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Water Quality Modeling of Freshwater Diversions in the Barataria Basin

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Water Quality Modeling of Freshwater Diversions in the Barataria Basin

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
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in
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by

Jeevan Neupane

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Abstract

A 1-D tidal, salinity and water quality model that analyzes the impacts of freshwater diversions with median and high flow on the water level, salinity and nutrient concentration of the Barataria Basin over a 2 period is presented here. The model predicts that the salinity of Lower Barataria decreases with the introduction of freshwater diversions. The model also predicts that nutrient concentration increases in Barataria Basin and decreases in Northern Gulf of Mexico with the introduction of diversions. The model shows the impact of freshwater diversions on water level except in the neighborhood of the diversion sites are small.

Keywords: Barataria Basin, Northern Gulf of Mexico, Water quality modeling, Freshwater Diversions, Water level, Salinity, Nutrient Concentration.

1.0 Introduction

1.1 The Barataria Basin

The site of this study is commonly called as Barataria Basin. The total area of the basin is approximately 6300 square kilometers. It is an irregularly shaped and is located in the north central Gulf of Mexico, just to the west of the Mississippi River Delta. The estuary is roughly 120 kilometers long and points southwest towards the Gulf of Mexico. The average depth is assumed to be 2 meter. The estuarine basin is bounded on the east by the levee of the Mississippi River, on the west by Bayou Lafourche and on the south by Gulf of Mexico. The northern part of the site consists of different lakes like Little Lake, Lake Salvador, Lake Cataouatche, Lac des Allemands, and Davis Pond. The southern half of the estuary contains tidally influenced marshes linked by the ponds, lakes, channels that terminates in a large bay system which finally outlets to the Gulf of Mexico through numerous passes like Caminada Pass, Barataria Pass, Pass Abel, Quatre Bayou Pass and Grand Bayou Pass. The wetland loss rates are very high in the basin for the last few years. The average wetland loss is nearly 25 square kilometers per year between 1974 and 1990. (Louisiana Coastal Wetlands Conservation and Restoration Task, 1993). The main reasons of the wetland loss in the Barataria Basin are natural process of sea level rise, subsidence and compaction, changes in deltaic sites of deposition, winds, tides, hurricanes and the human activities of channelization, levee construction, fluid withdrawal and development. (Coleman et al., 1988)

During the last 100 years so many artificial flood control levees have been constructed in the Mississippi River. The sources of the fresh water in the basin are very limited. Basically freshwater enters the basin from the three main sources: rainfall, manmade diversions and the Gulf Intracoastal Waterway (GIWW). The lack of freshwater and the loss of the accompanying sediments, nutrients, and hydrologic influence create the most critical problem of the Barataria Basin. The result of these problems is an increase in the tidal amplitude in the marshes in the central basin which finally results increased in salinities in the lower portion of the basin, increased land loss rates, and change in vegetation.

The wetland losses rate in the Barataria Basin is very high. If no proper actions are taken, another fifth of the basin's wetland would be lost to open water by 2045. With no actions, moderate wetland losses (about 20%) would occur in the middle of the basin and minor loss (about 8%) would occur in the upper basin over the next 50 years. The loss of the wetland means the loss of the aquatic life, nesting and nursery, destroying the natural habitat for economically and ecologically important fish, shellfish, alligator and several endangered species. The loss of wetland with relative increase in salinity would lead to lower diversity. (http://www.lacoast.gov/landchange/basins/ba/)

The salinity in the Barataria Basin is found to be increased as we go from north to south. The northern most part of the basin is almost all fresh. Fresh marshes are found near Lac Des Allemands, Lake Salvador, Lake Cataouatche and Davis Pond. Intermediate marshes start just south of Lake Salvador. Brackish marshes extend from Little Lake to the middle of the Bayou Barataria (Park 2002).

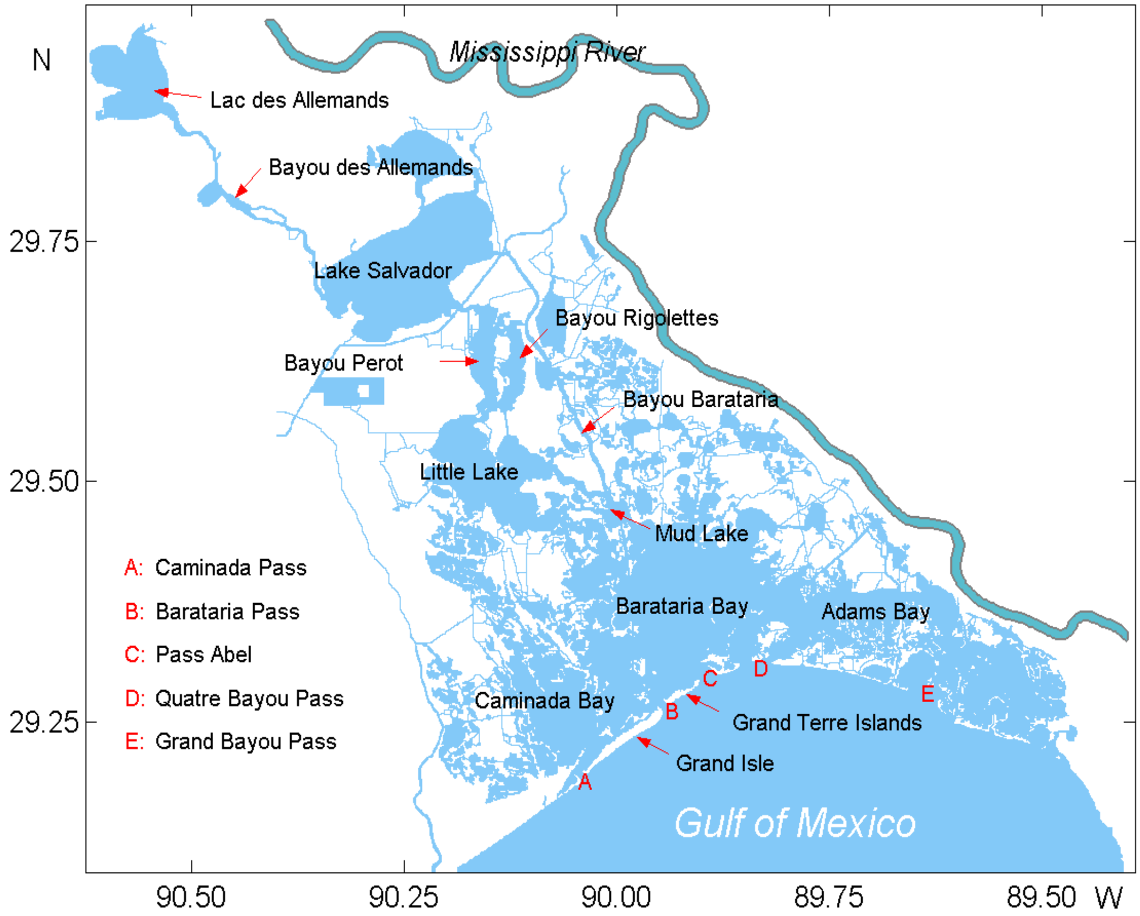

Figure 1.1-Overview of the Barataria Basin (Park, 2002)

1.2 *Freshwater diversions*

1.2.1 *Existing diversions*

Barataria Basin generally receives fresh water from the three sources: rainfall, manmade diversions from the Mississippi river and through The Gulf Intracoastal Waterway. The main goals of fresh water diversion are: to manage the productivity of wildlife and fishery resources by controlling salinity and to maintain the marsh elevation by introducing additional fresh water and sediments to the marsh (Park, 2002).The fresh water diversions can be beneficial in a number of ways. They reduce pressure on levees downstream, decrease salinities in wetland areas, and enhance marsh productivity and diversity, help wetland areas keep pace with sea level rise and can be good for recreational and commercial fisheries in a long term (Roblin, 2008;

Delaune, 2003; Lane, 1999). They have some negative impacts too. That can be expensive, can cause some adverse environmental impacts such as algal blooms, short or long term displacement of some species and fish kills (Roblin, 2008; Brammer, 2007; Turner and Boyer, 1997: LPBF 2005).

The Barataria Basin contains the following existing diversions.

1. Davis Pond (Sluiceway)
2. West Bay (Crevasse)
3. West Pointe a la Hache (Siphon)
4. Naomi (Siphon)
5. Harvey Canal (Lockage)
6. GIWW at the Mississippi River (Lockage)
7. GIWW at the Bayou Lafourche (Lockage

1.2.2 Proposed diversions

The State Master Plan has proposed six freshwater diversions projects in the Barataria Basin area (MLODS report).

1. Buras (Crevasse Type)
2. Deer range - just downstream of Myrtle Grove (Sluiceway)
3. Myrtle Grove (Sluiceway)
4. Jesuit Bend (Sluiceway)
5. Langan (near Des Allemands) (Sluiceway)
6. Johnson (near Des Allemands) (Sluiceway)

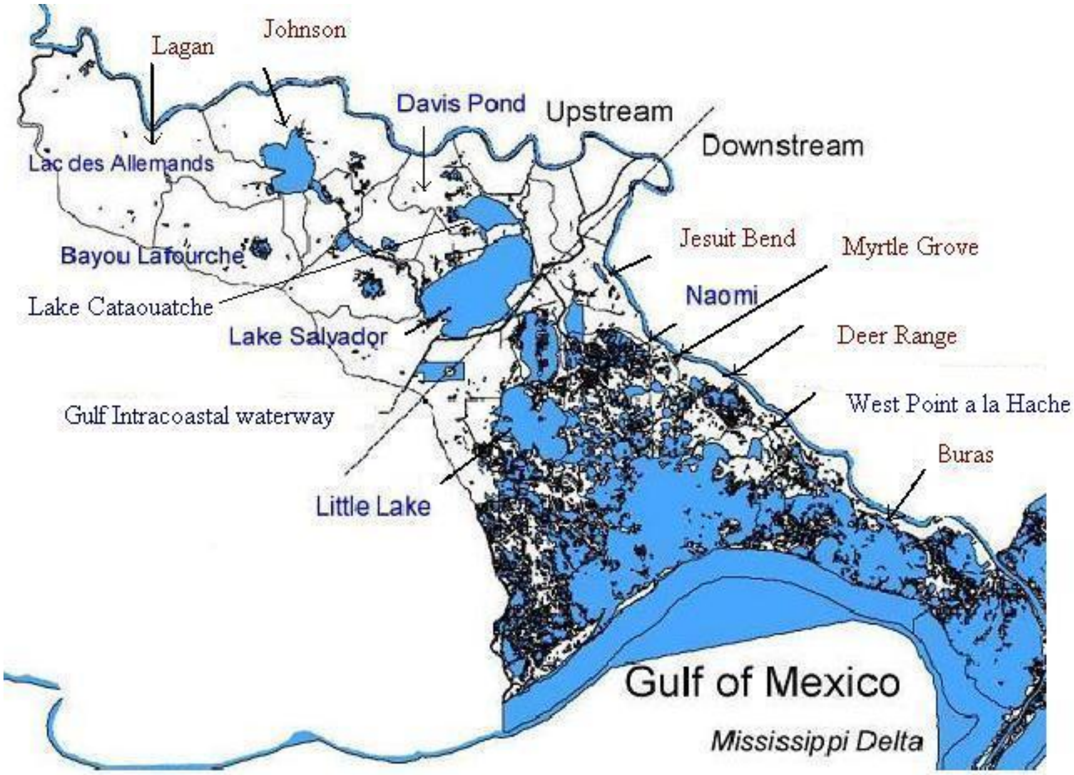

Figure 1.2-Barataria Basin with Future Diversion, (Park, 2002).

1.3 *Problem Statement*

The Hurricanes Katrina, Rita, Ike and Gustav caused considerable damages in the coastal area of Louisiana. Since Hurricane Katrina local, state and federal agencies are working together using a coast-wide recovery approach that incorporates natural restoration measures with artificial protection measures (Roblin, 2008). The fresh water diversions can help mitigate some of the damages. The proposed diversions will increase organic deposition, sediment deposition and compensate wetland losses. It is a really important issue to investigate how these diversions will impact on the water quality of the Barataria Basin. It is also necessary to examine the negative impacts of the diversions. The diversions are made from the Mississippi River which is rich in nutrients. This will increase the quantity of nutrients in the basin and can cause the problem like algal blooms.

The effects of similar freshwater diversions have been looked at previously in the Pontchartrain Estuary (Haralampides, 2000; Georgiou, 2002; McCorquodale et al., 2004; Dortch et al., 2007; McCorquodale et al., 2008). The UNO Cell Model which was originally developed for the Pontchartrain Basin was expanded to include the Barataria Basin. The Terrebonne Basin with two cells (Cell 107 and Cell 70) and a link to the Atchafalaya River was included to provide a better boundary condition on the west side of the Barataria Basin. A 1-D tidal, salinity and water quality model that analyzes the general effects freshwater diversions have on the water quality of the Barataria Basin over a 2-year period (2007 and 2008) is presented here.

1.4 Objectives

There are various objectives of this project. The important ones are:

- To develop, calibrate and apply a 1-D tidal, salinity and water quality model for the Barataria Basin ;
- To investigate the effects of future scenarios (median flows and high flows) on the water quality of the Barataria Basin;
- To apply the model to estimate possible impacts on nutrients loading to northern Gulf of Mexico.

These future scenarios include:

- Effect of the proposed freshwater diversions into the Barataria Basin on water quality, water level and salinity in the Barataria Basin;
- Effect of the closing of the West Bay Diversion on water quality, water level and salinity in the Barataria Basin;
- Effect of proposal diversions on the water quality in the northern Gulf of Mexico.

1.5 Methodology

The general procedure to accomplish the objectives is:

- Review existing literature to develop an understanding of water quality issues (both physical and ecological/biological);
- Collect long-term available hydrological, meteorological and water quality data records from stations located within the Barataria Basin;
- Review the available data including interpolating the missing data and fixing the datum conflicts;
- Modify the UNO 1-D code to make it applicable to the Barataria Basin;
- Prepare the data input files for the modified UNO 1-D model;
- Calibrate and validate the model to the water level salinity and water quality data collected from the Barataria Basin for 2007 and 2008;
- To predict the future scenarios using the calibrated model;
- Apply the modified 1-D tidal, salinity and water quality model.

2.0 Background

2.1 Coastal Wetlands

2.1.1 Formation of the Coastal Wetlands

According to the nature of rivers, the river picks up sediment and transports it downstream. The velocity of the flow decreases as the river reaches the mouth and it starts to deposit the suspended sediment. The huge accumulation of sediment for a long period of time forms a new land called the Coastal Wetlands. If the river changes its course a new coastal lobe will be formed and the former coastal lands will be eroded. The Teche, St. Bernard, Lafourche are the major deltas formed due to the course changing of the Mississippi River. The Mississippi has remained in the present course for the last 900 years and around 1400 square kilometers of new land have been formed in the northern Gulf of Mexico (US Army Corps of Engineers, New Orleans District).

2.1.2 Coastal Wetlands of Louisiana.

Louisiana coastal marshes consist of thin layer of primary organic soil held together and overtopped by mineral sediment deposited by the Mississippi River (US Army Corps of Engineers). The stability of coastal wetlands depends on the factors like subsidence and sea level rise. The rate of marsh accumulation in many areas is not sufficient to compensate the relative sea level rise and subsidence (Delaune et al., 2003). The rate of submergence is even more than 1.0 cm per year in the Mississippi River deltaic plain (Delaune 2003). The construction of the levees and the dams in the Mississippi river decrease the amount of sediment and nutrients that enter the coastal wetlands. "The salt water intrusion and the excess water logging increase the subsidence which finally reduces the organic carbon source below the minimum required value to maintain the marsh surface elevation at high level which cannot support the sufficient growth of marsh vegetation" (Delaune et al., 2003). Although organic matter accumulation plays more role than the mineral matter accumulation for vertical accretion in Louisiana marshes, a small amount of mineral sediment is needed for plant growth (Nyman et al., 1990; Delaney et al., 2003). The loss of coastal wetlands can be mitigated by supplying the sufficient amount of mineral sediment to the salt and freshwater marsh. This can be accomplished by freshwater diversion. The flow should be diverted according to the requirement of specific, salinity level and mineral sediment. The US Army Corps of Engineers has developed a plan of freshwater diversion projects from Mississippi River (US Army Corps of Engineers, New Orleans District). At the present there are a few freshwater diversion projects like Davis Pond Diversion, Naomi Diversion, and West Point a la Hache in Barataria Basin. These diversions direct the flow from Mississippi to the Barataria Basin. The Bonnet Carré Spillway and the Caernarvon diversion direct flow from Mississippi to the Pontchartrain Estuary.

The coastal wetlands of Louisiana are very productive. They provide natural habitat for many ecologically valued creatures. They also provide winter shelter for all types of waterfowl and migratory birds, (US Army Corps of Engineers, New Orleans District). According to the US Army Corps of Engineers the total benefits including sea food industry and menhaden landings from the coastal wetlands of Louisiana was about $2.6 billion in 2003. Moreover there was an economic benefit of $69 million from the wild and farmed alligator industry and $42 million from the crawfish industry in the same year. US Army Corps of Engineers, New Orleans District has also stated that the State of Louisiana has earned $792 million from recreation and salt water fishing in 2003. The protected areas of coastal Louisiana support agricultural production. In addition to all these, coastal Louisiana supports ecotourism which includes hiking, camping, swamp tours etc. The ecotourism has become an important source of income for the State.

2.2 Existing Diversions

2.2.1 Davis Pond Diversion

The Davis Pond Diversion Project (Figure 2.2) is located on the west bank of the Mississippi River, 35 kilometers upstream from New Orleans in St. Charles Parish. The diversion has maximum discharge of 300 m^3/s of freshwater to preserve about 135 square kilometers of marsh and 3,200 square kilometers marsh and bays (US Army Corps of Engineers). According to the US Army Corps of Engineers, New Orleans District, the construction of the project began in 1997 and completed in 2002. There were basically four main purposes of the project: reduce salt water intrusion, create a favorable salinity condition, reduce the wetland loss by supplying adequate amount of sediment and improve ecological life (Day, 2005). The diversion started to operate from summer 2002. After the operation of Davis Pond Diversion, the state of Louisiana has an estimated economic benefit of $ 15 million annually from fishing and $ 33, 000 from recreation (Day, 2005). It is predicted that the diversion will preserve 135 square kilometers of coastal wetlands and freshen 3150 square kilometers of marshes and bays in the next 50 years (US Army Corps of Engineers).

Figure 2.1-Davis Pond Freshwater Diversion Structure (Day, 2005).

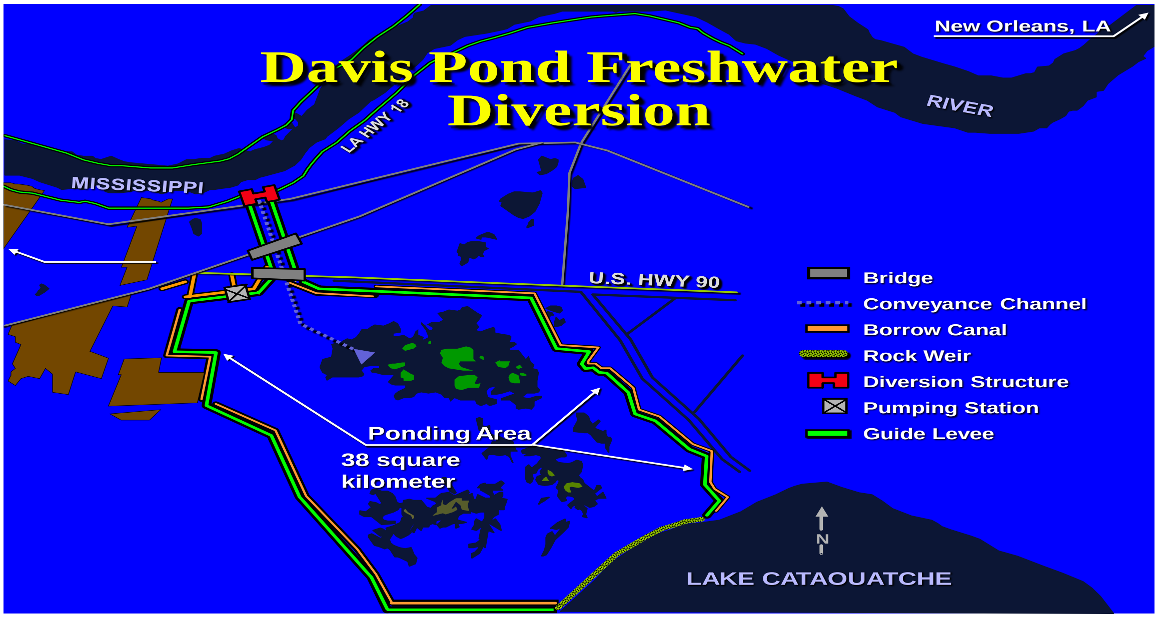

Figure 2.2-Davis Pond Freshwater Diversion (Day, 2005)

2.2.2 Caernarvon Diversion

The Caernarvon is the first freshwater diversion (Figure 2.3) project to be constructed through the Mississippi River levee system (US Army Corps of Engineers). The diversion Project is located on the east bank of the Mississippi River, 25 kilometers downstream from New Orleans just below the community of Caernarvon. The diversion actually diverts to flow to Pontchartrain estuary. The diversion has maximum discharge of 220 m^3/s of freshwater to preserve about 65 square kilometers of marsh and 1,100 square kilometers marsh and bays (US Army Corps of Engineers). The construction of the project began in 1988 and completed in 1991. The fresh water is diverted into Breton Sound Basin. There were basically four main purposes of the project: enhance the emergent marsh vegetation growth, reduce the wetland loss by supplying adequate amount of sediment, increase commercial and recreational fisheries productivity and improve ecological life, (Caernarvon Interagency Advisory Committee, 1993; Day, 2005). The project is estimated to have a total economic benefit of $9,155,000 from fishery, wildlife and recreation (Day, 2005).

After the operation of Caernarvon, the area of brackish marsh has been decreased considerably due to conversion to intermediate marsh. US Army Corps of Engineers find a net increase of 0.6 square kilometers marshland since 1990. Similarly the production of oyster has been increased by three times. The state has economic benefits of $ 15 million annually from fishing and $33, 000 from recreation, (Day, 2005). It is predicted that the diversion will preserve 135 square kilometers of coastal wetlands and freshen 3150 square kilometers of marshes and bays in the next 50 years, (US Army Corps of Engineers).

Figure 2.3-Aerial view of Caernarvon Diversion Structure (Day 2005).

2.2.3 Bonnet Carré Diversion

The Bonnet Carré Freshwater Diversion (Figure 2.4) is located on the east bank of Mississippi river, approximately 52 km upriver from New Orleans. This is a spillway type diversion. The Bonnet Carré Spillway is the only connection between the Mississippi River and the Pontchartrain Estuary. The structure contains 2.1 km weir and 9.2 kilometer long spillway (Roblin 2008). The spillway provides natural habitat to many species and it has become a good recreation area with approximately 250,000 visitors per year (Roblin, 2008).

The Bonnet Carré Spillway was designed to divert 7000 m^3/s of freshwater from the Mississippi river to the Lake Pontchartrain Basin and western Mississippi Sound. It has become a main source of sediments for many restoration projects located in the estuary (Roblin, 2008). According to the US Army Corps of Engineers, the diversion will reduce 43 square kilometers of marsh loss over the next 50 years.

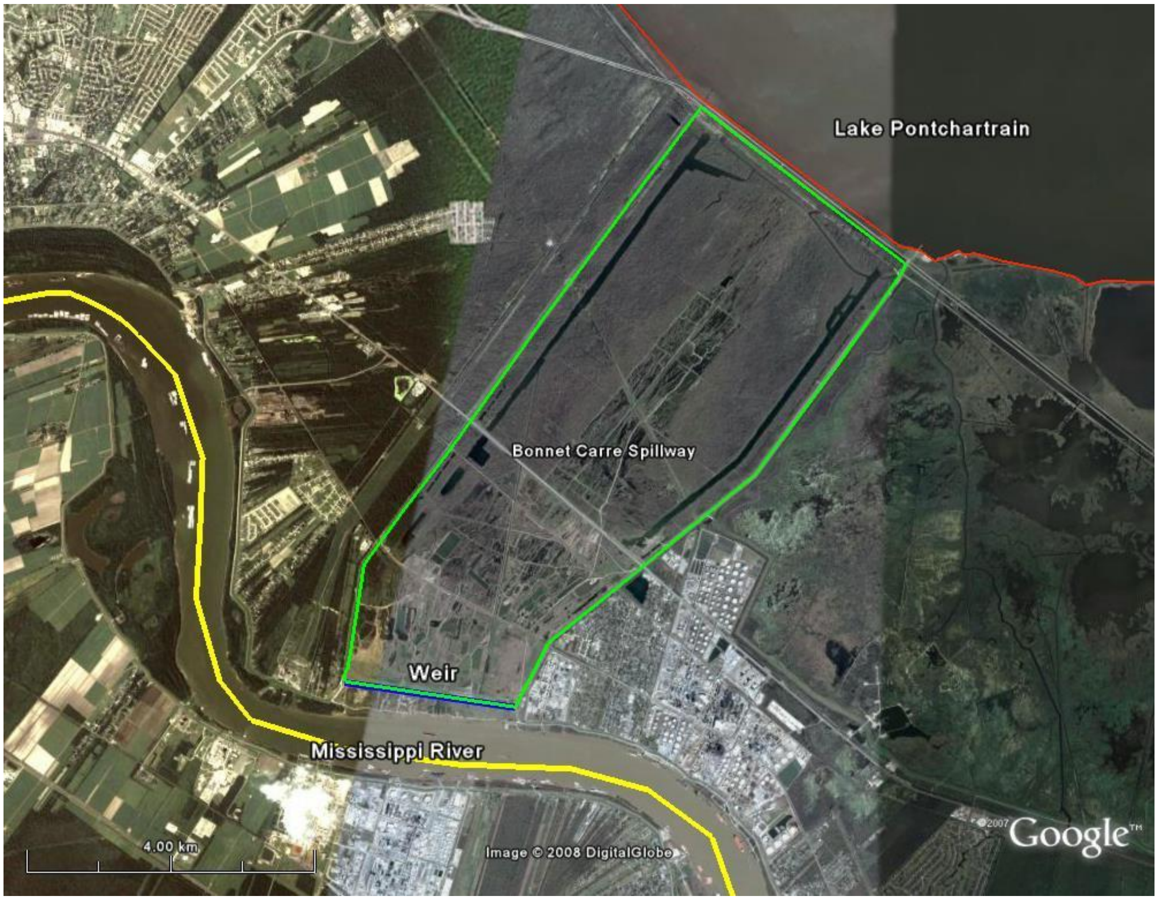

Figure 2.4-The Bonnet Carré Spillway (Roblin, 2008).

2.2.4 *Naomi Freshwater Diversion*

The Naomi Freshwater Diversion is located in the northeast Barataria Basin in Plaquemines and Jefferson Parishes. The project area comprises an area of about 52 square kilometers. Freshwater is diverted in to the project area through 8 separate siphons. The siphons have an average capacity to divert the flow of 56 m^3/s when all the pipes are in operation (LDNR). LDNR found that flows were the highest in the spring period although this was not planned. The ponding area receives water from the siphons and discharges into a single channel, 9.14 m wide and 1006 m long.

Figure 2.5-The Naomi Freshwater Diversion (LDNR)

LDNR has monthly record of salinity at 16 stations from 1992 to 1999 and 24 stations from 1999 to 2002. Some of the stations are shown in Figure 5.6. LDNR Report 2003 (BA-03c) states that the siphons can reduce the salinity in Naomi project area. According to the report, the salinity has been decreased considerably with the different flows (major and minor) on the siphons.

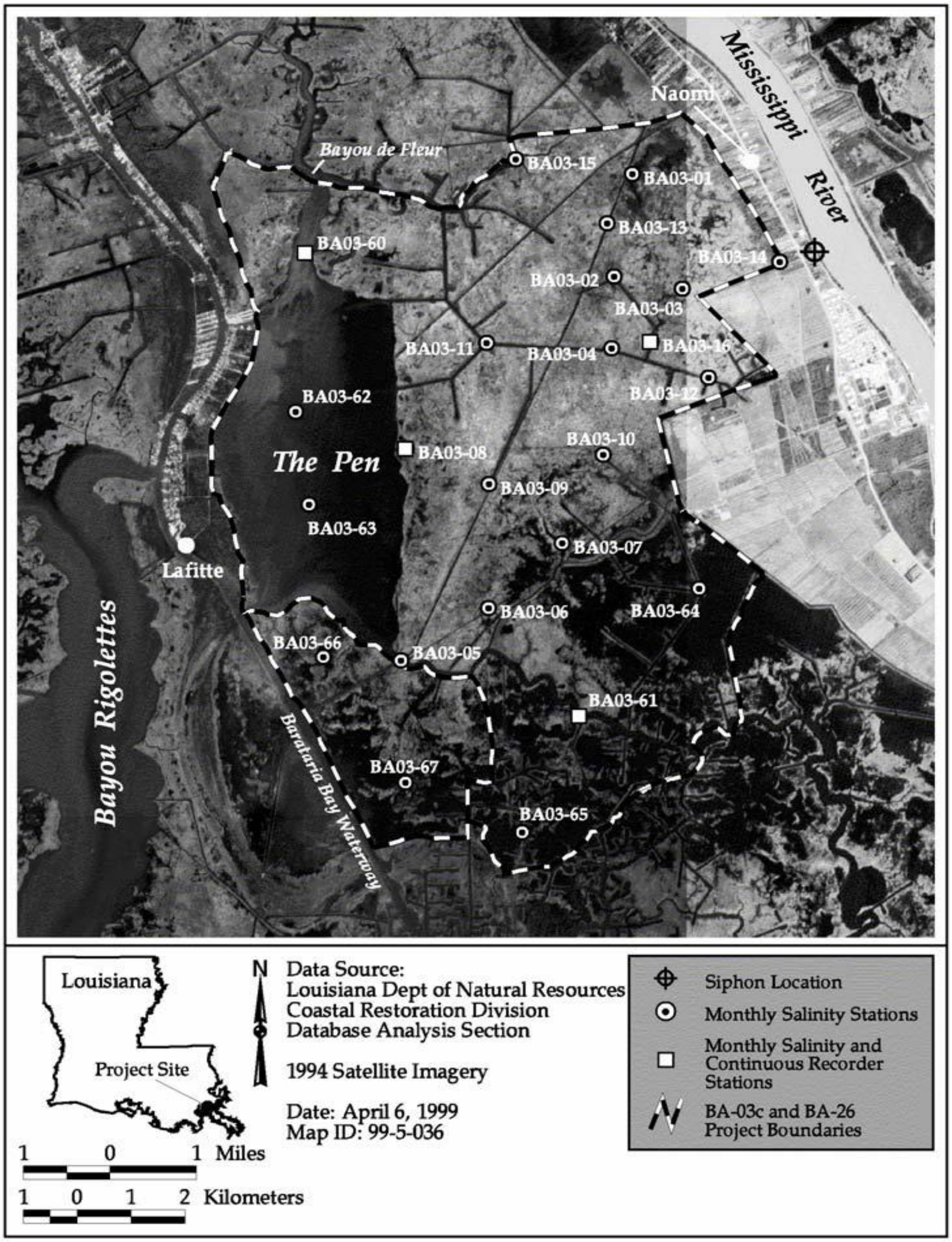

Figure 2.6-Data monitoring stations around Naomi Diversion (LDNR, 2003)

The LDNR report (2003) shows the variation of the average salinity for the years 1999-2003 in the different stations with the different flows in the siphons. The salinity in the station 16 was 3.6 ppt with no flows from the siphons, 1.8 ppt with minor discharge (less than 30 m^3/s) and 0.3 ppt with major discharge (greater than 30 m^3/s). Similarly the salinity in the station 61 was 7.4 ppt with no flows from the siphons, 5.5 ppt with minor discharge (less than 30 m^3/s) and 3.0 ppt with major discharge (greater than 30 m^3/s). The LDNR report (2003) also states that the high salinity brackish marsh of the southern part of the project area has been converted into low salinity brackish marsh after the introduction of the diversion.

2.2.5 West Point a la Hache

The West Point a La Hache diversion (Figure 5.7) is located within the Barataria Basin and in Plaquemines Parish. The project area comprises an area of about 66 square kilometers including open water and brackish marshes. Freshwater is diverted in to the project area through 8 separate siphons each consists of 792.5 m long steel pipe with a diameter of 1.8 m. The siphons have an average capacity to divert the flow of 60.7 m^3/s when all the pipes are in operation (LDNR Report 2005). Like other diversion structures as we discussed earlier, the main objective of this diversion is to protect the wetland loss by introducing fresh water from the Mississippi River. According to the Report of State of Louisiana, Department of Natural Resources, Coastal Restoration Division and Coastal Engineering Division (2005); the main goals of the project were to reduce average salinity, improve ecological life and to increase the open water ratio. The structure was constructed in 1992 and has been in operation since 1993.

Figure 2.7-The West Point a la Hache Freshwater Diversion (LDNR)

LDNR has monthly records of salinity at 17 different stations from 1993 to 2004. Some of the stations are shown in Figure 5.8. LDNR Report (2003) states that the siphons are can reduce the salinity in the project area and the mean salinity has been decreased considerably with the different flows (major and minor) from the siphons.

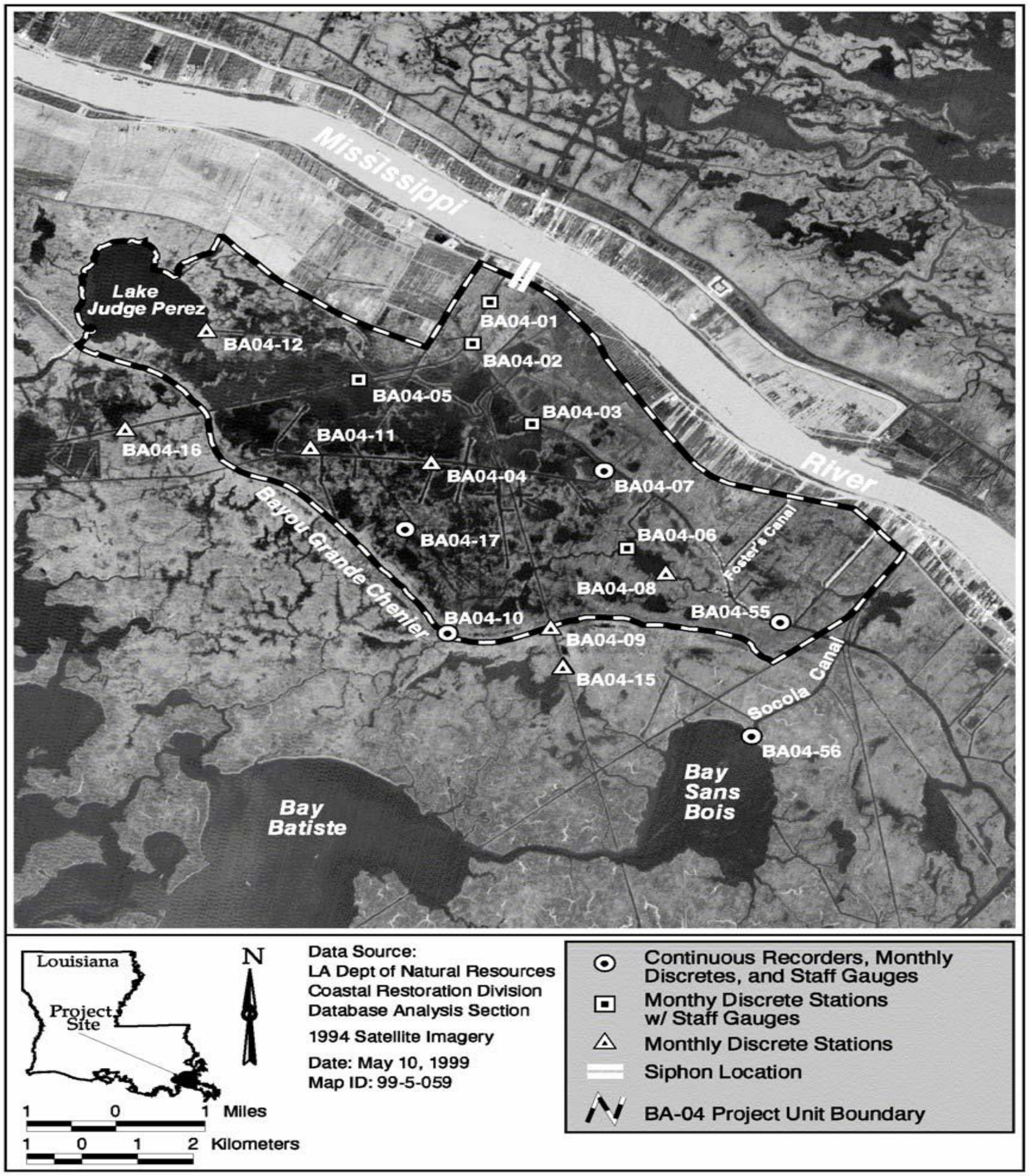

Figure 2.8-Data monitoring stations around West Point a la Hache Diversion (LDNR, 2005)

The LDNR report 2005 shows the variation of the average salinity for the years 1993-2004 in the different stations with the different flows in the siphons. The salinity in the station 7 was about 13 ppt with no flows from the siphons, 9 ppt with minor discharge (less than 30 m^3/s) and 7 ppt with major discharge (greater than 30 m^3/s). Similarly the salinity in the station 17 was about 10.5 ppt with no flows from the siphons, 7.5 ppt with minor discharge (less than 30 m^3/s) and 4.9 ppt with major discharge (greater than 30 m^3/s). According to the Report in 1995 the mean annual salinity is high as the flow in the siphons is low. The salinity not only depends on the flows in the siphons but also on different factors such as seasonal variability, rate of diffusion and existing salinity of the area.

3.0 Literature Review

3.1 *Introduction*

Eutrophication is defined as the process where water bodies receive excessive nutrients which cause excessive growth of algae (Nixon, 1995). This has been a major problem in many estuaries around the world for the last few decades, (Das et al., 2009). In this process the bodies of fresh water is enriched by the inorganic plant nutrients like nitrogen and phosphorus that may occur naturally or as a result of human activities like the use of fertilizers and sewage discharge. This process is mostly seen in the shallow lakes and slow moving rivers, (Jackson et al., 1998).

Hypoxia is a condition in which tissues are starved of oxygen and is defined as Dissolved Oxygen (DO) < 2 mg/L, (Britannica Concise Encyclopedia). Hypoxia has been observed over a large area in the Northern Gulf of Mexico for the last 20 years, (Das et al. 2009). Large hypoxic regions were not seen in the mid 1970s but the size of these regions increased steadily until the mid 1980s (Das et al., 2009). The hypoxic regions were observed after the flood of 1973 of the Mississippi and Atchafalaya Rivers (Krug, 2007). The magnitude of the Mississippi River's nutrient fluxes and the increasing of the hypoxia region in the Gulf of Mexico prove that the river borne nutrients play an important role in the development of the Hypoxic region in Northern Gulf of Mexico (Rabalis et al., 2007, Turner et al., 2008).

3.2 *Nitrogen Cycle*

The main reservoir of nitrogen is air that contains 79% of nitrogen gas. The nitrogen cycle is the transfer sequence that connects the process of life and decay of both plants and animals. The cycle corresponds to the biochemical uptake and degradation or decomposition of nitrogenous organic matter. The cycle is generally completed by nitrification and denitrification. The complete layout of an Ocean Nitrogen Cycle is shown in Figure 3.1.

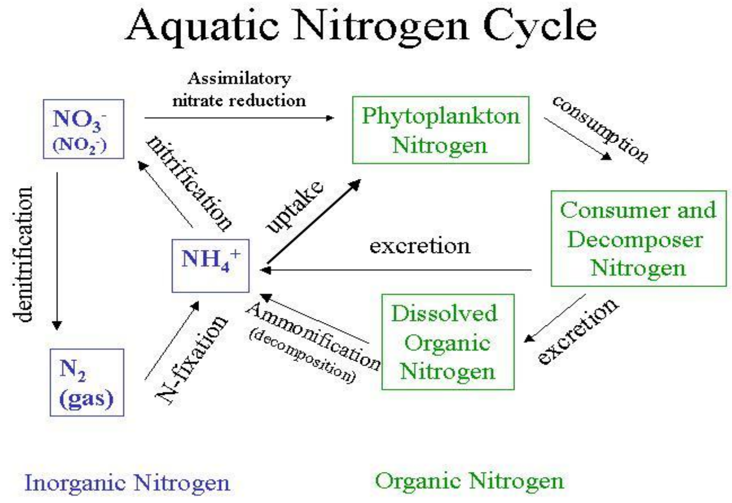

Figure 3.1 -Nitrogen Cycle (http://www.esf.edu).

The aquatic animals take nitrogen from the plants and the plants generally do not use the nitrogen from the atmosphere directly as the nitrogen molecule is quite inert; however algae can fix nitrogen from atmosphere. The process by which the nitrogen in the atmosphere is converted into ammonium is called the Nitrogen Fixation. The nitrogen fixing is done by nitrogen fixing microorganisms like Phytoplankton. Ammonium is then transferred to nitrite (NO_2^-) and subsequently to nitrate (NO_3^-) by a process is called nitrification. The denitrifying bacteria like Thiobacillus and Micrococcus convert the nitrites, nitrates and the nitrogen from excretion of aquatic animals into atmospheric N_2 again. In this way, the aquatic nitrogen cycle is completed.

3.3 Phosphorus Cycle

Phosphorus is a very important nutrient for plants and animals. The cycle that describes the movement of Phosphorus through the lithosphere, hydrosphere and biosphere is called Phosphorus cycle, (Wikipedia, 2008). Figure 3.2 shows the complete diagram of Phosphorus cycle in the water.

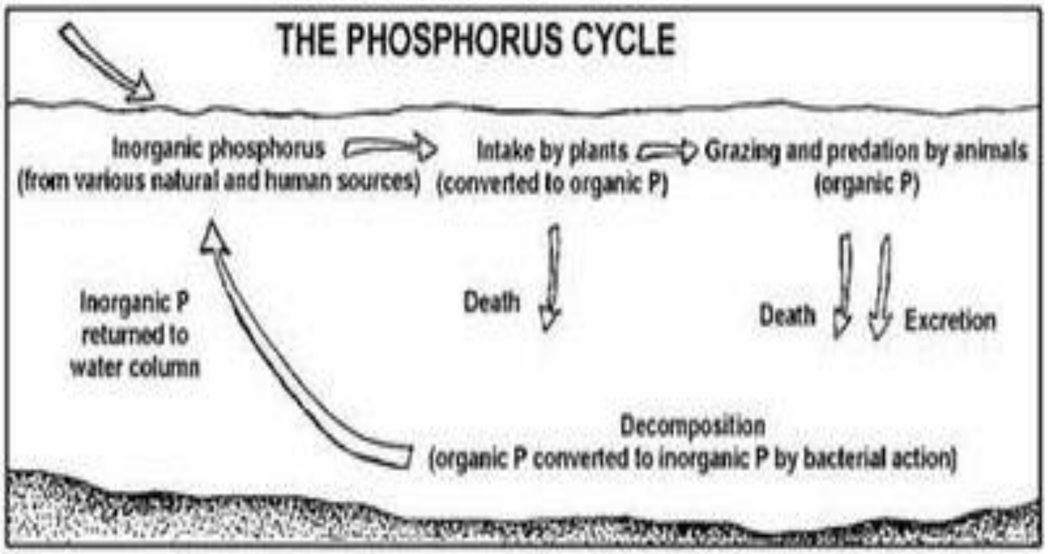

Figure 3.2-Phosphorus Cycle (http://water.epa.gov/type/rsl/monitoring/vms56.cfm).

The pure Phosphorus element (P) is rare. Phosphorus in the aquatic system occurs as organic and inorganic phosphates (US EPA, 2006). Plants can use only inorganic phosphates but animals can use both organic and inorganic phosphates. Both organic and inorganic phosphates are either dissolved in water or attached with the water column (US EPA, 2006).

Basically aquatic Phosphorus cycle start with the inorganic dissolved phosphorus present in water or suspended in soil. Aquatic Plants uptake the inorganic phosphorus for the photosynthesis process. Plants convert inorganic phosphorus to organic phosphorus. When animals consume the plants, the phosphorus is transferred to animals. Different bacteria and algae uptake organic phosphorus from the dead plants and animals and convert it into inorganic phosphorus. The phosphorus produced by the waste of animals before they die is also converted into inorganic phosphorus by the bacterial decomposition. The inorganic phosphorus gets back into the water column and a new cycle begins when the plants consume the inorganic phosphorus from the water column for the photosynthesis process (http://water.epa.gov/type/rsl/monitoring/vms56.cfm).

3.4 Carbon Cycle

The circulation of carbon between plants, animals and atmosphere is called Carbon Cycle. The cycle starts with the carbon dioxide in the atmosphere. Figure 3.3 shows the complete layout of Carbon Cycle.

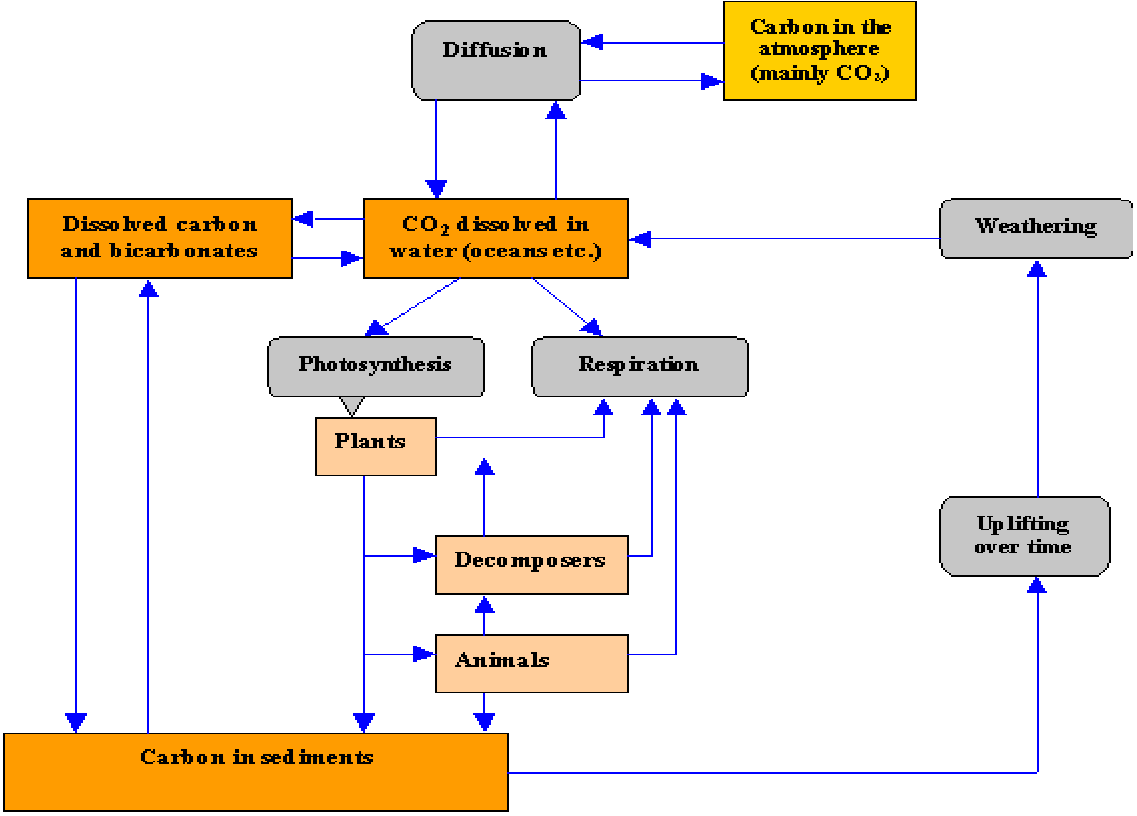

Figure 3.3-Carbon Cycle (http://www.lenntech.com/carbon-cycle.htm).

