & Mortality Weekly Report,* 54: 1018-21.

Centers for Disease Control and Prevention, 2005. "Vibrio illnesses after Hurricane Katrina--multiple states," August-September 2005, *MMWR - Morbidity & Mortality Weekly Report*, 54: 928-31.

Centers for Disease Control and Prevention, 2005. "Infectious disease and dermatologic conditions in evacuees and rescue workers after Hurricane Katrina--multiple states," August-September, 2005. *MMWR - Morbidity & Mortality Weekly Report*, 54: 961-4.

Environmental Protection Agency, Office of the Inspector General. 2006. *Evaluation Report: EPA Provided Quality and Timely Information Regarding Wastewater after Hurricane Katrina*, Report No. 2006-P-00018, March 28.

Krupa M. 2006. "Potable water ready to flow in Lower 9," *New Orleans Times-Picayune*, October 7 2006.

Morgan O. and de Ville de Goyet C, 2005. "Dispelling disaster myths about dead bodies and disease: the role of scientific evidence and the media," *Pan American Journal of Public Health,* 18: 33-6.

New Orleans Times-Picayune, December 9 2005.

Pardue, J., Moe, W., McInnis, D., Thibodeaux, L., Valsaraj, K., Maciasz, E., VanHeerden, I., Korevec, N. and Yuan, Q., 2005. "Chemical and Microbiological Parameters in New Orleans Floodwater Following Hurricane Katrina," *Environmental Science & Technology,* 39: 8591-8599.

Shultz J.M., Russell J. and Espinel Z., 2005. "Epidemiology of tropical cyclones: the dynamics of disaster, disease, and development," *Epidemiologic Reviews*, 27: 21-35.

The Sphere Project, 2004. *The Sphere Project: Humanitarian Charter and Minimum Standards in Disaster Response*. Oxford, UK: Oxfam Publishing.

APPENDIX A: BOIL WATER ORDERS BY PARISH

Parish	Facility	Population Served	Date Boil Water Order Lifted
ORLEANS	NEW ORLEANS CARROLLTON WW	268917	10/6/2005
		159083	10/7/2005
JEFFERSON	E JEFFERSON WW DIST NO 1	308362	9/12/2005
JEFFERSON	W JEFFERSON WW DIST NO 2	209972	9/12/2005
LAFOURCHE	LAFOURCHE WATER DISTRICT #1	78760	9/10/2005
ST BERNARD	ST BERNARD PAR WATERWORK	67900	
ST TAMMANY	SLIDELL WATER SUPPLY	38612	10/7/2005
ORLEANS	NEW ORLEANS ALGIERS WW	56707	9/12/2005
ST CHARLES	ST CHARLES WATER DIST NO 1	24081	9/10/2005
ST CHARLES	ST CHARLES WATER DIST NO 2	24081	9/15/2005
TANGIPAHOA	HAMMOND, CITY OF	18000	9/10/2005
JEFFERSON	GRETNA WATERWORKS	17500	9/28/2005
ASCENSION	PEOPLES WTR CO.-DVILLE	16224	9/10/2005
ST TAMMANY	BRIARWOOD TERRACE	15484	9/10/2005
PLAQUEMINES	BELLE CHASSE WATER DISTRICT	14205	9/28/2005
LIVINGSTON	WALKER, TOWN OF	14088	9/10/2005
WASHINGTON	BOGALUSA, CITY OF	14000	9/10/2005
ST TAMMANY	MANDEVILLE WATER SUPPLY	13700	9/10/2005
ST TAMMANY	BAYOU LIBERTY WATER ASSC	13504	9/22/2005
EAST FELICIANA	EAST FELICIANA RURAL WATER WORKS	12436	9/10/2005
JEFFERSON	WESTWEGO WATERWORKS	11599	9/10/2005
PLAQUEMINES	PORT SULPHUR WATER DIST	10904	
ST TAMMANY	NORTH PARK WATER SUPPLY	9648	9/28/2005
ST TAMMANY	EDEN ISLES WATER SUPPLY	8713	10/7/2005
ST TAMMANY	COVINGTON WATER SUPPLY	8483	9/10/2005
ST TAMMANY	GREENLEAVES UTILITIES	7600	9/12/2005
ST TAMMANY	KINGSPOINT SUBDIVISION	7164	10/7/2005
ST TAMMANY	CROSS GATE SUBDIVISION	7076	10/7/2005
ST TAMMANY	WHISPERWOOD ESTATES S/D	7076	9/10/2005
ST TAMMANY	BEAU CHENE WATER SYSTEM	6500	9/10/2005
ST TAMMANY	LEE ROAD WATER CORPORATION	6084	9/10/2005
ST TAMMANY	ST WATER DIST 2	5200	9/10/2005
WASHINGTON	BOGUE-LUSA W.W. DIST.	5200	9/15/2005
WASHINGTON	VARNADO RURAL WWKS	5100	9/15/2005
ST TAMMANY	THE MEADOWS	5016	9/10/2005
WASHINGTON	FRANKLINTON, TOWN OF	4150	9/10/2005
LIVINGSTON	ALBANY, VILLAGE OF	4000	9/28/2005

(*Source: Louisiana Department of Health and Hospitals*)

Acknowledgements

This report was prepared by the Multidisciplinary Center for Earthquake Engineering Research through a grant from the Earthquake Engineering Research Centers Program of the National Science Foundation (supplement to award number EEC-9701471), funding from New York State, and other sponsors.

The material herein is based upon work supported in whole or in part by the National Science Foundation, New York State and other sponsors. Opinions, findings, conclusions or recommendations expressed in this publication do not necessarily reflect the views of these sponsors or the Research Foundation of the State University of New York.


MCEER
EARTHQUAKE ENGINEERING TO EXTREME EVENTS
University at Buffalo, The State University of New York
Red Jacket Quadrangle ▪ Buffalo, New York 14261
Phone: (716) 645-3391 ▪ Fax: (716) 645-3399
E-mail: mceer@buffalo.edu ▪ WWW Site http://mceer.buffalo.edu
University at Buffalo The State University of New York