6.0. ECONOMIC RESOURCES

This section quantifies several major economic impacts of potential Phase 1 Study Area project alternatives compared to no-action. The driving force of these economic impacts will be the changes in hydrologic conditions associated with barrier island and wetlands losses. The estimation procedure is to select those potential impacts that are both important and quantifiable, and are physically tied to the storm and wave related changes that would result from barrier island and wetlands losses. The procedure is to compare future without project conditions and their economic implications, with the future with project conditions.

The economic impacts analyzed in this report are limited to those which are both likely to be important in magnitude and that are quantifiable given existing data and estimation methodologies. These economic impacts are a result of changes in coastal flooding regimes that may be altered by the project scenarios. These impacts are largely increases in costs associated with residing and operating businesses in flood prone coastal areas and with losses to recreational activity and the commercial fishing industry. Flooding scenarios under two types of Category 5 hurricanes will be used, along with flood damage functions to estimate the damages of storms for the three project conditions.

A complicating factor in analyzing economic impacts is the possible alteration of coastal population patterns under the three different project conditions. In principle, any increase in the likelihood or intensity of coastal flooding would adversely alter economic conditions in the coastal region. This would result in increases in the cost of living and doing business in coastal flood-prone areas. The effect may be to cause some people to reconsider coastal residence and business activity. One counteracting factor to any regional decline, however, would be broader economic development conditions in the state and region as a whole. These conditions may counteract any coastal out-migration. This study assumes that coastal populations will remain fixed at current levels. This may

be a reasonable assumption, as population stability has marked coastal Louisiana during the past decade (LADNR 1998f).

This report limits flood related damage and wetlands loss estimates to the study area defined for the barrier island project analysis. This area is limited to all or parts of an eleven-parish region in coastal Louisiana. The eleven parishes are: Ascension, Assumption, Jefferson, Lafourche, Orleans, Plaquemines, St. Charles, St. James, St. John, St. Mary and Terrebonne. These eleven parishes are shown in Figure 6-1. Flood damage analysis is performed at the Census Tract level. This level of resolution is dictated by the demographic and flood-depth resolutions.

In Section 6.1, a correlation between wetlands related loss is used to quantify impacts on the recreational and commercial fishing industries. Section 6.2 of this report outlines the hydrologic data used for deriving flooding conditions. Flood scenario data are coupled with US Army Corps of Engineer (USACE) flood damage data, which estimates total flood damages to residential and commercial properties from floods of varying depths. Section 6.1 explains these data and how they will be used in this report. Sections 6.3 and 6.4 present the prototype storm related flood damage estimates and analyses how these damages are expected to differ across the three project conditions. Section 6.5 is a summary of benefits of project Alternatives 1 and 2 compared to no-action.

Figure 6-1. The Eleven Parish Study Area
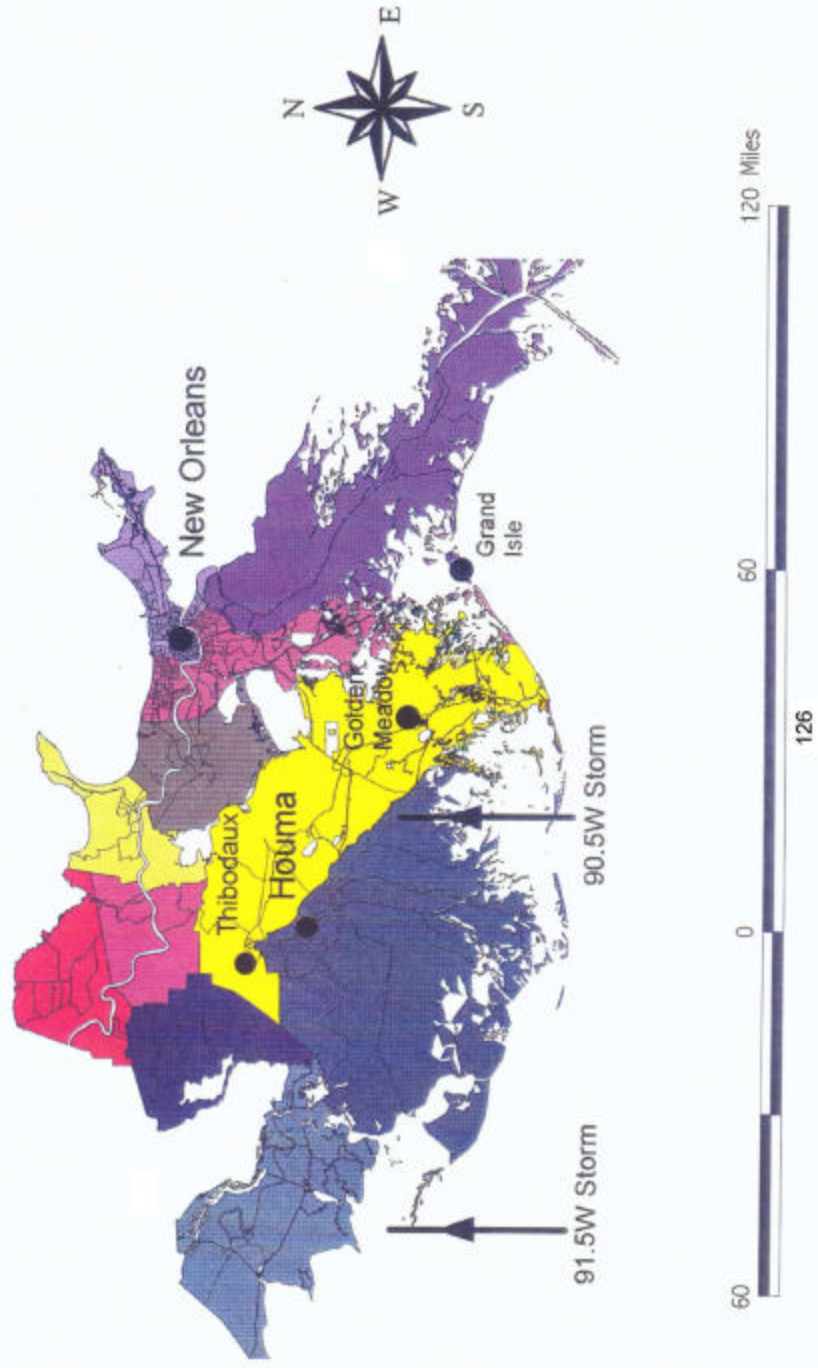
6.1. Wetlands And Marsh Losses

Wetland losses in the study area were estimated by the project team using historic loss rates projected to 30- and 100-years. The procedure is explained in the Step G Report (LADNR 1998g). The total acres of interior fresh, intermediate, brackish and saline marsh in the study area in 1990 was estimated to be 366,113 hectares (904,681 acres). The projected interior marsh area in 30-years under no-action at historic loss rates was estimated to be 307,482 hectares (759,802 acres), a loss of 16.0% of the 1990 wetlands acreage; and in 100-years only 231,373 hectares (571,733 acres), a loss of 36.8% of 1990 wetlands acreage. These represent losses of 58,630 hectares (144,877 acres) over the first 30-years under no-action, or 1,954 hectares (4,828 acres) per year; and an additional loss of 76,109 hectares (188,069 acres), or 1,087 hectares (2,686 acres) per year, over the remaining 70 years. Table 6-1 shows these annual wetlands losses for the no-action scenario.

The project alternatives alter these wetland losses. For example, under Alternative 1, the projected interior marsh area in 30-years is 311,095 hectares (768,729 acres), a savings of 3,613 hectares (8,928 acres) of interior wetlands compared to no-action (LADNR 1998g). Alternative 1 implies an annual wetlands loss of only 1,834 hectares (4,532 acres) per year, compared to 1,954 per year under no-action, as shown in Table 6-1. Over the remaining 30- to 100-year period, it is estimated that Alternative 1 will result in a total interior wetlands loss of only 71,586 hectares (176,892 acres), or an annual loss over that period of 1,023 hectares (2,528 acres) per year (LADNR 1998g). Table 6-1 shows these annual loss rates under the Alternatives for the two periods.

Under Alternative 1, interior wetlands will be 239,509 hectares (591,837 acres) in 100-years, compared to 1990 acreage of 366,113 hectares (904,681 acres), a reduction of 34.6%. This compares to a 36.8% loss under no-action. Alternative 2 would result in 234,956 hectares (580,587 acres) in 100-years, a reduction of 35.8% compared to 1990 wetlands acreage.

Table 6-1. Estimated Annual Interior Wetlands Losses under Project Alternatives and for No-action, 30-, and 100-Years*

Scenario	Total Interior Wetlands in 30-Years	Annual Loss Rate Over 0-30-year Period	Total Interior Wetlands in 100-years	Annual Loss Rate Over 30-100-year Period
No-action	307,482 ha	1,954 ha/yr	231,373 ha	1,087 ha/yr
Alternative 1	311,095 ha	1,834 ha/yr	239,509 ha	1,023 ha/yr
Alternative 2	307,798 ha	1,944 ha/yr	234,956 ha	1,041 ha/yr

* Acreage does not include marsh created on the barrier islands
1 hectare = 2.47 acres

Under Alternative 1, interior wetland acreage will be 239,509 hectares (591,837 acres) in 100-years, compared to 1990 acreage of 366,113 hectares (904,681 acres), a reduction of 34.6%. This compares to a 36.8% loss under no-action. Alternative 2 would result in 234,956 hectares (580,587 acres) in 100-years, a reduction of 35.8% compared to 1990 wetlands acreage.

In addition to reducing interior wetlands loss rates, Alternatives 1 and 2 will actually create new barrier island ecosystems. For example, Alternative 1 will create 4,990 hectares (12,331 acres) of new saline marsh within the barrier island system. Alternative 2 creates 2,637 hectares (6,516 acres) of saline marsh. Beach and Vegetated Dunes are also created under these Alternatives, as shown in Table 6-2.

Table 6-2. New Barrier Island Ecosystems Created by Project Alternatives

Ecosystem	Alternative 1	Alternative 2
Saline Marsh	4,990 ha	2,637 ha
Beach	967 ha	977 ha
Vegetated Dune	391 ha	394 ha

1 hectare = 2.47 acres

We can estimate and compare the economic value of interior wetlands saved and barrier island saline marsh created under the project alternatives. Wetland losses will result in reduced catch to commercial and recreational fishing due to reductions in habitat

and nutrient sources. For the economic section of this report, the simple assumption is made that stocks of commercial and recreational species diminish in proportion to wetlands area in the study area. Reduced commercial catch will lower profits, and reduced recreational catch will lower fishing enjoyment. The economic implications of these two effects can be measured. Effects of wetland habitat and nutrient losses will alter fish species composition. The Step H report suggests possible faunal impacts, although these effects are not quantified in a manner useful for estimation of economic losses (LADNR 1998h.i).

6.1.1. Commercial Fishery Losses

In order to estimate the impact on commercial fishing incomes, we make the simplistic assumption that fishing effort will remain constant in spite of reduced stock. (While effort would likely diminish, there is no way of estimating that.) The loss of catch is then the result of reduced catch for the same effort, and can be estimated using the marginal product of wetlands for commercial fishery harvest. Farber and Costanza (1987) have made such estimates for coastal Louisiana, and Bell (1989) has made estimates for coastal Florida. These studies estimate the present value of the marginal product of wetlands for commercial catch to be approximately $91 to $128 per hectare ($37 to $52 per acre) in 1990 dollars. Inflating this estimate to 1995 dollars using the Consumer Price Index results in a present value of $102.55 to $144.06 per hectare ($41.51 to $58.32 per acre). This means, for example, that losing one-hectare of wetlands, say, ten years from the present will result in a value loss at that time of $102.55 to $144.06 per hectare. The present value of that loss requires discounting the $102.55 or $144.06 per hectare over the ten-year period.

Recall that annual wetlands losses under no-action will be 1,954 hectare (4,828 acres) per year for the first 30-years, and 1,087 hectares (2,686 acres) per year for the remaining 70-years. The economic value of these losses is obtained by first calculating the value of wetlands losses in each of the 100-years, using the different loss rates for the 30- and 70-year periods. This stream of economic losses is then discounted using the

various discount rates employed in this study. The present values of these commercial fisheries losses over the 30- and 100-year periods are shown Table 6-3. Several discount rates are used, including the 8.25% discount rate mandated for US Army Corps of Engineers water projects (US Army Corps of Engineers, 1994) in 1993. For example, under no-action and the 8.25% discount rate, commercial fisheries losses attributable to loss of interior wetlands range from $2.204 million to $3.096 million over the 30-year period. Annualized losses over this 30-year period range from $0.182 to $0.256 million per year. The 5% and 3% discount rates generate present value loss estimates over the 100-year period ranging from $3.556 million to $7.343 million. Losses under Alternatives 1 and 2 are also shown in Table 6-3.

Table 6-4 summarizes the cost savings, or reductions in commercial fisheries losses under the two alternatives. For example, consider loss reductions under Alternative 1 compared to no-action. Table 6-3 shows that the low estimated present value of commercial fisheries losses over the 30-year period under no-action was $2.204 million, using the 8.25% discount rate. Comparable fisheries losses under Alternative 1 were $2.068 million. Hence, there was a reduction of $0.136 million in losses under Alternative 1 compared to no-action. This value is shown in column 5 of Table 6-4 below. This value represents the present value of commercial fishery benefits for Alternative 1 compared to no-action over the 30-year period. Table 6-4 shows that loss reductions, or benefits, over the 30-year period of Alternative 1 compared to no-action range from $0.136 to $0.339 million, depending on the discount rates used for present value calculations. The annualized values over this period range from $0.011 to $0.016 million per year.

Table 6-3. Present and Annualized Values of Commercial Fishery Losses Due to Wetlands Loss Under No-action and Project Alternatives ($ millions)

Base Condition	Compared to:	Period (Years)	Low/High	8.25% Present Value	8.25% Annualized Value	5.00% Present Value	5.00% Annualized Value	3.00% Present Value	3.00% Annualized Value
Current Condition	No-action	30	Low	$2.204	$0.182	$3.080	$0.155	$3.928	$0.124
			High	$3.096	$0.255	$4.327	$0.218	$5.517	$0.175
		100	Low	$2.319	$0.191	$3.555	$0.179	$5.220	$0.165
			High	$3.258	$0.269	$4.994	$0.252	$7.334	$0.232
Current Condition	Alternative 1	30	Low	$2.068	$0.171	$2.891	$0.146	$3.686	$0.117
			High	$2.906	$0.240	$4.061	$0.205	$5.179	$0.164
		100	Low	$2.177	$0.180	$3.338	$0.168	$4.903	$0.155
			High	$3.058	$0.252	$4.689	$0.236	$6.888	$0.218
Current Condition	Alternative 2	30	Low	$2.192	$0.181	$3.065	$0.154	$3.907	$0.124
			High	$3.080	$0.254	$4.305	$0.217	$5.489	$0.174
		100	Low	$2.303	$0.190	$3.519	$0.177	$5.146	$0.163
			High	$3.235	$0.267	$4.943	$0.249	$7.229	$0.229

Table 6-4 shows that the estimated loss reductions, or benefits, of Alternative 2 compared to no-action range from a present value of $0.011 to $0.028 million for the 30-year period, depending on discount rates. Table 6-4 also shows loss reductions, or benefits, of the Alternatives are greater for the 100-year than the 30-year period, as expected.