Carbon enters water from the atmosphere mainly in the form of Carbon Dioxide. Algae and other aquatic plants uptake dissolved carbon dioxide from water in photosynthesis and release carbon dioxide through respiration process. The dissolved Carbon Dioxide also reacts with water to form carbonate (CO_3^{2-}) and bicarbonate (HCO_3). Most of the CO_2 in the ocean is stored as bicarbonate. The dissolved carbon combines with the dissolved carbonates to form Calcium Carbonate (that generally forms the cells of microorganisms (Wikipedia, 2010). When these microorganisms die, limestone is formed after the sedimentation of Calcium Carbonates which is the largest reservoir of carbon in the carbon cycle. It takes a long time for carbon dioxide to be released from weathering of limestone.

3.5 Previous Studies

Das et al., (2009) used a box model called Tidal Prism Model to calculate the fluxes of water, nitrogen and carbon through the Barataria Passes and to study the role of nitrogen and carbon for the development of Hypoxia in the northern Gulf of Mexico. The model used was a dynamic model that gives the hourly water level, water volume and salinity of the individual boxes. The study area was divided into six boxes and the model calculates water level variations and volume of the boxes using the following mass balance equation:

$$Vi/\ t = Fi + Pi + Ri - Ei + Qi \tag{3.1}$$

Where Vi is the segment volume; Fi is the influx or outflux of water due to sea level variations in the Gulf of Mexico; Pi is the direct precipitation over the boxes; Ri is the runoff, from the adjacent wetland areas; Ei is evaporation and Qi is the runoff from the Mississippi River diversion.

The flux (Fi) was calculated as a product of the rate of sea level change, box area and the coefficient of tidal attenuation. The runoff is the difference between the direct precipitation and the evapotranspiration over the wetland areas associated with the respective boxes.
Das et al. (2009) used 2002 as a reference year for model calibration. The model inputs were hourly precipitation, evaporation, evapotranspiration, sea level variations and the Davis Pond discharge. They found the mean tidal pass flow of 6930 m^3/s which is roughly equivalent to 43% of the lower Mississippi River. Das et al. 2009 also found the mean nitrate load of $7*10^6$ kg N/year in Barataria estuary which is roughly 1% of the load in the Lower Mississippi River and the mean carbon load of $109.3 * 10^6$ kg/year that is exported from the estuary which is roughly 2.7% of the load in the Lower Mississippi River. This huge amount of the carbon load is responsible for the 34% of the observed wetland loss in the estuary between 1978 and 2000, (Das et al., 2009).

Park (2002) used a two-dimensional, depth integrated hydrodynamic model to study the impact of freshwater diversion by controlling the freshwater sources in the Barataria Basin. The model uses the equations of the conservation of mass and momentum written in Cartesian Coordinates. The model was initially developed for the study of some estuaries like Terrebonne-Timbalier Basin, Four League Bay and also Barataria Basin. He ran the model with and without freshwater diversions. The model was calibrated by adjusting the Manning’s coefficient. Park (2002) found that most of the Barataria Basin system water level is seemed to be affected within three days. However the effects noted were small except near the diversion sites and Gulf Intracoastal Waterway connection. Park (2002) also observed the impact of freshwater diversions on salinity. He compared results with diversion and without diversions. He found that the effect of freshwater diversion from Naomi can be seen on salinity and it takes 5 days for the impact to reach Barataria Bay. He also found that it takes 10 days for the impact to reach Barataria Bay from West Point a la Hache. According to Park (2002) most of the downstream regions was impacted after 20 days of freshwater release. With these two diversions maximum impact was seen in the upper portions of Barataria Bay, Lower Barataria, Little Lake and Barataria Waterway.

McCorquodale et al., (2009) used EPA's QUAL2K model in Tangipahoa River to simulate nutrients dynamics, algal production and dissolved oxygen with the impact of benthic and carbonaceous demand in streams. The model QUAL2K can be used in the streams with steady and non uniform flow. The model assumes streams to be trapezoidal. QUAL2K model has some advantages. The model is easy to use, is free, requires very few bathymetrical inputs and includes extensive graphical options for the results. Moreover the model models pH and alkalinity (McCorquodale et al., 2009). They calibrated the model on wet and dry event scenarios. The model provides a reasonable prediction of the pathogens. The model slightly over predicts the dissolved oxygen concentrations. DO must be higher than 5 mg/l in order to maintain a sound aquatic life. The model shows that DO could be less than 5 mg/l near the mouth of the river during dry conditions. The nitrogen cycle is very complex and it contains five major biological process: conversion of nitrogen gas to ammonium ion (nitrogen fixation), conversion of ammonium ion to nitrate or nitrite (nitrification), conversion of nitrate to nitrogen gas (denitrification), conversion of nitrogen to organic compounds (assimilation) and excretion, (Roblin, 2008). Moreover the model shows that the concentration of nitrate decreases as they approach towards the mouth of the river. The model did a good job in predicting the reduction of nitrate concentration in both the dry and wet weather scenarios. However the model over predicts the nitrate concentration in the river and this is due to extremely high tributary inputs.

Georgiou et al. (2009) used the Finite Volume Coastal Ocean Model (FVCOM) to study the impact of multiple freshwater diversions on the salinity distribution in the Pontchartrain Estuary under tidal forcing. FVCOM is a 3-D model and solves the momentum, continuity, temperature, salinity and density equations. The research objective was to test multiple diversions from the Mississippi River to the estuary to determine the flow and sediment required to restore the coastal wetlands. They studied the impacts from each diversion (Violet, Maurepas Swamp, Frenier, La Branche, and Bonnet Carré Spillway) and the effect of the closure of the MRGO channel on the distribution of salinity of the upper estuary.

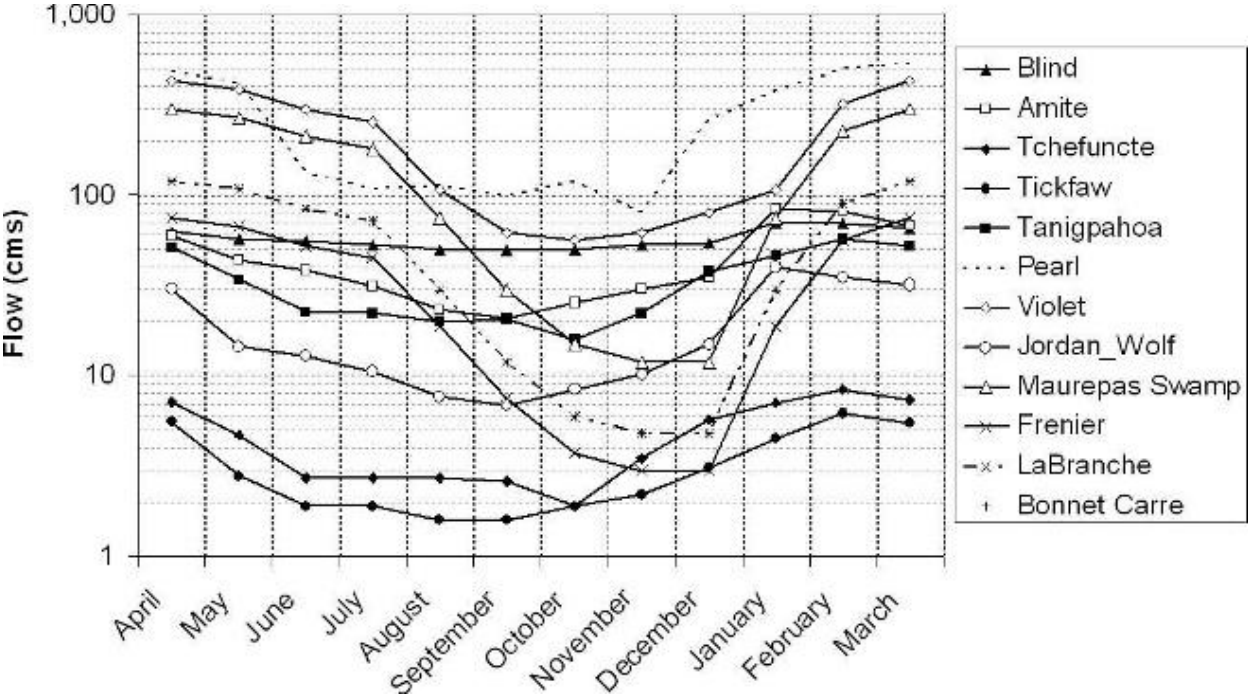

Figure 3.4-Tributaries and diversion flows used in the model; flows are monthly mean based on a 10 year record, (Georgiou et al., 2009).

Georgiou et al., (2009) found that the salinity in the estuary was reduced with the addition of freshwater which was noticed during the spring when peak diversion flows are equal to the tributary high flows. The long term average salinity in the Lake Pontchartrain is 4.2 ppt, (Georgiou et al., 2009, Haralamipides, 2000). With the introduction of the diversions the average salinity of the Lake Pontchartrain could be reduced to less than 3 ppt, (Georgiou et al., 2009). Georgiou et al., (2009) also found that with the introduction of the freshwater from the Blind River and the Maurepas swamp the average simulated salinities in the Lake Maurepas were reduced to near freshwater. In the Lake Borgne the simulated salinity was found to be very low after 180 days of simulation with the introduction of low and high diversion flows from Violet. Their study shows that the average salinities were reduced proportionally to the diversion flows introduced the respective areas. The average salinities in the Lake Pontchartrain were reduced to 1.2 ppt to 1.4 ppt for high flows after 6 months of simulation. Similarly the average salinities in the Lake Borgne were reduced to 1.7 ppt from 5.3 ppt depending upon the flows from the diversions.

McCorquodale et al., (2009) and Roblin (2008) used 1-D tidal, salinity water quality model for the study of salinity, Nutrient, and Sediment Dynamics in the Pontchartrain Estuary. The model uses a similar link –cell structure and connectivity matrix as used in the EPA EXTRAN model. The Pontchartrain estuary was divided into 10 different cells and they are interconnected by 15 different links. Wetland areas are hydraulically connected to each cell. The model inputs were air and water temperature, daily rainfall and evapotranspiration, tributary discharge, tributary loads (tributary nitrogen loading as nitrite + nitrate, tributary phosphorus loading, tributary ammonium loading, tributary organic nitrogen loading, tributary sediment loading) and atmospheric nutrients loading. The model was calibrated for the first 5 years (1990-1995) and validated for the next 12 years (1995-2006). The model predicted that the increased algal bloom in the estuary is mainly due to increased diversions from the Bonnet Carré Spillway. The leakage from the Bonnet Carré Spillway on average contributes approximately 7% of the total nitrogen load to the Lake Pontchartrain. (McCorquodale et al., 2009). The model predicted that the algal bloom which is found on the west side of the Lake Pontchartrain would also spread on the east side of the lake. However the model did not predict the expansion of the algal blooms in the Lake Borgne.

McCorquodale et al., (2009) compared their the total nitrogen load and the total phosphorus load with the nutrient and salinity budget created by Waldon and Bryan (1999) and it was found that 8380 t of total nitrogen and 1370 t of the total phosphorus enter Lake Pontchartrain through the tributaries. McCorquodale et al., (2009) estimated that the 7800 t of the total nitrogen load enter the lake Pontchartrain from all sources Their research found that the mass balance model did a good job to understand the nutrient and sediment dynamics in the Pontchartrain estuary and the model can be a useful tool to study the different future scenarios.

David et al. (2000) used an A11- Box Water Quality Model for Lake Malawi to simulate water quality. The model is useful as it can explain all the process that can affect the water quality subject to the availability of the data. The lake was divided into 11 boxes and the boxes are categorized into 4 different basins (North, Central, South and Outlet). The physical transports include the both horizontal advection and vertical transport. All the basins except Outlet contain the deep water layers deeper than 200 m and the layers can be divided into four parts (Epilimnion, Mesolinmnion, Hypolimnion and Sediment layers). The model uses the algal uptakes and there is regeneration between organic phosphorus and soluble reactive phosphorus with the effect of dissolved oxygen as shown in Figure 3.5. David et. al (2000) also added a nitrate and ammonia uptake and regeneration process to the nutrients process. The model was calibrated with the input of river discharges and the nutrients loading along with atmospheric loading for the year 1997. They found that the results were satisfactory with the very limited data available. The calibrated total phosphorus for the top layer of Outlet basin was found very accurate due to availability of more data. The model predicted anoxic condition in the bottom layer of North basin. However, the model simulated the regeneration of soluble reactive phosphorus concentration in that area. The model over predicted in the upper layers of all the basins except South basin. The model gave very good nitrate concentrations except for the bottom layer in the Central and North Basins because the observed data in those regions had a quite high variability.

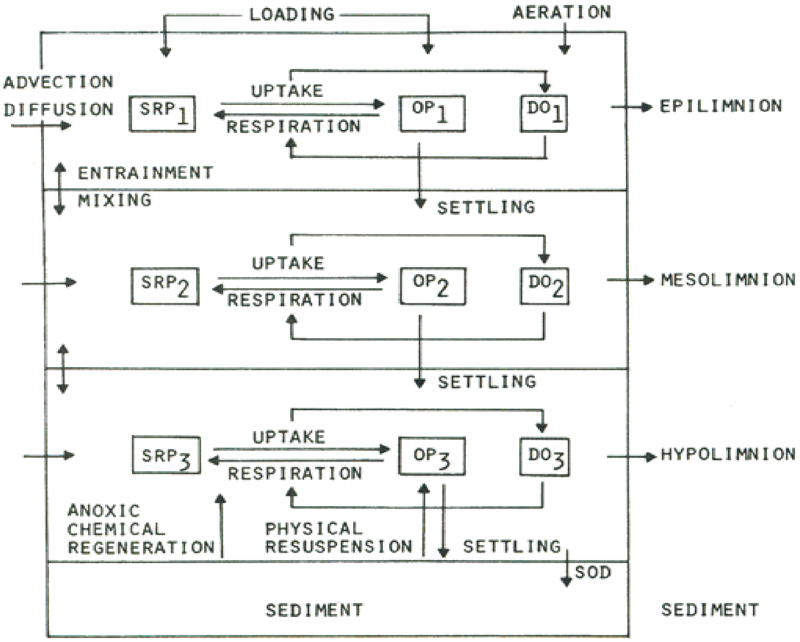

Figure 3.5-The physical and biochemical processes used in the box model, (David et. al 2002).

4.0 Model Description

4.1 Introduction

A number of 3-D models were used for the study of water quality parameters in the past. Dortch at al. (2007) used Curvilinear-grid Hydrodynamic 3-D model (CH3D) that looked at the changes in Mississippi Sound resulting from an opening of Bonnet Carré Spillway between March and October 1999 with moderate flows (Roblin, 2008). Park (2002) used a numerical 3-D model that used that uses equations of conservation of mass and momentum written in Cartesian coordinates in terms of depth-integrated transport, including the baroclinic pressure gradient. McCorquodale at al. (2004) used the 3-D hydrodynamic and contaminant transport model, Estuarine Coastal and Ocean Modeling System with Sediments (ECOMSED) (Roblin, 2008). These 3-D models have certain limitations. They are complex and require long execution times and can only simulate for the short periods, e.g. Less than one year.

Thus there was a need of simple model that can simulate for a long period of time. The UNO cell model that was originally developed for the Lake Pontchartrain is an ideal example of such a model. The model was expanded to include Barataria Basin. The Terrebonne Basin was also included in the model to provide a good boundary condition to the west side of the study area.

4.2 Model description

4.2.1 General model description

The UNO Cell model used in the study is 1-D tidal, salinity and water quality model. The model uses a similar link-cell structure and connectivity matrix to that used in the EPA EXTRAN model (the hydrodynamic part of the EPA Storm Water Management Model (SWMM) 5.0) for urban hydraulics, (Roblin, 2008). The model includes the following cell processes:

1. Local hydrology
2. Water levels variation and storage
3. Water fluxes due to pressure gradients from differential stages and salinities.
4. Salinity fluxes due to advection and diffusion/dispersion
5. Tributary inputs
6. Diversion inputs
7. Tidal boundary conditions
8. Sedimentation process
9. Nutrient exchanges.

The cell processes are shown in Figure 4.1.

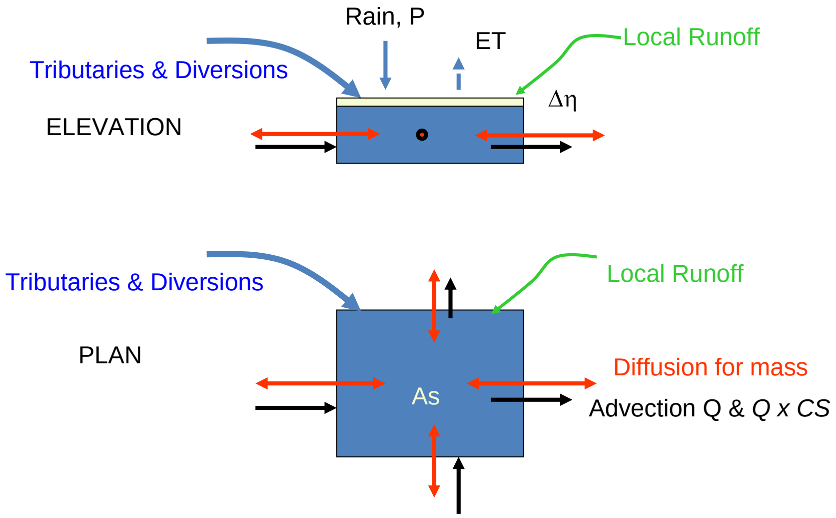

Figure 4.1-Cell Processes in the Model.

In Figure 4.1 Δη is the change is water level of the cell, Q is the flow from the cell and C_S is the Sediment Concentration (mg/l), P is precipitation (mm/day), ET is Evapotranspiration and As is the area of the cell.

In this model, study area is divided into a series of storage elements (cells) that are connected to one another through channels (links). The flow in the channels depends on the difference in water levels and densities between cells and friction. The short time wind effects are not included in the model whereas the tidal seasonal Gulf water level was included. The force due to earth's rotation (Coriolis force) is neglected.

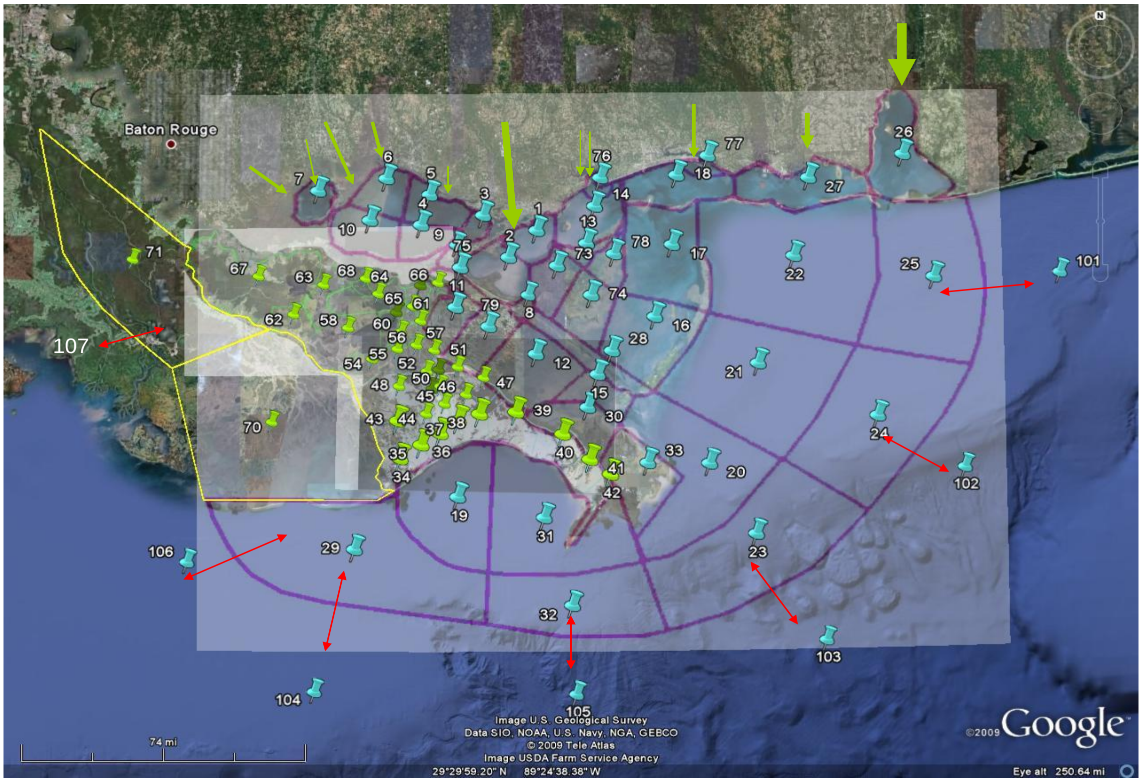

Figure 4.2-Layout of Barataria Basin with the cells, links and tributaries.

4.3 *Governing equations*

The UNO model solves the equations of continuity, 1-D momentum and mass transport. The water level in a cell is found using conservation on water expressed as:

$$\frac{d\eta_j}{dt} = n_j' = \left(\frac{\sum Q_{i,trib,div} + P_j - ET_j}{As_j}\right) + \frac{Run_j}{As_j} \qquad 4.1$$

$$Q_i = A_i \left\{ \frac{2g\left|\eta_j - \eta_{j+1}\right|}{\left(\sum k_{im} + 2gn_i^{\,2} \frac{L_i}{R_i^{\frac{2}{3}}}\right)} \right\}^{\frac{1}{2}} sign(\eta_j - \eta_{j+1}) \qquad 4.2$$

$$Run_j = A_{dj} \{ P_j - k_{ow} \times ET_j - (1 - k_{ow}) k_{crop} \times ET_j \qquad 4.3$$

where j is number of cells in model; i is number of links in model; η_j is stage in each cell; $Q_{i,trib,div}$ is inflow to each storage cell from links (i), tributaries (trib) and diversions (div); P_j is precipitation rate on each cell; ET_j is evapotranspiration rate on each cell; As_j is surface area of each storage cell; Run_j is runoff contribution for each cell; A_i is cross-sectional area of each link; k_{im} is eddy loss coefficients in each link; n_i is Manning's roughness coefficient for each link; L_i is length of each link; R_i is hydraulic radius of each link; the function *sign* assigns a negative or positive value to 1 depending on the value in the brackets; A_{dj} is hydraulically connected area for each cell; k_{ow} is fraction of open water in A_{dj}; and k_{crop} is crop factor (0.1 to 1), (Roblin, 2008).

The mass balance equations for salinity and suspended solids are given in Equations 4.4 and 4.5, (Roblin, 2008).

$$\frac{dCS_j}{dt} = \frac{\sum CS_{i,trib}Q_{i,trib}}{y_j As_j} - k_{dis}k_{diff}\sum_i \left(\frac{A_i}{L_i}\right)\left(\frac{CS_j - CS_{j,nb}}{y_j As_j}\right) - \frac{CS_j \eta_j^{'}}{y_j} \qquad 4.4$$

$$\frac{dCSS_j}{dt} = \frac{\sum CSS_{i,trib,div}Q_{i,trib,div}}{y_j A_j} - \frac{k_{set}VsCSS_j}{y_j} + \frac{k_{rs}k_{rsc}d_{ref}Vw^2 - k_{ls}CSS_j y_j}{2{y_j}^2 T_{res}} - \frac{CSS_j \eta_j^{'}}{y_j} - k_{dis}k_{diff}\sum_i \left(\frac{A_i}{L_i}\right)\left(\frac{CSS_j - CSS_{j,nb}}{y_j As_j}\right) + G_s \qquad 4.5$$

where CS_j is salinity concentration in each cell; $CS_{i,trib}$ is salinity concentration from each link and tributary; y_j is depth in each storage cell; k_{dis} is dispersion coefficient; k_{diff} is diffusion coefficient; A_i is area of each link; L_i is length of each link; $CS_{j,nb}$ is salinity concentration in neighboring cells; $\eta_j^{'}$ is rate of rise of stage in each cell; CSS_j is suspended sediment concentration in each cell; $CSS_{i,trib,div}$ is suspended sediment concentration from each link, tributary and diversion; k_{set} is settling velocity calibration factor; Vs is settling velocity; k_{rs} is wind resuspension coefficient; k_{rsc} is wind resuspension calibration factor; d_{ref} is reference depth; Vw is wind speed; k_{ls} is suspended sediments boundary calibration factor; T_{res} is residence time; $CSS_{j,nb}$ is suspended sediment concentration in neighboring cells; and G_s is the area based internal source generation rate (Roblin, 2008).

4.4 Nitrite + Nitrate as nitrogen chemical description

The nutrients load in the model always depends on the gain of the nutrients and the loss of the nutrients. The nitrite + nitrate as nitrogen growth rate in the model depends on the gains from nitrification and losses by denitrification and uptake rates from live algae (Roblin, 2008). Equation 4.6 shows the limitation imposed by live algae on the growth rate of NO3. Equation 4.7 illustrates nitrite + nitrate as nitrogen calculation in the model, (Roblin, 2008)

$$k_{NO3\rightarrow LA} = k_{g,LA} \times \left(\frac{CC(NO3)_j}{CC(DIN)_j + sm} \right) \times \left(\frac{1}{5.68} \right) \qquad 4.6$$

$$R(NO3)_j = k_{g0,NO3} \times CC(NO3)_j + k_{NH4\rightarrow NO3} \times CC(NH4)_j + k_{NO3\rightarrow LA} CC(LA)_j \qquad 4.7$$

where $k_{NO3\rightarrow LA}$ = growth limitation on NO3 imposed by live algae and the Redfield ratio; $k_{g0,NO3}$ = denitrification rate; and $k_{NH4\rightarrow NO3}$ = nitrification rate, (Roblin, 2008).

4.5 Organic nitrogen chemical description

The organic nitrogen growth rate in the model like nitrogen growth rate is limited by losses and gains. The loss is due to ammonification and settling and gain is from live algae inputs. Equation 4.8 shows the growth rate limitation of live algae applied to Organic Nitrogen. Equation 4.9 illustrates organic nitrogen calculation in the model, (Roblin, 2008).

$$k_{LA\rightarrow ON} = k_{g,LA} \times \left(\frac{1}{5.68} \right) \qquad 4.8$$

$$R(ON)_j = k_{g0,ON} \times CC(ON)_j + k_{ON\rightarrow NH4} \times CC(ON)_j + k_{LA\rightarrow ON} CC(LA)_j \qquad 4.9$$

Where $k_{LA\rightarrow ON}$ = growth rate of ON from live algae inputs limited by the Redfield ratio; $k_{g0,ON}$ = settling rate of ON; and $k_{ON\rightarrow NH4}$ = ammonification rate, (Roblin, 2008).

4.6 Phosphorus chemical description

The phosphorus growth rate in the model is similar to the nitrogen and ammonia growth rate is limited by losses and uptake rates from live algae .Equation 4.10 shows the growth rate limitation of live algae applied to Phosphorus. Equation 4.11 illustrates phosphorus calculation in the model, (Roblin, 2008).

$$k_{P\rightarrow LA} = k_{g,LA} \times \left(\frac{1}{41.10} \right) \qquad 4.10$$

$$R(P)_j = k_{g0,P} \times CC(P)_j + k_{P\rightarrow LA} CC(LA)_j \qquad 4.11$$

Where $k_{P\rightarrow LA}$ = growth limitation on NH4 imposed by live algae and the Redfield ratio; and $k_{g0,P}$ = settling rate of P, (Roblin, 2008).

5.0 Model Inputs

5.1 Introduction

Hydrological, hydraulics, meteorological, ecological and biological and water quality are some of the important factors that the model considers. The following classes of inputs are needed: tributary inputs, geometry of the storage cells and hydraulic links, hydrological inputs including rainfall, evapotranspiration and runoff of gauged and ungauged areas, diversion flow inputs and boundary conditions inputs. These data were obtained from the various sources such as the U.S. Geological Survey (USGS), the Louisiana Department of Environmental Quality (LADEQ), the U.S. Army Corps of Engineers (USACE), the Louisiana Universities Marine Consortium (LUMCON), National Climatic Data Center (NCDC), and Coastwide Reference Monitoring System (CRMS), National Data Buoy Center (NDBC). The years 2007 and 2008 were used as a base data for the calibration of the model. Due to hurricanes like Ike and Gustav, some of the data of 2008 were not continuous; this problem was solved by interpolating the missing data.

5.2 Model Cell and link inputs

The complete model was divided into 80 storage cells that include Barataria Estuary, Pontchartrain Estuary and Terrebonne Estuary as shown in Figure 5.1. As our study site is only Barataria Basin, the focus is on the Barataria cells (cell 34 to cell 69) and the offshore cells as shown in Figure 5.2. The border of each cell was determined by selecting a hydraulically defined water body and the associated drainage area. The area of each cell was determined using Google Earth. The 80 cells that make up the model were interconnected by 160 hydraulic links. The length of each links was also determined by using Google Earth whereas the depth of the links was obtained from the Bathymetry developed by Georgiou et al. (2010) and the map New Orleans Area, LA; MRC edition of 1985. The map was originally prepared by US Army Tropical Command and Corps of Engineers. It was compiled in 1954. The depth of the links was edited during the calibration. If the links are existing channels such as dredged waterways, the project depths and widths were used as given in the map. The Manning's n representing the friction in each link is a calibrated value. The minor loss constants (minor loss constants, the entrance loss coefficient and the loss exit coefficients) are the small constants which are fixed before the calibration and are based on structural losses. The numbering of the Barataria cells starts from 34 which is Grand Island and end on 69. The cell 48 in Figure 5.2 represents Little Lake. Similarly the cells 59, 64, 68 and 67 represent Lake Salvador, Lake Cataouatche, Davis Pond and Lake Des Allemands respectively.

The cells 19 and 31 in the northern Gulf of Mexico represent the offshore cells. The nodes 101, 102, 103, 104, 105 and 106 are the Gulf of Mexico boundary nodes. The node 107 is the Atchafalaya River boundary nodes.

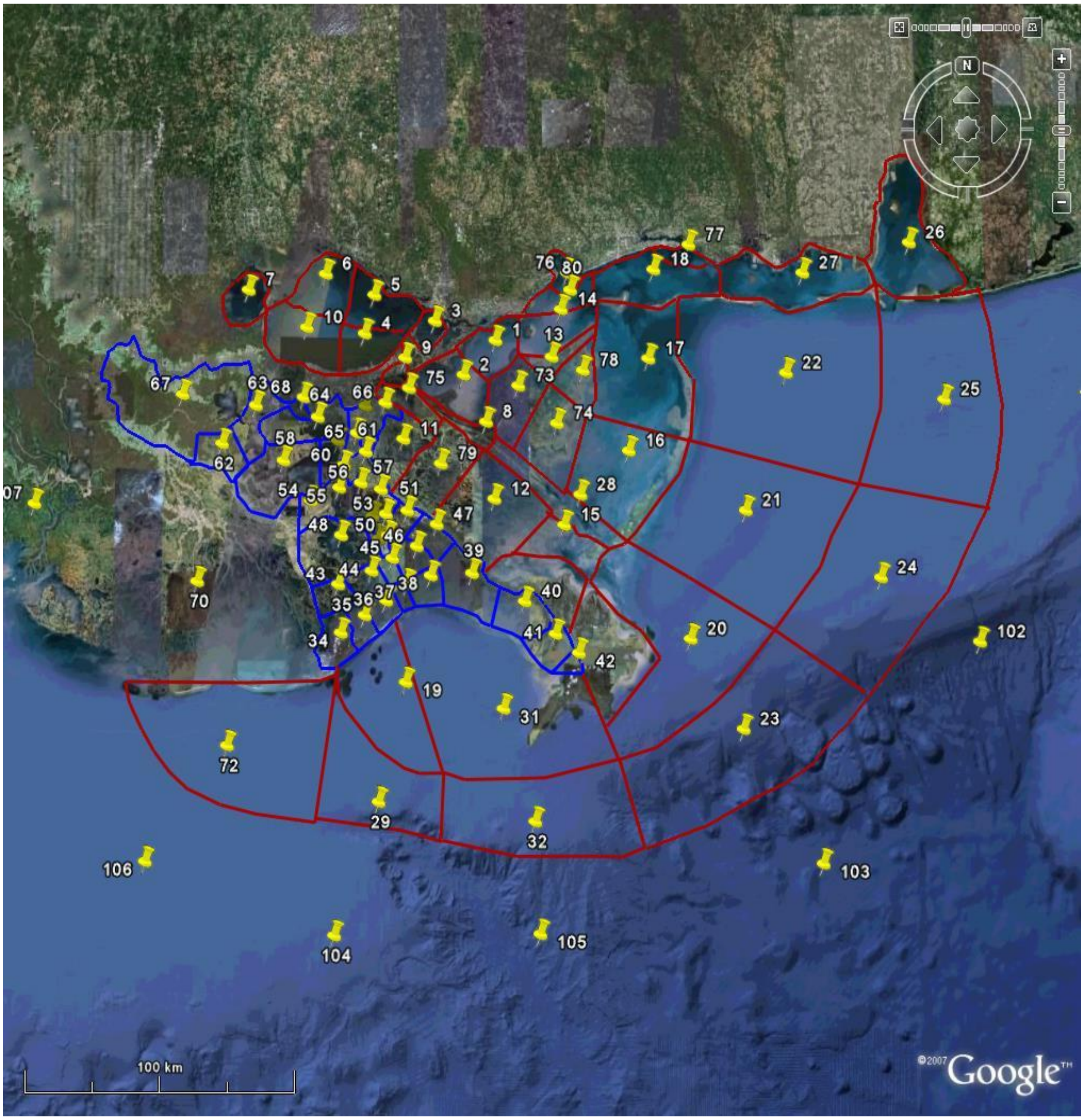

Figure 5.1-Whole Model Cells

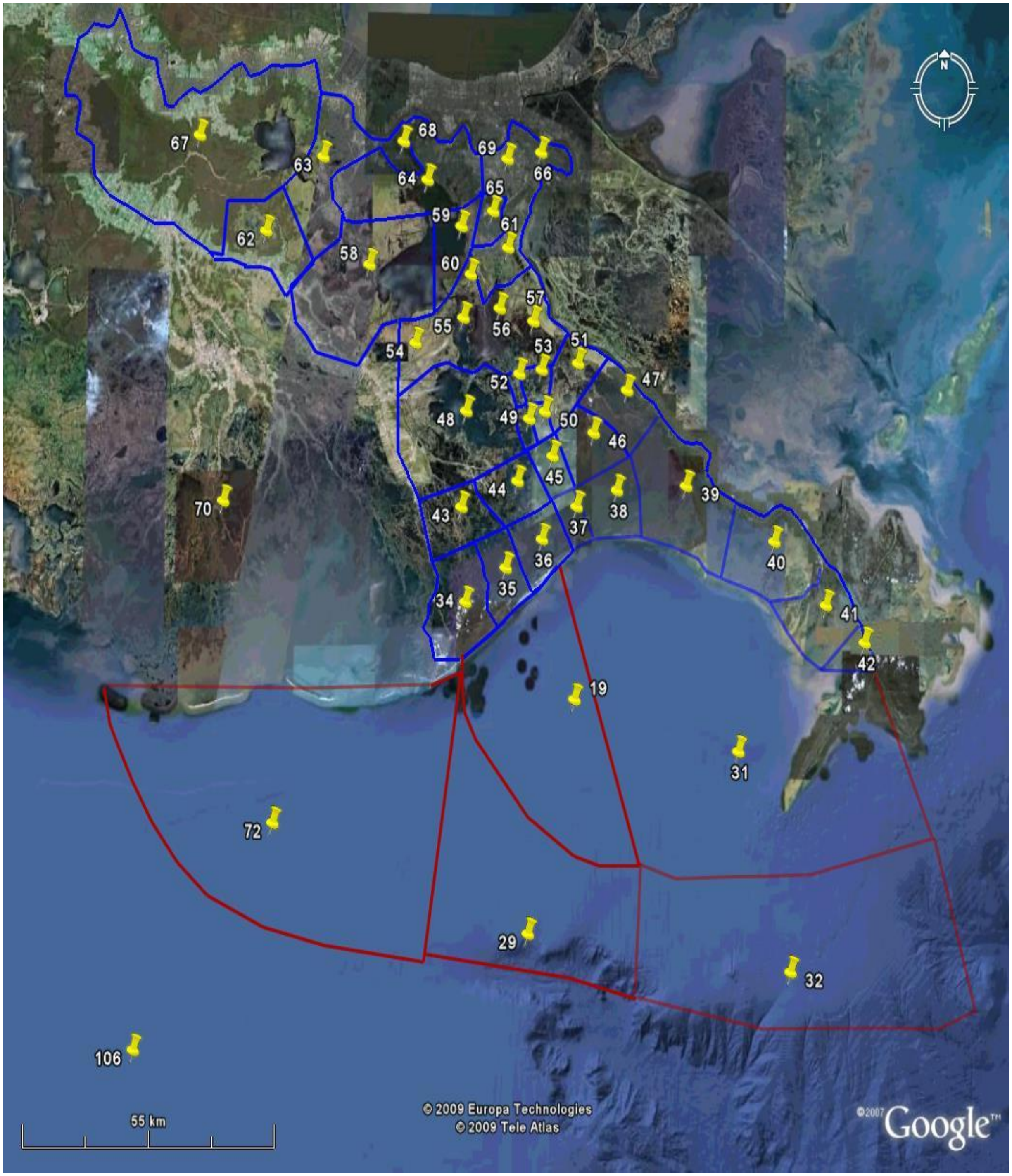

Figure 5.2-Barataria Cells

5.3 Tributary Inputs.

The tributaries of the Pontchartrain estuary and Mississippi Sound are considered in the model. There are eight gauged tributaries (Amite River, Bogue Chitto River, Comite River, Natalbany River, Tangipahoa River, Tchefuncte River, Tickfaw River and Pearl River) and several smaller ungauged tributaries that flow into the Pontchartrain estuary. The Figure 5.3 shows the Pontchartrain Estuary with its tributaries.

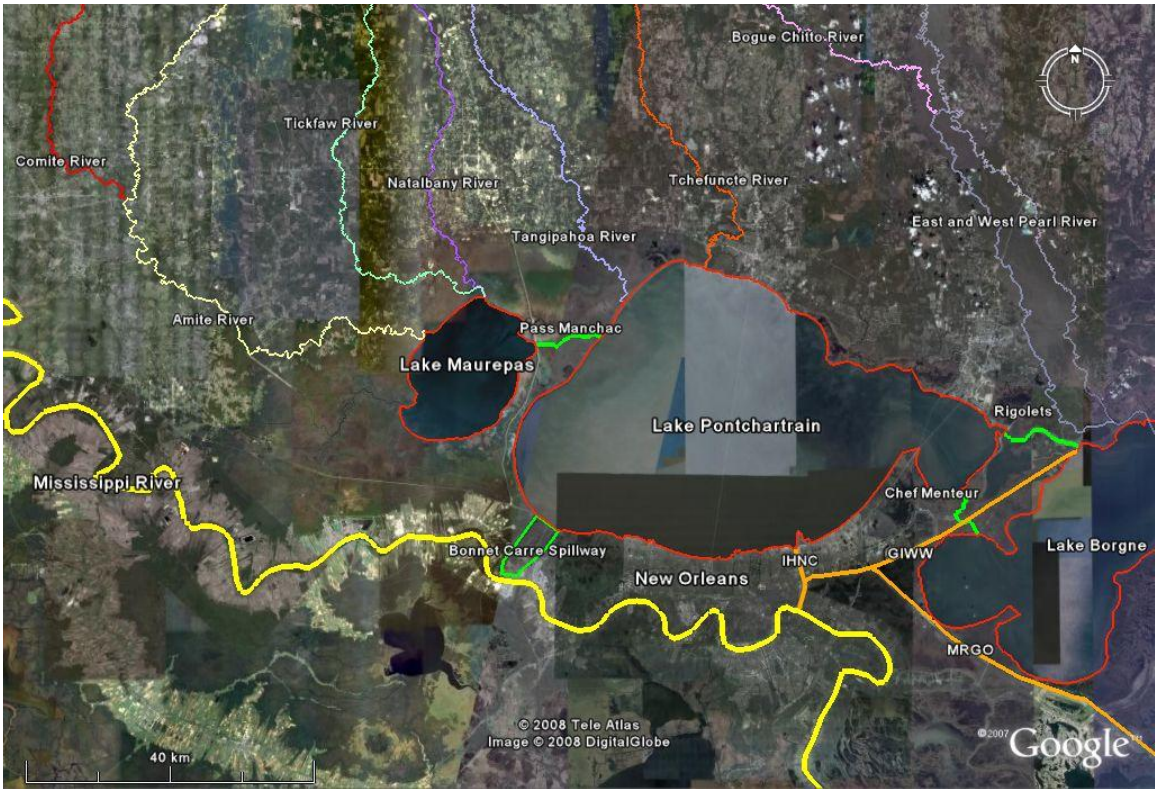

Figure 5.3-Pontchartrain Estuary with tributaries (Roblin, 2008)

There are five gauged tributaries (Wolf River, Jourdan River, Biloxi River, Pascagoula River and Mobile River) in the Mississippi Sound. The drainage area of the tributaries of the Pontchartrain estuary are tabulated in the Table 5.1 and the drainage area of the tributaries of the Mississippi Sound are tabulated in the Table 5.2

Table 5.1-Tributaries of the Pontchartrain Estuary with their drainage area (Roblin, 2008).

No.	Tributaries	Drainage Area (km^2)
1	Amite River	4,134
2	Bogue Chitto River	3,142
3	Comite River	736
4	Natalbany River	206
5	Tangipahoa River	1,673
6	Tchefuncte River	247
7	Tickfaw River	640
8	Pearl River	21,999
9	Ungaged Areas	5,274

Table 5.2-Tributaries of the Mississippi Sound with their drainage area (USGS).

No.	Tributaries	Drainage Area (km^2)
1	Wolf River	789
2	Mobile River	11,008
3	Pascagoula River	21,555
4	Biloxi River	246
5	Jourdan River	538

Figure 5.4 shows the mean daily flows of major tributaries that are included in the model. As discussed earlier the major tributaries are Amite River, Bogue Chitto River, Comite River, Natalbany River, Tangipahoa River, Tchefuncte River, Tickfaw River, Pearl River, Wolf River, Jourdan River, Biloxi River, Pascagoula River and Mobile River

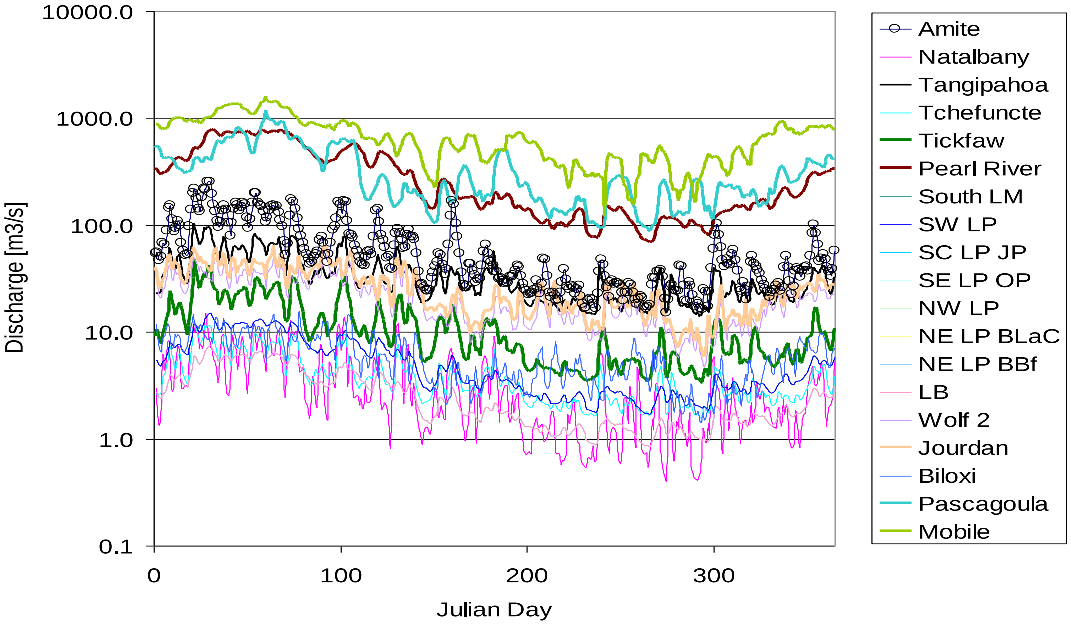

Figure 5.4 -Mean Daily Tributary Flows (19 year average) (Roblin, 2008).

5.4 Hydrological inputs.

Figure 5.4 illustrates the flow from the tributaries and the ungauged areas. The Table 5.1 and 5.2 show the drainage area of the tributaries and ungauged areas. The ungauged areas should be treated separately (McCorquodale et. al, 2009). The runoff per unit drainage area for ungauged areas is given by the Equation 5.1.

$$Y_Q = K\,(DA)^{-0.002} \qquad 5.1$$

Where Y_Q is runoff per unit drainage area ($m^3/s/\ km^2$);

K is proportional constant with the value of 0.019;

DA is the drainage area in square kilometers.

This relationship was used to estimate the flow to ungauged areas, (McCorquodale et. al, 2009). Precipitation, evaporation, wind and the nutrient deposition are the atmospheric forcing used in the model. The precipitation (Figure 5.5) was obtained from the Armstrong International Airport (MSY) for 2007-2008. The 6 hour forward average filtered precipitation data were then used in the model to account for the lag and attenuation due to the runoff from the land areas attached to the open water cells.

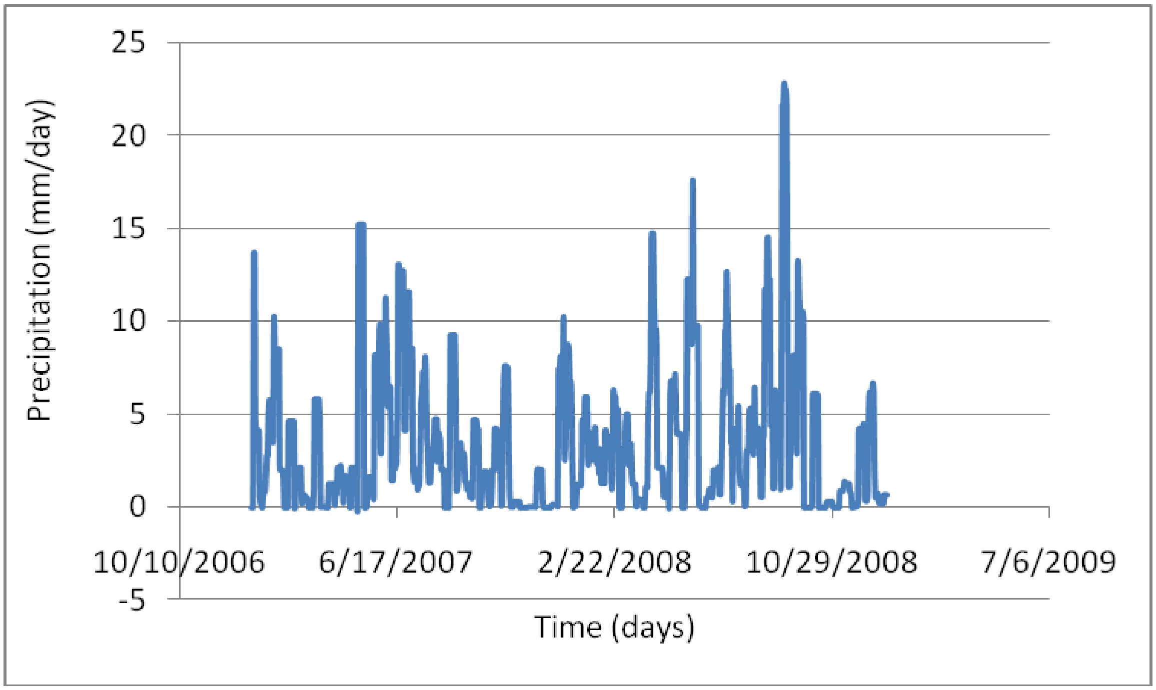

Figure 5.5-Filtered rainfall data used in the model (SRCC).

