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16. Abstract

This report was developed for use by TxDOT in planning efforts to reduce the degree of impact on the Texas highways in the event of a closure to the Texas Gulf Intracoastal Waterway. With the provision of up-to-date GIWW commodities and roadway conditions, the methodologies developed in this report can predict the expected tonnage to be shifted to the highway system and its associated detrimental effects.

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CLOSURE OF THE GIWW AND ITS IMPACT ON THE TEXAS HIGHWAY TRANSPORTATION SYSTEM: FINAL REPORT - VOLUME I

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IMPLEMENTATION

The information developed, analyzed, and presented herein can be used by TxDOT in planning efforts to reduce the degree of impact on the Texas highways in the event of a closure to the Texas Gulf Intracoastal Waterway. With the provision of up-to-date GIWW commodities and roadway conditions, the methodologies developed in this report can predict the expected tonnage to be shifted to the highway system and its associated detrimental effects. When one considers the magnitude of these effects, the usefulness of this study becomes clear.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

SUMMARY

The Texas Gulf Intracoastal Waterway (GIWW) plays an important role as a shipping mode for industries located along the coast. The advantages inherent in barge transportation, namely large carrying capacities, fuel efficiency and low cost, make waterborne transport the mode of choice for many bulk commodity movements and is a primary reason why firms have selected the Texas Gulf coast for their business location. The industrial commitment to the GIWW along the Texas Gulf coast coupled with the realization by the Texas Department of Transportation (TxDOT) that closure of the canal, whether planned or unplanned, is not outside the realm of possibility has prompted a closer look at the potential impacts of an interruption in service on the GIWW.

Findings in this research lead to the conclusion that there is a low probability of extended closure to the GIWW. Any unlikely extended closures, however, will most probably be caused by an environmental action or a lack of funding. Although this report tends toward low closure probabilities, this does not completely eliminate all GIWW interruption possibilities. The consequences of a GIWW closure are related to the time of closure. Interruptions which can be alleviated within two weeks will have little to no impact on GIWW industrial firms. On the other hand, if a closure event cannot be circumvented within 30 days time, the effect on the GIWW industries will be a modal shift from waterway to roadway and/or rail. Along the Texas reach of the GIWW, the location most susceptible to an extended interruption in service is the Laguna Madre.

The origin-destination and commodity flow data used in this study was obtained from the Waterborne Commerce Statistics Center (WCSC), U.S. Army Corps of Engineers, New Orleans, Louisiana. The data included both shipping and receiving information for over 20,000 shipments during the calendar year 1989. The data indicates that the Texas portion of the GIWW provided transportation for 65.9 million tons (59.7 million Mg) in 1989, with its primary constituents, refined petroleum, chemicals, crude petroleum, and metals and minerals, composing approximately 98% of that total.

This research was designed to provide the Texas Department of Transportation with a tool to predict and analyze the impacts of a closure on the GIWW on the Texas highway transportation system. The results of the research have been developed to depict the amount of material which could reasonably be expected to shift to the highway system, and the effects of that shift on accidents, fuel usage, emissions, hazardous materials movement, and roadway surface conditions. Since no one can predict where or even if a closure might occur, the model has been developed to predict the impact given an interruption at any milepoint along the 410 mile (660 Km) length of the canal. The exact length of Texas' portion of the GIWW can vary depending on the exact marker that is used to designate the waterway end in the south Texas (Brownsville) region. Given a beginning GIWW milepoint of 265 located at the Texas-Louisiana border marked by the Sabine River and an ending marker of 675 located at the Brownsville ship channel, the effective length of the GIWW in Texas is 410 miles (660Km). In using the model to predict closure impacts, a break in the waterway beyond milepoint 675 will not result in an interruption in service warranting a modal shift. The model works for discrete points of closure or for closure on entire reaches of the waterway. The foresight that can be gained by this research will allow TxDOT, state planners, and industries to take mitigating measures in prevention of detrimental modal shifting effects.

1.0 COMMODITY MOVEMENTS ON THE TEXAS GIWW

1.1 GIWW COMMODITY FLOW ANALYSIS

With over 80 million tons (72.5 million Mg) of commodities shipped on the Gulf Intracoastal Waterway (GIWW) each year, the canal plays a key transportation role for industries located along the Texas coastline. Figure 1 illustrates the Texas portion of the GIWW and the counties which are adjacent to the waterway. These industries, many of which are petroleum and chemical based, rely on barge shipments to import and export material or finished products. The advantages inherent in barge transportation, namely large carrying capacities, fuel efficiency and low cost, make waterborne transport the mode of choice for many bulk commodity movements and are the primary reasons why firms have selected the Texas gulf coast for their business locations.

The industrial commitment to the GIWW along the Texas Gulf coast coupled with the realization by the Texas Department of Transportation (TxDOT) that closure of the canal, whether planned or unplanned, is a real possibility has prompted a closer look at the potential impacts of an interruption in service on the GIWW. Erosion problems at Sargent Beach, Texas, which, left unchecked, could have severed the waterway below Freeport, were highly publicized and much discussed as a serious threat to the State's economic base. In response, the U.S. Army Corps of Engineers has moved ahead plans to erect a $100 million barrier to prevent further erosion.

The GIWW is vulnerable to other threats as well. The canal traverses several sensitive wildlife refuges and environmental action groups are requesting clear justification for dredging disposal site selection and disposal methods. Recently, the necessity of maintaining the lower reaches of the GIWW (that section passing through the Laguna Madre region of the coast), has been questioned both from an environmental and economic perspective. Critics have maintained that the relatively low volume of material moved on this section of the canal does not warrant the cost.

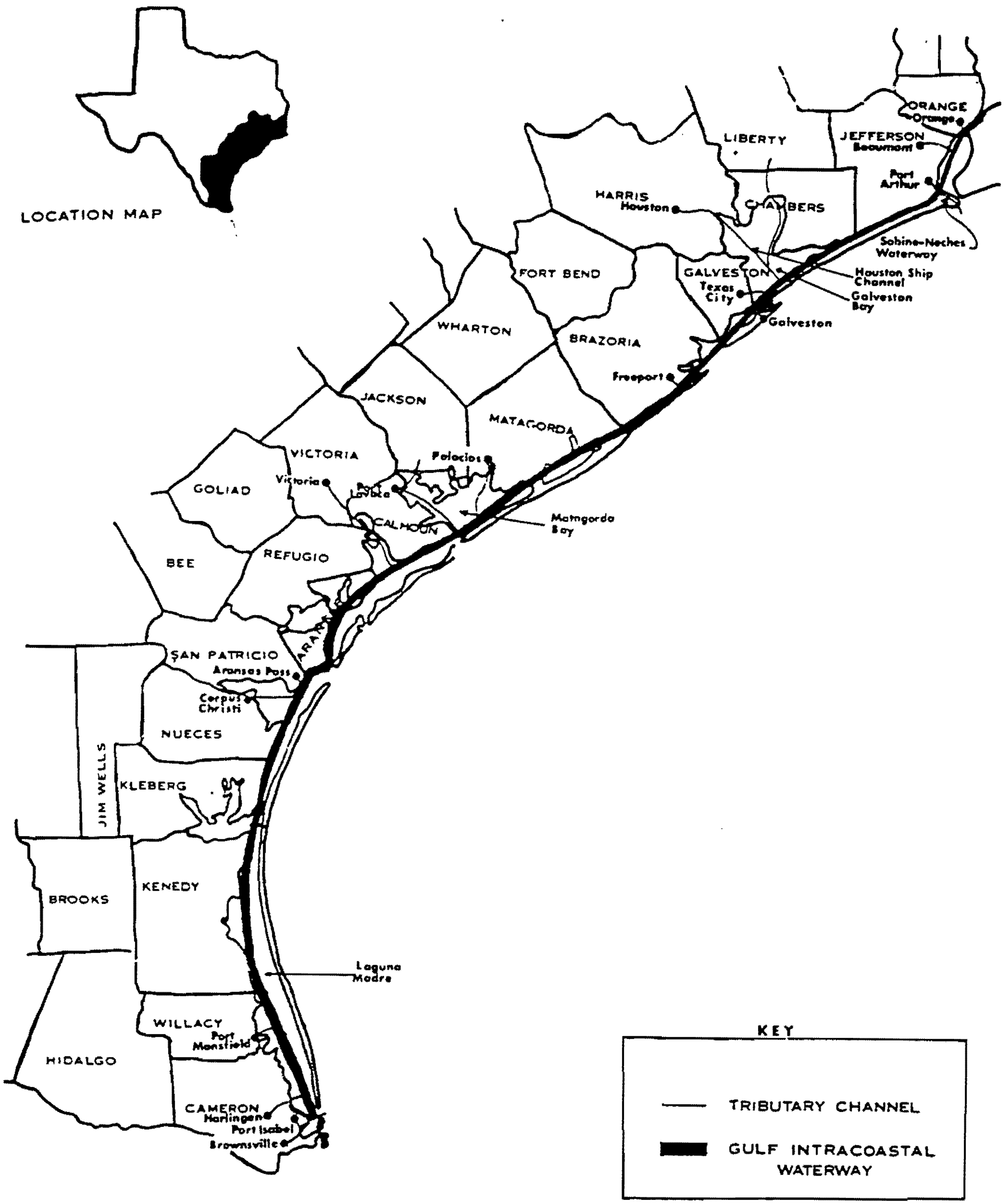

Figure 1. The Texas Gulf Intracoastal Waterway and Adjacent Counties

This research provides the Texas Department of Transportation with a tool to predict and analyze the impacts of a closure on the GIWW on the Texas highway transportation system. The results of the research depict the amount of material which could be expected to shift to the highway system, and the effects of that shift on accidents, fuel usage, emissions, hazardous materials movement, and roadway surface conditions. Since no one can predict where or even if a closure might occur, the model has been developed to predict the impact of an interruption at any milepoint along the 410 mile (660 Km) length of the canal. The model works for discrete points of closure and for closure on entire reaches of the waterway.

The remaining chapters of this report address events potentially affecting the operational integrity of the GIWW, the development of the predictive model, and impact analyses for several closure scenarios identified throughout the research. The remainder of Chapter 1 addresses the source, nature, and amounts of material potentially diverted to the Texas highway system.

Commodity Flow Data Sources

The origin-destination and commodity flow data used in this study was obtained from the Waterborne Commerce Statistics Center (WCSC), U.S. Army Corps of Engineers, New Orleans, Louisiana. The data included both shipping and receiving information for over 20,000 shipments during the calendar year 1989. The WCSC collects, compiles, and reports commodity flow data for each calendar year and publishes a report documenting the waterborne movement of material titled *Waterborne Commerce Of The United States.*

Commodity flow data are published at an aggregated level of detail to maintain the confidentiality of the commercial entities reporting shipment statistics. The confidentiality is maintained because schedules, amounts, and types of goods and materials shipped would be of value to competitors. However, the requirements of the current research demanded detailed data sufficient to track dock-to-dock movements by specific commodity categories. By working through the Texas Department of Transportation, the Federal Highway Administration, and the U.S. Army Corps of Engineers, detailed records were obtained in a form that facilitated computer analysis.

The commodity flow data obtained from the WCSC contained:

- shipping and receiving dates,
- shipping and receiving port and dock identified by dock location codes,
- commodity type specified by a standard transportation commodity code,
- tons transported, and
- vessel types.

The data indicate that the Texas portion of the GIWW provided transportation for 65.9 million tons (59.7 million Mg) in 1989, with its primary constituents -- refined petroleum, chemicals, crude petroleum, and metals and minerals -- composing approximately 98% of that total. Figure 2 presents the relative tonnage of these primary commodities.

The 65.9 million tons (59.7 million Mg) under modal shift consideration for this research is different from the 81.5 million tons (73.9 million Mg) projected in the interim report generated in September of 1992 (Roop, 1992). The reason centers on the fact that the WCSC manages commodity flow on the Texas GIWW in three discrete project sections. The first project section, an 83.9 mile (135.1 Km) stretch ranging from the Sabine River to Galveston, carried 53,586,769 tons (48,603,199 Mg) in 1989. The second section, a 189.5 mile (305.1 Km) reach from Galveston to the Corpus Christi ship channel, carried 26,000,866 tons (23,582,785 Mg) of freight in 1989. The final project section, from the Corpus Christi ship channel to Brownsville, carried 1,900,609 tons (1,723,852 Mg) in 1989.

The tons, when summed, add to the 81.5 million ton (73.9 million Mg) figure reported in the 1989 version of *Waterborne Commerce Of The United States* and repeated in the interim report. The discrepancy between this figure and the 65.9 million tons (59.7 million Mg) reported in this research, arises from shipments being counted twice when moved from one project into another. In those instances where a commodity crosses projects, the tonnages are recorded by each project through which a shipment moves. In summing across all three sections, some figures may be counted in all three project sections.

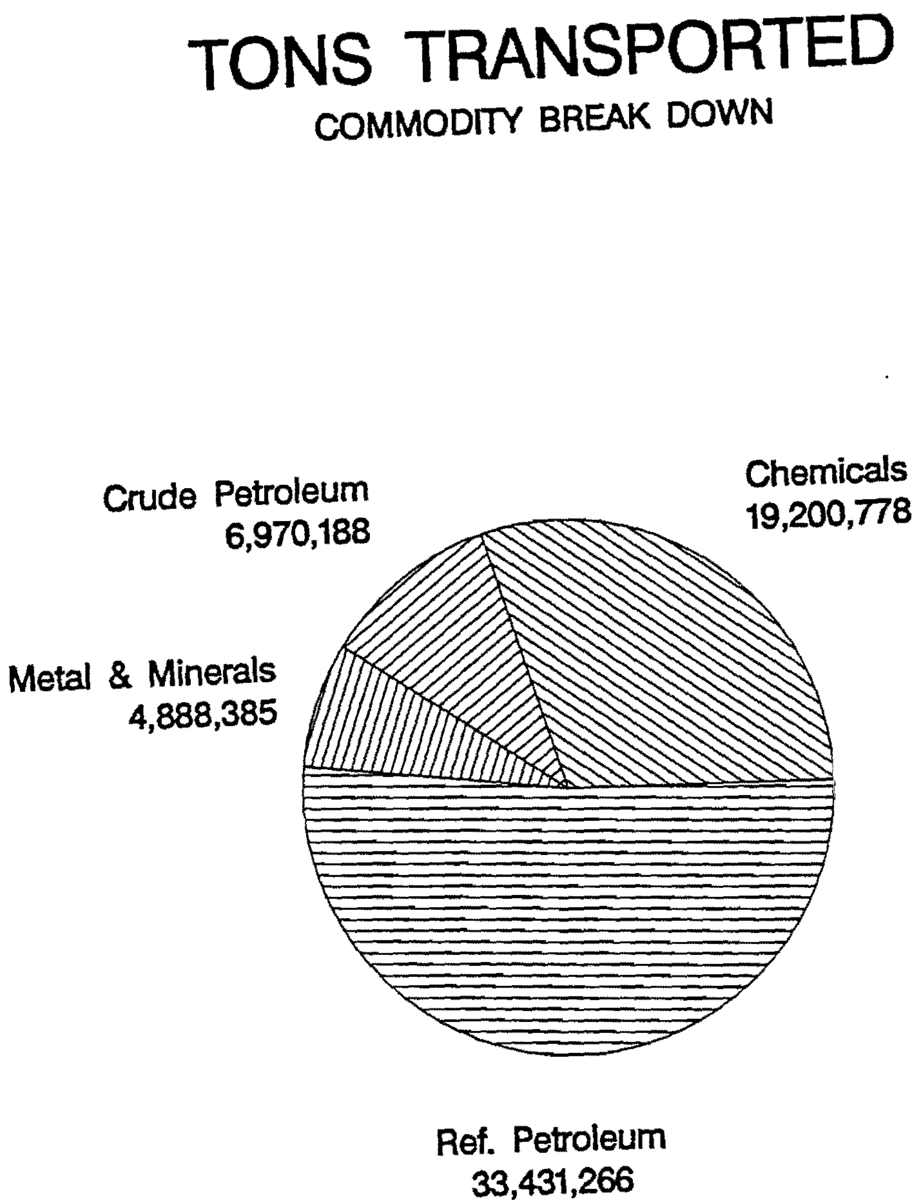

Figure 2. Tons Transported: Commodity Break Down

In obtaining the 65.9 million ton (59.7 million Mg) figure, discrete origin and destination pairs were summed to avoid freight overlap. In addition, a small portion of the difference between the 81.5 million tons (73.9 million Mg) and the 65.9 million tons (59.7 million Mg) can be attributed to the elimination of goods which are shipped and received at the same GIWW milepoint designation, such as across an open bay or into an inland river. In these cases, one milepoint designation has been assigned to an expansive GIWW location or the mouth of an inland river. The origin-destination pair, therefore, will indicate these shipments with the same number pair. These tonnages are discarded because they can not be impacted by an interruption on the GIWW.

Commodity Flow Concentrations

To further characterize commodity movements which may be impacted by an interruption in service on the GIWW, the analysis pinpointed shipping and receiving locations along the Waterway. With this data, critical areas of congestion were identified. Figure 3 presents the tonnages, broken down by their commodity components and plotted by ten mile location increments. The tonnage figures appearing in Figure 3 are a sum of shipping and receiving amounts.

The peak occurs around milepoint 350 with more than 32 million tons (29 million Mg) transported. As with Figure 2, the tons transported summary by milepoint is also heavily weighted by refined petroleum. The graph clearly shows the magnitude of the commodity movements around the Beaumont/Port Arthur (280/290), Houston/Galveston (350/360), and Corpus Christi (540) areas. Closure to the GIWW in these areas is more likely to cause highway and railway traffic congestion due to the sheer number of vehicles which would be necessary to transport shifted material at these locations.

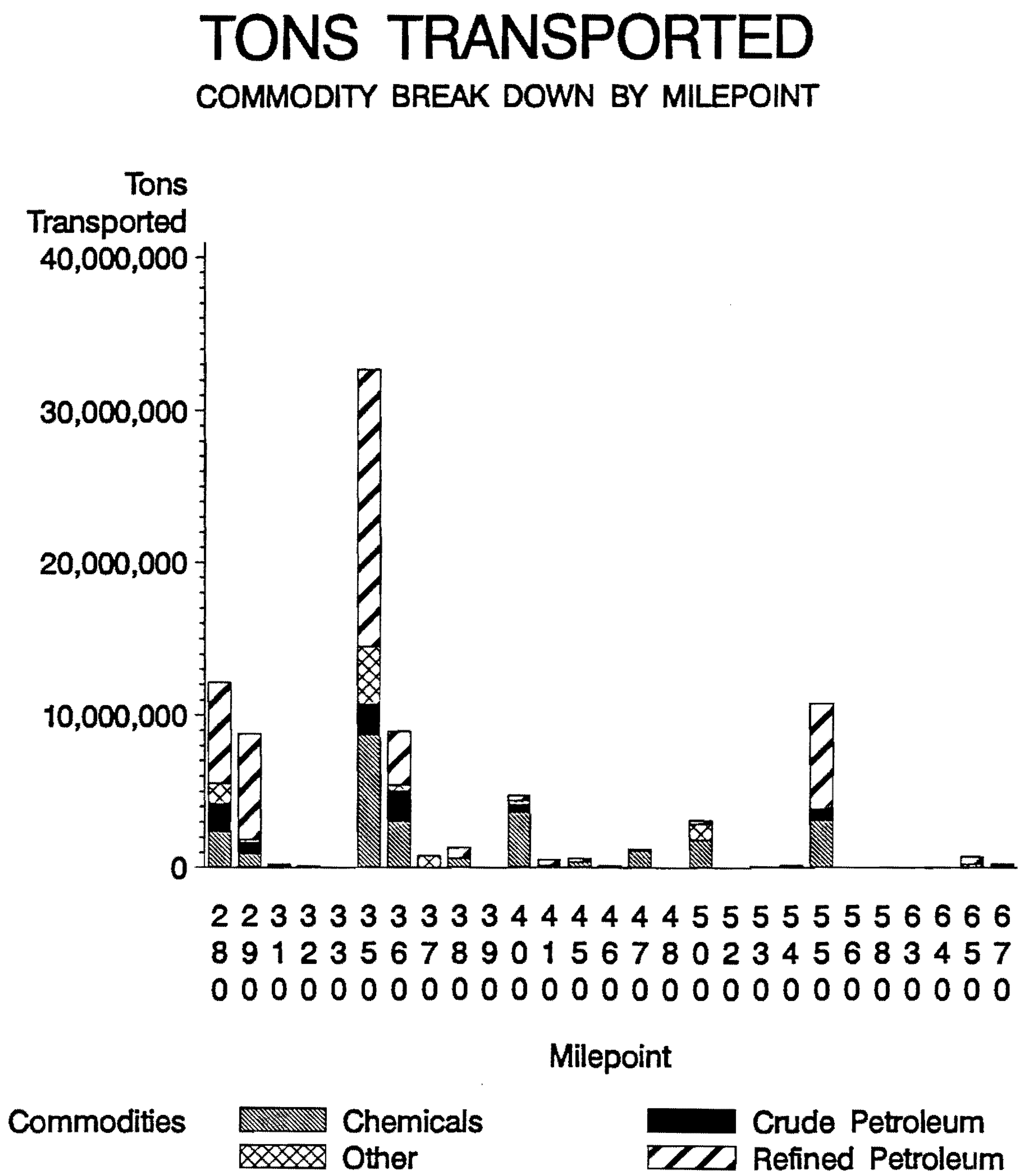

Figure 3. Tons Transported: Commodity Break Down by Milepoint

Seasonal Variation in Commodity Flow

Seasonal patterns were also examined to determine if the time of year of a closure would impact the tons shifted to highways. Figure 4 breaks down the shipping and receiving data by the month of shipment within the 1989 calendar year. The results show no dramatic differences in tons transported across calendar year 1989. A minor peak occurs in the months of May and July with approximately 5.5 million tons (5.0 million Mg) transported. The "off" months of February and December differ little from the peak season with just under 5 million tons (4.6 Mg) transported. The lack of variation by month shown in Figure 4 leads to the conclusion that potential freight diversion problems are not a function of month of closure. The impact of a modal shift from water to alternate transport modes is likely to be relatively constant throughout the year.

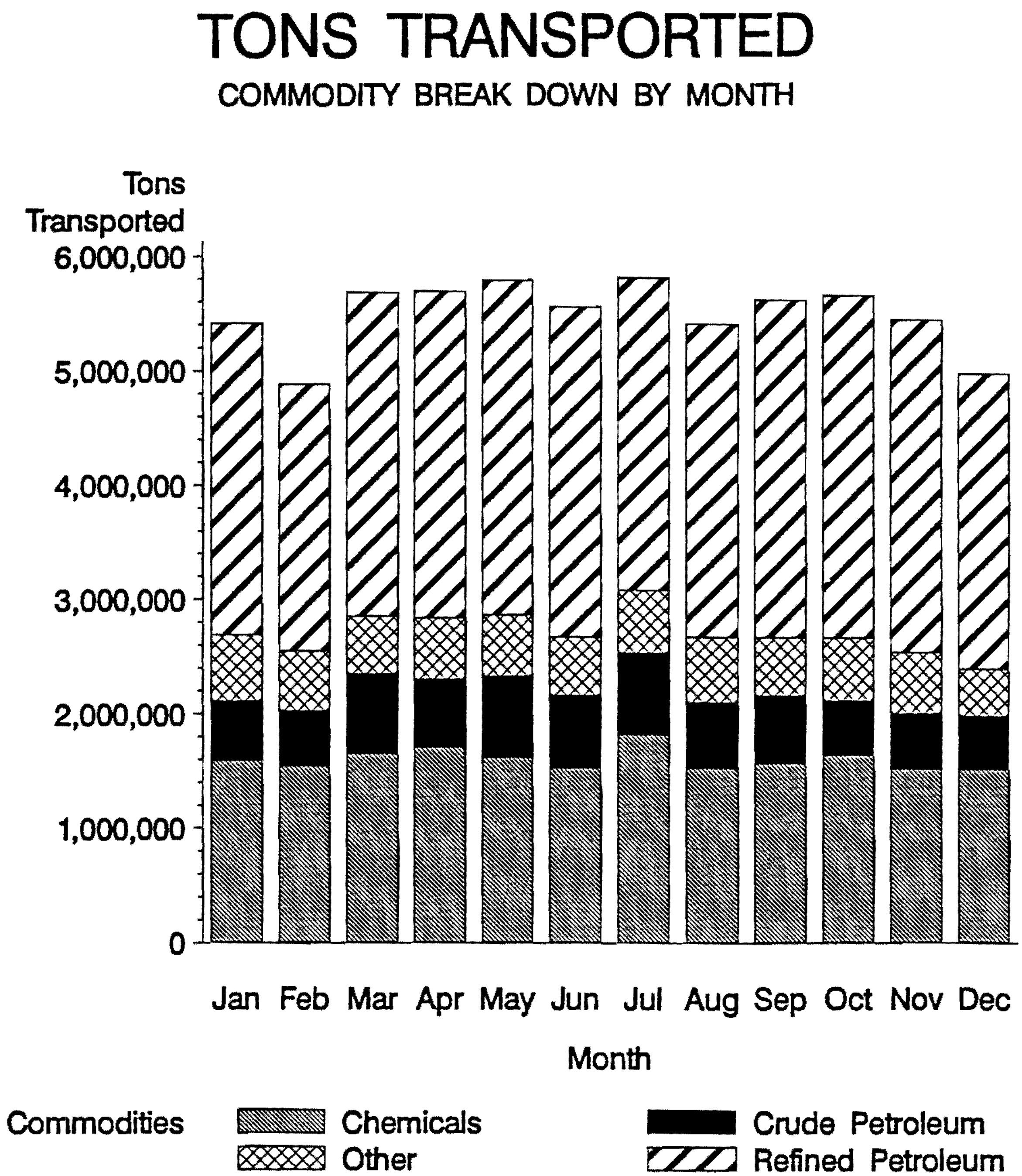

Figure 4. Tons Transported: Commodity Break Down by Month

2.0 GIWW CLOSURE EVENTS AND LIKELIHOOD

2.1 INTRODUCTION

The U.S. Army Corps of Engineers, various users of the inland waterway system, and state and local governments recognize that the inland waterway system in the United States faces mounting obstacles to safe and competitive operation. Concerns about the waterways are diverse and often involve interest groups with conflicting agendas. Recognizing the complex nature of waterway problems in general, and business and environmental concerns in particular, this chapter examines the events potentially disruptive to shipping on the GIWW in Texas and identifies their most likely locations.

Lieutenant General Henry J. Hatch, former Chief of Engineers, U.S. Army Corps of Engineers, identifies the two biggest challenges facing the waterways: a decrease in Federal funds for water resources projects, and requirements for increased protection of the environment. The barge industry, which is focused on remaining competitive, recognizes these as problems for two reasons. First, the impact of taxation to fund the waterways is seen as eroding users' present competitive position in relation to rail lines. Second, canals are often unable to use modern technologies because of environmental concerns blocking necessary structural improvements. In order to remain competitive, waterway improvements are necessary. Communities impacted by the waterways are also concerned. While some local governments and lobbyists are desperately soliciting Corps of Engineers intervention (such as at Sargent Beach, Texas), other government and interest groups are opposing Corps actions to maintain the waterway.

The examination of potential interruptions to service suggests that closure could occur as a result of two categories of events. The first involves closures due to structural or operational problems such as erosion, shoaling, natural disasters or accidents. The second category includes limitations to traffic due to environmental issues, political or financial issues, and issues related to national security. Each of these types of closures is discussed in detail below.

These categories are also described in a preliminary manner in Closure of the GIWW and Its Impact On The Texas Highway Transportation System: Interim Report (September 1992).

Structural and Operational Problems

These problems involve safety issues, requirements imposed by the U.S. Coast Guard or other agencies, navigation structures such as locks and dams that are necessary for safe and efficient operations by commercial barge traffic on the GIWW, channel configurations and intersections, and signals, markers, and other aids to navigation.

Traffic congestion, poor weather, and reduced visibility compound other structural and operational problems. A worst case accident caused by a combination of these problems resulting in closure of the GIWW would involve the collision of barges carrying hazardous chemicals or other materials. Such an accident would not only cause physical closure for some time, but could also result in considerable damage to the environment and require extensive cleanup. Of course, other less severe accidents may also result in closure.

Inadequate vessel control is responsible for 60 percent of the reported accidents. A National Waterways Study (Dietz, 1983) of factors contributing to vessel control accidents on inland rivers found that river segments with a high level of these accidents had one or more of the following characteristics in common:

- one or more bridges
- one or more locks
- bends or an intersection with another channel
- narrow channel width

Obstructions to navigation, such as bridges and locks, contribute significantly to safety problems. Bridges are the most commonly cited safety problem. Likewise, restrictive channel dimensions or unreliable channels (i.e.. channels with frequent shoaling) increase the burden on operators. Other factors contributing to safety problems include traffic growth, increases in tow and/or vessel delay at locks, increasing tow sizes, and high levels of hazardous cargoes. The measures applied to determine waterway problem areas include one or more of the following:

1) historical record of accidents,
2) narrow bridge clearance (horizontal or vertical),
3) lock approach, channel configuration, and dimensions,
4) density of traffic (measured in tons), and
5) amount or share of hazardous commodities (measured in tons or percent).

Bridge safety problems fall into two categories: major structural and minor structural. Major structural problems require solutions such as the alteration, replacement or removal of specific bridges deemed hazardous to navigation. Minor structural solutions at bridges involve the placement of navigation aids and minor protective measures. Lock safety problems are most readily solved by reducing hazardous navigation conditions in the vicinity of a given lock. Lock hazards include heavy traffic, terminals, bends, dangerous currents and shoals, as well as the lock configurations.

High risk accident areas along the GIWW due to channel, traffic congestion, and bridge, lock, and dam safety problems are displayed in Table 1.

Table 1. High Risk Accident Areas Along the GIWW

LOCATION	GIWW MILE POINTS	PROBLEM
Channel Safety Problems		
Houston Ship Channel	0-49	Shoaling, heavy traffic, restrictive bends at Baytown
Major Channel Congestion Problems		
Port Arthur	276 to 289	Terminals, heavy traffic intersections, hazardous cargo
Bridge Safety Problems		
Galveston	353 to 358	3 minor structural bridge safety problems
Freeport	393 to 405	minor structural bridge safety problems
Caney Creek	418	minor structural bridge safety problems
Matagorda	440 to 442	minor structural bridge safety problems
Aransas Pass	533	minor structural bridge safety problems
Freeport Harbor	6 to 8	2 minor structural bridge safety problems
Lock and Dam Safety Problems		
Brazos River Floodgates	404	When the Brazos River reaches .8 ft. (.24 m) above the GIWW, traffic is restricted to one loaded or two empty barges. Traffic is stopped at 1.8 ft. (.55 m) above the GIWW.
Colorado River Locks	445	Traffic stopped at 10 ft. (3 m) above the GIWW.

Source: (Dietz, 1983).

Shoreline Erosion

Shoreline erosion along the Texas coast, such as that at Sargent Beach, may interrupt traffic for some time while dredging or other engineering efforts are undertaken to restore normal operations on the waterway. Shoaling, or the buildup of bottom sediments in the channel, may also cause closure. Erosion and shoaling along the entire length of the GIWW is normally anticipated in the annual maintenance planning by the Galveston District of the U.S. Army Corps of Engineers. However, erosion and shoaling can occur at unusually high rates at critical places along the GIWW due to unexpected currents, tides, and other weather or natural phenomenon.

Quantification of recent Texas shoreline changes provides a basis for determining coastal erosional problem areas. Shoreline and Vegetation-line Movement, Texas Gulf Coast, 1974 to 1982 (Paine and Morton, 1989) provides the needed information to assign relevant closure probabilities relating to problems from the erosion of barrier islands. Historically, the shore-line and vegetation line along the Texas Gulf Coast have been erosional. Despite a slowing rate of sea level rise and a below-average hurricane incidence, approximately 45 percent of the shoreline and 56 percent of the vegetation line retreated between 1974 and 1982. Landfall of Hurricane Allen near Brownsville in 1980 was the most significant influence on shoreline and vegetation line position, causing a coast-wide retreat. In Table 2, the Gulf Coast of Texas is divided into eight areas and average shoreline and vegetation line movements for the 1974-1982 period are recorded.

Table 2. **Shoreline and Vegetation-line Changes from 1974 to 1982**

Reach	Shoreline rate of change	Vegetation-line rate change
Sabine Pass to Bolivar Roads	4.3 ft/yr (1.31 m/yr)	-2.8 ft/yr (-0.85 m/yr)
Bolivar Roads to San Luis Pass	-1.8 ft/yr (-0.55 m/yr)	-5.0 ft/yr (-1.52 m/yr)
San Luis Pass to Brown Cedar Cut	-4.7 ft/yr (-1.43 m/yr)	-9.1 ft/yr (-2.77 m/yr)
Brown Cedar Cut to Pass Cavallo	1.0 ft/yr (0.30 m/yr)	-10.9 ft/yr (-3.32 m/yr)
Pass Cavallo to Aransas Pass	-2.6 ft/yr (-0.79 m/yr)	-1.2 ft/yr (-0.37 m/yr)
Aransas Pass to Yarborough Pass	-2.4 ft/yr (-0.73 m/yr)	-1.7 ft/yr (-0.52 m/yr)
Yarborough Pass to Mansfield Channel	0.5 ft/yr (0.15 m/yr)	-7.2 ft/yr (-2.19 m/yr)
Mansfield Channel to Rio Grande	-3.6 ft/yr (-1.10 m/yr)	-13.9 ft/yr (-4.24 m/yr)

Source: (Paine and Morton, 1989).