Table 6-4. Present and Annualized Values of Reductions in Commercial Fishery Losses Attributable to Project Alternatives ($ millions)

Losses Under	MINUS Losses Under	Period (Years)	Low/High	8.25% Present Value	8.25% Annualized Value	5.00% Present Value	5.00% Annualized Value	3.00% Present Value	3.00% Annualized Value
No-action	Alternative 1	30	Low	$0.136	$0.011	$0.189	$0.010	$0.241	$0.008
			High	$0.190	$0.016	$0.266	$0.013	$0.339	$0.011
		100	Low	$0.142	$0.012	$0.217	$0.011	$0.317	$0.010
			High	$0.200	$0.016	$0.305	$0.015	$0.446	$0.014
No-action	Alternative 2	30	Low	$0.011	$0.001	$0.016	$0.001	$0.020	$0.001
			High	$0.016	$0.001	$0.022	$0.001	$0.028	$0.001
		100	Low	$0.016	$0.001	$0.036	$0.002	$0.075	$0.002
			High	$0.023	$0.002	$0.050	$0.003	$0.105	$0.003

In addition to reducing interior wetland losses, the project Alternatives will result in new barrier island salt marsh. Table 6-2 shows that Alternative 1 will create 4,982 hectares (12,311 acres) of new salt marsh, and Alternative 2 will create 2,637 hectares (6,516 acres). The assumption is that the newly created marsh will gradually become fully productive within 10 years of project initiation. We also assume its functionality will increase linearly over that period, so Alternative 1 will add 498 effective hectares (1,231 acres) of marsh per year over the 10 year period, and Alternative 2 will add 264 hectares (652 acres) per year over that period.

We can use the estimated $102.54 to $144.06 per hectare ($41.51 to $58.32 per acre) commercial fishery marginal productivity values described above to estimate the value of this new salt marsh. Table 6-5 shows the present and annualized values of the gains to commercial fisheries from new salt marsh. For example, under Alternative 1, 498 hectares (1,231 acres) are created per year for each of 10 years. When the marginal product of an acre of marsh is valued at $102.54 per hectare, the present value of this gain is estimated to be $0.339 million, using the 8.25% discount rate, as shown in column 4 of Table 6-5. The annualized value of this gain, when annualized over a project period of 30-years, is $0.031 million per year. Using the high value of marginal productivity, $144.06 per hectare, the present value of Alternative 1 new marsh creation is $0.476 million. The present values are the same whether a 30 or 100-year period of analysis is used, since the gains will be fully experienced within 10-years, by assumption. However, the annualized values will depend upon whether the period of analysis is 30- or 100-years. Table 6-5 shows that Alternative 2 provides less commercial fisheries gains than Alternative 1; for example gains of only $0.180 to $0.252 million for the 30-year period using the 8.25% discount rate.

Table 6-5. Commercial Fishery Gains from New Barrier Island Salt Marsh Creation by Project Alternative ($millions)

	Period (Years)	Low/ High	8.25% Present Value	Annualized Value	5.00% Present Value	Annualized Value	3.00% Present Value	Annualized Value
Alternative 1	30	Low	$0.339	$0.031	$0.394	$0.026	$0.436	$0.022
		High	$0.476	$0.043	$0.554	$0.036	$0.612	$0.031
	100	Low	$0.339	$0.028	$0.394	$0.020	$0.436	$0.014
		High	$0.476	$0.039	$0.554	$0.028	$0.612	$0.019
Alternative 2	30	Low	$0.180	$0.016	$0.416	$0.027	$0.530	$0.027
		High	$0.252	$0.023	$0.584	$0.038	$0.745	$0.038
	100	Low	$0.180	$0.015	$0.416	$0.021	$0.530	$0.017
		High	$0.252	$0.021	$0.584	$0.029	$0.745	$0.024

6.1.2. Recreational Losses

Recreation will be adversely impacted by barrier island loss due to reductions in wetland habitat and nutrient flows to fisheries. A study of Louisiana recreationists by Bergstrom and Stoll (1990) measured the loss to recreationists from reduced bag and catch in wetland areas. Recreationists would value a 50% reduction in catch or bag at $66 per year per user (1986), or $92 in 1995. Users place a value on current conditions but would place a lower value if catch or bag conditions were less desirable.

Estimated interior wetland losses under no-action over the 100-year period were estimated to be 36.8% of the 1990 wetlands area (see above). We assume that a 37% reduction in catch or bag would be valued at (37%)/(50%) = 0.74 times $92, or $68.08 per year per user. We also assume that catch or bag would fall proportionally with wetland loss over time, so the $68.08 annual loss would increase linearly from $0 at present to $68.08 in 100-years.

Estimated interior wetlands loss over the 100-year period under Alternative 1 was estimated in Step G to be 34.6% of 1990 acreage (see above) (LADNR 1998g). In addition, Alternative 1 would create 4,990 hectares (12,331 acres) of new barrier island saline marsh. If new marsh were simply added to the interior marsh acreage, Alternative

1 would result in a net loss of only 33.2% of original 1990 interior wetlands. Similarly, Alternative 2 would result in a loss of 35.8% of 1990 acreage; and when new barrier island saline marsh is added to the interior acreage, only a net loss of 35.1% is calculated over the 100-year period. Using the logic reflected in the no-action calculations, Alternative 1 results in an ultimate annual loss of $60.72 per year (33.2/50 = 0.66 times $92) in 100-years; and Alternative 2 results in an ultimate annual loss of $64.40 (35.1/50 = 0.70 times $92) in 100-years. A similar linearity assumption is made that these losses increase from $0 annually to $60.72 and $64.40 per year, respectively, over the 100-year period.

The Bergstrom and Stoll (1990) study estimated a total of 76,000 recreational users (not total visits) annually in 1986 within the seven parish regions surrounding Terrebonne-Barataria Bays. It is not obvious whether recreational use will increase, decrease or remain the same. Usage trends will depend upon population growth in the region, recreational interest, and the quality of recreational activity in the region. If recreational use will increase over time, losses in recreational value will be higher than if use remains constant, as more people will be experiencing diminished recreational enjoyment as wetlands disappear. We make two estimates of recreational losses: 1) recreational use remains constant at 76,000; and 2) recreational use diminishes at a rate proportional to wetland loss. For example, under no-action, wetlands losses in 100-years are projected to be 36.8% (LADNR 1998g), implying annual usage will fall from 76,000 users currently to 48,032 in 100-years. Similar usage rates can be estimated for wetland losses under the two project alternatives. Usage rates under Alternative 1 will fall by 33.2% to 50,768 users annually in 100-years; and rates under Alternative 2 will fall by 35.1% to 49,324 users.

The present values of these recreational losses over the 30- and 100-year periods are shown in Table 6-6. Using the 8.25% discount rate, the present value of these recreational losses under no-action range from $5.5 to 5.9 million for the 30-year period and from $7.47 to $8.20 million for the 100-year period. Losses under Alternative 1 range from $4.99 to $5.26 million for the 30-year period and from $6.36 to $6.87 million

for the 100-year period. The present values of losses are also shown for 5% and 3% discount rates. These are substantially higher than losses estimated using the 8.25% discount rate. Annualized values are also shown in Table 6-6.

Table 6-6. Present Value of Recreational Fishery Losses Due to Wetlands Loss Under Project Alternatives ($ millions)

Base Condition	Compared to:	Period (Years)	Low/High	8.25% Present Value	8.25% Annualized Value	5.00% Present Value	5.00% Annualized Value	3.00% Present Value	3.00% Annualized Value
Current No-action Condition		30	Low/	$5.529	$0.503	$9.246	$0.601	$13.183	$0.673
			High	$5.859	$0.533	$9.874	$0.642	$14.144	$0.722
		100	Low/	$7.473	$0.617	$17.985	$0.906	$38.842	$1.229
			High	$8.204	$0.677	$20.779	$1.047	$47.159	$1.492
Current Condition	Alternative 1	30	Low/	$4.990	$0.454	$8.352	$0.543	$11.913	$0.607
			High	$5.257	$0.478	$8.859	$0.576	$12.691	$0.648
		100	Low/	$6.769	$0.559	$16.383	$0.825	$35.583	$1.126
			High	$7.361	$0.608	$18.645	$0.939	$42.316	$1.339
Current Condition	Alternative 2	30	Low/	$5.260	$0.478	$8.799	$0.572	$12.548	$0.640
			High	$5.558	$0.505	$9.366	$0.609	$13.418	$0.685
		100	Low/	$7.121	$0.588	$17.184	$0.866	$37.212	$1.178
			High	$7.782	$0.642	$19.712	$0.993	$44.738	$1.416

Alternatives 1 and 2 result in lower recreational losses than no-action. Table 6-7 estimates these loss reductions, or benefits, of the alternatives compared to no-action. For example, column 5 shows these estimates using the 8.25% discount rate. Alternative 1 results in lower present values of recreational losses compared to no-action equal to $0.54 million over the 30-year period using the low estimate of recreational losses; and using the high value for losses, these reductions are $0.60 million. The annualized values of these savings, or benefits, of Alternative 1 compared to no-action range from $0.077 to $0.086 million per year over the 30-year period. The present value of loss reductions from Alternative 1 compared to no-action over the 100-year period range from $0.704 to $0.843 million; and annualized savings range from $0.058 to $0.069 million per year. Of course, the estimated present values of these reductions in recreational losses are higher when using smaller discount rates, as Table 6-7 illustrates.

Table 6-7. Present and Annualized Values of Reductions in Recreational Losses Attributable to Project Alternatives ($ millions)

Losses Under MINUS Losses Under	Period (Years)	Low/ High	8.25% Present Value	Annualized Value	5.00% Present Value	Annualized Value	3.00% Present Value	Annualized Value
No-action Alternative 1	30	Low/	$0.539	$0.049	$0.894	$0.058	$1.270	$0.066
		High	$0.602	$0.055	$1.015	$0.066	$1.453	$0.074
	100	Low/	$0.704	$0.058	$1.602	$0.081	$3.259	$0.103
		High	$0.843	$0.069	$2.134	$0.108	$4.843	$0.153
No-action Alternative 2	30	Low/	$0.269	$0.025	$0.447	$0.029	$0.635	$0.033
		High	$0.301	$0.028	$0.508	$0.033	$0.726	$0.037
	100	Low/	$0.352	$0.029	$0.801	$0.040	$1.630	$0.051
		High	$0.422	$0.035	$1.067	$0.054	$2.421	$0.076

Table 6-7 shows that the loss reductions are smaller for Alternative 2 compared to no-action than the savings from Alternative 1 compared to no-action. Alternative 1 does provide some loss savings compared to Alternative 2.

The losses in Tables 6-6 and 6-7 measure welfare losses to recreationists from reduced recreational enjoyment. They do not measure income losses to the recreational industry, nor do they estimate the reduction in recreational usage in a meaningful manner; they simply make an ad hoc proportional assumption. It has been estimated that recreational activities result in regional (Lafourche, Jefferson, Plaquemines and Terrebonne Parishes) spending of $956.2 million annually, and employment of 18,696 persons if we include direct and indirect economic impacts (Industrial Economics 1996). Recreational visitation and spending may decline with wetlands losses over the next 100-years. However, this will be a net result of quality of recreational experience, regional population growth, and recreational interests. Estimation of these trends, and implications for regional income and employment, would require an entire study.

6.2. Hydrologic Regimes

The coastal hydrologic regimes were established by the LSU project team using computerized hydrologic modeling. Two types of hydrologic phenomena were modeled:

* storm surge flood levels under two prototype storms

* average wave height elevations under normal conditions

The procedures for modeling these two phenomena are explained in the Step G report (LADNR 1998g). Preliminary analysis of the average wave height scenarios under the three conditions showed differences that were too small for any related economic analysis. Therefore, economic analysis was limited to the storm surge flood scenarios. However, the wetlands loss impacts of project alternatives attributable to changes in wave action were monetized for this study.

Hydrologic models were used to predict storm surge elevations ranging from 0 to 6.1 m for two worst case storms: Category 5 hurricanes reaching landfall at latitudes 90.5W and 91.5W. These latitudes are shown in Figure 6-1. Topographic models were used to estimate land elevations, a complex function of sea level rise, wetland loss and coastal subsidence. The difference between predicted storm surge and topographic elevations is flood-depth from storm surge. Flood-depth is then the height of the water level above the land surface. All elevations are measured to the National Geodetic Vertical Datum (NGVD). The flood-depth is used as the basis for flood damage estimation.

Flood-depth data were created at LSU using ArcInfo(GIS software and exported in a format for use by the Spatial Analyst Extension(in ArcView(, a GIS software for personal computers. These data are in raster form, with each pixel (small square) representing a predicted flood-depth. Flood-depths were developed as continuous data but were reclassified into discrete classes for visual and statistical analysis. The reclassification scheme was as follows:

Original Depth	Reclassified Depth
> 16.5 feet (5.0 m)	17 feet (5.2 m)
15.5-16.5 feet (4.7-5.0 m)	16 feet

((

1.5-2.5 feet (0.5-0.8 m)   2 feet (0.6 m)

0.5-1.5 feet (0.2-0.5 m)   1 feet (0.3 m)

< 0.5 feet (0.2 m)   0 feet (0.0 m) - No Flooding

A baseline tidal surge estimation was made for each of the two prototype storms using the present configuration of barrier islands and coastal topography. Figure 6-2 shows these tidal surge flood-depths for the 90.5W storm. This is a complicated map but illustrates the variation in flood-depths in the study area. In order to assist the reader in understanding the resolution of the surge flood data, Figure 6-3 is a magnified version of Figure 6-2 showing the same flood data overlaid with US Bureau of the Census census tract boundaries for Terrebonne and Lafourche parishes. Census tract boundaries were obtained from Wessex(and are based on Bureau of the Census Tiger 92 files.

Each pixel of the raster flood data in Figure 6-3 has a surge flood-depth associated with it. It was necessary to obtain a statistical flood-depth for each census tract in the study area. The mean and median of the raster flood-depth data were obtained for each census tract using the "Summary Zone" feature of the ArcView Spatial Analyst Extension(. The mean and median flood-depths can differ substantially within a census tract, as there is no general rule whether one will be greater than the other in a particular tract. As explained below, damage estimates were made using each of these statistics.

For example, census tract 221090002 in Terrebonne parish is shown in Figure 6-3 as the tract with the dot representing Houma. This tract contains 29 pixels of flood-depth data. The mean flood-depth for this tract is 0.10 m with the current configuration and 90.5W storm; and the median depth is 0.0 m. Census tract 220570216 is in Lafourche parish directly to the east of Houma in Figure 6-3. This tract contains 278 pixels, with a mean flood-depth of 0.48 meters (1.6 feet) and a median depth of 0.30 meters (1.0 feet). Similar mean and median flood-depth statistics were obtained for all census tracts in the study area, for each of the two prototype storms and the three project assumptions (no-

action, Alternative 1, Alternative 2) plus the baseline current configuration condition (the basis for Figures 6-2 and 6-3).

Flood-depths were modeled under the three project conditions for 30- and 100-years from the present. The economic impact methodology is not so highly developed that it can meaningfully analyze the smaller changes likely to occur over a 30-year period. Therefore, the procedure used in this report was to analyze flooding economic impacts for 100-years from the present and to presume that impacts 30-years from the present would be only 30% of the full 100-year impact; i.e., economic impacts occur linearly over time. This may or may not be the case. Only the 100-year analyses and maps are presented in this section.

Figure 6-2. Tidal Surge Flood Depths Under Current Barrier Shoreline with 90.5W Storm.