Monthly evapotranspiration rates (2007-2008) that were used in the Pontchartrain Estuary were also used in the Barataria Basin. These were proposed by Fontenot (2004) for the coastal regions of southern Louisiana, (McCorquodale et al., 2009). Fontenot used Penman-Monteith method to predict evapotranspiration. The methods proposed by Fontenot were also used to determine the open water evaporation where it was assumed that the evaporation was equal to the potential evapotranspiration. Figure 5.6 is long term monthly evapotranspiration (mm/month) for the coastal region.

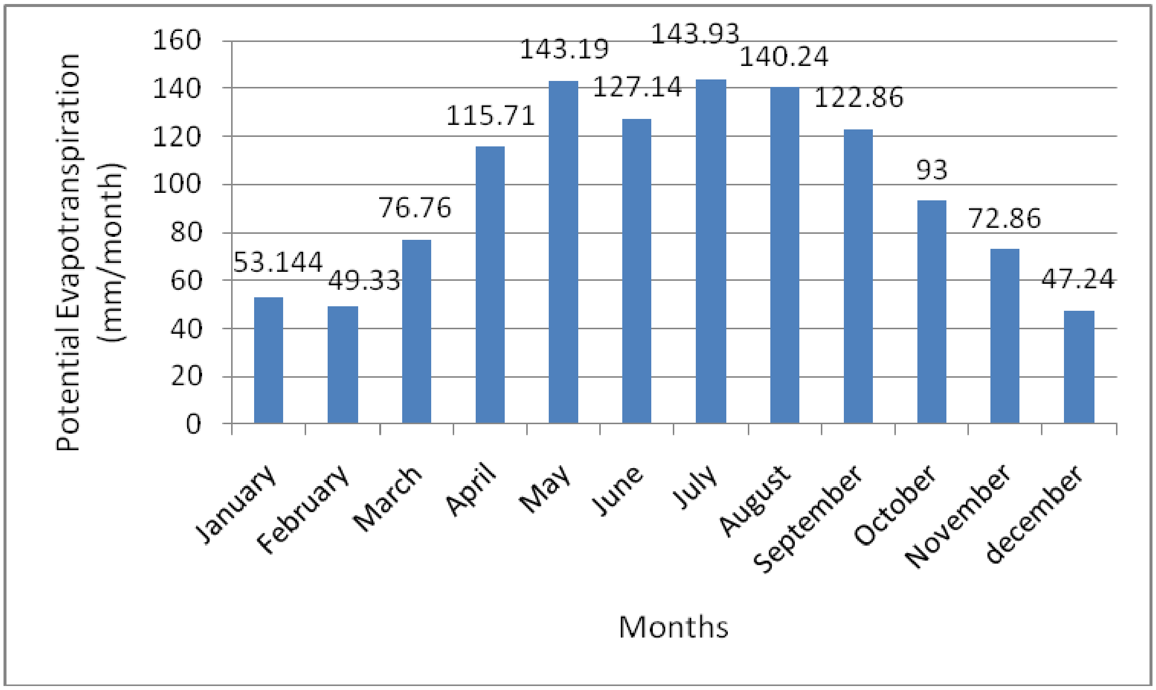

Figure 5.6- Long term monthly evapotranspiration (From Fontenot, 2004)

5.5 Diversion flow inputs.

The existing diversions in the Barataria Basin are: Davis Pond, West Bay, West Point a la Hache, Naomi, Gulf Intracoastal Waterway (GIWW) at the Mississippi River GIWW at the Bayou Lafourche and the Harvey Canal. Figure 5.7 shows a record of the flow from Davis Pond to the Basin. Davis Pond has a maximum capacity of 325 m^3/s in the peak period. Figure 5.8 shows a record of the flow from the West Point a la Hache to the basin. It has a maximum capacity of about 125 m^3/s in the peak period. Figure 5.8 shows the estimated flow from the West Bay which is about 8% of the Mississippi River flow.

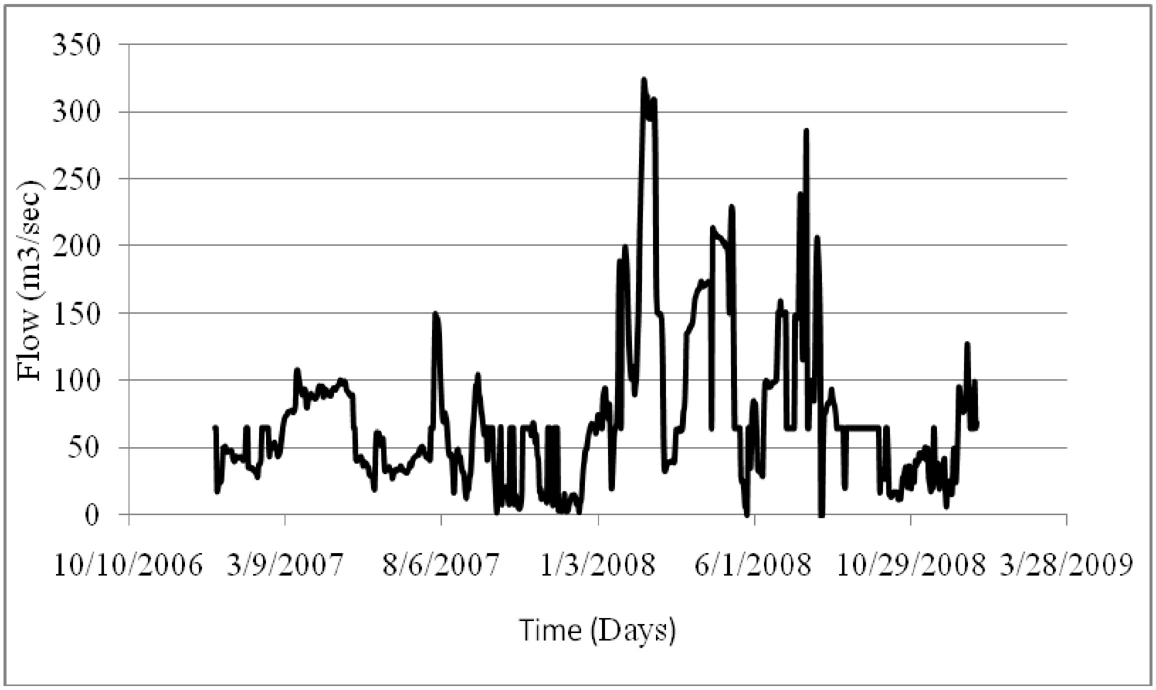

Figure 5.7-Davis Pond Diversion Flow (2007-2008), (US Army Corps of Engineers)

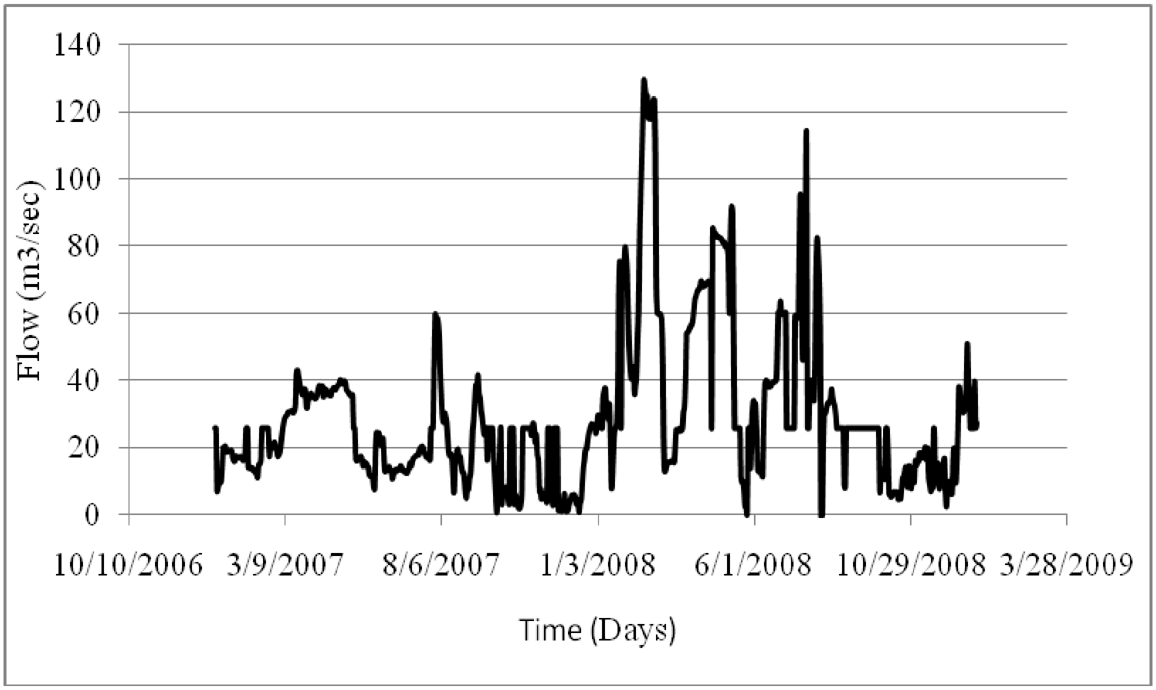

Figure 5.8-West Point a la Hache Flow (2007-2008), (US Army Corps of Engineers).

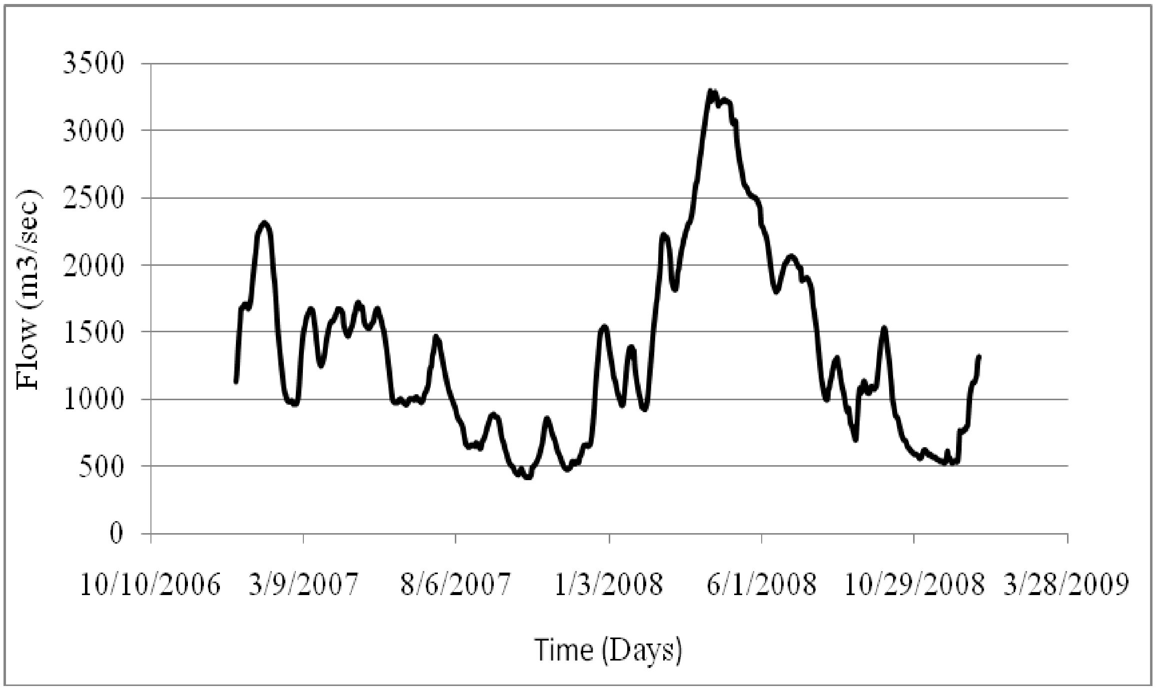

Figure 5.9 West Bay Flow (2007-2008), (US Army Corps of Engineers).

5.6 Mississippi Flow

Most of the diversions used in the model are from the Mississippi River. The normal flow (2007) and the flood flow (2008) were used for the calibration in order to see the response of flood year and the normal year. The study period of the model is 2007 and 2008.

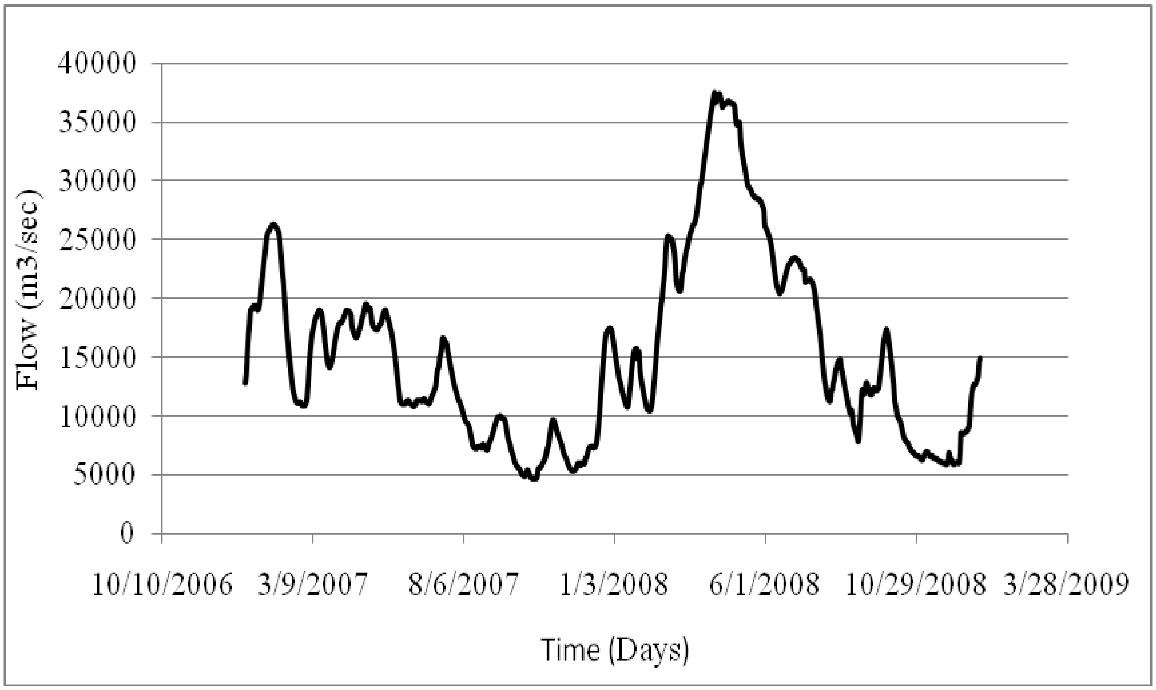

Figure 5.9-Mississippi River Discharge for 2007-2008 at Tarbert Landing (Normal and Flood year), (US Army of Corps of Engineers).

5.7 Open Boundary Conditions.

The tidal forcing of the Gulf of Mexico is the open boundary condition in the southern boundary of the study area. It was obtained by extrapolating the Southwest Pass tidal signal obtained from National Data Buoy Center. Figure 5.11 shows the stage height on every 3 hours which is the offshore open boundary condition of the study area. Figure 5.11 clearly shows the spring neap variations and the stage variations due to hurricanes. The Barataria Basin is connected with the Terrebonne Basin with the link to the Atchafalaya River to provide better boundary condition to the west side. The USGS has the daily measurement of the water level and it was interpolated to obtain values every 3 hours as shown in Figure 5.12.

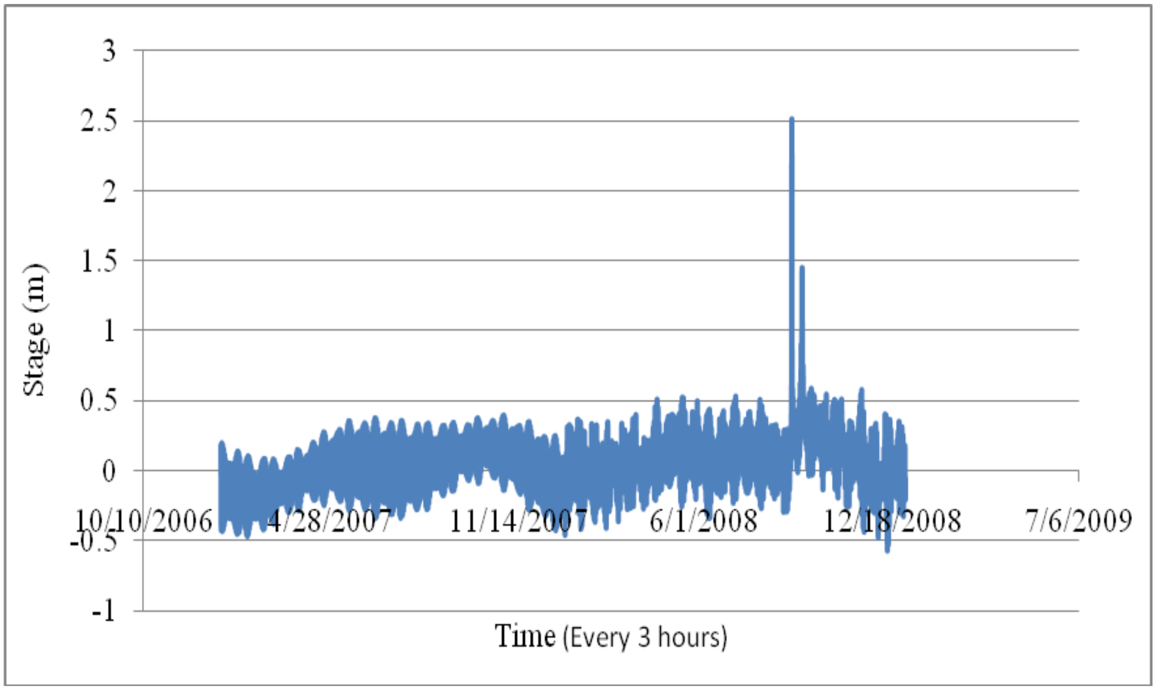

Figure 5.10- Open Water Boundary Condition Offshore of Barataria Basin (223207 m East, 3244585 m North) (2007-2008), (NDBC).

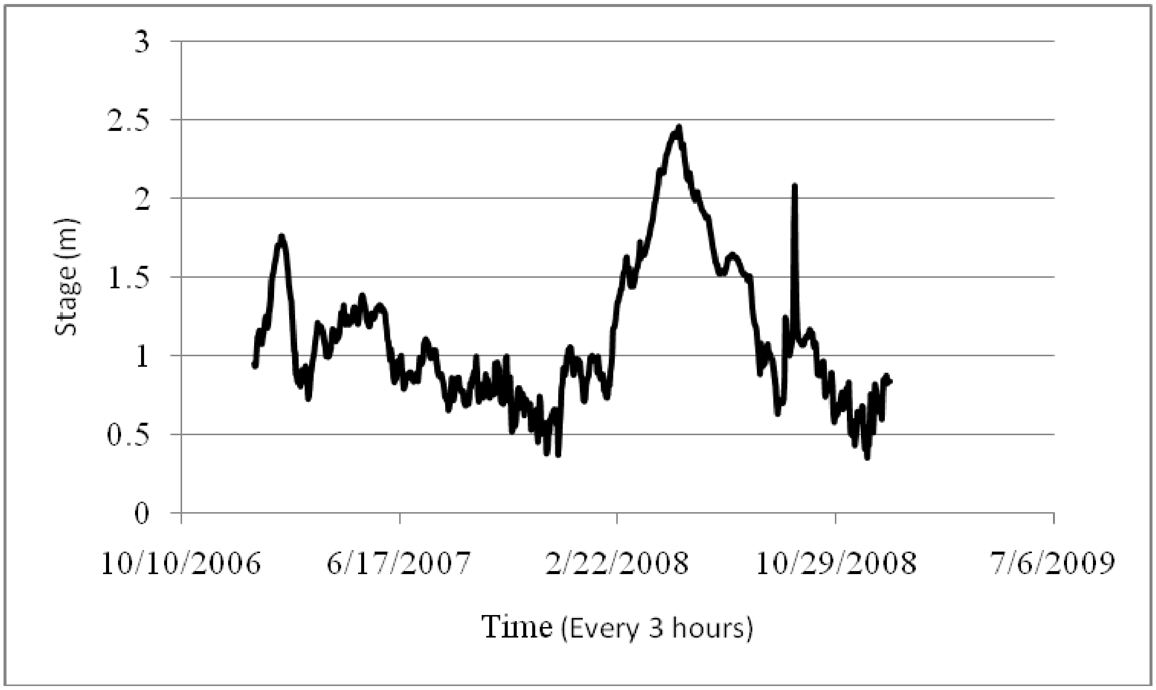

Figure 5.11-Open boundary condition on the west side of Barataria Bay (686545 m East and 3310085 m North) (2007-2008), (USGS).

As discussed earlier, the proposed diversions are from the Mississippi River or the Atchafalaya River, the concentrations of various nutrients (nitrite+nitrate, phosphorus, ammonuim and organic nitrogen) are taken as the boundary conditions for the nutrients. Figure 5.13 shows the concentrations of the various nutrients in the Mississippi River used as the boundary conditions se the model. These data were obtained from the Louisiana Department of Environmental Quality (LADEQ) and represent monthly average values.

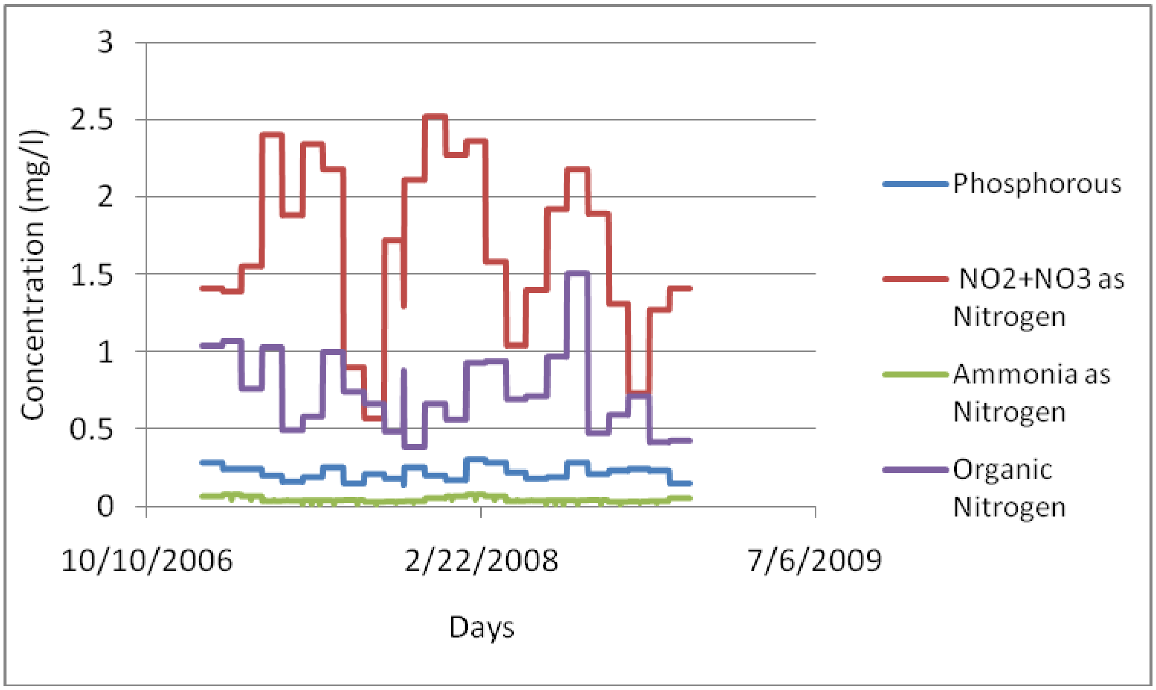

Figure 5.12-Nutrients in the Mississippi River, (LADEQ).

5.8 *Initial Boundary Conditions*

The initial water level of the open water cells are assigned zero. Thus the elevation of corresponding still water surface is also zero. The model starts the simulation from the rest and it takes an account of all the boundary conditions (tributaries flows and tidal elevation in the open boundary conditions). The early results are subject to a “spin up” effect. For the Barataria this period of time is approximately 15 days. The salinity at the open boundary is highly affected by the Mississippi River at high flows. The salinity of 15 ppt is assigned at the two ends of the open boundary near to the coastal regions and 34 ppt in the central deeper portion of the open boundary. The northern part of the study area is almost all freshwater and hence the salinity in those areas is assigned as 0.2 ppt.

5.9 *Future Scenarios*

The model is calibrated for normal year (2007) and the flood year (2008). Hence the diversion scenarios are run of two different Mississippi flows. The one year of median flow is used to create better starting conditions for the second year.

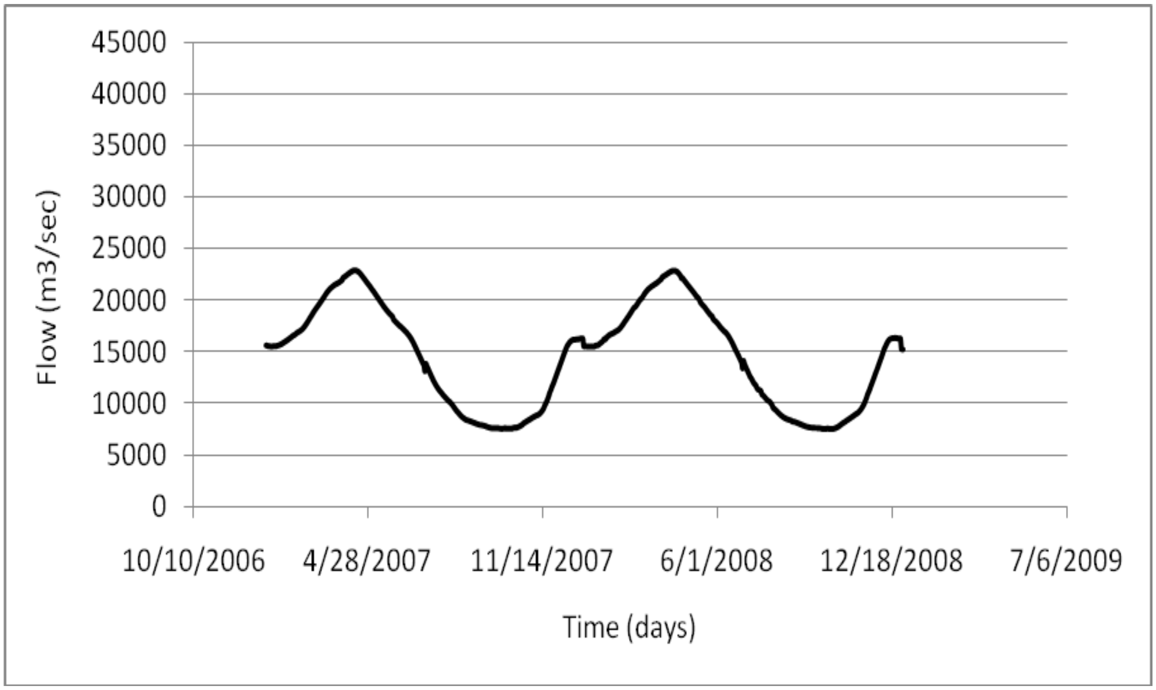

Figure 5.13-Mississippi Flows for Median Flow (Scenario I)

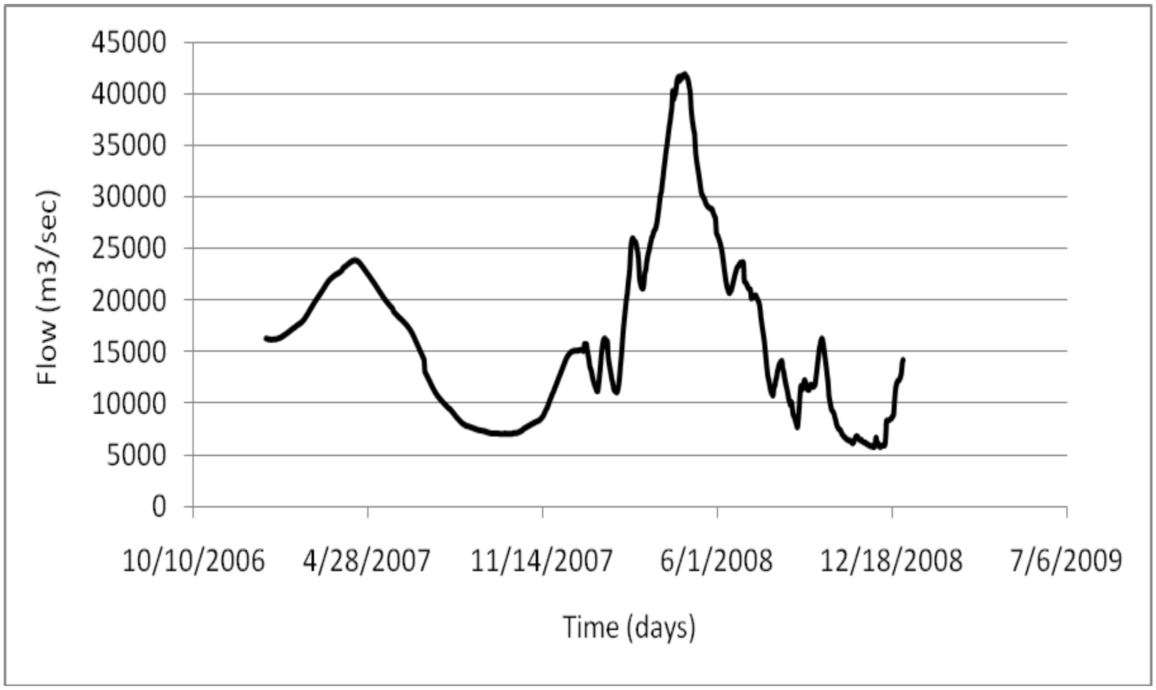

Figure 5.14-Mississippi Flows for High Flow (Scenario II)

As discussed earlier, there are some existing diversions and proposed diversions. The flows for each diversion for both scenarios are shown in Figure 5.16 and 5. 17.

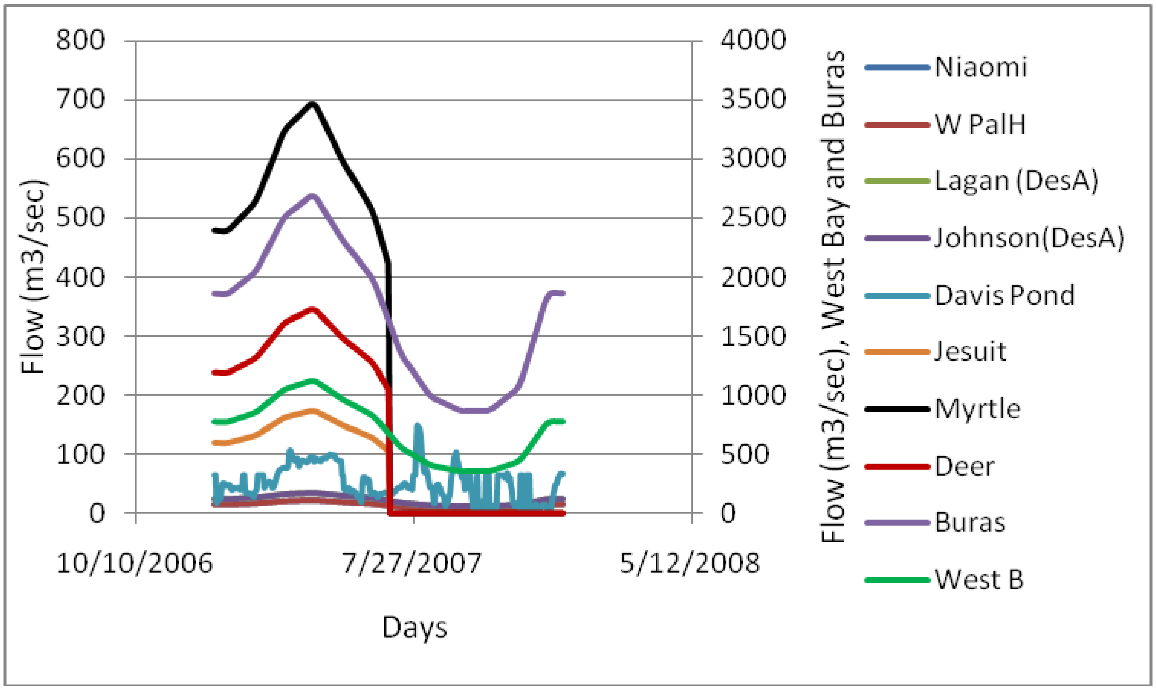

Figure 5.15-Proposed Diversion Flows from Median Mississippi River Flow (Scenario I).

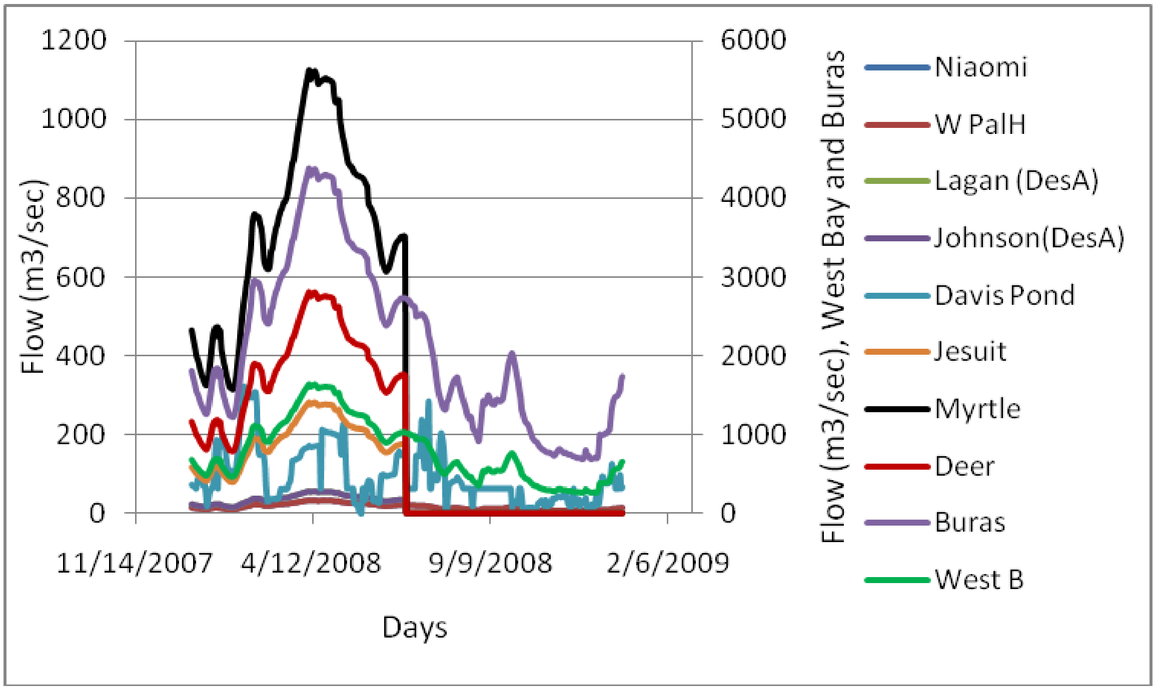

Figure 5.16-Proposed Diversion Flows from High Mississippi River Flow (Scenario II)

The average and high flow from each diversions for each scenarios are given in Table 5.2 and 5.3.

Table 5.3-Proposed flows from diversions in cubic meter per second (Scenario I).

Diversion	Average flow(m^3/s)	Maximum Flow (m^3/s)
Naomi	14	22
West Point a la Hache	14	22
Lagan	22	34
Johnson	22	34
Davis Pond	51	149
Jesuit Bend	72	173
Myrtle Grove	287	692
Deer Range	143	346
Buras	1697	2689
West Bay	708	1122
Mississippi River	12873	26335

Table 5.4-Proposed flows from diversions in cubic meter per second (Scenario II)

Diversion	Average flow (m^3/s)	Maximum Flow (m^3/s)
Naomi	16	33
West Point a la Hache	16	33
Lagan	18	56
Johnson	18	56
Davis Pond	94	323
Jesuit Bend	91	282
Myrtle Grove	363	1127
Deer Range	181	564
Buras	2091	4373
West Bay	782	1635
Mississippi River	18080	41885

6.0 Model Calibration

6.1 Introduction

Calibration is done by comparing some of the outputs of the model with the measured data. Only few parameters like stage, salinity, specific nutrients (nitrite +nitrate, phosphorus, organic nitrogen) are measured regularly around the Barataria Basin. The model was calibrated for a normal year (2007) and a flood year (2008). The calibration of stage is described in Section 6.2. The calibration of salinity is described in Section 6.3 and the calibration of nutrients is described in Section 6.4. The observed flow at the Davis Pond, West Point a la Hache and the best estimates for all the other diversions were used. Basically the calibrated parameters are Manning's n, the dispersion coefficient and the width and the depth of the links. There are some general parameters that were assigned during the calibration process. They are listed in Table 6.1.

Table 6.1-Some constants used in the calibration.

Parameters	Constants
Over water evaporation	1
Initial suspended solids	20 m^3/kg
Resuspension factor	2
Settling velocity factor	1
Upwind factor	0.501
Dispersion calibration factor	1

6.2 Calibration of Stage

The stations shown in Table 6.2 were used for the calibration of stage as there were sufficient data available.

Table 6.2-Stations of stage Calibration

No.	Stations	Universal Transverse Mercator (UTM)	
		East (m)	North (m)
1.	Grand Island	201781	3232913
2.	Lower Barataria (central)	226435	3251703
3.	Little Lake	193985	3265714
4.	Lake Salvador	193535	3290711
5.	Lake Cataouatche	186665	3305169
6.	Davis Pond	181637	3308158
7.	Lake Des Allemands	137149	3312572

The model seems to capture the variance and trend of stage at the Grand Island, Lower Barataria and the Little Lake which as shown in Table 6.3. Figure 6.1 shows the calibration of the water level in Grand Island from January 1, 2007 to October 6, 2008 in every 3 hour interval. Figure 6.2 shows the calibration of the water level in Lower Barataria from January 1, 2008 to December 31, 2008 in every 3 hour interval and Figure 6.3 shows the calibration of the water level in the Little Lake from February 13, 2008 to December 31, 2008 in every 3 hour interval. Moreover model shows a very good response to the hurricanes in 2008. Figures 6.4, 6.5, 6.6 and 6.7 show the daily calibration of water level in Lake Des Allemands, Lake Salvador, Davis Pond and Lake Cataouatche respectively. The modeled stage agrees with the mean trend of the measurement at these stations but fails to capture the variance since the output was were converted to daily output. The constant value of 0.4 meter was added in the Davis Pond output due to the presence of a weir upstream of Lake Cataouatche. The Table 6.3 also shows the average and the standard deviation of the stage at Lake Des Allemands, Lake Salvador, Davis Pond and Lake Cataouatche for the years 2007 and 2008. Moreover the model did not capture the wind seiche because it does not have wind shear on the open water.

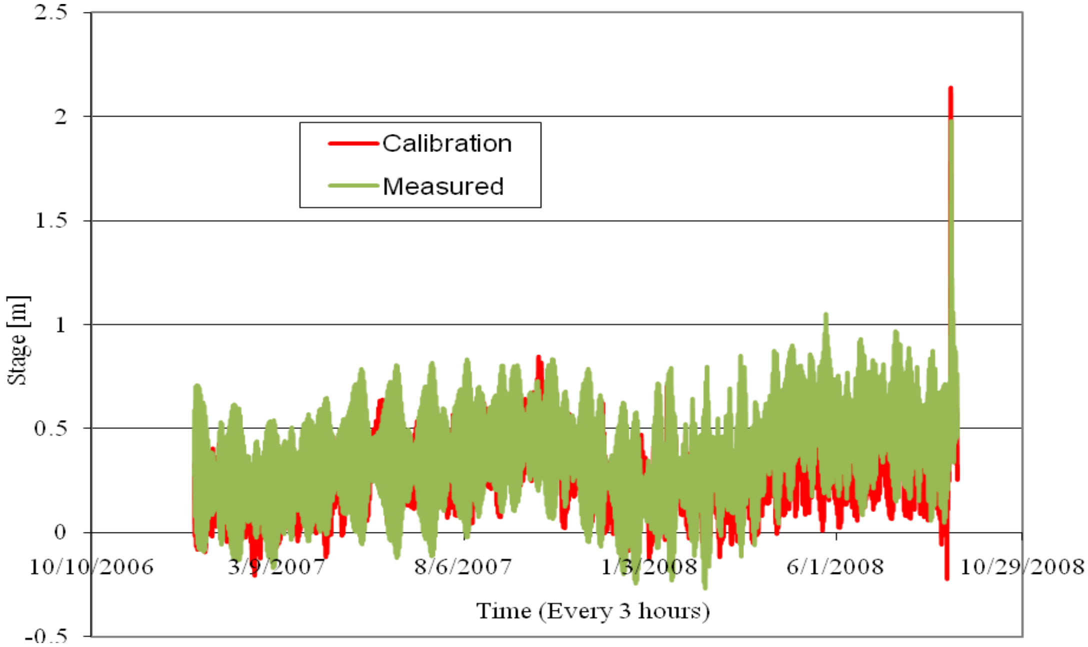

Figure 6.1-Water Level comparison between measured and calibrated data at Grand Island.

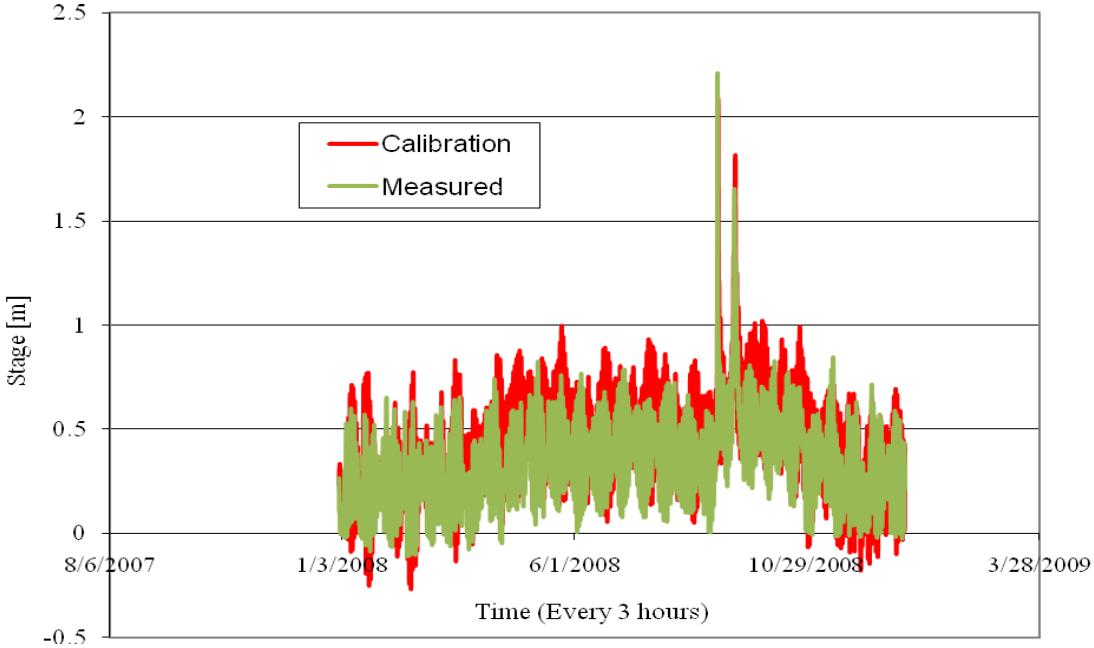

Figure 6.2-Water Level comparison between measured and calibrated data at Lower Barataria.

