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Relative Impact of Highway Construction on Wetland Hydrology in Environmentally Sensitive Areas in Southeast Louisiana

RELATIVE IMPACT OF HIGHWAY CONSTRUCTION ON WETLAND HYDROLOGY IN ENVIRONMENTALLY SENSITIVE AREAS IN SOUTHEAST LOUISIANA

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ABSTRACT

Located along the southeastern coast of Louisiana, St. Tammany Parish has minimal overland slope and is home to a diverse collection of environmentally sensitive areas. An Environmental Impact Statement emphasizing wetland hydrology and water circulation patterns was developed to examine potential environmental issues due to the proposed construction of LA-3241 from Interstate-12 to Bush, LA. Several roadway alignments were evaluated using hydrologic and hydraulic numerical models to determine possible impacts to environmentally sensitive areas. Changes to topography, canopy, water levels, and inundation durations were thoroughly examined to determine the least impactful alignment.

1. INTRODUCTION

The Interstate-12 (I-12) to Bush, LA, Environmental Impact Statement (EIS) evaluated potential environmental and socioeconomic impacts due to roadway construction for the United States Army Corps of Engineers (USACE) and the Louisiana Department of Transportation and Development (LADOTD). The proposed roadway was authorized by the Louisiana State Legislature and funded by the Transportation Infrastructure Model for Economic Development (TIMED) program (TetraTech 2010). The United States Environmental Protection Agency (EPA), the United States Department of the Interior – Fish and Wildlife Services (USFWS), the Louisiana Department of Wildlife and Fisheries (LDWF), and the Louisiana State Historic Preservation Office participated in I-12 to Bush EIS.

This proposed four-lane roadway would link Washington and St. Tammany Parishes to I-12 providing regional transportation and stimulating economic growth in the region. This paper presents the hydrologic and hydraulic wetland impact modeling of existing conditions and four alternative roadway alignments.

The study area was located in St. Tammany Parish, Louisiana, and fell within portions of three major watersheds: Bogue Chitto, Liberty Bayou-Tchefuncta, and Lower Pearl (Figure 1). Light Detection and Ranging (LiDAR) data was used to delineate the study area into 19 hydrologic basins

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totaling 145.3 square miles (93,002 acres). These basins were further delineated into approximately 420 subbasins.