Legend:
- No Flooding
- 1 foot NGVD
- 2
- 3
- 4
- 5
- 6
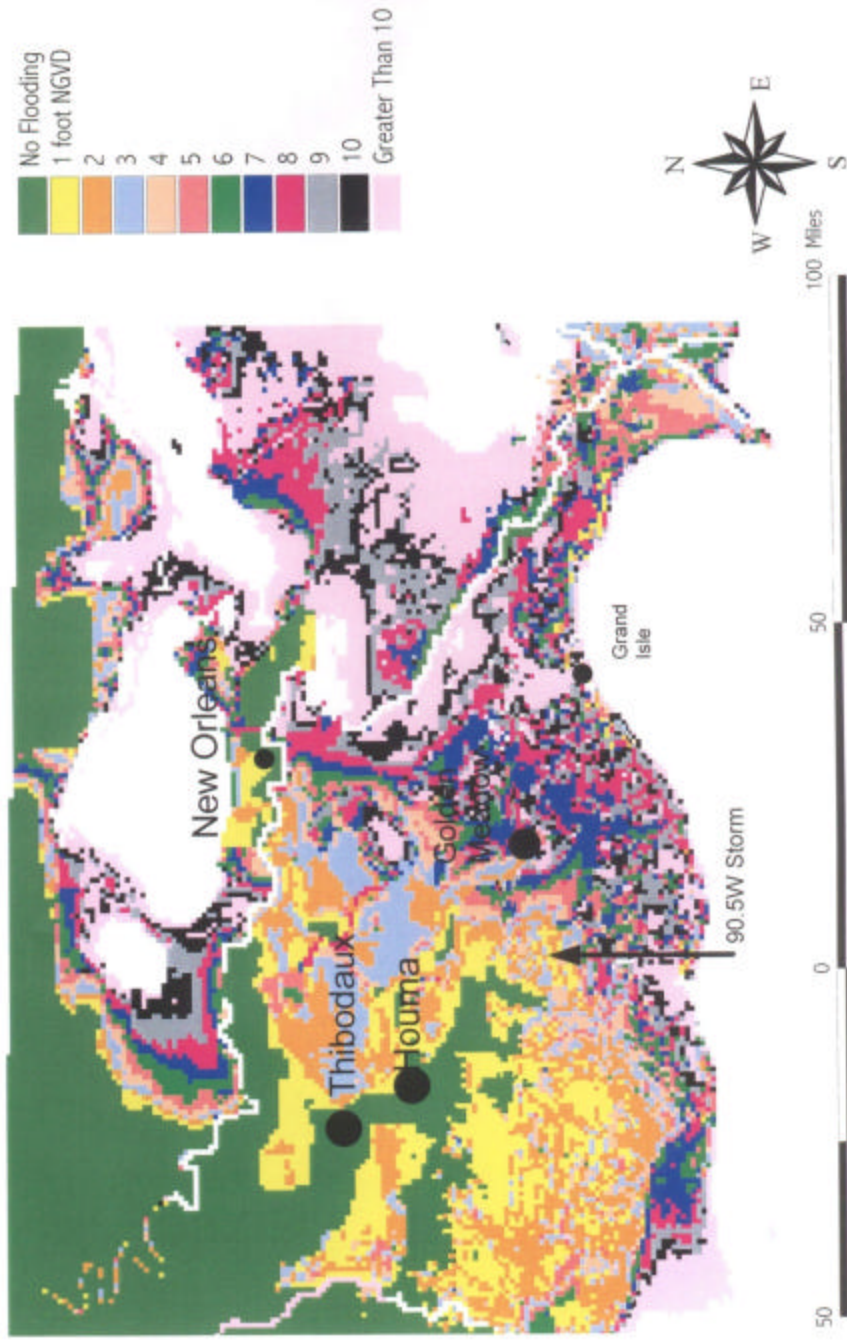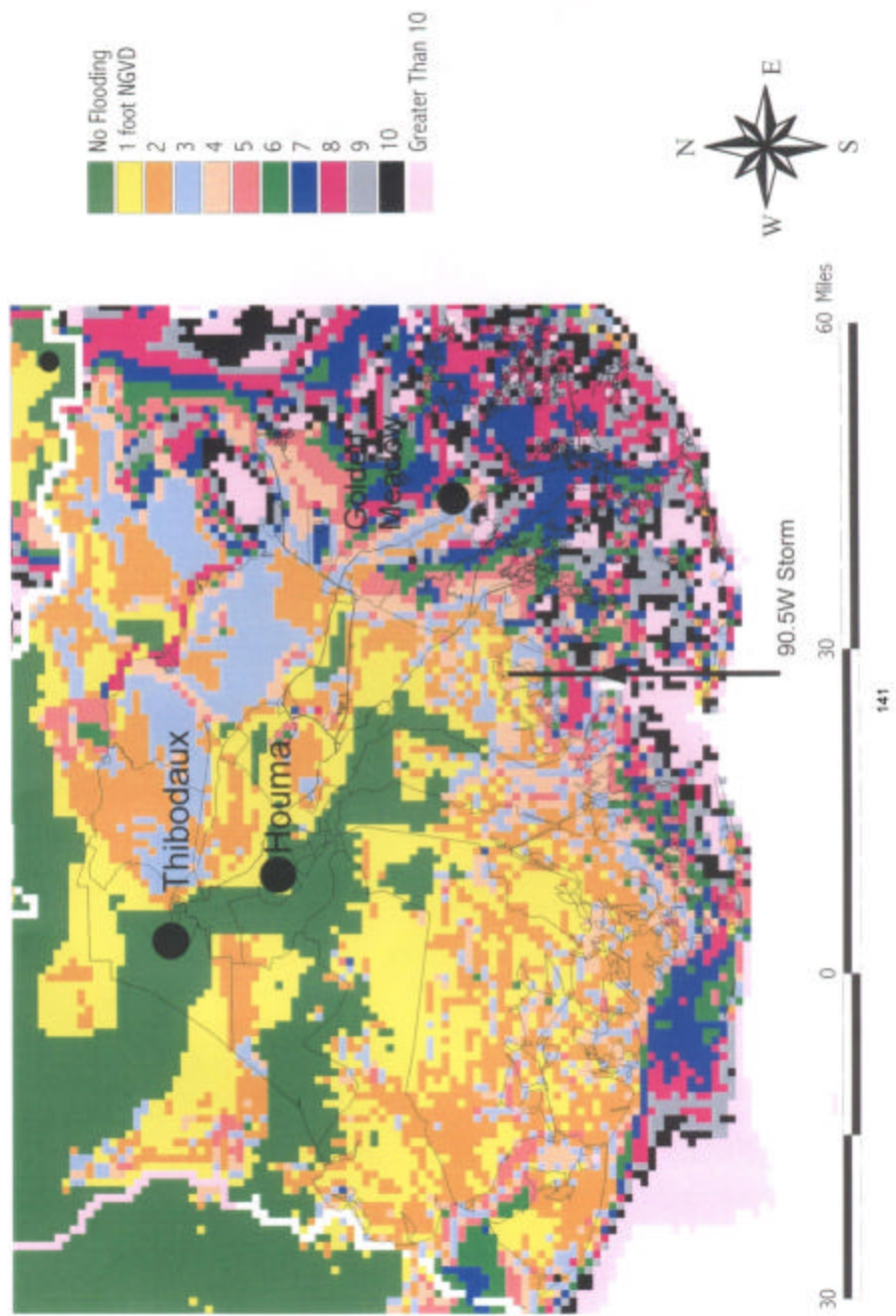- 7
- 8
- 9
- 10
- Greater Than 10

Figure 6-3. Zoom of Tidal Surge Flood Depths Under Current Barrier Shoreline with 90.5W Storm Showing Terrebonne and Lafourche Parish Census Tracts.

The effects of the different project assumptions on flood-depths can be analyzed using the GIS system employed in this study. While the purpose of this study is to investigate economic impacts of these assumptions, it is illustrative to show how one can use the flood-depth data to estimate flood-depth impacts of the project assumptions. For example, we can compare flood-depths of a 90.5W storm occurring at present with depths of the identical storm 100-years from the present under a no-action assumption; i.e., barrier islands are allowed to disintegrate. Figure 6-4 shows the pixel-by-pixel expected increases in depths under this no-action assumption for the census tracts in Terrebonne and Lafourche parishes. Census tract 221090002 in Terrebonne Parish is expected to have flood-depths increase from a mean of 0.11 meters (0.36 feet) presently to 0.17 meters (0.56 feet) in 100-years under the no-action assumption (i.e., an increase of 0.06 meters (0.20 feet)). Similarly, tract 220570216 in Lafourche parish is expected to have an increase in mean depth from 0.48 meters (1.6 feet) under present conditions to 0.87 meters (2.9 feet) in 100-years under the no-action assumption (i.e., an increase of 0.39 metes (1.3 feet)).

Figure 6-5 shows flood-depth implications for the 91.5W prototype storm comparing flood-depths after 100-years under no-action to flood-depths expected for the same storm in the present. Increased flooding under the no-action case impacts the entire study area; the majority of these increases are between 0.0 and 0.61 meters (0.0 and 1.0 feet).

Figure 6-4. Increases in Flood Depth in 100-Years Under No-Action Compared to Current Flood Depths for 90.5W Storm, Showing Terrebonne and Lafourche Parish Census Tract
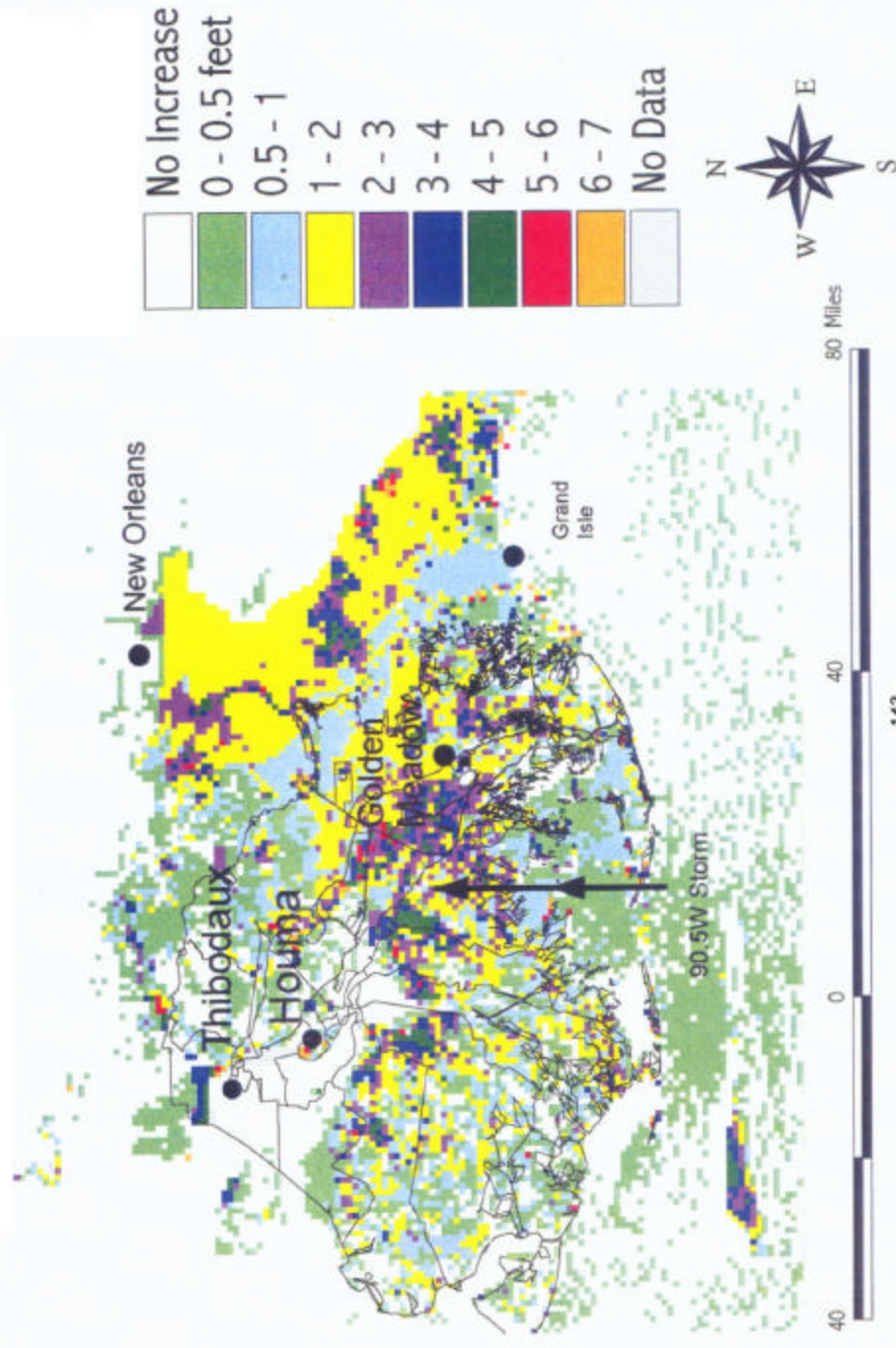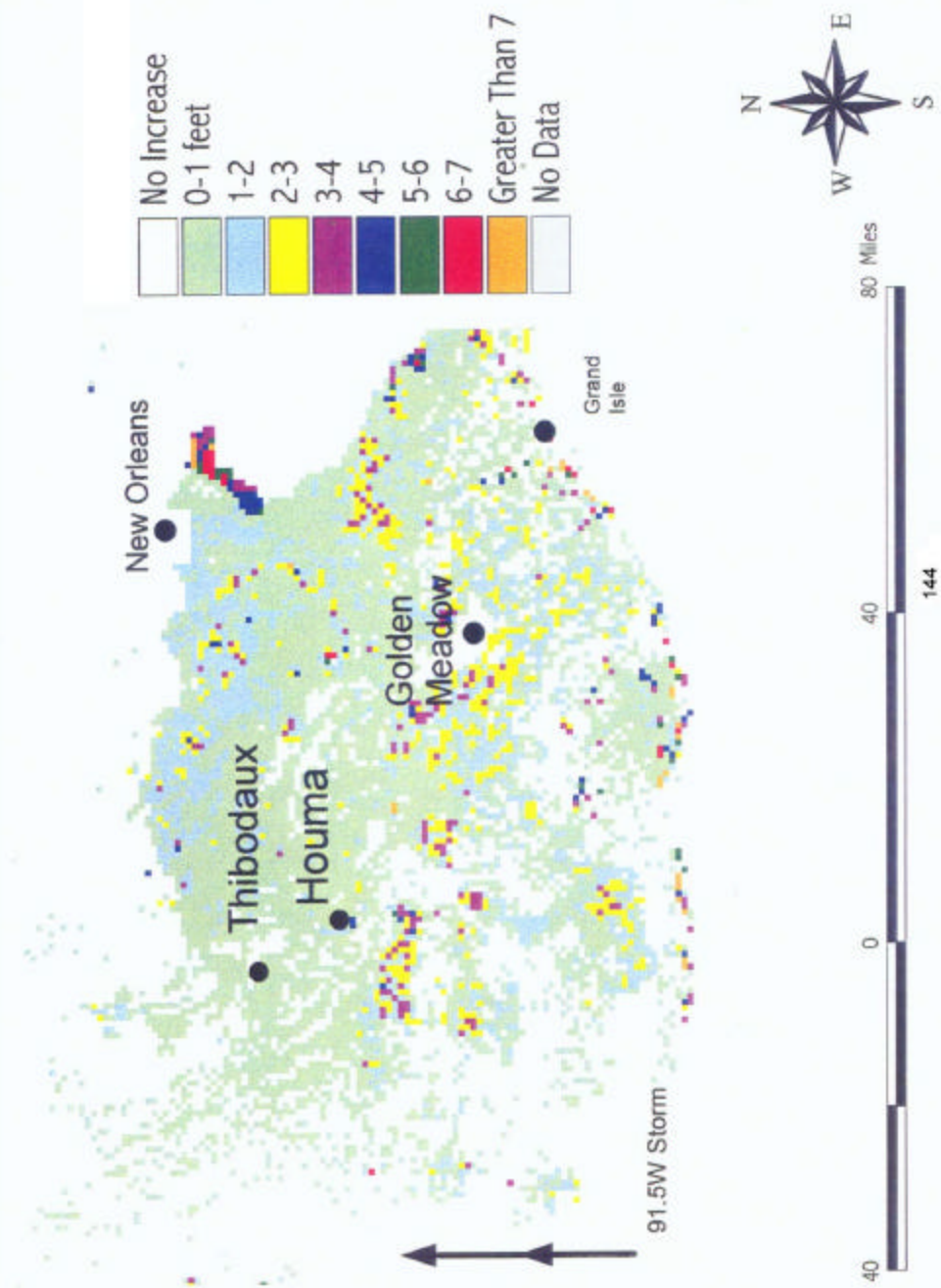
No Increase
0 - 0.5 feet
0.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
No Data

New Orleans

Thibodaux

Houma

Golden Meadow

Grand Isle

90.5W Storm

40   0   40   80 Miles

143

Figure 6-5. Increases in Flood Depth in 100-Years Under No-Action Compared to
Current Flood Depths for 91.5W Storm

No Increase
0-1 feet
1-2
2-3
3-4
4-5
5-6
6-7
Greater Than 7
No Data

New Orleans

Thibodaux

Houma

Golden
Meadow

Grand
Isle

91.5W Storm

N
W   E
S

40   0   40   144   80 Miles

The expected flooding mitigation effects of Alternatives 1 and 2 can be illustrated for the 100-year horizon using the GIS system. Figures 6-6 and 6-7 show the increases in flood-depths from the 90.5W prototype storm for no-action compared to maintaining Alternatives 1 and 2 respectively.