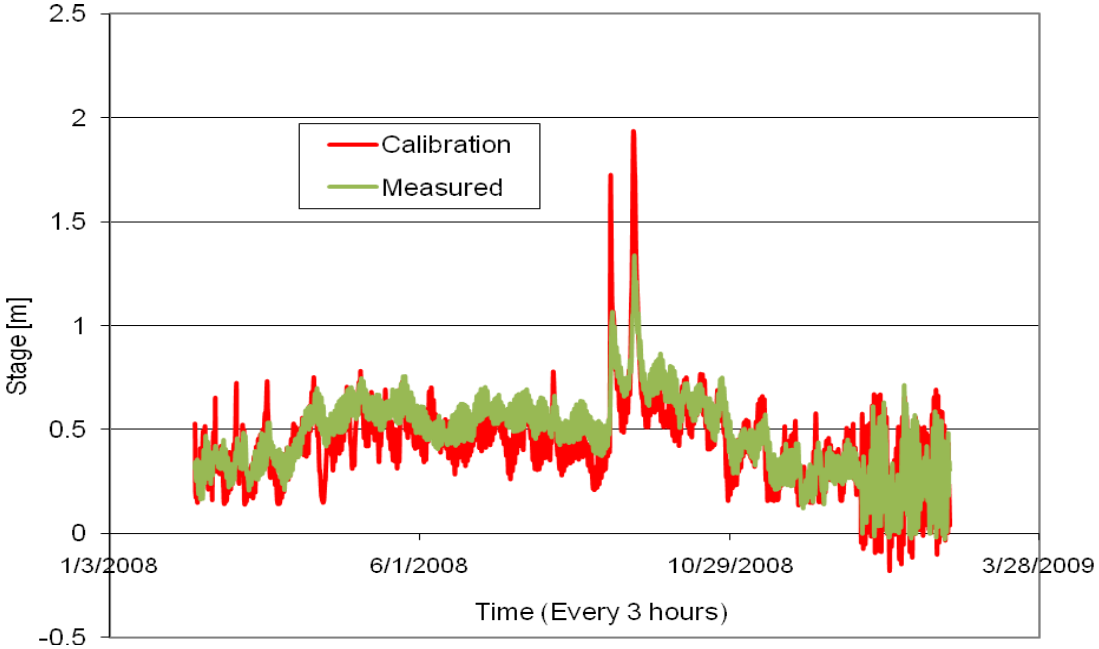

Figure 6.3-Water Level comparison between measured and calibrated data at Little Lake

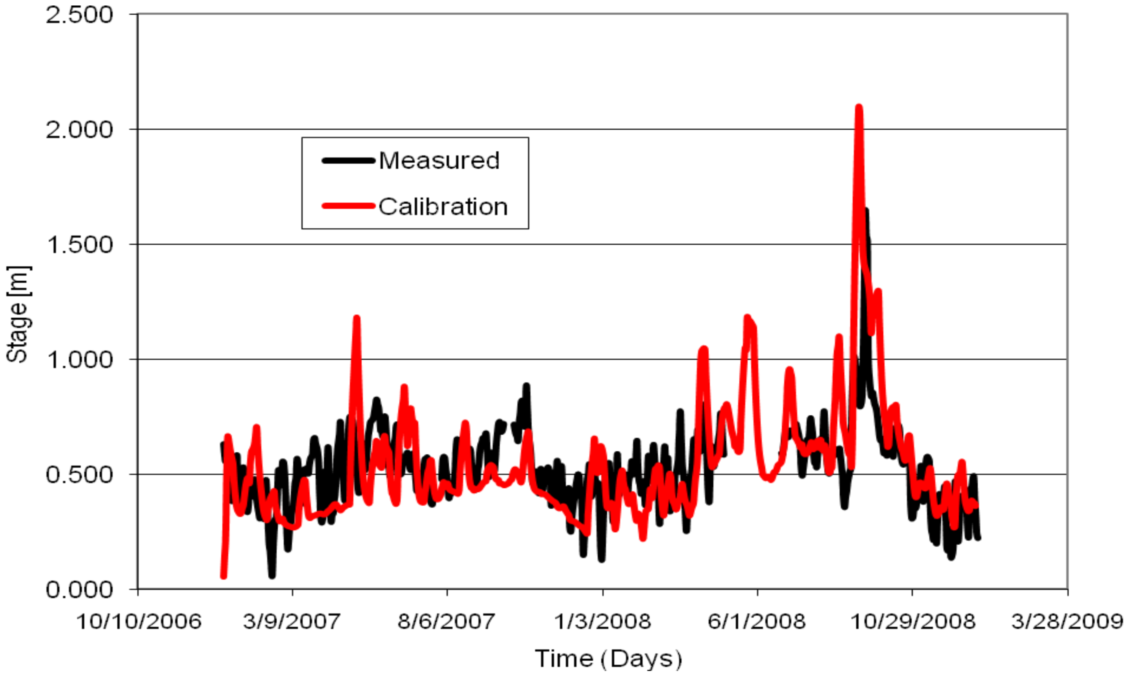

Figure 6.4-Water Level comparison between measured and calibrated data at Lake Des Allemands, (Daily model output)

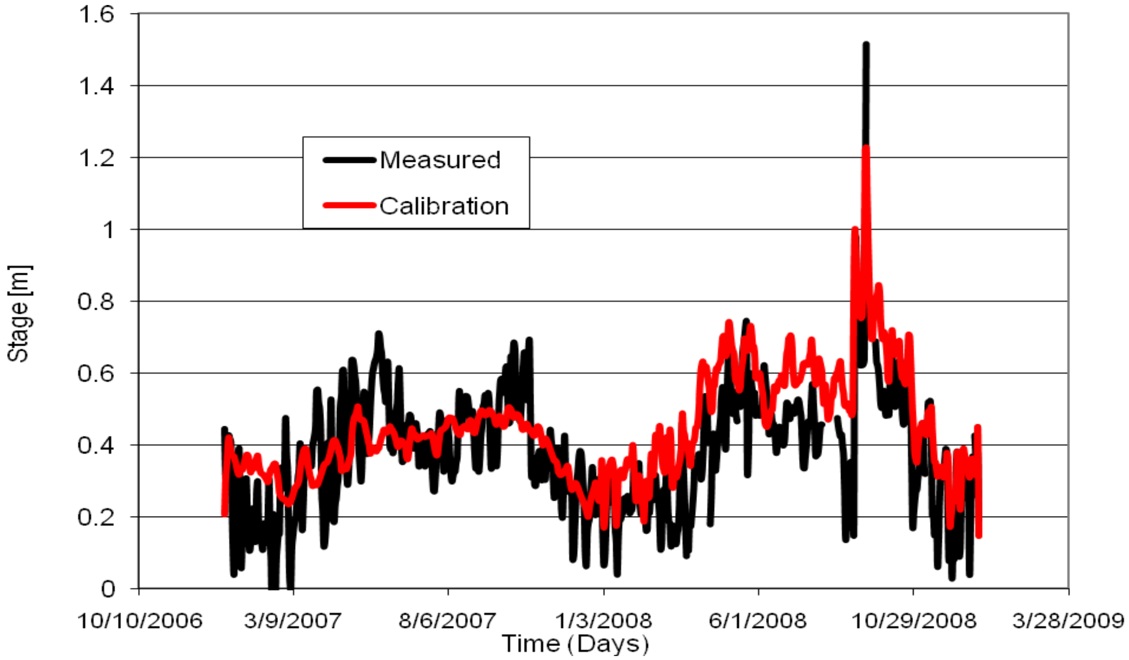

Figure 6.5-Water Level comparison between measured and calibrated data at Lake Salvador, (Daily model output**)**

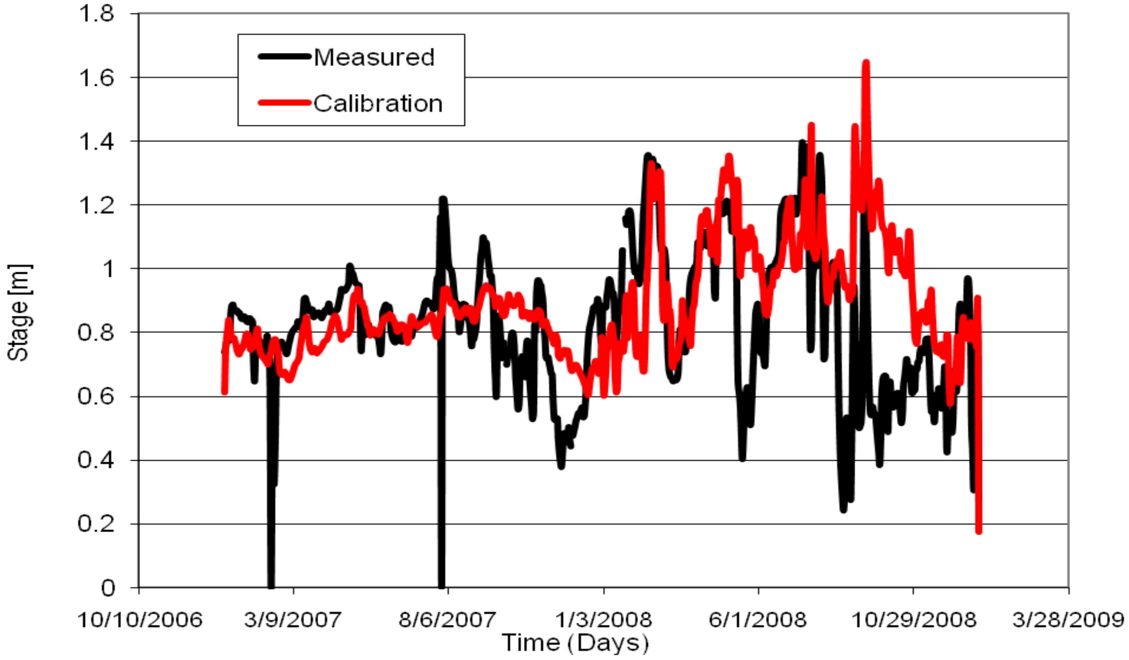

Figure 6.6-Water Level comparison between measured and calibrated data at Davis Pond, (Daily model output**)**

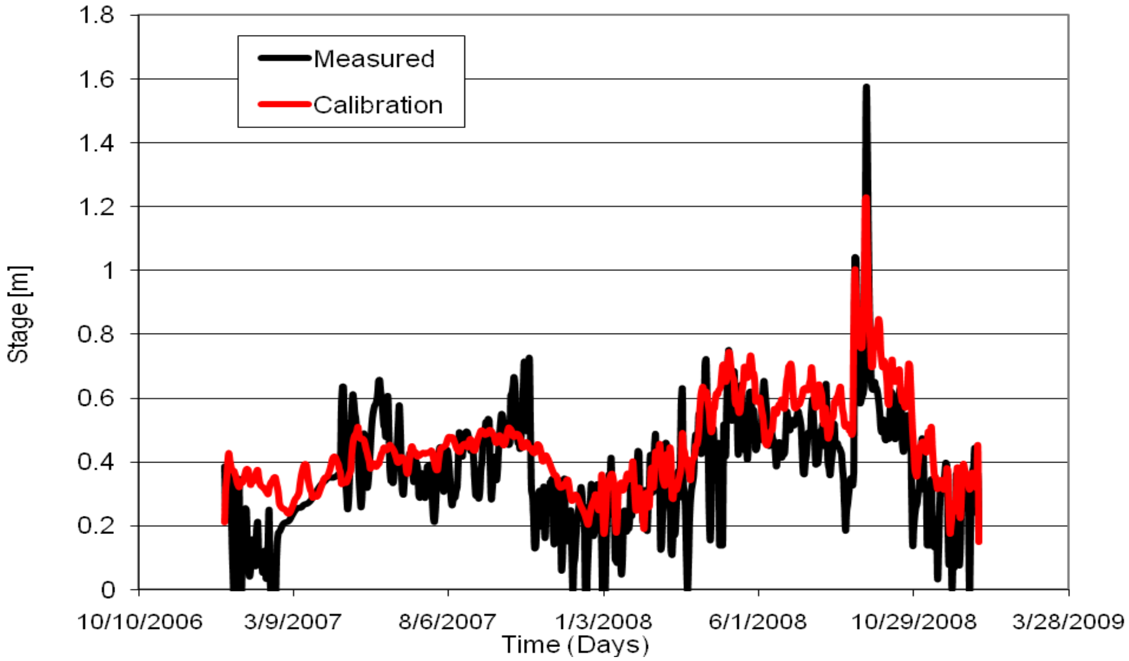

Figure 6.7-Water Level comparison between measured and calibrated data at Lake Cataouatche, (Daily model output)

Table 6.3-Mean and Standard deviation of measured and calibrated value of some stations.

Station	Model average(m)	Measured Average(m)	Model Standard Deviation	Measured Standard Deviation
Grand Island	0.366	0.264	0.216	0.163
Lower Barataria	0.42	0.343	0.244	0.209
Little Lake	0.510	0.456	0.16	0.19
Lake Salvador	0.448	0.378	0.148	0.166
Lake Cataouatche	0.449	0.365	0.148	0.183
Davis Pond	0.894	0.828	0.174	0.223
Lake Des Allemands	0.544	0.53	0.255	0.17

6.2 Calibration of Salinity

The stations in Table 6.4 were used for the calibration of salinity as there were sufficient data available.

Table 6.4-Stations of salinity Calibration

No.	Stations	Universal Transverse Mercator (UTM)	
		East (m)	North (m)
1.	Grand Island	201781	3232913
2.	Lower Barataria (central)	226435	3251703
3.	Little Lake	193985	3265714
4.	Lake Salvador	193535	3290711
5.	Lake Des Allemands	137149	3315249

The model shows that the upper Barataria that includes Lake Des Allemands, Lake Cataouatche, Lake Salvador and Little Lake is almost all freshwater. Figure 6.8 shows the calibration of salinity of Grand Island for the year 2008. The mean measured salinity of Grand Island for the year 2008 is 15.01 ppt with standard deviation 3.37 whereas the mean calibrated salinity was found to be 12.80 ppt with 4.018 ppt standard deviation. Figure 6.9 shows the calibration of salinity of Lower Central Barataria for the year 2008. The mean measured salinity of Lower Central Barataria for the year 2008 is 16.88 ppt with standard deviation 7.66 ppt whereas the mean calibrated salinity is 14.21 ppt with 4.50 ppt standard deviation. Figure 6.10 shows the calibration of salinity of the Little Lake from January 1, 2007 to October 30, 2008. The mean measured salinity of the Little Lake for this period of time is 4.99 ppt with standard deviation 4.72 ppt whereas the mean calibrated salinity is 4.93 ppt with 2.65 ppt standard deviation. The measured salinity for the Little Lake is found to be fluctuated as the lake receives occasionally different forms of water various sources including the Bayou Lafourche. Figures 6.11, 6.12 and 6. 13 show the salinity calibration at Davis Pond, Lake Des Allemands and Lake Catoauatche respectively. The average salinity of Des Allemands, Lake Cataouatche, and Davis Pond is less than 1ppt which is shown in Table 6.5. The model shows that the salinity decreases as we go towards from south to north i.e. from the Lower Barataria to the Upper Barataria.

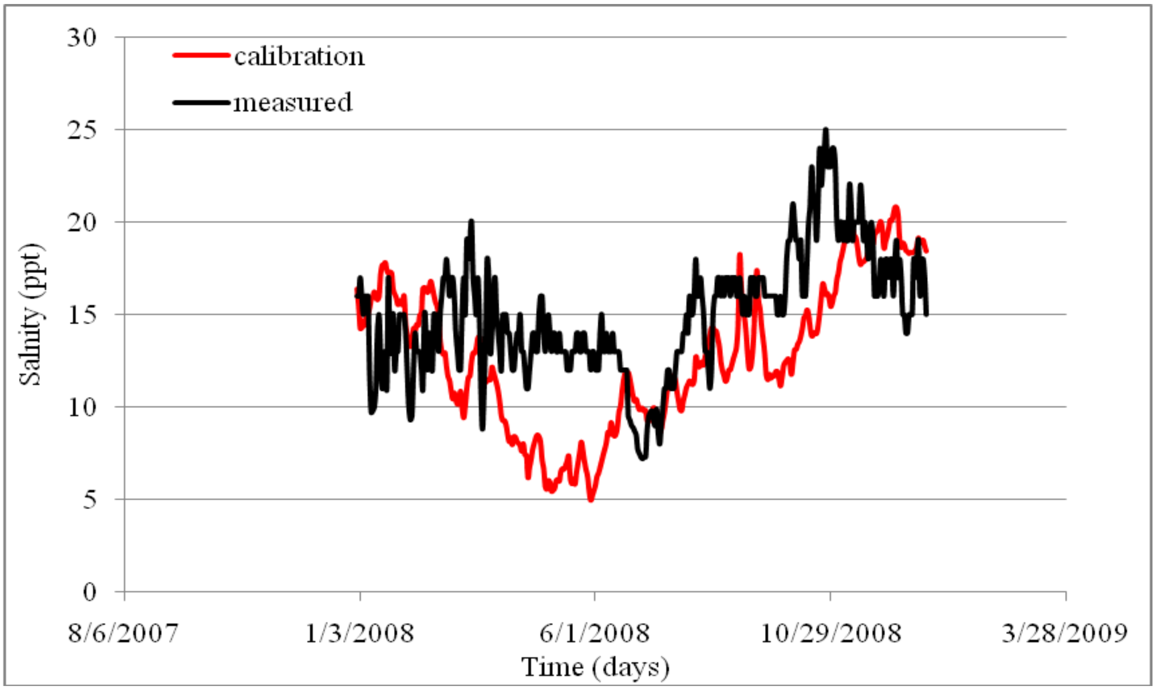

Figure 6.8-Salinity comparison between measured and calibrated data at Grand Island (2008)

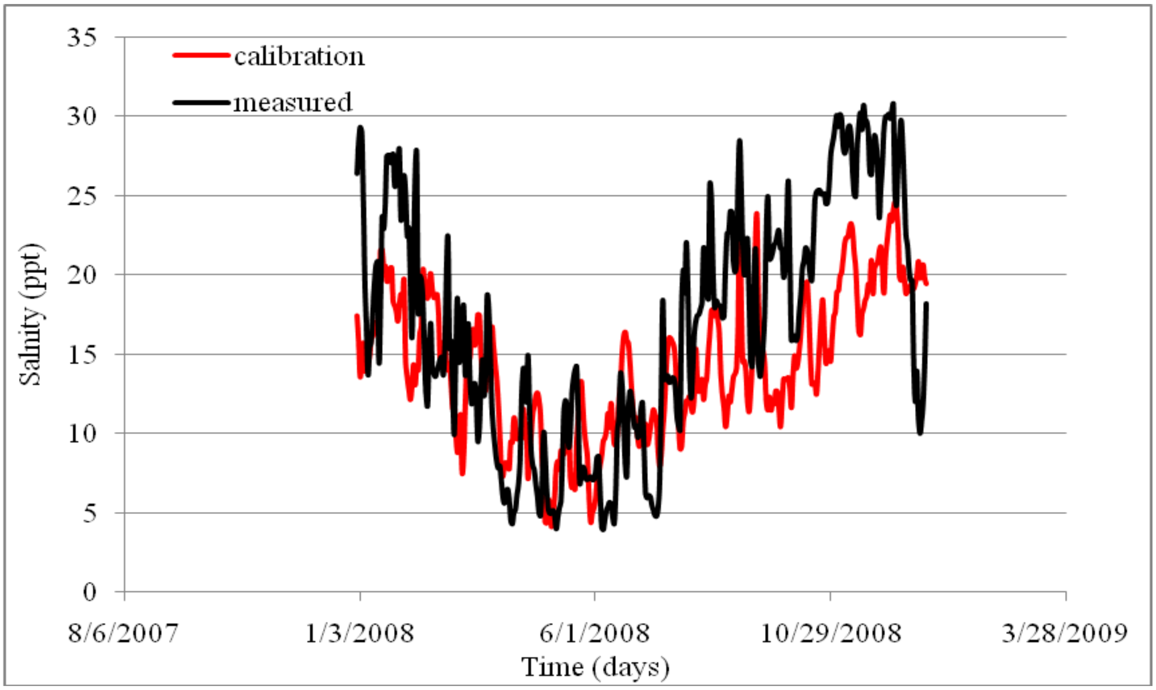

Figure 6.9-Salinity comparisons between measured and calibrated data at Lower Barataria

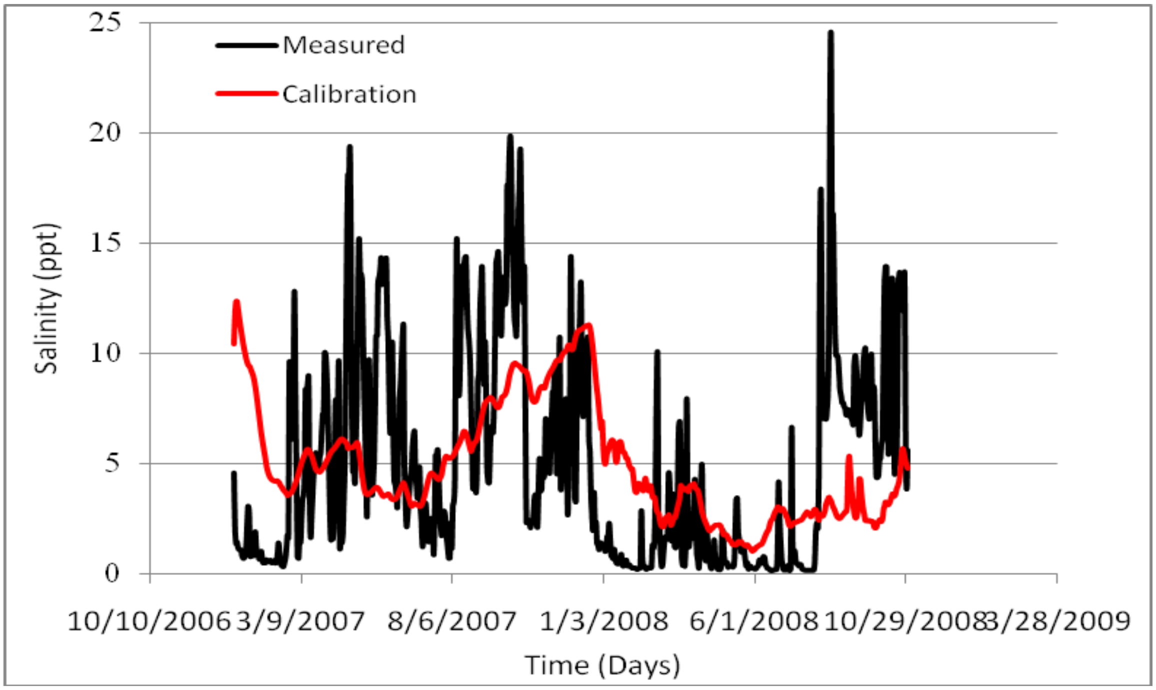

Figure 6.10-Salinity comparisons between measured and calibrated data at Little Lake (2007-2008).

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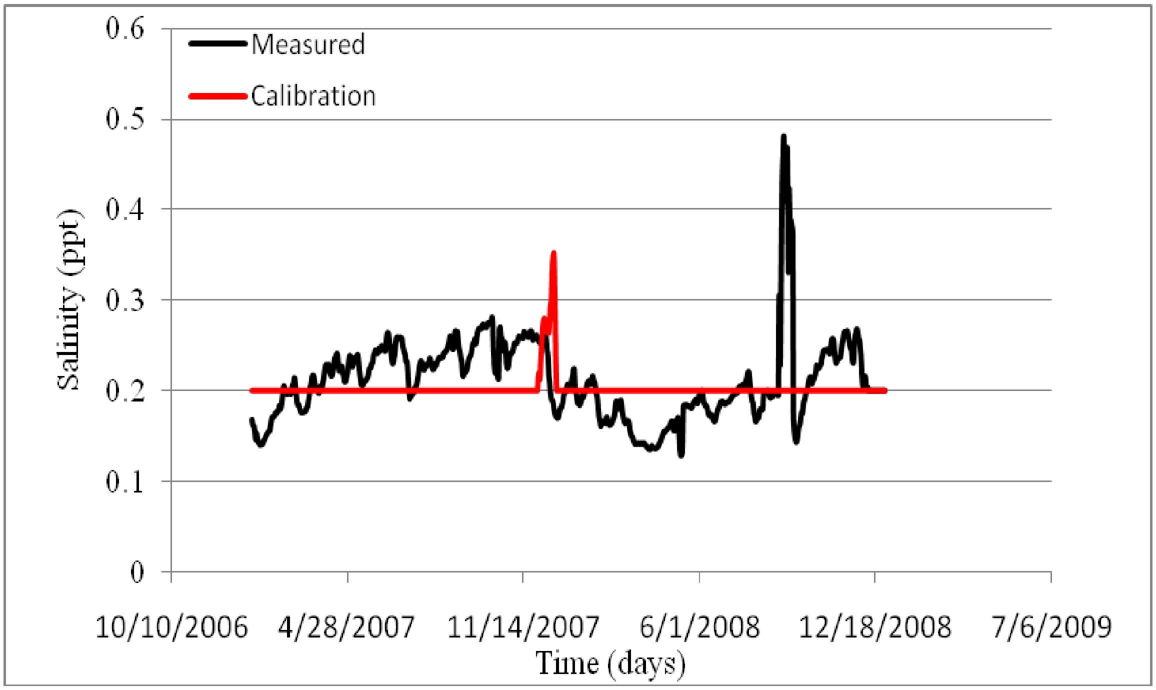

Figure 6.11-Salinity comparisons between measured and calibrated data at Davis Pond (2007-2008).

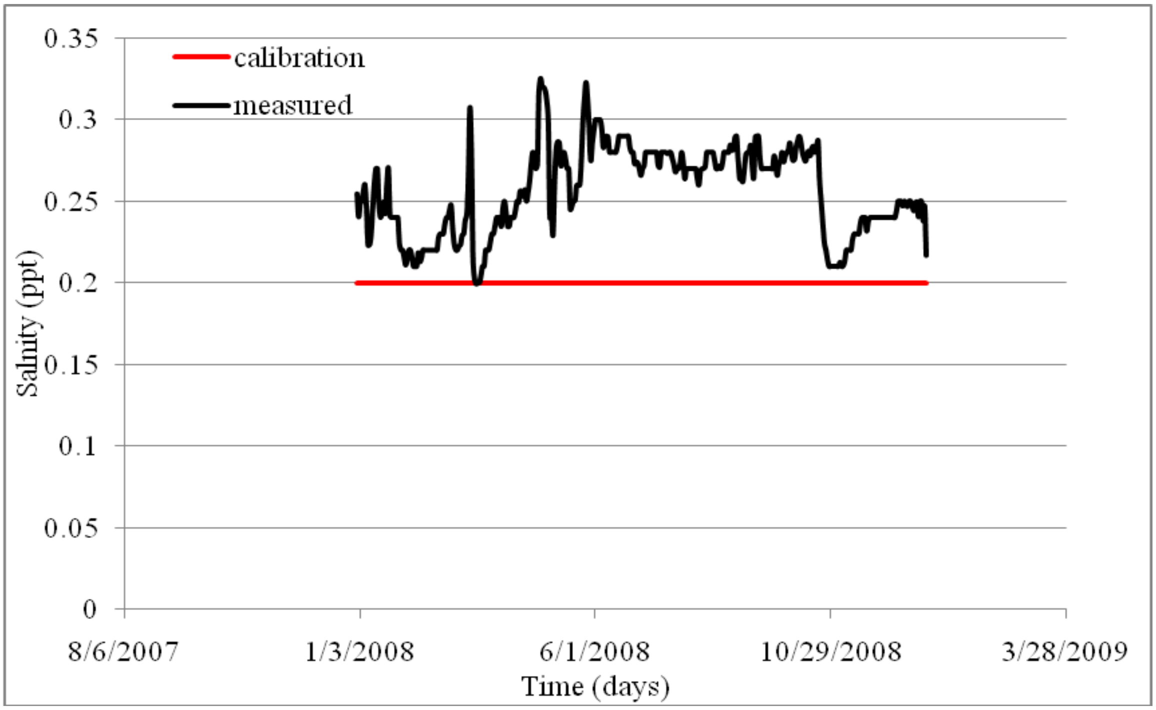

Figure 6.12-Salinity comparisons between measured and calibrated data at Lac Des Allemands.

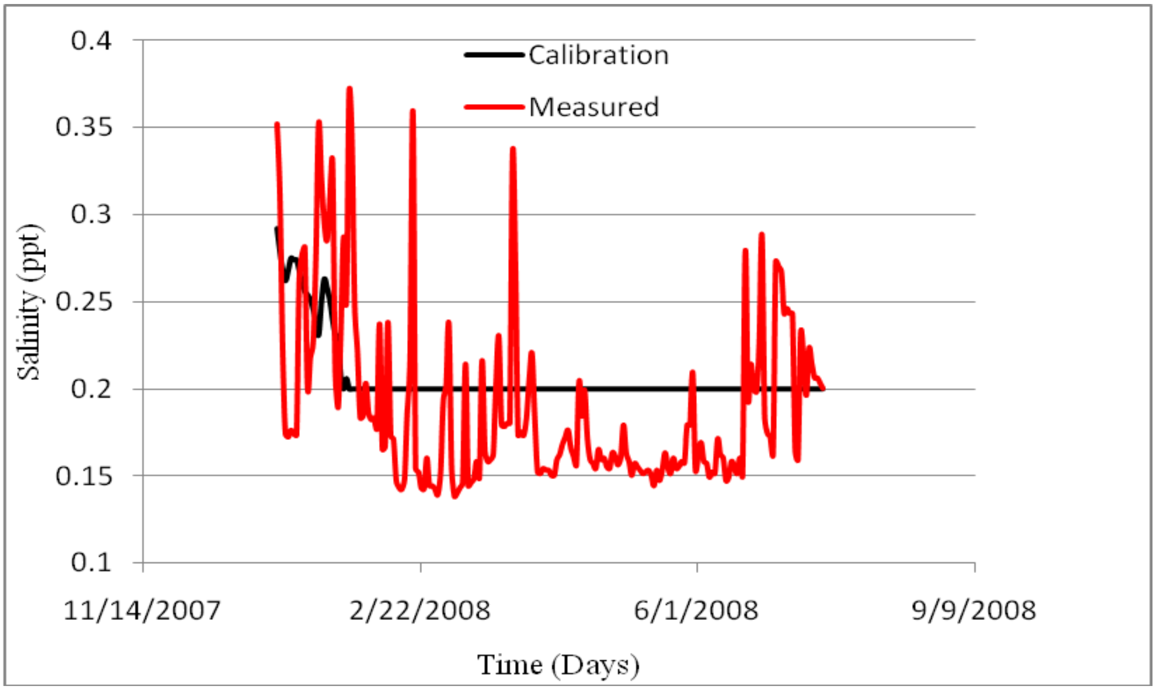

Figure 6.13-Salinity comparisons between measured and calibrated data at Lake Cataouatche.

Table 6.5- Mean and Standard Deviation of calibrated and measured salinity at different stations

Station	Model average(ppt)	Measured Average(m)	Model Standard Deviation	Measured Standard Deviation
Grand Island	12.80	15.01	4.018	3.37
Lower Barataria	14.29	16.88	4.50	7.66
Little Lake	4.93	4.99	2.65	4.72
Lake Cataouatche	0.206	0.189	0.018	0.049
Davis Pond	0..202	0.211	0.014	0.04
Lake Des Allemands	0.544	0.53	0.255	0.17

6.3 *Calibration of Nutrients*

The stations shown in Table 6.6 were used for the calibration of nutrients;

Table 6.6-Stations used in the calibration of Nutrients

No.	Stations	Universal Transverse Mercator (UTM)	
		East (m)	North (m)
1.	Grand Island	201781	3232913
2.	Little Lake	193985	3265714
3.	Lake Salvador	193535	3290711
4.	Lake Cataouatche	186665	3305169

Daily data of all the nutrients is not available for the Barataria Basin. The Louisiana Department of Environmental Quality (LADEQ) measures some of the nutrients a few times per year. The average of the calibrated value and the mean of the measured data of nitrogen as nitrite+nitrate, organic nitrogen and the Phosphorus are shown in the Table 6.7. The mean of measured data of nitrite+nitrate near Little Lake is found to be a more than the calibrated value. It is because the Little Lake receives more nitrogen from the City Houma and bayou Lafourche. Figures 6.14, 6.15,6.16 and 6.17 show the calibration of nitrite+nitrate, organic nitrogen and the phosphorus which shows that the model is doing good job in the predict nutrients concentrations at the selected stations in the Basin.

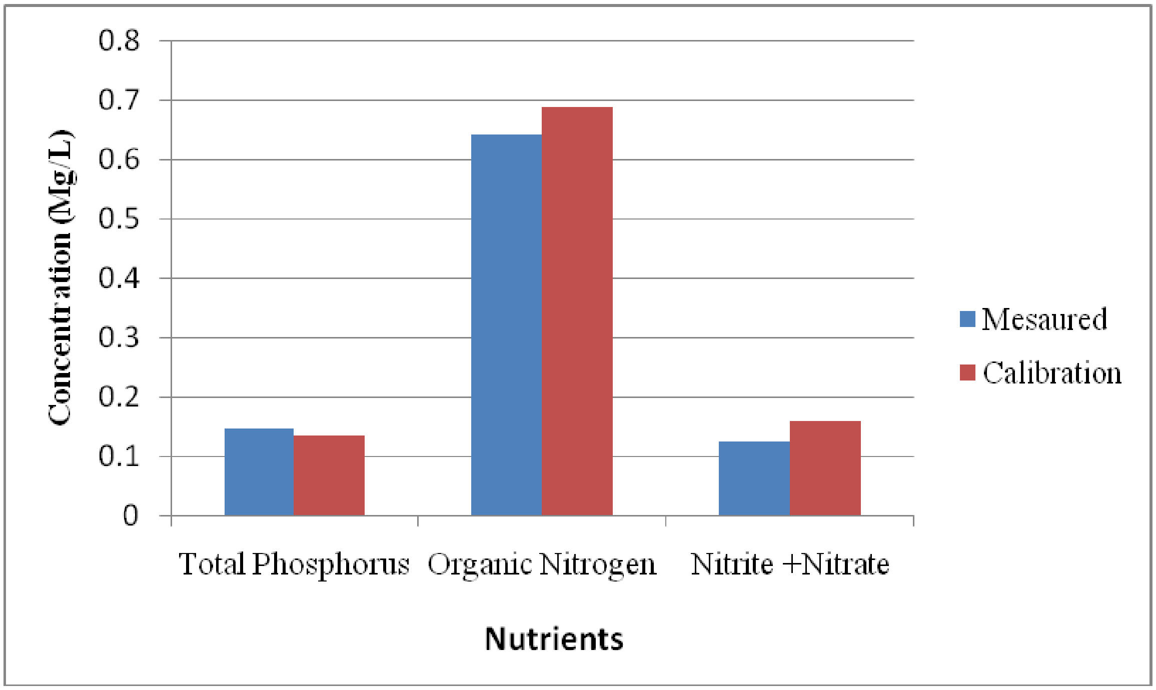

Figure 6.14- Nutrient's concentration comparison between measured and calibrated data at Grand Island.

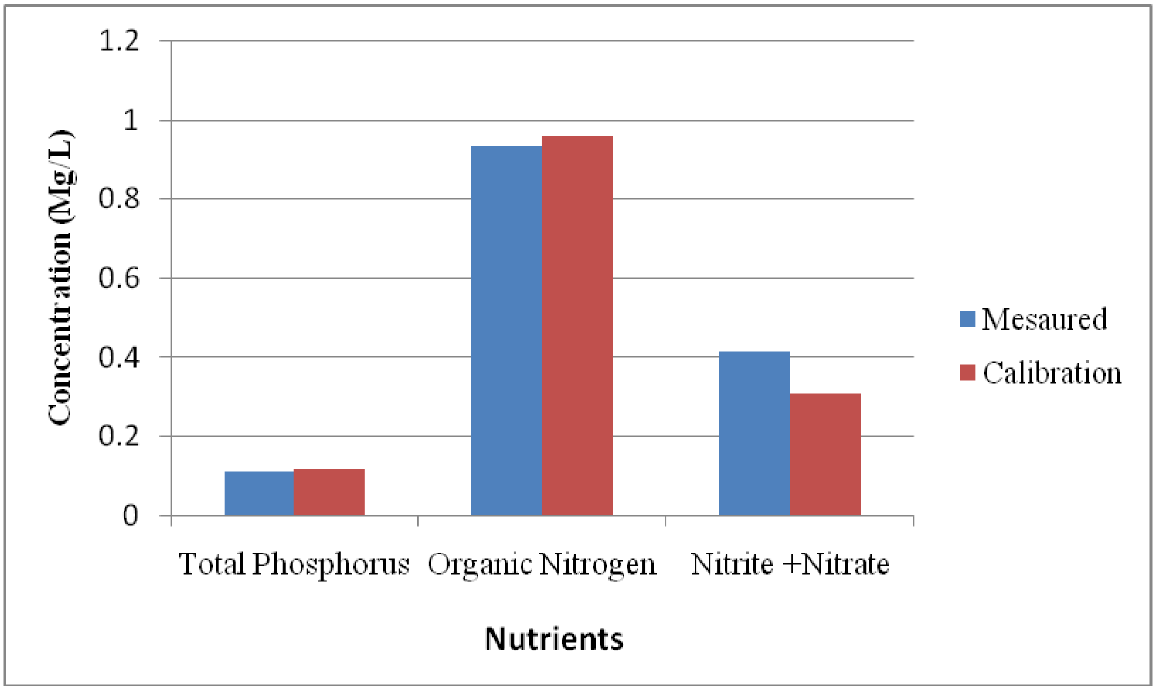

Figure 6. 15 Nutrient's concentration comparison between measured and calibrated data at Little Lake.

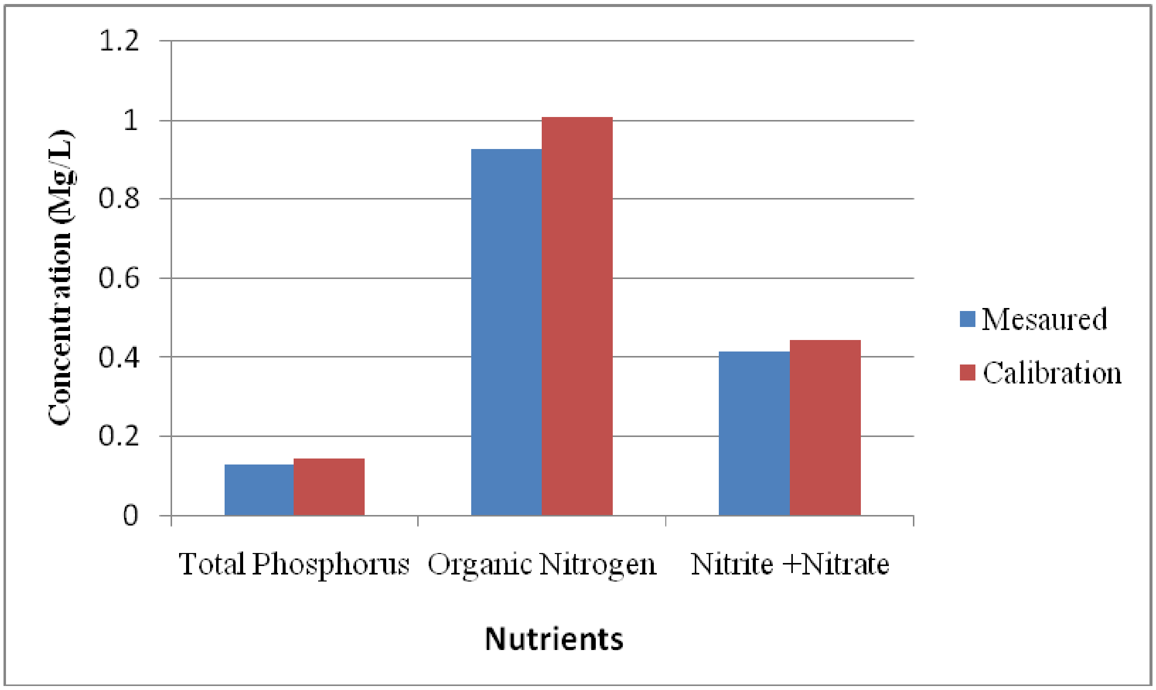

Figure 6.15- Nutrient’s concentration comparison between measured and calibrated data at Lake Salvador

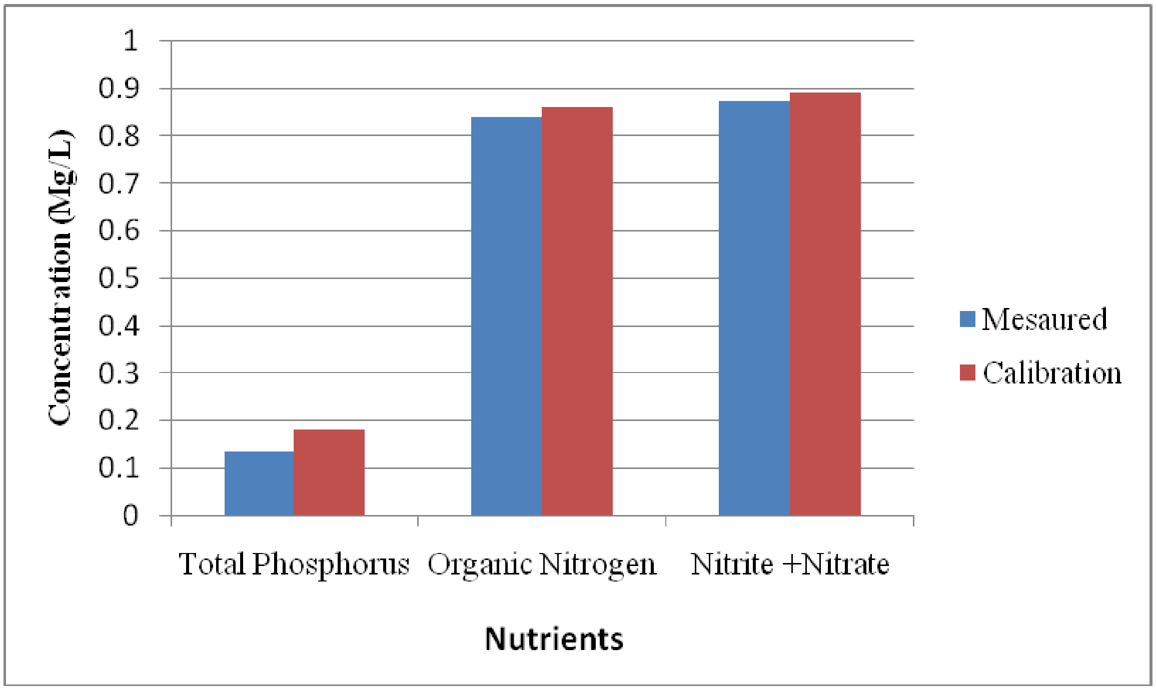

Figure 6.16-Nutrient’s concentration comparison between measured and calibrated data at Lake Cataouatche

Table 6.7- Comparison of measured and calibrated nutrients

Stations	Nutrients	Measured (mg/l)	Calibration (mg/l)
Grand Island	Phosphorus	0.146	0.135
	Organic Nitrogen	0.643	0.688
	Nitrite+Nitrate	0.126	0.16
Little lake	Phosphorus	0.11	0.12
	Organic Nitrogen	0.934	0.96
	Nitrite+Nitrate	0.414	0.309
Lake Salvador	Phosphorus	0.13	0.142
	Organic Nitrogen	0.928	1.0069
	Nitrite+Nitrate	0.416	0.4438
Lake Cataouatche	Phosphorus	0.136	0.18
	Organic Nitrogen	0.84	0.86
	Nitrite+Nitrate	0.87	0.89

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7.0 Results

7.1 Introduction

After calibration and validation, the model was run for future scenarios. Future scenarios include the median and high flow in the Mississippi River and the corresponding flows in the future proposed diversions. It includes the median flow scenario (Scenario I, reference year 2007) and the high flow scenario (Scenario II, reference year 2008). As discussed in the Chapter 1, the proposed diversions are Buras, Deer Range, Myrtle Grove, Jesuit Bend, Langan and Johnson. The flows from these diversions for future scenarios are shown in Figure 5.16 and 5.17. (In Chapter 5) The Mississippi flow for the future scenarios is shown in Figure 5.14 and 5.15. (In Chapter 5). The impacts of diversions on salinity are presented in Section 7.2. The impacts of diversions on salinity gradients are discussed in Section 7.3. The effect of closing of West bay is discussed in section 7.4. The impacts of diversions on water level are presented in Section 7.4 and the impacts of diversions on nutrients concentration are presented in Section 7.5. The location of all the future diversions is shown in Figure 1.6 (In Chapter 1). The coordinates of the diversions are shown in Table 7.1. The average and maximum flows from the proposed diversions for the future scenarios are illustrated in Table 5.2 and 5.3. (In Chapter 5).

Table 7.1-Universal Transverse Mercator of the Proposed Diversion

No.	Proposed Diversion	Universal Transverse Mercator (UTM)	
		East (m)	North (m)
1.	Buras	255939	3249568
2.	Deer Range	218402	3283187
3.	Myrtle Grove	215406	3265714
4.	Jesuit bend	207362	3294737
5.	Johnson	151103	3327119
6.	Lagan	132946	3322412

7.2 Impacts of Diversions on Salinity

Figure 7.1 to Figure 7.9 show the salinity in different stations of Barataria Basin for different scenarios. The location of the stations (Universal Transverse Mercator) is given in Table 7.2.

Table 7.2-Universal Transverse Mercator of Stations of Salinity Study.