Paine and Morton find that the shorelines retreated between 1974 and 1982 at an average rate of 0.9 feet/year (0.27 m/yr) and vegetation-lines retreated at an average rate of 5.5 feet/year (1.68 m/yr). About 330 acres (130 ha) of Gulf beach were eroded and vegetation removed from 2,000 acres (790 ha) of beach. Erosion was most severe at the Brazos, Colorado and Rio Grande headlands and along South Padre Island. Net vegetation retreat on the upper Texas coast increased southward from an average of 25 feet (7.62 m) between Sabine Pass and Bolivar Roads to 90 feet (27.4 m) on Matagorda Peninsula. During the study period, the coast remained erosional despite reduced rates of relative sea level rise and below-average hurricane frequency. The authors predicted higher erosion rates after 1982 because of hurricanes and increasing rates of relative sea level rise. Continued reduction of sediment supply due to construction and maintenance of reservoirs, jetties, and navigation channels has also contributed to higher erosion rates.

The most rapidly retreating shoreline was from San Luis Pass to Brown Cedar Cut. This area includes Sargent Beach. The next most erosional area was between the mouth of the Rio Grande and Mansfield channel where erosion progressed at an average rate of 3.6 feet/year (1.10 m/yr). Areas along the coast that receive the most river sediment were the areas where the highest shoreline erosion occurred. Shorelines along the central Texas coast had a lower rate and less widespread erosion than did the Rio Grande and Brazos-Colorado headlands. Galveston Island also experienced low rates of erosion. The highest level of retreat occurred to the west of the seawall. Like the islands between the Rio Grande and Brazos-Colorado headlands, Galveston Island benefits from erosion of the Brazos-Colorado headlands. Although the upper Texas coast between Bolivar Roads and Sabine Pass has a long history of erosion, 1982 shorelines were mostly seaward of 1974 shorelines along this segment. Changes along this section may reflect changes in tide level rather than beach accretion. Much of the shoreline along central Padre Island (Yarborough Pass to Mansfield Channel) advanced between 1974 and 1982. Relative shoreline stability in this area is due to its location near the convergence of northward and southward longshore-drift currents.

As was the case for the shoreline, the vegetation line near the Brazos-Colorado and Rio Grande headlands retreated at relatively high rates. Retreat was most widespread along Matagorda Peninsula. Vegetation retreat averaged 10.9 feet/year (3.32 m/yr) here. Between the rapidly retreating vegetation-lines along the Rio Grande and Brazos-Colorado headlands, vegetation-lines along Matagorda Island, San Jose Island, Mustang Island, and North Padre Island were relatively stable.

The most widespread and rapid retreat of shorelines and vegetation-lines occurred on large promontories such as the Rio Grande and Brazos-Colorado river headlands where waves eroded sand-poor deposits, and longshore currents carried them away. Sediment supplied from the erosion of these headlands helped reduce rates of shoreline erosion in other zones where longshore sediments converge. Continued reduction in sediment contribution by the Rio Grande, Brazos River, and Colorado River, increasing segmentation of the Texas coast by jetty construction and channel dredging, and rising sea levels will all contribute to increased erosion rates in the future.

Along the GIWW, the banks of the waterway are exhibiting increased erosion. This is due to a combination of boat wakes and wind-driven waves. As the channel widens, the effects of wind increase and erosion may be accelerated. This erosion not only cuts into, and directly destroys, habitats, but also disrupts drainage patterns and causes increased salt water intrusion into surrounding marshes. Furthermore, erosion is threatening the Corps' spoil disposal sites, and dredged material may soon be eroding back into the channel from these areas. Table 3 describes areas of severe erosion along the Texas coast and the GIWW.

Table 3. Severe Erosion Areas in the Texas Barrier Islands and Along the Texas Gulf Coast

Location	GIWW Mile Points	Erosion Rate
Sargent Beach	418	33 ft/year (10 m/yr)
South Padre Island	552-670	5 to 10 ft/year (1.5 to 3.0 m/yr)
San Luis Pass	380	67 ft/year (20.4 m/yr)
High Island	319-325	8 ft/year (2.4 m/yr)
Willacy County Line	628-642	16 ft/year (4.9 m/yr)
Erosion Attributed to Effects from the GIWW		
Aransas National Wildlife Refuge	500-504	2 ft/year (0.61 m/yr)

Source: (Seeling, September 1973).

Shoaling

The natural forces of wind, waves and currents, and rain continually reduce the depth of the GIWW by filling the bottom with sediments. This is called shoaling, and in order to keep the waterway in use, this material must be removed by dredging. Dredging maintenance causes concern on the part of various interest groups. Frequently, the most environmentally-appealing method of disposal of dredged material is the worst economic alternative, and vice versa. Solving the problems associated with waterway maintenance require a delicate balance between economic and environmental considerations (Atturio et al., 1976). Without necessary maintenance dredging, the channel would soon become shoaled to the extent that navigation on the waterway would become hazardous, or even impossible. According to Atturio, sediment can enter the waterway from five sources. Table

4 lists these sources. Tables 5 and 6 show areas of shoaling and high dredging maintenance along the GIWW during the past sixty year period.

Table 4. Sediment Sources

SOURCE	MECHANISM OR CAUSE
Bottom	Wind and ship-generated waves Wind and wave-generated currents Ocean swells Tidal currents Propeller-generated currents Shrimp trawlers Dredging operations Spoil mound erosion
Bank	Wind and ship-generated waves Wind and wave-generated currents Ocean swell Tidal currents Industrial or municipal outfalls
Surface	Upland runoff Wind-blown sand Spoil-mound erosion
River	Suspended and bedload material
Gulf	Littoral drift Hurricane washovers

Source: (Atturio et al, 1976).

Using maintenance dredging records for the period 1933 to 1974, Atturio et. al. computed shoaling rates. The average rate for the GIWW in Texas was found to be 10.5 in./yr (26.7 cm/yr).

Table 5. Shoaling Rates

Location	GIWW mile point	Year completed	Shoaling rate
High Island to Port Bolivar (319.3-349.3)	325.5	33	1.21 ft/yr (0.37 m/yr)
	327.4	33	1.21 ft/yr (0.37 m/yr)
	343.5	33	1.10 ft/yr (0.34 m/yr)
	348.2	33	2.29 ft/yr (0.70 m/yr)
Port Bolivar to Galveston Causeway (349.3-357.2)	351.1	54	2.01 ft/yr (0.61 m/yr)
	355.8	54	1.25 ft/yr (0.38 m/yr)
Galveston Causeway to Bastrop Bayou (357.2-382.2)	361.5	34	1.41 ft/yr (0.43 m/yr)
	362.5	34	1.22 ft/yr (0.37 m/yr)
	364.4	34	1.02 ft/yr (0.31 m/yr)
	374.8	40	1.60 ft/yr (0.49 m/yr)
	377.6	40	1.02 ft/yr (0.31 m/yr)
Freeport Harbor to Cedar Lakes (395.1-405.6)	398.5	42	1.28 ft/yr (0.39 m/yr)
	401.3	42	1.49 ft/yr (0.45 m/yr)
	404.1	42	1.51 ft/yr (0.46 m/yr)
	405.1	42	1.10 ft/yr (0.34 m/yr)
Cedar Lakes to Colorado River (405.6-441.0)	426.9-441.0	42	.995 to 2.10 ft/yr (0.30 to 0.64 m/yr)
Colorado River to Matagorda Bay (441.0-461.4)	441.0-459.1	42/45	.777 to 4.83 ft/yr (0.24 to 1.47 m/yr)
Matagorda Bay to San Antonio Bay (461.4-492.2)	473.3	45	1.15 ft/yr (0.35 m/yr)
San Antonio Bay to Aransas Bay (492.3-518.1)	492.3-503.6	45	1.54 to 2.78 ft/yr (0.47 to 0.85 m/yr)
	512.1-521.5	45	1.33 to 2.70 ft/yr (0.41 to 0.82 m/yr)
Aransas Bay to Corpus Christi Bay (518.1-550.0)	531.0	60	3.17 ft/yr (0.97 m/yr)
	532	60	1.10 ft/yr (0.34 m/yr)
	549.1	47	1.07 ft/yr (0.33 m/yr)
Corpus Christi Bay to Mud Flats (550.0-614.0)	567.1-607.1	48	.745 to 2.24 ft/yr (0.23 to 0.68 m/yr)
	611.3-614	49	1.00 to 1.93 ft/yr (0.30 to 0.59 m/yr)

Source: (Atturio et al., 1976).

Table 6. High Dredging Maintenance Areas Along the GIWW

LOCATION	GIWW MILE POINTS	SHOALING RATE
Galveston Bay	348	2.3 ft/year (0.70 m/yr)
Intersection of GIWW and Houston Ship Channel	351.1	2.0 ft/year (0.61 m/yr)
Brazos River	400.4	4.0 ft/year (1.22 m/yr)
Matagorda Bay	454.3 to 457	5.0 ft/year (1.52 m/yr)
San Antonio Bay	492 to 500	2.7 ft/year (0.82 m/yr)
Redfish Bay	531	3.2 ft/year (0.98 m/yr)
Baffin Bay	596 to 605	2.0 ft/year (0.61 m/yr)
Laguna Madre	657 to 660	2.7 ft/year (0.82 m/yr)

Source: (Atturio, 1976)

Natural Disasters

Natural disasters, such as unusual flooding on rivers along the Texas coast, high water levels on the GIWW itself, or hurricanes and storms, may cause closure due to debris in the waterway, the destruction of navigation structures and aids, and the attendant erosion and shoaling that may be caused by such a disturbances.

As discussed in the Interim Report, between the years 1871-1973, 43 hurricanes made landfall on the coast of Texas. Since the storm of 1890, Texas has dealt with 24 major hurricanes that have claimed nearly 3,500 lives, cost billions of dollars in damages, and stolen miles of beach front property. On average, the Texas coast endures a hurricane every other year and a tropical storm every third year. The vulnerable season for hurricanes on the Texas coast begins in June and lasts through October.

Ruch (1986) divides the coast into 50-mile (80.5 Km) segments. The probability of tropical storm and hurricane occurrence is computed during any one year period for each segment to show variability along the coast and to estimate frequency of damage. The computed segment percentages are smaller than those given for the entire Texas coast because of the shorter coastline involved.

Figure 5 presents data from the Henry and McCormack study. Data summarizing the average number of years between significant storms are presented in terms of all hurricanes as well as extreme hurricanes. One occurrence in five years represents a 20 percent probability of storm occurrence.

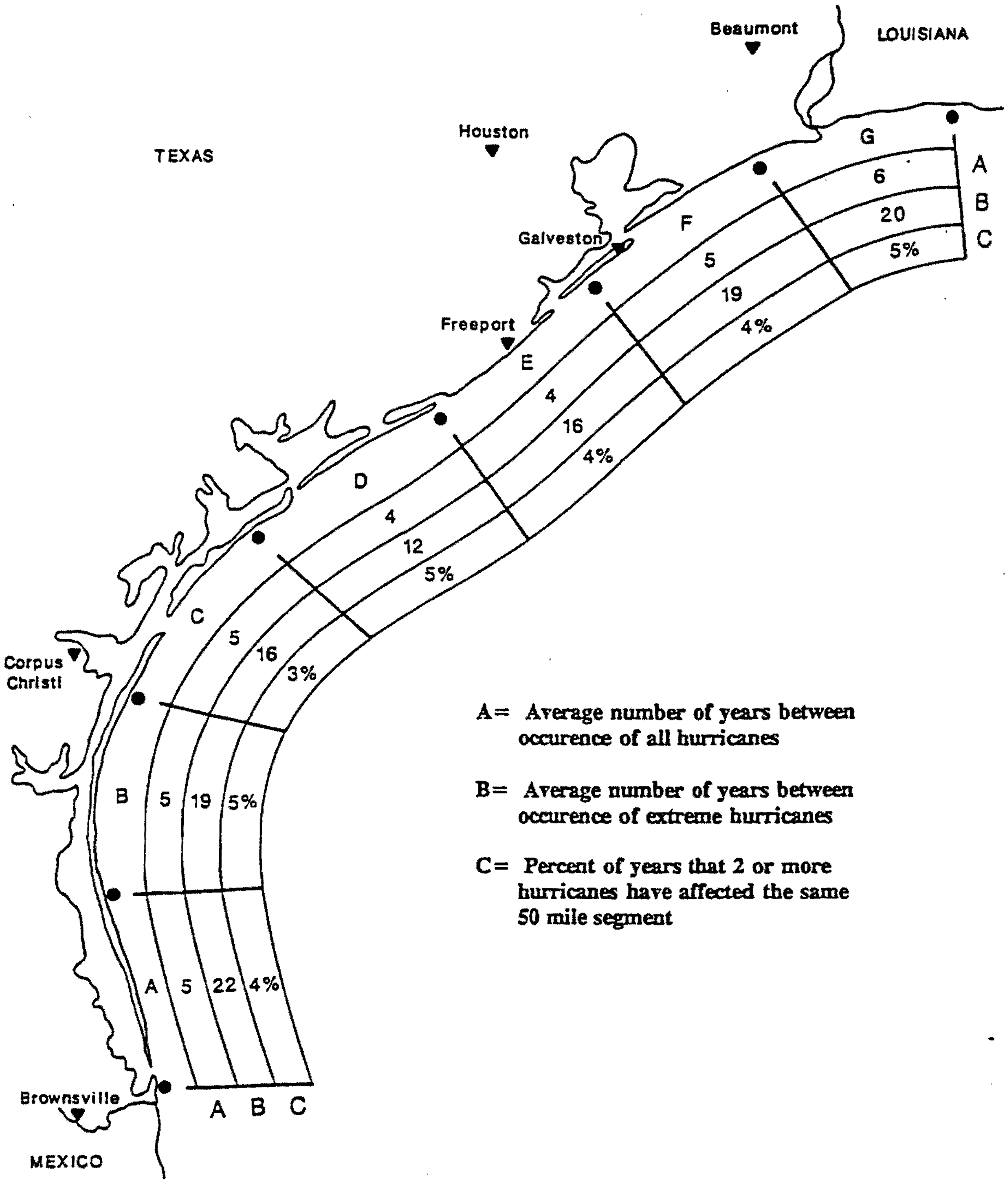

Figure 5. Texas Gulf Coast Hurricane Experience

Hurricanes which make landfall in any one of the 50-mile segments (80.5 Km) affect the segment to the right. A hurricane is considered to affect all segments within 50 miles (80.5 Km) of the eye. An extreme hurricane influences the area 100 miles (161 Km) to the right and 50 miles (80.5 Km) to the left of the eye. Significant storms which come within 50 miles (80.5 Km) of the coast are also considered to affect coastal segments. Table 7 shows, in terms of probability of occurrence, areas of hurricanes and tropical storms that may affect the Texas coast during any one year.

Table 7. Probability of Tropical Storms and Hurricanes Affecting the Texas Coast During Any One Year

AREA	GIWW Mile POINTS	PROBABILITY IN PERCENT		
		All tropical storms and all hurricanes	All hurricanes	Extreme hurricanes only
Port Arthur - High Island	288.6 to 332.2	32	21	3
Galveston Bay	333.2 to 391.8	34	23	5
Brazos River - Matagorda Bay	391.8 to 452.4	33	23	7
Matagorda - San Antonio Bay	452.4 to 510.2	41	30	9
Aransas Bay - Corpus Christi	510.2 to 568.1	37	23	7
Northern Laguna Madre	568.1 to 627	32	18	7
Southern Laguna Madre	627 to 669.5	31	18	4

Source: (Henry, 1975).

Environmental Issues

Environmental issues and actions involve the interests of many organizations and resource agencies. Among them are the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the U.S. Army Corps of Engineers, the Texas Parks and Wildlife Department, and the Gulf Coast Conservation Association. Each of these organizations is concerned with the impact on the environment of continued operations and maintenance of the GIWW along the Texas coast. Particular concerns are those related to commercial barge traffic and maintenance dredging in the Laguna Madre reach of the GIWW between Brownsville and Corpus Christi, maintenance of the GIWW adjacent to the Aransas National Wildlife Refuge, and dredging of the GIWW across Galveston Bay.

As discussed in the Interim Report, the 1984 publication of the Gulf Intracoastal Waterway In Texas highlighted some inherent problems that arise when environmental concerns become a part of the planning process for the GIWW (TxDOT, 1984). The route of the Gulf Intracoastal Waterway leads through some of the most productive, yet sensitive, areas of the Texas coast. As a result, several state and federal agencies administer the regulations necessary to protect the wetlands during water management projects.

The counties adjacent to the Gulf Intracoastal Waterway in Texas are home to several endangered species. Texas coastal counties are Orange, Jefferson, Chambers, Galveston, Brazoria, Matagorda, Calhoun, Refugio, Aransas, San Patricio, Nueces, Kleberg, Kenedy, Willacy, and Cameron. Several endangered species are found along the path of the waterway. The interim report provides a complete listing of the endangered species affected by activities on the GIWW. Presently, GIWW advisory committees composed of members from concerned organizations have been organized to unite the state in addressing GIWW maintenance needs. One need involves finding dredged material disposal sites which do not interfere with the delicate coastal ecosystem. It should be noted that dredging does not always have a negative effect on the environmentally sensitive areas along the entire GIWW. The interim report rates the likelihood of dredging impact on selected lengths of the waterway.

Financial Issues

Lack of funding for normal annual maintenance and operations of the GIWW could result in physical limitations to waterway traffic. Normal maintenance and operations include the acquisition, construction, and maintenance of dredged disposal areas. Although not anticipated, there could occur a lack of Federal funding for annual maintenance and operation of the project, as well as inadequate funding by Texas, the non-federal sponsor of the waterway, for the acquisition of disposal areas. Additionally, there are numerous federal and state agencies that have some political influence over water resource and transportation policy and, therefore, influence over the operation and maintenance of the GIWW.

The *National Waterways Study* also addresses issues involving funding problems for our inland waterways system (Dietz, 1983). Recent legislation and regulations have increased intervention by opposing economic interests. Litigation over navigation projects' compliance with these new regulations has further delayed modernization. A recurring issue in litigation concerns the incremental nature of navigation project evaluation. The existing planning process is often unable to cope with rapidly changing technology and market shifts. Incorporation of state and local governments as well as public concerns may delay projects designed to address national goals.

The federal government is moving away from a project evaluation and is working toward an overall plan for the nation's waterways. Variance among national, state, and local goals has delayed or halted projects important to national economic objectives (Dietz, 1983). One strategy proposed by the *National Waterways Study* would provide funds for major structural actions by federal abandonment of shallow draft navigation segments with high ratios of costs per ton-mile of commercial traffic. All ports and side channels with less than one million tons (90.7 million Mg) of annual traffic would also be dropped.

The inland waterway system is no longer totally subsidized by the federal government. In 1978 the Inland Waterway Revenue Act was passed which imposed a 4 cent per gallon (1 cent per liter) fuel tax on tow boats and tugs moving commerce on 26 specified shallow-draft navigation channels. Another piece of landmark legislation was the Water Resource Development Act of 1986. This bill established the rules for the cost-sharing principle agreed to in 1978, and increased the barge fuel tax over a ten year period until a maximum of 20 cents per gallon (5.3 cents per liter) in 1995 is reached.

Political Issues

More than thirty separate federal agencies have influenced national water resource/transportation policy. The U.S. Coast Guard, the U.S. Army Corps of Engineers, and the U.S. Maritime Administration are the principle federal agencies involved in inland marine commerce. Furthermore, the Office of Management and Budget contributes to the availability of funds for all civil-work projects. Final approval for all civil works projects rests with the U.S. Congress which authorizes and funds projects, and approves, modifies, or rejects the budgets of federal agencies.

In Texas, a number of executive agencies, most under nominal control of the governor and responsible for a single specific resource, are involved in waterway matters. For example, the General Land Office manages submerged lands; the Railroad Commission regulates the oil industry; the Department of Parks and Wildlife enforces policy for coastal fisheries; and the Texas Natural Resource Conservation Commission monitors water quality. In addition, the Texas Department of Health, the Texas Water Development Board, the Texas Department of Agriculture, and the Texas Department of Transportation have jurisdiction over various issues that affect those reaches of the GIWW which span the Texas coast.

National Security

The GIWW could be closed, or have limitations imposed on commercial traffic, for indefinite periods of time because of national security. These closures or limitations would likely occur in those reaches closest to ports that have national security significance, such as Beaumont/Port Arthur (280/290), Galveston/Houston (350/360), and Corpus Christi (540).

2.2 REACTION TIME TO AN ACTUAL CLOSURE

Reaction time to a closure needs to be assessed ahead of time. Current actions by resource agencies and environmental groups to interrupt operational maintenance pose outcomes which must also be evaluated.

In the case of an actual closure, the Galveston District of the U.S. Army Corps of Engineers has responsibility to activate emergency plans to reopen the waterway at the earliest possible time. These plans entail the survey of damages to the waterway or related navigation structures and the procurement of contractors to undertake repairs, dredging, or other corrective measures. The District emergency operations plans call for a closure to be reopened within fourteen days or sooner, depending on the nature of the closure. An example of such a plan has been prepared for the reach of the GIWW next to Sargent Beach. Along this reach an expected restriction to the waterway would be due to extensive erosion and shoaling resulting from storm action. This type of damage is considered to be an extreme example and one that would require the most time to repair. Other forms of closure, such as barge collisions and navigation safety problems, could be expected to reopen in less time. The length of time that a single closure would be expected to affect freight movement on the GIWW, therefore, would be a two-week period. Based on the findings of the current research, no physical closure would be expected to interrupt service for more than 30 days.

Actions by resource agencies and environmental groups focusing on the impact of continued operation and maintenance of the GIWW on marine life and the environment do not present themselves as imminent causes of closure of the waterway. These actions, however, may result in some future limitations on the use of the waterway by commercial barge traffic and, as a consequence, modification of the level of annual maintenance and usage.

Environmental issues require extensive time for definition and eventual resolution, whether by negotiation or by legal action. Any change to the GIWW as an existing Federal project would involve Federal and State consideration relative to economic and transportation system impacts. Therefore, limitations that may be imposed on the waterway because of environmental issues should be anticipated so that freight diversions and modal shifts can be managed accordingly.

2.3 WHERE CLOSURES OR LIMITATIONS TO TRAFFIC MAY OCCUR

Compiled by the Galveston District, U.S. Army Corps of Engineers, Table 8 describes the entire length of the GIWW by Mile Marker and includes the most likely reasons, in order of priority, for closure or limiting action of use. There is no attempt here to assign a mathematical probability to a reason for closure other than those indicated priorities of "most likely" occurrence. For example, a closure on the High Island to Port Bolivar reach (Mile 319 to 350) would first be expected due to a structural or operational navigation safety problem; second, an accident due to the configuration of the channel in this reach; third, an environmental issue; and fourth and least likely, closure because of shoaling or other reason due to a natural disaster.

The Galveston District completed a Section 216 Reconnaissance Report of the GIWW in November 1989. The 216 Report presents more specific problem descriptions and a summary of the most critical spots along the GIWW (Table 9). The likelihood of closure or limited use is provided in Table 10. The summary establishes a basis for potential freight diversions and modal shifts along the Texas coast as addressed later in this report (U.S. Army Corps of Engineers, 1989).

Table 8. GIWW Reaches/Reasons for Closure or Limited Use

MILE MARKER	REACH	REASON FOR CLOSURE
266 - 319	Sabine River to High Island	Structural/Operational; Funding; Environment
319 - 350	High Island to Port Bolivar	Structural/Operational; Environment; Natural Disaster
350 - 378	Port Bolivar to Chocolate Bayou	Environment; Natural Disaster
378 - 395	Chocolate Bayou to Freeport Harbor	Structural/Operational; Funding
395 - 401	Freeport Harbor to Brazos River	Structural/Operational
401 - 442	Brazos River to Colorado River	Structural/Operational; Natural Disaster
442 - 460	Colorado River to Matagorda Bay	Funding
469 - 473	Across Matagorda Bay	Structural/Operational; Environment
473 - 492	Port O'Connor to San Antonio Bay	Environment; Structural; Natural Disaster; Funding
492 - 501	Across San Antonio Bay	Structural/Operational; Environment; Natural Disaster
501 - 517	San Antonio Bay to Aransas Bay	Environment; Structural; Natural Disaster
517 - 540	Aransas Bay to Corpus Christi Bay	Environment; Structural
540 - 548	Across Corpus Christi Bay	Funding
548 - 610	Corpus Christi Bay to Mud Flats	Funding
610 - 669	Mud Flats to Port Isabel	Environment; Structural; Funding; Natural Disaster

Source: (Dietz, 1983).

Table 9. Critical Problem Areas on the GIWW

MILE MARKER	AREA	PROBLEM
319 - 325	High Island	Navigation of two 90 degree bends
360 - 380	West Galveston Bay	Bank erosion; loss of wetlands
393 - 394	Freeport	Double "S" curve at Bridge Harbor Marina
405	Brazos River	Maneuvering through floodgates
418	Sargent Beach	Beach erosion adjacent to GIWW
442	Colorado River	Maneuvering through locks
474	Port O'Connor	Traffic congestion
500 - 504	Aransas NWR	Shoaling; environmental impact
575 - 666	Laguna Madre	Shoaling; environmental impact
668 - 670	Port Isabel	Maneuvering through channel and swing bridge

Source: (U.S. Army Corps of Engineers, 1989).

Table 10 presents a summary of the most critical areas along the GIWW. This is intended to display the most likely closure scenarios across occurrence in one or more areas.

Table 10. Most Critical Areas For Closure or Limited Use

PROBLEM	LOCATION
Structural/Operational	High Island Freeport Brazos River Colorado River Port Isabel Port O'Connor All inland reaches (See Note 1)
Erosion/shoaling	West Galveston Bay Sargent Beach
Environmental impact	Aransas NWR Laguna Madre (See Note 2)

Source: (U.S. Army Corps of Engineers, 1989).

Note 1: All inland reaches of the GIWW are considered hazardous to barge traffic due to current, inadequate dimensions of the waterway and the sizes of barges.

Note 2: Limited use due to environmental issues can be forecasted so that impacts on the system are minimal.

Closure due to a natural disaster could occur at any time or at any location and present a variety of obstacles (erosion, shoaling, debris) to reopening the waterway. Similarly, funding limitations and national security measures may cause limited use with little or no notice. The locations, times, and durations of these potential impacts on the GIWW are not possible to forecast and, therefore, require real-time management at the time of occurrence.

2.4 IMPROBABLE GIWW CLOSURE AREAS

In the event of a closure, there are a few reaches of open bay where the waterway could be reopened within a minimum amount of time. There would, in such instances, be no expected delays in traffic on the GIWW because detours around closures are possible. There would also be no impact on the normal movement of freight. These open bay areas are:

Galveston Bay	Mile 349 to 357
Matagorda Bay	Mile 457 to 473
San Antonio Bay	Mile 492 to 500
Corpus Christi Bay	Mile 540 to 548

2.5 SUMMARY

Areas with the highest potential for a closure are shown in Table 10 under the categories of Structural/Operational. Critical navigation spots are hazardous because of the difficulty of maneuvering barge tows through existing channel alignments, locks, and floodgates. Traffic congestion compounds these navigation conditions and contributes to the potential for a single barge tow to have an operational problem that may result in a closure. Accidents or collisions involving two or more barges may also occur in a congested area such as Port O'Connor or at any location along the inland reaches of the waterway. On these reaches the dimensions of the channel are essentially obsolete and inadequate for the present-day size of barges and tows.

The likelihood of a closure due to erosion or shoaling in areas such as West Galveston Bay or Sargent Beach is considered remote. However, in the event of a hurricane or excessive flooding along the Texas coast there could be erosion and shoaling conditions at most any location resulting in closure. The Laguna Madre and the Aransas National Wildlife Refuge are currently the two most prominent areas where the potential is high for limited use of the waterway because of environmental interests. Closure of the waterway because of political or financial issues is unlikely in the short term, but as described in this report, there are long range issues that must be resolved if the GIWW is to continue as a viable transportation asset to Texas.

Findings in this research lead to the conclusion that there is a low probability of extended closure to the GIWW. Any unlikely extended closures, however, will most probably be caused by an environmental action or a lack of funding. Although this report tends toward low closure probabilities, it does not completely eliminate all GIWW interruption possibilities. The consequences of a GIWW closure are related to the duration of closure. Interruptions which can be alleviated within two weeks will have little to no impact on GIWW industrial firms. On the other hand, if a closure event cannot be circumvented within 30 days time, the effect on the GIWW industries will be a modal shift from waterway to roadway and/or rail. Along the Texas reach of the GIWW, the location most susceptible to an extended interruption in service is the Laguna Madre. These extended interruptions and the consequential modal shifts are the primary targets of the remainder of this report.

3.0 MODAL SHIFT

3.1 MODAL SHIFT ANALYSIS

The Interim Report defined several factors that impact the shipping industry's choice of transportation mode. Among the factors cited were shipment distance, cost, speed of transport, and flexibility. The fact that many firms have located along the Texas Gulf coast attests to their selection of water transport as best for their commodity and competitive position. Waterborne transport is the most cost efficient mode available in terms of ton-miles transported per dollar.

The characteristics associated with the waterborne shipment of goods and material are documented as follows:

- bulk commodities
- low value commodity (per unit volume)
- long shipment distances
- low time-to-market sensitivity

The industries which have located along the Texas Gulf coast generally match these characteristics. The modest transport speed associated with barge shipments seems to be off-set somewhat by the regularity of the shipments themselves. The large quantities of material shipped by many firms suggest that the GIWW is used much like a pipeline, with a constant input of goods maintaining a constant output at the market destination. This "pipeline" characteristic makes the GIWW more sensitive to interruptions in service than initial data might indicate.

Modal Shift

A scenario in which a shipper's first modal choice is lost, either temporarily or for the longer-term, sets the conditions for a phenomenon referred to as "modal shift". A modal shift results from a change in choice of transportation mode. The change can be voluntary, such as one motivated by cost or customer service, or it can be forced by lack of service availability. This study focuses on a forced modal shift. The emphasis of the research is finding the alternative mode shippers will choose in lieu of the GIWW. Of key importance is the number of shippers choosing truck transport as the alternative to waterborne shipments.

Recognizing the study focus, the following material presents the method used to formulate a modal shift model for Texas Gulf coast industries. The model was designed to allocate commodities currently shipped on the GIWW to alternate transportation modes with the ultimate goal of determining the amounts shipped on the Texas highway system. Both rail and pipeline alternatives were considered as was the potential for reduction in the productive capacity of industries which have lost water transport.

Development of Modal Shift Model

The modal shift model was developed by examining current modal shares between rail and truck for the predominant commodities shipped on the GIWW and establishing the relationship between distance and modal share. Model development proceeded in four steps to model formulation.

The first step focused on current origin-destination data characterizing the markets served by the Texas portion of the GIWW. Origin-destination data from the Waterborne Commerce Statistics Center detailing GIWW commodity flows helped to determine the geographic location of the markets linked to Texas through the GIWW. These data were evaluated to determine the largest and most frequently serviced markets. Table 11 details the states linked to Texas by the Texas portion of the GIWW and the predominate commodities shipped.

The commodity code key to interpret Table 11 is as follows:

01 farm products
10 metallic ores
11 coal/lignite
13 crude petroleum
14 non-metallic minerals
20 food
33 primary metals
28 chemicals
29 petroleum/coal
40 waste/scrap
24 lumber/wood products
32 clay, concrete, glass or stone products
39 misc. products of manufacturing
41 misc. freight shipments

Table 11. Commodity Shipments from Texas Ranked by Total Tons

STATE	1st	2nd	3rd	4th	5th	OTHER
Louisiana	29	28	13	01	14	20,24,32,33,39,40,41
Illinois	28	29	40	32	33	
Alabama	29	28	13	33		
Florida	29	28	14	13	20	32,40
Mississippi	29	28	13	14	33	
Pennsylvania	29	13	28	33	40	
Tennessee	28	29	33			
Minnesota	29	28	13	40		
NY/NJ	29		13			
Ohio	28	29	33			
Indiana	28	29	33			
California	29	28				
Georgia	29	14				
Alaska	29	28	13	33		
Kentucky	28	29				
Arkansas	29	28				
North Carolina	29	28	14			
Washington	29					
Connecticut	28	29				
Delaware	13	29	28			
Massachusetts	29	28				
Maryland	29	28				
Maine	29					
Oregon	29	28				
Rhode Island	29					
South Carolina	29	28				
Virginia	29	28	13			

Source: (Waterborne Commerce Statistics Center)

For the second step of model development, sample markets were selected based on geographic location, commodity type, and tons shipped. These selections served as the basis for acquiring regional modal share reports from Reebie Associates, a Washington, D.C.-based transportation consulting firm. The reports provide modal share data for regional origin-destination pairs. A region is defined as a market region -- examples being Cincinnati, Miami, and Mobile. The regions may cross state lines and may vary in size.

The Texas Gulf coast was defined by four regions: Beaumont, Houston, Corpus Christi, and Brownsville. These served as the origin or destination for each report. The markets served by the Texas GIWW were matched to market regions. On this basis, 43 origin-destination reports were acquired and the data detailing commodity and modal share were extracted for analysis.

Step three involved assigning surface transportation distances to the modal share data so that each origin-destination pair contained data on commodities transported, modal share (in tons), origin-destination, and shipment distance in miles.

In the fourth and final step, the data was analyzed using regression techniques to investigate modal share (percentage transported by truck) as a function of shipment distance. The analysis was performed for each commodity type as well as for total tons transported. Figure 6 shows the linear relationships derived from this analysis for five commodity classes.

The percentage of commodities moved by truck decreases with distance for four of the five commodities displayed. Importantly, commodity classes 28 and 29, chemical and petroleum products respectively, showed the most pronounced trend. Significantly, these commodities account for over 80 percent of the material shipped on Texas reaches of the GIWW. When commodity shipments were analyzed as a composite, i.e. total tons transported without respect to commodity class, these commodity classes served to disproportionately weight the results.