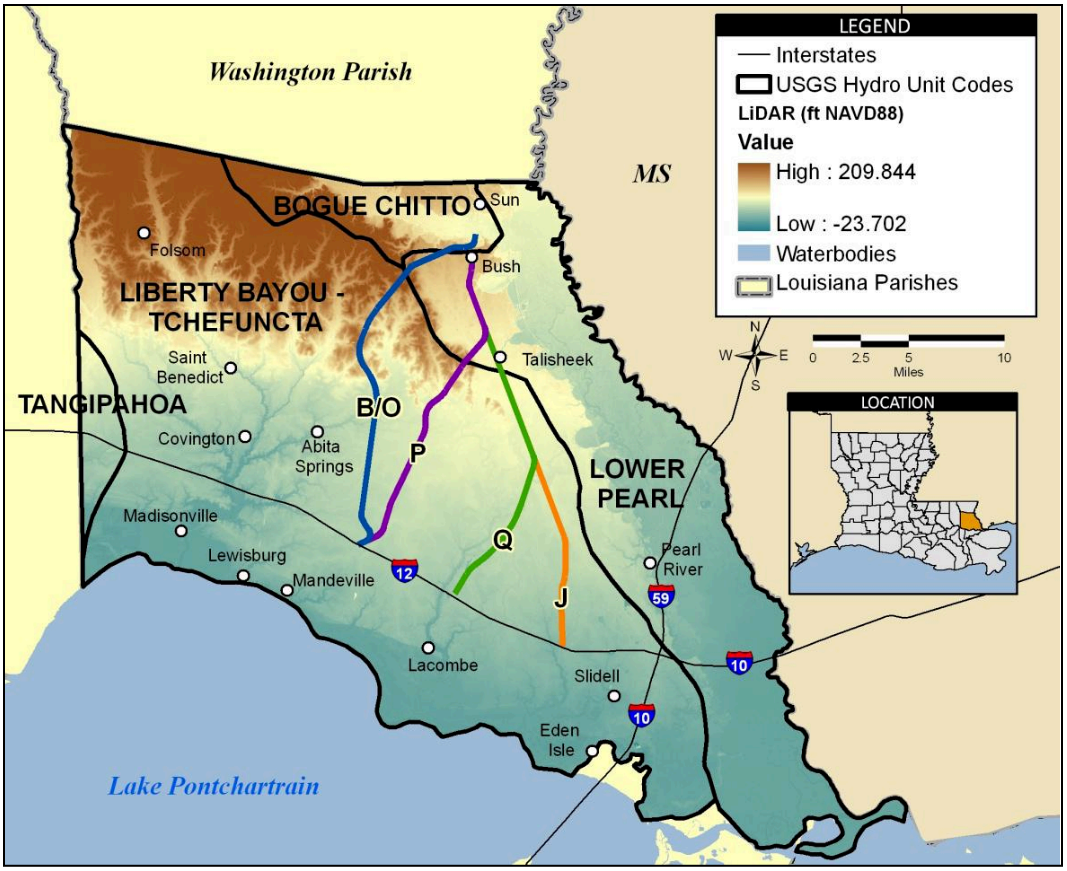

Figure 1 Roadway Alignments and Watersheds

Four roadway alignments were ultimately selected for analysis. Alignment B/O widened LA-21 to a four-lane highway from Bush to Waldheim, LA, and continued south approximately 19.5 miles, with 12.5 miles of new alignment. Alignment P began at the intersection of LA-41 and LA-40 in Bush, LA, proceeding south approximately 17.4 miles to LA-1088 with nearly 13.3 miles of roadway construction. Alignment Q included construction of a four-lane highway beginning at I-12 exit 74, tying into LA-434, and following an abandoned railroad corridor. This alignment was approximately 20.0 miles long, with 9.8 miles using the abandoned railroad embankment, 8.7 miles on new alignment, and 1.3 miles on existing roadway. Alignment J constructed a new four-lane highway from I-12 exit 80, connecting to Airport Road, and following the abandoned railroad corridor to Bush. This proposed route was approximately 21.1 miles long, with 14.2 miles using the abandoned railroad embankment, 5.4 miles on new alignment, and 1.5 miles of existing roadway.

2. METHOD

Roadway alignments that cross channels, swamps, and wetlands alter natural drainage patterns disrupting ecology and hydrology within environmentally sensitive areas. Impacts from the proposed alignments on the natural overland sheet flow and adjacent environmentally sensitive areas were analyzed using MIKE FLOOD developed by the Danish Hydraulic Institute (DHI 2011).

MIKE FLOOD provided an integrated one and two-dimensional numerical modeling approach which allowed for the assessment of over 380 miles of channel and overland flow within the 93,002 acre study area.

MIKE FLOOD can be used to model the flow exchange between wetlands, open water bodies, and channel network systems. It couples the one-dimensional, open channel flow modeling capabilities of MIKE11 with the two-dimensional, overland flow modeling of MIKE21 (Figure 2). MIKE11 was capable of modeling the complex channel network need for I-12 to Bush, and the wetting and drying capability of MIKE21 allowed for accurate modeling of overland flow, shallow ponds, and other open water bodies.