No.	Stations	Universal Transverse Mercator (UTM)	
		East (m)	North (m)
1.	Grand Island	201781	3232913
2.	Lower Barataria (central)	226435	3251703
3.	Little Lake	193985	3265714
4.	Lake Salvador	193535	3290711
5.	Lake Des Allemands	137149	3315249

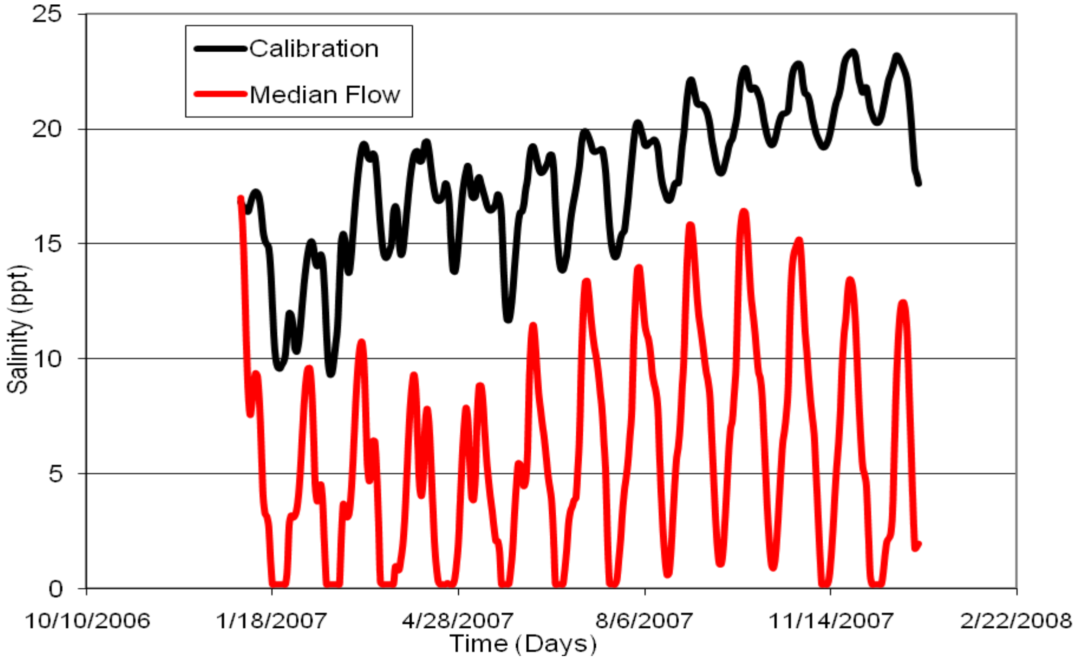

Figure 7.1-Lower Barataria Bay -- Model Results for Scenario I (Reference Year 2007) with 1 year Operation of the Diversions

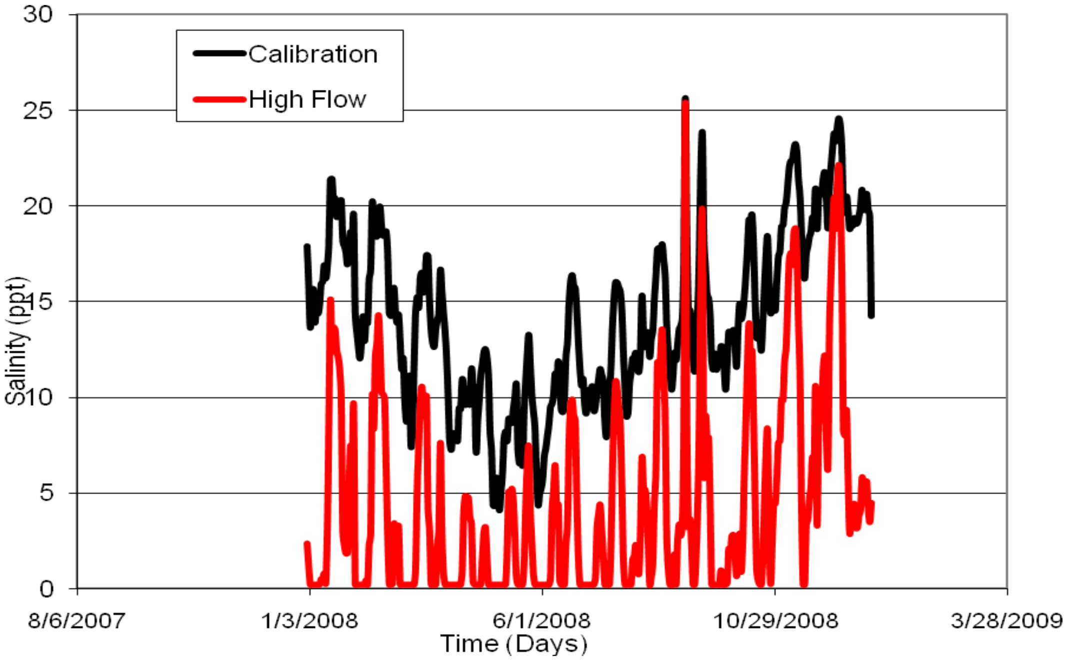

Figure 7.2-Lower Barataria Bay -- Model Results for Scenario II (Reference Year 2008) with 1 year Operation of the Diversions

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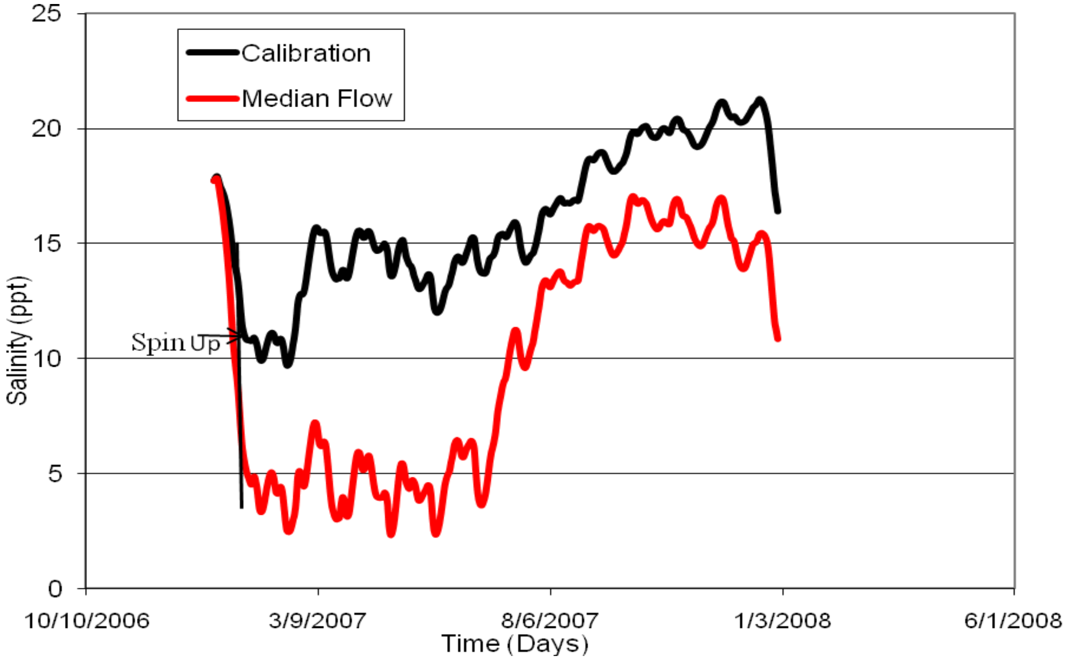

Figure 7.3-Grand Island -- Model Results for Scenario I (Reference Year 2007) with 1 year Operation of the Diversions

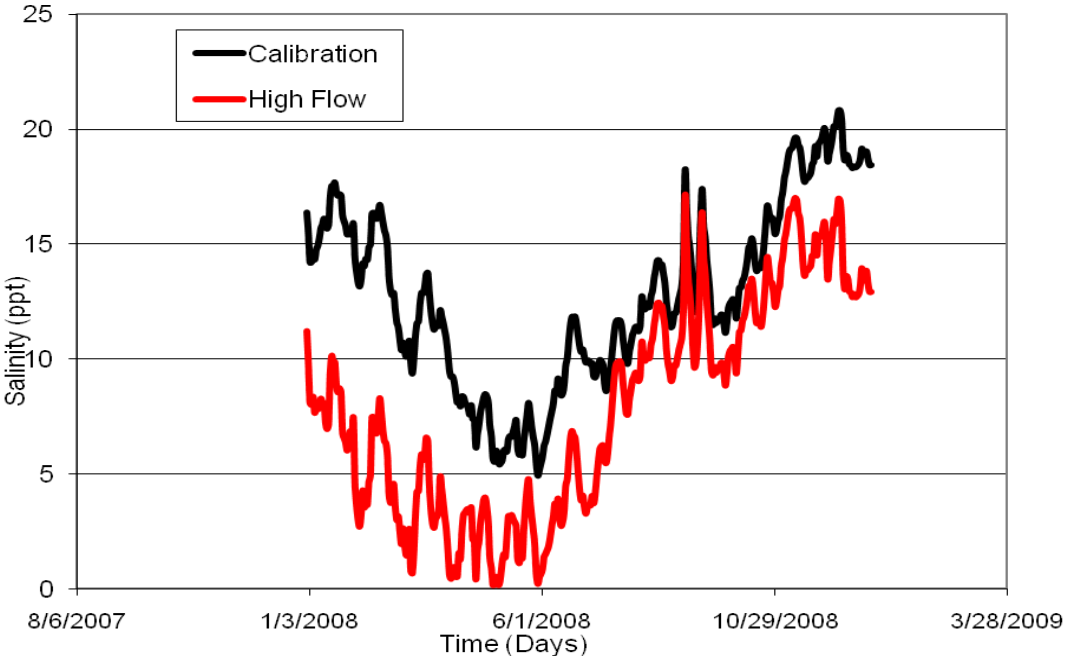

Figure 7.4- Grand Island -- Model Results for Scenario II (Reference Year 2008) with 1 year Operation of the Diversions

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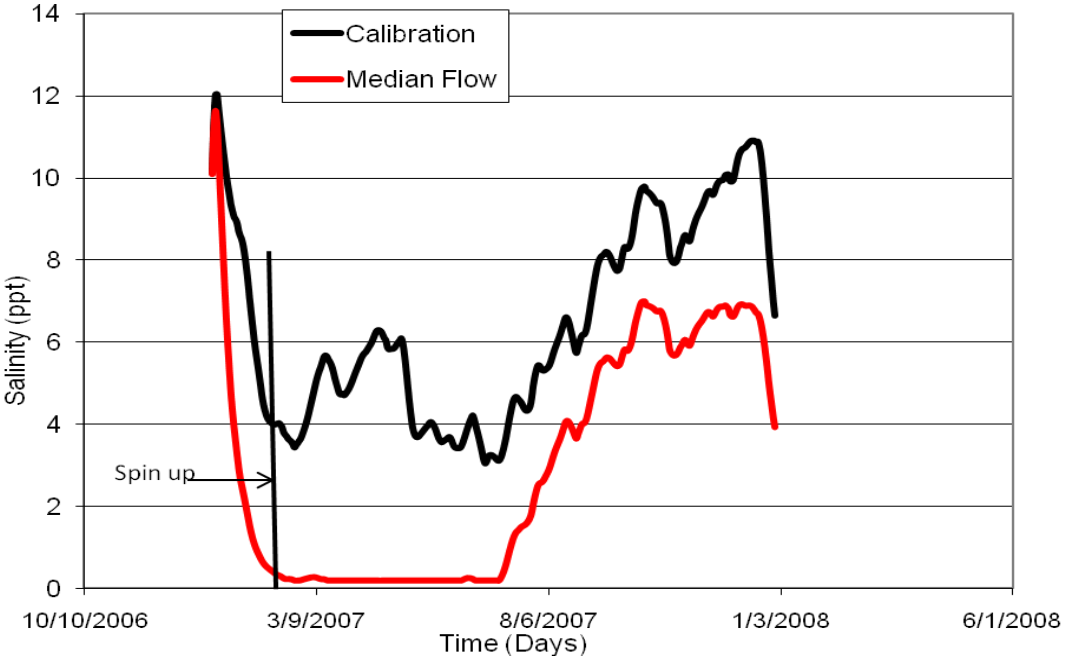

Figure 7.5-Little Lake -- Model Results for Scenario I (Reference Year 2007) with 1 year Operation of the Diversions**.**

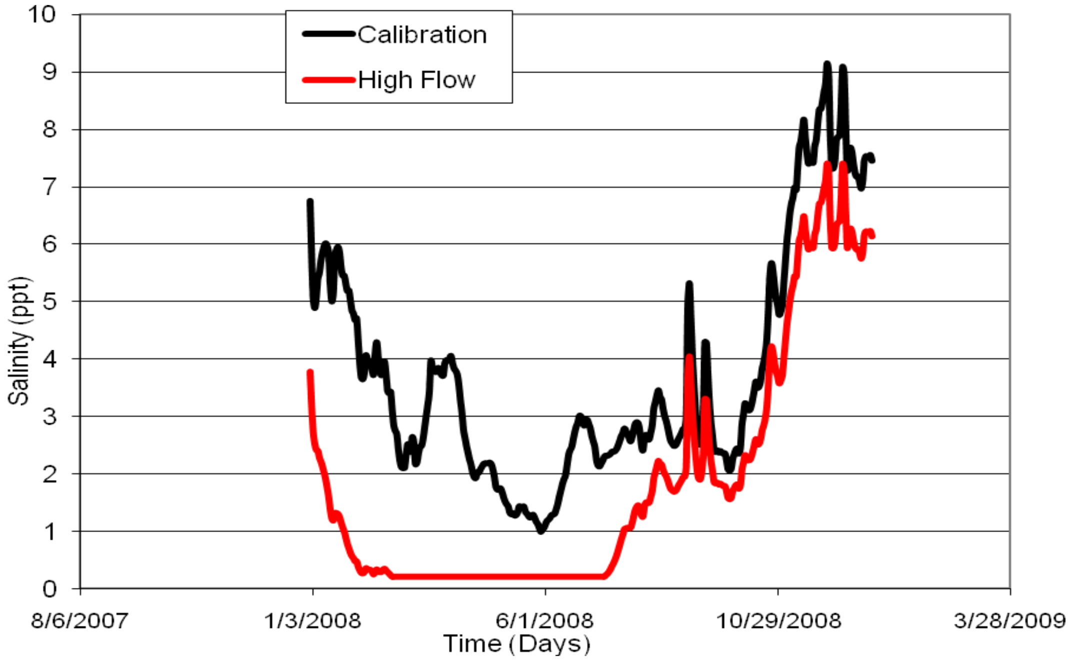

Figure 7.6-Little Lake -- Model Results for Scenario II (Reference Year 2008) with 1 year Operation of the Diversions

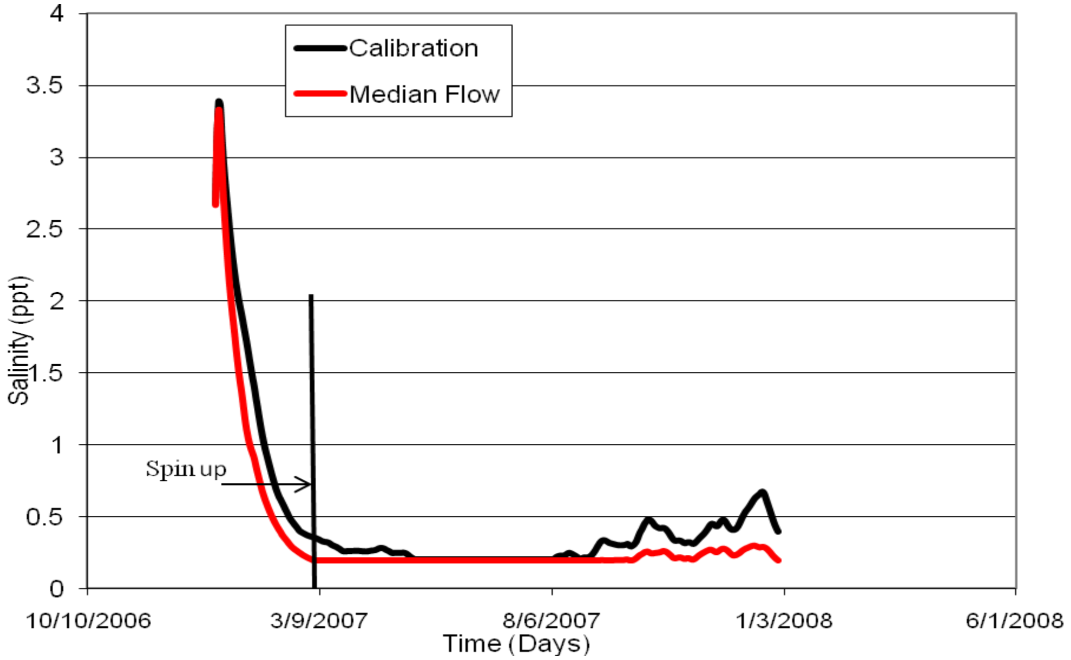

Figure 7.7-Lake Salvador -- Model Results for Scenario I (Reference Year 2007) with 1 year Operation of the Diversions.

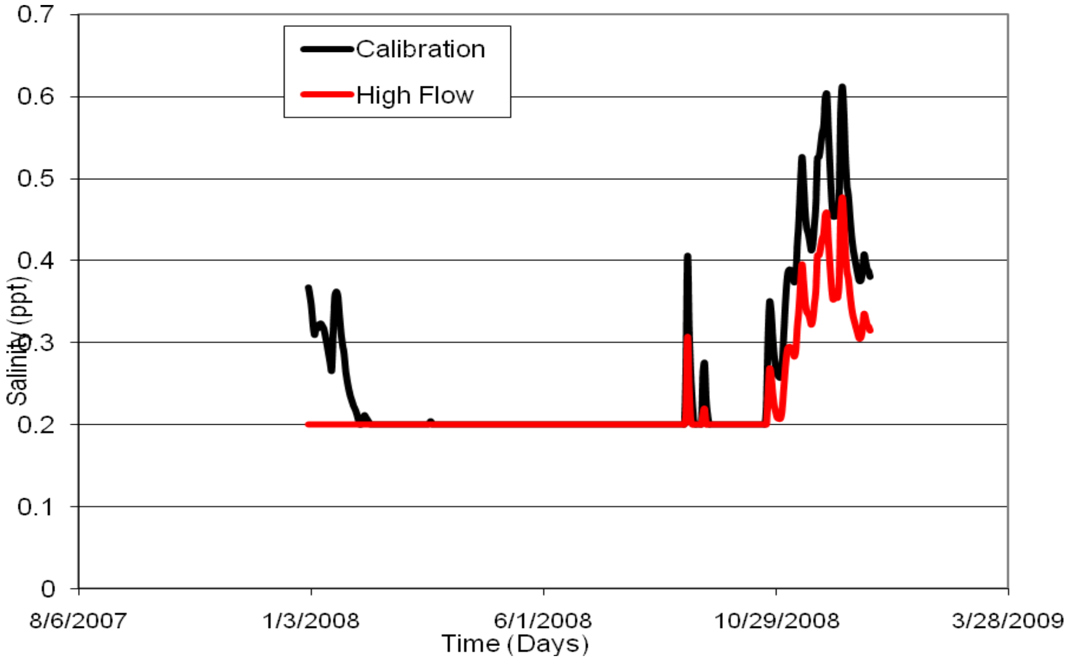

Figure 7.8-Lake Salvador -- Model Results for Scenario II (Reference Year 2008) with 1 year Operation of the Diversions

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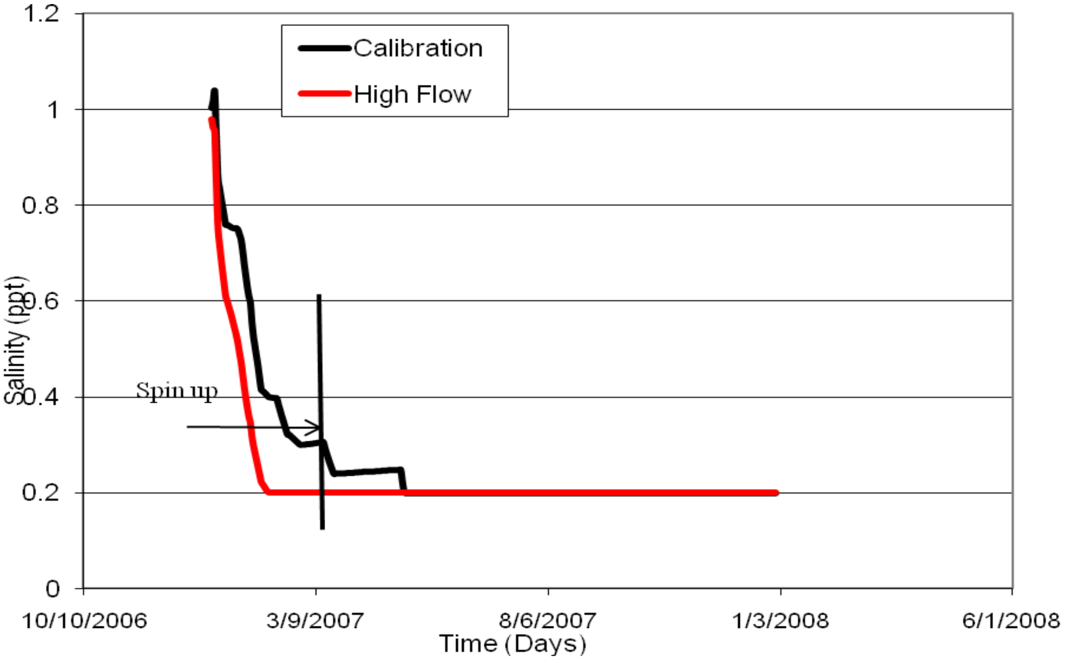

Figure 7.9-Lake Des Allemands-- Model Results for Scenario I (Reference Year 2007) with 1 year Operation of the diversions.

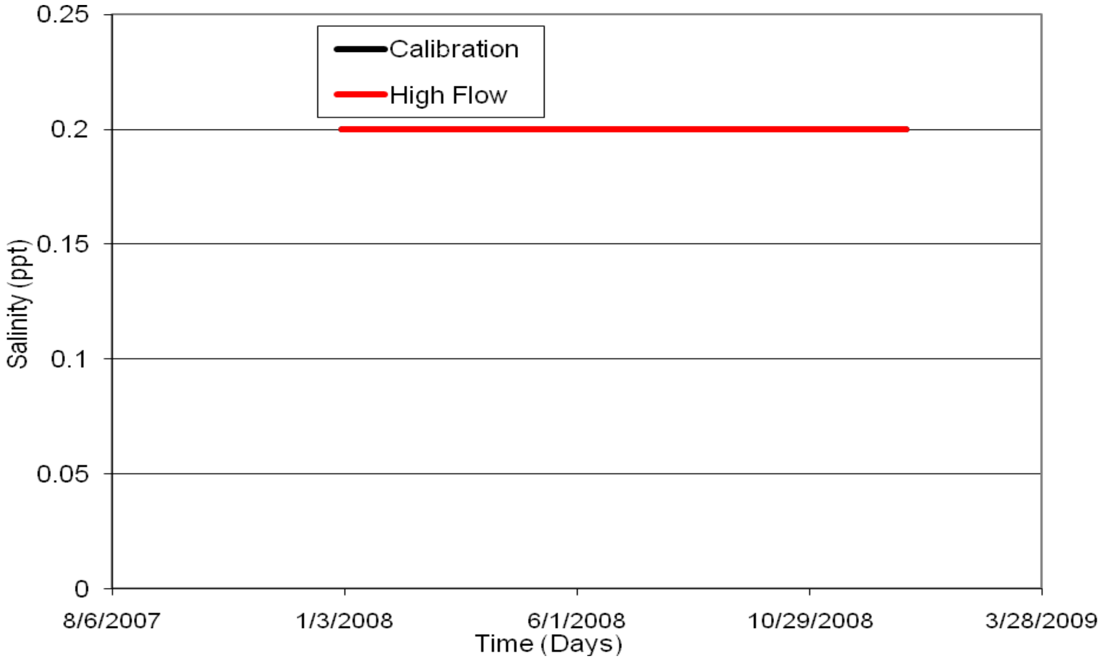

Figure 7.10-Figure 7.10 Lake Des Allemands-- Model Results for Scenario II (Reference Year 2008) with 1 year Operation of the Diversions.

Table 7.3-Mean and Standard deviation of Salinity of Calibration and Median Flow (2007), (Scenario I)

Station	Calibration Average salinity(ppt)	Future Median Average salinity (ppt)	Calibration Standard Deviation (ppt)	Future Median Standard Deviation (ppt)
Grand Island	16.07	9.92	3.11	5.19
Lower Barataria	17.91	6.13	3.21	4.25
Little Lake	6.5	2.97	2.42	2.91
Lake Salvador	0 .47	0.35	0.55	0.48
Lake Des Allemands	0.26	0.22	0.15	0.11

Table 7.4-Mean and Standard deviation of Salinity of Calibration and High Flow (2008), (Scenario II)

Station	Calibration Average Salinity(ppt)	Future High Average Salinity (ppt)	Calibration Standard Deviation (ppt)	Future Median Standard Deviation (ppt)
Grand Island	12.79	7.92	4.01	4.75
Lower Barataria	14.26	4.47	4.49	5.10
Little Lake	3.76	1.83	2.03	2.14
Lake Salvador	0.25	0.225	0.09	0.05
Lake Des Allemands	0.2	0.2	0	0

The model shows that the proposed future diversions would significantly impact on the salinity of the Lower Barataria Basin. The impacts were not significant in the Upper Barataria as this part is already dominated by the freshwater. Basically the freshwater in this area is due to the rainfall runoff, the Davis Pond Diversion and inflow from the Gulf Intracoastal Waterway (GIWW). There were some noticeable impacts in the middle part of the Basin from Little Lake to Lake Salvador. The salinities decreased by a small amount in this area with the introduction of diversions. The major impacts of diversions on salinities were seen in the Lower Barataria. The peak salinity in the Lower Barataria was reduced slightly but the average salinity was reduced significantly. Figures 7.1 and 7.2 illustrate the variation of salinity with the introduction of the proposed diversions in Lower Barataria for the year 2007 (Scenario I) and 2008 (Scenario II) respectively. The average salinity in Lower Barataria for the year 2007(Scenario I) before the introduction of diversion was 17.9 ppt with standard deviation 3.2 ppt and the average salinity for the year 2007 after the introduction of diversion for median flow was 6.13 ppt with standard deviation 4.25 ppt. The average salinity in Lower Barataria for the year 2008 (Scenario II) before the introduction of diversion was 14.26 ppt with standard deviation 4.49 ppt and the average salinity for the year 2008 after the introduction of diversion for high flow was 4.47 ppt with standard deviation 5.10 ppt. Figures 7.3 and 7.4 illustrate the variation of salinity with the introduction of the proposed diversions in Grand Island for the year 2007 (Scenario I) and 2008 (Scenario II) respectively. The average salinity in Grand Island for the year 2007(Scenario I) before the introduction of diversion was 16.07 ppt with standard deviation 3.11 ppt and the average salinity for the year 2007 after the introduction of diversion for median flow is 9.92 ppt with standard deviation 5.19 ppt. The average salinity in Grand Island for the year 2008 (Scenario II) before the introduction of diversion is 12.79 ppt with standard deviation 4.01 ppt and the average salinity for the year 2008 after the introduction of diversion for high flow is 7.92

ppt with standard deviation 4.75 ppt . Similarly Figures 7.5 and 7.6 illustrate the variation of salinity with the introduction of the proposed diversions in Little Lake for the year 2007 (Scenario I) and 2008 (Scenario II) respectively. The average salinity in Little lake for the year 2007(Scenario I) before the introduction of diversion was 6.5 ppt with standard deviation 2.42 ppt and the average salinity for the year 2007 after the introduction of diversion for median flow is 2.97 ppt with standard deviation 2.91 ppt. The average salinity in Little Lake for the year 2008 (Scenario II) before the introduction of diversion is 3.76 ppt with standard deviation 2.03 ppt and the average salinity for the year 2008 after the introduction of diversion for high flow is 1.82 ppt with standard deviation 2.14 ppt. Figures 7.7 and 7.8 show the impacts of proposed diversions were not significant in Lake Salvador as the lake is already dominated by freshwater. Similarly Figure 7.9 and 7.10 show that there is no impact of diversions in Lake Des Allemands. The salinity in the beginning of the year 2007 was found to be high value than the average salinity in Lake Salvador and Lake Des Allemands and it is due to the initial condition. It is called the "Spin up" effect.

7.3 Impacts of Diversions Scenarios on Salinity Gradients.

Figures 7.11 and 7.12 show the average calibrated salinities for the year 2007 and 2008 respectively. Figures 7.13 and 7.14 show the average salinities for the reference year 2007 (Scenario I) and the reference year 2008 (Scenario II). Figures 7.11, 7.12, 7.13 and 7.14 also show that the salinity decreases as we go from Lower Barataria to Upper Barataria.

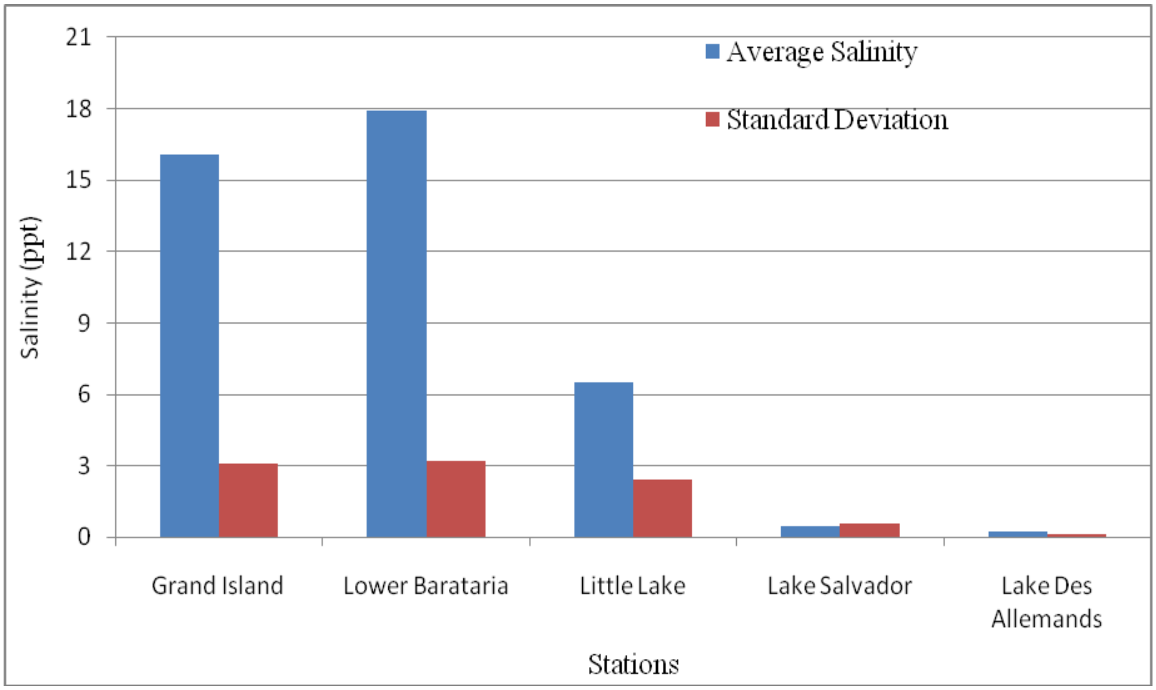

Figure 7.11-Calibrated Average Salinities and Standard Deviation for the year 2007.

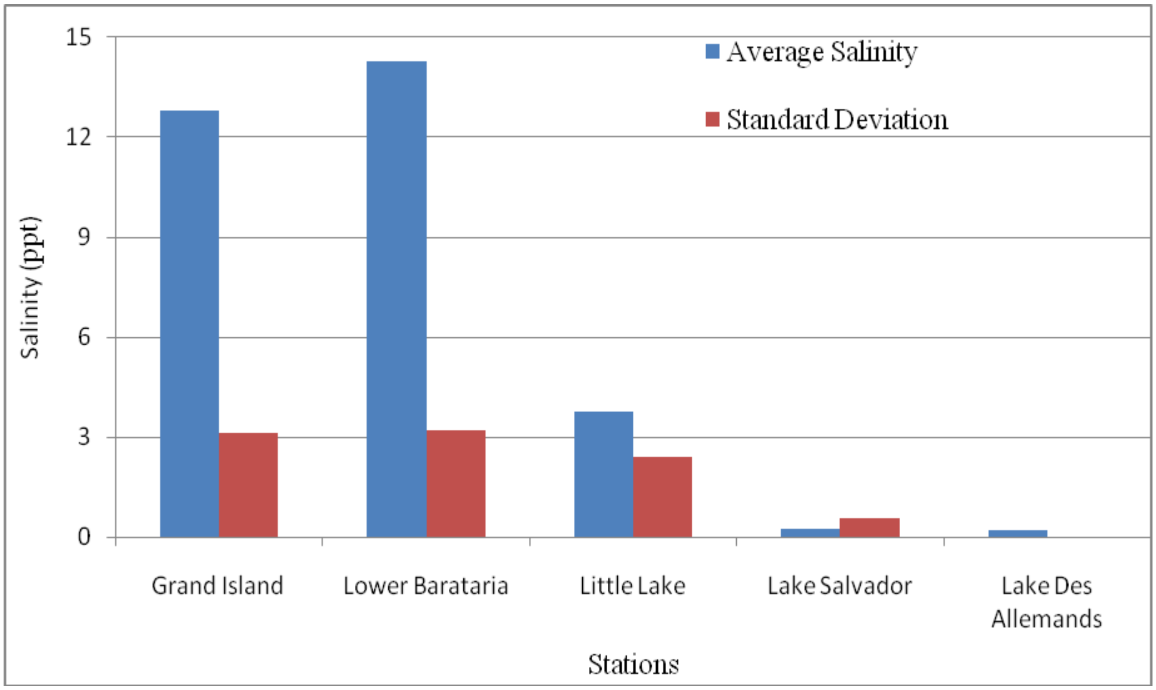

Figure 7.12-Calibrated Average Salinities and Standard Deviation for the year 2008.

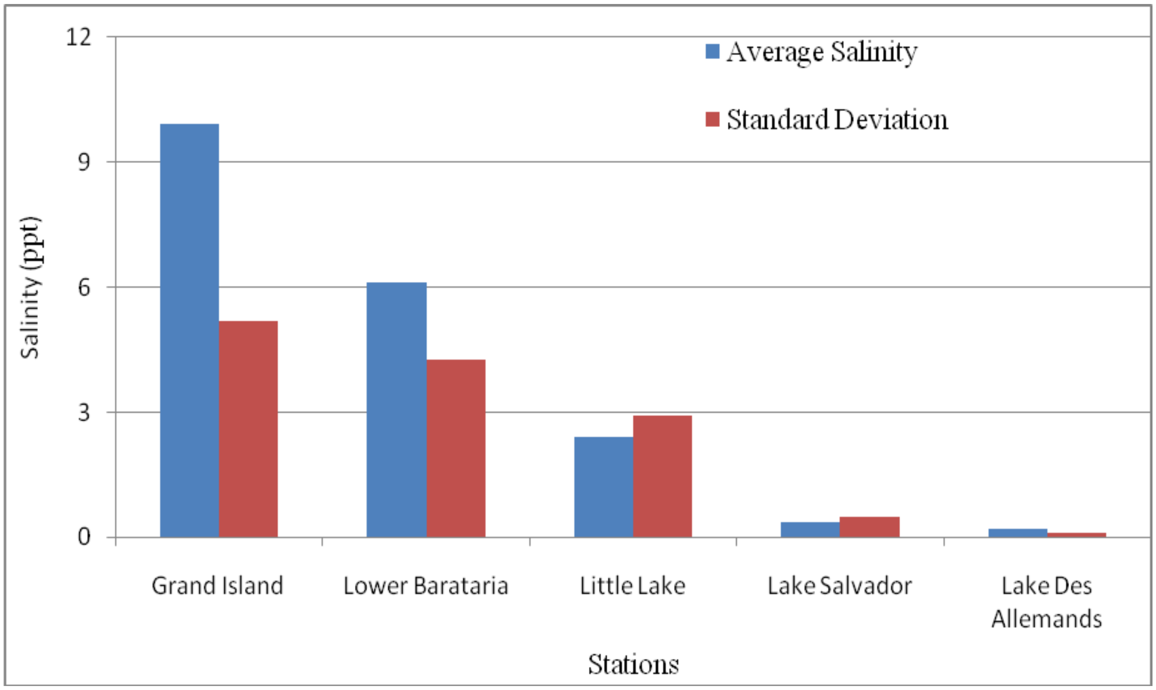

Figure 7.13-Average Salinities and Standard Deviation for Median Flow, 2007 (Scenario I)

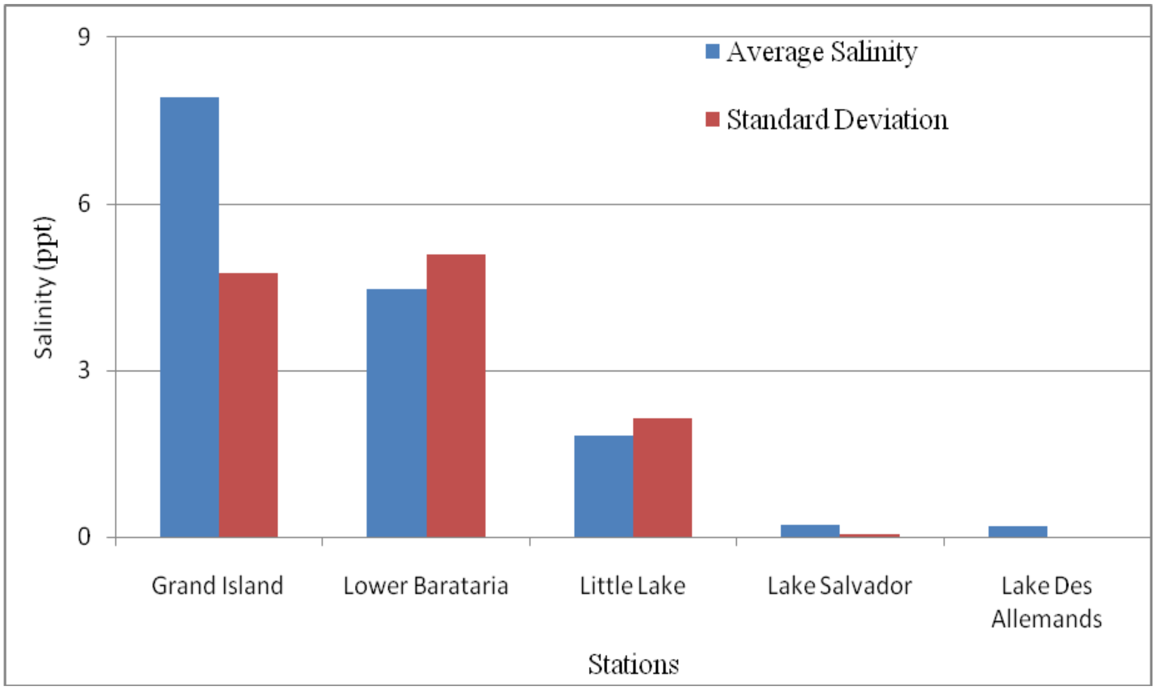

Figure 7.14-Average Salinities and Standard Deviation for High Flow, 2008 (Scenario II)

The mean salinities vary from less than 1 ppt to more than 17 ppt from upper Barataria to lower Barataria. The model provides a good prediction on the mean salinities; however it tends to under predict the standard deviation. The model does not have the wind shear in the open boundary, so it does not capture any seiche produced by wind and hence it is under estimating the standard deviation.

7.4 Effect of Closing of West Bay

On January 2010, the State of Lousiana declared that West Bay Diversion would be closed. Thus some more simulations were done for the both scenarios with the West Bay closed. There were no impacts of this closure on except in the areas that are near to the West Bay. Figures 7.15 and 7. 16 show that there no significant effect of closing of the West Bay Diversion in Lower Barataria. Figures 7.17 and 7.18 show that the maximum increase in salinity in West Bay when the West Bay Diversion is closed is 5 ppt.

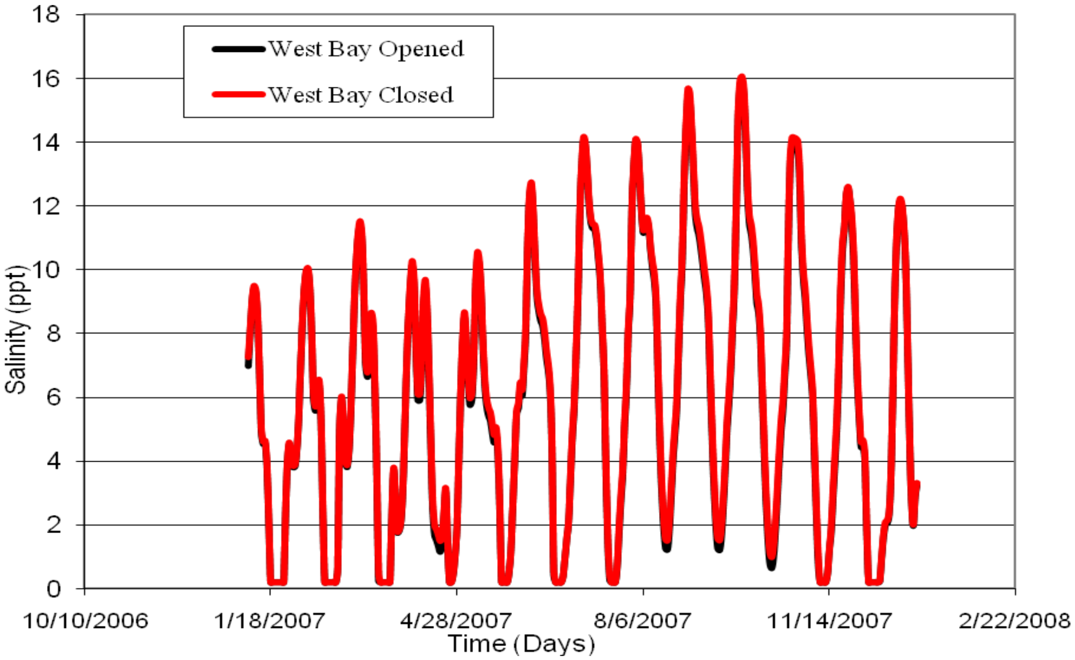

Figure 7.15-Salinity variations in Lower Barataria with West Bay Opened and West Bay Closed for the Future Median Flow, 2007. (Scenario I)

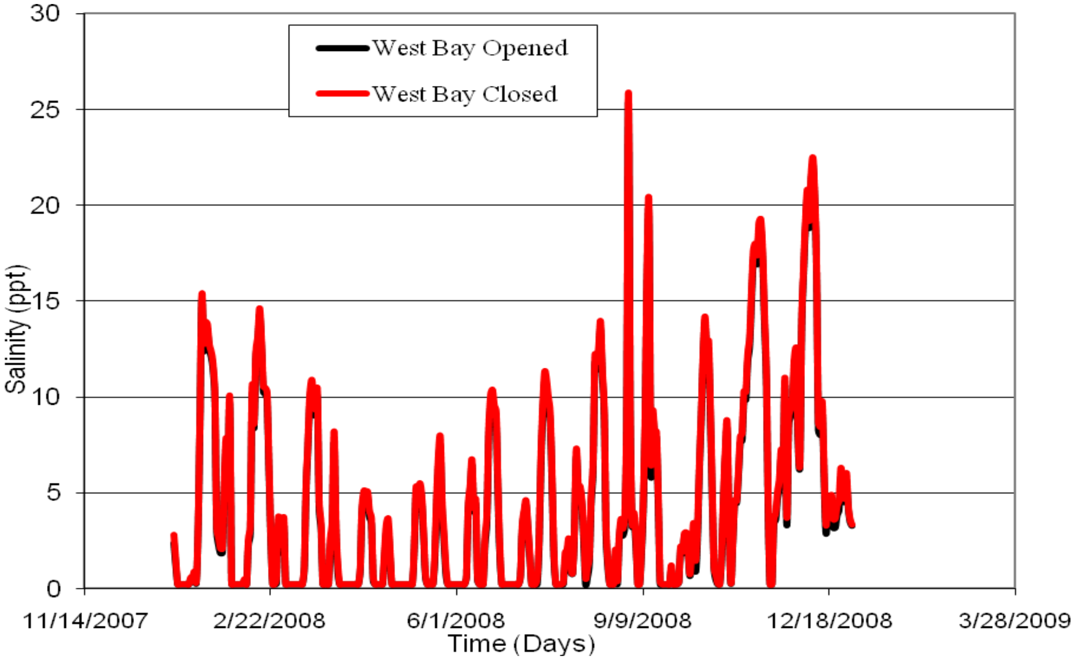

Figure 7.16-Salinity variations in Lower Barataria with West Bay Diversion Opened and West Bay Diversion Closed for the Future Median Flow. (Scenario I)

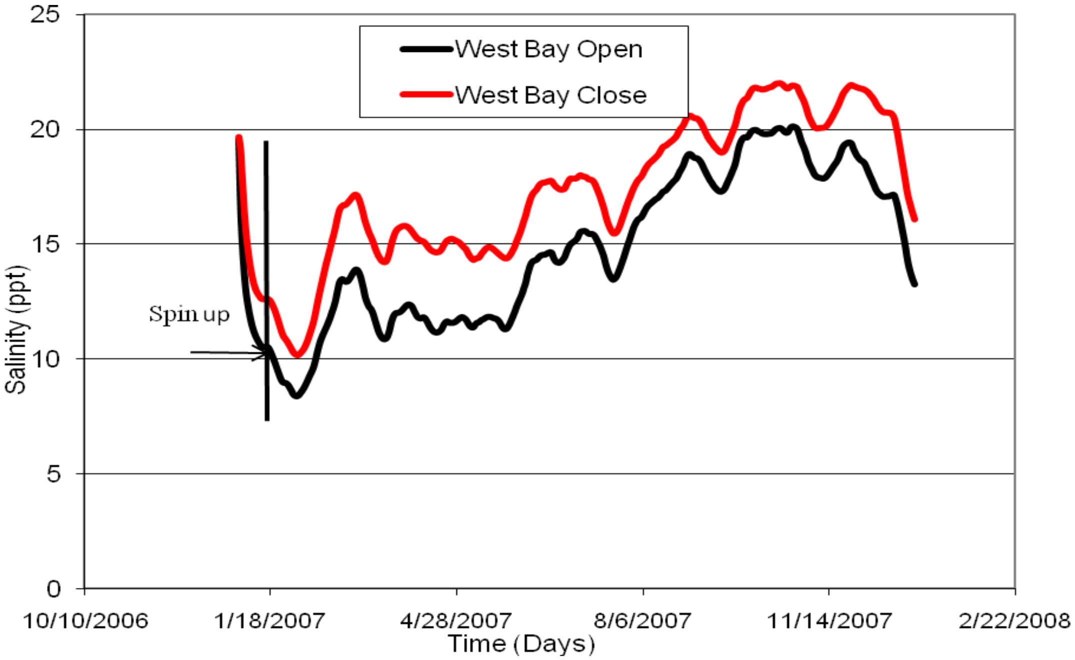

Figure 7.17-Salinity variations in West Bay with West Bay Diversion Open and West Bay Diversion Close for the Future Median Flow. (Scenario I)

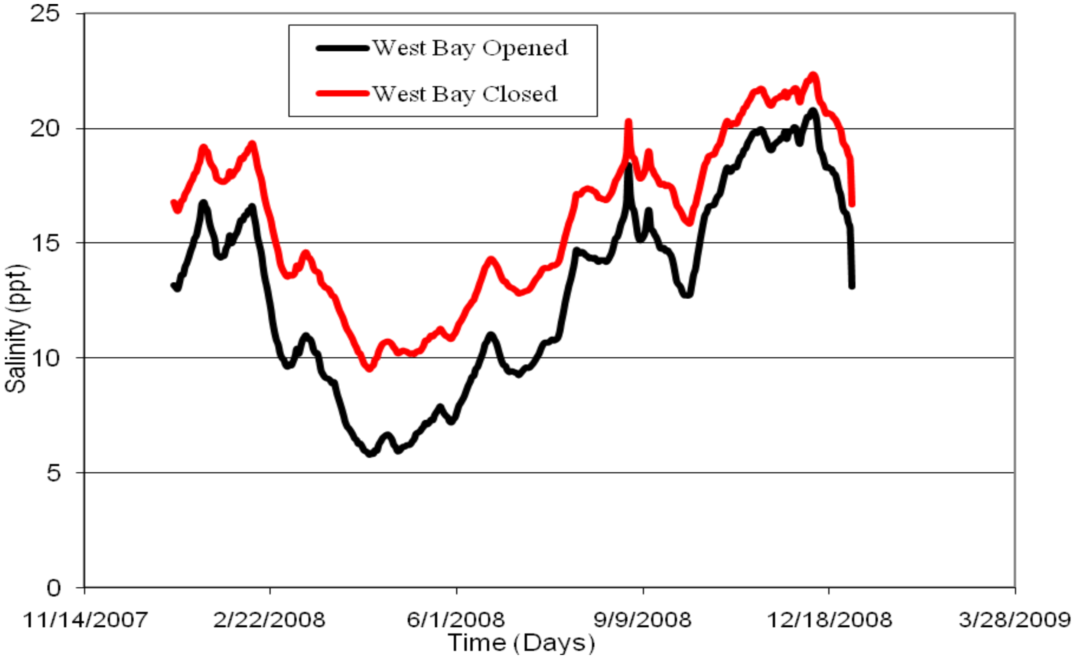

Figure 7.18-Salinity variations in West Bay with West Bay Diversion Opened and West Bay Diversion Closed for the Future High Flow. (Scenario II)

7.5 Impacts of Diversions on Water Level:

The reference case (2007 -2008) was used as in the calibration. The model was then run with flows from the proposed diversions with the different scenarios: the future median flow (Scenario I) and the future high flow (Scenario II). Figures 7.19, 7.20, 7.21, 7.22, 7.23, 7.24, 7.25 and 7.26 show the impacts of freshwater diversions on water level in Lower Barataria, Little Lake, Lake Salvador, Lake Cataouatche, Davis Pond, Myrtle Grove, Deer Range and Jesuit Bend respectively.

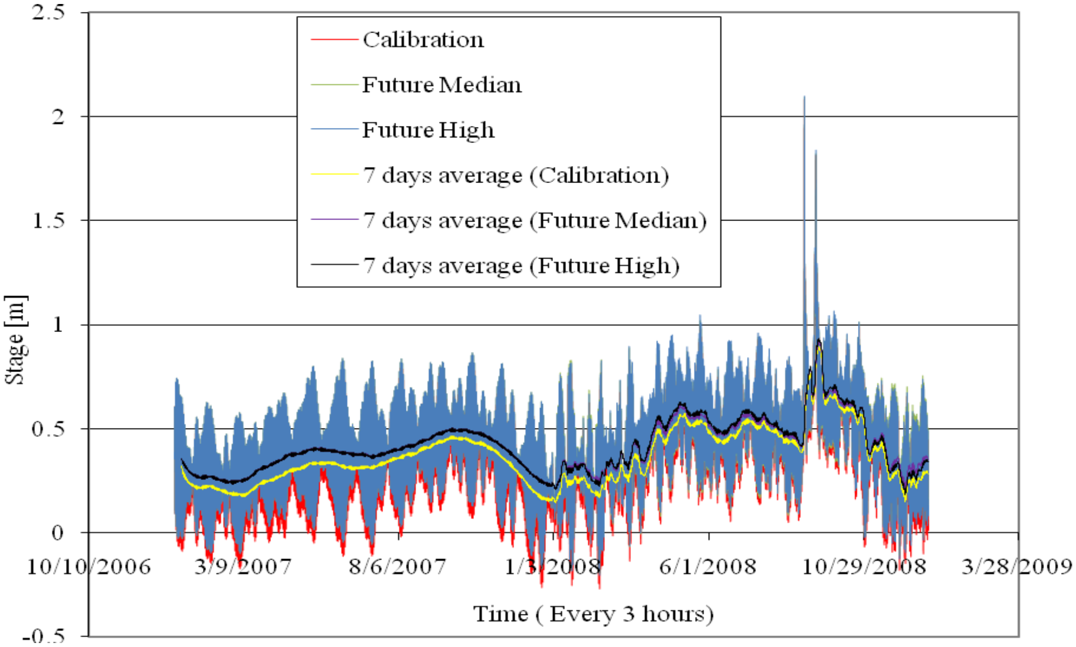

Figure 7.19-Comparison of Future Scenarios with Reference Water Level in Lower Barataria.

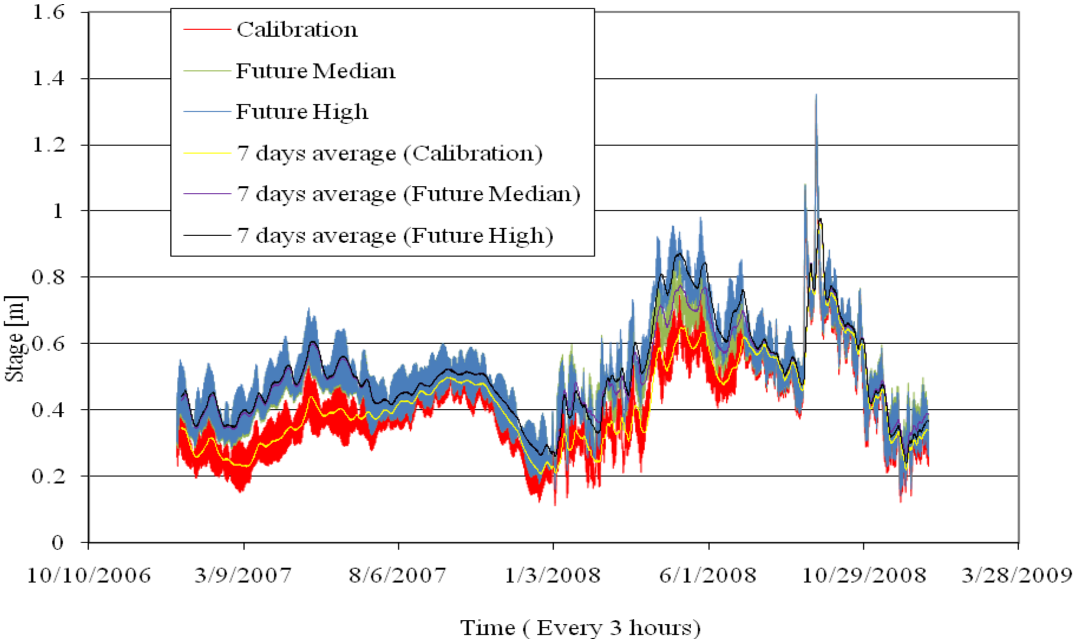

Figure 7.20-Comparison of Future scenarios with Reference Water Level in Little Lake.