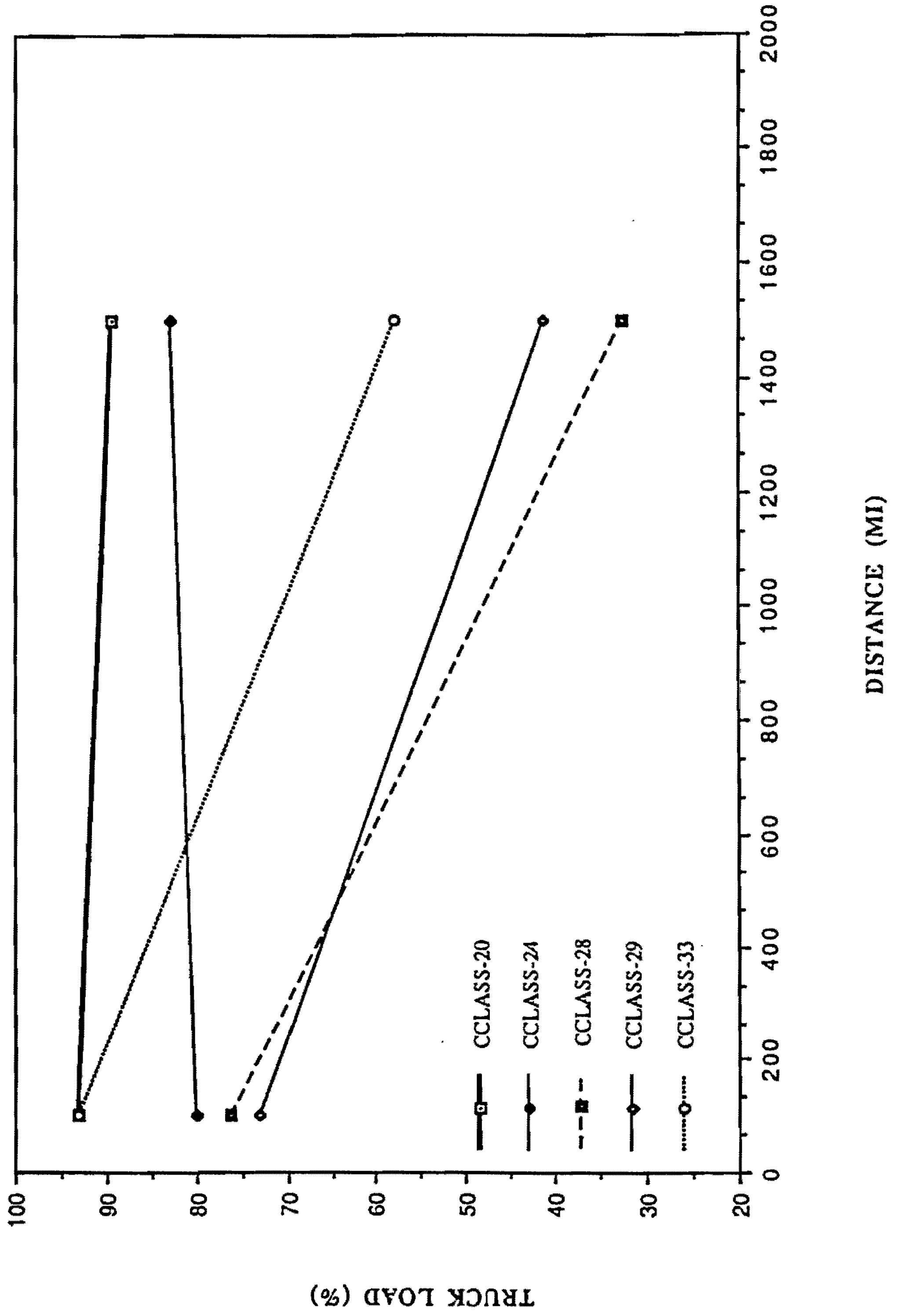

Figure 6. Trucking Loading Variations with Transport Distance

The stability and overall statistical significance of the composite model (all commodities) was better than that found with single-commodity models. The results were further improved by categorizing distances into one of five zones, representing short, intermediate, and long-haul movements. Table 12 presents the results of the modal shift analysis. The modal shift model is presented below:

$$P_t = 84.426 + ((D_c(-17.491))$$

where:

P_t = Percentage of GIWW commodity tonnage shifted to truck transport

D_c = Distance Category 1-5

Table 12. Shipment Distance Categories and Truck Transport Percentages

CATEGORY		SHIPMENT MILES	% SHIPPED BY ROAD
Short	1	0 - 280 mile (0 - 451 Km)	66.94
Intermediate	2	281 - 540 miles (452 - 869 Km)	49.44
	3	541 - 830 miles (870 - 1336 Km)	31.95
	4	831 - 1130 miles (1337 - 1819 Km)	14.46
Long	5	> 1130 miles (> 1820 Km)	0.0

The results of the model were adjusted for Category 5 to 0.00 percent since the modeling process predicted a value slightly less than zero.

An examination of GIWW commodity flow relative to the distance categories reveals a bi-modal distribution of commodity tons by distance. Figure 7 presents the data. The distribution shows large quantities for Categories 1 and 2, a small amount for Category 5, and substantial amounts for Categories 3 and 4. Given the modal-distance relationship established in the modal shift model, with approximately one-half and one-third of the commodities shifted to roadway transport for Categories 1 and 2 respectively, large amounts of material could potentially shift to Texas highways as a result of an interruption in service on the GIWW. Not all the tonnages depicted in Figure 6 will necessarily be diverted given an interruption in service. The location and nature of the interruption will determine the specific origin-destination pairs impacted.

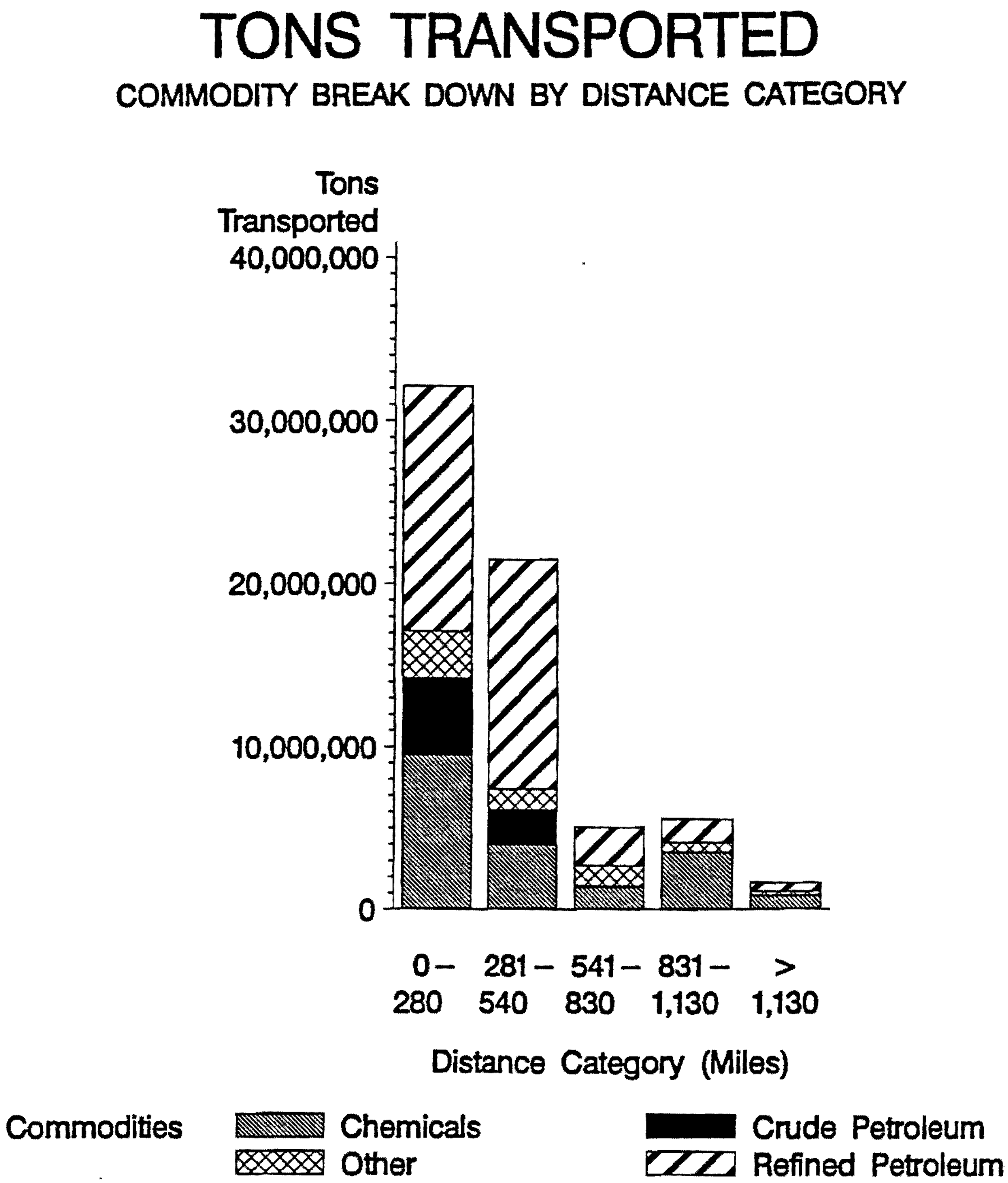

Figure 7. Tons Transported: Commodity Break Down by Distance Category

3.2 POTENTIAL DECREASES IN PRODUCTION -- OUTPUT DECREMENT

A prolonged interruption in service of more than 30 days on the GIWW could have serious consequences for businesses dependent on the canal for the shipment or receipt of goods and material. An analysis of current transportation patterns along the Texas Gulf coast indicates that some firms are wholly dependent on the GIWW while others distribute their transportation business among two or more modes. Those firms using some combination of water, rail, and truck, would, it can be assumed, have an easier time shifting waterborne commodities to an alternative mode.

Can those commercial entities exclusively using water transport find alternative transport modes? If alternatives are found, the issue becomes the degree to which productive output must be curtailed during the transition period. A final, and unfortunate, class of businesses currently rely on the GIWW exclusively and cannot feasibly shift to alternate modes. For these firms the GIWW represents a commercial lifeline to markets unreachable by any other means.

The grey area between the black and white study of current practice becomes the degree to which the productive capability of firms is impaired as a result of an inability to receive raw material or to ship finished goods. A 1991 TTI study on the industrial impact of a closure in the GIWW at Sargent Beach provides insight on typical firm responses to the question of a manufacturing output decrement as a consequence of closure of the GIWW.

The study focused on an interruption in service at Sargent Beach, GIWW mile point 420. Firms were asked, via structured questionnaire, a series of questions designed to gauge the impact of a closure on production and employment, the temporal sensitivity to interruptions in service, and the feasibility of shifting to alternative modes of transportation. On average, firms reported 62 % probability that an interruption in service at Sargent Beach would inhibit their operations. In addition, respondents were asked to estimate the percentage of their productive capacity that would be curtailed. Fifty six % reported that 50% or more of their productive capacity would be eliminated in response to the loss of barge transportation. Thirty three percent of those who responded estimated a 90-100% reduction in plant capacity.

The probability of curtailment in conjunction with the estimated percentage of reduction in capacity serves as the basis for a composite figure that corresponds to the expected *output decrement*. A firm estimating a 0.50 probability of shut down and a potential 50% reduction in capacity had an expected output decrement of 25%. An average of this value, collected from the 1991 TTI sample, suggested a likely output decrement of 41.475% (Roop, 1991).

Given the number of firms located along the Texas portion of the GIWW, the current study did not include a similar survey. The fact that firms have located along the Texas coast in proximity to the GIWW attests to their selection of the canal as the best means to transport goods and material for their business activity. Previous analyses and telephone interviews with several dozen companies prove some firms are wholly dependent on the GIWW for continuity of operations. To accurately project the amount of material diverted to Texas highways, an output decrement as well as the selection of alternate modes such as rail must be considered.

Therefore, to enhance the accuracy of results (i.e., tonnages diverted to Texas highways), the current research has presented the data as a range of values. The upper range was defined as the total amount of material diverted to Texas highways, exclusive of alternate modes, assuming continued production at current levels. The lower range was defined as 60 percent of the upper range, taking into consideration a likely reduction in output as suggested by previous studies of the problem.

3.3 INDUSTRIAL SITE SURVEY

In an attempt to assess the potential behavior of GIWW users and their view of alternatives to waterborne commodity movements, a telephone survey was conducted of 55 firms located along the waterway. The survey was directed, whenever possible, to the transportation manager of companies. The survey was presented as part of a "modal selection" survey rather than as a study of the impacts of a closure of the GIWW. This approach was taken to enable the research staff to focus exclusively on GIWW users while at the same time removing the implied threat of a closure in the waterway.

The coastal firms contacted were purposefully chosen because of their diverse commodity designation so that responses would be more representative of the large number of sites potentially impacted by an interruption in service. The broad commodity base included metals and minerals, food and beverages, water and waste, in addition to petroleum products and chemicals. Industrial functions included manufacturing, processing, refining, and mining.

The results of the telephone survey confirmed that distance of shipment and commodity type were used as primary determinants in the choice of freight transport. Responses indicated that truck transport was used for short hauls, water for long hauls, and rail for intermediate hauls. Further, the respondents indicated that rail was employed to handle the "overflow" material when water transport could not move the quantities needed. The general consensus from respondents of the survey was that there is no viable, cost-effective alternative for long distance freight movements by water. For shorter shipments, however, truck and rail modes were offered as alternatives.

4.0 CLOSURE IMPACT MODEL

Previous sections of this report suggest that an interruption in service on the GIWW of more than 30 days is unlikely. The indications from other research are that temporary closures of less than two weeks are insufficient to motivate any significant shift in freight from water to alternative modes. Systemic modal shifts, it appears, are only likely under conditions of permanent closure of sections of the waterway.

Given a permanent closure of some segment of the waterway, a diversion of traffic to other modes of transport, including the Texas highway system, is inevitable. To stay in business, firms located along the GIWW must find other means of shipping and/or receiving goods and material. The options available to most businesses include highway, rail, and pipeline. This section describes the development of an *Impact Model* predicting the location of freight diversions on Texas highways and the resulting damage inflicted on roadway surfaces and structures. Commodities moved by rail and pipeline will not be considered in the roadway impact analysis.

4.1 ROADWAY IMPACT SUB-MODEL

Description of Roadway Impact Sub-Model Objective

In order to gauge the impact additional truck traffic has on Texas roadways, a sub-model predicting highway life-span under different loading conditions must be identified and tailored to meet the needs of the current study. There are several roadway degradation models available. Each has been developed for a specific application and may or may not have characteristics of interest to the current work. Roadways are complex structures, and, consequently, pavement models predicting deterioration over time are often extremely complex as well. As a result, this research staff established two criteria by which it would select an appropriate sub-model for the current research. First, the sub-model selected was to include as many of the variables affecting highway life-span as possible, yet not so many that data collection itself would become a problem.

Second, the sub-model output was to be in terms that were understandable to, and usable by, practitioners, yielding results easily translatable into dollars.

Roadway Impacts - Method of Assessment

The roadway impact analysis was directed at a wide array of state and federally funded roads including Interstates, U.S. Highways, State Highways, and Farm-to-Market roads. Roadway structures vary due to ranging construction techniques, the materials used, the environment, and the sub-soils upon which they are built. The factors contributing to the diversity found in roadway structure and durability include pavement type (rigid or flexible), thickness, supporting foundation, and climate.

Roadway surfaces may be categorized as either rigid or flexible. Rigid pavements are those constructed with concrete and contain steel reinforcing material. These surfaces are extremely durable, and offer a high quality ride, but have high initial costs. Flexible pavements are those constructed over a crushed rock base. They are most frequently constructed of asphalt or some other similar petroleum product and have bases of varying thickness. The flexible roadway is an integrated system composed of soil, base material, and surfacing material. The construction results in a system that flexes as loaded vehicles pass. The greater the loading, the more flexing that may be observed in the roadway surface.

Loading (weight of vehicles and cargo) plays a primary role in roadway degradation. The weight of the vehicle and its cargo relative to the number of axles and the specific physical configuration of the vehicle determine the amount of loading. To systematically and uniformly evaluate loads, a convention for measurement has been established. This widely used standard is referred to as the 18 Kip Equivalent Single Axle Loading (18 K-ESAL). The unit of measure relates to the effects of an 18,000 pound load on one axle.

Two other factors relate to roadway performance and the speed to which they degrade under conditions of accelerated load. These are the supporting foundation upon which the roadway is built and the general climate within which the structure resides. The supporting foundation relates to the amount of support given by soil type, i.e., clay, sand, etc., which can vary greatly. Each soil foundation is represented by an index relating to its support strength. Climate interacts with soil and helps determine the life-span or speed of deterioration of a roadway. For example, roads located in the dry regions of West Texas can be built with a thinner sub-base than the roads paved in the humidity of Southeast Texas. This factor is accounted for by a regional index which generalizes the amount of rainfall and average temperature in each given district of study. In order to accurately assess the behavior of a roadway, these factors, in addition to pavement type and thickness, must be measured and weighed accordingly. A number of sub-models were examined for use in the present study.

1) **RENU**: RENU is a computerized procedure for estimating pavement rehabilitation and maintenance expenditures. This procedure focuses on projecting the cost of highway rehabilitation (Diaz, 1986). The RENU program provides a comprehensive treatment of most of the pavement degradation issues faced under conditions of increased traffic loading. The inputs for RENU include traffic loading, various pavement types, soil support values, and climatic conditions.

   However, for RENU to be used effectively many complexities had to be overcome. Inputs such as historical maintenance expenditures, interest rates, highway network statistics, and rate of change of salvage values are extremely complicated and were well beyond the scope of this project. Although some of RENU's functions parallel those required by the present research, RENU was found to be overwhelmingly complicated and not at all user-friendly.

2) **Oil Field Pavement Damage Program**: The Oil Field Pavement Damage Program was developed at the Texas Transportation Institute to predict the time to roadway failure for roads surrounding new oil wells (Mason et. al., 1985). The program provides potentially useful output such as ride index, maintenance cost, and time to roadway failure. In order to generate these outputs, values for Thornthwaite Index, average rainfall, air freeze-

thaw cycle, mean dynaflect deflection, and subgrade plasticity index must be known and entered. For the vast number of highways and sections which need to be analyzed in this study, these inputs were difficult to obtain.

A major drawback of the Oil Field Pavement Damage Program is its dependency upon the number of oil wells to be drilled as a driving factor in roadway loading. Attempts to establish a separate relationship between the expected traffic and the number of oil wells were not successful.

3) **Reconstruction Modified Incremental Approach (RMIA)**: The RMIA program predicts the estimated cost of roadway upkeep based on damage produced by traffic categorized by vehicle axle types and vehicle miles traveled (Burke, 1993). The specialized nature of this model, with its emphasis on global financial ramifications, rendered it impractical for the present application.

4) **Pavement and Traffic Analysis System (PTAS)**: In reviewing the specific needs of the current research the staff determined that no ready system or approach was well enough suited to use. A new sub-model called the Pavement and Traffic Analysis System (PTAS) was created from AASHTO pavement analytical functions to satisfy the dual requirements of accuracy and simplicity. Each sub-model function was included to address a specific output and to accommodate the characteristics of the Texas Gulf coast and the GIWW.

The sub-model allows linkage to commodity flow data, roadway data, and distance information essential to meet the goals of the project. Furthermore, all of the parameters in the sub-model are easily and accurately obtainable. For example, the PTAS sub-model addresses the separation of pavement types into rigid and flexible classes thereby allowing the results to address differential pavement behavior. In addition, PTAS evaluates roadways by discrete control and section numbers to avoid overlapping pavement characteristics. The sub-model supports an analysis across the variety of soil types which exist in the affected regions of Texas along the Gulf Intracoastal Waterway. PTAS summarizes roadway condition by using the well-known and understood *Present Serviceability Index (PSI)*. The PSI is a function of rutting, raveling, patching, cracking, and other pavement performance indices (AASHTO, 1986).

The PTAS sub-model establishes present roadway conditions and predicts future roadway behavior. PTAS components consist of refined functions and constants derived from the Guide for Design of Pavement Structures and the Principles of Pavement Design. The structure of the Pavement and Traffic Analysis System allows the sub-model to be fitted into a database with other existing data and can be tailored to suit the specific needs of the research.

Pavement and Traffic Analysis System Model Components

The analysis of pavement behavior performed as a part of roadway impact sub-model development resulted in the finding that rigid pavements need not be included. Rigid pavement is not susceptible to degradation or destruction as a result of the kind and amount of extra loading projected to result from a traffic shift. Therefore, prior to analysis, roadways were divided into flexible and rigid pavement types with all rigid sections in the impact zones omitted from the degradation analysis.

Flexible Pavements

Flexible pavements are generally constructed with a flexible base ranging in thickness from 6 to 16 inches (15 to 41 cm). This base is overlaid with an asphalt-type surface ranging in thickness from 1.5 to 6 inches (3.8 to 15 cm). The behavior of flexible pavements is governed by the following logarithmic function:

$$\log W_{t18} = 9.36\log(SN+1)-0.20+\log[(Pi-Pt)/(4.2-1.5)]/$$
$$\{0.40+[1094/(SN+1)_{5.19}]\}+\log(1/R)+0.372(Si-3.0)$$

This expression relates the number of 18 Kip Equivalent Single Axle Loadings (W_{t18}) required to degrade the roadway to a predetermined terminal serviceability index (Pt) for a given structural number (SN), initial serviceability index (Pi), climatic condition (R), and support value (Si). The 18 Kip Equivalent Single Axle Loading (ESAL) is an industry standard by which different axle loadings (single, tandem, tridem, etc.) are normalized to the same scale to allow comparative measures. The output of this function results in a basis to which comparison of new roadway conditions can later be made (Yoder, 1975).

Serviceability Index

The serviceability factor is an index compiled from various pavement distress factors and surface riding indices. In effect, this serviceability index is the score by which the condition of the roadway will be rated. Ideally, a newly constructed road should be rated at a serviceability index of 5.0. Realistically, however, ideal conditions cannot be achieved and a maximum rating of 4.2 is assigned. The low end of the roadway operating range falls between 2.0 and 2.5 (AASHTO, 1986).

The exact serviceability index is a function of the average volume of the roadway and the thickness of the pavement. The terminal serviceability (Pt) for any given roadway is reached whenever the road is no longer able to operate at the service level for which it was designed. For the roadways to be impacted in this study the critical Pt were set at 2.0, 2.3, and 2.5, depending on the level of thickness of the flexible pavement. The initial serviceability index (Pi) indicates the present condition of the road at the time of testing. For the purpose of this analysis the most up-to-date PSI readings were taken from a 1991 Pavement Evaluation System (PEST) run provided by TxDOT. Visual inspection should be performed when this sub-model is used to update the serviceability condition of the pavement.

Pavement Types

The types of pavements found in Texas can be divided into ten categories. The categories are defined as:

1. Construction Reinforced Concrete Pavement
2. Jointed Concrete Reinforced Pavement
3. Jointed Concrete Unreinforced Pavement
4. Asphaltic Thick Hot Mix > 5" (12.7 cm)
5. Asphaltic Intermediate Hot Mix < 2.5" - 5.5" (6.35 - 14.0 cm)
6. Asphaltic Thin Hot Mix < 2.5" (6.35 cm)
7. Unwidened Asphalt Over Concrete
8. Widened Asphalt Over Concrete
9. Overlay, Asphalt on Asphalt
10. Surface Treated < 0.5" (1.3 cm)

Note that pavement types 1-3 are rigid pavements, while the remaining pavements are flexible. The classification of these roadway types are specified in the Pavement Evaluation System (PEST) run provided by TxDOT.

Structural Numbers

For flexible pavements, the variable that distinguishes one pavement structure from another is the structure number.

Analytically, the structure number is given by:

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

where: Di values are respective layer thicknesses

ai values are layer coefficients

This empirical relationship between SN for a pavement structure and layer thickness expresses the relative ability of a material to function as a structural component of the pavement. The layer coefficient relates to the material typing for the surface, base, and sub-base of the roadway. For the roadways affected in this study, layer coefficients were attained from the AASHTO Road Test using crushed stone, gravel, cement-treated gravel, and bituminous-treated gravel. Table 13 shows the results of the AASHTO Road Test.

Table 13. Layer Coefficients

Course Type	Course Component	Coefficient
Surface course	Roadmix (low stability) Plantmix (high stability) Sand Asphalt	0.20 0.44 0.40
Base course	Sandy Gravel Crushed Cement	0.07 0.14
Cement-treated (no soil-cement) Compressive strength @ 7 days	650 psi (45.8 Kg/cm^2) or more 400 psi to 650 psi (28.2 - 45.8 Kg/cm^2) 400 psi (28.2 Kg/cm^2) or less	0.23 0.20 0.15
Bituminous-treated	Coarse-graded Sand asphalt Lime treated	0.34 0.30 0.15-0.30
Subbase course	Sandy gravel Sand or sandy clay	0.11 0.05-0.10

Source: (Yoder, 1975)

With these layer coefficients and pavement surface thicknesses, the following structural numbers were estimated:

$$SN=(6.0*0.42) + (16.0*0.14) = 4.76$$

$$SN=(5.0*0.42) + (6.0*0.17) + (7.0*0.095) = 3.785$$

$$SN=(5.0*0.42) + (4.0*0.25) + (7.5*0.095) = 3.8125$$

$$SN=(0.5*0.40) + (5.0*0.42) + (4.0*0.25) + (7.5*0.095) = 4.0125$$

Regional Factor (Environmental Conditions)

The regional factor (R) is an index between 0.5 and 4.0 used to compensate for the effects of climatic conditions on existing roadways. Specifically, average temperature and the amount of rainfall can have adverse expansion and moisture seepage effects on highway durability. The region of concern in this modal shift study, namely the southeast Texas Gulf Coast line, has a fairly constant regional factor ranging from 1.0 to 1.5. Figure 8 presents a contour map which generalizes regional factors for the United States based upon NCHRP environmental studies.

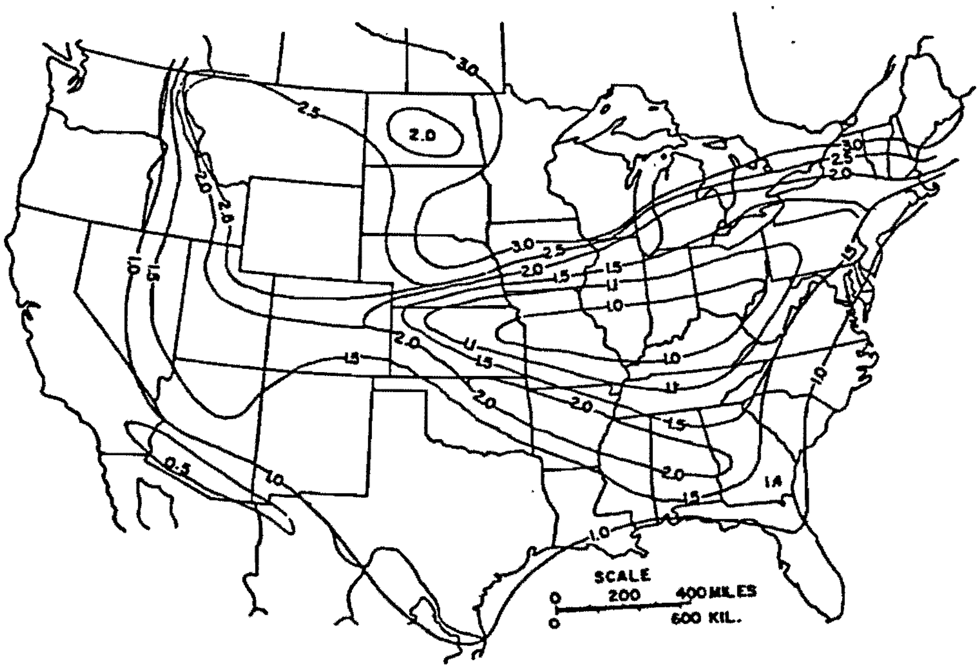

Figure 8. U.S. Regional Factors Contour Map

Interpolation was used to assign regional factors to the Gulf Coast divided by district (Yoder, 1975). Figure 9 shows the division into the districts of impact.

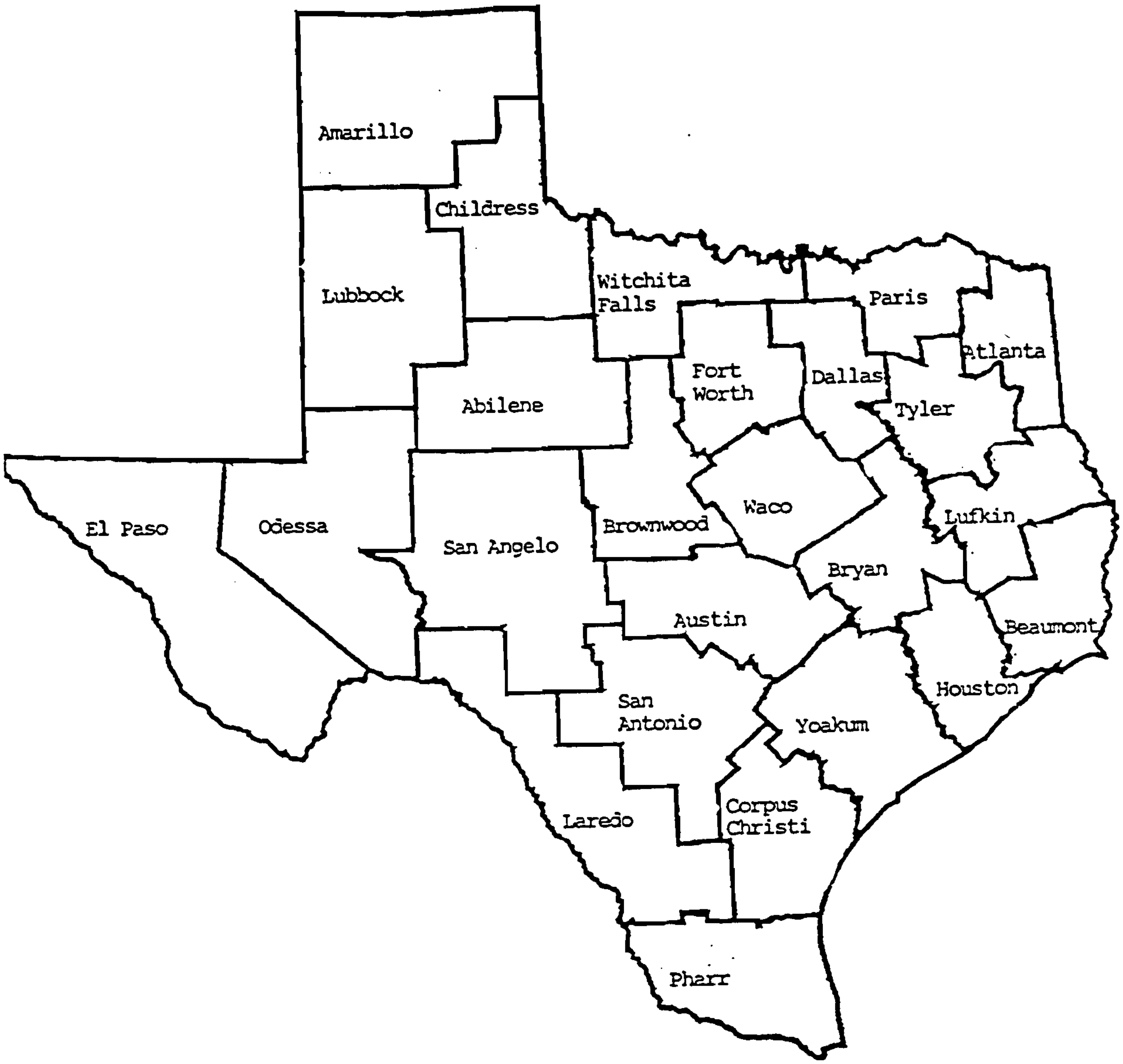

Figure 9. Texas District Division Map

Estimated regional factors (R) are allocated to these districts as follows:

Beaumont District	R = 1.5
Houston District	R = 1.4
Yoakum District	R = 1.2
Corpus Christi District	R = 1.1
Pharr District	R = 1.0

Soil Support

The amount of structural support provided for roadways by soil is referred to as the soil support value (Si). The soil support value can be somewhat arbitrary because many methods of soil support testing exist. Therefore, a correlation between soil tests and soil support values must be established. Figure 10 is an example of such a correlational scale from which support values can be drawn (Yoder, 1975).