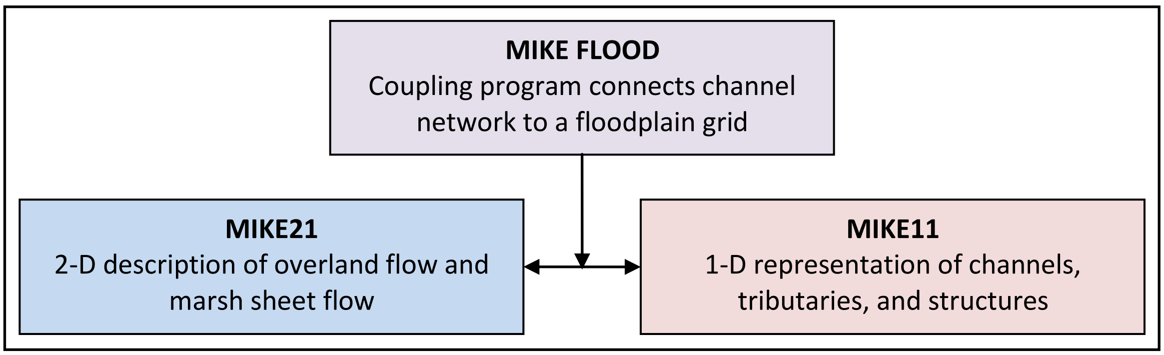

Figure 2 Schematic Diagram of MIKE FLOOD

2.1 MIKE11 Setup

The channel network was digitized directly from geo-referenced Digital Orthophoto Quarter Quads (DOQQ) imagery, topographic maps, and LiDAR data (Figure 3). A total of 178 channel branches were included in the MIKE11 model spanning 381 stream miles.

Cross section cut-lines were extracted from LiDAR data, and channel inverts were approximated using Federal Emergency Management Agency (FEMA) hydraulic models. In areas lacking FEMA data, channel widths were estimated from aerial photography, and overall channel geometries were assumed to follow a generic parabolic shape (Figure 4). Invert elevations were set based on typical depths from comparable streams, and linearly increased downstream. In the absence of detailed field measurements and survey data, the embankments for the hydraulic structure crossings within the system were estimated and included in the channels' cross-section geometry. Over 150 existing structures were identified and 7,409 cross sections were included in the model.