It is clear from these maps that the eastern portion of the study area would experience increased flooding depths under no-action compared with the alternatives. Compared to no-action, Alternative 1 reduces flood depths by 0.9-1.5 meters (3-5 feet) in the eastern portion of the study area, while Alternative 2 reduces flooding by 0.6-0.9 meters (2-3 feet).

Figures 6-8 through 6-9 show flood-depth implications of the alternatives for the 91.5W prototype storm. The figures show a pervasive flood-depth increase across the study area after 100-years when no-action is compared to both alternatives. Compared to no-action, Alternative 1 reduces flood depths by 0.0 and 0.9 meters (0.0 and 3.0 feet), with larger reductions of 0.9 to 1.8 meters (3.0 to 6.0 feet) in the southern portion of the study area.

Some types of economic impacts of flooding are more dependent upon whether the area is flooded at all, rather than upon the elevation of the flooding. For example, road damages would be more related to whether the road is flooded than to the elevation of the water above the road surface. For this reason, Figures 6-10 and 6-11 illustrate those areas where locations not flooded currently under a 90.5W storm would likely be flooded in 100-years under the no-action plan. These are the flooding "margins." Figure 6-10 shows these margins for the 90.5W storm. Bands of newly flooded areas run across the center of the study area below Houma and run in a band between Thibodaux and Houma. Figure 6-11 shows the 91.5W storm margins consisting primarily of two bands: one southeast of New Orleans and another running along Grand Isle and Grand Terre. The flooding margins for the no-action compared to Alternatives 1 and 2 are considerably smaller than those shown in Figures 6-10 and 6-11; they are so small that this study does not estimate the costs associated with those margins.

Figure 6-6. Increases in Flood Depth of 90.5W Storm in 100-Years Under No-Action Compared to Alternative 1.

Legend:
- No Increase
- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- Above 6
- No Data

New Orleans

Thibodaux

Houma

Golden Meadow

Grand Isle
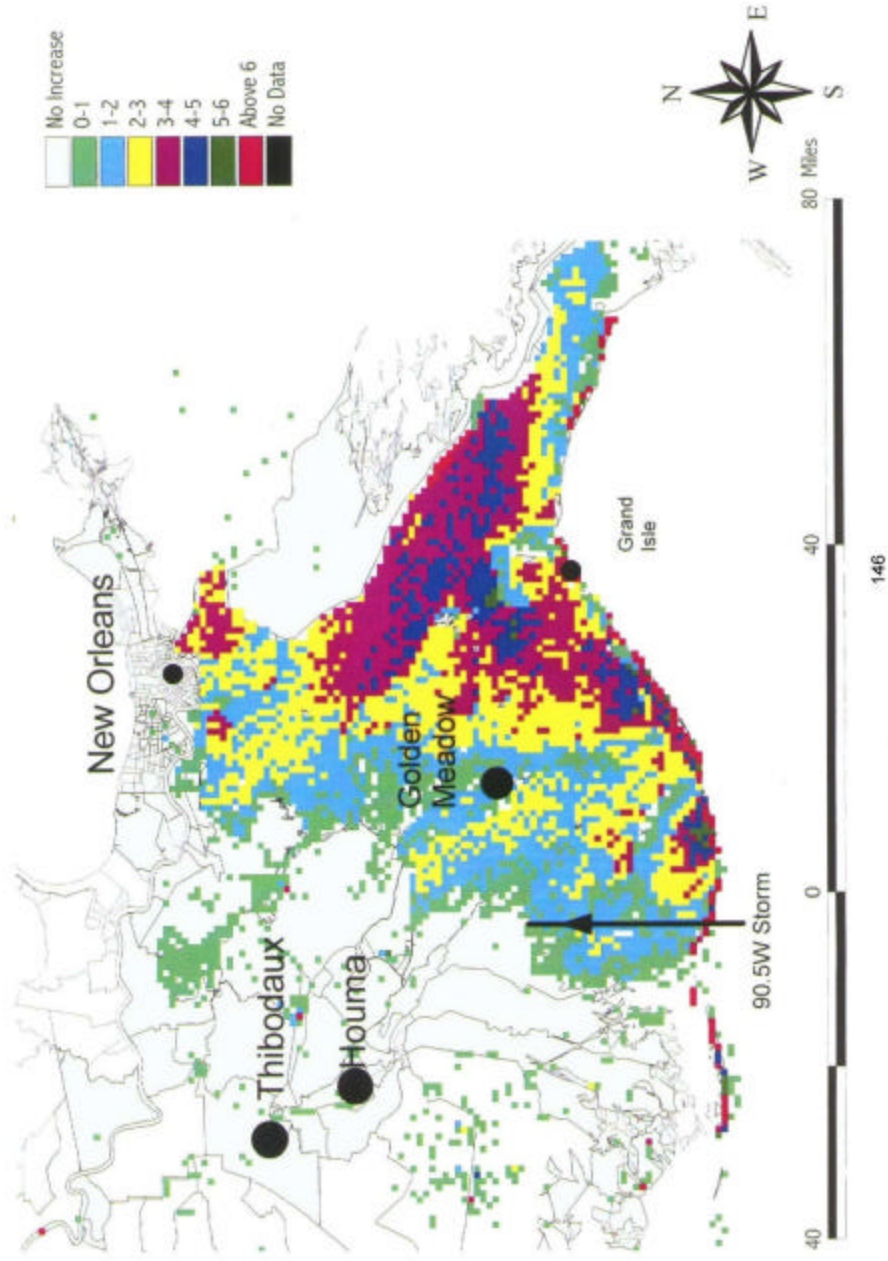
90.5W Storm

40   0   40   80 Miles

146

Figure 6-7. Increases in Flood Depth of 90.5W Storm in 100-Years Under No Action
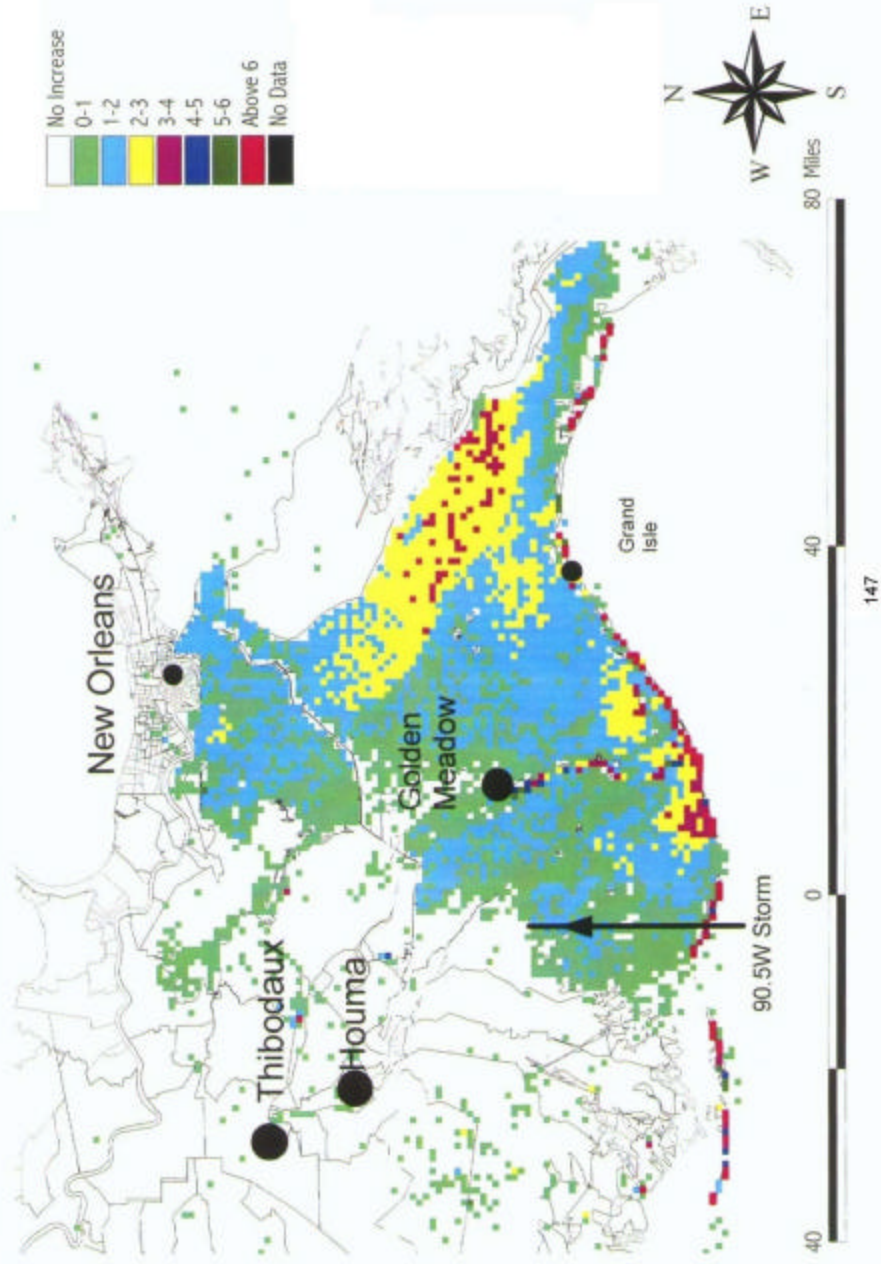Compared to Alternative 2.