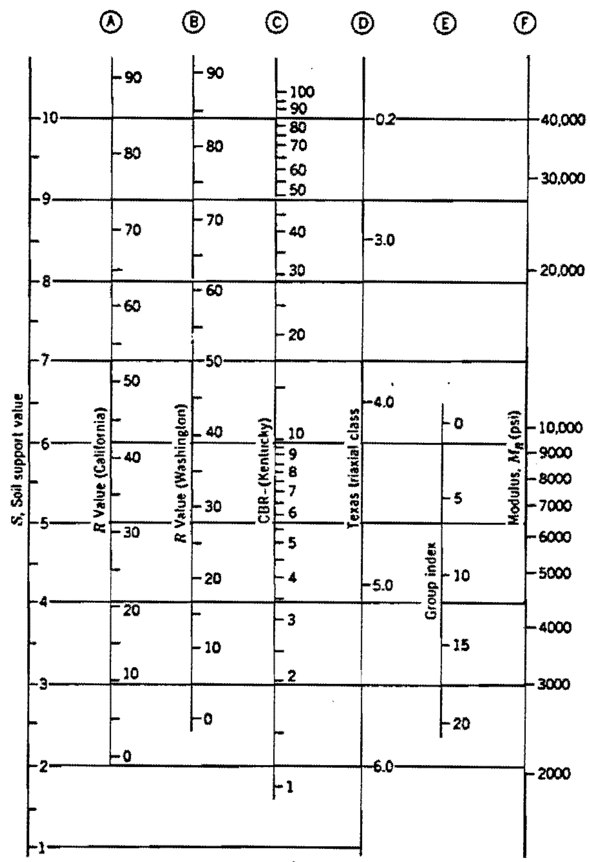

Figure 10. AASHTO Flexible Pavement Soil Support Indices

For those counties affected by a GIWW modal shift, the following subgrade soil support values have been assigned:

Table 14. Subgrade Soil Support Values

DIST NAME	COUNTY #	COUNTY NAME	Si	COUNTY #	COUNTY NAME	Si
Houston	20	Brazoria	4.3	102	Harris	5.4
	80	Fort Bend	4.3	170	Montgomery	6.5
	85	Galveston	5.4			
Yoakum	29	Calhoun	4.3	143	Lavaca	5.4
	45	Colorado	6.5	158	Matagorda	4.3
	62	DeWitt	6.5	235	Victoria	5.4
	90	Gonzales	5.4	241	Wharton	4.3
	121	Jackson	4.3			
Corpus Christi	4	Aransas	4.3	149	Live Oak	5.4
	13	Bee	5.4	178	Nueces	4.3
	89	Goliad	6.5	196	Refugio	4.3
	126	Jim Wells	4.3	205	San Patricio	4.3
	137	Kleberg	4.3			
Beaumont	36	Chambers	4.3	146	Liberty	5.4
	101	Hardin	4.3	181	Orange	4.3
	124	Jefferson	4.3			
Pharr	24	Brooks	5.4	66	Kenedy	5.4
	31	Cameron	4.3	245	Willacy	4.3

Source: (Yoder, 1975).

Rigid Pavements

Rigid pavements are a concrete structure built to withstand very large loads. Due to their rigidity and high modulus of elasticity, concrete pavements tend to distribute the load over a large area so that minor variations in subgrade and base strength types have little impact on the structural capacity of the pavement. From structure mechanics:

$$\text{Modulus of Elasticity} = \text{Stress/Strain}$$

where:

Strain = Change in Length/Original Length

A high modulus results from a low strain factor which yields a small change in pavement size. In effect, the degradation of a rigid pavement then becomes only a function of the volume and the number of repetitions of load (AASHTO, 1986). Figure 11 presents a typical degradation curve of a concrete structure from an initial serviceability index (c_o) to a critical serviceability index (c_t).

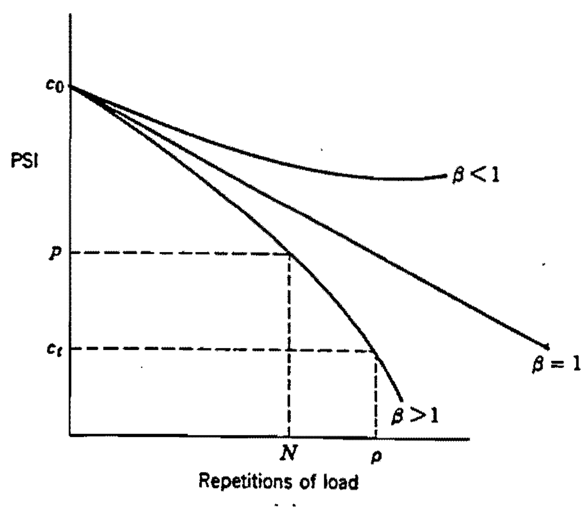

Figure 11. Rigid Pavement Degradation Curve

The serviceability concept for rigid pavements parallels that applied to flexible pavements. Figure 11 clearly shows the dependency on the repetitions of load, and illustrates the path of the curve rides on the volume of the load.

The critical serviceability index for rigid pavements has been set at 2.0 for the present study. To simplify the degradation analysis, a linear slope (B=1) has been assumed for the degradation slope. The following functions govern the condition of a concrete pavement as the number of axles traversing the roadway increases (Yoder, 1975):

$$PSI = B(N) + c_o$$

where:

PSI = the present serviceability index

N = the repetitions of load

c_o = the initial serviceability index (y-intercept)

And:

$$Pt = 2.0 = B(P) + 4.2$$

where:

P = the critical number of 18 Kip Equivalent Single Axle Loadings necessary to reach a terminal serviceability of 2.0.

18 Kip Equivalent Single Axle Loadings (ESAL)

In order to effectively compare relative loadings caused by various types of vehicles such as passenger cars, empty 18 wheelers, and trucks filled to their carrying capacities, all weights must be scaled to an equivalent single axle loading measure. Regardless of the axle type (single, tandem, tridem, etc.), all axle types can be converted through the use of a Load Equivalence Factor (LEF).

Defined in the AASHTO Guide for Design of Pavement Structures, "LEFs represent the ratio of the number of repetitions of any axle load and axle configuration necessary to cause the same reduction in PSI as one application of an 18-Kip Single Axle Load." Through years of field testing, load equivalence factors have been generated for flexible and rigid pavements, varying axle configurations, and varying terminal serviceabilities. The tables in Appendix A are example outputs of these tests used in the present research.

The LEFs for flexible pavements have been measured as functions of structural numbers and axle loads, whereas rigid pavement LEFs are functions of pavement thickness and axle loads. The SNs calculated to represent the pavements under analysis for this study do not readily match the SNs in the tables. Furthermore, the critical serviceability of 2.3 for certain impacted roadways is not displayed. Therefore, mathematical interpolation was used to fill in load equivalence factors corresponding to the selected structural numbers.

However, the LEF variance is not linear so that third order polynomials were generated to model the LEF trends. Appendix B contains graphical depictions of the functions used for LEF interpolation. Empirically, the generation of 18-K ESALs follows from the product of the axle load equivalent factor and the number of vehicles (AASHTO, 1986):

$$\text{18-K ESAL} = (\text{LEF}) \times (\text{ADT}).$$

The LEFs generated for the affected critical serviceabilities of 2.0, 2.3, and 2.5 are shown in Tables 15 - 17.

Table 15. Load Equivalency Factors - Pt = 2.0

Pt = 2.0		**SINGLE**	**SINGLE**	**TANDEM**	**TANDEM**	**TANDEM**
		1.625K	**12K**	**5K**	**19.5K**	**34K**
PType 4	SN=4.76	0	0.1763	0	0.0935	1.0800
PType 5,6,7,8	SN=3.785	0	0.1840	0	0.1020	1.0800
PType 9	SN=3.9125	0	0.1842	0	0.1015	1.0800
PType 10	SN=4.0125	0	0.1830	0	0.1000	1.0800

Source: (Yoder, 1975).

Table 16. Load Equivalency Factors - Pt = 2.3

Pt = 2.3		SINGLE	SINGLE	TANDEM	TANDEM	TANDEM
		1.625K	12K	5K	19.5K	34K
PType 4	SN=4.76	0	0.1875	0	0.1034	1.0902
PType 5,6,7,8	SN=3.785	0	0.2041	0.0008	0.1200	1.0994
PType 9	SN=3.9125	0	0.2039	0.0006	0.1186	1.0992
PType 10	SN=4.0125	0	0.2007	0.0004	0.1164	1.0980

Source: (Yoder, 1975).

Table 17. Load Equivalency Factors - Pt = 2.5

Pt = 2.5		SINGLE	SINGLE	TANDEM	TANDEM	TANDEM
		1.625K	12K	5K	19.5K	34K
PType 4	SN=4.76	0	0.1950	0	0.1100	1.0970
PType 5,6,7,8	SN=3.785	0	0.2175	0.0013	0.1320	1.1123
PType 9	SN=3.9125	0	0.2170	0.0010	0.1300	1.1120
PType 10	SN=4.0125	0	0.2125	0.0007	0.1273	1.1100

Source: (Yoder, 1975).

Vehicle Types

For the purposes of the present study, traffic on Texas highways was represented by the Average Daily Traffic (ADT) measure. To facilitate data processing, this traffic was distributed into passenger cars with only single axles averaging 1.625 kips each and 5 axle trucks which are subdivided into full, half-full, and empty trucks. Each truck is equipped with a single cab axle and two tandem axles. The distribution is allocated according to percentage truck figures obtained from traffic analysis data (RI2T) provided by TxDOT.

For ease of data handling, commodities shifted from water transport to highway transport were distributed among full and empty 5 axle trucks with a carrying capacity of 58,000 lbs (26,332 Kg).

The axle configurations employed for analysis are as follows:
(Note: O denotes single axle and OO denotes tandem axle)

Empty Truck:	**O** 12K	**OO** 5K	**OO** 5K
Half Full:	**O** 12K	**OO** 19.5K	**OO** 19.5K
Full Truck:	**O** 12K	**OO** 34K	**OO** 34K
Automobile:	**O** 1.625K	**O** 1.625K	

This analysis produced an estimated number of vehicles necessary to deliver/receive tonnages transferred from waterway movement to highway transport. These new traffic levels, in conjunction with the LEFs, were then used to translate the tonnages into additional 18-K ESALs. The projected number of vehicles and additional ESALs is then compared to the number of critical 18-K ESALs that a roadway is designed to withstand. The results yield an updated life expectancy of each highway segment.

4.2 ROADWAY SELECTION

Commodity Origin and Destination

The shipping and receiving location mile points designated by the GIWW commodity flow data indicates a general area of prospective roadway impact. To further pinpoint these shipping and receiving locations, industrial clusters located along the GIWW were flagged by an identifying mile point corresponding to the parallel GIWW mile point. The assumption was made, and verified by inspection, that goods shipped by inland barges along the Gulf Intracoastal Waterway are produced or received by industrial sites located on or near the GIWW (CISMAP, 1990).

By identifying plant locations (those commercial entities responsible for shipping and receiving goods and material on the GIWW), the research staff was able to identify the roadways likely used by companies in lieu of a functional GIWW. In addition, since a given roadway can have distinctively different structural/behavioral characteristics across its length, each control and section number was flagged with a responding GIWW mile point identifier. This direct identification allowed the commodity allocation model to pinpoint the precise control and section number where commodities would enter the Texas highway transportation system.

Arterial and Collector Roads

The impact a GIWW closure would have on the Texas highway system depends on the location of that closure. Roadway impacts cannot be isolated to specific regions of the highway system. The nature of commodity movements, with multiple origin-destination (O-D) pairs, means that any road may carry incoming or outgoing material as the result of a GIWW closure and freight diversion.

This realization presented a problem to researchers. A roadway network, when inspected closely, can support a multitude of alternate routes to any given destination. The problem was predicting the impacts on meaningful subsets of the highway transportation system. To predict only the amount of material or the additional trucks was considered by the research staff to be of limited utility. Therefore, in order to facilitate the prediction of impacts on specific roads as a result of interruptions at specific GIWW mile points, the Texas roadway network was simplified.

The simplifying assumption was that shippers, even though denied access to the GIWW, still had a need to transport goods or material to the same destination. Once a modal choice was made, they would choose as their route the most economical path. The roadways most heavily impacted by a closure of the GIWW would be those roads that parallel or approximate the path of the canal.

Since industrial clusters are the overwhelming source and destination for GIWW commodities, a simplified Texas highway system was identified by examining the best paths from each industrial cluster to every other industrial cluster. Roads were categorized into one of two groups. Arterial roads are defined as those highways which parallel the Texas Gulf Coast and connect large distances of the State. These roads are generally Interstates, U.S. highways, or state highways. Collector roads are defined as those roads which run in close proximity to the plant sites and lead into the larger arterial roads. Collector roads are observed, generally, to be Farm-to-Market roads or state highways. Figure 12 illustrates the concept of the roadway modal shift model.

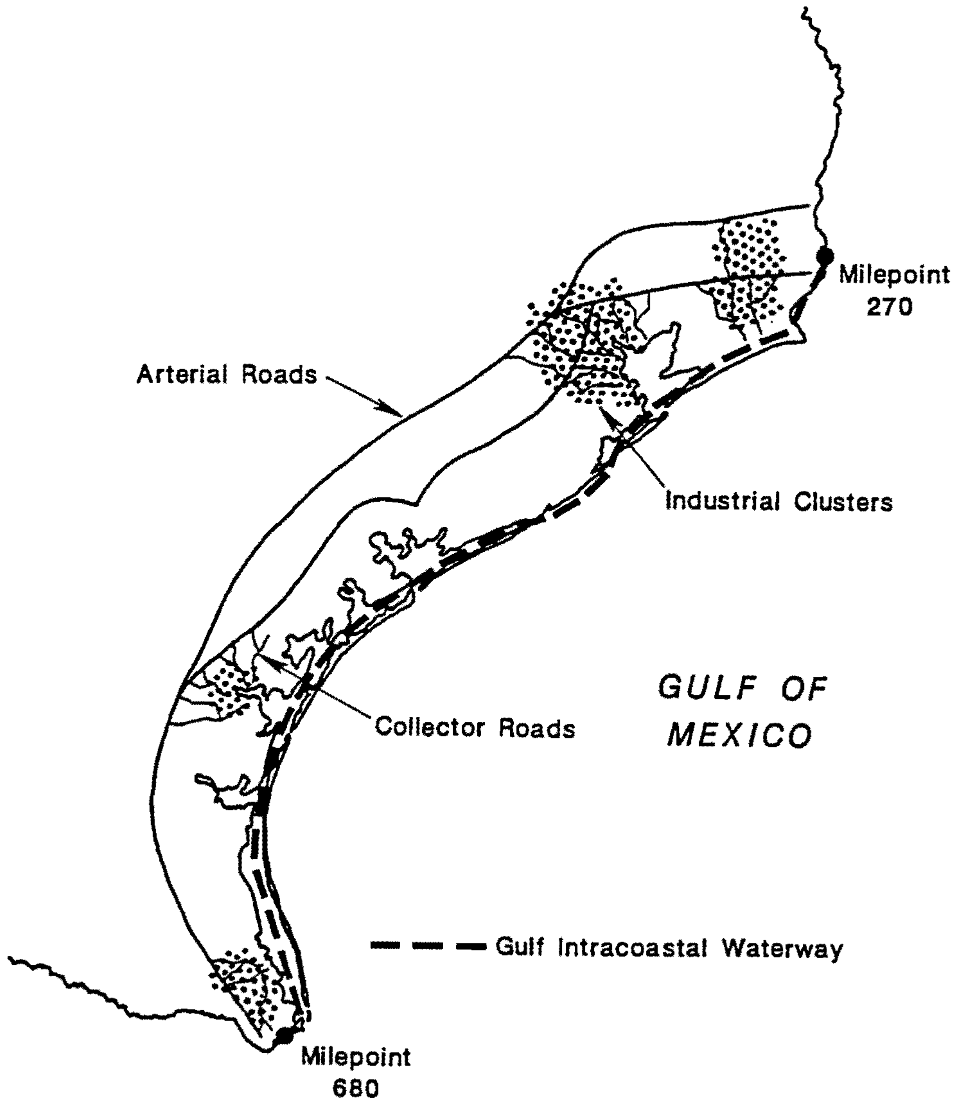

Figure 12. Arterial and Collector Roads

The arterial roads running along the Texas coast have been further categorized into two groups. The *inland* arterial, which is characterized by its uninterrupted length, would be used to carry longer hauls, as well as freight movements destined for locations outside of Texas. The *coastal* arterial, characterized by numerous connections of shorter highways, would be used to move goods from one point on the Texas coast to another.

The roadway model presented in Figure 12 simplifies the complex highway network through a manageable form representing predicted user behavior patterns. The predicted shipping pattern can be described in three phases. First, shippers will traverse outbound collector roads from the origin point to the nearest arterial road running in the direction of the destination. Second, the shipper will travel the arterial toward the ultimate destination, minimizing travel time rather than distance. Third, the shipper will disembark from the arterial onto collector roads nearest the shipment destination. Shippers will complete the haul in a fashion similar to what would have been possible on an operational GIWW.

Intermediate distances between industrial clusters or plant sites and the arterial roads would be traversed by collector roads. When two or more collector roads appeared to be viable alternatives for transport, ADT truck percentages on each road were used to pro-rate commodities among the set of candidate roadways. The pro-ration procedure is performed at the control and section number level to ensure accurate load distribution. This procedure is performed one control and section number at a time starting at each industrial cluster and working toward the point of arterial intersection.

4.3 NON-ROADWAY IMPACTS

A long-term interruption in service of the GIWW at some point in Texas would impact more than roadway degradation. Conservation and environmental concerns associated with additional fuel usage and emissions, safety issues associated with the surface transportation of hazardous materials, increased accident rates, and highway serviceability expressed in terms of traffic congestion would all result from a GIWW interruption.

Fuel Consumption and Cost

Modal fuel efficiency varies throughout studies, so it is presented as a range in this report. In the calculations of fuel consumption, a high end and a low end measurement was used rather than an average or best estimate. Table 18 shows the high and low end efficiencies for large diesel trucks, rail cars, and inland barges. The unit of measure, ton mile/gallon, specifies the number of miles that one ton can be moved on one gallon of fuel.

Table 18. Modal Fuel Efficiency Ranges

	Diesel Trucks	Railroads	Inland Barges
High End	60 ton mi/gal (23.2 Mg Km/L)	320 ton mi/gal (123.5 Mg Km/L)	510 ton mi/gal (196.9 Mg Km/L)
Low End	40 ton mi/gal (15.4 Mg Km/L)	250 ton mi/gal (96.5 Mg Km/L)	450 ton mi/gal (173.7 Mg Km/L)

On average, inland barges can carry ten times more cargo per gallon of fuel than diesel trucks and approximately one and a half times more than railroads.

Information provided by a specialist of the CONOCO Tax Group shows that Rail and barge spend $0.65/gallon ($0.172/liter) for diesel fuel, while diesel trucks spend about $1.00/gallon ($0.264/liter). This effectively breaks down into a dollars/ton mile (dollars/megagram kilometer) comparative analysis which is summarized in Table 19.

Table 19. Modal Fuel Cost Ranges

	Diesel Trucks	Railroads	Inland Barges
High End	$0.0167/ton mi ($0.0114/Mg Km)	$0.00203/ton mi ($0.00139/Mg Km)	$0.00127/ton mi ($0.00087/Mg Km)
Low End	$0.025/ton mi ($0.017/Mg Km)	$0.0026/ton mi ($0.0018/Mg Km)	$0.00144/ton mi ($0.00099/Mg Km)

Shipping cost based upon capacities and fuel cost would increase in the event of a closure. The extent of this increase depends upon the location of closure and amount of production drop-off.

Emissions

A modal shift would also have an immediate impact upon the environment by virtue of increased engine emissions. Inland barges emit approximately 0.37 lbs (0.044 Kg) of contaminant per gallon (liter) of fuel burned. Diesel trucks emit 0.31 lbs/gallon (0.037 Kg/L) and rail locomotives emit 0.69 lbs/gallon (0.083 Kg/L). Although barges emit more pollution per gallon than trucks, when one considers the greater barge carrying capacity and efficiency, the contaminants emitted by trucks far out-weigh those of barges. The constituents of diesel engine emission are categorized into five groups, as shown below (Stehly, 1993):

1. Carbon Monoxide	(CO)	70.5%
2. Oxides of Nitrogen	(NOx)	13.2%
3. Hydrocarbons	(HC)	11.8%
4. Oxides of Sulfur	(SOx)	1.6%
5. Particulates		2.9%

Highway Congestion Analysis

The capacity of a multilane highway is defined as the maximum sustained hourly flow rate at which vehicles can travel over a section of roadway. The flow of traffic tends toward this capacity when the traffic free-flow speed is compromised. Free-flow speed is the theoretical speed of traffic as density approaches zero (i.e. average desired speed of all drivers). The speed of traffic is insensitive to traffic volume to the point where the volume to capacity ratio approaches 1.00.

The congestion factor, measured in units of passenger cars per hour per lane (pcphpl), varies as a function of average traffic volume and the number of accessible highway lanes.

For the categories of roadways studied in the current research, the following congestion factor capacities have been set:

Roadway Class	pcphpl
State Highways:	1400
FM Roadways:	1400
U. S. Highways:	2200
Interstates:	2200

The congestion factor for any given section of road can easily be calculated by using the relationship:

C.F. = (0.75)(pc-total)/(# hrs analysis)(# lanes)

where:

pc-total = the total number of passenger cars

In qualifying this relationship, certain traffic analysis assumptions were made. A peak-hour traffic factor compensated for the temporal variation in traffic flow within a given 24-hour time frame. The analysis period spanned from 6:00 am to 6:00 pm and accounted for 75% of the average daily traffic. Furthermore, all traffic was normalized to a measure of passenger car equivalents. Thus, truck traffic was converted to passenger car equivalents using a factor of 2.0 provided by a TTI congestion expert. Each additional truck added two passenger car equivalents to the ADT. The new congestion factor, computed from a sum of present traffic and GIWW modal shift traffic, can be compared to the previously determined roadway capacities to identify segments in danger of highway congestion.

Hazardous Materials

Certain materials expected to undergo a modal shift from waterway transport to an alternate mode are hazardous. These materials have been generalized into three basic categories: chemicals, forms of gasoline, and liquified petroleum gases. Spillage of these commodities can expose the public, as well as the environment, to high levels of danger. Movement of hazardous materials, tonnages, and a study of roadways impacted are highlighted as separate data items in the roadway impact output.

Accidents

The rate at which accidents occur on the highways is based on the number of vehicle miles traveled. The standard trucking accident rate is approximately 76.6 accidents/100 million miles (161 million Km) traveled. This rate, when applied to each shipment shifted from the GIWW to the Texas highways, will readily project the increased rates at which accidents are likely to occur. The calculation follows:

Shifted # of accidents = (76.6 accidents/100,000,000 truck miles) x (# of miles) x (# shifted trucks)

The nature of this accident analysis precludes the accidents which may be caused by passenger vehicles, and is justified by the constant number of vehicles and miles traveled by passenger cars unaffected by a modal shift. New accident rates can be determined through a simple addition of present traffic accident rates and the number of accidents projected here.

4.4 IMPACT MODEL DEVELOPMENT

The overall Impact Model, developed from the combination of sub-models, integrates a wide array of data. As with any simulation, the challenge was to develop a model that tied together data from a number of sources representing the real world which the model attempted to duplicate. The data must be linked with functions or operations paralleling the behavior of real systems, whether the systems are human decision making processes, economic outcomes, or physical phenomenon. Ideally, the model should be based on readily obtainable data and provide the opportunity for updating as new information becomes available. Finally, the model should require only limited input from the user to avoid extensive documentation and training.

The GIWW Impact Model meets most, if not all, of these requirements. The model combines the following data:

1. Origin-destination data The O-D data includes commodity types, amounts, and transaction dates for over 20,000 individual shipment records.
2. Shipment-distance data Developed from the origin-destination data, distance measures provide the mechanism by which commodities are allocated to rail or highway transportation alternatives.
3. Roadway-network data The roadways of the Texas highway transportation system likely to be impacted in the event of a closure of the GIWW. This data includes physical parameters, such as surface type, thickness, and subgrade, and it includes traffic parameters, such as ADT and percent of truck traffic.
4. Roadway degradation functions These functions describe the degradation behavior of a set of roadway types across a variety of geographic locations.

The input requirement for the Impact Model consists of the mile point(s) at which a break or an interruption in service has taken place. The input can be a single mile point or represent a range of mile points corresponding to an entire reach of the canal. Once a mile point is specified, the Impact Model determines those shipments impacted. Figure 13, included as a conceptual aid, shows how a portion of the shipments are not impacted by an interruption in service. The loops depicted in Figure 12 represent commodity movements *not diverted* as a result of a break. As the location of the break point moves up or down the waterway, the size of the loops increase or decrease corresponding to the length of the canal segment not interrupted. One loop will get larger and the other smaller as the break approaches one end or the other of the Texas portion of the canal. The size of the loops correspond to the distances within which un-interrupted shipment can continue to navigate. Thus, there will always be a subset of the total commodity flow which is not impacted by a break in the GIWW.

Once commodity movements have been selected based on a given break point, each shipment is categorized by the distance between its origin point and its destination. The origin can be a location along the Texas coast or outside the state, but given the fact that the Texas portion of the GIWW terminates at Brownsville, at least one terminal point of a shipment must be in Texas. The total tonnages within each shipment distance category are then divided between the proportion predicted to move by rail, and the proportion predicted to move by highway. Highway tons are converted to the number of truckloads required to carry the specific quantity assuming the standard capacities reported in earlier sections of this report.

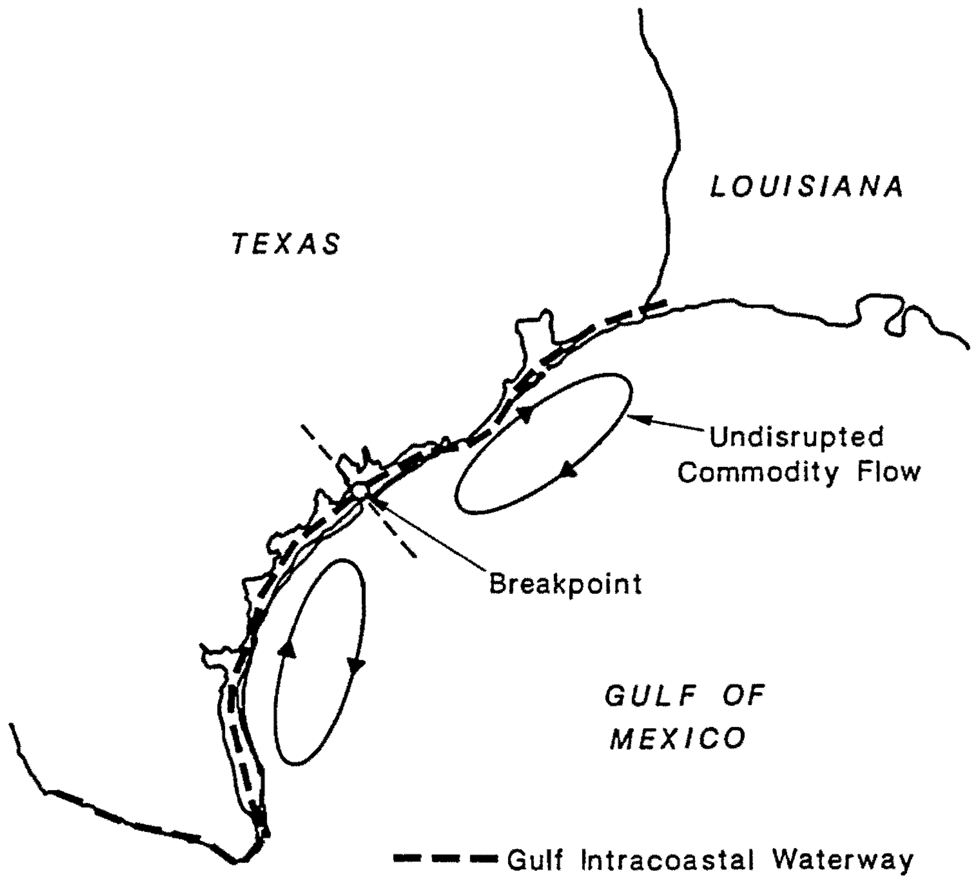

Figure 13. Uninterrupted Commodity Flow

For shipments diverted to highway transportation, roadways are selected based on the individual shipment's origin and destination points. In this manner each shipment defines a surface transportation path paralleling as closely as possible the path of the GIWW. Tonnages traversing the same roadway path are accumulated so that the data reported for selected roads represents total *annual* tons. The impacted roadways are then matched with roadway data (surface type, ADT, etc.) at a control and section number level to allow the assessment of impacts. Additional truck traffic is assumed to be *twice* the number required to carry a given quantity of material. Half of the total number are fully loaded when making the delivery. The other half are assumed to be making an empty return run. Roadway degradation calculations take into account the double number by assigning appropriate axle loadings to full versus empty trucks.

Fuel use and emissions are based on the loads and the movement distances required to deliver those loads. Fuel efficiency ratings, capacities for both rail and truck, and distance calculations are figured into the results using the high and low efficiency ratings previously cited. Hazardous materials, identified from the array of commodities handled on the GIWW, are singled-out for separate reporting.

4.5 DATA ANALYSIS PROGRAMS

The following section provides a brief overview of the data processed by the Impact Model programs. The program hard-copy output, the analytical programs, and the categories of program output are described.

Input Data Sets

SHIP.DAT and RECEIVE.DAT. These two data sets contain shipment information detailing the origin and destination of the shipment, the commodity being transported, the date of transport, and the number of tons being transported.

GIWWMILE.DAT. This data set contains distance information that allows each origin and destination to be assigned a distance in miles from a reference point on the GIWW.

These three data sets were combined and the modal shift equation was applied to determine (based on the distance between the origin and destination) the number of tons that would be transported by truck were there to be an interruption in service on the GIWW.

PTYPE.DAT. This data set contains pavement information (ADT, number of lanes, percent of trucks, present serviceability index, type of pavement) all tied to control and section numbers. County, district, and mile point are also included.

ROUTE.DAT. This data set contains a "map" of probable highway routes to take for every origin-destination combination. A pro-ration factor was included to account for the possibility of multi-route transport.

These two data sets were combined thus tagging every potential origin-destination pair with the characteristics of the pavement for those control and sections to be found along the route.

All of the above data sets were then combined providing the master repository from which all program output was derived. If, for example, there is a break on the GIWW at mile point 400 and a shipment is being transported from mile points 650 to 280, one can derive the number of tons that will be shipped by truck, the probable route that will be taken, the pavement control and section numbers that will be impacted, and the effect that the tonnage will have on the pavement.

Computer Programs and Output

The computer programs and the output they produce can be characterized as independent or dependent upon the GIWW closure point. Output produced by the programs consists of both listings and graphical representations of the data. All programs are written in the SAS language.

OVERALL.PGM is a program that reads the master repository and produces graphical output detailing information such as commodity distribution of tonnage transported (overall), commodity distribution of tonnage transported by GIWW mile point, and the tonnage shifted to highways were there a break on any point of the GIWW. This program requires no input from the user.

BREAKPNT.PGM is a program that produces listings and graphical output of a specific GIWW break point supplied by the user. The break point supplied can either be a single mile point (e.g., 405 -- Brazos River) or a range of mile points (e.g., 575-666 -- Laguna Madre). The graphical output produced contrasts cost of fuel, tons of emissions, and emission components following a modal shift due to a break on the GIWW. The graphs are produced for both low and high ton-mile efficiency.

PAVEMENT.PGM produces a linear graph displaying the predicted decline in the life of a specific section of pavement impacted by the addition of shifted tonnage due to a GIWW break. User input consists of a break point and a control and section number.

5.0 RESULTS

5.1 DISCUSSION OF ASSUMPTIONS

A comprehensive treatment of a hypothetical closure of the GIWW, with all of the complexities inherent in business decisions, transportation logistics, market forces, and the future, is beyond the scope of the current research. Key assumptions have been made and a few of the complexities have been simplified. The research staff has not attempted to deal with questions at a micro-economic level such as whether an individual firm will relocate or transfer its activities to another location following the loss of water transport. Questions concerning the immediate availability of rail or truck alternatives were not examined beyond the finding that the potential quantities transferred to these modes were well within the absorption capacity of the respective industries. Market forces were left to discover precise "hows" and "whens" transportation adjustments would occur.

Information about pipelines, which are privately owned and operated, was not easy to obtain. The research staff assumed that pipeline facilities, either because of access limitations or capacity restrictions, would not significantly mitigate the effects of a closure in the GIWW. Any product that does shift from water to pipeline, thereby taking away from the quantities moved by rail or truck, was accounted for by the 40 percent range assigned to commodities shifted to deal with the expected decrement in productive activity.

A prolonged interruption in service on the GIWW (an interruption lasting in excess of 30 days), would have differential impacts as a function of the duration and location of the closure event. Previous research (Roop, 1991) has shown that due to the "pipeline" nature of many GIWW transport operations, temporal sensitivity is greater than at first might be expected. In this research, an analysis of the economic impact of a GIWW closure at Sargent Beach, Texas, suggested that many firms would begin to experience negative ramifications on operations and production after as few as 7 days. Most firms reported some degree of output reduction after 10 to 20 days. The assumption that these time frames would hold true for firms at other GIWW locations seems reasonable. The duration of closure, therefore, could be expected to generate a transitional effect across most firms during the first 30 days, with a maximum and sustained effect following the first 30 days of closure.

In the event of a closure, the realization by companies that waterborne transport is no longer an option for a significant period of time would motivate them to locate alternatives. The section on modal shift addresses some of the considerations evaluated under that scenario. Firms shift, if possible, to the alternative which costs the least. The circumstances to consider include commodity type, market distance, and transport availability. Some firms, because they lack access or the necessary infrastructure, will be denied the use of pipeline or rail. In these cases, truck transport will be the only alternative, and if distance to market and industry price structure allows, trucking presents a feasible alternative.

Because many firms can switch to truck transport, a closure in the GIWW has ramifications for the integrity of the Texas highway transportation system. Depending on where the closure event takes place, goods and material could be transferred to roadways in significant quantities. The model described in previous sections assesses the location, examines the origins and destinations impacted, determines the distances involved, the proportions shifted to roadways, retrieves the roadways catalogued and keyed to the affected location, and calculates an array of impacts. The impacts deal with location-specific measures such as those linked to control and section numbers (ADT, surface type and condition), and distance-specific measures such as truck and rail ton-miles transported per gallon of diesel fuel.

The model predicts impacts for 410 single-mile point scenarios, and for much larger range-specific scenarios, i.e., mile point 500 to mile point 550. The single-mile point scenarios simulate closures like that feared at Sargent Beach, while range-specific closures model the closure of entire reaches of the canal. The overall model results are depicted in Figure 14, which shows the predicted tonnages transferred to Texas highways by each of the 410 single-mile point scenarios. For any given mile point, the tons potentially shifted to the coastal roadway network are given on the vertical axis (only the 100 percent value is shown). The impacts on the Texas highway transportation system diminish as the break-point approaches the Brownsville vicinity.