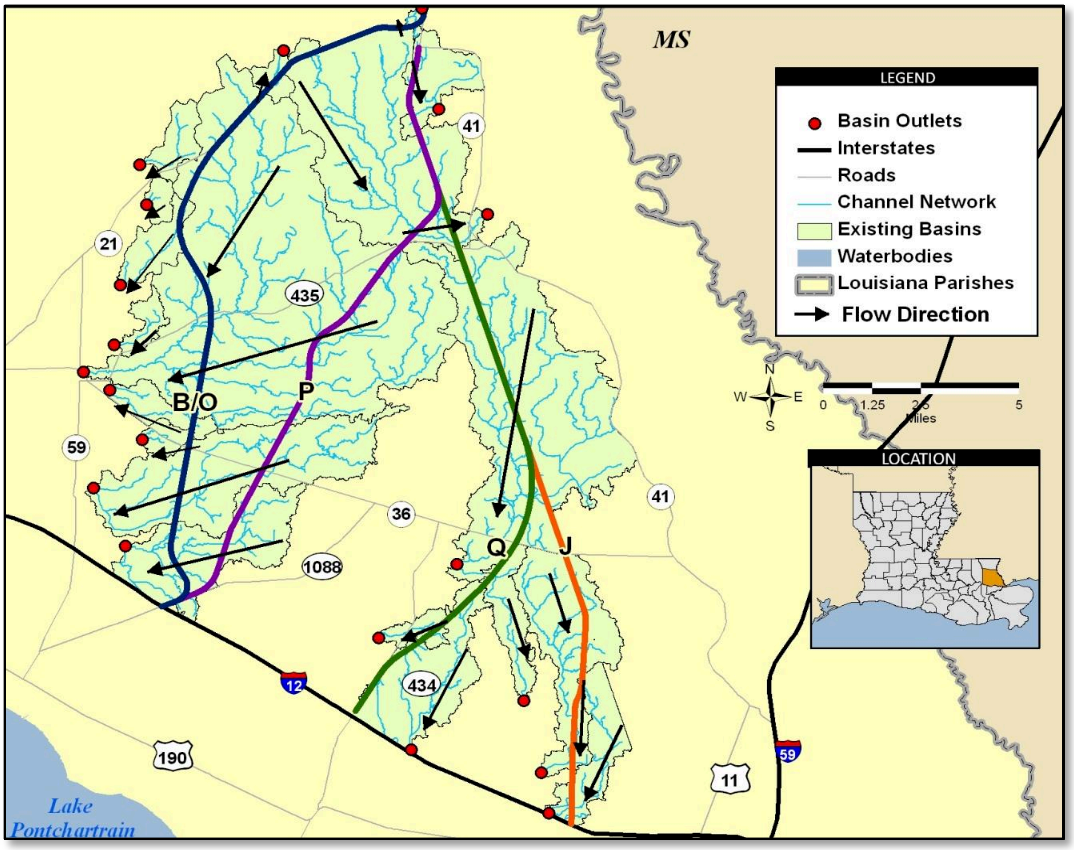

Figure 3 Flow Direction and Channel Network

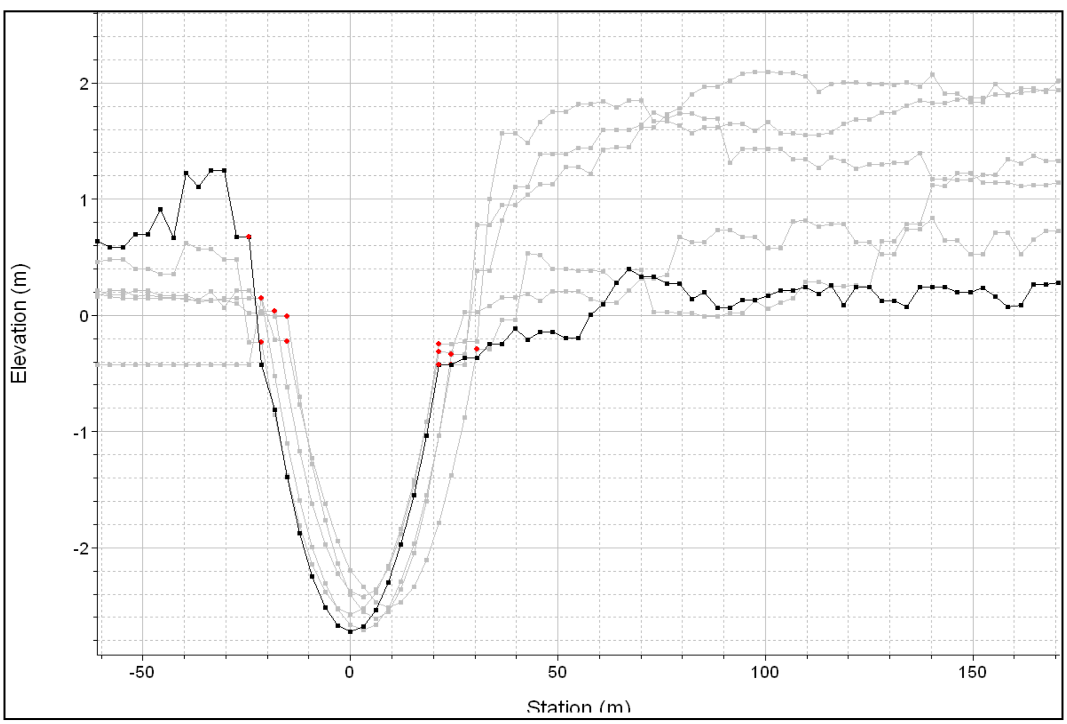

Figure 4 Estimated Channel Cross-section Geometries

2.2 MIKE21 Setup

A two-dimensional, rectangular grid was developed to capture flows in the overland areas. Numerical simulations were performed with various spatial resolutions to determine appropriate grid size. A spatial resolution of 100 meters by 100 meters adequately represented overland flow. A Manning's coefficient of 0.33 was assumed for the overland areas to reflect resistance caused by the dense brush and forests within the study area.

2.3 MIKE FLOOD Setup

The MIKE11 and MIKE21 models were linked to capture flow exchange between the channel network and overland areas. Under the current setup, the model run time is 12 hours of computational time for a four-day storm event.

The existing conditions model was verified against the April 2008 Preliminary FEMA Flood Insurance Rate Map (FIRM). The 100-year Soil Conservation Service (SCS) Type III frequency storm (NRCS 1986) was used as the rainfall boundary condition, with the April 2008 Preliminary FEMA Base Flood Elevations (BFEs) used as tail-water boundary conditions. Peak discharges from MIKE FLOOD were compared to those listed in the FEMA Flood Insurance Study (FIS). This verification approach does not provide a full assessment of the model performance, however, in absence of stage or discharge field measurements, the BFEs and FISs provided by FEMA were considered the best available data to assess model performance.