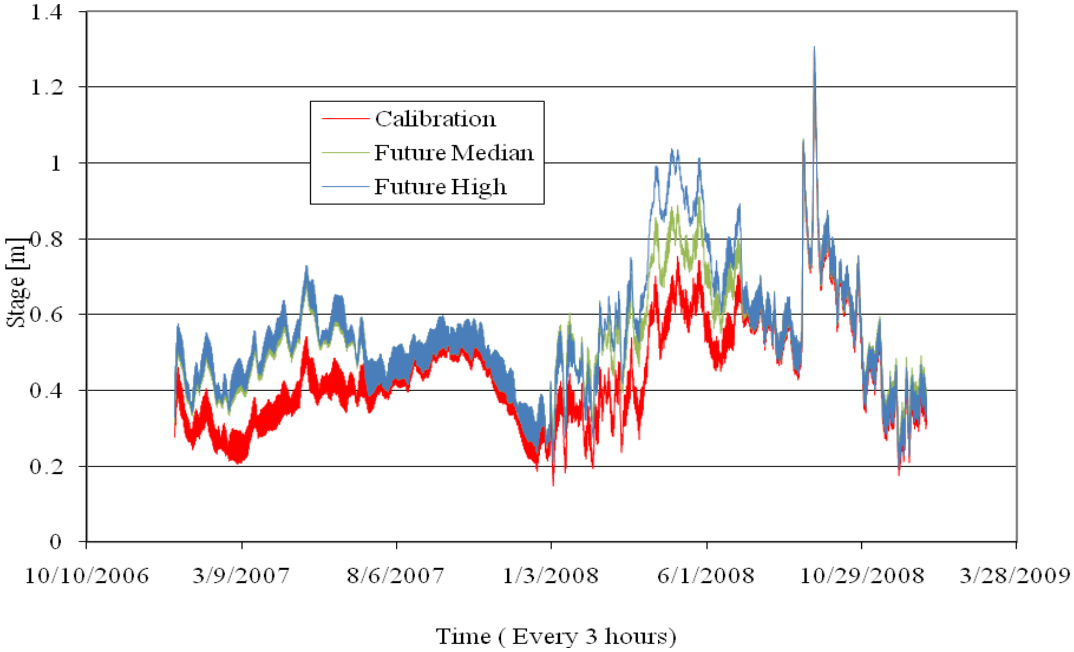

Figure 7.21-Comparison of Future Scenarios with Reference Water Level in Lake Salvador.

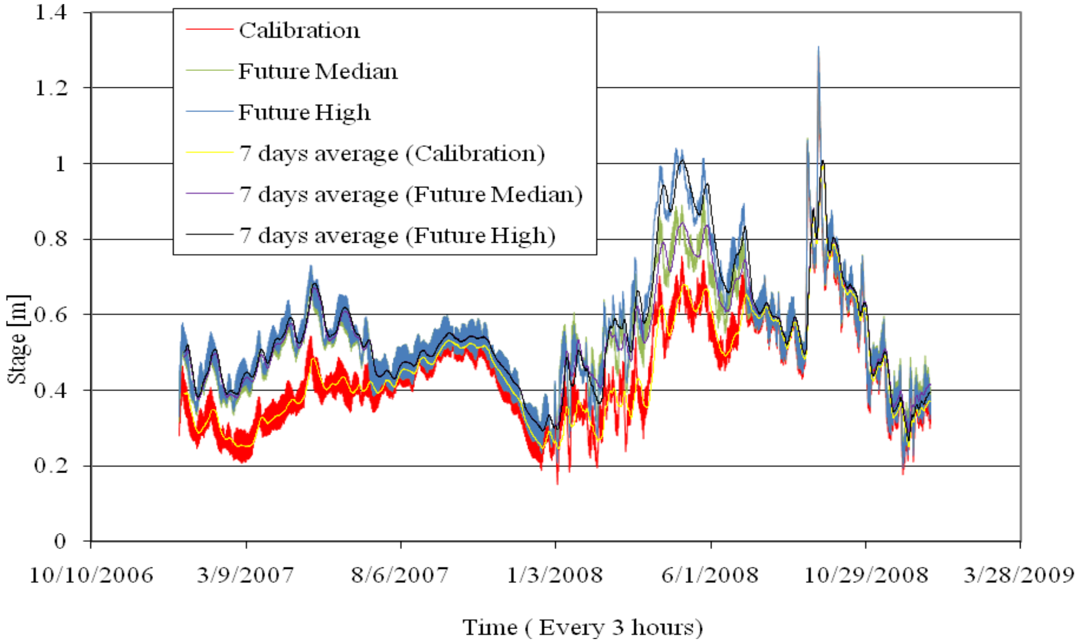

Figure 7.22-Comparison of Future Scenarios with Reference Water level in Lake Cataouatche.

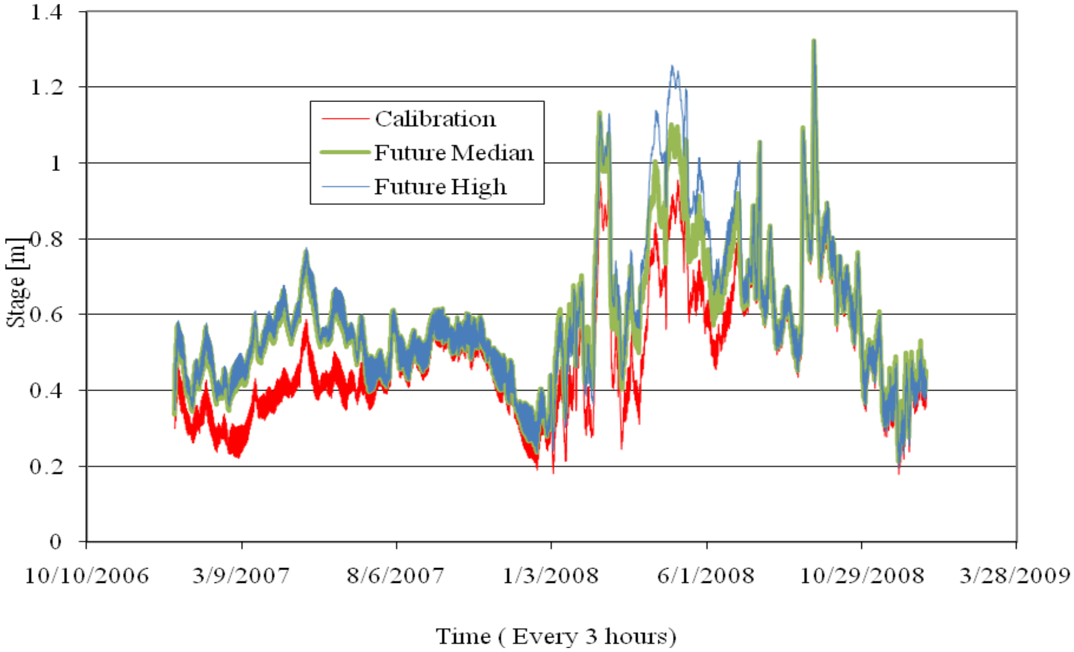

Figure 7.23-Comparison of Future Scenarios with Reference Water level in Davis Pond.

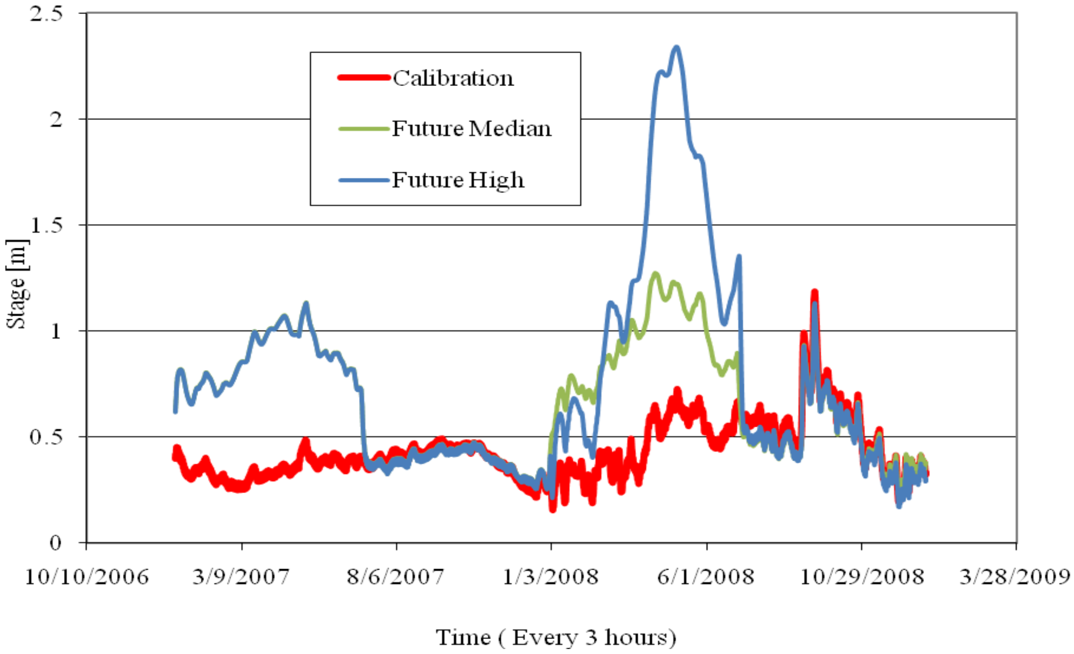

Figure 7.24-Comparison of Future Scenarios with Reference Water Level in Myrtle Grove.

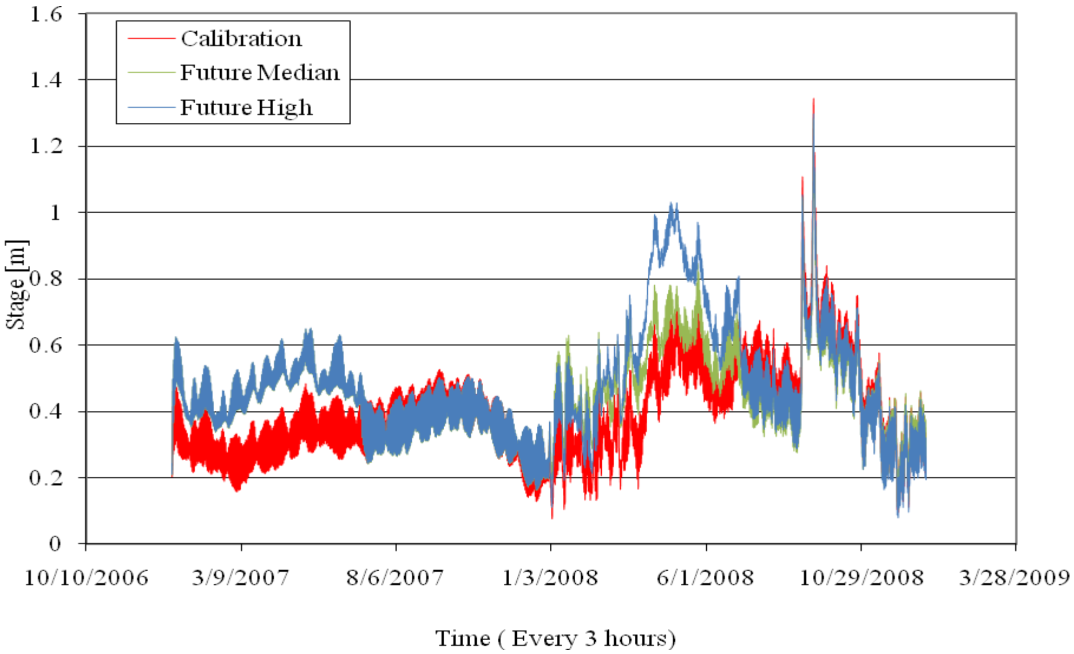

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Figure 7.25-Comparison of Future Scenarios with Reference Water level in Deer Range.

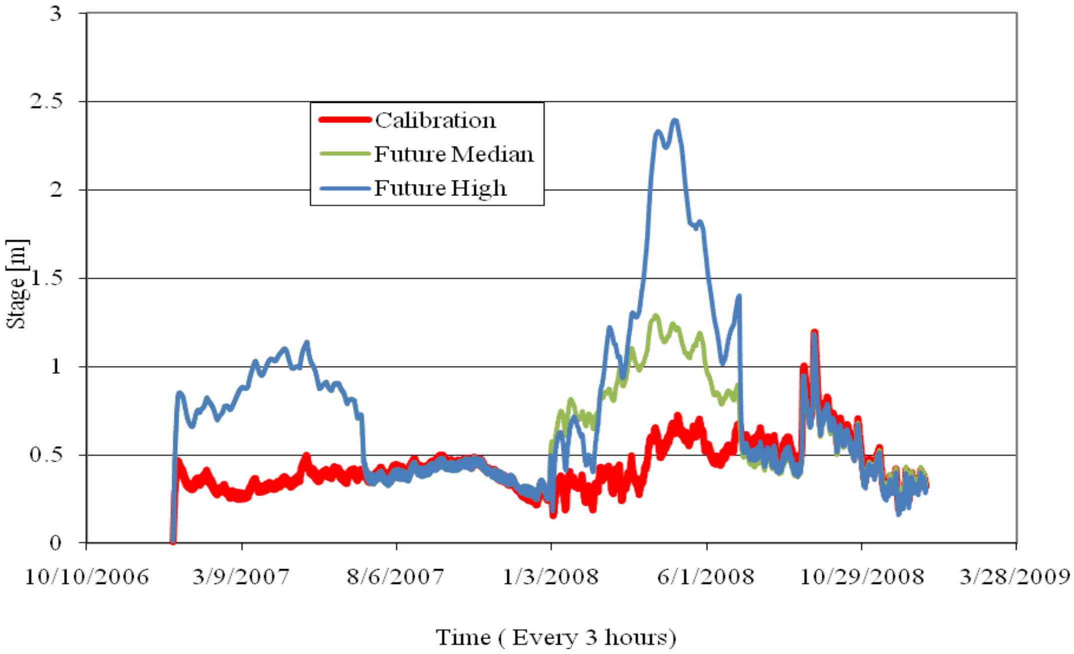

Figure 7.26-Comparison of Future scenarios with Reference Water Level in Jesuit Bend.

Tables 7.5, 7.6, 7.7, and 7.8 show that there is negligible change in water level in Lower Barataria with the introduction of the diversions. Moreover the model indicated that there would be significant change in water level in the areas where the diversions were located. The 7- days average trendlines in Figure 7.19 shows the there is little increase in the water level in Lower Barataria with the introduction of diversions, however the effect of Future High Flow is not significantly higher than the effect of Future Median Flow. The average water level in Lower Barataria for the first 6 months of year 2007 is 0.267 m for the calibration whereas for the future median and future high flow, it is 0.33 m and 0.31 m respectively. The average water level in Lower Barataria for the second 6 months of year 2007 is 0.352 m for the calibration whereas for the future median and future high flow, it is 0.402 m. The average water level in Lower Barataria for the first 6 months of year 2008 is 0.372 m for the calibration whereas for the future median and future high flow, it is 0.425 m and 0.431 m respectively. The average water level in Lower Barataria for the second 6 months of year 2008 is 0.352 m for the calibration whereas for the future median and future high flow, it is 0.505 and 0.506 respectively. The 7- days average trendlines in Figure 7.20 shows the there is signicicant increase in the water level in the Little Lake with the introduction of diversions. The effect of Future High Flow is significantly higher than the effect of Future Median Flow in the Little Lake. Figure 7.20 indicates that the maximum change in water level in Little Lake is about 0.1 m. The average water level in Little Lake for the first 6 months of year 2007 is 0.323 m for the calibration whereas for the future median and future high flow, it is 0.453 m and 0.460 m respectively. The average water level in Little Lake for the second 6 months of year 2007 is 0.398 m for the calibration whereas for the future median and future high flow, it is 0.434m. The average water level in Little Lake for the first 6 months of year 2008 is 0.439 m for the calibration whereas for the future median and future high flow, it is 0.560 m and 0.597 m respectively. The average water level in Little Lake for the second 6 months of year 2008 is 0.530 m for the calibration whereas for the future median and future high flow, it is 0.553 and 0.551 respectively Figures 7.21, 7.22, 7.23, 7.24, 7.25 and 7.26 show the there is signicicant increase in the water level in the Lake Salvador, Lake Cataouatche, Davis Pond, Myrtle Grove, Deer Range and Jesuit Bend respectively with the introduction of diversions. The effect of Future High Flow is significantly higher than the effect of Future Median Flow in these area. Figure 7.22 shows that the maximum change in water level in Lake Cataouatche is about 0.2 m with the introduction of the diversions. However the model indicates that the water flows from Lake Cataouatche to Lake Salvador. The model indicated that the changes in stage at Davis Pond would be lower than Lake Cataouatche. Figure 7.23 shows that the maximum change in water level in Davis Pond is about 0.1 m. The model gave a quite low value of water level in Davis Pond and a constant value of 0.4 m had to be added to the value given by the model to account for the presence of weir in upstream of Lake Cataouatche. Moreover the effect is even more significant in Myrtle Grove, Deer Range and Jesuit Bend because of the presense of the diversions in these areas. Figure 7.24 shows even more significant change in water level and it is due to the presence of the diversion (Myrtle Grove). The maximum change in water level at Myrtle Grove site is about 2 m due to the introduction of diversions. The average water level at Myrtle Grove site for the first 6 months of year 2007 is about 0.34 m for the calibration whereas for the future median and future high flow, it is about 0.86 m The average water level at Myrtle Grove site for the second 6 months of year 2007 is about 0.34 m for the calibration whereas for the future median and future high flow, it is about 0.86 m. The average water level at Myrtle Grove site for the first 6 months of year 2008 is about 0.45 m for the calibration whereas for the future median and future high flow, it is about 0.92 m and 1.3 m respectively. The average water level at Myrtle Grove site for the second 6 months of year 2008 is about 0.54 m for the calibration whereas for the future median and future high flow, it is about 0.5 and 0.511 respectively. Figure 7.25 shows even more significant change in water level which is due to the presence of the diversion (Deer Range). The maximum change in water level at Deer Range site is about 0.5 m due to the introduction of diversions. The average water level at Deer Range site for the first 6 months of year 2007 is about 0.31 m for the calibration whereas for the future median and future high flow, it is about 0.47 m The average water level at Deer Range site for the second 6 months of year 2007 is about 0.35 m for the calibration whereas for the future median and future high flow, it is 0.36 m. The average water level at Deer Range for the first 6 months of year 2008 is about 0.4 m for the calibration whereas for the future median and future high flow, it is about 0.53 m and 0.61 m respectively. The average water level at Deer Range site for the second 6 months of year 2008 is about 0.5 m for the calibration whereas for the future median and future high flow, it is 0.5 and 0.51 respectively. 7.26 shows even more significant change in water level and it is due to the presence of the diversion (Jesuit Bend). The maximum change in water level at Jesuit Bend site is about 2 m due to the introduction of diversions. The average water level at Jesuit Bend site for the first 6 months of year 2007 is 0.34 m for the calibration whereas for the future median and future high flow, it is 0.87 m The average water level in Jesuit Bend site for the second 6 months of year 2007 is 0.39 m for the calibration whereas for the future median and future high flow, it is 0.39 m. The average water level at Jesuit Bend site for the first 6 months of year 2008 is 0.45 m for the calibration whereas for the future median and future high flow, it is 0.93 m and 1.3 m respectively. The average water level at Jesuit Bend site for the second 6 months of year 2008 is 0.5 m for the calibration whereas for the future median and future high flow, it is 0.5 and 0.51 respectively.

Table 7.5-Mean Water Level at Different Areas of Barataria Basin for the first 6 months of 2007.

Stations	Calibration (m) (mean)	Future Median (m) (mean)	Future High (m) (mean)
Lower Barataria	0.26	0.33	0.33
Little Lake	0.32	0.45	0.46
Lake Salvador	0.35	0.49	0.50
Lake Cataouatche	0.35	0.49	0.51
Davis Pond	0.9	0.92	0.93
Myrtle Grove	0.34	0.86	0.86
Deer Range	0.31	0.47	0.47
Jesuit Bend	0.34	0.87	0.87

Table 7.6-Mean Water Level at Different areas of Barataria Basin for the second 6 months of 2007.

Stations	Calibration (m) (mean)	Future Median (m) (mean)	Future High (m) (mean)
Lower Barataria	0.35	0.40	0.40
Little Lake	0.39	0.43	0.43
Lake Salvador	0.42	0.45	0.45
Lake Cataouatche	0.43	0.46	0.46
Davis Pond	0.87	0.87	0.87
Myrtle Grove	0.39	0.40	0.40
Deer Range	0.35	0.36	0.36
Jesuit Bend	0.39	0.39	0.39

Table 7.7-Mean Water Level at Different Areas of Barataria Basin for the first 6 months of 2008

Stations	Calibration (m)(mean)	Future Median (m) (mean)	Future High (m) (mean)
Lower Barataria	0.37	0.42	0.43
Little Lake	0.43	0.56	0.59
Lake Salvador	0.46	0.61	0.67
Lake Cataouatche	0.46	0.61	0.67
Davis Pond	1.18	1.15	1.18
Myrtle Grove	0.45	0.92	1.27
Deer Range	0.4	0.53	0.62
Jesuit Bend	0.45	0.93	1.30

Table 7.8-Mean water level at Different Areas of Barataria Basin for the second 6 months of 2008

Stations	Calibration (m)(mean)	Future Median (m) (mean)	Future High (m) (mean)
Lower Barataria	0.46	0.50	0.50
Little Lake	0.53	0.55	0.55
Lake Salvador	0.55	0.57	0.57
Lake Cataouatche	0.55	0.57	0.57
Davis Pond	1.01	1.01	1.01
Myrtle Grove	0.5	0.51	0.51
Deer Range	0.5	0.5	0.51
Jesuit Bend	0.5	0.51	0.51

7.6 *Impacts of Diversions on Nutrients*

There were some impacts on nutrients like nitrogen, phosphorus and organic nitrogen due to the introduction of diversion. Most of the diversions are from the Mississippi River and the Atchafalaya River and the rivers are very rich in nutrients. Thus the concentration of nutrients increases with the introduction of diversion in the Basin. The impacts of diversions are mainly studied on the Northern Gulf of Mexico and some areas on Barataria Basin. The location of study area of nutrient's concentration variation are shown in Table 7.9

Table 7.9-The location of study area of nutrient's concentration variation.

No.	Study areas	Universal Transverse Mercator (UTM)	
		East (m)	North (m)
1.	Grand Island	201781	3232913
2.	Northern Gulf of Mexico (cell 19)	216142	3215896
3.	Northern Gulf of Mexico (cell 20)	320323	3227685
4.	Northern Gulf of Mexico (cell 31)	350555	3315176
5.	Lower Barataria (Central)	226435	3251703
6.	Little Lake	193985	3265714
7.	Upper Barataria (Davis Pond)	181637	3308158

Figures 7.27, 7.28 and 7.29show the concentration of nitrite+ nitrate, total phosphorus and Organic nitrogen increases in Northern Gulf of Mexico (Cell 19) with the introduction of proposed diversions. The average concentration of nitrite+nitrate in Grand Island was 0.189 mg/l in calibration whereas it is 0.213 mg/l and 0.215 mg/l with the introduction of proposed diversions with median and high flow respectively. The impacts very small in phosphorus and organic nitrogen concentration. The average concentration of total phosphorus in Cell 19 was 0.134 mg/L in calibration whereas it is 0.136 mg/ Lwith the introduction of proposed diversions with median and high flow. The average concentration of organic nitrogen in Cell 19 was 0.47 mg/l in calibration whereas it was 0.473 mg/L with the introduction of proposed diversions with median and high flow.

Figures 7.30, 7.31 and 7.32 show the that the concentration of nitrite +nitrate, total phosphorus and organic nitrogen respectively in the Northern Gulf of Mexico (Cell 31 in the model) increases with the introduction of diversions. The average concentration of nitrite+nitrate in Northern Gulf of Mexico (Cell 31 in the model) was 0.849 mg/l in calibration whereas it is

0.742 mg/L and 0.738 mg/L with the introduction of proposed diversions with median and high flow respectively. The average concentration of total Phosphorus in Northern Gulf of Mexico (Cell 31) was 0.134 mg/L in calibration whereas it was 0.136 mg/L with the introduction of proposed diversions with median and high flow. Similarly The average concentration of organic nitrogen in Northern Gulf of Mexico (Cell 31 in the model) was 0.655 mg/L in calibration whereas it is 0.632 mg/L and 0.631 mg/L with the introduction of proposed diversions with median and high flow respectively.This effect is simillar in the other cell of Northern gulf of Mexico (Cell 20 in the model). Figures 7.33, 7.34 and 7.35 show the concentration of nitrite +nitrate, total phosphorus and organic nitrogen respectively in the Northern Gulf of Mexico (Cell 20 in the model)The concentrations of nutrients decreases with the introduction of diversions in the Northern Gulf of Mexico. This is due to less amount of flow of Mississiippi River being discharged in the Northern Gulf of Mexico as some of the flows were diverted to the Basin from the future proposed diversions.

The effect is opposite in Barataria Basin. The concentration of nutrients increases due to introduction of the diversions. Figures 7.36, 7.37 and 7.38 show the concentration of nitrite+ nitrate, Total phosphorus and Organic nitrogen increases in Grand Island with the introduction of the proposed diversions. The average concentration of nitrite+nitrate in Grand Island was 0.402 mg/l in calibration whereas it is 0.455 mg/l and 0.501 mg/l with the introduction of proposed diversions with median and high flow respectively. The impacts are smaller in phosphorus and organic nitrogen concentration. The average concentration of total phosphorus in Grand Island was 0.147 mg/l in calibration whereas it is 0.165 mg/l and 0.168mg/l with the introduction of proposed diversions with median and high flow respectively. The average concentration of organic nitrogen in Grand Island was 0.719 mg/l in calibration whereas it was 0.810 mg/l and 0.820 mg/l with the introduction of proposed diversions with median and high flow respectively. Figures 7.39, 7.40 and 7.41 show the concentrations of nitrite+ nitrate, total phosphorus and Organic nitrogen increase in Lower Barataria with the introduction of the proposed diversions. The average concentration of nitrite+nitrate in Lower Barataria was 0.442 mg/L in calibration whereas it is 1.578 mg/L and 1.593 mg/L with the introduction of proposed diversions with median and high flow respectively. The average concentration of total phosphorus in Lower Barataria was 0.157 mg/L in calibration whereas it is 0.232 mg/L and 0.123mg/L with the introduction of proposed diversions with median and high flow respectively. The average concentration of organic nitrogen in Lower Barataria was 0.764 mg/L in calibration whereas it was 0.867 mg/L and 0.872 mg/L with the introduction of proposed diversions with median and high flow respectively. Figures 7.42, 7.43 and 7.44 show the concentration of nitrite+ nitrate, total phosphorus and organic nitrogen increases in Little Lake with the introduction of the proposed diversions. The average concentration of nitrite+nitrate in Little Lake was 0.253 mg/L in calibration whereas it was 0.448 mg/L and 0.567 mg/L with the introduction of the proposed diversions with median and high flow respectively. The average concentration of total phosphorus in Little Lake was 0.109 mg/L in calibration whereas it is 0.152 mg/L and 0.154 mg/L with the introduction of the proposed diversions with median and high flow respectively. The average concentration of organic nitrogen in Little Lake was 0.844 mg/L in calibration whereas it was 0.854 mg/L and 0.864 mg/L with the introduction of proposed diversions with median and high flow respectively. Figures 7.45, 7.46 and 7.47 show that there is no effect of diversions on the nutrient's concentration in Davis Pond.

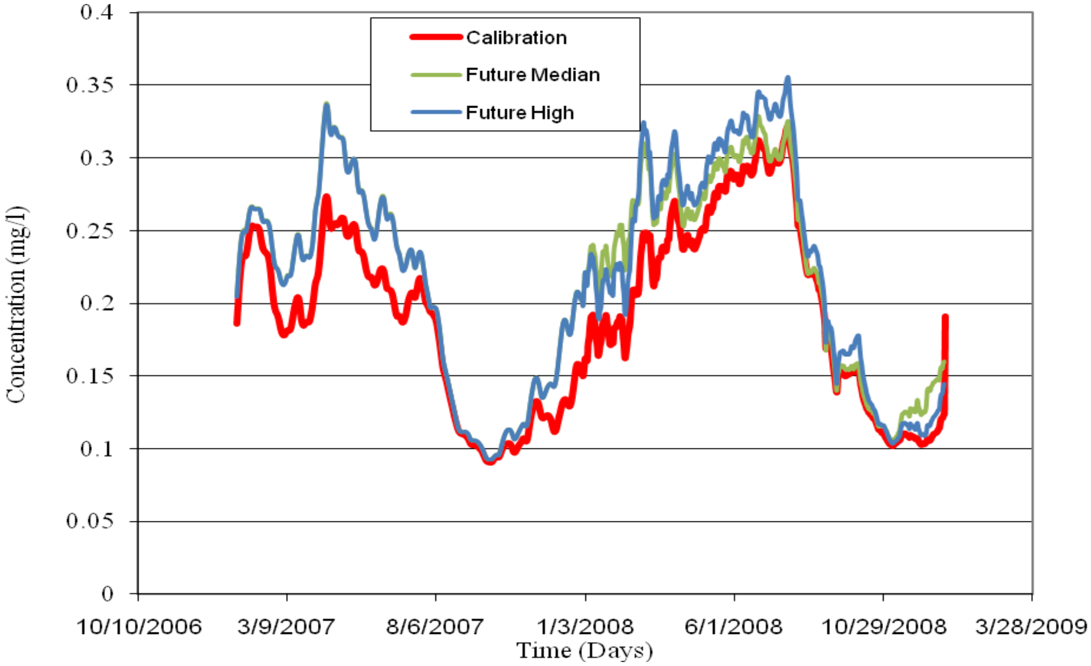

Figure 7.27-Variation of Nitrite+Nitrate concentration in Northern Gulf of Mexico (Cell 19) with the introduction of diversions

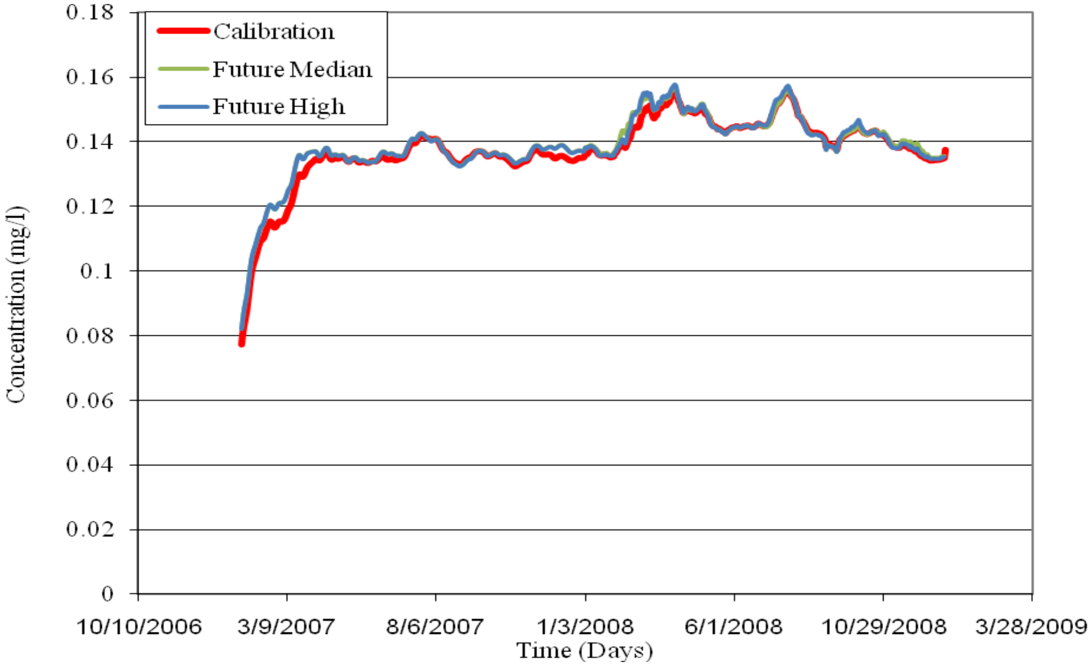

Figure 7.28-Variation of Total Phosphorus concentration in Northern Gulf of Mexico (Cell 19) with the introduction of diversions

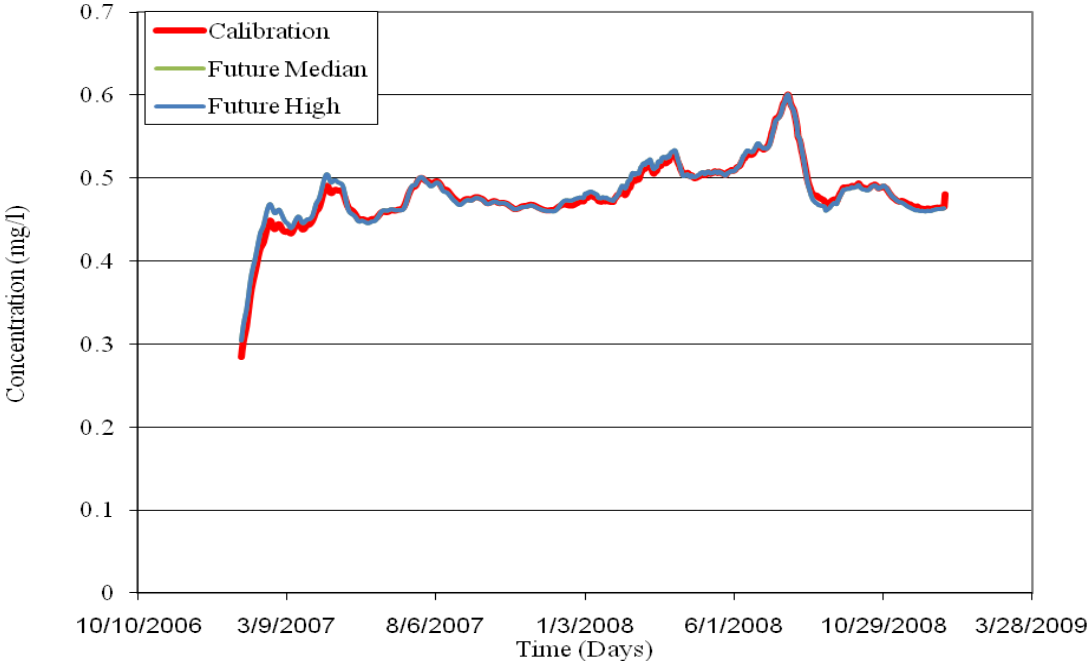

Figure 7.29-Variation of Organic Nitrogen concentration in Northern Gulf of Mexico (Cell 19) with the introduction of diversions

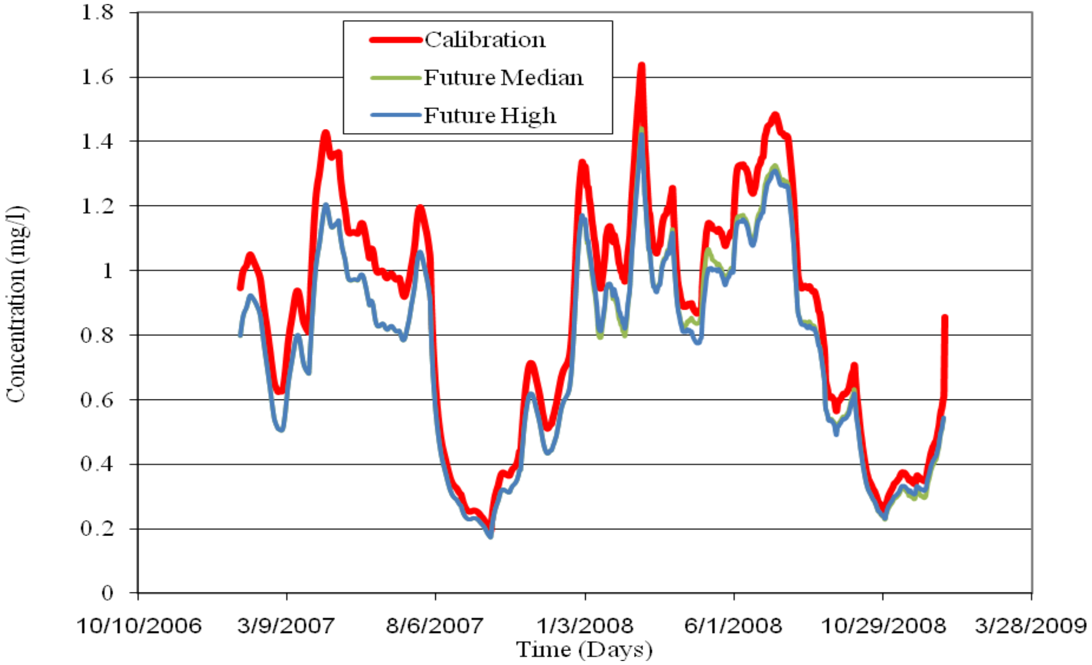

Figure 7.30-Variation of Nitrite +Nitrate concentration in Northern Gulf of Mexico (Cell 31) with the introduction of diversions

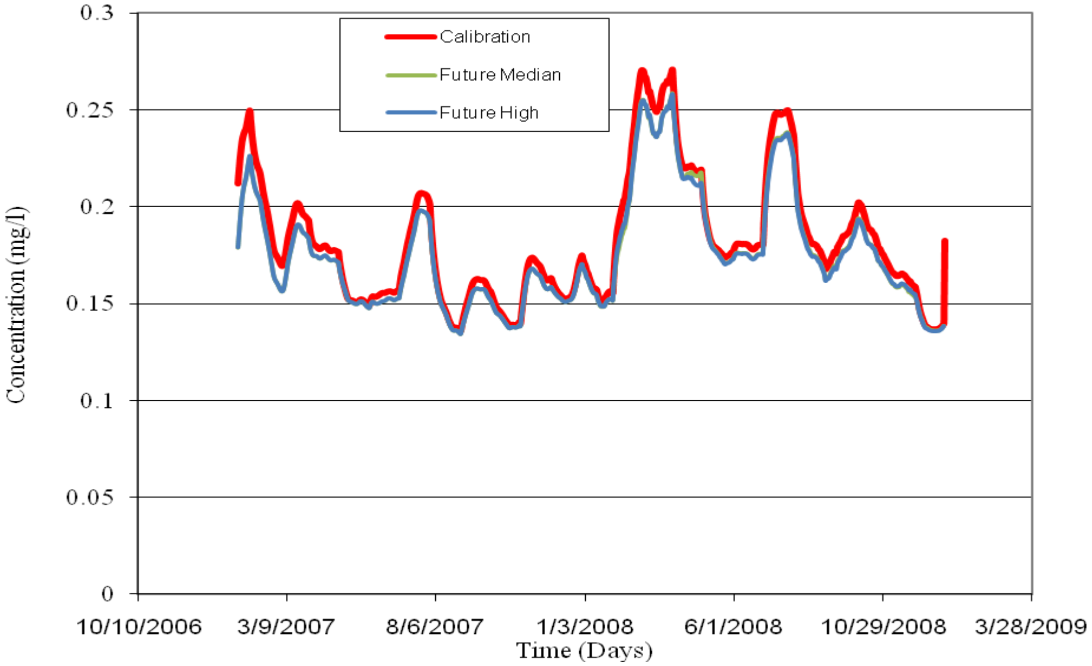

Figure 7.31-Variation of Total Phosphorus concentration in Northern Gulf of Mexico (Cell 31) with the introduction of diversions

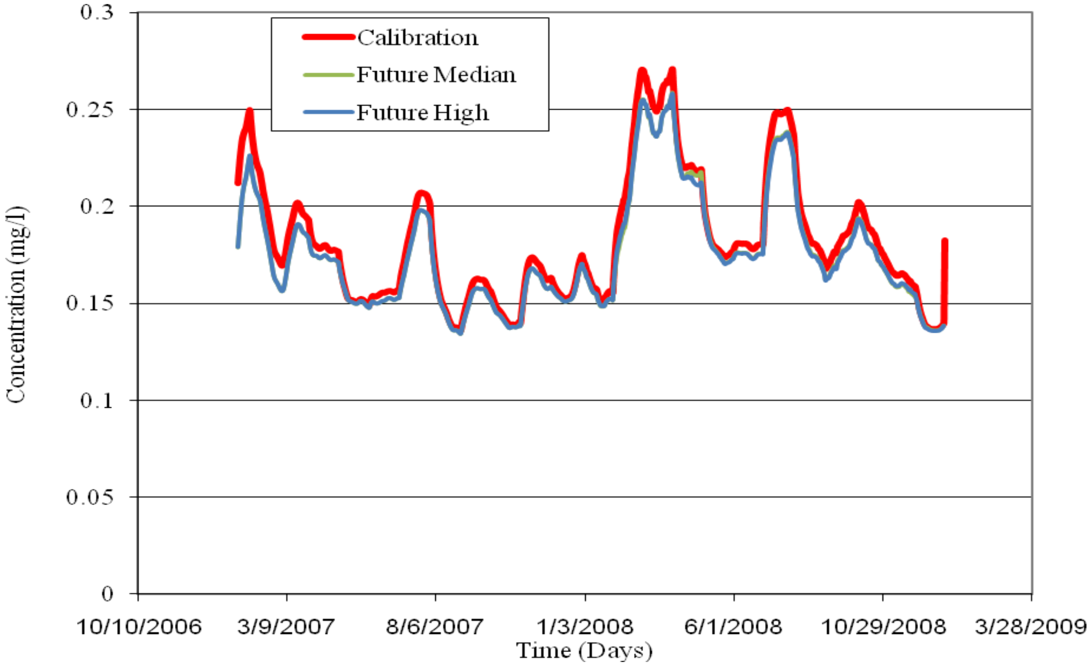

Figure 7.32- Variation of Organic Nitrogen concentration in Northern Gulf of Mexico (Cell 31) with the introduction of diversions

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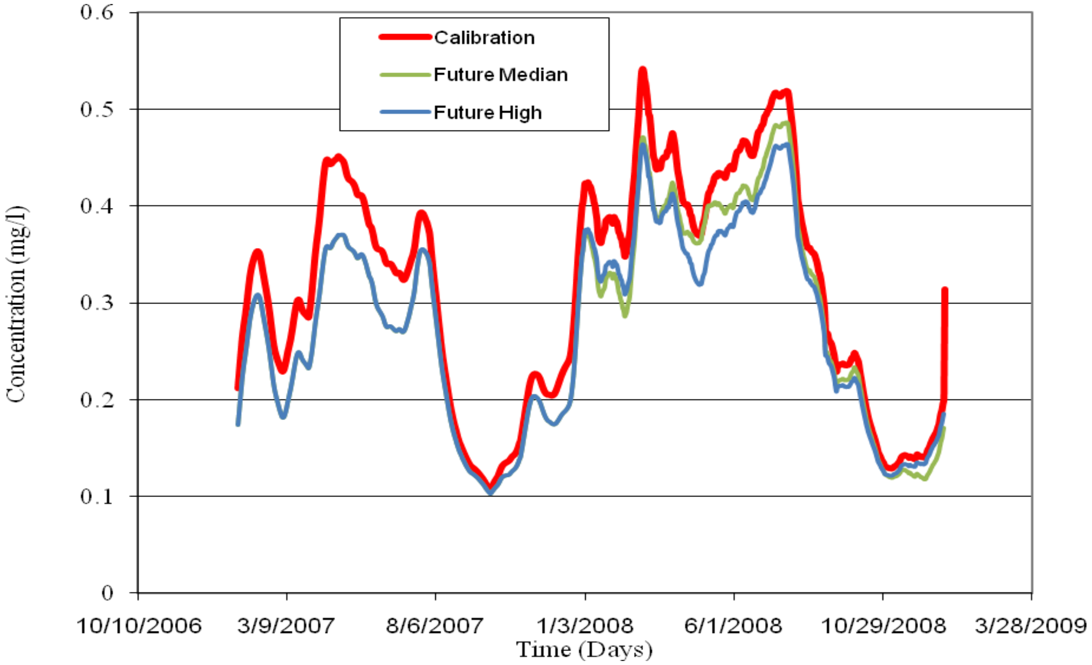

Figure 7.33-Variation of Nitrite +Nitrate concentration in Northern Gulf of Mexico (Cell 20) with the introduction of diversions

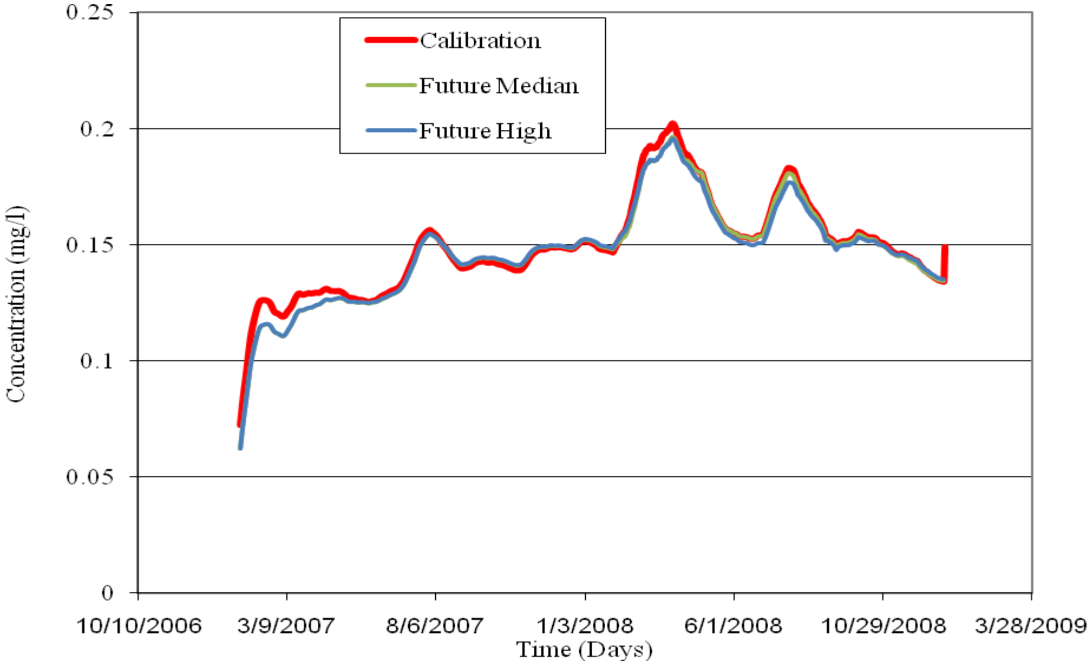

Figure 7.34-Variation of Total Phosphorus concentration in Northern Gulf of Mexico (Cell 20) with the introduction of diversions

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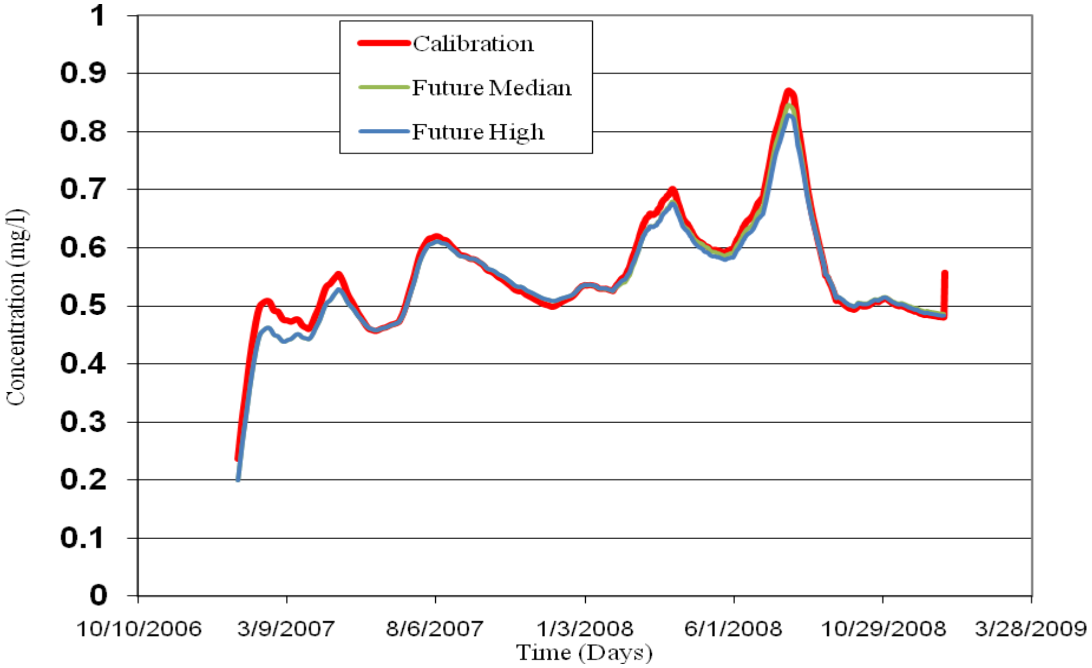

Figure 7.35-Variation of Organic Nitrogen concentration in Northern Gulf of Mexico (Cell 20) with the introduction of diversions

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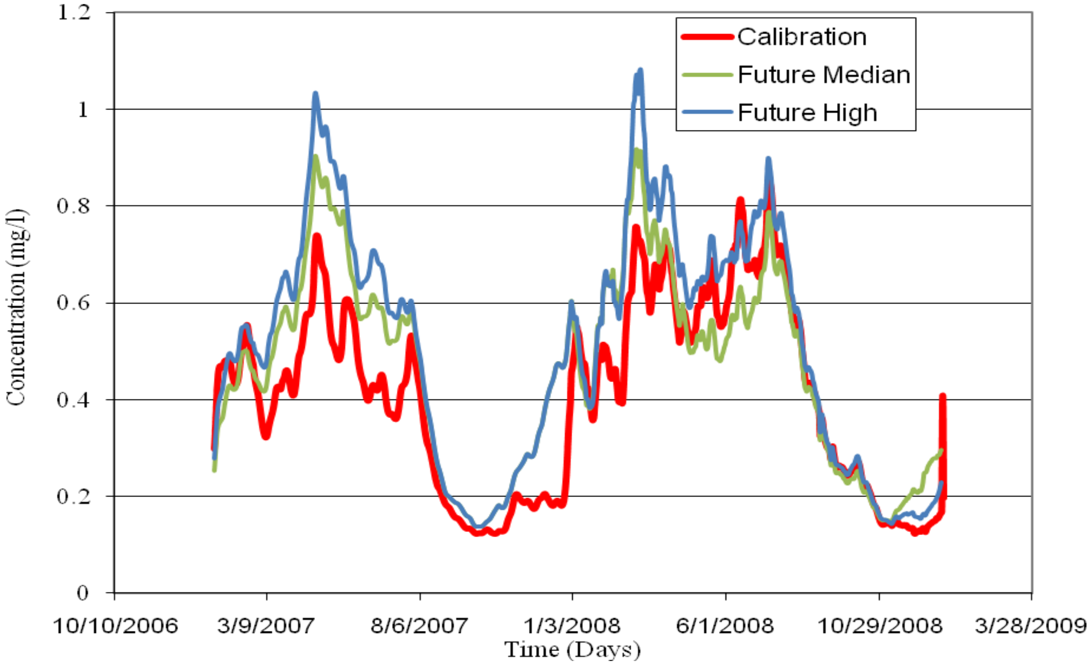

Figure 7.36-Variation of Nitrite+ Nitrate concentration in Grand Island with the introduction of diversions.