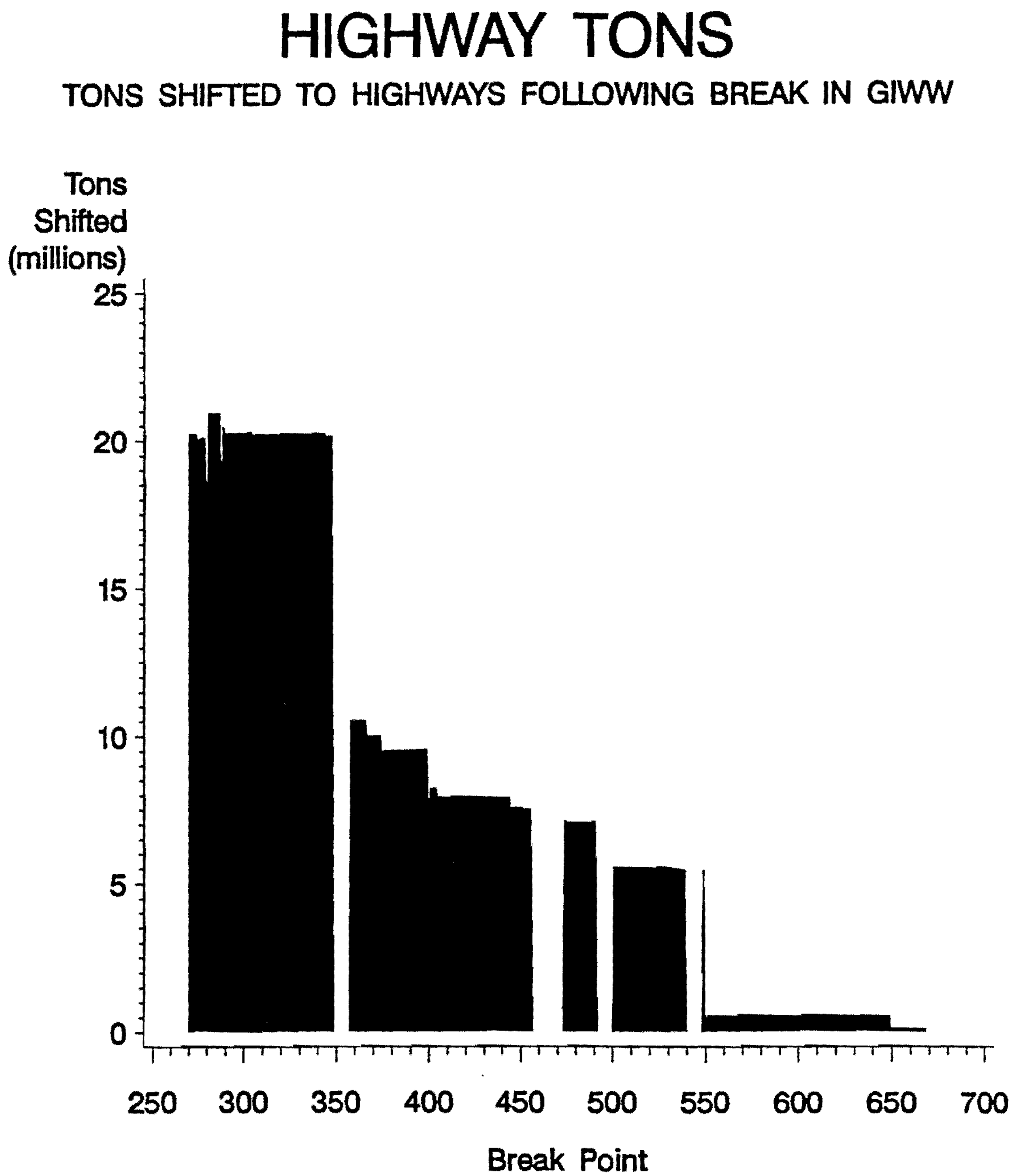

Figure 14. Highway Tons: Tons Shifted to Highways Following Break in GIWW

5.2 SELECTED CASE ANALYSES

Ten GIWW break points representing those locations considered most vulnerable to conditions conducive to waterway closure were analyzed using the model described in the preceding section. The break points were either discrete points of interruption, such as Sargent Beach, or entire stretches of the canal which might be closed as a result of some form of outside intervention. The specific cases analyzed and documented for this report were:

Mile Point	Description
319-325	High Island
360-380	West Galveston Bay
393-394	Freeport
405	Brazos River
418	Sargent Beach
442	Colorado River
474	Port O'Connor
500-504	Aransas NWR
575-666	Laguna Madre
668-670	Port Isabel

Results are organized into 10 appendices, one for each of the above break points. Each appendix contains a graphical or listing analysis (or both) for:

- pavement lifetime degradation (in years),
- tons transported,
- cost of fuel, and
- emissions.

The graph and listing descriptions (and the order in which they appear) follow.

Pavement Lifetime Plot

This plot displays, for a given break point, the degradation in pavement lifetime that can be expected under conditions of accelerated vehicle loading. The graph displays pavement lifetime degradation for a single control and section number.

Figure 15 combines four such graphs depicting the expected degradation in pavement lifetime for US 77, control and section 37203, located around Port Aransas. The horizontal axis of the graph depicts expected pavement lifetime in years. The vertical axis of the graph depicts the serviceability index of the section of highway. The pavement has an initial index of 4.2. The terminal serviceability index (when the pavement becomes unusable) is 2.3.

Under normal circumstances, the lifetime of this section of pavement would be 15.17 years (pre-break). Following a break on the GIWW (e.g., break point 319-325, High Island) the additional tonnage that would be shifted to the highway would result in an expected pavement lifetime of only 7.9 years. In addition to displaying the effect of a break at High Island, the graph shows the effect on pavement lifetime for breaks at West Galveston Bay, Aransas NWR, and Laguna Madre.

Tons Transported Plot

This plot displays the number of tons transported (by truck or rail) as a function of modal shift model predictions based on route distance.

Cost of Fuel Bubble Plot (Low Ton-Miles Efficiency)

Bubble plots show the relative magnitude of one quantity (in this case, cost of fuel) in relation to two other variables that define the horizontal and vertical axes (mode of transport and tons transported, respectively). Instead of displaying a plot symbol, bubble plots draw a circle, the size of which is determined by the magnitude of the quantity being plotted. This plot displays cost of fuel for barge, rail, and truck assuming a low ton-miles efficiency.

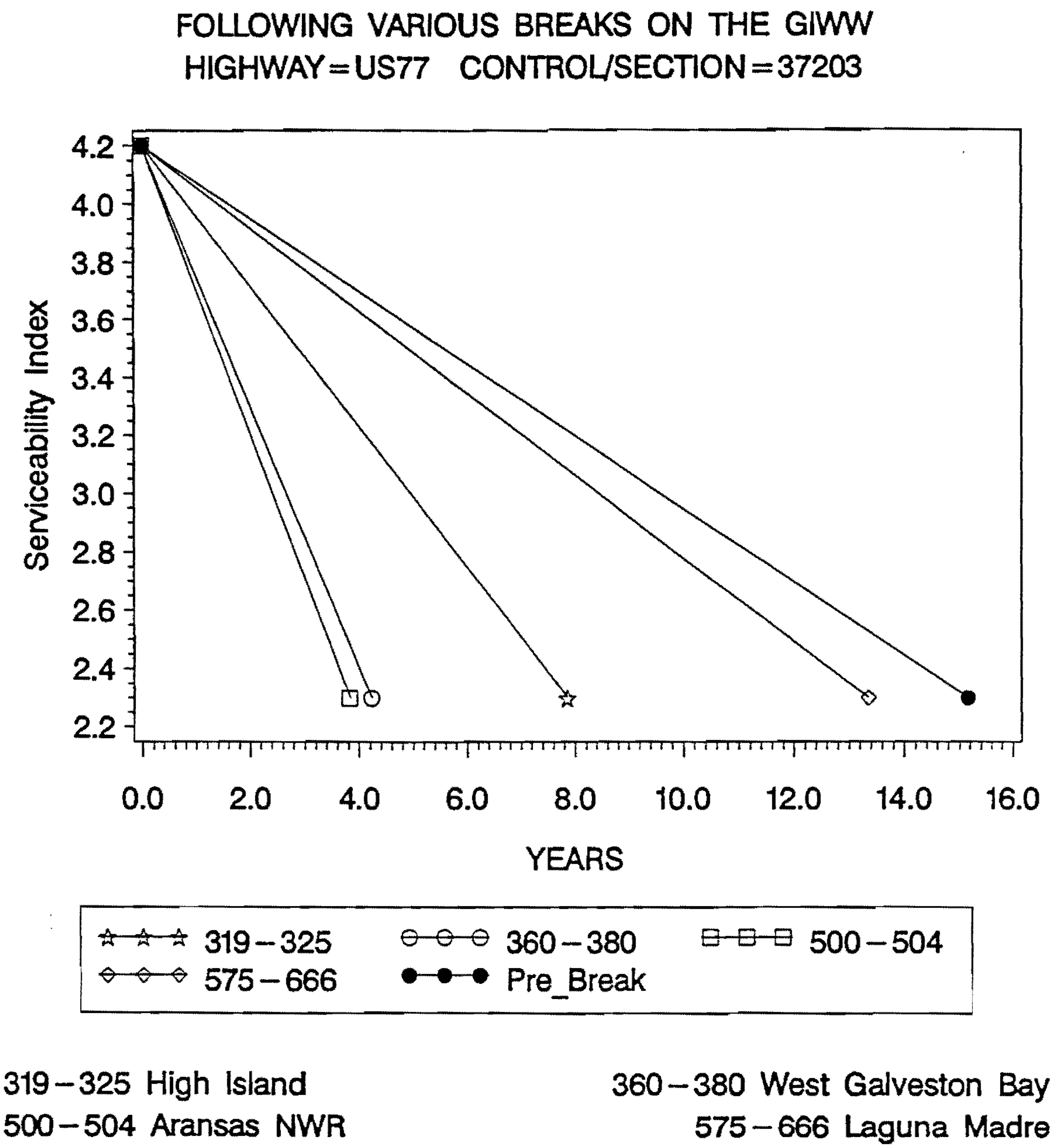

Figure 15. Pavement Lifetime Following Various Breaks on the GIWW

Emissions Bubble Plot (Low Ton-Miles Efficiency)

As with the cost of fuel bubble plot, the emissions bubble plot displays the relative magnitude of emissions (in tons) as a function of tons transported and mode of transport. The larger the bubbles, the greater the emissions. This plot shows emissions for barge, rail, and truck assuming a low ton-miles efficiency.

Emissions Bar Chart (Low Ton-Miles Efficiency)

The emissions bar chart breaks down the emissions for the three modes of transport (barge, rail, and truck) into their constituent parts -- carbon monoxide, hydrocarbons, nitrogen oxides, particulates, and sulfur oxides. The emissions break-down assumes a low ton-miles efficiency.

Cost of Fuel Bubble Plot (High Ton-Miles Efficiency)

This bubble plot displays the cost of fuel assuming a high ton-mile efficiency. This plot is like the cost of fuel plot described above.

Emissions Bubble Plot (High Ton-Miles Efficiency)

This bubble plot is exactly the same as the emissions bubble plot described above, except the magnitude of emissions displayed assumes a high ton-miles efficiency.

Emissions Bar Chart (High Ton-Miles Efficiency)

This bar chart is exactly the same as the bar chart described above, except the emissions break-down assumes a high ton-miles efficiency.

Origin-Destination Listing (Low Ton-Miles Efficiency)

This listing, titled "Detailed Analysis of Affected Tonnage," displays affected tonnage (the tonnage that would be shifted following a break), fuel costs, and emissions for each of the three modes of transport, as well as the projected accident rates for truck transport. Any barge figures displayed represent tonnage figures assuming a break has not occurred. Hazardous tons transported by trucks are also displayed as well as the net cost of fuel and the net emissions that would occur were tonnage to be shifted to rail and truck. Origin and destination indices are defined by mile points displayed in ten mile increments (a mile point value of "1" indicates the origin or destination is outside the

Texas GIWW). Tons, costs, and emissions are totaled at the end of the report. The report assumes low ton-miles efficiency.

Origin-Destination Listing (High Ton-Miles Efficiency)

This listing portrays exactly the same information as the above listing, except high ton-miles efficiency is assumed.

Control & Section Numbers Affected Listing

Sorted by district, this listing displays those highway control and sections that would be affected in the event of a GIWW break. The listing displays the tonnage that would impact the section, the amount of hazardous tons, years of useful life the section of pavement would have under normal circumstances, years to failure were the additional tons transported, percent increase in maintenance cost expected following the break, percentage of truck traffic before and after a break, and congestion figures.

The final listings in all appendices are origin-destination listings, and control and section number listings representing an expected 40% decline in production that would occur following a GIWW break.

5.3 EXAMPLE ANALYSIS -- DISCUSSION OF HIGH ISLAND

The material found in Appendix C will be discussed in detail to describe the form and intent of the reports. The subsequent appendices, D-L (see Volume II), contain similar graphs and listings, as Appendix C, organized in the same manner. Appendix C contains results generated from the analysis of a break at mile points 319-325 (High Island). The following discussion will focus on High Island, making generalizations to the other appendices when appropriate.

Pavement Lifetime

The section of pavement depicted in the plot (Highway US 77, Control and Section 37203) has an expected lifetime of 15.1 years under current usage conditions. Following a break at High Island, 1,693,835 of the tons (1,536,308 of the megagrams) shifted from the GIWW will specifically impact this section of pavement. The effect of this additional tonnage would reduce the predicted lifetime of the pavement to 8.0 years.

The degradation in lifetime for a section of pavement varies greatly depending on where a break occurs on the GIWW. For example, if a break were to occur at mile points 500-504 (Aransas NWR -- see Volume II, Appendix J) the pavement lifetime would be reduced to only 3.8 years. A break at mile points 668-670 (Port Isabel -- Volume II, Appendix L) modestly reduces the lifetime of the pavement to 14.6 years.

Tons Transported

This plot contrasts the number of tons that would be transported by truck and rail following a GIWW break at High Island. Shorter routes are associated with truck transportation, while, as shipment distances increase, rail becomes the dominant mode of shipment. This relationship is essentially repeated for each of the break points analyzed.

Cost of Fuel (Low Ton-Miles Efficiency)

This bubble plot shows the dramatic impact a break at High Island would have on fuel costs. Annual fuel costs for barge transport of the 41,568,120 tons (37.7 million Mg) traversing the 319-325 reach is estimated at $25,358,833. Truck and rail fuel costs would be $150,887,698 and $29,761,388 respectively. The net cost in fuel of a break at High Island would be $155,290,253.

Emissions (Low Ton-Miles Efficiency)

The bubble plot depicting tons of emissions mirrors that of fuel costs in that a break at High Island would result in an emissions growth of over 500%. Annual barge transport of the almost 42 million tons (38 million Mg) generates 7,162 tons (6500 Mg) of emissions. The same tonnage transported by truck and rail generates 39,169 tons (35,526 Mg) of emissions. The net growth in emissions following a break would be 32,007 tons (29,029 Mg).

Emissions Bar Chart (Low Ton-Miles Efficiency)

Emissions for the three modes of transportation are further broken-down into constituent components by a bar chart depicting the mix of carbon monoxide, hydrocarbons, nitrogen oxides, particulates, and sulfur oxides that compose the total emission output. Carbon monoxide is by far the largest component emitted with nitrogen oxides a distant second. This component mix is true regardless of which of the three modes of transport is used. Were there to be a break at High Island, over 70% of the 39,169 tons (35,526 Mg) of emissions generated by truck and rail would be carbon monoxide.

Cost of Fuel (High Ton-Miles Efficiency)

An assumption of high ton-mile efficiency results in 41,568,120 barge tons (37.7 million barge Mg) affected by a break, annually costing $22,375,441. Truck and rail fuel costs would be $100,591,799 and $23,251,085 respectively. The net cost in fuel of a break at High Island would be $101,467,442.

Emissions (High Ton-Miles Efficiency)

Substituting high ton-miles efficiency results in barge emissions of 6,320 tons (5,732 Mg) annually. Truck and rail together generate 27,909 tons (25,313 Mg) of emissions. The net growth in emissions following a break would be 21,589 tons (19,580 Mg).

Emissions Bar Chart (High Ton-Miles Efficiency)

Breaking down emissions into component parts in the high ton-miles case results in the two top emissions being carbon monoxide and nitrogen oxides. Rail, being the greatest emitter, generates

8,634 tons (7,831 Mg) of carbon monoxide. Truck transport emits 11,042 tons (10,015 Mg) of carbon monoxide. Barge emits the least carbon monoxide with 4,455 tons (4,040 Mg).

Origin-Destination Listing (Low Ton-Miles Efficiency)

This listing displays the basic information from which many of the previously discussed graphs and bar charts were generated. For each of the origin-destination combinations, specific values are given for tons moved by truck and rail, hazardous tons moved by truck, cost of fuel (for each mode of transport), net cost were there to be a shift to truck and rail, emissions, and net increases in emissions in case of an interruption in GIWW service at High Island.

A mile point value of "1" represents an origin or destination outside of Texas. Mile points were displayed in increments of ten in an effort to reduce output, and all values displayed are sums for the specific ten mile increment depicted. For example, the "Affected Tons" truck value for origin/destination 280 and 350 represents the sum of tons impacted by a break at High Island originating at mile points 271-280 and arriving at the mile point destinations of 341-350. From the commodity database, this listing shows (assuming low ton-mile efficiency) the impact of a break at High Island, at every origin and destination, on tons shifted to highways, tons shifted to rail, hazardous tons shifted to highways, the cost in fuel for the different modes of transport, and the emissions that would result as a function of such a break. Looking at truck transport alone, a break at High Island would shift 20,212,016 commodity tons (18.3 million Mg), would cost $150,887,698 in fuel, and would result in 23,493 additional tons (21,308 Mg) of truck-produced emissions.

Origin-Destination Listing (High Ton-Miles Efficiency)

This listing displays the same information as shown in the low ton-miles efficiency listing, except that the numbers are generated assuming high ton-miles efficiency. The impact of this change may be found in the cost of fuel and emissions figures (affected tons stay the same). Following a break at High Island, the cost of fuel for trucks is estimated to be $100,591,799 (approximately 66% of the cost of fuel in the low ton-miles efficiency situation). A similar decrease is to be found in the emissions figure for trucks, which falls to 15,662 tons (14,205 Mg).

Control & Section Numbers Affected Listing

Following a break at High Island, shifted tonnage will impact any highways used to circumvent the break. The control and section numbers listing displays, for each district affected, those pavement sections impacted by shifted tonnage. The impact on a section of pavement can be quite severe. For example, state highway 134 (see Appendix C, page 1, district 12), control and section number 37602, will experience an estimated increase of over 11.6 million tons (10.5 million Mg) of truck transport. Such an increase in load will reduce the expected pavement lifetime from 20 years to 4.13 years. The estimated maintenance cost increase will be over 79%. Of potential concern is the fact that almost 4 million (3.6 million Mg) of the shifted tons are categorized as hazardous. None of the affected sections of highway are expected to experience critical levels of congestion. This was true regardless of the break points analyzed.

5.4 PRODUCTION DECREMENTED RESULTS

The origin-destination listings and the control and section numbers listing are reproduced to include the 40% production decrement discussed in detail in Chapter 2. The decrement provides a lower limit for potential tonnages shifted to Texas highways and thereby accounts for realistic industrial reactions to the loss of primary transportation mode.

5.5 SUMMARY

The impacts from a closure in the GIWW appear to be most significant in terms of fuel costs, emissions, and, for selected break locations, roadway life-span and the associated highway maintenance and rehabilitation expense. Impact is limited in terms of congestion, and thus in terms of traffic accidents which normally accompany greater numbers of vehicles. The results also show that the absolute magnitude of hazardous materials transported by highway would increase, but given only modest increases in congestion, may not create a noticeably greater hazard to the motoring public.

Table 20 summarizes fuel costs and emissions resulting from each of the 10 GIWW break points analyzed in detail. The values represent the impact of a modal shift to trucks and rail. High and low values are provided to contrast higher and lower ton-mile efficiency.

Table 20. Estimated Annual Cost and Emissions of Modal Shift from Water to Truck and Rail

LOCATION	MILE POINT	FUEL COSTS		EMISSIONS	
		LOW	HIGH	LOW	HIGH
High Island	319-325	155,290,253	101,467,442	32,007 tons (29,029 Mg)	21,589 tons (19,580 Mg)
W. Galveston Bay	360-380	70,832,468	46,281,195	14,130 tons (12,814 Mg)	9,491 tons (8,607 Mg)
Freeport	393-394	66,074,014	43,172,193	13,232 tons (12,000 Mg)	8,893 tons (8,065 Mg)
Brazos River	405	55,403,553	36,200,186	11,087 tons (10,055 Mg)	7,450 tons (6,756 Mg)
Sargent Beach	418	55,445,079	36,227,315	11,094 tons (10,061 Mg)	7,455 tons (6,767 Mg)
Colorado River	442	55,445,079	36,227,315	11,094 tons (10,061 Mg)	7,455 tons (6,767 Mg)
Port O'Connor	474	49,708,554	32,478,704	9,768 tons (8,859 Mg)	6,548 tons (5,938 Mg)
Aransas NWR	500-504	41,759,861	27,285,586	8,385 tons (7,604 Mg)	5,637 tons (5,111 Mg)
Laguna Madre	575-666	3,034,364	1,982,515	560 tons (507 Mg)	372 tons (337 Mg)
Port Isabel	668-670	788,610	515,248	148 tons (134 Mg)	99 tons (89 Mg)

A shift of commodity transport to highways substantially decreases the lifespan predicted for many roads. The decrease can be translated to maintenance dollars by recognizing that roadway rehabilitation is a scheduled undertaking. When damage to roads in a District is accelerated, as would be predicted following a closure in the waterway, the financial resources earmarked for regular maintenance becomes insufficient to handle the need. In the hypothetical High Island closure, maintenance costs for the roads impacted by additional truck traffic increase as much as

70% in the Houston, Yoakum, and Corpus Christi Districts. Intermediate amounts are seen in the Beaumont and Pharr Districts showing maintenance cost increases of over 40 and 20%, respectively.

5.6 CONCLUSIONS

The results of this research suggest that the probability for extended closures are low. In the event of a closure, the U.S. Army Corps of Engineers seems well prepared to minimize the down-time of the waterway. According to Corps representatives, physical closures of the GIWW are not expected to interrupt service for more than 30 days. Within this 30 day time frame, it is unlikely that commodities would be shifted to other modes.

However, given the uncertainties of the world within which we live, one cannot completely disregard the chances of prolonged GIWW closure. Some of the more unpredictable closure events listed in chapter 2, such as hurricanes, could, given all the right conditions, render the GIWW useless for a prolonged period of time. With an extended interruption, shifting of commodities to the Texas highway system could occur.

This research has focused on that portion of the goods currently moving by water which, under the right conditions, could be projected to be moved on the Texas highways. Through a modal shift distance matrix developed for this study, the report predicts that some portion of 34,538,282 tons (31.3 million Mg) could be shifted to Texas roadways (52%). However, since not all goods are impacted by a break in the waterway, the maximum shifted tonnage totals for any one break is on the order of 20 million tons (18.1 million Mg). An analysis of the GIWW from east (milepoint 280) to west (milepoint 670) shows a dramatic decrease in shifted highway goods. Furthermore, the location of a potential GIWW interruption also plays a role in the modal shifting process. The degree of modal shift varies with the GIWW point of closure.

The primary factor used in determining the roadway impact was a decrease in the serviceability index. In effect, the expected life-span of the pavements is shortened by escalated traffic. The degree of degradation from roadway to roadway, measured in years to failure, varied from a few months to 15 years for the scenarios tested.

The modal shift impact was also reflected in the general increase in fuel cost, vehicular emissions, congestion factors, and accident rates. Although the cost of fuel for barges and rail was found to be the same, the larger carrying capacity of barges makes them less costly to operate on a per ton mile basis. Trucks, on the other hand, not only carry far less than railcars or barges, their fuel cost is also $0.35/gallon ($0.09/L) more than barge fuel, making them all the more expensive to operate. Modal capacity differences can also be expressed in terms of engine emissions. Greater fuel usage by truck and rail translates directly into greater emissions.

The research also examined congestion on Texas highways as a result of an interruption in service on the GIWW. The data suggests that increased truck traffic would result in higher congestion factors on affected roadways. However, none of the roads analyzed for the scenarios tested reached a critical level of congestion. A similar result was observed for accident rates. Even though all affected roads were subjected to a higher risk of accidents due to elevated traffic flow, the level of accidents does not grow at an alarming rate.

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APPENDIX A

AASHTO Standard Load Equivalence Factors

Axle load equivalency factors for flexible pavements, single axles and p_t of 2.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0002	.0002	.0002	.0002	.0002	.0002
4	.002	.003	.002	.002	.002	.002
6	.009	.012	.011	.010	.009	.009
8	.030	.035	.036	.033	.031	.029
10	.075	.085	.090	.085	.079	.076
12	.165	.177	.189	.183	.174	.168
14	.325	.338	.354	.350	.338	.331
16	.589	.598	.613	.612	.603	.596
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.59
22	2.49	2.44	2.35	2.31	2.35	2.41
24	3.71	3.62	3.43	3.33	3.40	3.51
26	5.36	5.21	4.88	4.68	4.77	4.96
28	7.54	7.31	6.78	6.42	6.52	6.83
30	10.4	10.0	9.2	8.6	8.7	9.2
32	14.0	13.5	12.4	11.5	11.5	12.1
34	18.5	17.9	16.3	15.0	14.9	15.6
36	24.2	23.3	21.2	19.3	19.0	19.9
38	31.1	29.9	27.1	24.6	24.0	25.1
40	39.6	38.0	34.3	30.9	30.0	31.2
42	49.7	47.7	43.0	38.6	37.2	38.5
44	61.8	59.3	53.4	47.6	45.7	47.1
46	76.1	73.0	65.6	58.3	55.7	57.0
48	92.9	89.1	80.0	70.9	67.3	68.6
50	113.	108.	97.	86.	81.	82.

Axle load equivalency factors for flexible pavements, tandem axles and p_t of 2.0.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0003	.0003	.0003	.0002	.0002	.0002
6	.001	.001	.001	.001	.001	.001
8	.003	.003	.003	.003	.003	.002
10	.007	.008	.008	.007	.006	.006
12	.013	.016	.016	.014	.013	.012
14	.024	.029	.029	.026	.024	.023
16	.041	.048	.050	.046	.042	.040
18	.066	.077	.081	.075	.069	.066
20	.103	.117	.124	.117	.109	.105
22	.156	.171	.183	.174	.164	.158
24	.227	.244	.260	.252	.239	.231
26	.322	.340	.360	.353	.338	.329
28	.447	.465	.487	.481	.466	.455
30	.607	.623	.646	.643	.627	.617
32	.810	.823	.843	.842	.829	.819
34	1.06	1.07	1.08	1.08	1.08	1.07
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.76	1.75	1.73	1.72	1.73	1.74
40	2.22	2.19	2.15	2.13	2.16	2.18
42	2.77	2.73	2.64	2.62	2.66	2.70
44	3.42	3.36	3.23	3.18	3.24	3.31
46	4.20	4.11	3.92	3.83	3.91	4.02
48	5.10	4.98	4.72	4.58	4.68	4.83
50	6.15	5.99	5.64	5.44	5.56	5.77
52	7.37	7.16	6.71	6.43	6.56	6.83
54	8.77	8.51	7.93	7.55	7.69	8.03
56	10.4	10.1	9.3	8.8	9.0	9.4
58	12.2	11.8	10.9	10.3	10.4	10.9
60	14.3	13.8	12.7	11.9	12.0	12.6
62	16.6	16.0	14.7	13.7	13.8	14.5
64	19.3	18.6	17.0	15.8	15.8	16.6
66	22.2	21.4	19.6	18.0	18.0	18.9
68	25.5	24.6	22.4	20.6	20.5	21.5
70	29.2	28.1	25.6	23.4	23.2	24.3
72	33.3	32.0	29.1	26.5	26.2	27.4
74	37.8	36.4	33.0	30.0	29.4	30.8
76	42.8	41.2	37.3	33.8	33.1	34.5
78	48.4	46.5	42.0	38.0	37.0	38.6
80	54.4	52.3	47.2	42.5	41.3	43.0
82	61.1	58.7	52.9	47.6	46.0	47.8
84	68.4	65.7	59.2	53.0	51.2	53.0
86	76.3	73.3	66.0	59.0	56.8	58.6
88	85.0	81.6	73.4	65.5	62.8	64.7
90	94.4	90.6	81.5	72.6	69.4	71.3

Axle load equivalency factors for flexible pavements, single axles and p_t 2.5.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.	102.	79.	60.	53.	55.

Axle load equivalency factors for flexible pavements, tandem axles and p_t of 2.5.

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470
30	.611	.648	.703	.695	.658	.633
32	.813	.843	.889	.887	.857	.834
34	1.06	1.08	1.11	1.11	1.09	1.08
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.73	1.69	1.68	1.70	1.73
40	2.21	2.16	2.06	2.03	2.08	2.14
42	2.76	2.67	2.49	2.43	2.51	2.61
44	3.41	3.27	2.99	2.88	3.00	3.16
46	4.18	3.98	3.58	3.40	3.55	3.79
48	5.08	4.80	4.25	3.98	4.17	4.49
50	6.12	5.76	5.03	4.64	4.86	5.28
52	7.33	6.87	5.93	5.38	5.63	6.17
54	8.72	8.14	6.95	6.22	6.47	7.15
56	10.3	9.6	8.1	7.2	7.4	8.2
58	12.1	11.3	9.4	8.2	8.4	9.4
60	14.2	13.1	10.9	9.4	9.6	10.7
62	16.5	15.3	12.6	10.7	10.8	12.1
64	19.1	17.6	14.5	12.2	12.2	13.7
66	22.1	20.3	16.6	13.8	13.7	15.4
68	25.3	23.3	18.9	15.6	15.4	17.2
70	29.0	26.6	21.5	17.6	17.2	19.2
72	33.0	30.3	24.4	19.8	19.2	21.3
74	37.5	34.4	27.6	22.2	21.3	23.6
76	42.5	38.9	31.1	24.8	23.7	26.1
78	48.0	43.9	35.0	27.8	26.2	28.8
80	54.0	49.4	39.2	30.9	29.0	31.7
82	60.6	55.4	43.9	34.4	32.0	34.8
84	67.8	61.9	49.0	38.2	35.3	38.1
86	75.7	69.1	54.5	42.3	38.8	41.7
88	84.3	76.9	60.6	46.8	42.6	45.6
90	93.7	85.4	67.1	51.7	46.8	49.7

Axle load equivalency factors for rigid pavements, single axles and p_t of 2.0.