Figure 6-8. Increases in Flood Depth of 91.5W Storm in 100-Years Under No Action Compared to Alternative 1.
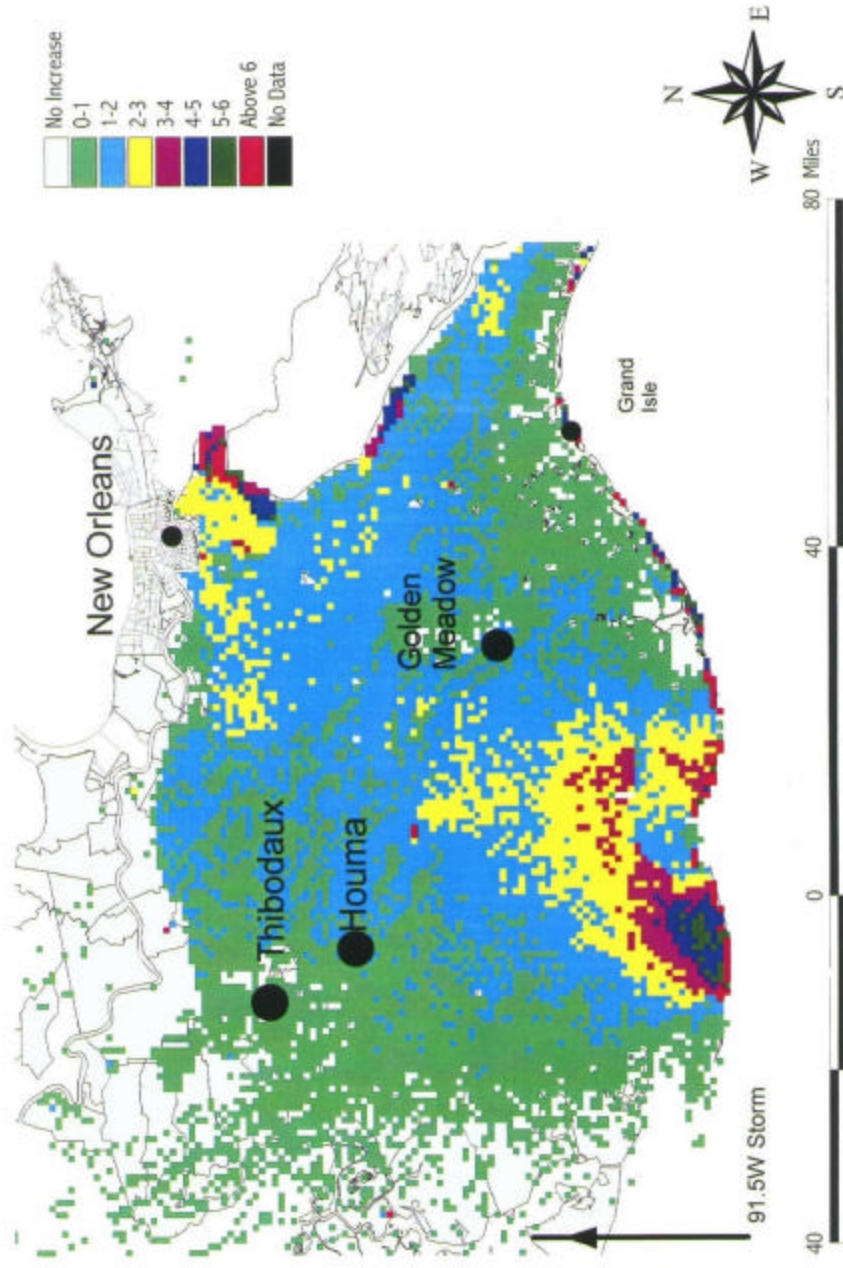
Figure 6-9. Increases in Flood Depth of 91.5W Storm in 100-Years Under No-Action Compared to Alternative 2.
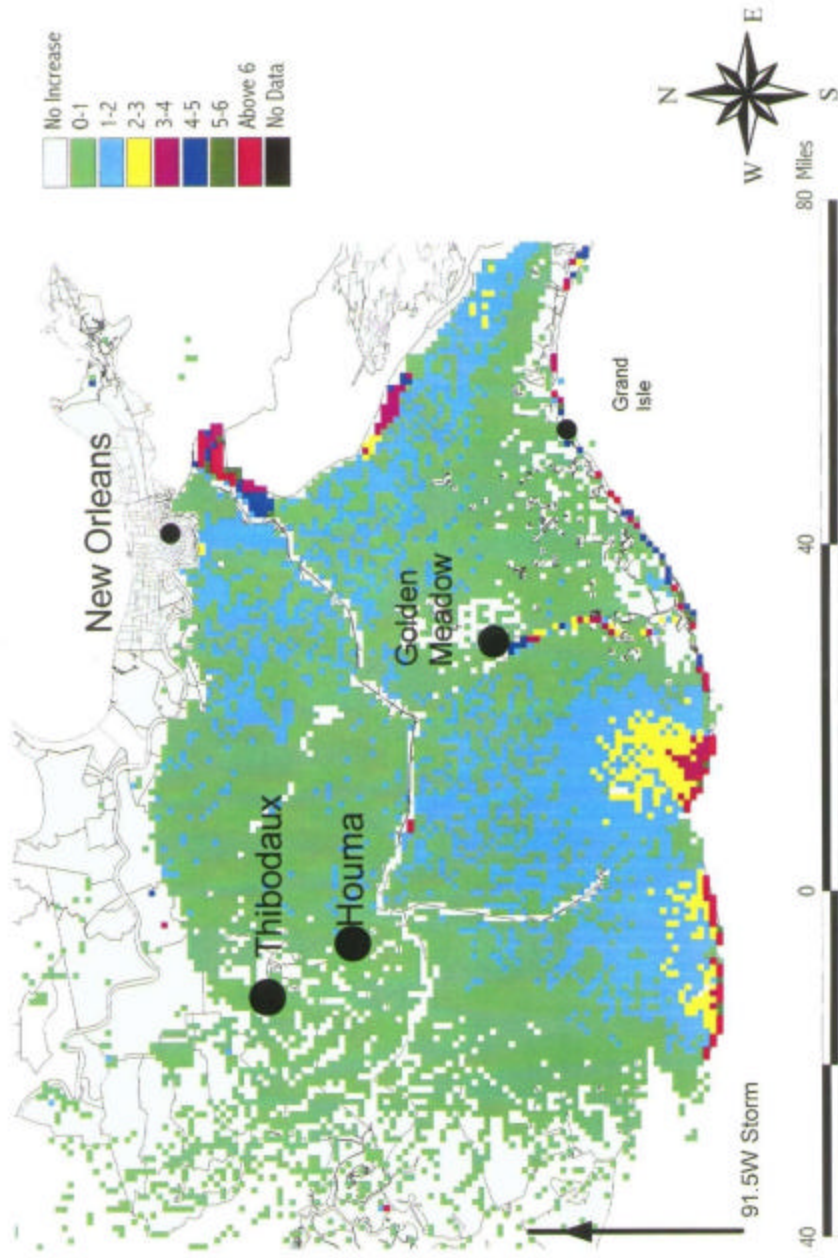
Figure 6-10. Areas Newly Flooded by 90.5W Storm in 100 Years Under No-Action But Not Currently Flooded in 90.5W Storm.
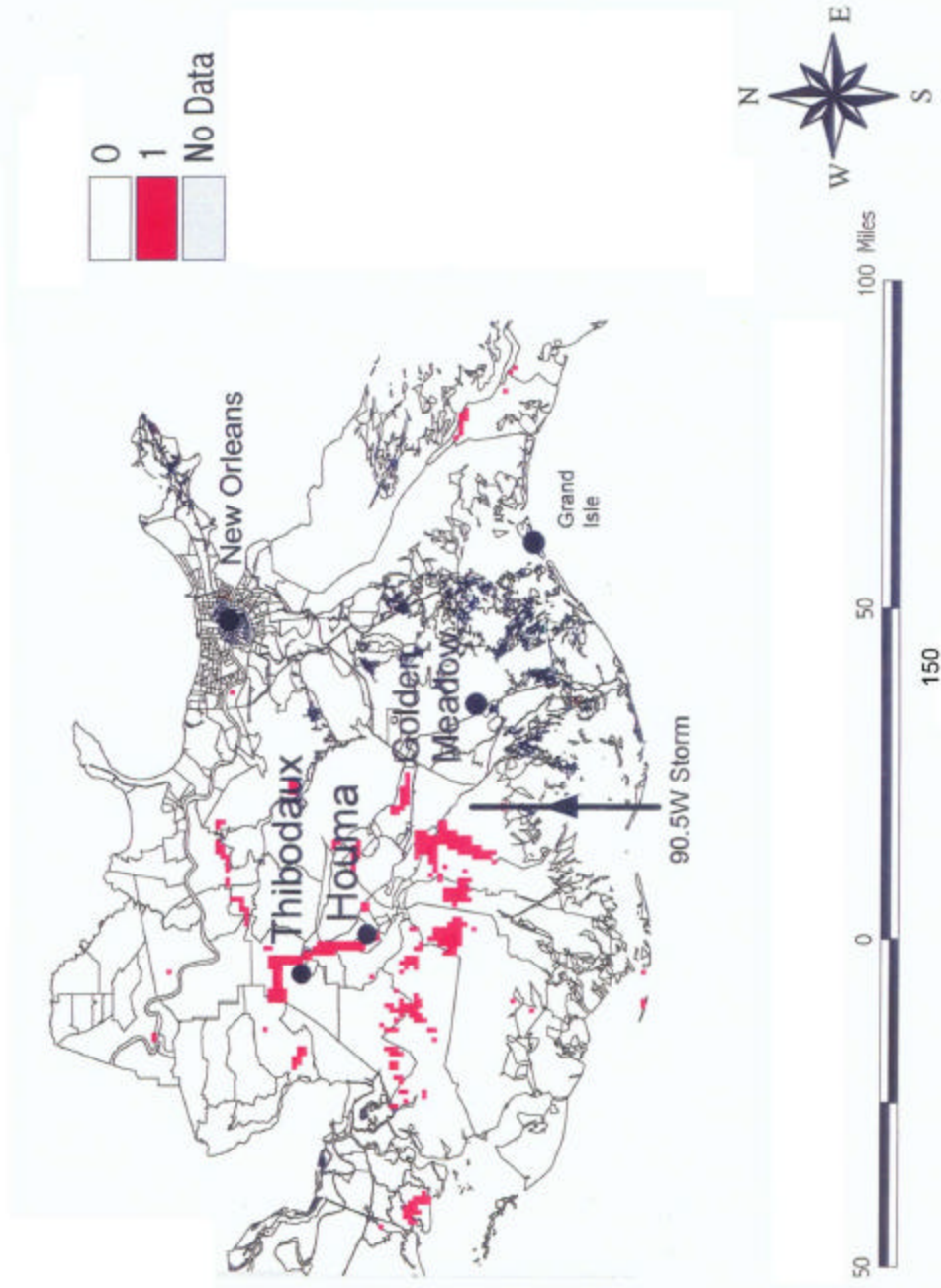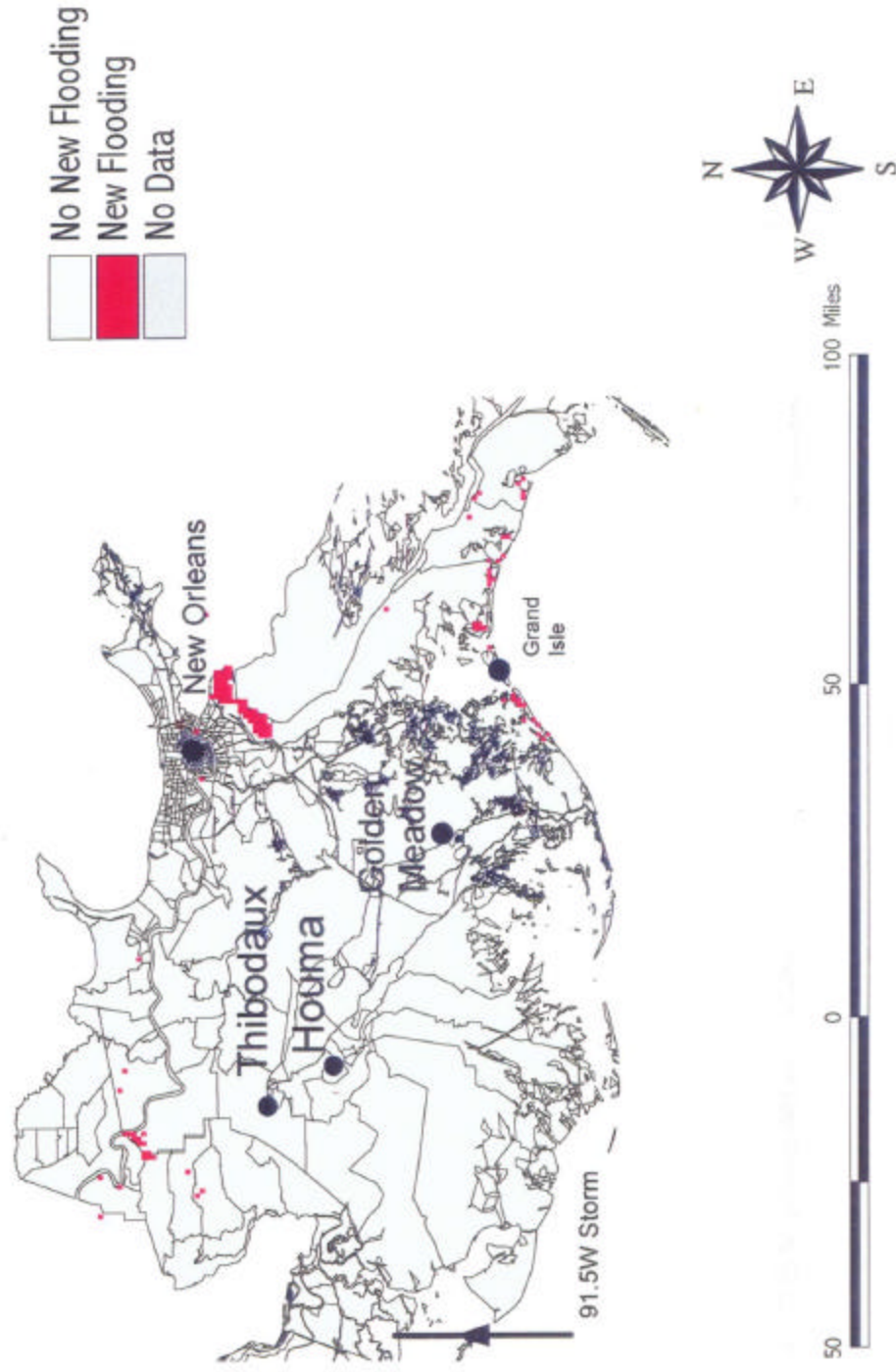
Figure 6-11. Areas Newly Flooded by 91.5 W Storm in 100 Years Under No-Action, But Not Currently Flooded in 91.5W Storm.

No New Flooding
New Flooding
No Data

New Orleans

Thibodaux

Houma

Golden Meadow

Grand Isle

91.5W Storm

N
W   E
S

50   0   50   100 Miles

151

Average wave heights were also modeled under normal conditions. As noted above, there was too little difference in these elevations to perform any meaningful economic analysis. This is not to say there were not differences; only that the resolution of the economic data was not high enough to perform any analysis of these wave heights.

6.3. Flood Damages To Structures

This section of the report estimates the impact of barrier island project alternatives on flood damages to structures from the two prototype storms. These estimates use a damage function developed from data provided by the US Army Corps of Engineers (USACE) and from the US Bureau of the Census. The damage function is then applied to the storm surge flood-depths obtained from the hydrologic modeling outlined in Section 6.2.

6.3.1. Flood Damage Data

The USACE has developed flood stage-damage functions for Water Resource Units (WRU) in some regions of coastal Louisiana (USACE 1994). These stage-damage functions show structural damages to properties under varying flood stages. Structural damage categories include:

* residential (including mobile homes)
* commercial
* industrial
* public
* farm buildings
* automobiles

Damages to public structures would include damages to schools and other public buildings, but not to public infrastructure, such as roads and piers. These damages are presented in 1993 price levels and are used directly for this report. For example, WRU

148A (near Morgan City) has 5863 1 or 2 story residential structures, 610 commercial and industrial structures and an estimated 5,863 automobiles at risk (it was assumed that each household would leave one vehicle at their residence when evacuating). Total structural damages from various flood stages were estimated to be:

Stage Elevation	Damages ($1000's)
4.0 ft (1.2 m)	$0.0
5.0 ft (1.5 m)	$847.5
6.0 ft (1.8 m)	$4,377.0
7.0 ft (2.1 m)	$25,589.7

Flood damages do not begin until elevations reach 1.2 meters (4.0 feet); and they increase more than proportional to elevation (USACE 1994).

The stage-damage data presented in the USACE study were used to establish a statistical damage function. The functional form presumed a logistic function, whereby damages first increase more than proportional to flood-depth then eventually less than proportional to flood-depth, reaching a maximum ceiling damage level. This is reasonable as location patterns would suggest more properties at risk as flood levels rise, but only a maximum amount of damage can be done. The functional form also presumed that damages would be proportional to residential structures in a WRU. This implies that commercial, industrial and public structures at risk are assumed to be proportional to residential structures. While this residential proportion-logistic function is reasonable theoretically, other functional forms were tested.

Data for the six WRU's published in the USACE study were used to estimate the logistic function. The regression procedure in SAS(resulted in the following estimation:

log(Damages) = 1.443852 - 2.710987 x (1/Flood-depth) + 0.11726 x log(Residences)
(t=1.346)   (t=-7.493)   (t=6.746)
Adjusted R-sq = 0.50; N=92

Damages were total damages to structures in a WRU; and Residences were the number of 1 or 2 story residential units in the WRU, published in the same USACE report. Flood-depth was flood-stage elevation minus the elevation at which damages became positive. So this variable represents depth of water above land, not flood elevation. Use of this variable was necessary in order to use the LSU modeled depth of flood data, which were not flood elevations but depth of flood above land. This estimating model explained one-half of the variance in the data. The coefficient for log(Residences) was not significantly different from 1, implying damages are proportional to residential units. Other function forms did not have as high R-sq values as this logistic function.

6.3.2. Flood Damage Estimates

Flood damages were estimated for all storm and project scenarios using the damage function presented in Section 6.4. Damages were estimated by census tract. The census tract data for the variable "residences" in the damage function equation was the total number of unattached (non-mobile home) residential structures in a tract. This is the census statistic most like the 1 and 2 story structures used to estimate the damage function. This statistic was obtained from the Wessex(census database and software. It is important to note that mobile home damages are included in the variable, Damages, in the damage function, so damages to these structures are included in the estimates.

The flood variable "Flood-depth" in the damage function was estimated for each census tract. The average flood-depth for a tract was obtained by applying the ArcView(procedure, Summarize Zones, to the flood scenarios modeled by the LSU project team. Both mean and median flood-depths were estimated for each census tract in the study area. They were estimated for both prototype storms, and for each of the barrier island project assumptions.

Table 6-8 shows estimated flood damages in each study area parish from the 90.5W storm. These include damages to residential (including mobile homes), commercial, industrial and public structures. For example, the expected flood damage using mean flood-depths to Ascension parish, if there is such a storm at present is shown in Column 1, is $15.588 million. Expected damages, using median flood-depths, are $6.117 million. The estimate using median depths is substantially lower than the estimate using mean depths in this case. In other instances, such as the estimate for Plaquemines parish, the estimate using the median is slightly higher than the estimate using the mean flood-depths. The bottom row of Columns 1 and 2 show estimated total damages in the study area from a current 90.5W prototype storm to be between $862.361 and $928.388 million.