Historical records of precipitation data were obtained from three rainfall stations located within St. Tammany Parish (Slidell, Abita Springs, and Covington, Louisiana). These stations recorded data from 1900 to 2010, with a common period of 1973 to 2010. Based on the available records, the average monthly rainfall for the St. Tammany area is approximately 5.2 inches (Figure 5).

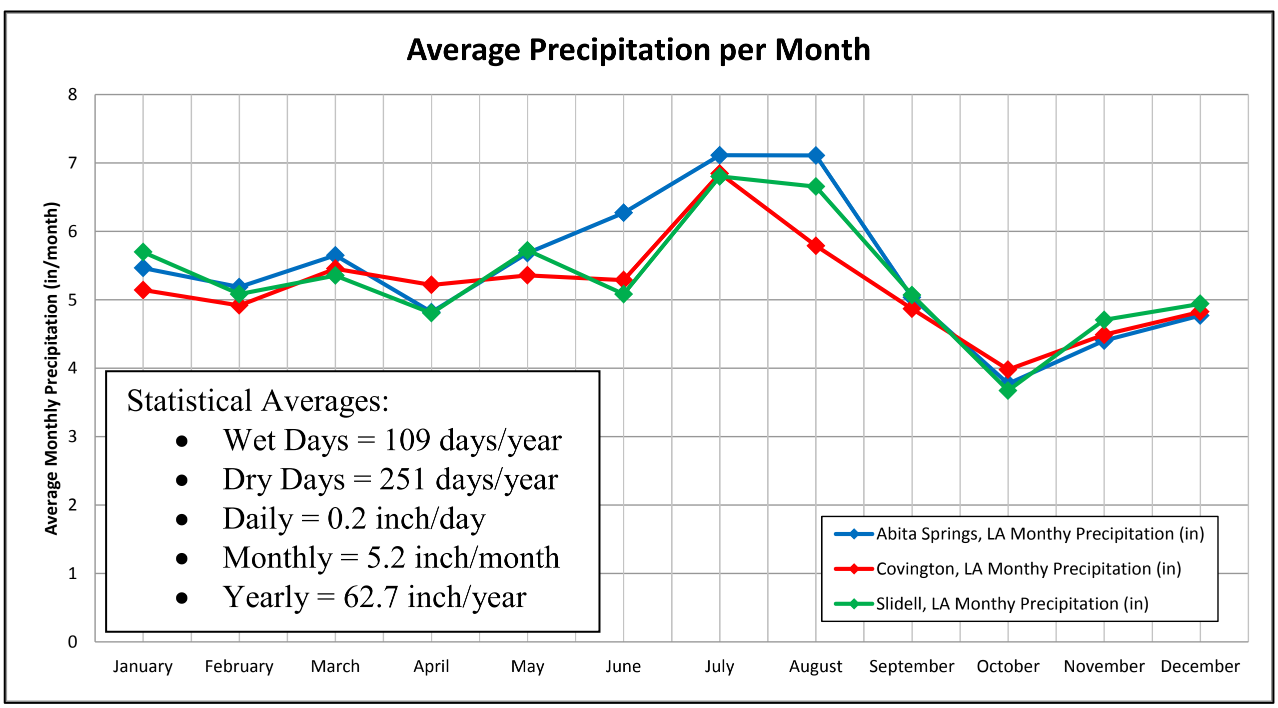

Figure 5 Precipitation Statistics and Average Monthly Precipitation

3. RESULTS

Roadway construction in shallow systems such as eastern St. Tammany Parish may alter the natural drainage patterns and flow exchange between streams and surrounding wetland areas. Several analysis methods were investigated in this EIS to determine wetland impacts (Wright 2006):

- Topography and Canopy Impacts
- Inundation Impacts
- Water Level Impacts

Changes to sedimentation and nutrient loading within channels may occur as a result of roadway construction and urbanization to a natural wetland system. These changes are directly tied to velocities and other hydraulic parameters within the channels. Since no channel surveys were available during this EIS, it was not possible to quantify the indirect impacts on wetlands due to sediment deposition, pollutant accumulation, or nutrient discharges.