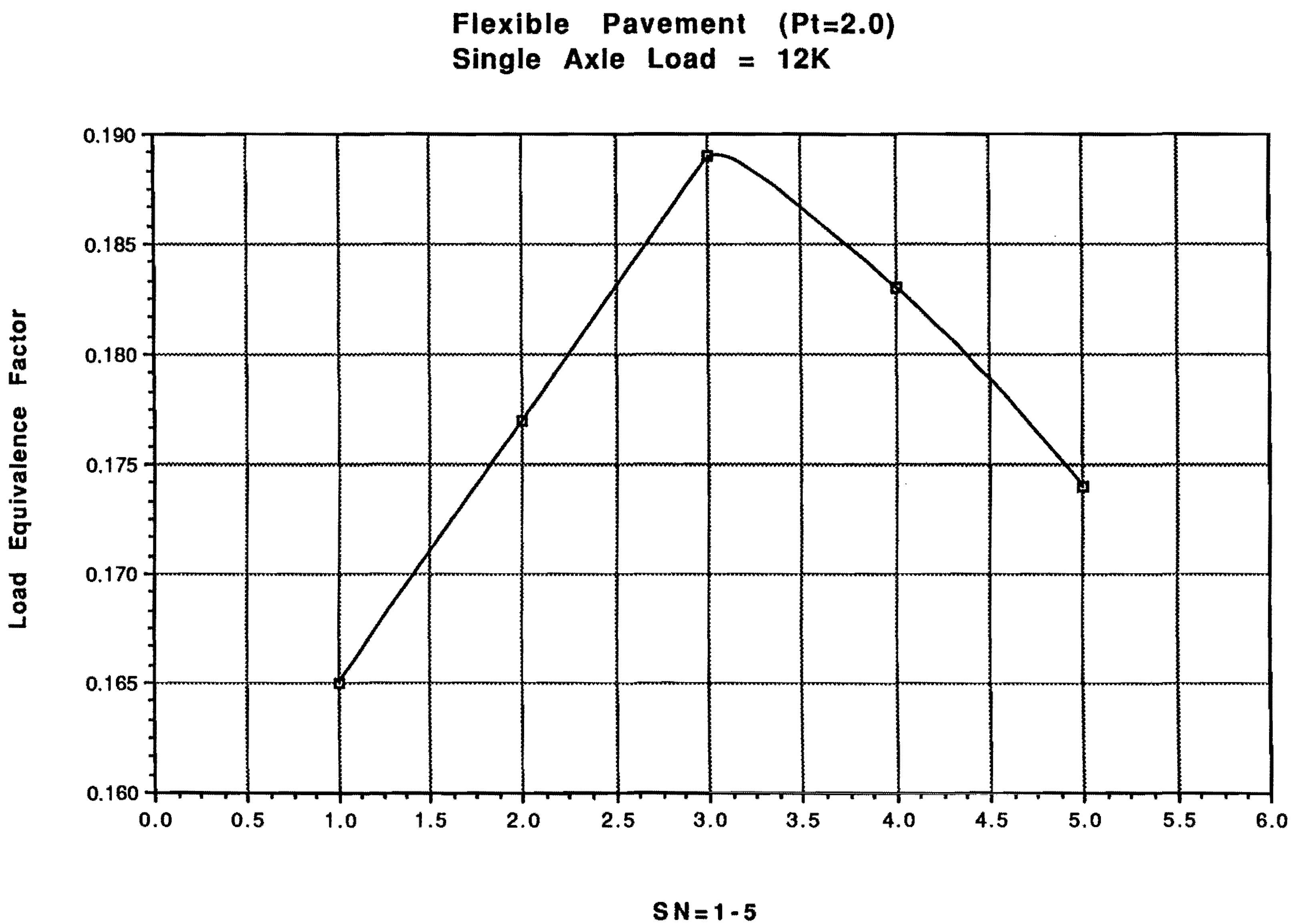
Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
4	.002	.002	.002	.002	.002	.002	.002	.002	.002
6	.011	.010	.010	.010	.010	.010	.010	.010	.010
8	.035	.033	.032	.032	.032	.032	.032	.032	.032
10	.087	.084	.082	.081	.080	.080	.080	.080	.080
12	.186	.180	.176	.175	.174	.174	.173	.173	.173
14	.353	.346	.341	.338	.337	.336	.336	.336	.336
16	.614	.609	.604	.601	.599	.599	.598	.598	.598
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.55	1.56	1.57	1.58	1.58	1.59	1.59	1.59	1.59
22	2.32	2.32	2.35	2.38	2.40	2.41	2.41	2.41	2.42
24	3.37	3.34	3.40	3.47	3.51	3.53	3.54	3.55	3.55
26	4.76	4.69	4.77	4.88	4.97	5.02	5.04	5.06	5.06
28	6.58	6.44	6.52	6.70	6.85	6.94	7.00	7.02	7.04
30	8.92	8.68	8.74	8.98	9.23	9.39	9.48	9.54	9.56
32	11.9	11.5	11.5	11.8	12.2	12.4	12.6	12.7	12.7
34	15.5	15.0	14.9	15.3	15.8	16.2	16.4	16.6	16.7
36	20.1	19.3	19.2	19.5	20.1	20.7	21.1	21.4	21.5
38	25.6	24.5	24.3	24.6	25.4	26.1	26.7	27.1	27.4
40	32.2	30.8	30.4	30.7	31.6	32.6	33.4	34.0	34.4
42	40.1	38.4	37.7	38.0	38.9	40.1	41.3	42.1	42.7
44	49.4	47.3	46.4	46.6	47.6	49.0	50.4	51.6	52.4
46	60.4	57.7	56.6	56.7	57.7	59.3	61.1	62.6	63.7
48	73.2	69.9	68.4	68.4	69.4	71.2	73.3	75.3	76.8
50	88.0	84.1	82.2	82.0	83.0	84.9	87.4	89.8	91.7

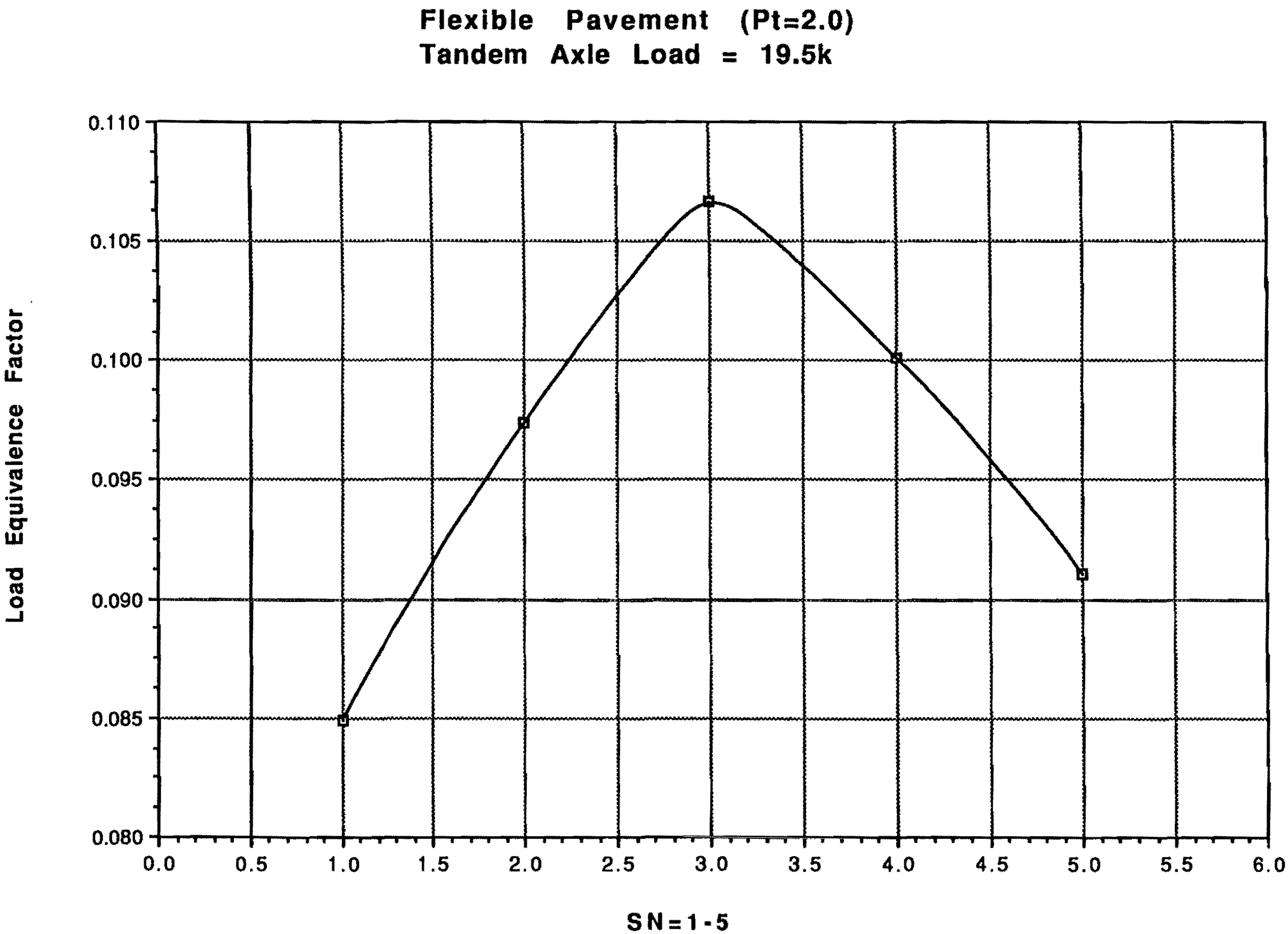
Axle load equivalency factors for rigid pavements, tandem axles and p_t of 2.0.

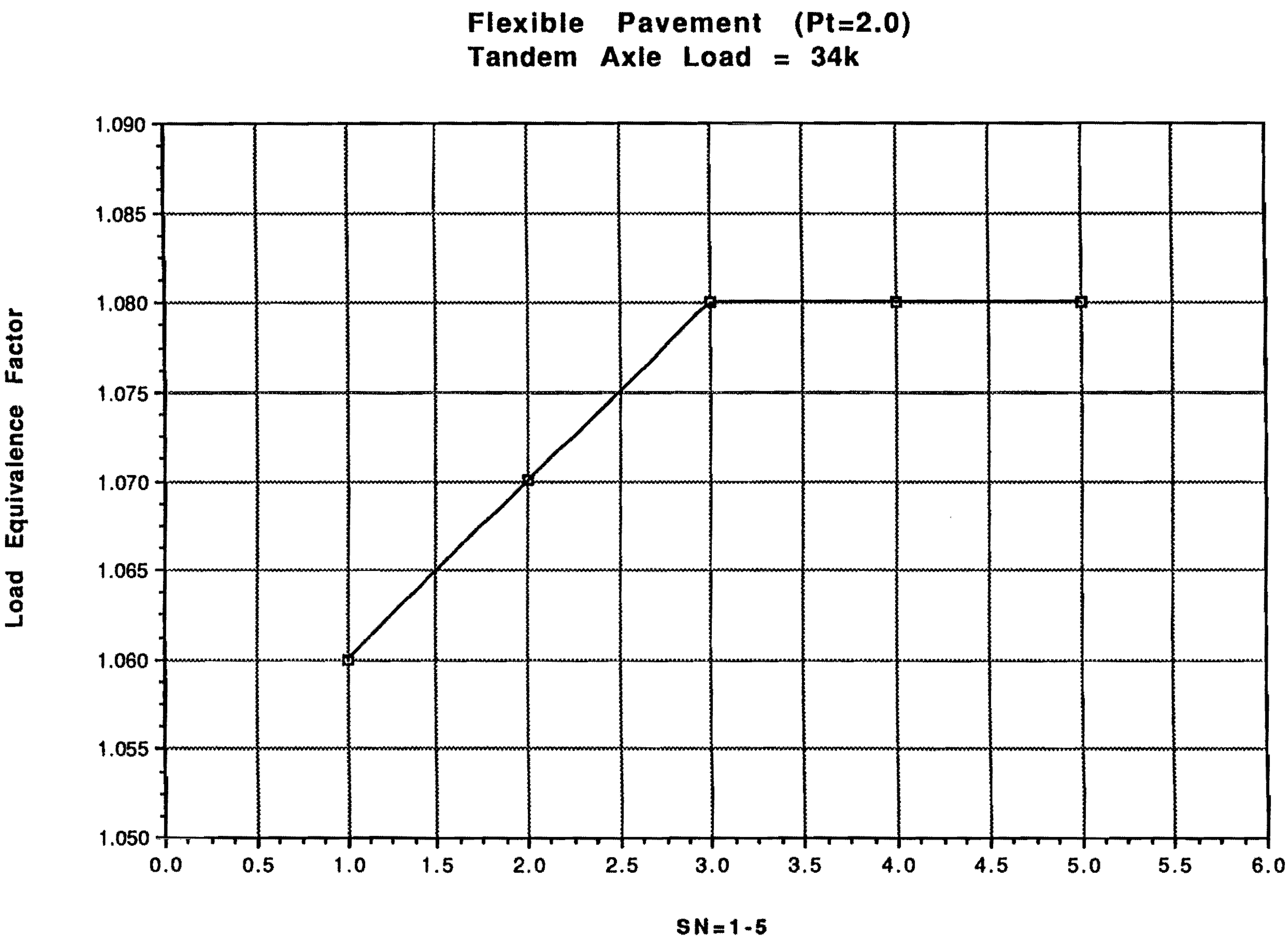
Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005
6	.002	.002	.002	.002	.002	.002	.002	.002	.002
8	.006	.006	.005	.005	.005	.005	.005	.005	.005
10	.014	.013	.013	.012	.012	.012	.012	.012	.012
12	.028	.026	.026	.025	.025	.025	.025	.025	.025
14	.051	.049	.048	.047	.047	.047	.047	.047	.047
16	.087	.084	.082	.081	.081	.080	.080	.080	.080
18	.141	.136	.133	.132	.131	.131	.131	.131	.131
20	.216	.210	.206	.204	.203	.203	.203	.203	.203
22	.319	.313	.307	.305	.304	.303	.303	.303	.303
24	.454	.449	.444	.441	.440	.439	.439	.439	.439
26	.629	.626	.622	.620	.618	.618	.618	.618	.618
28	.852	.851	.850	.850	.850	.849	.849	.849	.849
30	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14
32	1.48	1.48	1.49	1.50	1.51	1.51	1.51	1.51	1.51
34	1.90	1.90	1.93	1.95	1.96	1.97	1.97	1.97	1.97
36	2.42	2.41	2.45	2.49	2.51	2.52	2.53	2.53	2.53
38	3.04	3.02	3.07	3.13	3.17	3.19	3.20	3.20	3.21
40	3.79	3.74	3.80	3.89	3.95	3.98	4.00	4.01	4.01
42	4.67	4.59	4.66	4.78	4.87	4.93	4.95	4.97	4.97
44	5.72	5.59	5.67	5.82	5.95	6.03	6.07	6.09	6.10
46	6.94	6.76	6.83	7.02	7.20	7.31	7.37	7.41	7.43
48	8.36	8.12	8.17	8.40	8.63	8.79	8.88	8.93	8.96
50	10.00	9.69	9.72	9.98	10.27	10.49	10.62	10.69	10.73
52	11.9	11.5	11.5	11.8	12.1	12.4	12.6	12.7	12.8
54	14.0	13.5	13.5	13.8	14.2	14.6	14.9	15.0	15.1
56	16.5	15.9	15.8	16.1	16.6	17.1	17.4	17.6	17.7
58	19.3	18.5	18.4	18.7	19.3	19.8	20.3	20.5	20.7
60	22.4	21.5	21.3	21.6	22.3	22.9	23.5	23.8	24.0
62	25.9	24.9	24.6	24.9	25.6	26.4	27.0	27.5	27.7
64	29.9	28.6	28.2	28.5	29.3	30.2	31.0	31.6	31.9
66	34.3	32.8	32.3	32.6	33.4	34.4	35.4	36.1	36.5
68	39.2	37.5	36.8	37.1	37.9	39.1	40.2	41.1	41.6
70	44.6	42.7	41.9	42.1	42.9	44.2	45.5	46.6	47.3
72	50.6	48.4	47.5	47.6	48.5	49.9	51.4	52.6	53.5
74	57.3	54.7	53.6	53.6	54.6	56.1	57.7	59.2	60.3
76	64.6	61.7	60.4	60.3	61.2	62.8	64.7	66.4	67.7
78	72.5	69.3	67.8	67.7	68.6	70.2	72.3	74.3	75.8
80	81.3	77.6	75.9	75.7	76.6	78.3	80.6	82.8	84.7
82	90.9	86.7	84.7	84.4	85.3	87.1	89.6	92.1	94.2
84	101.	97.	94.	94.	95.	97.	99.	102.	105.
86	113.	107.	105.	104.	105.	107.	110.	113.	116.
88	125.	119.	116.	116.	116.	118.	121.	125.	128.
90	138.	132.	129.	128.	129.	131.	134.	137.	141.

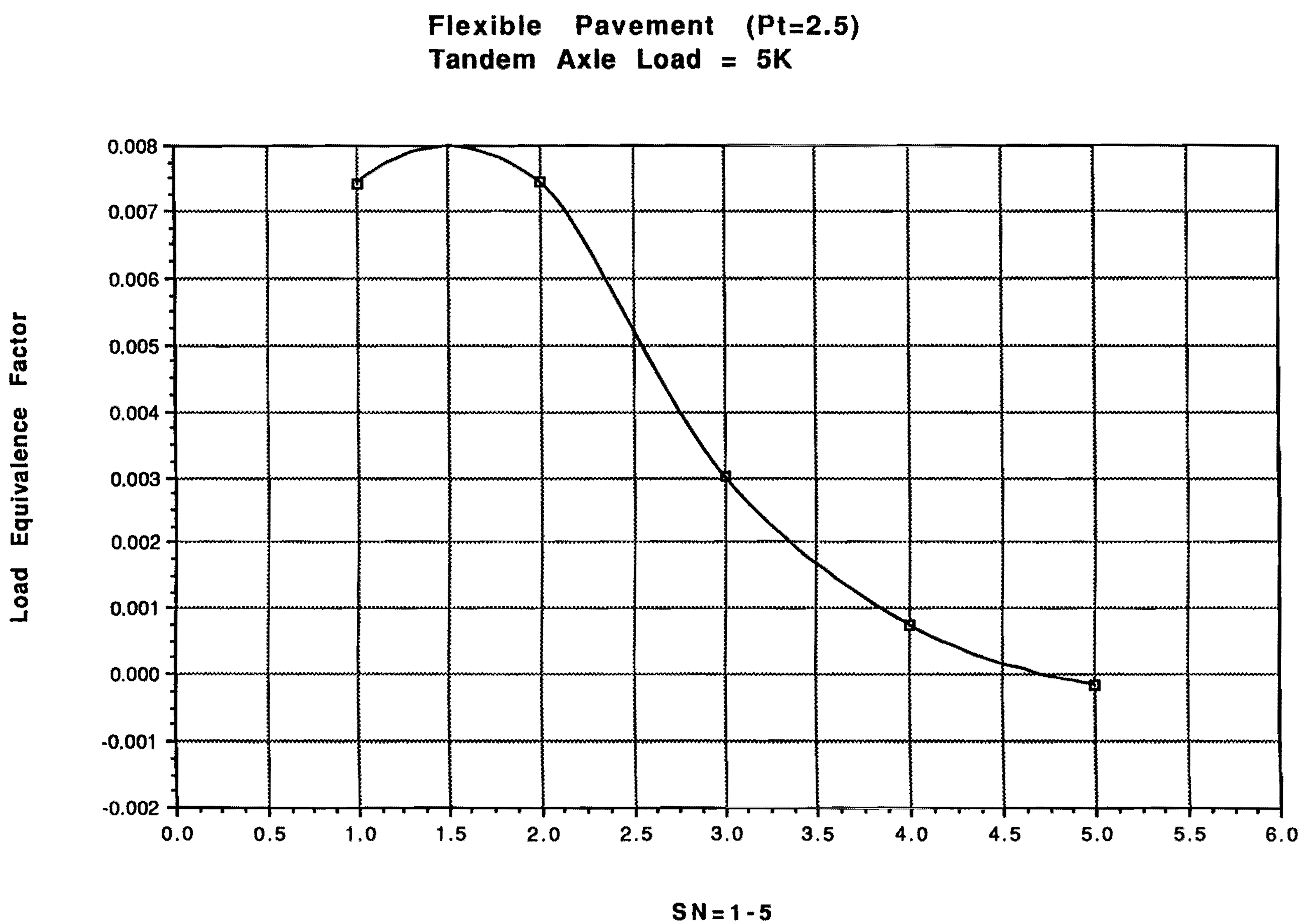
APPENDIX B

LEF Interpolations

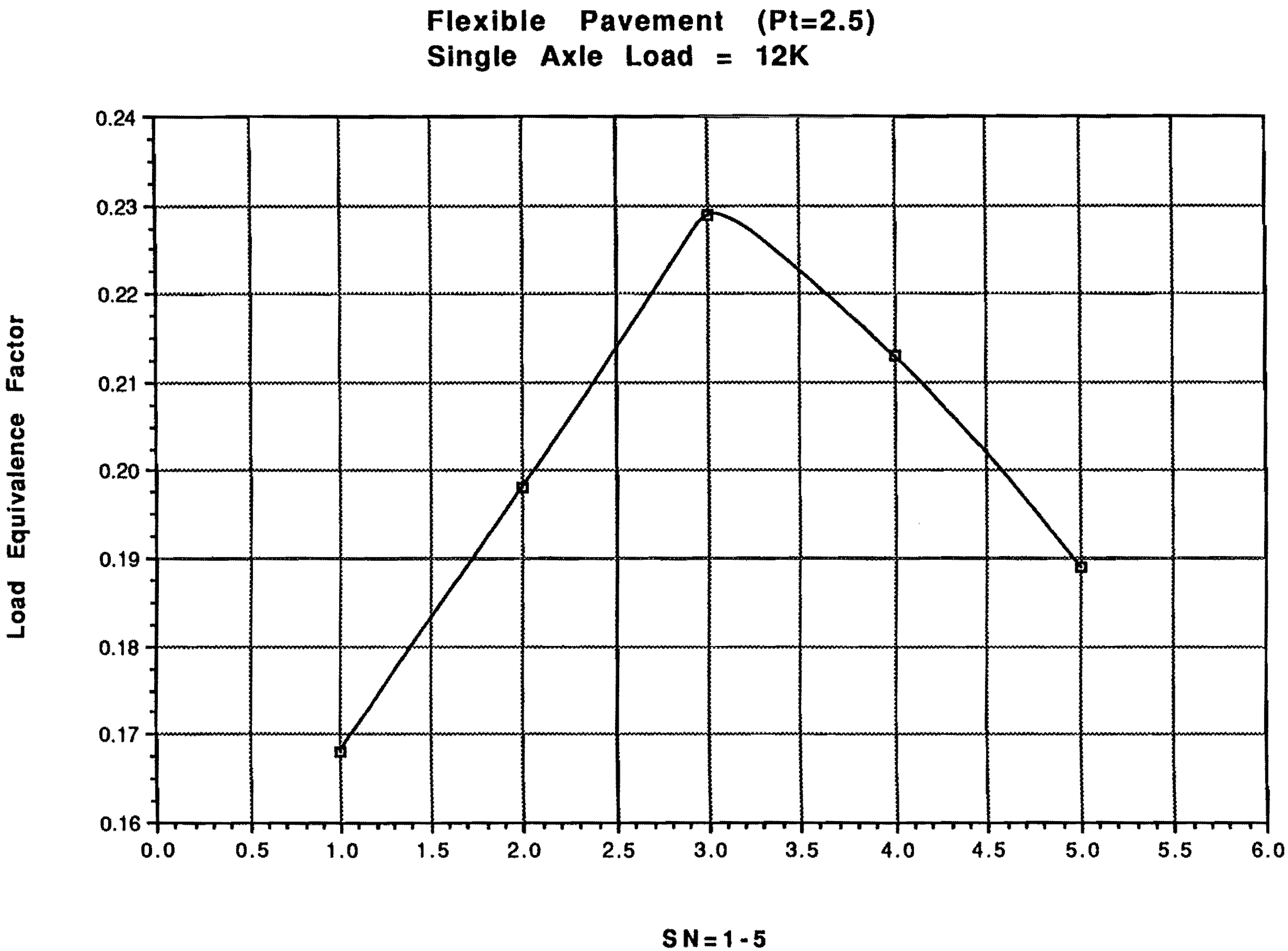

Flexible Pavement (Pt=2.0)
Single Axle Load = 12K
Load Equivalence Factor
0.190
0.185
0.180
0.175
0.170
0.165
0.160
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SN=1-5

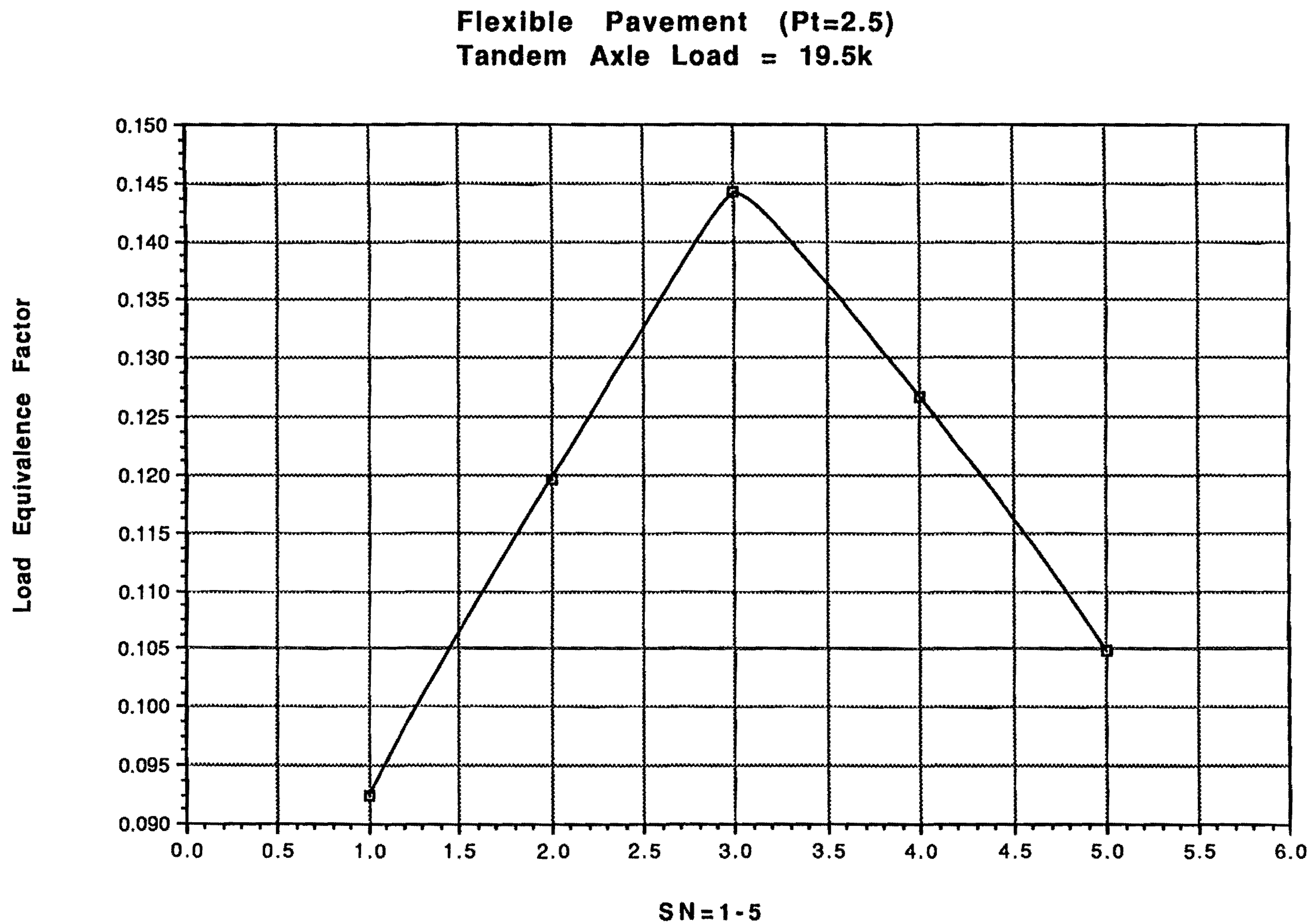

Flexible Pavement (Pt=2.0)
Tandem Axle Load = 19.5k
Load Equivalence Factor
0.110
0.105
0.100
0.095
0.090
0.085
0.080
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SN=1-5


Flexible Pavement (Pt=2.0)
Tandem Axle Load = 34k
Load Equivalence Factor
1.090
1.085
1.080
1.075
1.070
1.065
1.060
1.055
1.050
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SN=1-5



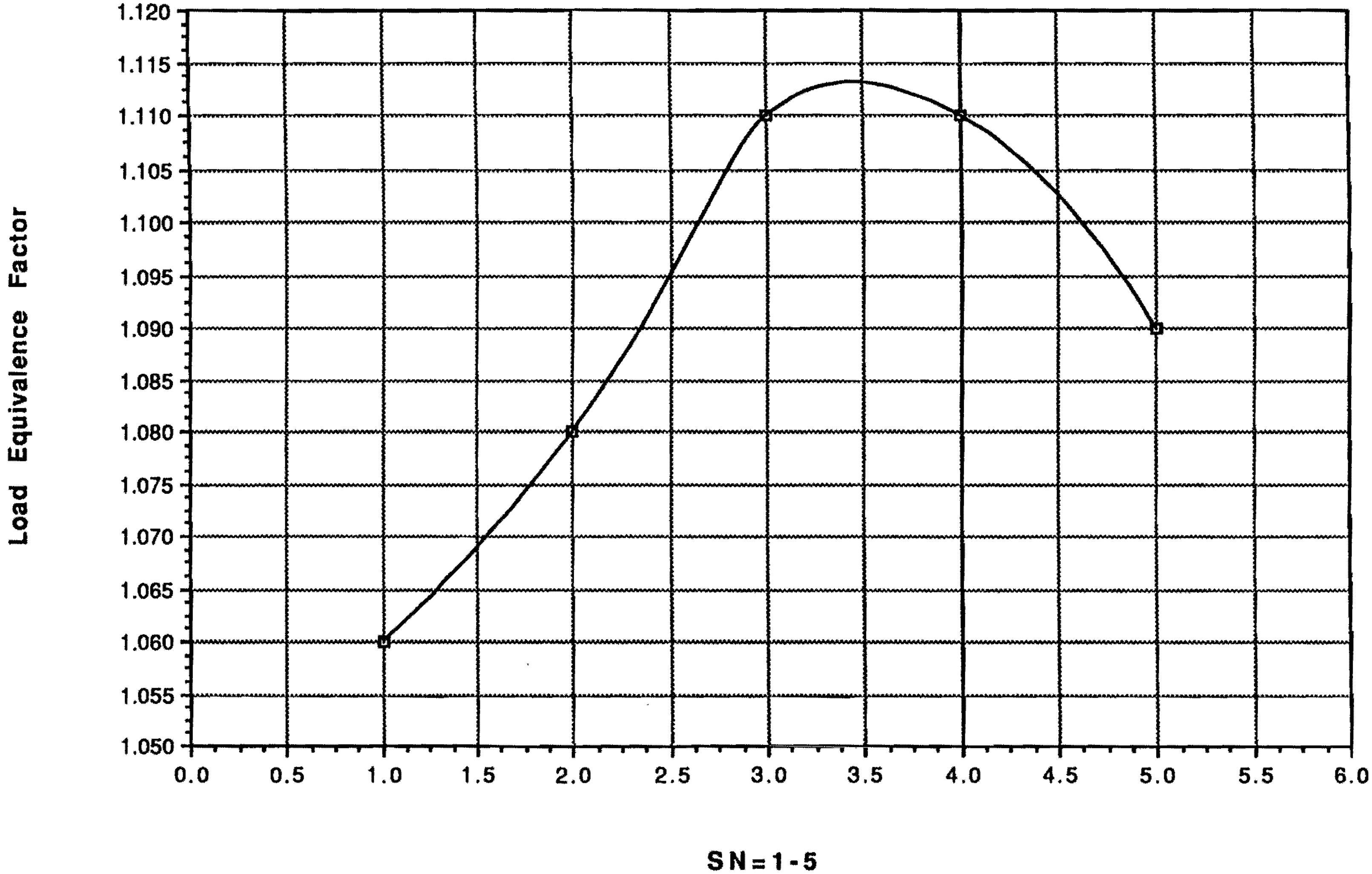
Flexible Pavement (Pt=2.5)
Tandem Axle Load = 5K
Load Equivalence Factor
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SN=1-5


Flexible Pavement (Pt=2.5)
Single Axle Load = 12K
Load Equivalence Factor
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SN=1-5



Flexible Pavement (Pt=2.5)
Tandem Axle Load = 19.5k
Load Equivalence Factor
0.150
0.145
0.140
0.135
0.130
0.125
0.120
0.115
0.110
0.105
0.100
0.095
0.090
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SN=1-5

Flexible Pavement (Pt=2.5)
Tandem Axle Load = 34k

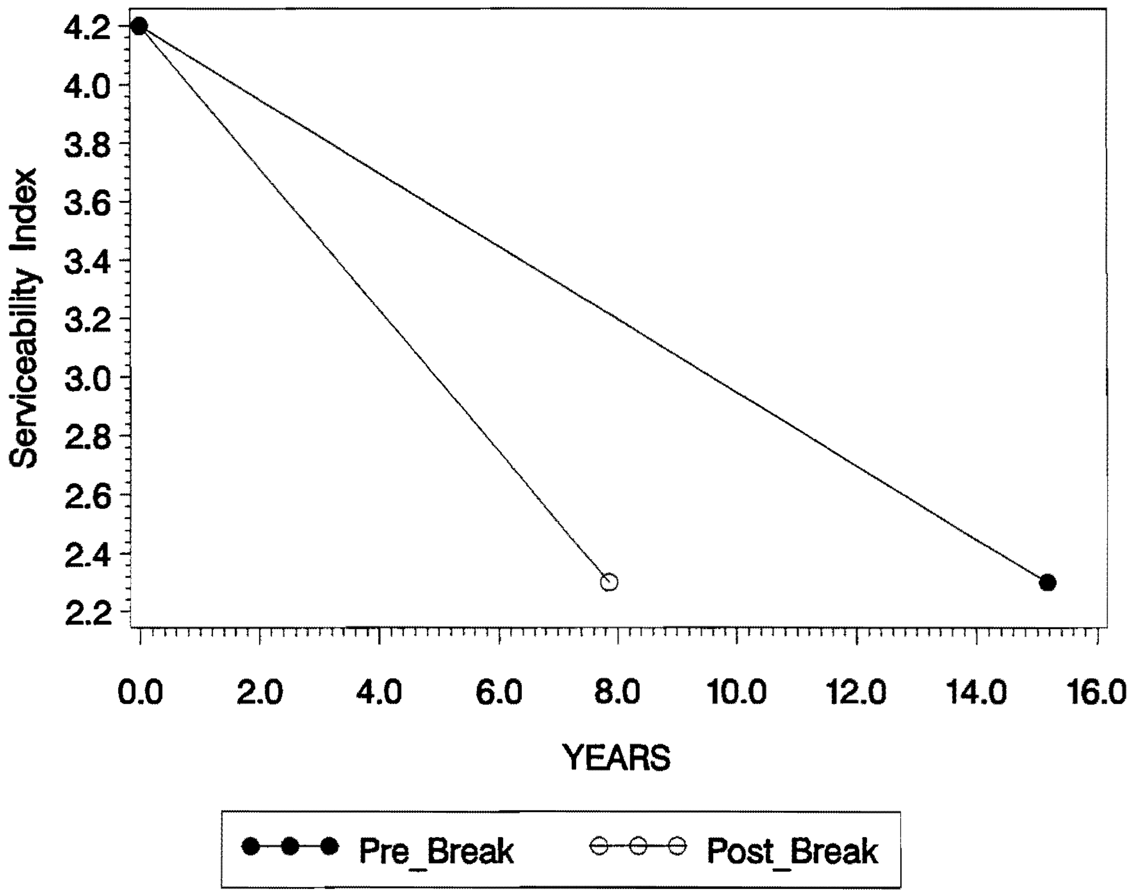


APPENDIX C

High Island Break Range (319-325)