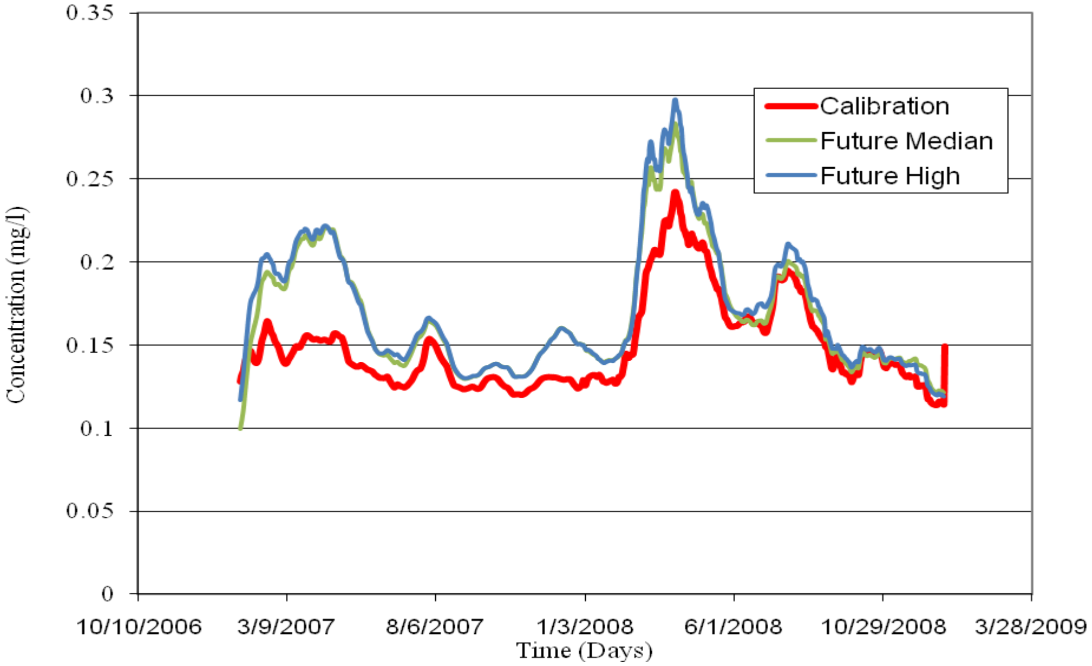

Figure 7.37-Variation of Total Phosphorus concentration in Grand Island with the introduction of diversions.

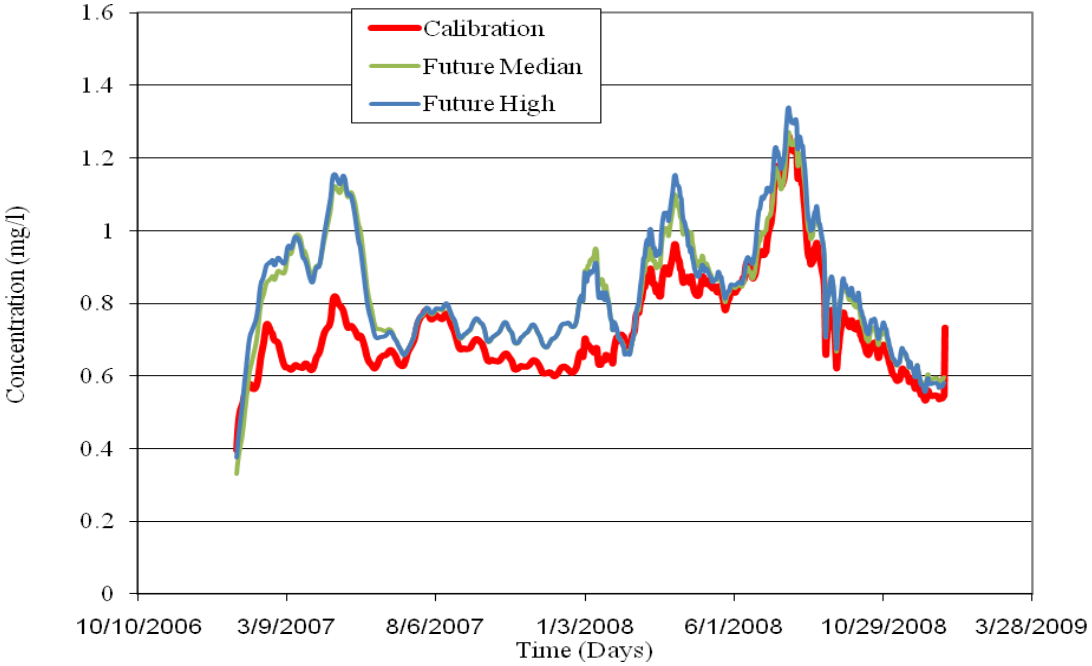

Figure 7.38-Variation of Organic Nitrogen concentration in Grand Island with the introduction of diversions.

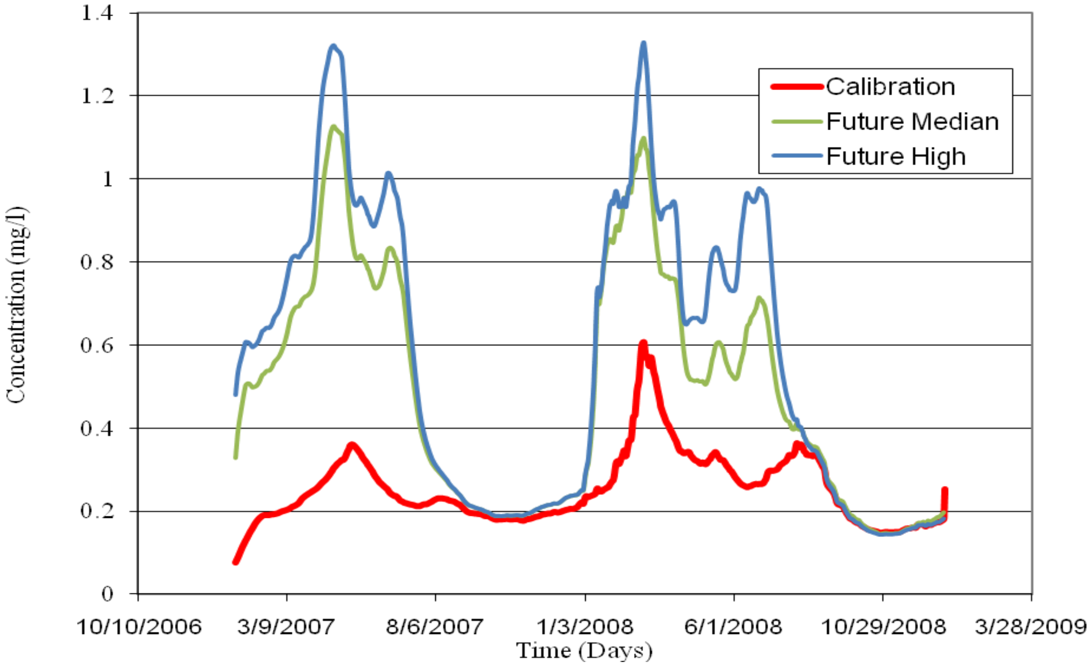

Figure 7.39-Variation of Nitrite + Nitrate concentration in Little Lake with the introduction of diversions

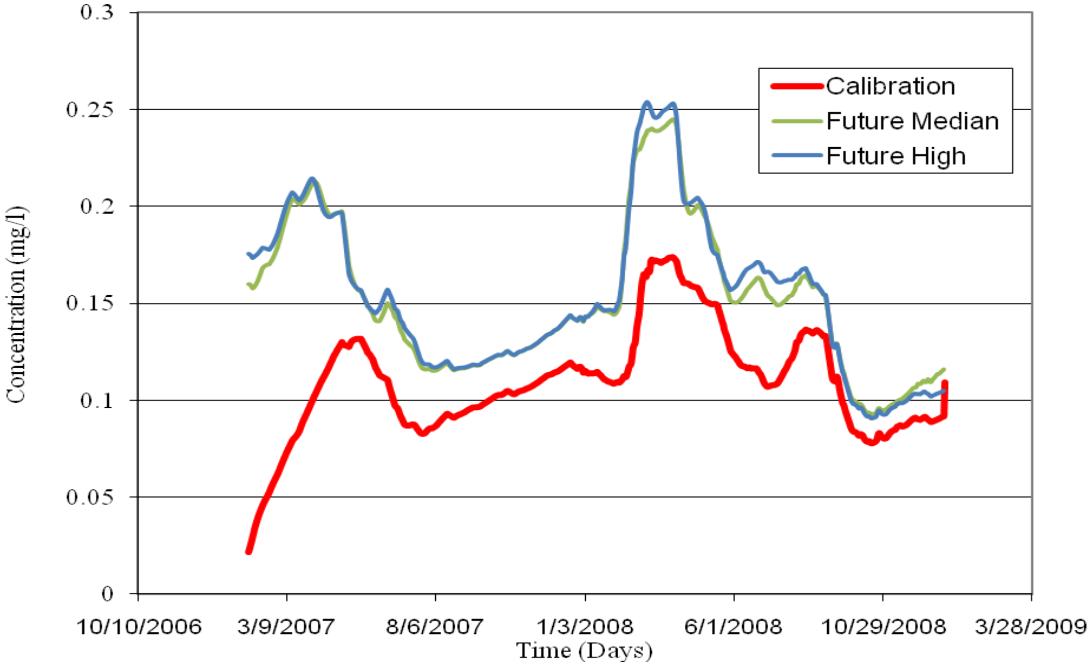

Figure 7.40-Variation of Total Phosphorus concentration in Little Lake with the introduction of diversions

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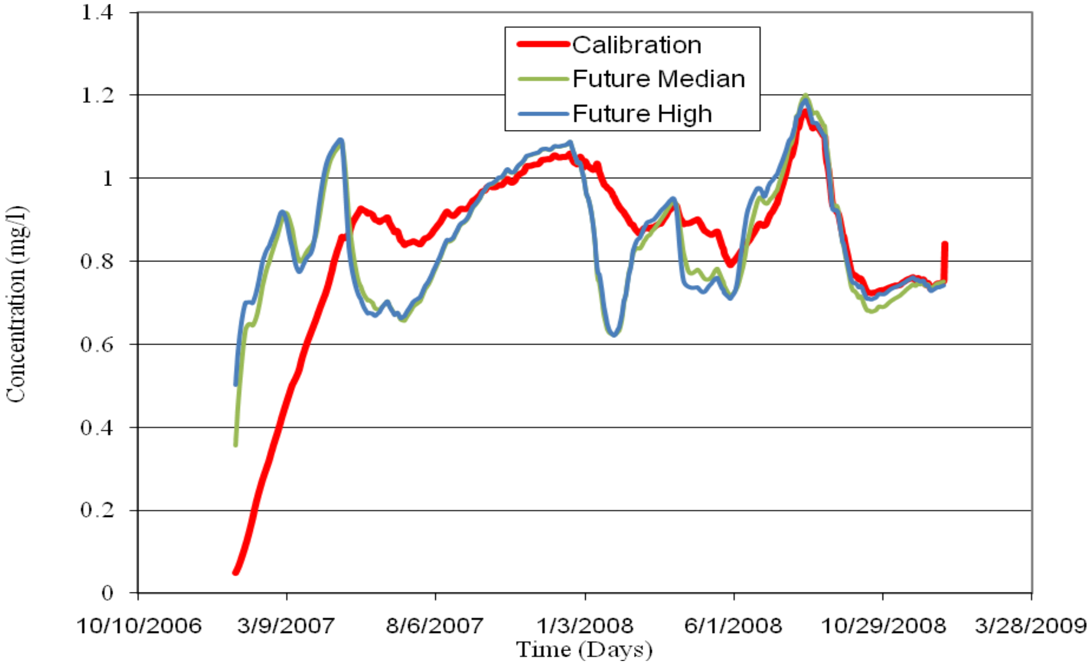

Figure 7.41-Variation of Organic Nitrogen concentration in Little Lake with the introduction of diversions

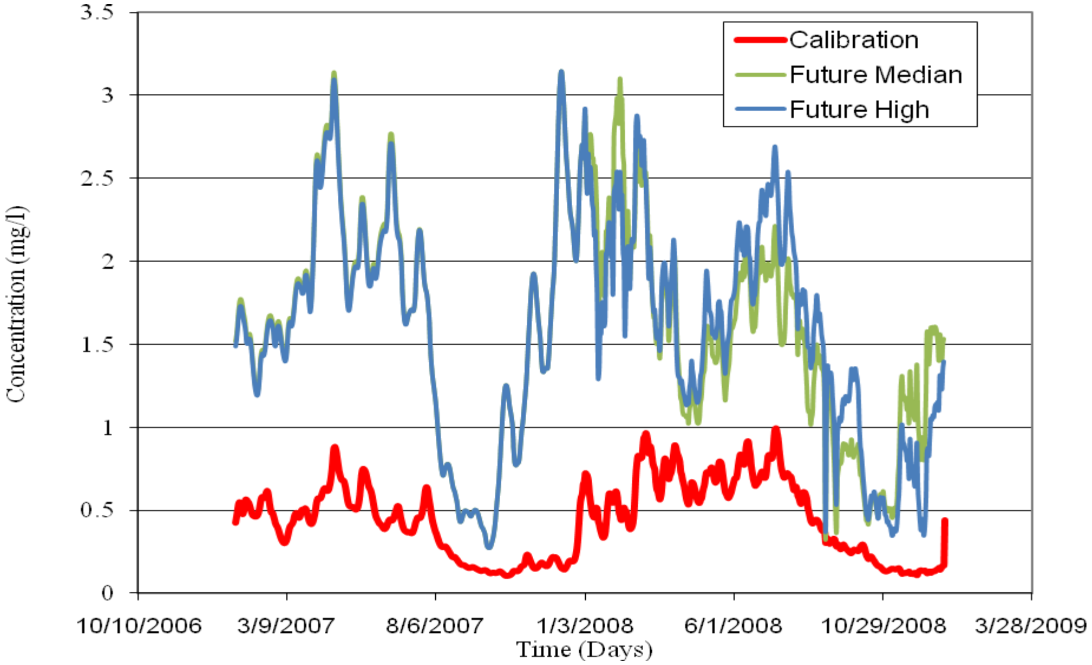

Figure 7.42-Variation of Nitrite + Nitrate concentration in Lower Barataria with the introduction of diversions.

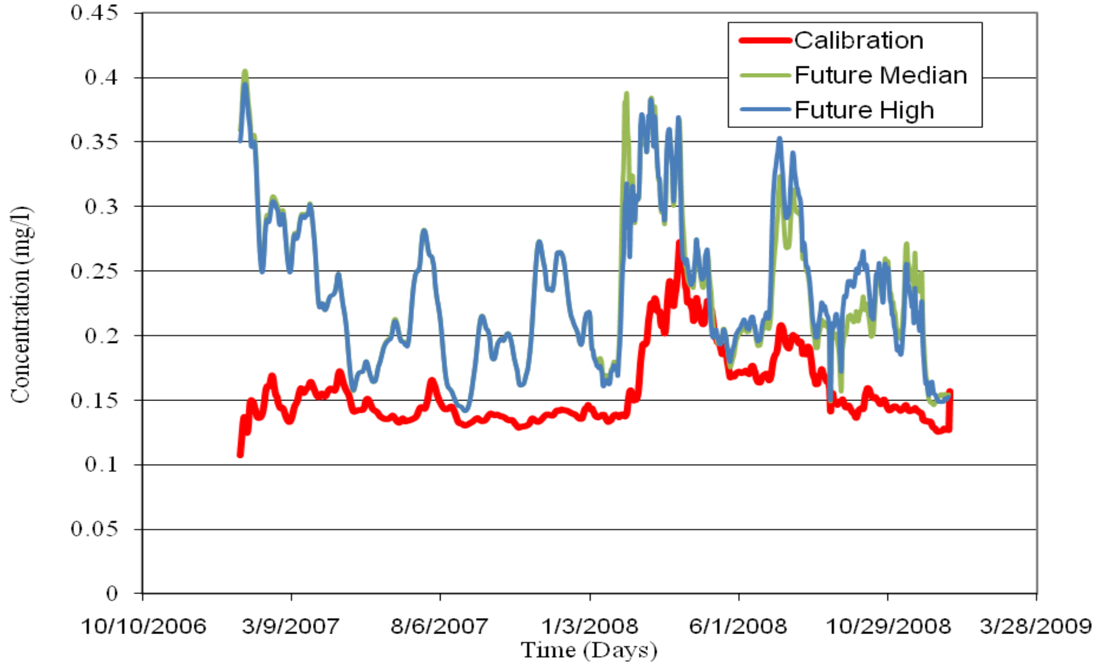

Figure 7.43-Variation of Total Phosphorus concentration in Lower Barataria with the introduction of diversions

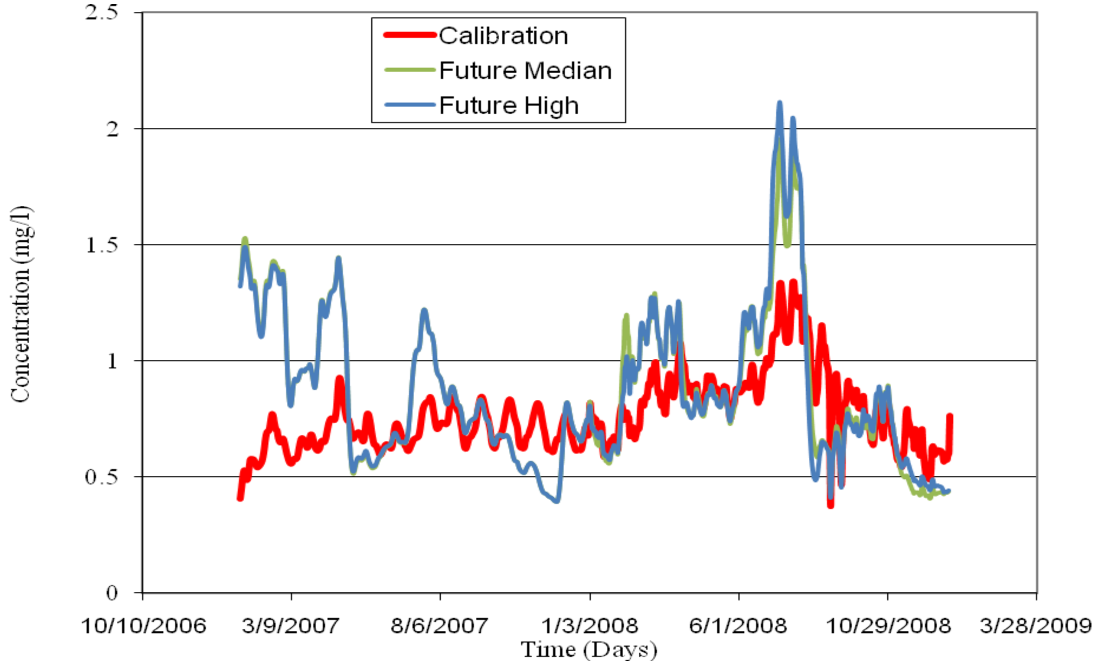

Figure 7.44-Variation of Organic Nitrogen concentration in Lower Barataria with the introduction of diversions

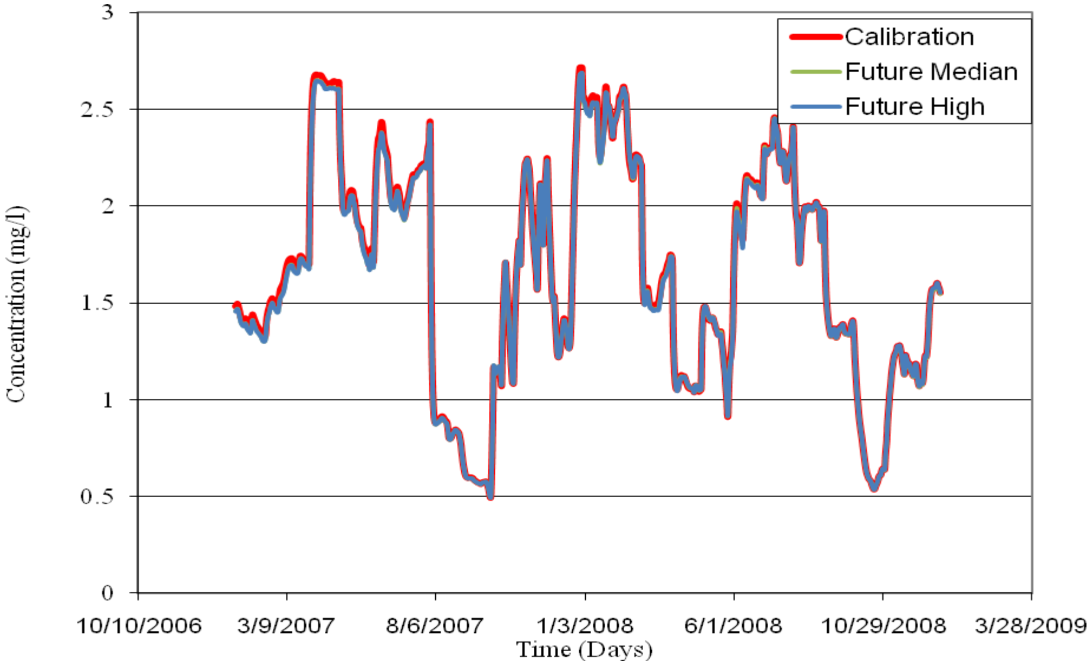

Figure 7.45-Variation of Nitrite+ Nitrate concentration in Davis Pond with the introduction of diversions

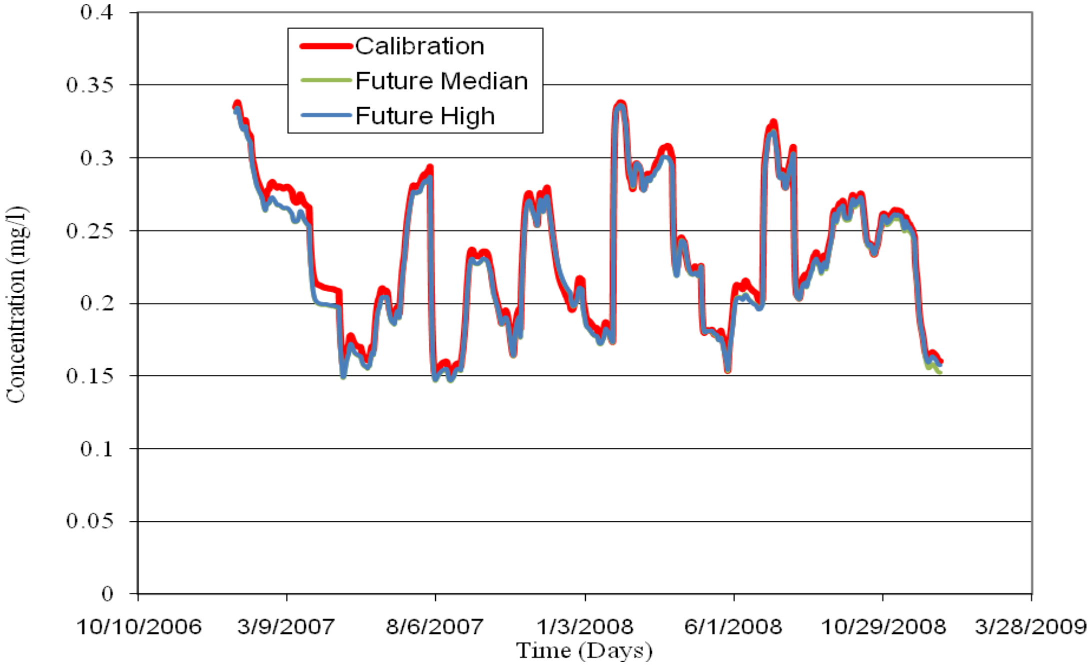

Figure 7.46-Variation of Total Phosphorus concentration in Davis Pond with the introduction of diversions

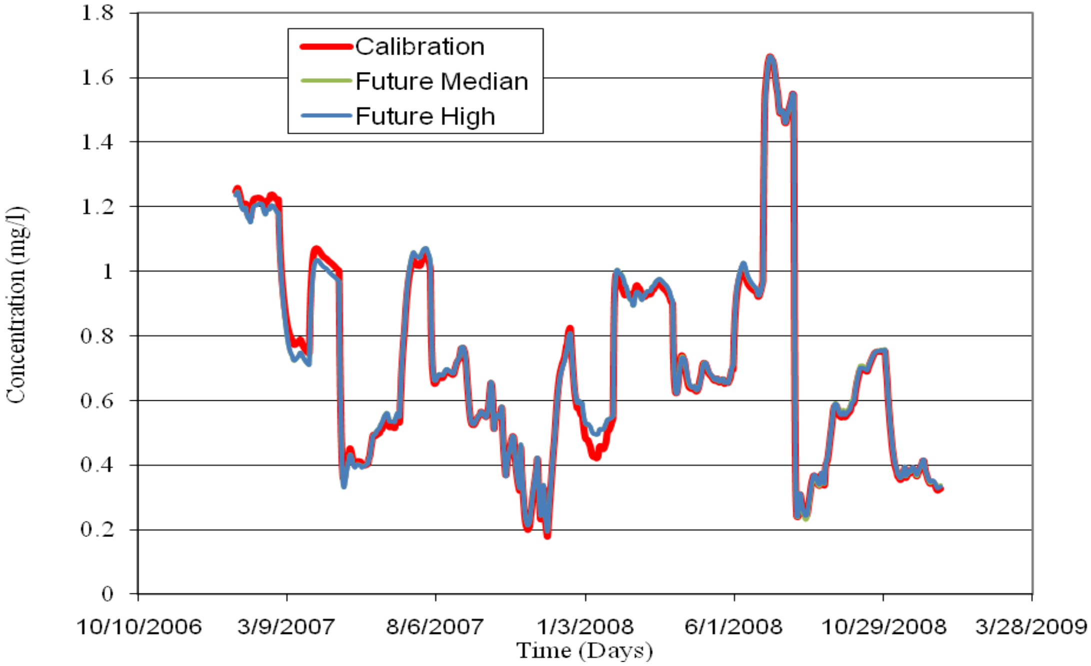

Figure 7.47-Variation of Organic Nitrogen concentration in Davis Pond with the introduction of diversions

Table 7.10-Average Concentration of Nitrite + Nitrate (mg/l) in different scenarios.

Stations	Calibration	Future Median	Future High
Northern Gulf of Mexico (cell 19)	0.189	0.213	0.215
Northern Gulf of Mexico (cell 20)	0.309	0.273	0.269
Northern Gulf of Mexico (cell 31)	0.849	0.742	0.738
Grand Island	0.402	0.455	0.501
Lower Barataria	0.442	1.578	1.593
Little Lake	0.253	0.488	0.567
Davis Pond	0.717	0.717	0.717

Table 7.11-Average Concentration of Total Phosphorus (mg/l) in different scenarios.

Stations	Calibration	Future Median	Future High
Northern Gulf of Mexico (cell 19)	0.134	0.136	0.136
Northern Gulf of Mexico (cell 20)	0.146	0.144	0.143
Northern Gulf of Mexico (cell 31)	0.181	0.174	0.174
Grand Island	0.147	0.165	0.168
Lower Barataria	0.157	0.232	0.233
Little Lake	0.109	0.152	0.154
Davis Pond	0.233	0.229	0.229

Table 7.12-Average Concentration of Organic Nitrogen (mg/l) in different scenarios.

Stations	Calibration	Future Median	Future High
Northern Gulf of Mexico (cell 19)	0.470	0.473	0.473
Northern Gulf of Mexico (cell 20)	0.546	0.538	0.536
Northern Gulf of Mexico (cell 31)	0.655	0.632	0.631
Grand Island	0.719	0.810	0.820
Lower Barataria	0.764	0.867	0.872
Little Lake	0.842	0.854	0.860
Davis Pond	0.717	0.717	0.717

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8.0 Discussions

8.1 Introduction

The model was calibrated for water level, salinity and nutrients at several stations in the Barataria Basin for the year 2007 and 2008. The model was run with some future scenarios after the calibration and validation. The water level was calibrated at Grand Island, Lower Barataria, Little Lake, Lake Salvador, Lake Cataouatche, Davis Pond and Lake Des Allemands. The salinity was calibrated at Grand Island, Lower Barataria, Little Lake, Lake Salvador and Lake Des Allemands. The nutrient concentration was calibrated at Grand Island, Little Lake, Lake Salvador and Lake Cataouatche.

8.2 Uncertainty

Although the model shows good response to the water level, there were certain errors in the model outputs. The model output for the mean water level in the stations is slightly different than measured values. Similarly the standard deviations of the model output are slightly different than the standard deviation of the measured values. Table 6.3 shows mean and standard deviation of measured and calibrated values. The difference in water level in model output is the measured value is 0.1 m, 0.08m, 0.05 m, 0.06m, 0.07 m, 0.07 m and 0.01 m in Grand Island, Lower Barataria, Little Lake, Lake Salvador, Lake Cataouatche, Davis Pond and Lake Des Allemands respectively. Similarly, Table 6.3 shows that the standard deviations of the model outputs are larger than the standard deviation of the measured values. There can be so many reasons of these certainties. One reason is the model does not capture wind seiche since it does not have wind shear on the open water. The model assumes the relative sea level rise to be zero but this could be the range of 0.01m to 0.02m per year. The Lower Barataria is brackish whereas the Upper Barataria is dominated by freshwater. The average model salinity is 12.8 ppt, 14.29 ppt, 4.93 ppt, 0 .20 ppt, 0.2 ppt and 0.54 ppt in Grand Island, Lower Barataria, Little Lake, and Lake Cataouatche respectively. The average measured salinity is 15.01 ppt, 16.88 ppt, 4.99 ppt, 0.189 ppt. 0.2 ppt and 0.53 ppt respectively. The model shows salinity increases with the increase in water level in Lower Barataria and decreases with increase in water level in the Upper Barataria which is because the Lower Barataria is linked with the Gulf of Mexico which is highly brackish and the Upper Barataria is linked with the freshwater diversions from the Mississippi River. Thus the model over predicts salinity in Lower Barataria and under predicts in the Upper Barataria. Moreover the salinity depends on different factors like characteristics of landscape, human activities, climate, weathering and erosion of surface rocks, properties of soil, existing conditions. The model shows the general trend line of salinity in Little Lake but the measured salinity is found to be highly variable. It may be due to the fact that the lake receives different forms of water from the City of Houma, Bayou Lafourche and Barataria Bay.

The model shows a good prediction of nutrient concentration. Table 6.7 shows the measured and calibrated nutrient's concentration. The measured nitrogen concentration in Little Lake is found to be higher than the calibrated value which may reflect a source such as Bayou Lafourche or the City of Houma. It may be due to the fact that the lake receives different forms of water from the City Houma and Bayou Lafourche.

Another reason for the uncertainties could be conflicts on the data available. The model needs extensive data input sets. Different agencies measure data at different stations with different datum. The nutrient data are very limited. Most of the agencies do not have continuous data due to hurricanes and unavailability of the materials needed to record the data. The missing data were interpolated what could be a reason of uncertainties.

8.3 Impacts of the Proposed Diversions

The impacts of the proposed diversions on water level, salinity and nutrient concentration were discussed in Chapter 7. There was no significant increase in water level except in the areas where there are diversions. The increase in water level in the site of Deer Range, Jesuit Bend and Myrtle Grove was found to be even greater than 2 m during the peak flows but the increase in water level in other areas like Grand Island, Little Lake, lake Salvador and Lake Cataouatche was less than 0.2 m. The model shows that the salinity decreases as we go from the Lower Barataria to the Upper Barataria. The impacts of diversions on salinity were highly significant. There is a chance of overland flow and flow through marsh vegetation near the diversion sites due to increase in pressure gradient near the head of the diversions. To prevent such effect, the diversion site was connected with the neighboring cells by a link with small depth, large width and high Manning's roughness. The average salinity in Lower Barataria decreases to 5 ppt from 15 ppt with the introduction of the proposed diversions. Similarly the average salinity in Grand Island decreases to 8 ppt from 13 ppt and the salinity in Little Lake decreases to 2 ppt from 4 ppt. The average salinity is not affected in the Upper Barataria as the region is already dominated by freshwater. The salinity in the Lower Barataria decreases as the Manning's n of the links connecting the cells and Gulf of Mexico is increased and the diffusion constant of the links is decreased.

The impacts of the proposed diversions are highly significant in the concentration of nutrients in Barataria Basin and Northern Gulf of Mexico. The impact was more in nitrite+nitrate than in phosphorus and organic nitrogen which is because is most of the diversions are from the Mississippi River and the River is richer is nitrogen than in phosphorus relative to Gulf of Mexico. The concentration of nutrients in the Northern Gulf of Mexico decreases with the introduction of the proposed diversions. This is because the less amount of flow from the Mississippi River is discharged directly to the Gulf of Mexico due to fact that some of the flows were diverted to the Barataria Basin through the proposed diversions. The concentration of nutrients increases in the Barataria Basin as the diverted flow has a higher concentration of nutrients than the present values. The concentration of nutrients depends on the different factors like human activities, climate, existing aquatic, vegetation and soil condition. The initial condition for water level and the concentration of nutrients in the beginning of the year 2007 was set to zero and with time it starts to increase. Similarly, due to initial conditions the salinity in the beginning of the year 2007 was higher than the average values. This is called "Spin Up effect". In 2010 the State of Louisiana has decided to close to West Bay Diversion on 2010. The closing of the West Bay diversion did not affect other areas significantly except in the neighborhood of the diversion. The salinity of the West Bay site was increased by about 5 ppt when the diversion was closed.

8.4 Impacts of Tributaries

The model contains certain are tributaries like Amite River, Bogue Chitto River, Comite River, Natalbany River, Tangipahoa River, Tchefuncte River, Tickfaw River, Pearl River, Wolf River, Jourdan River, Biloxi River, Pascagoula River , Mobile River and several smaller ungauged tributaries. Since all of these rivers are east of the Mississippi River they have no impacts in Barataria Basin. Amite River, Bogue Chitto River, Comite River, Natalbany River, Tangipahoa River, Tchefuncte River and Tickfaw River are located in Pontchartrain Estuary. Pearl River, Wolf River, Jourdan River, Biloxi River, Pascagoula River and Mobile River are located in Mississippi Sound.

8.5 Application of the Model

The model is simple and can simulate for a long period of time. The model can be used in to see the long term impacts of diversion in Barataria Basin. The impacts include: water level, salinity and concentration of nutrients. The model can be used if some more diversions are proposed. The model can be useful to investigate the effect of rainfall, evapotranspiration, diversion inflows, and Mississippi River flow on water level, salinity and nutrients concentration of Barataria Basin and Northern Gulf of Mexico. Some neighboring areas of Barataria Basin can be included in the model provided that sufficient input data are available.

8.6 Advantages and Limitations of the Model.

- The model has certain advantages like:
    - It can simulate for a long period of time,
    - It can simulate water level, salinity, concentration of nutrients and sediment at the same time ,
    - It can be expanded to neighboring basins,
    - It shows a good response to hurricanes ,
    - It can run with more diversions,
    - It can be used for closing and closing of some of the existing diversions.
- The model has certain limitations like:
    - It does not include stratification,
    - It assumes salinity is fully mixed within the basin,
    - It neglects the wind setup and wind setdown,
    - It uses the simple hydrology (Runoff=Rainfall- Evaporation).

9.0 Conclusions

The conclusions developed from this research are:

- A tidal, salinity and water quality model initially developed for the Pontchartrain Estuary was expanded to include Barataria Basin, Terrebonne Basin and Northern Gulf of Mexico and was successfully calibrated and applied.
- The model includes freshwater inputs from the Mississippi River and Atchafalaya River.
- The model includes open boundary salinity and tidal input in the Gulf of Mexico.
- Long-term hydrological, hydraulics, meteorological, ecological and biological and water quality data around Barataria Basin for the years 2007 and 2008 were collected and used in the model.
- The model includes hydraulic conveyances of the major passes, canals, waterways and interconnecting channels.
- The model showed a very good response to the hurricanes like Gustav and Ike.
- The model shows the impacts of the proposed diversions on the water level, salinity and the nutrient's concentration on Barataria Basin and some parts of Northern Gulf of Mexico.
- The salinity of the Upper Barataria is not affected by the diversions whereas the salinity Lower Barataria is highly affected by the diversions. Salinity decreases with the increasing flow from the diversions in Lower Barataria.
- The impacts on water level are small except in the neighborhood of diversions except in the site of the diversions. The water level at Myrtle Grove, Jesuit Bend and Deer Range increases significantly due to the presence of the diversions. The change is water level in other areas was less than 0.2 meter.
- The impacts of diversions on the concentration of nutrients were highly significant. The concentration of nutrients increase in Barataria Basin with the introduction of the proposed diversions but the concentration of nutrients decreases in Northern Gulf of Mexico.

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Appendix A

Table- A1- Cell Input File

!node	Askm2	Esom	Bedm	dsowm	Es	ADAkm2	% of water
1	325	0	-2.7	2.7	0	50	15
2	340	0	-2.7	2.7	0	50	15
3	200	0	-2.58	2.58	0	150	15
4	350	0	-3.8	3.8	0	10	10
5	350	0	-4	4	0	15	20
6	350	0	-3.5	3.5	0	15	20
7	350	0	-3.5	3.5	0	25	20
8	80	0	-6.5	6.5	0	30	20
9	80	0	-6.5	6.5	0	60	20
10	350	0	-3.2	3.2	0	2.5	20
11	200	0	-1	1	0	200	15
12	1290	0	-1.65	1.65	0	100	15
13	85	0	-1.1	1.1	0	55	45
14	325	0	-3.5	3.5	0	5	50
15	640	0	-2	2	0	50	15
16	1120	0	-2.5	2.5	0	50	15
17	1340	0	-2.5	2.5	0	50	15
18	700	0	-2.65	2.65	0	2.5	75
19	2500	0	-8	8	0	520	40
20	3015	0	-15	15	0	50	15
21	2880	0	-20	20	0	550	20
22	3850	0	-20	20	0	50	15
23	3075	0	-100	100	0	50	15
24	2900	0	-100	100	0	50	15
25	2990	0	-100	100	0	50	15
26	1030	0	-4	4	0	50	15
27	800	0	-3.1	3.1	0	50	25
28	550	0	-4.2	4.2	0	2	50
29	3000	0	-100	100	0	1	50
30	400	0	-1	1	0	500	20
31	1200	0	-5	5	0	1220	20
32	3000	0	-50	50	0	1	50
33	420	0	-1	1	0	400	10
34	68.9	0	-3.417	3.4	0	140.9	33

Table A-1 (Continued)- Cell Input file

!node	Askm2	Esom	Bedm	dsowm	Es	ADAkm2	% of water
34	68.9	0	-3.417	3.4	0	140.9	33
35	94.9	0	-1.255	1.3	0	16.3	85
36	102.1	0	-1.852	1.9	0	18.4	85
37	46.7	0	-1.351	1.4	0	3	94
39	222.7	0	-1.442	1.4	0	144	20
40	174.8	0	-0.811	0.8	0	91.8	66
41	133.2	0	-1.566	1.6	0	43	76
42	30	0	-1.161	1.2	0	18.8	61
43	65.8	0	-0.946	0.9	0	85.1	44
44	86.2	0	-1.667	1.7	0	38.7	69
45	57.6	0	-1.5	1.5	0	4.4	93
46	88.4	0	-1.535	1.5	0	42.8	67
47	39.5	0	-0.809	0.8	0	101.4	28
48	211.1	0	-1.413	1.4	0	254.3	45
49	11.7	0	-1.986	2	0	9.3	56
50	15.7	0	-1.118	1.1	0	10.7	60
51	40.9	0	-1.234	1.2	0	76.1	35
52	10.25	0	-1.263	1.3	0	13	16
53	16	0	-1.312	1.3	0	23.2	41
54	6.8	0	-1.989	2	0	65.7	9
55	65.6	0	-1.841	1.8	0	91.7	42
56	37.1	0	-1.147	1.1	0	63.1	37
57	52.6	0	-0.713	0.7	0	85.7	38
58	120	0	-1.766	1.8	0	160	10
59	68.5	0	-1.8	1.8	0	56.4	10
60	10.31	0	-4	4	0	27.5	10
61	11.2	0	-4	4	0	101	10
62	7.3	0	-0.5	0.5	0	128	10
63	15	0	-0.725	0.7	0	246.6	10
64	17.6	0	-0.746	0.7	0	342.3	10
65	5.1	0	-4	4	0	46.2	10
66	9.4	0	-4	4	0	84.5	10
67	66	0	-1.997	2	0	1212	10
68	7.9	0	-1.28	1.3	0	43.7	10

Table A-1 (Continued) - Cell Input file

!node	Askm2	Esom	Bedm	dsowm	Es	ADAkm2	% of water
69	7.8	0	-4	4	0	70	10
70	1400	0	-0.99	0.99	0	500	20.9
71	300	0	-1.99	1.99	0	4120	10.9
72	1200	0	-6	6	0	1220	1
73	124	0	-1	1	0	373	15
74	248	0	-1	1	0	248	15
75	20	0	-1.5	1.5	0	20.18	15
76	50	0	-2.5	2.5	0	20	25
77	50	0	-2.5	2.05	0	50	25
78	91	0	-1.5	1.5	0	60	45
79	220	0	-1.5	1.5	0	200	15
80	150	0	-3.5	3.5	0	5	50

Table A-2. - Dimensions and Manning’s roughness constant of the links.

!link	no.!jus	jds	itype	Invert	depth	Length	Width	n
1	1	14	1	-5.54	5.54	3000	15000	0.016
2	3	1	0	-10.5	10.5	10500	985	0.0245
3	2	1	0	-4.05	4.05	15000	15000	0.021
4	3	2	0	-8	8	7850	360	0.025
5	8	28	1	-6.5	6.5	60420	320	0.023
6	9	8	0	-6.5	6.5	20000	300	0.023
7	9	2	0	-4.05	4.05	12000	200	0.03
8	4	9	0	-8.5	8.5	15000	155	0.025
9	5	3	0	-3	3	20000	20000	0.0235
10	5	4	0	-4.3	4.3	40000	40000	0.02
11	6	5	0	-3.9	3.9	40000	20000	0.02
12	7	6	0	-8.1	8.1	8800	395	0.024
13	8	2	0	-4.05	4.05	2000	50	0.03
14	10	6	0	-3.75	3.75	20000	20000	0.025
15	10	4	0	-3.95	3.95	40009	20000	0.025
16	1	13	0	-2.1	2.1	13500	1500	0.03
17	80	18	0	-5	5	10000	20000	0.015
18	18	27	0	-5	5	15000	20000	0.02
19	27	26	0	-5	5	20000	20000	0.032
20	26	25	0	-5	5	5000	4000	0.032
21	2	73	0	-1	1	5000	650	0.075
22	14	13	0	-1	1	7000	400	0.08
23	14	17	0	-6	6	3000	7500	0.02
24	78	17	0	-2	2	3500	5000	0.058
25	17	22	0	-11.08	11.08	10000	10000	0.018
26	27	22	0	-5	5	5000	10000	0.023
27	22	25	0	-19	19	30000	55000	0.02
28	74	16	0	-1	1	4000	500	0.045
29	16	17	0	-4.6	4.6	20000	15000	0.022
30	16	21	0	-11.5	11.5	3000	18000	0.02
31	21	22	0	-8	8	20000	15000	0.02
32	21	24	0	-21	21	30000	60000	0.02
33	24	25	0	-11	11	30000	20000	0.02
34	28	20	0	-5	5	20000	4000	0.02

Table A-2 (Continued) - Dimensions and Manning's roughness constant of the links.