A normalized score was used for each hydrologic stressor to present a comparative analysis and ranking system for each alignment (Equation 1). This scoring system is designed such that an alignment with no impact would receive a score of zero and the alignment with the largest impact would receive a score of ten (Table 1).

$$Normalized\ Score = \frac{alignment\ value}{\max alignment\ value} \times 10 \quad (1)$$

Table 1 Definition of Normalized Values

Normalized Value	Definition
0	No Impact
10	Largest Impact

3.1 Topography and Canopy Impacts

Roadway construction may require clearing of canopy and vegetation, and may change the existing canopy and topography when constructed on undeveloped terrain. For the purpose of this EIS, it was assumed alignments constructed on existing roadways or abandoned rail beds posed no additional impact to the surrounding environment. Each alignment was assessed to determine the length of new roadway construction on undeveloped land (Table 2).

Table 2 Topography and Canopy Impact Ranking

Rank	Alignment	Length of New Roadway (miles)	Normalized Score
1	ALT J	5.4	3.6
2	ALT Q	8.7	5.9
3	ALT B/O	12.5	8.4
4	ALT P	14.8	10

Wetland areas were delineated using hydric soil classifications (USGS 2010) and LiDAR data (Figure 6). These wetland areas were used for analysis purposes only, and may not match with areas classified as wetlands in other publications. In order to properly classify an area as a wetland a complete field investigation and wetland delineation outside of the alignment right-of-ways is needed. Such extensive field investigation was beyond the scope of this EIS. The analysis shown in Table 3 examined direct wetland impacts by determining the acreage of wetland area within each alignments 250 feet right-of-way.

Table 3 Direct Wetland Impact Ranking

Rank	Alignment	Direct Wetland Impacts (acres)	Normalized Score
1	ALT Q	305	7.9
2	ALT P	358	9.3
2	ALT J	373	9.7
4	ALT B/O	385	10