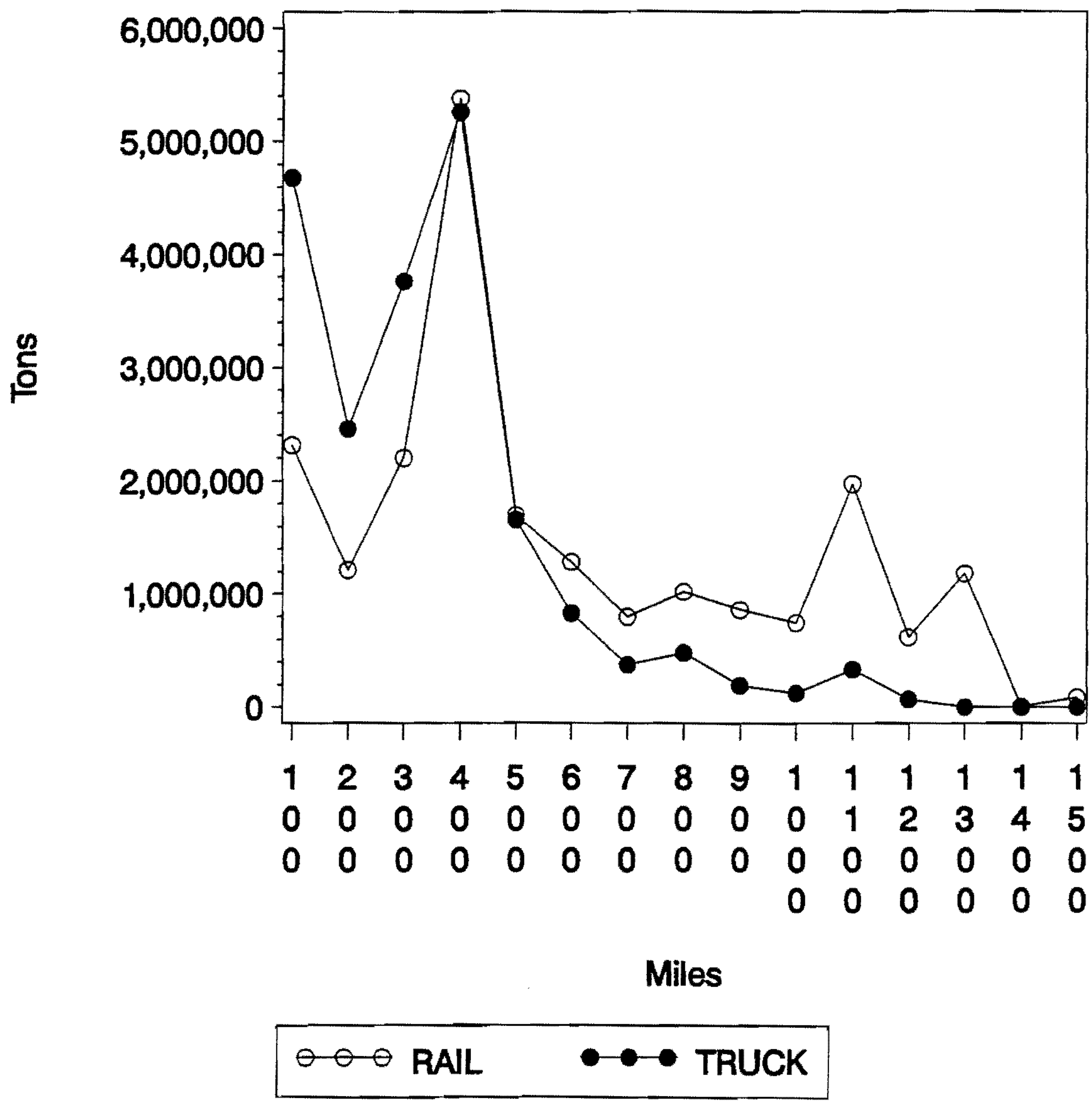
PAVEMENT LIFETIME

BEFORE & AFTER BREAK IN GIWW
BREAK POINT 319–325 / High Island
HIGHWAY=US77 CONTROL/SECTION=37203



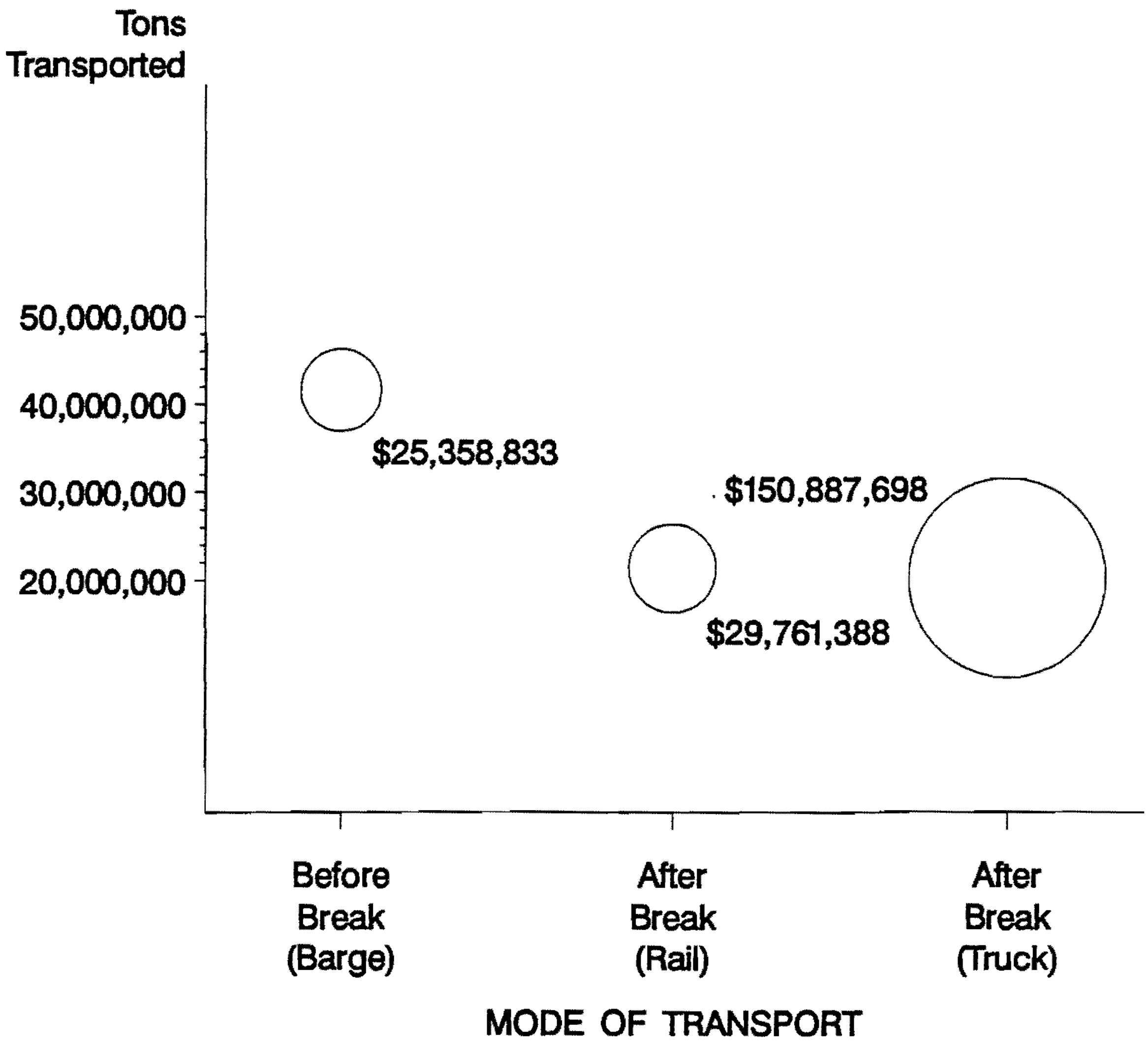
TONS TRANSPORTED

AS A FUNCTION OF DISTANCE
BREAK POINT 319-325 / High Island



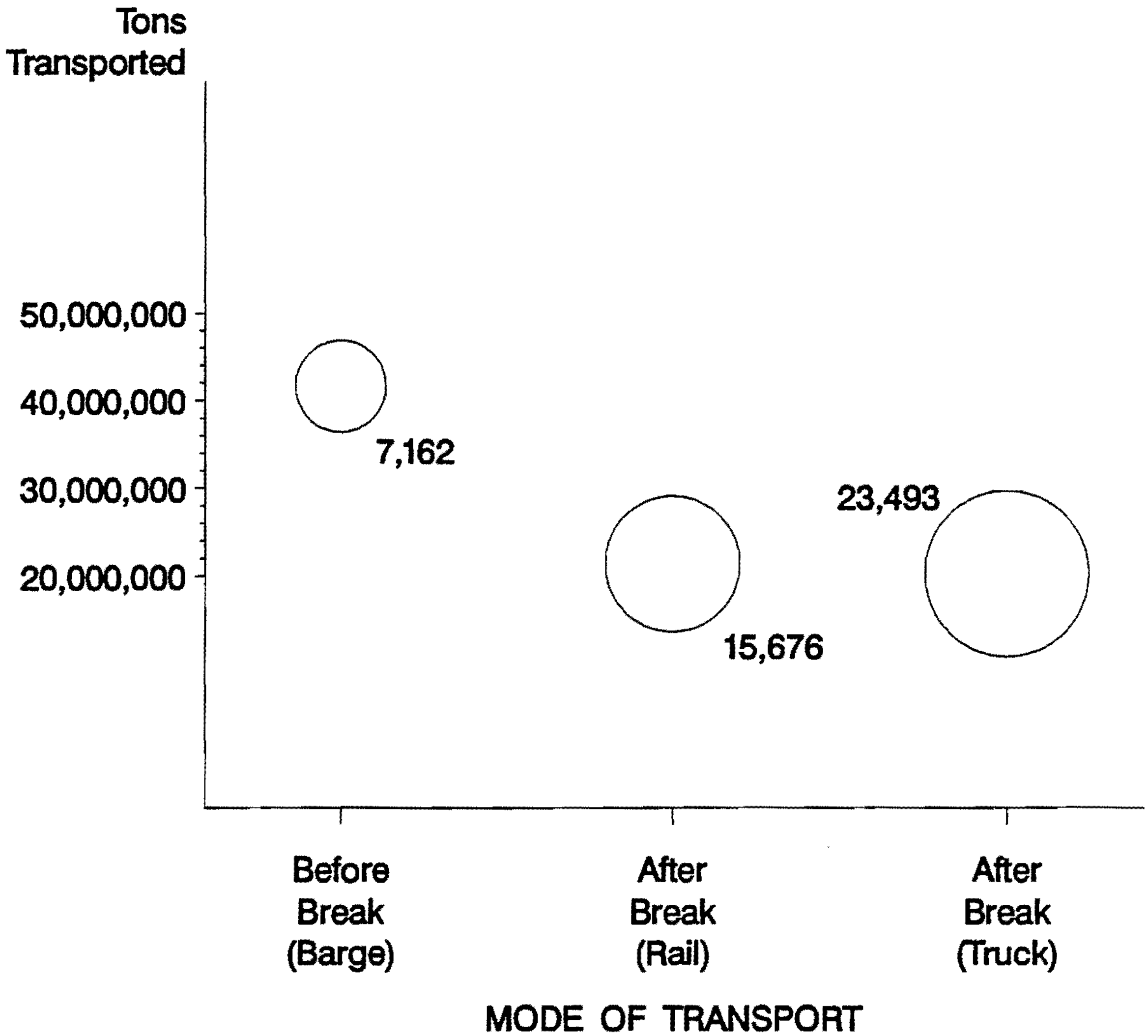
COST OF FUEL

AS A FUNCTION OF TONS TRANSPORTED
LOW END OF TON-MILES EFFICIENCY
BREAK POINT 319-325 / High Island



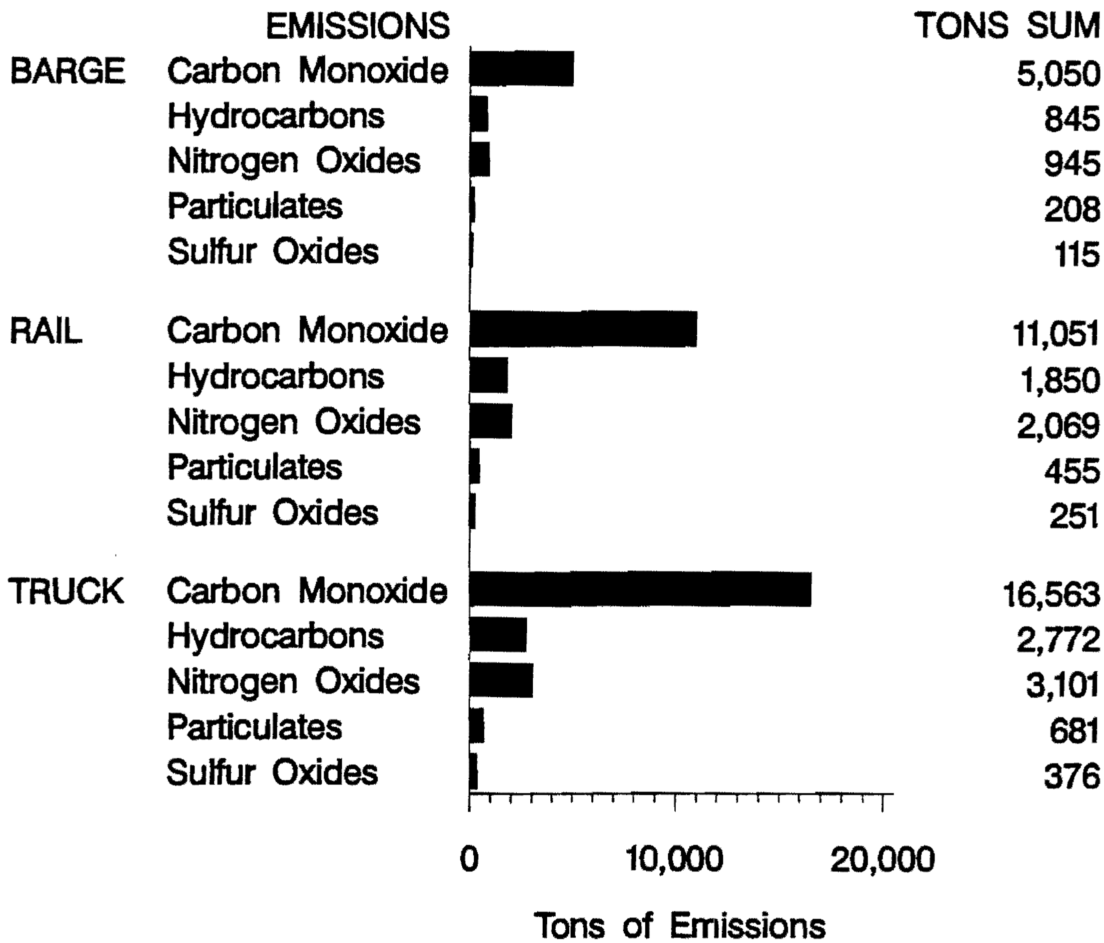
EMISSIONS (Tons)

AS A FUNCTION OF TONS TRANSPORTED
LOW END OF TON-MILES EFFICIENCY
BREAK POINT 319-325 / High Island



EMISSIONS (Tons)

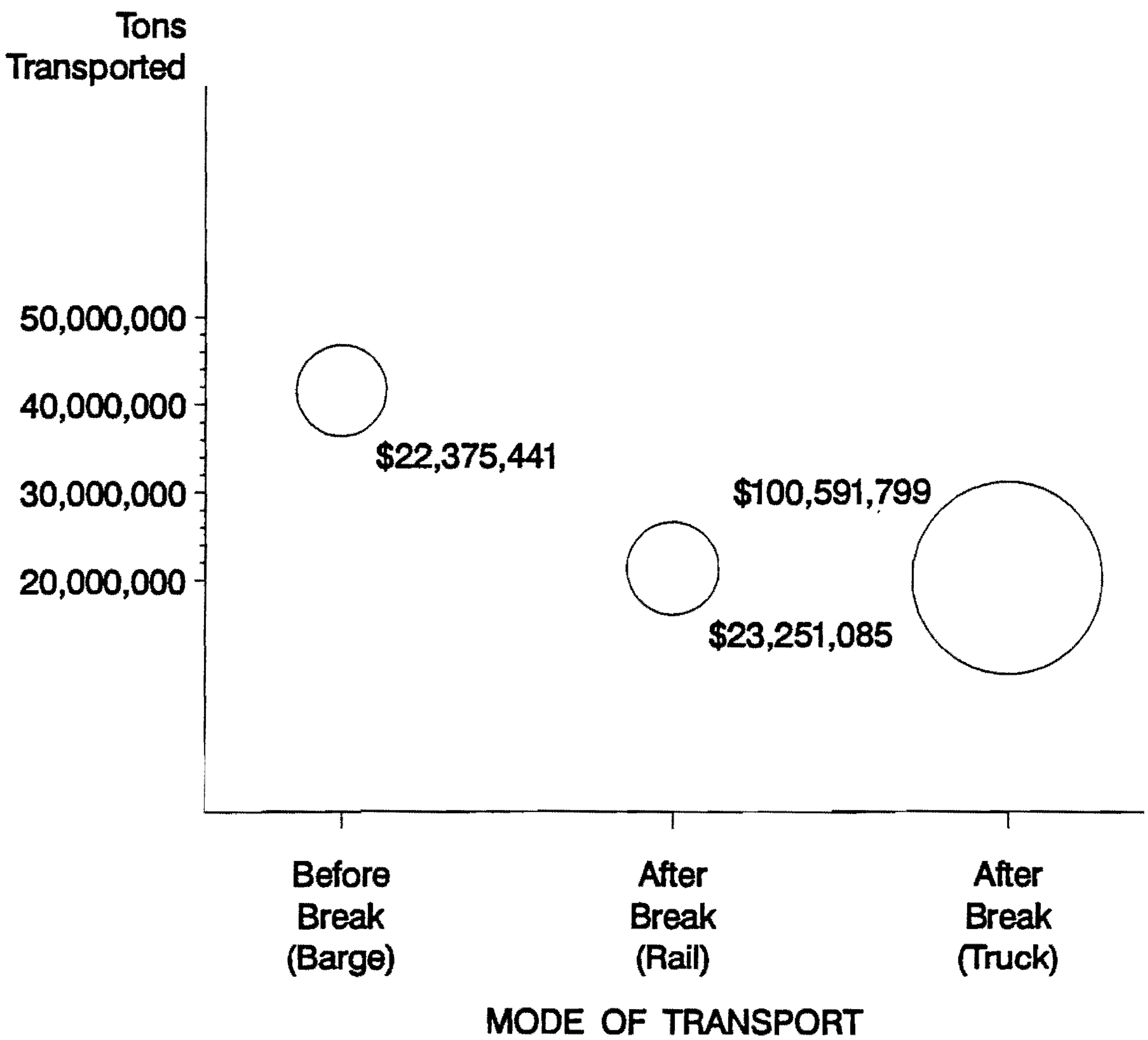
LOW END OF TON-MILE EFFICIENCY
BREAK POINT 319-325 / High Island



Note: Barge emissions are pre-break
Rail & Truck emissions are post-break

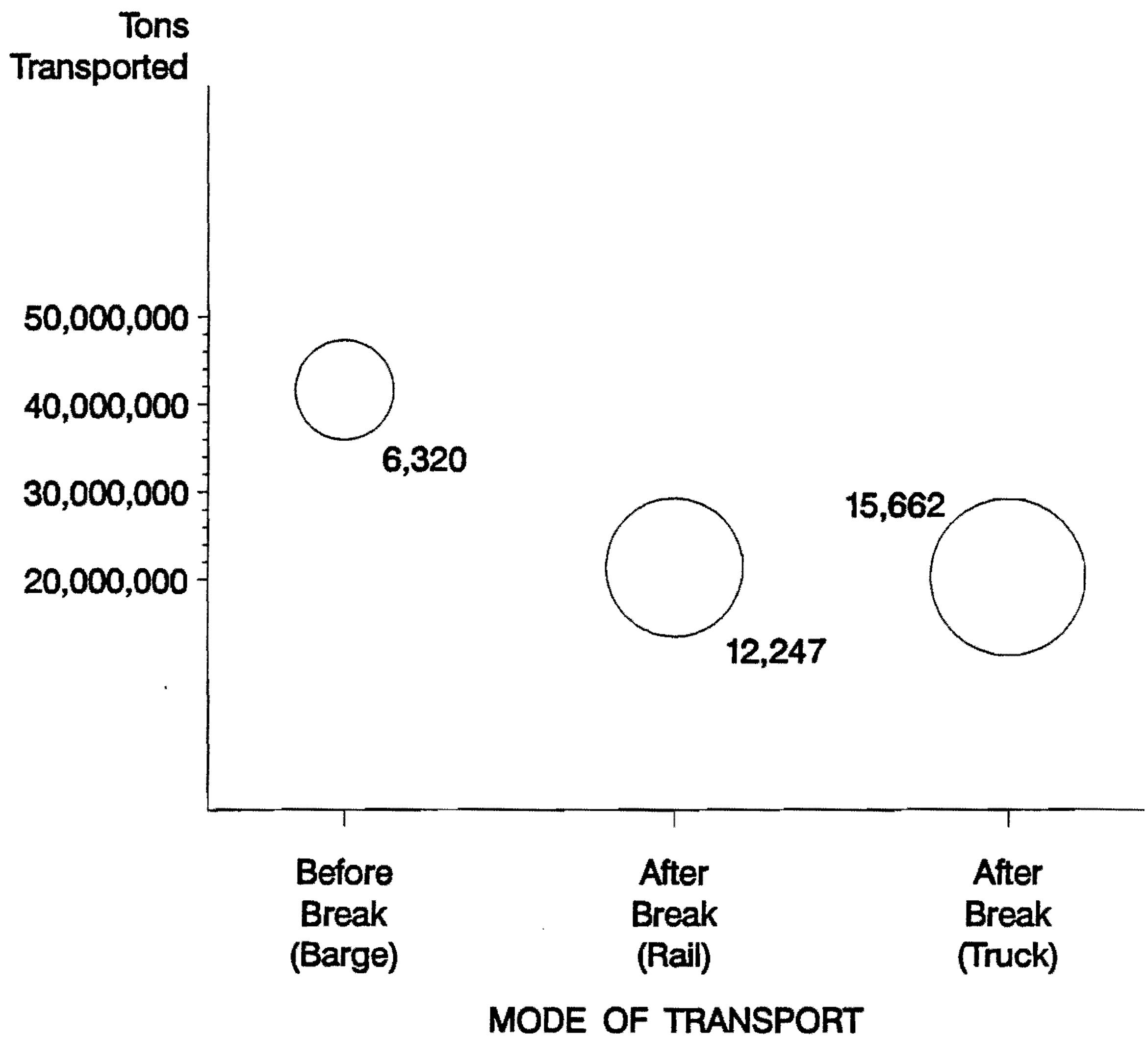
COST OF FUEL

AS A FUNCTION OF TONS TRANSPORTED
HIGH END OF TON-MILES EFFICIENCY
BREAK POINT 319-325 / High Island



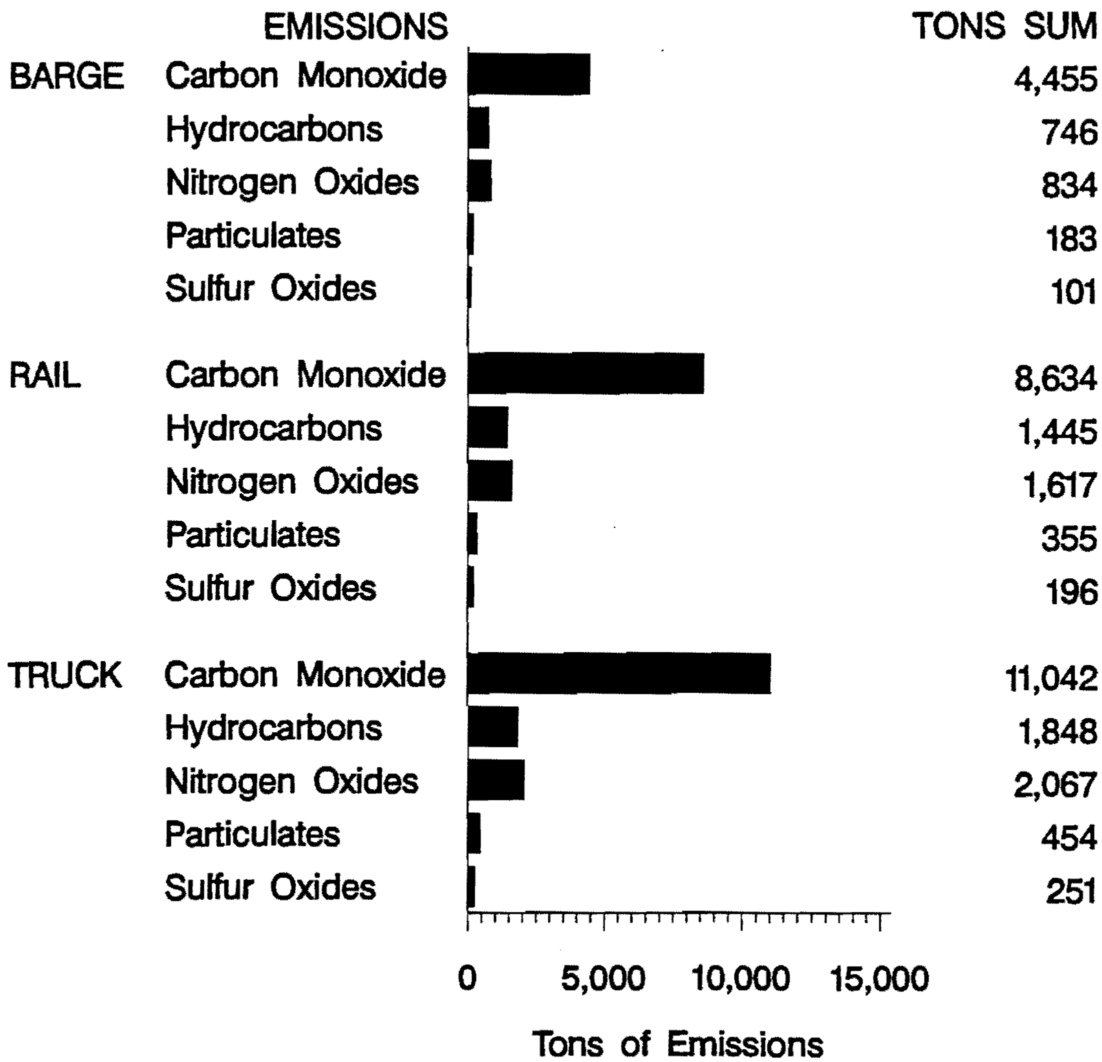
EMISSIONS (Tons)

AS A FUNCTION OF TONS TRANSPORTED
HIGH END OF TON-MILES EFFICIENCY
BREAK POINT 319-325 / High Island



EMISSIONS (Tons)

HIGH END OF TON-MILE EFFICIENCY
BREAK POINT 319-325 / High Island



CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island

DISTRICT=CORPUS CHRISTI DISTRICT
(continued)

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
S44	10201	1,637,975	769,057	1,316,451	8.73	4.42	49.43	7.4	9.9	7,700	7,917	120.31	127.10	0.09
US77	37102	1,704,106	776,668	2,129,917	4.02	3.12	22.43	19.9	21.7	10,043	10,269	156.92	163.98	0.07
US77	37103	1,704,106	776,668	2,129,917	20.00	4.53	77.36	18.8	35.1	900	1,126	14.06	21.13	0.01
US77	37104	1,704,106	776,668	2,483,647	6.83	4.80	29.64	18.8	21.3	7,300	7,526	114.06	121.13	0.06
US77	37203	1,693,835	771,379	2,483,647	15.17	7.86	48.21	7.8	10.3	7,933	8,158	123.95	130.97	0.06
US77	37201	1,693,835	771,379	2,483,647	4.38	3.45	21.18	16.2	17.6	13,200	13,425	206.25	213.27	0.10
US77	37301	1,693,835	771,379	1,167,359	1.42	1.20	15.61	16.0	16.9	19,475	19,700	304.30	311.32	0.14
US77	10202	55,859	2,322	1,167,359	1.52	1.51	0.65	20.7	20.8	13,975	13,982	218.36	218.59	0.10
US77	10203	55,859	2,322	1,167,359	1.33	1.32	0.57	20.4	20.4	16,300	16,307	254.69	254.92	0.12
US77	10204	55,859	2,322	2,483,647	3.34	3.32	0.67	22.7	22.8	12,386	12,393	193.53	193.76	0.09
US77	32701	55,859	2,322	2,483,647	4.78	4.73	0.96	28.9	29.0	6,800	6,807	106.25	106.48	0.05

DISTRICT=BEAUMONT DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
I10	73902	18,463,928	6,349,156	4,790,983	2.67	1.39	47.84	26.5	32.9	26,000	28,449	406.25	482.77	0.22
I10	73901	18,463,928	6,349,156	4,790,983	2.55	1.36	46.70	28.9	35.2	25,000	27,449	390.63	467.15	0.21
I10	50803	18,463,928	6,349,156	4,790,983	2.56	1.36	46.80	26.2	32.2	27,500	29,949	429.69	506.21	0.23
I10	50802	18,463,928	6,349,156	4,790,983	2.56	1.36	46.76	23.8	29.5	30,333	32,782	473.95	550.48	0.25
US90	2807	1,108,197	629,284	1,436,461	2.65	2.24	15.51	8.1	8.6	25,333	25,480	395.83	400.42	0.18
US90	2806	1,108,197	629,284	1,436,461	6.02	4.24	29.45	12.7	14.4	7,122	7,269	111.28	115.87	0.05

DISTRICT=PHARR DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM106	142503	43,244	2,322	1,673,506	20.00	19.11	4.44	10.9	11.1	2,900	2,906	90.63	90.98	0.06
FM2925	63003	43,244	2,322	1,673,506	20.00	15.09	24.54	7.7	8.6	587	593	18.34	18.70	0.01
FM508	34204	43,244	2,322	1,673,506	20.00	18.13	9.35	6.6	6.8	2,160	2,166	67.50	67.86	0.05
S100	33102	12,615	.	1,673,506	4.04	4.03	0.27	10.8	10.8	14,500	14,502	453.13	453.23	0.32
S48	22005	12,615	.	3,096,382	16.69	16.59	0.59	4.7	4.7	15,657	15,659	244.64	244.69	0.17
US77	32702	55,859	2,322	5,006,733	9.84	9.75	0.98	29.6	29.7	6,500	6,507	101.56	101.79	0.05
US77	32703	55,859	2,322	5,006,733	10.24	10.14	1.02	30.3	30.4	6,100	6,107	95.31	95.54	0.04

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island

DISTRICT=PHARR DISTRICT
(continued)

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
US77	32704	55,859	2,322	5,006,733	10.38	10.27	1.03	30.4	30.5	6,000	6,007	93.75	93.98	0.04
US77	32705	55,859	2,322	5,006,733	9.39	9.30	0.93	30.1	30.2	6,700	6,707	104.69	104.92	0.05
US77	32710	55,859	2,322	1,951,437	3.48	3.45	0.89	25.6	25.7	8,287	8,294	129.48	129.72	0.06
US77	32708	55,859	2,322	1,951,437	13.66	13.20	3.40	5.4	5.5	10,000	10,007	104.17	104.32	0.05
US77	3907	55,859	2,322	1,951,437	1.14	1.14	0.29	23.2	23.2	27,920	27,927	436.25	436.48	0.20
US77	3908	12,615	.	1,951,437	2.82	2.81	0.16	11.8	11.8	22,200	22,202	346.88	346.93	0.16
US77	3909	12,615	.	1,951,437	1.99	1.99	0.12	11.8	11.8	31,400	31,402	490.63	490.68	0.22

DETAILED ANALYSIS OF AFFECTED TONNAGE
LOW END OF TON-MILES EFFICIENCY (40% TONNAGE REDUCTION)
Break Point 319-325 / High Island