!link	no.!jus	jds	itype	Invert	depth	Length	Width	n
35	28	16	0	-5	5	20000	10000	0.02
36	15	28	0	-5	5	20000	10000	0.018
37	28	74	0	-2	2	20000	10000	0.08
38	20	21	0	-7	7	20000	15000	0.018
39	20	23	0	-21	21	30000	50000	0.018
40	23	24	0	-15	15	30000	20000	0.02
41	11	79	0	-2	2	10000	400	0.032
42	12	15	0	-2.75	2.75	20000	25000	0.0218
43	15	20	0	-4	4	10000	5000	0.032
44	20	31	0	-6	6	10000	5000	0.032
45	23	32	0	-25	25	45000	25000	0.032
46	19	29	0	-35	35	20000	10000	0.025
47	73	74	0	-1	1	5000	1000	0.1
48	18	17	0	-2	2	15000	15000	0.023
49	30	15	0	-2	2	8000	2000	0.0232
50	33	20	0	-3	3	10000	20000	0.0232
51	12	30	0	-5	5	20000	300	0.02
52	32	29	0	-5	5	20000	15000	0.025
53	31	19	0	-7.5	7.5	20000	15000	0.025
54	31	32	0	-4	4	20000	40000	0.035
55	25	101	0	-30	30	30000	20000	0.028
56	24	102	0	-30	30	30000	20000	0.0302
57	23	103	0	-30	30	30000	20000	0.0302
58	29	104	0	-35	35	30000	20000	0.0302
59	32	105	0	-35	35	30000	20000	0.0302
60	9	2	0	-1.5	1.5	5000	800	0.061
61	34	19	0	-4	4	1000	1100	0.02
62	35	19	0	-6.8	6.8	2000	100	0.02
63	36	19	0	-2	2	1000	400	0.04
64	37	19	0	-6	6	2000	2300	0.035
65	38	19	0	-3	3	800	5000	0.035
66	35	31	0	-6	6	2000	870	0.03
67	36	31	0	-2	2	2000	400	0.04
68	37	31	0	-6	6	2000	500	0.05
69	38	31	0	-4.5	4.5	2000	600	0.03
70	34	35	0	-3.09	3.09	10638	25723.3	0.025
71	35	36	0	-4	4	9222	11877	0.025

Table A-2 (Continued) - Dimensions and Manning's roughness constant of the links.

!link	no.!jus	jds	itype	Invert	depth	Length	Width	n
72	37	36	0	-2	2	9366	8883.6	0.025
73	38	37	0	-1	1	9157	9189.4	0.025
74	39	38	0	-2	2	15047	13679.4	0.025
75	39	40	0	-2	2	21372	12021.8	0.025
76	70	72	0	-2	2	54374	8280.3	0.025
77	71	70	0	-1.05	1.05	38280	443	0.0325
78	40	41	0	-1	1	15659	3218	0.025
79	41	42	0	-1	1	10573	9350.3	0.025
80	43	34	0	-1	1	16238	11072.3	0.025
81	43	35	0	-1	1	10815	6936.3	0.025
82	44	36	0	-1	1	11169	10911.4	0.025
83	45	37	0	-1	1	10026	5278.6	0.025
84	46	38	0	-1	1	11426	10364.2	0.025
85	47	39	0	-1	1	16093	80.5	0.025
86	43	44	0	-1	1	12907	11345.9	0.025
87	45	44	0	-1	1	8723	10219.3	0.025
88	46	45	0	-1	1	7242	8690.5	0.025
89	47	46	0	-1	1	7725	241.4	0.025
90	48	44	0	-1.5	1.5	4522	3347.4	0.025
91	49	45	0	-1.5	1.5	5279	1400.1	0.025
92	50	45	0	-1	1	2140	80.5	0.025
93	51	46	0	-1	1	3444	1448.4	0.025
94	51	47	0	-1	1	9061	1062.2	0.025
95	48	49	0	-1.5	1.5	12778	2043.9	0.025
96	54	48	0	-1	1	11475	193.1	0.025
97	55	48	0	-3	3	4345	1432.3	0.025
98	52	49	0	-1	1	7886	289.7	0.025
99	53	50	0	-1	1	7081	708.1	0.025
100	56	52	0	-1	1	11459	257.5	0.025
101	52	53	0	-1	1	4828	160.9	0.025
102	53	51	0	-1	1	1883	273.6	0.025
103	48	52	0	-1	1	3267	450.6	0.025
104	55	56	0	-2	2	5150	321.9	0.025
105	56	57	0	-0.2	0.2	8964	3379.6	0.07
106	57	51	0	-0.5	0.5	2865	193.1	0.035
107	57	53	0	-0.5	0.5	4989	402.3	0.05
108	59	55	0	-8	8	1685	452.3	0.025

Table A-2 (Continued) - Dimensions and Manning's roughness constant of the links.

!link	no.!jus	jds	itype	Invert	depth	Length	Width	n
109	58	54	0	-5.48	5.48	22128	160.9	0.025
110	60	55	0	-3.66	3.66	7129	2912.9	0.04
111	61	60	0	-2	2	4571	80.5	0.04
112	61	56	0	-1	1	6759	318	0.025
113	61	57	0	-1	1	4587	482	0.025
114	65	59	0	-5.49	5.49	10252	160.9	0.025
115	65	61	0	-2	2	3074	32.2	0.035
116	66	61	0	-1	1	2639	16.1	0.1
117	69	65	0	-3.5	3.5	9930	136.8	0.03
118	64	59	0	-4	4	3541	643.7	0.025
119	64	58	0	-4	4	2816	643.7	0.025
120	63	58	0	-2	2	19650	241.4	0.04
121	62	63	0	-1	1	5343	380.3	0.035
122	67	63	0	-1.5	1.5	7178	1134.6	0.03
123	68	64	0	-2	2	2044	170.8	0.0235
124	58	59	0	-2	2	12392	10621	0.025
125	66	61	0	-4.9	4.89	21050	160	0.03
126	51	50	0	-1	1	6759	804	0.08
127	59	56	0	-3.5	3.5	16000	50	0.03
128	72	29	0	-10	10	20000	10000	0.0232
129	72	19	0	-8	8	20000	15000	0.0232
130	72	106	0	-8	8	20000	12000	0.02532
131	74	17	0	-1	1	5000	100	0.1
132	1	73	0	-1.2	1.2	5000	1000	0.05
133	73	13	0	-1.1	1.1	5000	1000	0.078
134	74	78	0	-1.1	1.1	5000	1000	0.078
135	8	73	0	-1.25	1.25	15000	1000	0.1
136	8	2	0	-6	6	1000	140.55	0.023
137	76	80	0	-2.65	2.65	4000	2000	0.023
138	77	18	0	-2.31	2.31	4000	1000	0.023
139	13	78	0	-1.8	1.8	5000	6000	0.0352
140	79	12	0	-1.2	1.2	10000	6400	0.042
141	75	9	0	-3	3	10000	50	0.03
142	75	8	0	-4.05	4.05	12000	200	0.03
143	30	33	0	-2	2	8000	3000	0.03
144	15	28	0	-3	3	1000	200	0.03

Table A-2 (Continued) - Dimensions and Manning’s roughness constant of the links.

!link	no.!jus	jds	itype	Invert	depth	Length	Width	n
145	75	8	0	-6	6	250	250	0.03
146	80	14	0	-2.7	2.7	10000	12000	0.03
147	71	107	0	-2	2	8000	500	0.035
148	71	58	0	-1.5	1.5	10000	200	0.035
149	50	49	0	-1	1	4828	160.9	0.025
150	62	58	0	-2	2	19650	241.4	0.05
151	71	48	0	-1	1	38500	10.4	0
152	55	54	0	-3	3	16000	50	0.03
153	48	43	0	-2	2	6000	50	0.03
154	57	51	0	-0.2	0.2	6000	10000	0.1
155	61	57	0	-0.2	0.2	6000	4820.8	0.1
156	59	61	0	-1	1	2000	100	0.1
157	61	60	0	-0.5	0.5	4571	3000	0.1
158	61	56	0	-0.5	0.5	6759	4000	0.1
159	61	57	0	-0.5	0.5	4587	5000	0.1
160	41	31	0	-2	2	10000	10000	0.03

Appendix B

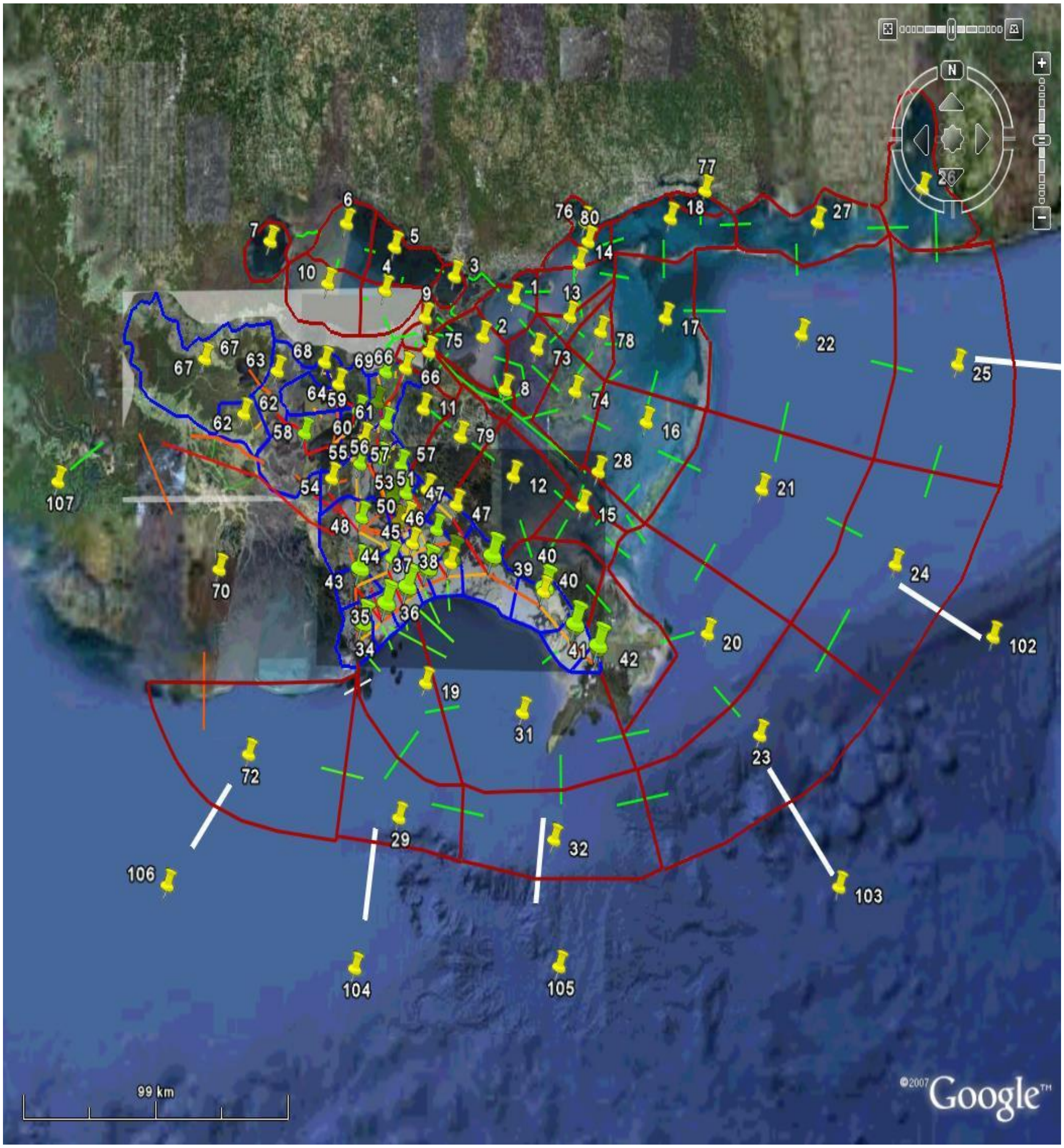

Figure B1- Whole Barataria Cells with links.

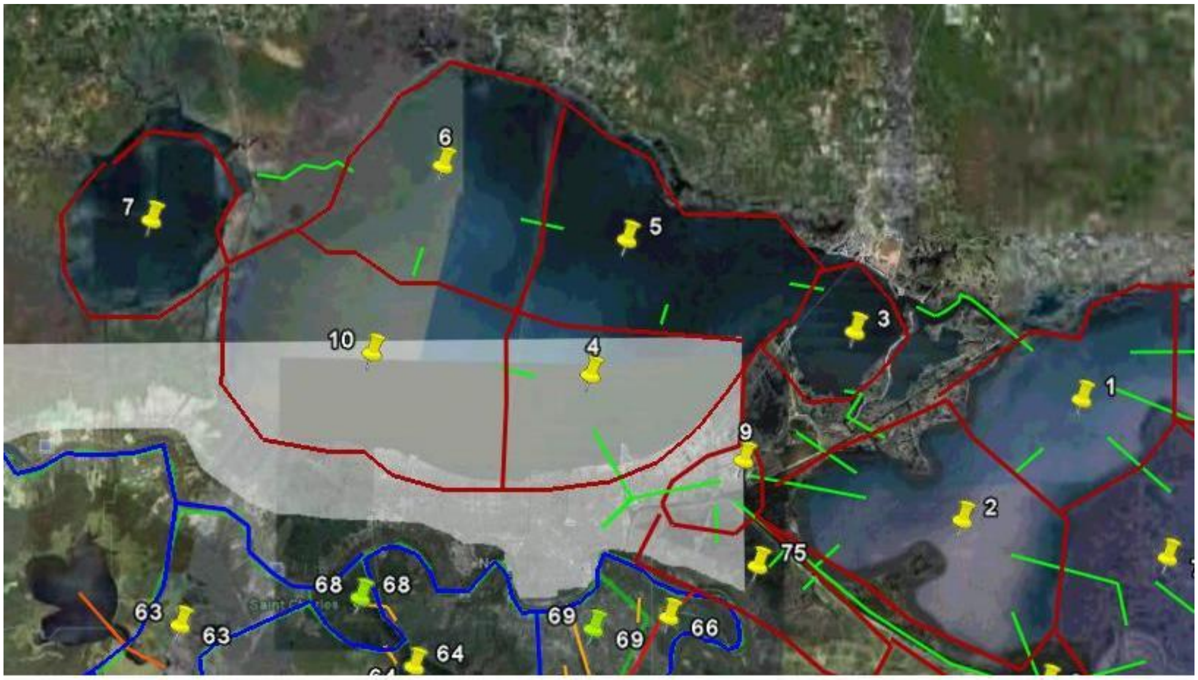

Figure B2- Pontchartrain Cells with links.

Appendix C

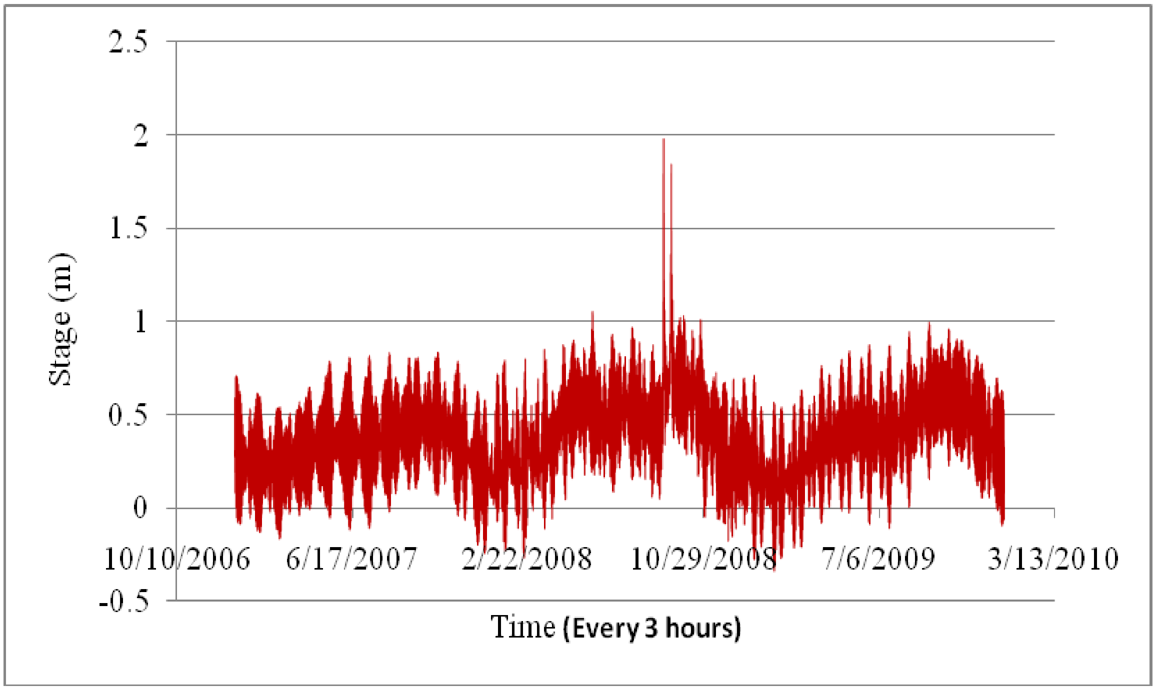

Figure C1- Water level at Grand Island (calibration) (2007-2009).

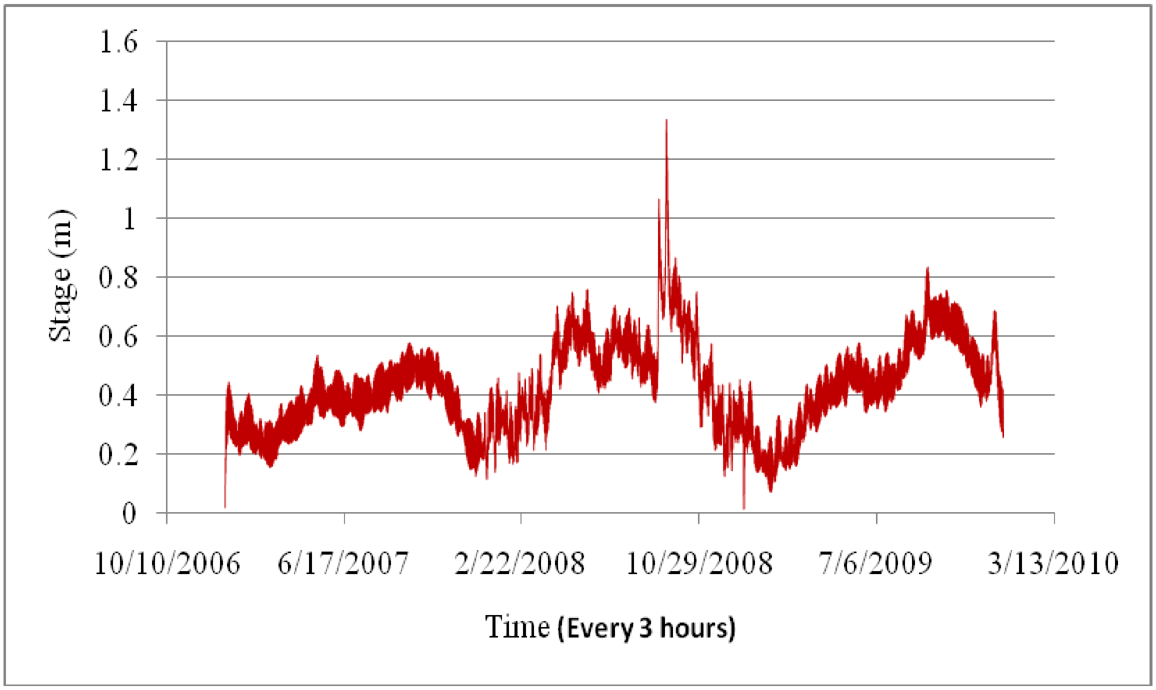

Figure C2- Water level at Little lake (calibration) (2007-2009).

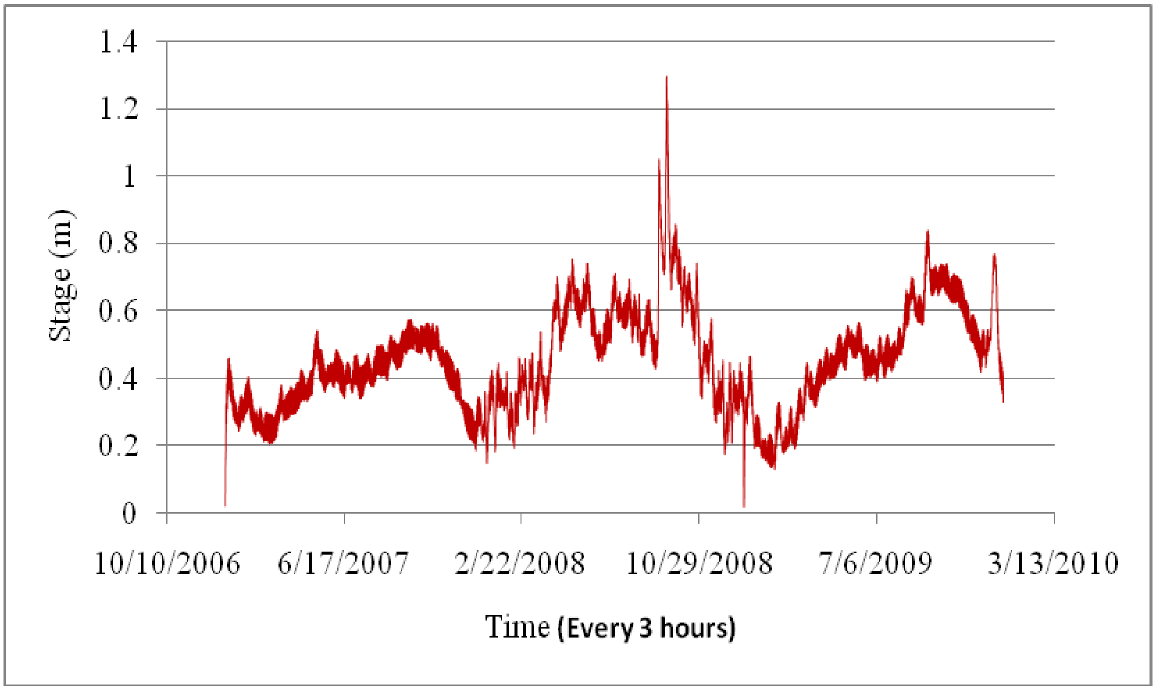

Figure C3- Water level at Lake Salvador (calibration) (2007-2009).

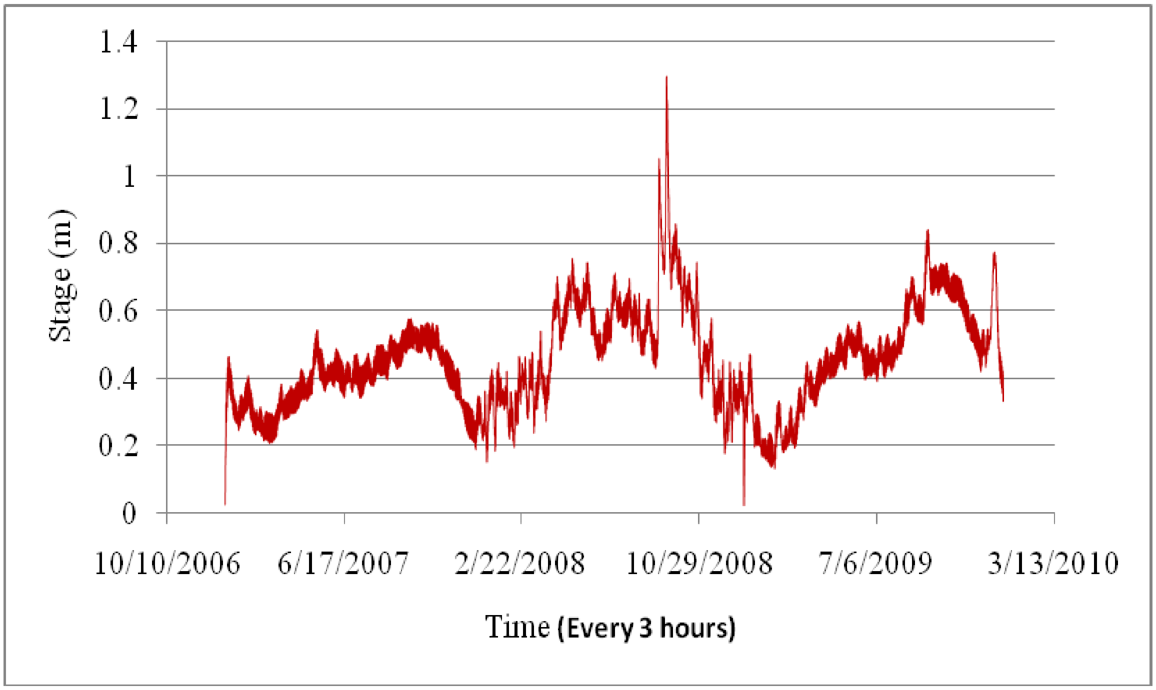

Figure C4- Water level at Lake Cataouatche(calibration) (2007-2009).

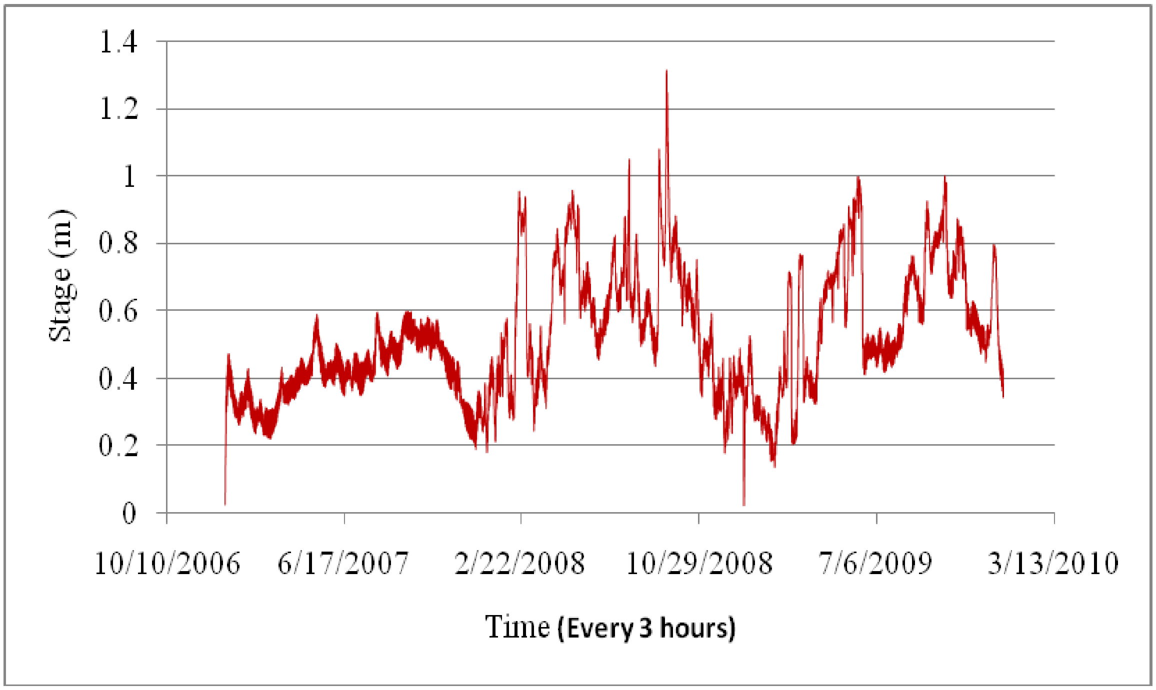

Figure C5- Water level at Davis Pond (calibration) (2007-2009).

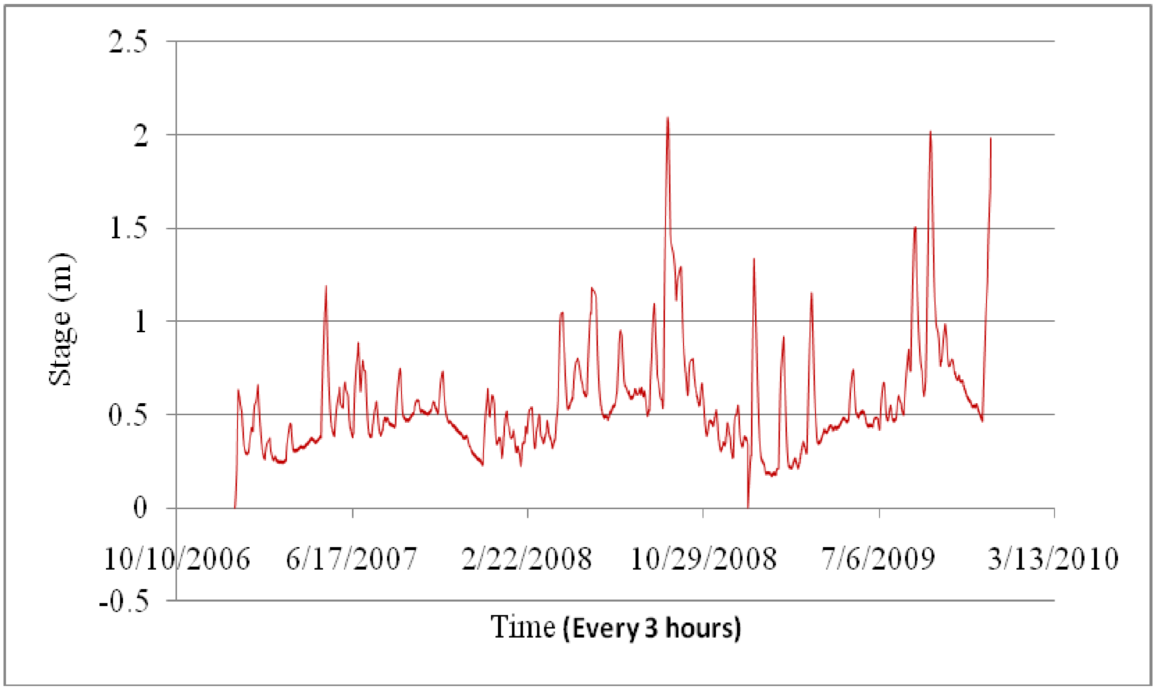

Figure C6- Water level at Lake Des Allemands (calibration) (2007-2009).

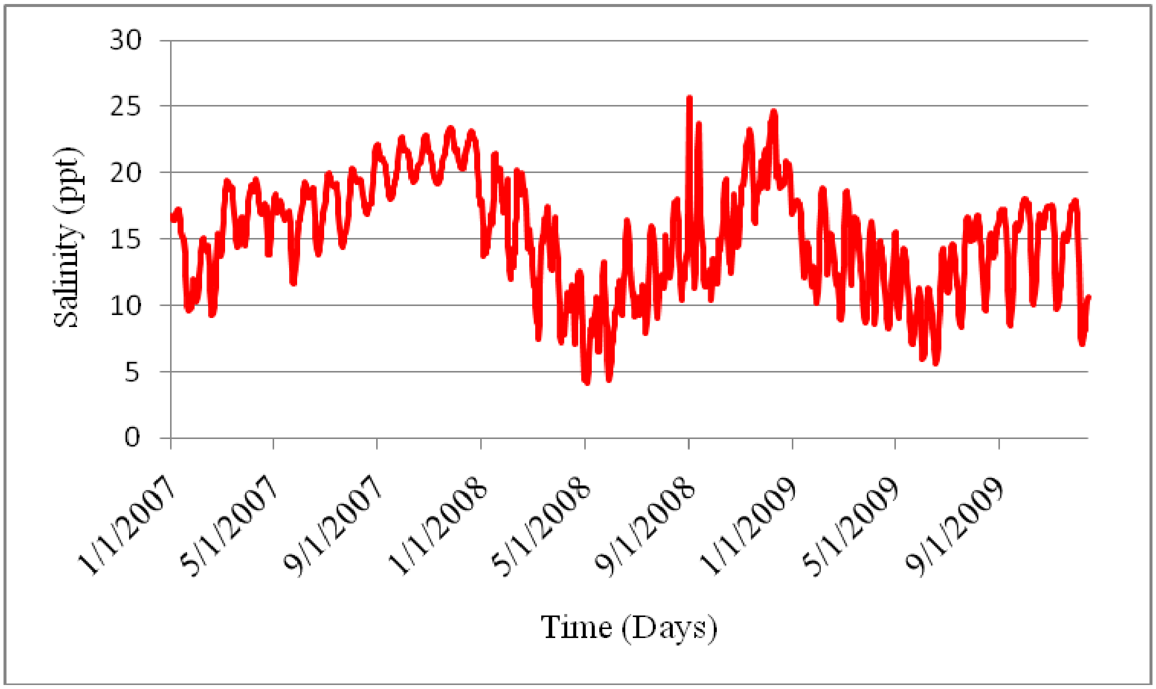

Figure C7- Salinity at Lower Barataria (calibration) (2007-2009).

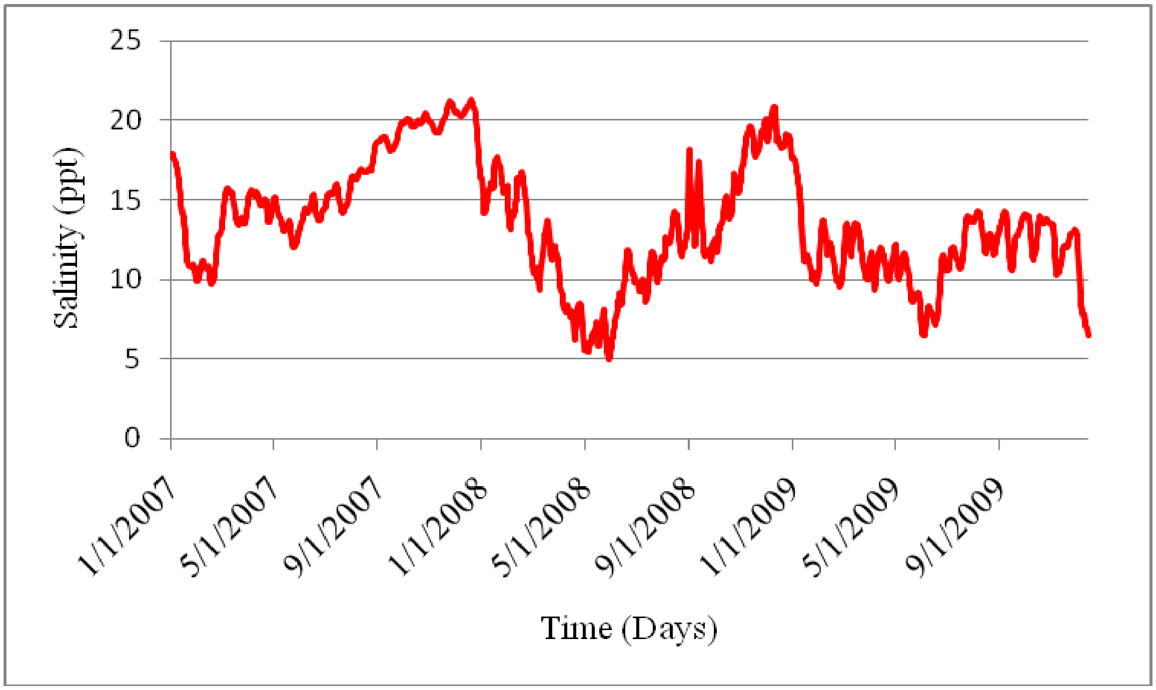

Figure C8- Salinity at Grand Island (calibration) (2007-2009).

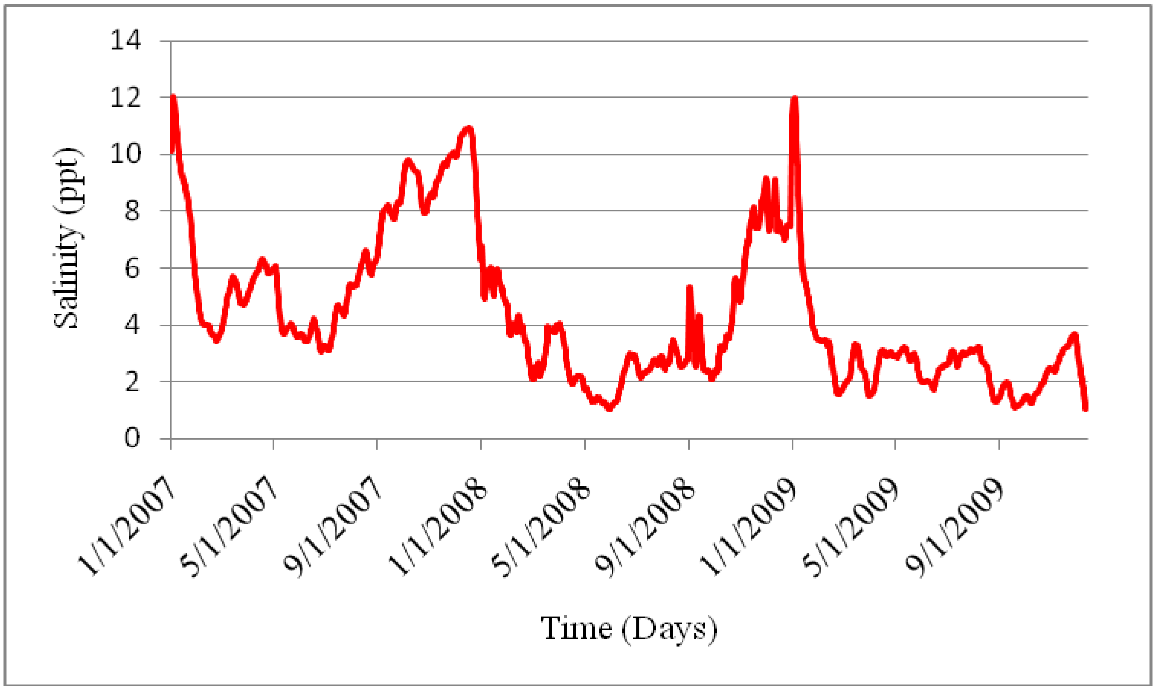

Figure C9- Salinity at Little Lake (calibration) (2007-2009)

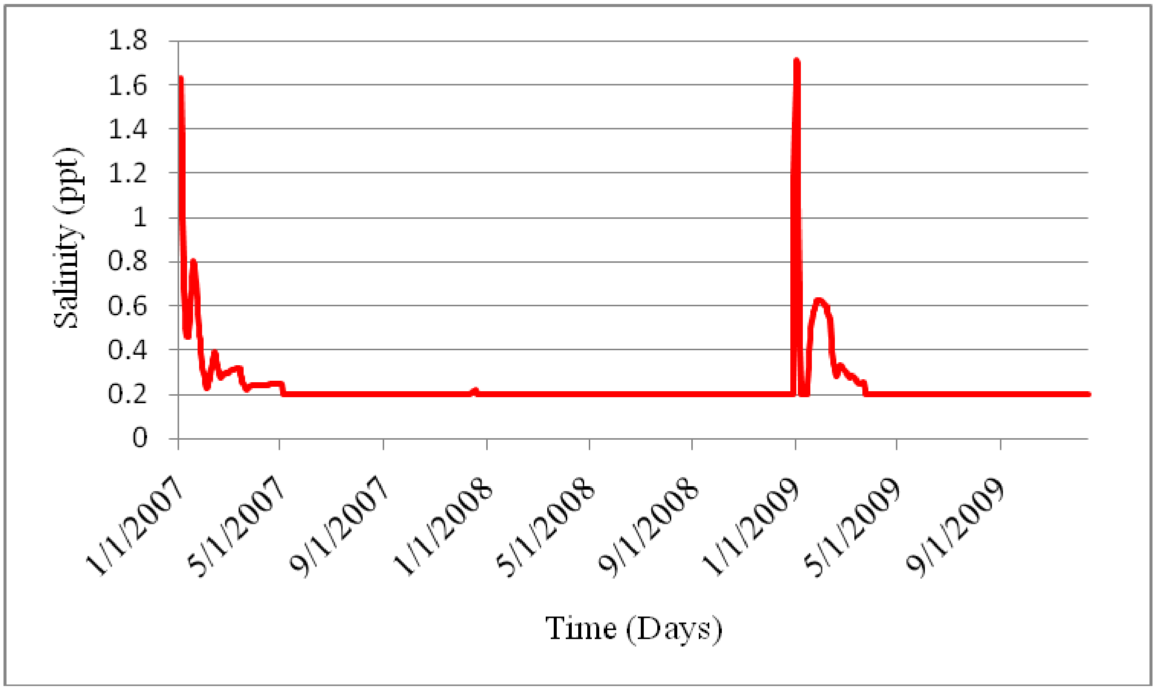

Figure C10- Salinity at Lake Des Allemands (calibration) (2007-2009).

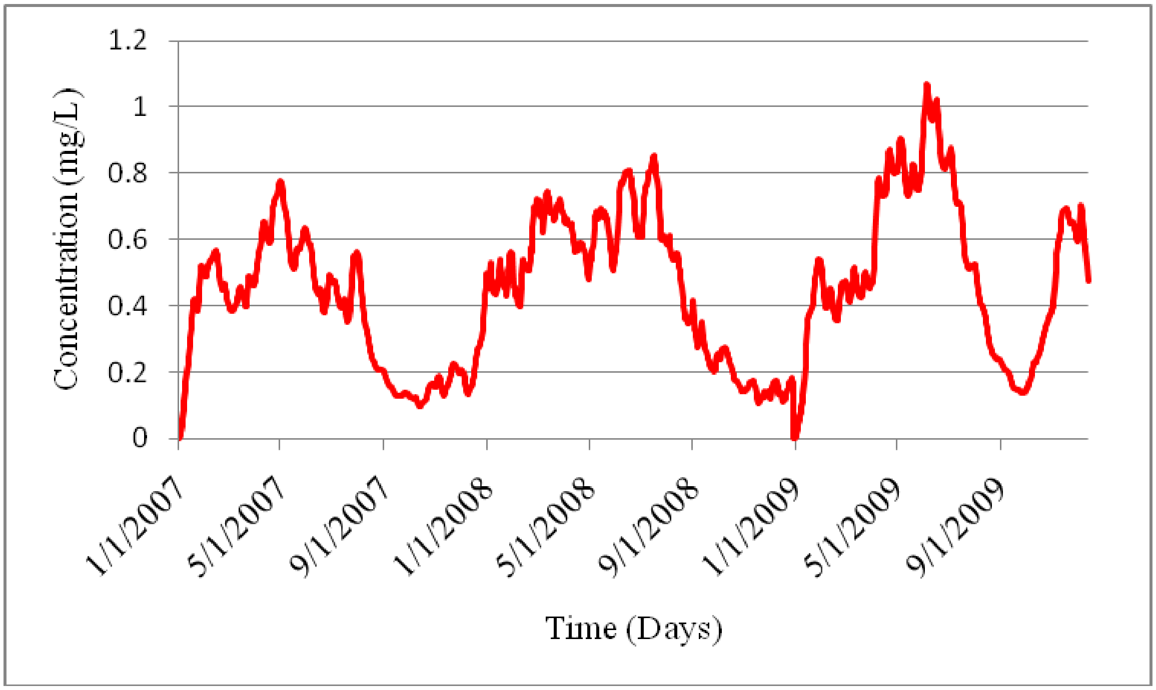

Figure C11- Concentration of Nitrite +Nitrate (calibration) at Grand Island (2007-2009).

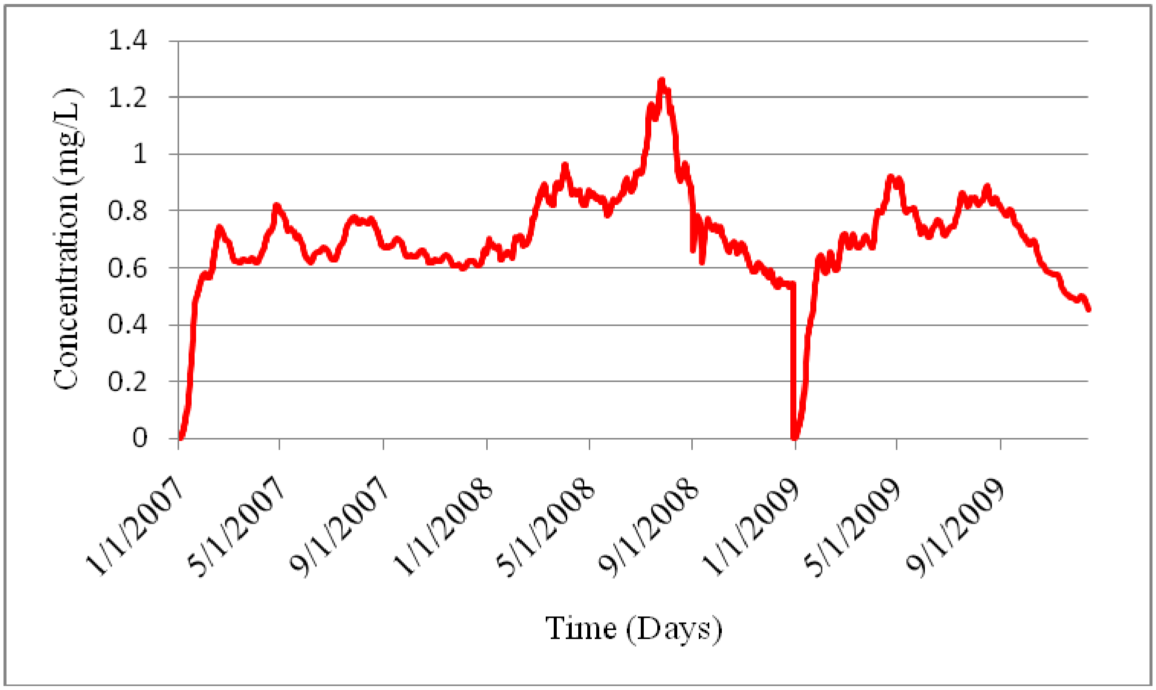

Figure C12- Concentration of Organic Nitrogen (calibration) at Grand Island (2007-2009).

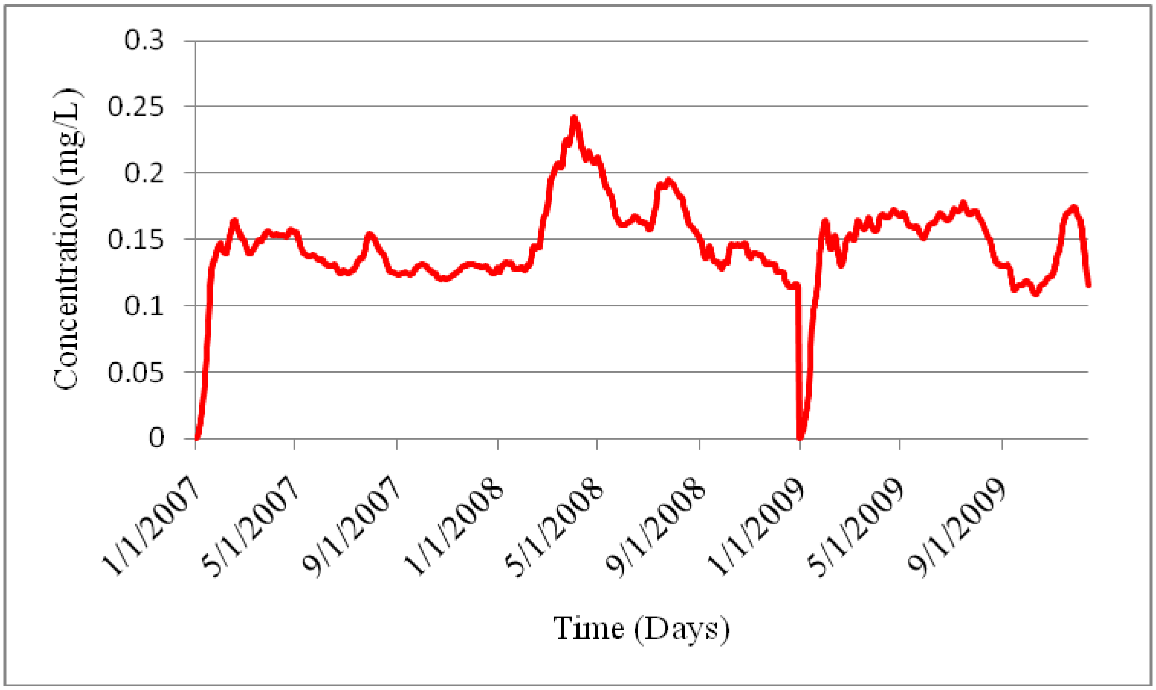

Figure C13- Concentration of Total Phosphorus (calibration) at Grand Island (2007-2009).

Vita

Jeevan Neupane was born in 1983 in Lekhnath, Pokhara, Nepal. He obtained a Bachelor in Engineering in 2007 from Institute of Engineering, Tribhuwan University, Nepal. After graduating in 2003, Jeevan worked as Teaching Assistant in Institute of Engineering, Tribhuwan University in Dharan, Nepal. In January 2009, Jeevan moved to New Orleans for his masters degree in the Department of Civil and Environmental Engineering at the University of New Orleans. This thesis was completed in partial fulfillment of the degree Master of Science in Engineering Science for the Department of Civil and Environmental Engineering at the University of New Orleans in December 2010.