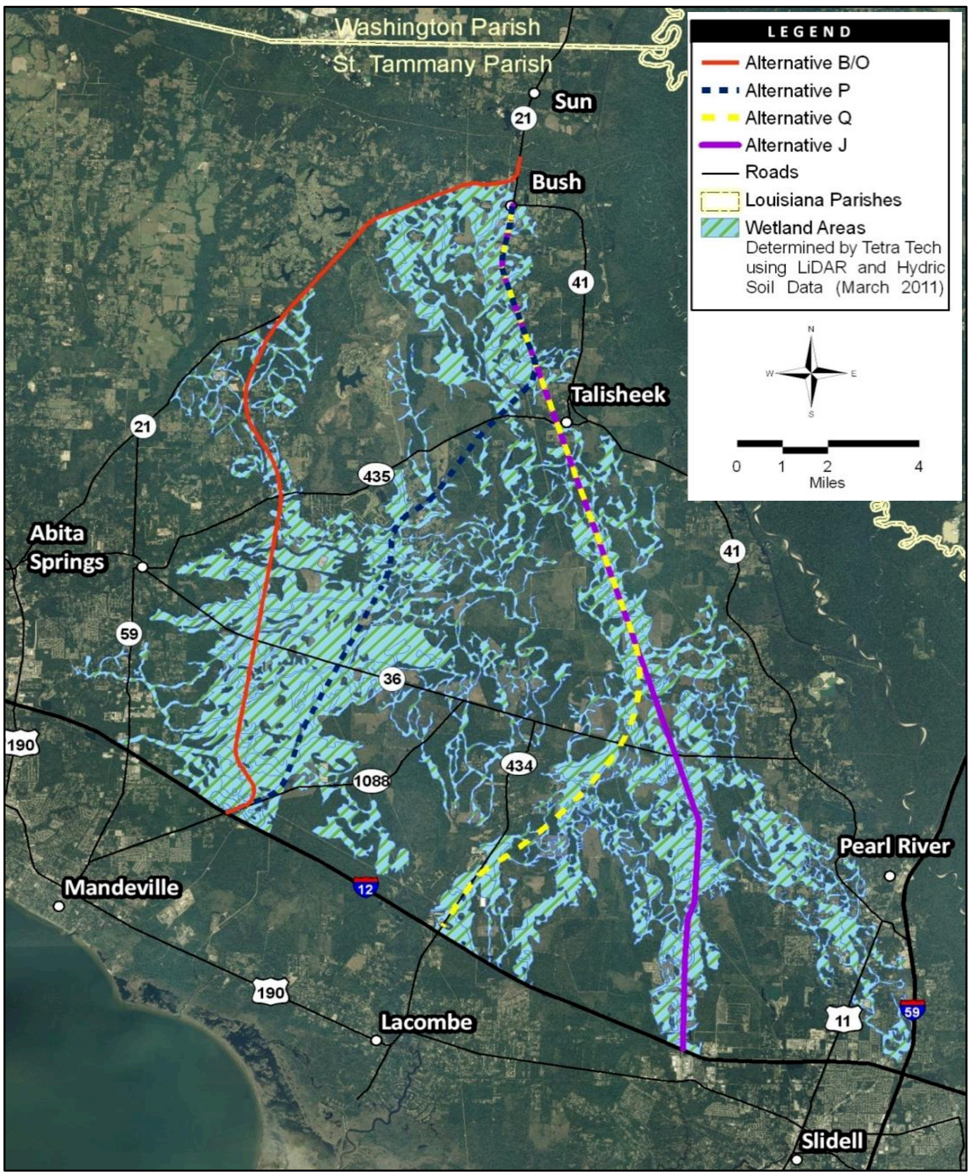

Figure 6 Wetland Areas Delineated Using Hydric Soil and LiDAR Data

3.2 Inundation Impacts

Wetland inundation duration impacts may occur when roadway construction alters the natural overland flow. Increasing or reducing the inundation duration may lead to changes in wetland type, function, and quality (Wright 2006). This analysis examined wetland (Figure 6) impacts to inundation for each alignment using a typical monthly rainfall described in Section 2.3. Three, five, and seven day durations were agreed upon as sufficient to affect wetlands through discussions with the participating agencies, wetland scientists, and researchers.

Wetland inundation was analyzed for the existing conditions and compared to each alignment. Inundation increase was defined as wetland areas inundated for three, five, or seven consecutive days with a depth greater than 0.025 meters compared to existing conditions; and inundation reduction were those areas that had depths less than 0.025 meters for three, five, or seven day compared to exiting conditions. As shown in Figure 7, the comparison between the existing conditions and a given alignment reveals areas that have not been impacted, new inundated areas, and areas that have been drained as a result of constructing a given alignment.

The results for the three, five, and seven-day inundation analyses are summarized in Tables 4 and 5. Overall, the analysis shows that the number of days of inundation duration is not a critical factor in terms of identifying the acreage of wetlands impacted.

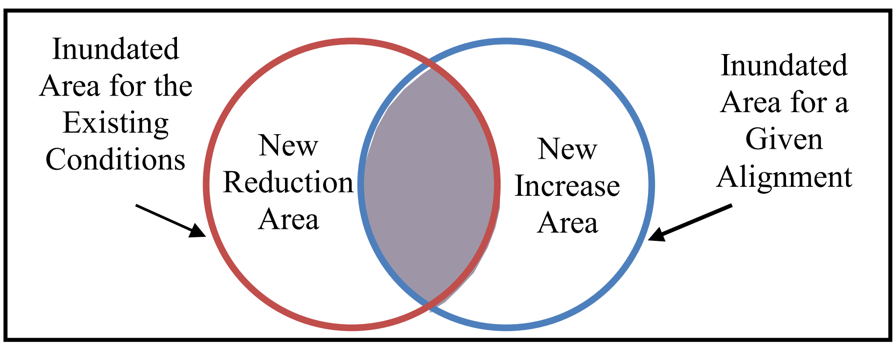

Figure 7 Inundation Impact Schematic

Table 4 Increase in Wetland Inundation Impact Ranking

Duration (days)	Rank	Alignment	Increase in Wetland Inundation (Acres)	Normalized Score
3	1	ALT J	264	5.8
3	2	ALT Q	335	7.4
3	3	ALT B/O	441	9.7
3	4	ALT P	454	10
5	1	ALT P	288	5.7
5	2	ALT Q	312	6.2
5	3	ALT J	436	8.7
5	4	ALT B/O	501	10
7	1	ALT P	329	6.9
7	2	ALT Q	339	7.1
7	3	ALT B/O	406	8.5
7	4	ALT J	475	10