Columns 3 through 8 of Table 6-8 show estimated damages from a 90.5W prototype storm in 100-years under different barrier island project assumptions. These estimates presume a constant coastal population distribution and number of residential structures over this time period; i.e., a fixed number of residences in the same census tracts (the basis of this assumption was provided in the Introduction). For example, Column 3 shows that a prototype Category 5 storm would result in an estimated $15.589 million in structural damages to Ascension parish in 100-years under a no-action plan, when mean flood-depths are used as the basis for estimation. This is roughly equivalent to the damages to Ascension parish under a similar storm occurring currently, shown in Column 1. However, Column 3 shows that damages to Jefferson, Lafourche and Terrebonne parishes would be substantially higher for a storm which occurs in 100-years under the no-action plan than a similar storm occurring currently. The total damages from the 90.5W prototype Category 5 storm occurring in 100-years under the no-action plan, using mean depths, are expected to be $987.604 million, as shown in Column 3.

Table 6-8. Estimates of Flood Damages to Residential, Commercial, Industrial and Public Structures from the 90.5W Storm

Parish	Current Condition Date: Present Mean $1000's	Current Condition Present Median $1000's	No Action 100 Years Mean $1000's	No Action 100 Years Median $1000's	Alternative 2 100 Years Mean $1000's	Alternative 2 100 Years Median $1000's	Alternative 1 100 Years Mean $1000's	Alternative 1 100 Years Median $1000's
	1	2	3	4	5	6	7	8
Ascension	$ 15,589	$ 6,117	$ 15,589	$ 6,117	$ 15,650	$ 6,117	$ 15,589	$ 6,117
Assumption	$ 602	$ 495	$ 506	$ 495	$ 833	$ 495	$ 1,267	$ 1,919
Jefferson	$ 379,403	$ 346,814	$ 401,756	$ 387,280	$ 380,410	$ 349,056	$ 358,666	$ 329,817
Lafourche	$ 55,779	$ 53,211	$ 74,870	$ 71,901	$ 73,721	$ 65,605	$ 67,286	$ 62,798
Orleans	$ 255,108	$ 253,488	$ 257,786	$ 256,995	$ 260,164	$ 252,303	$ 258,795	$ 250,025
Plaquemines	$ 34,725	$ 35,165	$ 35,754	$ 36,195	$ 34,794	$ 35,130	$ 33,373	$ 34,124
St. Charles	$ 59,043	$ 52,246	$ 60,616	$ 54,153	$ 60,160	$ 55,218	$ 59,559	$ 52,246
St. James	$ 18,145	$ 17,870	$ 18,715	$ 17,870	$ 18,625	$ 17,870	$ 18,669	$ 17,870
St. John	$ 66,951	$ 64,403	$ 67,270	$ 64,403	$ 67,125	$ 64,403	$ 67,088	$ 64,403
St. Mary	$ 22,711	$ 12,017	$ 22,687	$ 12,017	$ 23,255	$ 12,017	$ 22,687	$ 12,017
Terrebonne	$ 20,332	$ 20,535	$ 32,055	$ 31,746	$ 61,351	$ 44,496	$ 30,752	$ 30,767
TOTAL	$ 928,388	$ 862,361	$ 987,604	$ 939,172	$ 996,088	$ 902,710	$ 933,731	$ 862,103

Storm damages under no-action can be compared to the $928.386 million in damages under a similar storm occurring currently, shown in Column 1 of Table 6-8. In other words, a no-action plan would result in $59.218 million more damages from a storm in 100-years than the same storm occurring currently. This increase in damages is attributable to two factors. The hydrologic modeling, that is the basis for this estimate, allows two phenomena to occur over this 100-year period. First, the barrier islands are permitted to deteriorate naturally under the no-action assumption. Secondly, subsidence, sea-level rise and wetlands disintegration are also permitted to continue naturally. This means that the increased storm damages are due to these two factors jointly; i.e., not simply to the no-action.

Median depths of flooding can also be used as a basis for estimating flood damages. The median may be a superior statistic to represent the average depth. This is because the mean can be highly skewed by a few extremely large or small values. An example of this problem is illustrated in census tracts near Houma. Figure 6-12 shows that census tract 006 has most of its area flooded at a depth of 0.30 meters (1.0 feet). However, there are several pixels with very high flood-depth predictions: 1 pixel at 3.66 meters (12.0 feet), two pixels at 4.27 meters (14.0 feet) and 1 pixel at 4.57 meters (15.0 feet). The mean depth is 1.02 meters (3.3 feet) but the median depth is only 0.30 meters (1.0 feet). The median is more representative of flood-depth in this tract. This type of situation is typical of many of the census tracts in the study area. Therefore, the median based damage estimates are likely to be more appropriate than the mean based estimates.

Figure 6-12. Zoomed View of Flood Depths from 90.5W Storm in 100 Years for Terrebonne Parish Under Alternative 2.
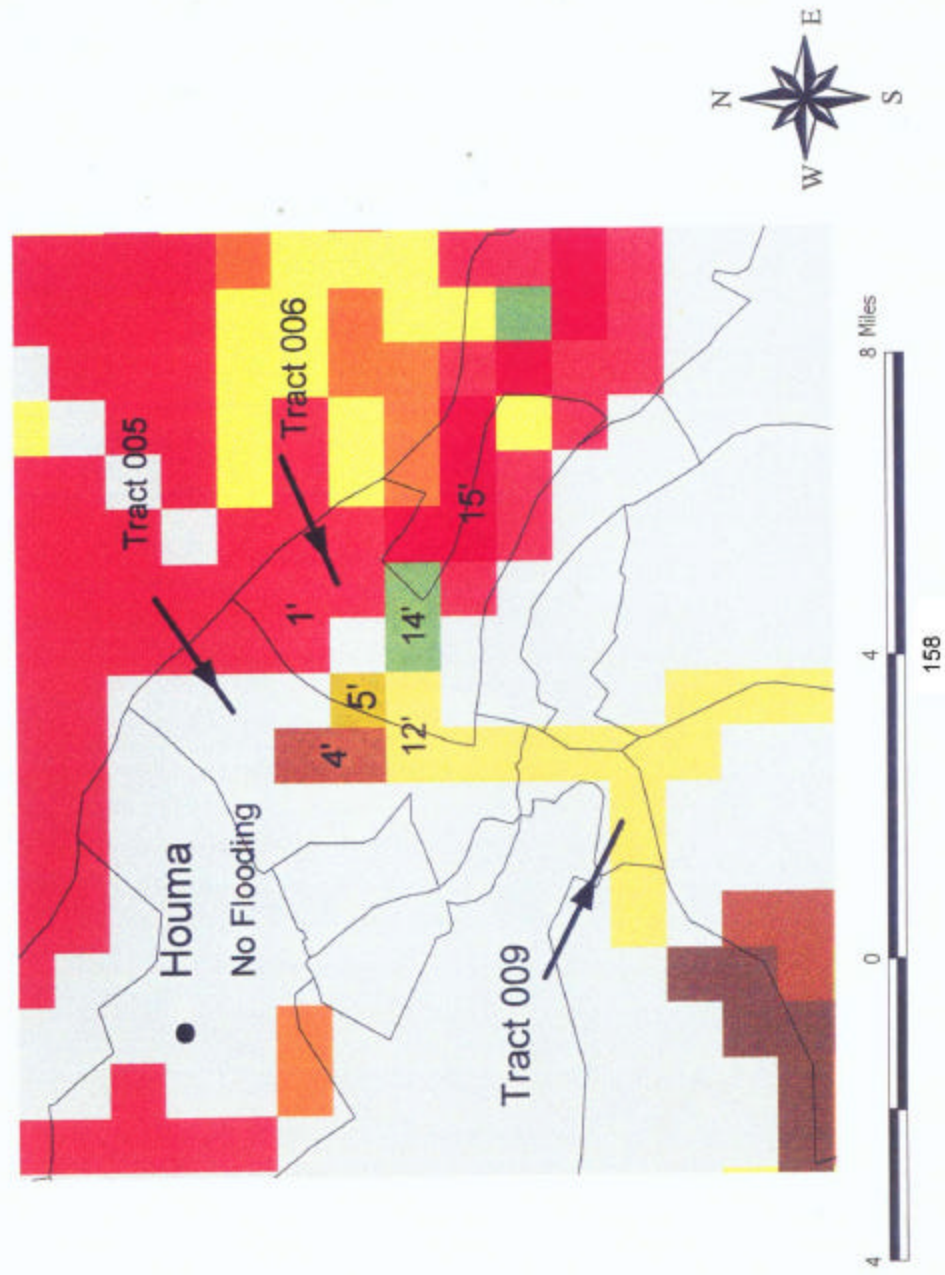
Median based damage estimates for the 90.5W storm, $862.361 million, are shown for a current storm in Column 2 of Table 6-8. The corresponding 100-year no-action median damage estimates, $939.173 million, are shown in Column 4. Table 6-8 also shows damage estimates for other barrier island project assumptions. Columns 5 and 6 show estimated damages under Alternative 2; and Columns 7 and 8 show damages under Alternative 1. These estimates are used as the basis for establishing comparisons of damages under different project assumptions in the following section.

Table 6-9 shows flood damage estimates for various project assumptions using the prototype Category 5 storm reaching landfall at 91.5W. Damage estimates for this storm are slightly lower than for the 90.5W storm shown in Table 6-8. For example, the mean and median total damages from a storm occurring currently (Columns 1 and 2) are $876.670 and $787.636 million, respectively, compared to $928.386 and $862.361 million, respectively, from the 90.5W storm in Table 6-8. Table 6-9 also shows expected damages under the various project alternatives.

6.3.3. Comparing Flood Damage Estimates for Different Project Assumptions

Tables 6-8 and 6-9 can be used to establish damage comparisons across project assumptions. Table 6-10 shows these median flood damages under the two prototype storms and project alternatives. For example, under a storm occurring at present with Current Conditions of the barrier islands, a 90.5W storm will cause an estimated $862.361 million in damages. If the same 90.5W storm occurs in 100-years, during which the no-action alternative prevailed, the flood damages would be $939.173 million. The same storm occurring in 100-years under Alternative 1 would cause $862.103 million in damages, and under Alternative 2 would cause $902.710 million in damages. Table 6-10 shows comparable storm flood damages estimates for the 91.5W prototype storm.

Table 6-13 has been constructed to permit the comparison of flood storm damage estimates under the various project alternatives. Using the data from Table 6-10, Table 6-

11 shows that damage in 100-years under no-action would be $77.070 million greater than damages in 100-years under Alternative 1 for a 90.5W storm. This means Alternative 1 would save $77.070 million in flood damages compared to no-action if such a storm occurred in 100-years. For the same type of storm, Table 6-11 shows that damages in 100-years under no-action would be $36.463 million greater than damages in 100-years under Alternative 2. Similarly, Table 6-11 shows that damage costs under Alternative 1 would be $136.377 million lower than under no-action for the 91.5W storm; and damage costs under Alternative 2 would be $74.795 million lower than under no-action.

Table 6-9. Estimates of Flood Damages to Residual, Commercial, Industrial and Public Structures from the 91.5W Storm

Parish	Current Condition Date: Present Mean $1000's 1	Current Condition Present Median $1000's 2	No Action 100 Years Mean $1000's 3	No Action 100 Years Median $1000's 4	Alternative 2 100 Years Mean $1000's 5	Alternative 2 100 Years Median $1000's 6	Alternative 1 100 Years Mean $1000's 7	Alternative 1 100 Years Median $1000's 8
Ascension	$ 25,978	$ 17,670	$ 26,136	$ 18,187	$ 26,110	$ 17,670	$ 26,120	$ 17,670
Assumption	$ 25,737	$ 22,061	$ 27,238	$ 24,287	$ 25,846	$ 22,681	$ 25,553	$ 22,681
Jefferson	$ 249,478	$ 235,284	$ 290,690	$ 282,847	$ 252,679	$ 236,667	$ 216,232	$ 200,317
Lafourche	$ 123,345	$ 119,266	$ 134,935	$ 131,458	$ 127,581	$ 123,998	$ 122,755	$ 116,797
Orleans	$ 111,680	$ 91,402	$ 115,327	$ 95,779	$ 133,029	$ 95,027	$ 128,446	$ 85,377
Plaquemines	$ 26,014	$ 20,102	$ 31,138	$ 31,318	$ 28,565	$ 20,102	$ 24,261	$ 19,817
St. Charles	$ 54,344	$ 33,006	$ 59,233	$ 38,766	$ 56,541	$ 35,654	$ 55,443	$ 34,106
St. James	$ 10,682	$ 8,100	$ 11,829	$ 8,951	$ 10,945	$ 8,100	$ 10,743	$ 8,100
St. John	$ 31,478	$ 29,226	$ 31,806	$ 29,716	$ 31,592	$ 29,226	$ 34,279	$ 32,209
St. Mary	$ 51,649	$ 46,403	$ 51,425	$ 46,403	$ 51,000	$ 46,403	$ 50,899	$ 46,403
Terrebonne	$ 166,285	$ 165,116	$ 172,611	$ 171,149	$ 170,456	$ 168,540	$ 160,311	$ 159,007
TOTAL	$ 876,670	$ 787,636	$ 952,368	$ 878,861	$ 914,344	$ 804,068	$ 855,042	$ 742,484

Table 6-10. Median Flood Damages Under Two Prototype Storms and Project Alternatives ($millions)

	90.5W Storm	91.5W Storm
Present Storm Under Current Conditions	$862.361	$787.636
Damages in 100-years Under:		
No-action	$939.173	$878.862
Alternative 1	$862.103	$742.485
Alternative 2	$902.710	$804.067

Table 6-11. Comparison of Median Flood Damage Estimates in 100-years for Project Alternatives ($millions)

	90.5W Storm	91.5W Storm
Damage in 100-years Under No-action MINUS Damage in 100-years Under Alternative 1	$77.070	$136.377
Damage in 100-years Under No-action MINUS Damage in 100-years Under Alternative 2	$36.463	$74.795

It is very important to recognize what Table 6-11 shows. It shows only the potential flood damage cost savings under the two project alternatives compared to no-action if a prototype storm hits the study area in 100-years. It tells us nothing about the probabilistic damage savings; i.e., expected damage savings considering the likelihood of the storm event. It also tells us nothing about damage cost savings in 30- or 50-years.

6.3.4. Using Flood Damage Estimates for Evaluating Benefits of Alternatives 1 and 2

The flood damage estimate comparisons presented in Section 6.3.3 can be used to estimate benefits of project alternatives. However, using them is not straightforward.

First, these comparisons are based on damage estimates for storms occurring 100-years from the present. Project evaluation procedures require annual comparisons of circumstances over a 30-year period rather than a snapshot comparison for an event in 100-years. A 30-year comparison requires some method of interpolating results from a 100-year analysis to an annual 30-year period. Second, benefits of project alternatives should be expected benefits; based on both the expectations of the effects of hydrologic changes, modeled for use in this study, as well as expectations that the events modeled will occur. Expected benefits are probabilistic, based on probabilities that the events analyzed will occur.   Third, the storms analyzed are Category 5 hurricanes. Analyses were not performed for of storms of varying intensities. The estimated comparisons are only valid for this one type of storm, so this cannot be used to represent other storms.