Table 5 Reduction in Wetland Inundation Impact Ranking

Duration (days)	Rank	Alignment	Decrease in Wetland Inundation (Acres)	Normalized Score
3	1	ALT Q	197	5.8
3	2	ALT P	214	6.3
3	3	ALT B/O	286	8.4
3	4	ALT J	340	10
5	1	ALT Q	192	6.2
5	2	ALT P	197	6.3
5	3	ALT B/O	230	7.4
5	4	ALT J	310	10
7	1	ALT P	196	6.2
7	2	ALT Q	200	6.3
7	3	ALT B/O	234	7.4
7	4	ALT J	316	10

3.3 Water Level Impacts

Water level impacts examined the difference in maximum and minimum water levels in a wetland for a given frequency storm; often used to quantify a wetland's hydro period. Water level typically increases in response to moderate or large storm events, but quickly returns to base levels. These changes in water level are commonly referred to as the "bounce" in water levels during and after a storm event. Research shows that changes to wetland water level fluctuations may cause a consistent decline in diversity and often an increase in invasive species (Wright 2006). The water level impact analysis was performed for the 2, 25, and 100-year storm events (Table 6).

Table 6 Frequency Storm Precipitation

Frequency Storm	Rainfall Depth (inches)
2-Year	4.8
25-Year	9.6
100-Year	12.6

Changes to wetland water levels between the existing conditions and each alignment were recorded if the change exceeded a 0.025 meters (whether an increase or decrease). The wetland area registering such a change is shown in Table 7.

Table 7 Increase in Wetland Inundation Impact Ranking

Frequency Storm (years)	Rank	Alignment	Water Level Impacts (Acres)	Normalized Score
2	1	ALT P	937	4.7
2	2	ALT B/O	1,235	6.2
2	3	ALT Q	1,374	6.8
2	4	ALT J	2,007	10
25	1	ALT P	1,629	5.7
25	2	ALT Q	1,759	6.1
25	3	ALT B/O	1,894	6.6
25	4	ALT J	2,869	10
100	1	ALT Q	2,470	6.4
100	2	ALT B/O	2,487	6.4
100	3	ALT P	2,516	6.5
100	4	ALT J	3,864	10

4. CONCLUSIONS

The impact of each alignment is shown in Table 8. The five day increase and reduction in wetland inundation was selected as the comparison period since there were minimal differences between the three analysis periods. The two year water level fluctuation was selected because this storm event occurs more often of the three frequency storms analyzed. A summary of normalized scores is shown in Table 9. Based on the drainage, direct wetland impact, and indirect wetland impact analyses Alignment Q is the most favorable alignment. Alignment P is a close second with Alignments B/O and J showing the largest impacts.

Table 8 Alignment Impact Summary

Alignment	Length of New Roadway (miles)	Direct Wetlands Impact (acres)	5-day Increase in Wetland Inundation (acres)	5-day Reduction in Wetland Inundation (acres)	2-year Water Level Fluctuation (acres)
ALT B/O	12.5	385	501	230	1,235
ALT J	5.4	373	436	310	2,007
ALT P	14.8	358	288	197	937
ALT Q	8.7	305	312	192	1,374

Table 9 Alignment Normalized Ranking Summary

Rank	Alignment	Normalized Score
1	ALT Q	33.1
2	ALT P	36.1
3	ALT B/O	42.0
4	ALT J	42.0

This EIS examined multiple direct and indirect wetland impacts caused by roadway construction. As shown in Tables 8 and 9, multiple factors were analyzed and a normalized ranking system was developed to determine the least impactful alignment. Sedimentation and nutrient loads were out of the scope of this EIS and were not studied.

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