The reason this study based its analysis on the storm event in 100-years is that changes in flooding regimes over a 30-year period were anticipated to be small relative to the statistical procedures that would be used in the study. For example, it was anticipated that mean values could not be used as reasonable basis for estimation and that median values were a better basis. Also, continuous flood depth data had to be grouped into integer (1', 2', 3', etc.) categories for analysis by the GIS. This meant that depth changes less than 0.2 meters (0.5 ft) would become lost in the statistical procedures. We can interpolate to 30-years by assuming that hydrologically related damages would increase linearly over time. This means that if Alternative 2, compared to no-action, would save $36.463 million (Table 6-11) when the prototype storm event occurred in 100-years, it would save 30% of that amount, $10.939 million, if the storm event occurred in 30-years. It would save 15% of that amount, $5.469 million, if it occurred in 15-years.   Of course, the linearity assumption underestimates savings at 30-years if most of the hydrologic changes were to occur early in the 100-year period; and, conversely, overestimates savings for the opposite case. Table 6-12 makes this interpolation in estimates of damage cost savings under the project alternatives for the 30-year period of analysis.

Expected damage cost savings represents the product of savings when a storm event occurs times the probability of that event:

Expected Damage Cost Savings = Cost Savings When Event Occurs x Probability of Event

Section 6.3.3 has estimated the cost savings when a storm event occurs (i.e., the estimates in Tables 6-11 and 6-12). The storm event modeled was a Category 5 hurricane. This magnitude storm is rare in the study area. Only one such storm has directly hit the study area during the period 1900-1992 (Federal Emergency Management Agency 1994). During this period, a total of 11 storms (Category 1-5) have directly hit within the latitudes 89W-91W which encompass the study area. Unfortunately, we do not have hydrologic data to make estimates for damages from non-Category 5 storms. Given the rarity of a Category 5 storm and the fact that we do not have estimates of damages for lesser storms, we do not feel it is appropriate to estimate the Expected Damage Cost Savings.

Table 6-13 uses the 30-year damage cost savings from Table 6-12 to estimate the present values of those savings using various discount rates. For example, using the US Army Corps of Engineers 8.25% discount rate applicable for 1993 (USACE 1994), Table 6-13 shows that the present value of damages in 30-years under no-action MINUS damages in 30-years under Alternative 1 is $2.144 million for the 90.5W storm. The present value of damage cost savings for Alternative 2 is $1.014 million using the same discount rate. The 91.5W storm cost savings under the two alternatives are greater than the 90.5W storm savings. Lower discount rates increase the present values of the damage cost savings.

Table 6-12. Comparison of Median Flood Damage Estimates in 30-years for Project Alternatives - Interpolated Estimates from Table 6-8 ($ millions)

	90.5W Storm	91.5W Storm
Damage in 30-years Under No-action MINUS Damage in 30-years Under Alternative 1	$23.121	$40.913

Damage in 100-years Under No-action MINUS Damage in 100-years Under Alternative 2	$10.939	$22.439

Table 6-13. Present Value Comparison of Median Flood Damage Estimates in 30-Years for Project Alternatives ($millions)

	90.5W Storm:			91.5W Storm:		
	8.25%	5%	3%	8.25%	5%	3%
Damage in 30-years Under No-action Minus Damage in 30-years Under Alternative 1	$ 2.144	$ 5.350	$ 9.526	$ 3.793	$ 9.466	$16.856
Damage in 30-years Under No-action Minus Damage in 30-years Under Alternative 2	$ 1.014	$ 2.531	$ 4.507	$ 2.080	$ 5.192	$ 9.245

6.4. Other Cost Impacts of Barrier Island Projects

The impacts of project alternatives on structural damage costs from flooding are likely to be the most significant monetary benefits associated with barrier island restoration and maintenance. These project impacts were estimated in Section 6.3, and included cost savings to residential, commercial, industrial and public infrastructure. However, there may be other monetary benefits from barrier island projects. These would include:

* oil and gas infrastructure cost savings

* highway and street maintenance cost savings

* water supply cost savings

* agricultural crop flood damage cost savings

In addition to these monetary benefits, there may be non-monetary benefits from the preservation of lifestyles and social relations for coastal residents whose residence and employment are barrier island dependent.

While these monetary and non-monetary benefits may be very real, they are more difficult to estimate than structural damage benefits. This is because of data availability problems as well as conceptual measurement problems. Very ad hoc assumptions may have to be made to make estimates of these benefits. This section attempts to address several of these benefits that are likely to be somewhat quantifiable.

6.4.1. Oil and Gas Infrastructure

Oil and gas infrastructure (wells, pipelines, processing plants, compressor and metering stations, etc.) face increased storm risk as the barrier islands deteriorate. Changes in normal wave contours predicted under barrier island loss should not be so severe as to adversely impact structures in open water. The loss of barrier islands would diminish their usefulness as anchors for pipelines; requiring reburial. This could be a substantial cost. Pipelines traversing wetlands may have to be reburied if protected marshland areas convert to open water. Storm impacts from increased tidal surge elevations could require some redesign of well structures in open water.

The primary hydrologic and geologic effects of proposed barrier island projects are storm surge protection of open water and inland areas, and barrier island stabilization and wetland loss protection. Barrier island stabilization has the straightforward benefit of providing an anchor point for offshore oil and gas pipelines; barrier island loss would require more expensive engineering of these pipelines. Current and future oil and gas

wells located in open waters landward of the barrier islands benefit from barrier island stabilization insofar as the islands moderate tidal surge heights.

6.4.1.1.   Barrier Island Pipeline Reburial Costs

Barrier islands are anchoring structures for some offshore pipelines. There are currently nearly 60 pipelines coming onshore in the study area comprising the Terrebonne-Timbalier Bay and the Barataria Bay complexes. They range in size from 15 cm to 91 cm, with an average size of 41 cm. These are the pipelines most vulnerable to the projected barrier island losses in these complexes. Pipeline reburial occurs regularly as lines rise and washovers remove line cover. However, this reburial rate would increase as barrier islands disintegrate. We cannot predict how much more frequently and how much more severe reburial will be.

Increases in barrier island pipeline reburial costs were estimated for the 30- and 100-year no-action scenario in Step H (LADNR 1998h.ii). These estimates assumed that 60 lines currently crossing the islands would have to be reburied in 30-years at a reburial cost of $1.2 million at that time. The present and annualized values of those costs are shown in Table 6-14. For example, barrier island related pipeline reburial costs are estimated to have a present value of $0.11 million, using the USACE 8.25% discount rate, and $0.49 million using a 3% discount rate. Annualized values range from $0.01 million per year using the 8.25% discount rate to $0.03 million per year using the 3% discount rate.

Table 6-14. Expected Barrier Island Pipeline Reburial Costs for No-action Compared to Current Conditions ($ millions)

Current Condition Compared to:	No-action 30-years	No-action 100-years
Discount Rate		
1	2	3	4

8.25%	Present Value	$0.11	$0.12
	Annualized Value	$0.01	$0.01
5.00%	Present Value	$0.28	$0.34
	Annualized Value	$0.02	$0.02
3.00%	Present Value	$0.49	$0.70
	Annualized Value	$0.03	$0.04

We make the assumption that either Alternative 1 or Alternative 2 would avoid these reburial costs. The estimates in Table 6-14 would then be benefits of these Alternatives. However, we assume no additional benefit of Alternative 1 over Alternative 2. (At least these benefits would be too small to be measurable using the very crude procedures employed in this study.)

6.4.1.2. Wetlands Pipeline Reburial Costs

Many miles of pipeline also run through the coastal wetlands. For example, there are roughly 1,207.5 kilometers (750 miles) of pipelines, ranging from 13 cm to 91 cm (5 to 36 inch) lines, running through the wetlands region adjacent to the Terrebonne-Timbalier and Barataria Bays. These estimates were calculated from pipeline maps and include all pipelines within approximately 8 km (5 miles) of these bays. These wetlands provide some protection against wave action and storms. Loss of wetlands may require the repositioning of vulnerable lines, including reburial.

The increases in interior wetlands pipeline reburial costs were estimated for no-action compared to current conditions in Step H (LADNR 1998h.ii). These estimates are reproduced in Table 6-15. Pipeline reburial cost savings of project alternatives can be estimated by assuming these savings, relative to the costs of no-action, are proportional to the wetlands saved by the project alternatives relative to wetlands lost under no-action. For example, 30-year wetlands losses under no-action were estimated in Step G (LADNR 1998g) to be 58,630 hectares (144,877 acres), and can be estimated using Table 6-1.

Wetland losses under Alternative 1 were estimated to be only 55,018 hectares (135,952 acres) during this 30-year period. This implies that wetlands losses under Alternative 1 were 6.0% less than under no-action. Therefore, we assume that pipeline reburial costs under Alternative 1 would be 6.2% less than under no-action. Table 6-15 shows that the present value of reburial costs in interior wetlands would be $4.064 million, using the 8.25% discount rate over a 30-year period. Therefore, reburial costs under Alternative 1 would be $0.25 million (6.2% x $4.064) less than under no-action. This cost savings is shown in Column 5 of Table 6-16.

Table 6-15. Expected Interior Wetlands Pipeline Reburial Costs for No-action Compared to Current Conditions ($ millions)

Current Condition Compared to:		No-action 30-years	No-action 100-years
Discount Rate 1	2	3	4
8.25%	Present Value	$4.064	$4.478
	Annualized Value	$0.370	$0.370
5.00%	Present Value	$5.682	$7.336

	Annualized Value	$0.370	$0.370
3.00%	Present Value	$07.244	$11.679
	Annualized Value	$0.370	$0.370

Table 6-16. Interior Wetlands Pipeline Reburial Cost Savings from Project Alternatives ($ millions)

Losses Under	MINUS Losses Under	Period (Years)	Wetlands Loss Avoided	8.25% Present Value	Annualized Value	5.00% Present Value	Annualized Value	3.00% Present Value	Annualized Value
No-action	Alternative 1	30	6.2%	$0.25	$0.02	$0.35	$0.02	$0.45	$0.02
		100	6.0%	$0.27	$0.02	$0.44	$0.02	$0.70	$0.02
No-action	Alternative 2	30	0.5%	$0.02	$0.00	$0.03	$0.00	$0.04	$0.00
		100	2.7%	$0.12	$0.01	$0.20	$0.01	$0.32	$0.01

The cost savings for Alternative 2 compared to no-action are also shown in Table 6-16, as are savings for Alternative 1 compared to Alternative 2. These savings are small compared to the storm, recreational and commercial fisheries benefits of project alternatives.

6.4.1.3. Oil and Gas Wells and Related Structures

There are roughly 340 oil and gas fields and nearly 19,000 wells in the study area, with 270 fields and over 17,000 wells located in the five parishes adjacent to the barrier islands (LADNR 1998f). The associated well structures may be subject to greater washover intensities from storms in the absence of protective barrier islands. If these inland structures are typically built to withstand washovers, there will be no increased engineering and maintenance costs to these inland well structures from increased tidal surge elevations. Figures 6-4 and 6-5 suggest these increased tidal elevations would typically range up to 0.30 meters (1.0 feet) in the regions immediately adjacent to the barrier island complexes.

Wells and associated structures in open waters lying landward of the barrier islands may be subject to substantial increased storm risk in the absence of those protective islands. In the Step H report (LADNR 1998h.ii), there are 4,166 such wells in fields located in open waters in Terrebonne-Timbalier and Barataria Bays. While these are the wells at risk, estimating increased costs to these wells under alternative project scenarios is problematic. The report also estimates the expected well platform construction cost increases for these bayside wells under no-action compared to Current Conditions are shown in Table 6-17.

Table 6-17. Expected Well Platform Construction Cost Increases for Anticipated Bayside Wells Under No-Action Compared to Current Conditions ($ millions)

Losses Under	Period (Years)	8.25% Present Value	Annualized Value	5.00% Present Value	Annualized Value	3.00% Present Value	Annualized Value
No-action	30	$0.269	$0.024	$0.355	$0.023	$0.436	$0.022
	100	$0.269	$0.024	$0.355	$0.023	$0.436	$0.022

We assume that both Alternatives 1 and 2 will avoid the need for bayside well platform construction that would arise under no-action. This is because these alternatives essentially provide the same barrier island protection against surges and wave action as the islands in the current conditions. Therefore, the cost savings of these alternatives would be the no-action cost increases compared to Current Conditions as shown in Table 6-18. For example, Alternatives 1 and 2 would provide costs savings of $0.269 million over no-action, using the 8.25% discount rate. The cost savings are the same for both alternatives, since the Step H Report assumed that all additional well construction costs would accrue within the 30-year period due to the age of the fields in the impacted area (LADNR 1998h.ii). In addition, Alternative 1 is expected to provide no construction cost savings over Alternative 2.

Table 6-18. Expected Well Platform Construction Cost Savings for Anticipated Bayside Wells Under Project Alternatives ($ millions)

Losses MINUS	8.25%	5.00%	3.00%

Under Losses Under	Period (Years)	Present Value	Annualized Value	Present Value	Annualized Value	Present Value	Annualized Value
No-action Alternative 1	30	$0.269	$0.024	$0.355	$0.023	$0.436	$0.022
	100	$0.269	$0.024	$0.355	$0.023	$0.436	$0.022
No-action Alternative 2	30	$0.269	$0.024	$0.355	$0.023	$0.436	$0.022
	100	$0.269	$0.024	$0.355	$0.023	$0.436	$0.022

6.4.1.4. Oil and Gas Refineries and Processing Plants

There are five active refineries and 23 gas processing plants in the study area (LADNR 1998f). Estimation of potential flood damage costs to these structures is problematic. However, flood damage estimation methodology used in Section 6.3 included damages to industrial structures insofar as these structures were included in the USACE estimates. However, there is reason to believe that costs to refineries and processing plants are likely to be omitted using that methodology. The reason is that damages were tied to residential units in the WRU's (Water Resource Units) studied by the USACE. Refineries and processing plants in coastal Louisiana are likely to be isolated from residences so the residential based methodology used in Section 6.3 may omit, or undervalue, damages to these industrial structures. Damages to these unique structures would have to be estimated using a typical refinery and processing plant. We do not know of any study that has made such an estimate. While there may be effects of project alternatives on flood damage costs to these structures, we are not able to estimate them.

6.4.2. Highway and Street Maintenance

The increased possibility of flooding may impact road and street maintenance expenses. However, the manner in which this may occur is not obvious. The depth of flooding of roads is not as important in determining road damages as whether the road is flooded at all, the flow rate of water across the road and flood duration. Figures 6-10 and 6-11 show those portions of the study area, called flood risk margins, that are more likely

to be flooded from one of the prototype storms under the no-action alternative in 100-years than would be the case for a current storm. Figure 6-13 reproduces those areas of increased flooding likelihood and adds a data layer of highways and streets from the Wessex(database of Tiger 92 street files. The streets in these areas are at risk from greater flooding under no-action compared to current conditions.

These increased inland flood risks under no-action are due to a combination of factors, including sea level rise, wetland subsidence and the loss of barrier islands under no-action. Sea level rise and wetlands subsidence will continue regardless of the barrier island projects. It is probably for this reason that the hydrologic models did not yield substantially different flood risk margins under no-action, and Alternatives 1 and 2 (See Section 6.2). The risk margins were so small that we could not reasonably estimate differences in highways and streets flooded between the no-action scenario and Alternatives 1 and 2.

6.4.3. Water Supply

Public water supplies in the study area rely on both groundwater and surface waters (LADNR 1998f). Alterations of the barrier islands may periodically change salinity regimes of surface waters and make some water supplies unreliable. Furthermore, permanent changes in salinity levels and movement of salinity isoclines landward may alter salinity levels of groundwater supplies. The Step H Report (LADNR 1998h.ii) estimated the increases in water supply costs for no-action compared to current conditions. Since water supply problems are more likely to arise from sea level rise and wetlands subsidence, they may not be mitigated by barrier island projects. Therefore, we assume that the drinking water costs under no-action and Alternatives 1 and 2 will be the same.

6.4.4. Agricultural Crop Flood Damages

Increased flood damages to agricultural crops could be due to two effects: inundation of previously unflooded lands, and longer inundation periods. These are two separate effects. We have no data on length of flooding under the various project alternatives, so this effect cannot be estimated. However, Figures 6-10 and 6-11 show newly flooded areas under no-action compared to current Category 5 storms. If any of these areas are agricultural lands, they may face increased expected flood damages to crops. Figure 6-13 shows these newly flooded lands and associated streets. The Step H Report estimated the agricultural costs of these newly flooded lands (LADNR 1998h.ii). However, as noted in Section 6.2, the marginal increases in newly flooded lands between no-action and Alternatives 1 and 2 were too small to analyze. Therefore, we presume the agricultural cost differences between these project options will be small and we cannot estimate them.

Figure 6-13. Streets Likely to be Newly Flooded by 90.5W or 91.5W Storm Under No-Action, But Not Flooded Under Current Storm.
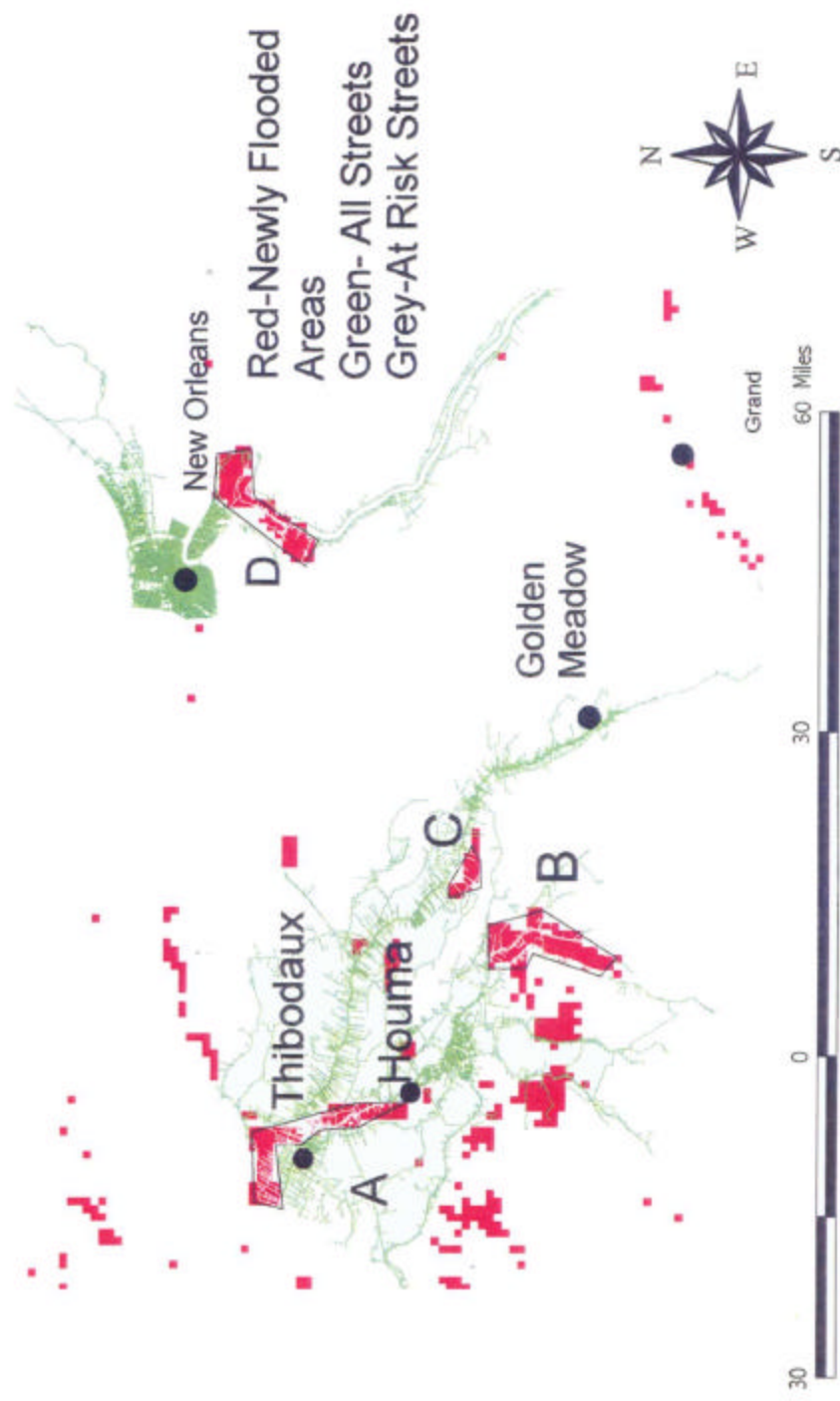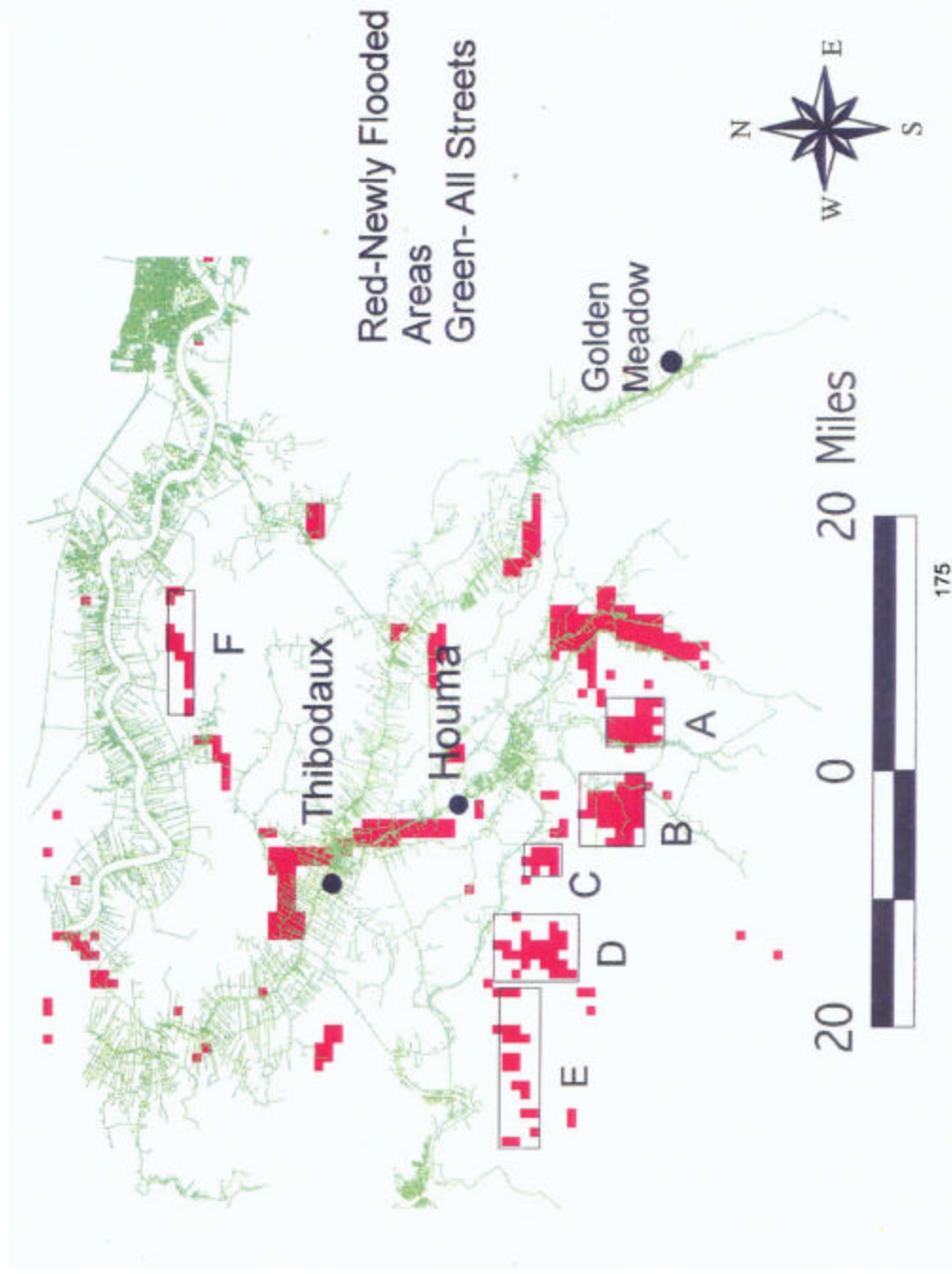
Red- Newly Flooded Areas
Green- All Streets
Grey- At Risk Streets

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Figure 6-14. Agricultural Areas Likely to be Newly Flooded by 90.5W or 91.5W Storm Under No- Action, But Not Flooded Under Current Storm.

6.5. Summary Of Economic Benefits Of Project Alternatives

This study has estimated some of the benefits of barrier island project alternatives; or, conversely, the costs of not engaging these projects. There are three related pathways for project impacts on study area economic benefits and costs: alterations of normal and storm related hydrologic regimes, alterations of barrier island configurations, and alterations of wetland configurations. After considering the maps showing changes in normal wave conditions under project alternatives, the study concluded that economic impacts of these changes would be small. The study then focused on project impacts of storms, barrier island configurations and wetland losses.

Project alternatives included no-action, Alternative 1, and Alternative 2. Compared to no-action, the alternatives could possibly reduce economic losses from storms and wetlands deterioration. These reductions in losses would be the benefits of the alternatives compared to no-action.

Storm damages were estimated for two prototypic, Category 5 storms occurring 100-years from the present. These damages were estimated under the project alternatives. These damage comparisons are shown in Table 6-19. For example, if a Category 5 storm hit coastal Louisiana at 90.5W in 100-years, there would be $77.1 million less flood damage under Alternative 1 than under no-action. The damage cost savings for a 91.5W storm in 100-years is $136.4 million. Alternative 2 would result in damage cost savings compared to no-action equal to $36.4 or $74.8 million, depending on where the storm hit. In other words, Alternative 1 results in roughly twice the damage cost savings compared to no-action as Alternative 2. It is extremely important to understand the information provided by Table 6-19. It is only an estimate of damage savings if such a storm occurs. It is an estimate of damage savings at that time (i.e., 100-years from present).

Table 6-19. Comparison of Median Flood Damage Estimates for Storms Occurring in 100-years for Project Alternatives ($ millions)

	90.5W Storm	91.5W Storm
Damage in 100-years Under No-action MINUS Damage in 100-years Under Alternative 1	$77.070	$136.377
Damage in 100-years Under No-action MINUS Damage in 100-years Under Alternative 2	$36.463	$74.795

Table 6-20 shows damage savings if a storm occurs in 30-years. This estimate is simply thirty percent of the 100-year damage savings estimates shown in Table 6-19. In order to understand these savings in present value terms, Table 6-21 has estimated the present value of damage cost savings if a storm occurs in 30-years. For example, the $23.121 million in damages savings from a 90.5W storm under Alternative 1 compared to no-action for the 30-year storm, shown in Table 6-20, has a present value of $2.1 million when using the USACE's 8.25% discount rate (USACE 1994) applicable to the base year of this study, 1993. This present value cost savings is $9.526 million when a discount rate of 3% is used. The present value of cost savings in the case of a 91.5W storm is roughly twice as large. These values tell us the present value equivalents of the damage savings if a storm occurs in 30-years.

Table 6-20. Comparison of Median Flood Damage Estimates for Storms Occurring in 30-years for Project Alternatives ($ millions)

	90.5W Storm	91.5W Storm
Damage in 30-years Under No-action MINUS Damage in 30-years Under Alternative 1	$23.121	$40.913
Damage in 100-years Under No-action MINUS Damage in 100-years Under Alternative 2	$10.939	$22.439

Lesser category storms were not analyzed, so storm damage benefits of alternatives would be underestimated by considering only Category 5 storms. We would have a better understanding of project alternative cost savings if we could have analyzed a range of storms, and applied probabilities to those damages based on historic storm occurrence data. Study funding limitations did not allow this.

Recreational and commercial fishery losses were associated with wetland areas. The wetland areas differed across alternatives, as barrier island configurations would impact wetlands loss rates. Other benefits of project alternatives were considered, including pipeline reburial costs, oil and gas well construction costs, highway and street maintenance, water supply and agricultural crop damages. Highway and street infrastructure damage costs savings could not be estimated given the resolution of the data available. This was also the case for water supply and agricultural damages.

Table 6-21. Present Value Comparison of Median Flood Damage Estimates for Storms Occurring in 30-years for Project Alternatives ($ millions)

	90.5W Storm:			91.5W Storm:		
	8.25%	5%	3%	8.25%	5%	3%
Damage in 30-years Under No-action Minus Damage in 30-years Under Alternative 1	$2.144	$5.350	$9.526	$3.793	$9.466	$16.856
Damage in 30-years Under No-action Minus Damage in 30-years Under Alternative 2	$1.014	$2.531	$4.507	$2.080	$5.192	$9.245

Table 6-22 shows the summary estimates of present values of non-storm related benefits for Alternatives 1 and 2 compared to no-action. These benefits include only recreational and commercial fishery benefits, and oil and gas infrastructure benefits of the alternatives. High and low estimates were made for both 30 and 100-year periods, using difference discount rates. For example, Table 6-22 shows the non-storm present value of cost savings, or benefits, of Alternative 1 compared to no-action over this 30-year period as being $1.6 to $1.9 million using the 8.25% discount rate. The annualized value of this cost savings, or benefit, ranges from $145,000 to $168,000 per year over the 30-year period of amortization. The present value of these cost savings ranges from $3.3 to $3.8 million using a 3% discount rate. The present and annualized cost savings, or benefits, of Alternative 2 compared to no-action are roughly one-half the savings that Alternative 1 provides.

It is important to emphasize that Table 6-22 cannot be added to Table 6-21. Table 6-22 represents the cost savings over the next 30 or 100-years anticipated from the two project alternatives. Table 6-21 only shows the damage cost savings if a prototype storm occurs. Such a storm, while likely to occur over the next 100-years, may or may not occur. Storm damage savings from the project alternatives could only be added to Table 6-22 if we had annual estimates of the expected storm damages, taking into consideration both the damages if a storm occurs and the probability of such a storm. While such estimates are possible, they could not be made for this study due to budget limitations.

Table 6-22. Summary of Non-Storm Cost Savings and Benefits of Project Alternatives 1 and 2 Compared to No-action ($ millions)

Losses Under	MINUS Losses Under	Period (Years)	Low/High	8.25% Present Value	8.25% Annualized Value	5.00% Present Value	5.00% Annualized Value	3.00% Present Value	3.00% Annualized Value
No-action	Alternative 1	30	Low	$1.643	$0.145	$2.462	$0.157	$3.323	$0.168
			High	$1.897	$0.168	$2.820	$0.178	$3.780	$0.188
		100	Low	$1.844	$0.152	$3.348	$0.175	$5.848	$0.209
			High	$2.178	$0.178	$4.128	$0.214	$7.737	$0.268
No-action	Alternative 2	30	Low	$0.859	$0.076	$1.544	$0.100	$2.151	$0.113
			High	$0.968	$0.086	$1.779	$0.115	$2.465	$0.128
		100	Low	$1.057	$0.089	$2.148	$0.116	$3.691	$0.142
			High	$1.206	$0.102	$2.596	$0.139	$4.727	$0.175