ORIGIN	DESTINATION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
1	350	3,210,881	878,337	3,039,964	6,250,845	26,022,849	3,713,937	3,585,255	26,151,531	4,051.77	1,956.20	1,012.63	4,995.34	27.62
1	360	713,750	95,673	573,855	1,287,605	5,036,505	641,696	651,060	5,027,141	784.19	337.99	183.89	938.29	5.35
1	380	164,952	152,185	129,398	294,350	1,318,486	140,467	155,149	1,303,803	205.29	73.99	43.82	235.45	1.40
1	390	343	343	351	694	3,449	371	408	3,412	0.54	0.20	0.12	0.62	0.00
1	400	314,432	202,858	319,856	634,288	2,839,579	344,531	357,480	2,826,630	442.12	181.47	100.97	522.63	3.01
1	450	578	.	761	1,339	4,617	891	765	4,742	0.72	0.47	0.22	0.97	0.00
1	470	70,170	34,979	73,030	143,200	738,699	81,341	88,392	731,647	115.02	42.84	24.97	132.89	0.78
1	480	181	181	185	366	2,051	221	243	2,029	0.32	0.12	0.07	0.37	0.00
1	500	86,294	68,541	88,719	175,013	939,635	102,222	111,745	930,112	146.30	53.84	31.56	168.58	1.00
1	540	6,163	3,173	10,745	16,908	82,151	16,244	13,829	84,566	12.79	8.56	3.91	17.44	0.09
1	550	138,850	43,928	236,218	375,068	1,737,400	444,080	348,324	1,833,157	270.51	233.90	98.38	406.04	1.84
1	560	0	.	300	300	0	1,007	560	448	0.00	0.53	0.16	0.37	0.00
1	650	5,610	.	11,946	17,556	87,278	19,566	15,975	90,870	13.59	10.31	4.51	19.38	0.09
1	670	7,569	.	16,118	23,687	121,200	27,171	22,183	126,187	18.87	14.31	6.27	26.92	0.13
280	350	862,478	274,500	426,053	1,288,531	1,659,646	86,308	145,014	1,600,940	258.41	45.46	40.96	262.91	1.76
280	360	190,406	41,522	94,058	284,464	392,659	20,420	34,309	378,770	61.14	10.76	9.69	62.20	0.42
280	380	37,348	13,131	18,449	55,798	99,674	5,183	8,709	96,148	15.52	2.73	2.46	15.79	0.11
280	400	25,101	21,191	12,400	37,501	82,462	4,288	7,205	79,545	12.84	2.26	2.04	13.06	0.09
280	410	3,080	.	1,522	4,602	10,541	548	921	10,168	1.64	0.29	0.26	1.67	0.01
280	500	81,213	81,213	40,118	121,331	484,265	25,184	42,313	467,135	75.40	13.26	11.95	76.71	0.51
280	550	55,931	8,365	57,187	113,118	413,568	44,515	48,918	409,165	64.39	23.45	13.82	74.02	0.44
290	330	406	.	201	607	467	24	41	450	0.07	0.01	0.01	0.07	0.00
290	350	723,016	87,634	357,161	1,080,177	1,227,082	63,813	107,218	1,183,677	191.06	33.61	30.28	194.39	1.30
290	360	206,061	26,708	101,791	307,852	371,374	19,313	32,449	358,237	57.82	10.17	9.17	58.83	0.39
290	380	69,205	7,136	34,187	103,392	164,829	8,572	14,402	158,998	25.66	4.51	4.07	26.11	0.17
290	400	36,020	34,567	17,794	53,814	110,444	5,743	9,650	106,537	17.20	3.03	2.73	17.50	0.12
290	470	1,074	.	531	1,605	5,353	278	468	5,163	0.83	0.15	0.13	0.85	0.01
290	500	2,849	2,849	1,407	4,256	16,145	840	1,411	15,574	2.51	0.44	0.40	2.56	0.02
290	530	1,769	.	874	2,644	11,723	610	1,024	11,308	1.83	0.32	0.29	1.86	0.01
290	550	32,205	2,375	32,928	65,132	230,891	24,852	27,311	228,432	35.95	13.09	7.71	41.33	0.25
290	650	862	862	882	1,744	8,547	920	1,011	8,456	1.33	0.48	0.29	1.53	0.01
310	350	1,846	.	912	2,758	2,274	118	199	2,193	0.35	0.06	0.06	0.36	0.00
310	360	15,690	.	7,751	23,441	21,477	1,117	1,877	20,717	3.34	0.59	0.53	3.40	0.02
350	1	2,286,113	883,913	2,961,121	5,247,234	20,533,469	4,869,288	3,906,068	21,496,689	3,197.07	2,564.74	1,103.24	4,658.57	21.79
350	280	366,043	176,604	180,820	546,863	720,665	37,477	62,969	695,174	112.21	19.74	17.79	114.16	0.76
350	290	109,832	30,000	54,256	164,088	186,421	9,695	16,289	179,827	29.03	5.11	4.60	29.53	0.20
360	1	590,682	205,854	1,012,135	1,602,817	7,099,382	1,952,327	1,499,837	7,551,873	1,105.38	1,028.33	423.62	1,710.09	7.53
360	280	235,007	140,935	116,090	351,098	484,730	25,208	42,354	467,584	75.47	13.28	11.96	76.79	0.51
360	290	29,964	15,365	14,802	44,766	54,890	2,854	4,796	52,949	8.55	1.50	1.35	8.70	0.06
380	1	77,126	55,282	124,748	201,874	1,057,981	216,558	182,186	1,092,353	164.73	114.06	51.46	227.34	1.12
380	280	17,361	9,582	8,576	25,937	47,983	2,495	4,193	46,285	7.47	1.31	1.18	7.60	0.05
400	1	277,600	258,145	426,218	703,819	2,875,099	690,185	551,588	3,013,697	447.65	363.53	155.79	655.40	3.05
400	280	25,936	23,474	12,812	38,747	90,414	4,702	7,900	87,216	14.08	2.48	2.23	14.32	0.10
400	290	12,836	12,258	6,341	19,177	39,358	2,047	3,439	37,966	6.13	1.08	0.97	6.23	0.04

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

DETAILED ANALYSIS OF AFFECTED TONNAGE
LOW END OF TON-MILES EFFICIENCY (40% TONNAGE REDUCTION)
Break Point 319-325 / High Island

ORIGIN	DESTINATION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
410	1	70,226	1,238	76,316	146,542	795,891	98,895	101,490	793,296	123.92	52.09	28.67	147.35	0.84
410	280	517	517	256	773	1,770	92	155	1,708	0.28	0.05	0.04	0.28	0.00
450	1	406	.	415	821	3,811	410	451	3,770	0.59	0.22	0.13	0.68	0.00
470	1	71,170	69,397	332,372	403,542	1,504,190	810,521	538,263	1,776,448	234.20	426.92	152.03	509.09	1.60
470	290	15,136	.	7,477	22,613	74,585	3,879	6,517	71,947	11.61	2.04	1.84	11.82	0.08
500	1	26,522	24,607	54,871	81,393	360,708	121,610	88,657	393,661	56.16	64.05	25.04	95.18	0.38
500	280	62,934	17,474	31,089	94,023	377,692	19,641	33,001	364,332	58.81	10.35	9.32	59.83	0.40
500	290	10,187	10,187	5,032	15,220	57,172	2,973	4,995	55,150	8.90	1.57	1.41	9.06	0.06
550	1	471,316	287,954	1,345,919	1,817,235	7,486,482	2,832,931	2,011,701	8,307,713	1,165.65	1,492.15	568.19	2,089.61	7.95
550	280	234,152	111,253	239,408	473,560	1,731,006	186,320	204,750	1,712,577	269.52	98.14	57.83	309.83	1.84
550	290	50,331	7,560	51,461	101,792	361,005	38,857	42,701	357,161	56.21	20.47	12.06	64.62	0.38
650	1	19,474	531	43,478	62,953	340,599	81,472	65,182	356,889	53.03	42.91	18.41	77.53	0.36
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		12,127,209	4,424,379	12,813,663	24,940,872	90,532,619	17,856,833	15,215,300	93,174,152	14,095.99	9,405.51	4,297.45	19,204.04	96.08

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

DETAILED ANALYSIS OF AFFECTED TONNAGE
HIGH END OF TON-MILES EFFICIENCY (40% TONNAGE REDUCTION)
Break Point 319-325 / High Island

ORIGIN	DESTINATION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
1	350	5,351,468	1,463,894	5,066,607	10,418,075	28,914,276	4,835,856	5,272,435	28,477,698	4,501.97	2,547.13	1,489.16	5,559.94	46.03
1	360	1,189,583	159,454	956,425	2,146,008	5,596,116	835,541	957,441	5,474,217	871.32	440.09	270.42	1,040.99	8.91
1	380	274,920	253,641	215,664	490,584	1,464,984	182,900	228,161	1,419,723	228.10	96.34	64.44	259.99	2.33
1	390	572	572	585	1,157	3,832	483	600	3,715	0.60	0.25	0.17	0.68	0.01
1	400	524,054	338,096	533,093	1,057,147	3,155,087	448,609	525,706	3,077,990	491.25	236.29	148.48	579.06	5.02
1	450	963	.	1,268	2,231	5,130	1,160	1,125	5,165	0.80	0.61	0.32	1.09	0.01
1	470	116,950	58,298	121,717	238,667	820,776	105,912	129,989	796,700	127.80	55.79	36.71	146.87	1.31
1	480	302	302	308	610	2,279	287	357	2,210	0.35	0.15	0.10	0.41	0.00
1	500	143,824	114,235	147,864	291,688	1,044,039	133,102	164,331	1,012,810	162.56	70.11	46.41	186.25	1.66
1	540	10,271	5,289	17,909	28,180	91,279	21,152	20,337	92,093	14.21	11.14	5.74	19.61	0.15
1	550	231,416	73,213	393,697	625,113	1,930,444	578,230	512,241	1,996,433	300.57	304.56	144.68	460.46	3.07
1	560	0	.	500	500	0	1,312	823	489	0.00	0.69	0.23	0.46	0.00
1	650	9,350	.	19,910	29,260	96,976	25,477	23,492	98,960	15.10	13.42	6.64	21.88	0.15
1	670	12,615	.	26,864	39,479	134,667	35,378	32,622	137,423	20.97	18.63	9.21	30.39	0.21
280	350	1,437,464	457,500	710,088	2,147,552	1,844,051	112,380	213,256	1,743,175	287.12	59.19	60.23	286.08	2.94
280	360	317,344	69,204	156,763	474,107	436,288	26,588	50,455	412,422	67.93	14.00	14.25	67.68	0.69
280	380	62,247	21,884	30,749	92,996	110,749	6,749	12,808	104,691	17.24	3.55	3.62	17.18	0.18
280	400	41,836	35,319	20,666	62,502	91,624	5,584	10,596	86,612	14.27	2.94	2.99	14.21	0.15
280	410	5,134	.	2,536	7,670	11,712	714	1,354	11,072	1.82	0.38	0.38	1.82	0.02
280	500	135,355	135,355	66,863	202,218	538,072	32,791	62,225	508,638	83.78	17.27	17.58	83.47	0.86
280	550	93,219	13,942	95,311	188,530	459,521	57,963	71,939	445,544	71.55	30.53	20.32	81.76	0.73
290	330	677	.	334	1,011	519	32	60	490	0.08	0.02	0.02	0.08	0.00
290	350	1,205,027	146,057	595,268	1,800,295	1,363,425	83,090	157,674	1,288,841	212.29	43.76	44.53	211.52	2.17
290	360	343,435	44,513	169,652	513,087	412,637	25,147	47,720	390,065	64.25	13.25	13.48	64.02	0.66
290	380	115,342	11,893	56,978	172,320	183,143	11,161	21,180	173,125	28.52	5.88	5.98	28.41	0.29
290	400	60,034	57,612	29,656	89,690	122,715	7,479	14,191	116,002	19.11	3.94	4.01	19.04	0.20
290	470	1,791	.	884	2,675	5,947	362	688	5,622	0.93	0.19	0.19	0.92	0.01
290	500	4,748	4,748	2,346	7,094	17,939	1,093	2,075	16,958	2.79	0.58	0.59	2.78	0.03
290	530	2,949	.	1,457	4,406	13,026	794	1,506	12,313	2.03	0.42	0.43	2.02	0.02
290	550	53,675	3,958	54,879	108,554	256,545	32,360	40,163	248,742	39.94	17.04	11.34	45.65	0.41
290	650	1,437	1,437	1,470	2,907	9,496	1,198	1,487	9,208	1.48	0.63	0.42	1.69	0.02
310	350	3,076	.	1,520	4,596	2,527	154	292	2,388	0.39	0.08	0.08	0.39	0.00
310	360	26,150	.	12,918	39,068	23,863	1,454	2,760	22,558	3.72	0.77	0.78	3.70	0.04
350	1	3,810,188	1,473,189	4,935,202	8,745,390	22,814,966	6,340,219	5,744,218	23,410,966	3,552.31	3,339.50	1,622.41	5,269.40	36.32
350	280	610,072	294,339	301,367	911,439	800,739	48,799	92,602	756,936	124.68	25.70	26.15	124.22	1.27
350	290	183,054	50,000	90,426	273,480	207,135	12,623	23,954	195,804	32.25	6.65	6.77	32.13	0.33
360	1	984,471	343,089	1,686,891	2,671,362	7,888,202	2,542,093	2,205,642	8,224,653	1,228.20	1,338.97	622.97	1,944.20	12.56
360	280	391,679	234,891	193,484	585,163	538,589	32,823	62,285	509,126	83.86	17.29	17.59	83.55	0.86
360	290	49,940	25,609	24,670	74,610	60,989	3,717	7,053	57,653	9.50	1.96	1.99	9.46	0.10
380	1	128,543	92,136	207,913	336,456	1,175,535	281,976	267,921	1,189,590	183.03	148.52	75.67	255.88	1.87
380	280	28,935	15,971	14,293	43,228	53,314	3,249	6,166	50,398	8.30	1.71	1.74	8.27	0.08
400	1	462,667	430,241	710,364	1,173,031	3,194,554	898,679	811,158	3,282,075	497.39	473.35	229.11	741.64	5.09
400	280	43,226	39,123	21,353	64,579	100,460	6,122	11,618	94,964	15.64	3.22	3.28	15.58	0.16
400	290	21,394	20,430	10,568	31,962	43,731	2,665	5,057	41,339	6.81	1.40	1.43	6.78	0.07

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

DETAILED ANALYSIS OF AFFECTED TONNAGE
HIGH END OF TON-MILES EFFICIENCY (40% TONNAGE REDUCTION)
Break Point 319-325 / High Island

ORIGIN	DESTINA-TION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
410	1	117,043	2,063	127,193	244,236	884,323	128,770	149,250	863,843	137.69	67.83	42.15	163.36	1.41
410	280	862	862	426	1,288	1,967	120	227	1,859	0.31	0.06	0.06	0.31	0.00
450	1	676	.	692	1,368	4,234	534	663	4,106	0.66	0.28	0.19	0.75	0.01
470	1	118,616	115,662	553,954	672,570	1,671,322	1,055,366	791,563	1,935,125	260.23	555.88	223.57	592.53	2.66
470	290	25,226	.	12,462	37,688	82,873	5,050	9,584	78,339	12.90	2.66	2.71	12.86	0.13
500	1	44,204	41,011	91,451	135,655	400,787	158,347	130,379	428,755	62.40	83.40	36.82	108.98	0.64
500	280	104,890	29,123	51,815	156,705	419,657	25,575	48,531	396,701	65.34	13.47	13.71	65.10	0.67
500	290	16,979	16,979	8,387	25,366	63,525	3,871	7,346	60,050	9.89	2.04	2.07	9.85	0.10
550	1	785,527	479,923	2,243,198	3,028,725	8,318,313	3,688,713	2,958,383	9,048,643	1,295.17	1,942.91	835.57	2,402.50	13.24
550	280	390,253	185,422	399,014	789,267	1,923,340	242,605	301,103	1,864,842	299.47	127.78	85.04	342.21	3.06
550	290	83,885	12,600	85,769	169,654	401,116	50,596	62,796	388,917	62.45	26.65	17.74	71.37	0.64
650	1	32,457	884	72,464	104,921	378,443	106,083	95,856	388,670	58.92	55.88	27.07	87.73	0.60
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		20,212,016	7,373,965	21,356,104	41,568,120	100,591,799	23,251,085	22,375,441	101,467,442	15,662.21	12,246.75	6,319.78	21,589.18	160.14

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island
40 PERCENT TONNAGE REDUCTION

------ DISTRICT=HOUSTON DISTRICT ------

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM1495	58701	606,941	474,685	2,342,909	20.00	7.45	62.77	3.4	5.5	3,600	3,680	112.50	117.53	0.08
FM1764	160701	293,779	78,614	4,149,703	14.52	13.29	8.47	4.5	4.7	24,000	24,039	375.00	376.22	0.27
FM1764	160702	195,853	52,409	4,149,703	20.00	18.31	8.47	3.0	3.1	24,000	24,026	750.00	751.62	0.54
FM2918	293901	73,824	1,755	4,334,935	20.00	11.57	42.15	7.0	8.8	500	510	15.63	16.24	0.01
FM360	52706	662,602	462,583	5,014,448	20.00	7.52	62.39	9.2	14.2	1,500	1,588	46.88	52.37	0.04
FM523	100301	72,440	58,288	1,867,826	20.00	17.88	10.59	3.2	3.3	6,625	6,635	207.03	207.63	0.15
I45	11004	274,403	73,429	12,973,790	6.95	6.86	1.30	11.4	11.4	62,000	62,036	968.75	969.89	0.44
I45	11005	241,564	64,641	5,528,218	2.18	2.16	0.85	10.0	10.1	95,667	95,699	1494.8	1495.8	0.68
I45	67508	418,694	112,040	15,422,523	12.91	12.51	3.06	17.4	17.5	26,000	26,056	406.25	407.99	0.19
S134	37602	7,018,137	2,254,685	7,009,427	20.00	6.04	69.78	6.5	11.7	15,900	16,831	496.88	555.05	0.40
S146	38905	2,061,370	568,738	2,496,949	9.75	5.65	41.99	6.2	7.8	15,700	15,973	245.31	253.86	0.18
S146	38906	2,061,370	568,738	2,496,949	10.65	5.95	44.16	7.5	9.6	11,786	12,059	184.16	192.70	0.14
S146	38912	2,061,370	568,738	2,496,949	9.98	5.73	42.57	4.8	6.1	19,700	19,973	307.81	316.36	0.23
S197	38911	353,351	94,555	3,294,557	20.00	14.49	27.56	5.4	6.2	5,833	5,880	182.28	185.21	0.13
S288	59804	324,655	266,536	2,655,275	6.85	6.38	6.80	12.2	12.5	12,600	12,643	196.88	198.22	0.14
S330	50807	4,843,827	1,526,438	2,496,949	4.54	2.53	44.19	8.0	10.2	26,000	26,642	406.25	426.33	0.30
S332	58601	184,188	148,203	2,057,202	11.46	10.52	8.21	8.1	8.4	8,767	8,791	273.97	275.50	0.20
S341	62801	391,705	104,818	4,149,703	20.00	13.94	30.32	6.0	6.9	5,100	5,152	79.69	81.31	0.06
S348	68601	731,183	195,661	7,909,001	19.32	16.72	13.46	11.2	11.8	14,500	14,597	453.13	459.19	0.33
S35	17801	134,507	105,044	1,764,574	5.81	5.59	3.83	5.3	5.4	21,500	21,518	335.94	336.49	0.24
S35	17802	134,507	105,044	2,342,909	10.26	9.74	5.03	6.3	6.4	13,773	13,791	215.20	215.76	0.15
S35	17803	134,507	105,044	2,342,909	13.82	12.90	6.66	7.2	7.4	8,900	8,918	139.06	139.62	0.10
S35	17901	34,614	13,554	2,342,909	10.29	10.15	1.35	10.4	10.4	8,300	8,305	129.69	129.83	0.09
S35	17902	34,614	13,554	2,342,909	10.46	10.31	1.37	10.3	10.4	8,222	8,227	256.94	257.22	0.18
S35	17903	34,614	13,554	2,342,909	13.90	13.65	1.81	10.5	10.6	6,067	6,072	189.59	189.88	0.14
S36	18705	666,200	463,101	2,535,398	13.80	10.40	24.59	15.1	16.7	4,600	4,688	143.75	149.27	0.11
S36	18801	666,200	463,101	2,535,398	11.10	8.79	20.78	8.7	9.5	9,900	9,988	309.38	314.90	0.22
S36	18802	666,200	463,101	2,535,398	19.72	13.45	31.79	10.2	11.9	4,750	4,838	148.44	153.96	0.11
S36	18803	666,200	463,101	3,516,385	20.00	14.53	27.35	10.2	11.5	6,013	6,101	187.91	193.43	0.14
S36	18804	666,200	463,101	3,516,385	16.53	12.98	21.44	7.4	8.1	11,367	11,455	355.22	360.74	0.26
S36	18805	666,200	463,101	3,516,385	20.00	13.56	32.18	8.1	9.4	6,000	6,088	187.50	193.02	0.14
S36	18806	666,200	463,101	3,516,385	20.00	13.90	30.50	7.7	8.9	6,820	6,908	213.13	218.65	0.16
S87	37606	1,965,871	526,056	6,504,983	20.00	8.15	59.23	9.2	13.7	5,000	5,261	156.25	172.55	0.12
US59	17707	2,084,534	1,224,975	4,149,703	2.37	2.14	9.69	6.2	6.5	106,000	106,276	1656.3	1664.9	0.76
US75	5104	1,965,871	526,056	6,011,120	10.14	7.81	22.97	6.2	6.9	36,000	36,261	562.50	570.65	0.26
US90	2801	326,519	217,270	3,715,330	12.14	11.07	8.75	7.1	7.3	16,375	16,418	255.86	257.21	0.12
US90	2802	326,519	217,270	3,715,330	20.00	17.08	14.59	7.3	7.7	8,900	8,943	139.06	140.42	0.06
US90A	2710	91,583	24,507	3,715,330	13.96	13.54	3.00	3.8	3.8	26,480	26,492	413.75	414.13	0.19

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island
40 PERCENT TONNAGE REDUCTION

DISTRICT=YOAKUM DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM2031	60401	984	.	1,252,801	20.00	19.87	0.65	7.9	7.9	660	660	20.63	20.63	0.01
FM2717	271401	71,514	47,406	2,094,784	20.00	8.67	56.64	7.9	11.4	240	249	7.50	8.09	0.01
FM2760	271403	86,217	57,151	2,568,860	20.00	13.56	32.21	9.5	11.0	660	671	20.63	21.34	0.02
S316	58001	157,731	104,557	1,642,425	20.00	7.97	60.16	4.8	7.4	740	761	23.13	24.43	0.02
S35	17904	31,016	13,036	2,276,676	7.94	7.87	0.96	10.5	10.5	10,317	10,321	161.20	161.33	0.12
S35	17906	31,016	13,036	2,276,676	11.85	11.68	1.43	11.8	11.9	6,150	6,154	96.09	96.22	0.07
S35	17907	31,016	13,036	2,276,676	15.25	14.97	1.83	16.4	16.5	3,430	3,434	107.19	107.44	0.08
S35	17908	31,016	13,036	2,276,676	20.00	18.82	5.89	6.4	6.5	2,638	2,642	82.44	82.69	0.06
S35	17909	31,016	13,036	2,276,676	18.12	17.73	2.17	15.3	15.4	3,100	3,104	96.88	97.13	0.07
S35	17910	31,016	13,036	1,795,577	8.02	7.92	1.23	10.0	10.0	8,500	8,504	132.81	132.94	0.09
S35	18001	14,806	13,036	1,795,577	6.49	6.46	0.48	13.1	13.1	7,964	7,966	248.88	249.00	0.18
S60	24101	984	.	1,952,424	16.05	16.04	0.07	10.8	10.8	4,260	4,260	133.13	133.13	0.10
S60	24102	984	.	2,276,676	15.73	15.72	0.06	8.7	8.7	6,325	6,325	98.83	98.83	0.07
S60	24103	984	.	2,276,676	20.00	19.97	0.16	3.6	3.6	5,800	5,800	90.63	90.63	0.06
S60	24104	984	.	2,276,676	20.00	19.96	0.20	6.9	6.9	2,400	2,400	75.00	75.01	0.05
US59	8905	1,420,948	762,392	2,112,832	2.78	2.38	14.39	21.1	22.2	13,600	13,788	212.50	218.39	0.10
US59	8904	1,420,948	762,392	2,112,832	2.78	2.38	14.41	21.4	22.5	13,400	13,588	209.38	215.26	0.10
US59	8903	1,420,948	762,392	2,112,832	2.39	2.09	12.62	21.8	22.7	15,350	15,538	239.84	245.73	0.11
US59	8901	1,420,948	762,392	5,841,189	11.03	8.89	19.45	13.6	14.6	14,767	14,955	230.73	236.62	0.11
US59	8804	1,022,644	466,182	5,841,189	11.42	9.68	15.24	15.0	15.9	12,867	13,003	201.05	205.29	0.09
US87	14306	141,521	104,557	5,841,189	20.00	16.90	15.51	9.2	9.8	2,850	2,869	89.06	90.24	0.04
US87	14307	141,521	104,557	5,841,189	20.00	15.29	23.53	9.2	10.2	1,700	1,719	53.13	54.30	0.02
US87	14308	141,521	104,557	8,872,292	20.00	18.40	7.99	9.2	9.5	6,020	6,039	188.13	189.30	0.09
US87	14309	141,521	104,557	8,872,292	20.00	18.46	7.72	10.1	10.4	5,667	5,686	177.09	178.27	0.08
US87	14310	141,521	104,557	5,009,267	19.39	18.48	4.70	11.8	12.0	8,280	8,299	258.75	259.92	0.12
US87	14401	141,521	104,557	5,009,267	20.00	17.98	10.08	6.7	7.0	6,363	6,382	198.84	200.02	0.09
US87	14403	141,521	104,557	2,276,676	20.00	17.64	11.79	7.5	7.9	4,800	4,819	150.00	151.17	0.07

DISTRICT=CORPUS CHRISTI DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM1069	154904	2,859	1,472	3,436,383	20.00	19.93	0.33	5.8	5.8	5,100	5,100	79.69	79.70	0.06
FM2725	275601	3,303	1,701	3,074,361	20.00	19.83	0.84	6.7	6.7	2,000	2,000	62.50	62.53	0.04
S35	18003	1,769	.	1,791,737	15.08	15.06	0.13	14.0	14.0	3,200	3,200	100.00	100.01	0.07
S35	18004	1,769	.	1,791,737	6.71	6.71	0.06	9.5	9.5	10,592	10,592	331.00	331.01	0.24
S35	18005	1,769	.	1,791,737	7.71	7.71	0.07	9.9	9.9	8,867	8,867	277.09	277.11	0.20
S358	61701	982,785	461,434	2,810,157	5.12	4.41	13.76	4.3	4.6	48,638	48,768	506.65	509.36	0.36

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island
40 PERCENT TONNAGE REDUCTION

DISTRICT=CORPUS CHRISTI DISTRICT
(continued)

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
S361	18010	6,163	3,173	1,470,362	9.81	9.77	0.37	10.3	10.3	5,500	5,501	171.88	171.93	0.12
S44	10201	982,785	461,434	1,316,451	8.73	5.50	36.97	7.4	8.9	7,700	7,830	120.31	124.39	0.09
US77	37102	1,022,463	466,001	2,129,917	4.02	3.42	14.79	19.9	21.0	10,043	10,179	156.92	161.16	0.07
US77	37103	1,022,463	466,001	2,129,917	20.00	6.56	67.21	18.8	29.5	900	1,036	14.06	18.30	0.01
US77	37104	1,022,463	466,001	2,483,647	6.83	5.45	20.18	18.8	20.3	7,300	7,436	114.06	118.30	0.05
US77	37203	1,016,301	462,827	2,483,647	15.17	9.74	35.83	7.8	9.3	7,933	8,068	123.95	128.17	0.06
US77	37201	1,016,301	462,827	2,483,647	4.38	3.77	13.88	16.2	17.1	13,200	13,335	206.25	210.46	0.10
US77	37301	1,016,301	462,827	1,167,359	1.42	1.28	9.99	16.0	16.6	19,475	19,610	304.30	308.51	0.14
US77	10202	33,516	1,393	1,167,359	1.52	1.52	0.39	20.7	20.7	13,975	13,979	218.36	218.50	0.10
US77	10203	33,516	1,393	1,167,359	1.33	1.33	0.34	20.4	20.4	16,300	16,304	254.69	254.83	0.12
US77	10204	33,516	1,393	2,483,647	3.34	3.32	0.40	22.7	22.7	12,386	12,390	193.53	193.67	0.09
US77	32701	33,516	1,393	2,483,647	4.78	4.75	0.58	28.9	28.9	6,800	6,804	106.25	106.39	0.05

DISTRICT=BEAUMONT DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
I10	73902	11,078,357	3,809,493	4,790,983	2.67	1.72	35.50	26.5	30.5	26,000	27,469	406.25	452.16	0.21
I10	73901	11,078,357	3,809,493	4,790,983	2.55	1.67	34.46	28.9	32.8	25,000	26,469	390.63	436.54	0.20
I10	50803	11,078,357	3,809,493	4,790,983	2.56	1.68	34.55	26.2	29.9	27,500	28,969	429.69	475.60	0.22
I10	50802	11,078,357	3,809,493	4,790,983	2.56	1.67	34.51	23.8	27.3	30,333	31,802	473.95	519.87	0.24
US90	2807	664,918	377,570	1,436,461	2.65	2.38	9.92	8.1	8.4	25,333	25,421	395.83	398.58	0.18
US90	2806	664,918	377,570	1,436,461	6.02	4.81	20.03	12.7	13.7	7,122	7,210	111.28	114.04	0.05

DISTRICT=PHARR DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM106	142503	25,946	1,393	1,673,506	20.00	19.46	2.72	10.9	11.0	2,900	2,903	90.63	90.84	0.06
FM2925	63003	25,946	1,393	1,673,506	20.00	16.73	16.33	7.7	8.2	587	590	18.34	18.56	0.01
FM508	34204	25,946	1,393	1,673,506	20.00	18.83	5.83	6.6	6.7	2,160	2,163	67.50	67.72	0.05
S100	33102	7,569	.	1,673,506	4.04	4.03	0.16	10.8	10.8	14,500	14,501	453.13	453.19	0.32
S48	22005	7,569	.	3,096,382	16.69	16.63	0.35	4.7	4.7	15,657	15,658	244.64	244.67	0.17

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island
40 PERCENT TONNAGE REDUCTION

DISTRICT=PHARR DISTRICT
(continued)

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
US77	32702	33,516	1,393	5,006,733	9.84	9.79	0.59	29.6	29.6	6,500	6,504	101.56	101.70	0.05
US77	32703	33,516	1,393	5,006,733	10.24	10.18	0.61	30.3	30.3	6,100	6,104	95.31	95.45	0.04
US77	32704	33,516	1,393	5,006,733	10.38	10.31	0.62	30.4	30.4	6,000	6,004	93.75	93.89	0.04
US77	32705	33,516	1,393	5,006,733	9.39	9.34	0.56	30.1	30.1	6,700	6,704	104.69	104.83	0.05
US77	32710	33,516	1,393	1,951,437	3.48	3.46	0.53	25.6	25.6	8,287	8,291	129.48	129.62	0.06
US77	32708	33,516	1,393	1,951,437	13.66	13.38	2.07	5.4	5.4	10,000	10,004	104.17	104.26	0.05
US77	3907	33,516	1,393	1,951,437	1.14	1.14	0.18	23.2	23.2	27,920	27,924	436.25	436.39	0.20
US77	3908	7,569	.	1,951,437	2.82	2.81	0.10	11.8	11.8	22,200	22,201	346.88	346.91	0.16
US77	3909	7,569	.	1,951,437	1.99	1.99	0.07	11.8	11.8	31,400	31,401	490.63	490.66	0.22

DETAILED ANALYSIS OF AFFECTED TONNAGE
LOW END OF TON-MILES EFFICIENCY
Break Point 319-325 / High Island

ORIGIN	DESTINATION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
1	350	5,351,468	1,463,894	5,066,607	10,418,075	43,371,415	6,189,896	5,975,426	43,585,885	6,752.96	3,260.33	1,687.72	8,325.57	46.03
1	360	1,189,583	159,454	956,425	2,146,008	8,394,174	1,069,493	1,085,100	8,378,568	1,306.98	563.32	306.48	1,563.82	8.91
1	380	274,920	253,641	215,664	490,584	2,197,476	234,111	258,582	2,173,006	342.15	123.31	73.03	392.42	2.33
1	390	572	572	585	1,157	5,748	619	680	5,687	0.89	0.33	0.19	1.03	0.01
1	400	524,054	338,096	533,093	1,057,147	4,732,631	574,219	595,800	4,711,050	736.87	302.45	168.28	871.05	5.02
1	450	963	.	1,268	2,231	7,694	1,485	1,275	7,904	1.20	0.78	0.36	1.62	0.01
1	470	116,950	58,298	121,717	238,667	1,231,165	135,568	147,321	1,219,412	191.69	71.41	41.61	221.49	1.31
1	480	302	302	308	610	3,418	368	404	3,382	0.53	0.19	0.11	0.61	0.00
1	500	143,824	114,235	147,864	291,688	1,566,059	170,370	186,242	1,550,187	243.84	89.74	52.60	280.97	1.66
1	540	10,271	5,289	17,909	28,180	136,918	27,074	23,049	140,943	21.32	14.26	6.51	29.07	0.15
1	550	231,416	73,213	393,697	625,113	2,895,667	740,134	580,540	3,055,261	450.86	389.84	163.97	676.73	3.07
1	560	0	.	500	500	0	1,679	933	746	0.00	0.88	0.26	0.62	0.00
1	650	9,350	.	19,910	29,260	145,464	32,610	26,624	151,449	22.65	17.18	7.52	32.31	0.15
1	670	12,615	.	26,864	39,479	202,000	45,284	36,972	210,312	31.45	23.85	10.44	44.86	0.21
280	350	1,437,464	457,500	710,088	2,147,552	2,766,076	143,847	241,690	2,668,233	430.68	75.77	68.26	438.18	2.94
280	360	317,344	69,204	156,763	474,107	654,432	34,033	57,182	631,283	101.90	17.93	16.15	103.67	0.69
280	380	62,247	21,884	30,749	92,996	166,123	8,639	14,515	160,247	25.87	4.55	4.10	26.32	0.18
280	400	41,836	35,319	20,666	62,502	137,437	7,147	12,009	132,575	21.40	3.76	3.39	21.77	0.15
280	410	5,134	.	2,536	7,670	17,568	914	1,535	16,947	2.74	0.48	0.43	2.78	0.02
280	500	135,355	135,355	66,863	202,218	807,108	41,973	70,522	778,558	125.67	22.11	19.92	127.86	0.86
280	550	93,219	13,942	95,311	188,530	689,281	74,192	81,531	681,942	107.32	39.08	23.03	123.37	0.73
290	330	677	.	334	1,011	778	40	68	751	0.12	0.02	0.02	0.12	0.00
290	350	1,205,027	146,057	595,268	1,800,295	2,045,137	106,355	178,697	1,972,795	318.43	56.02	50.47	323.98	2.17
290	360	343,435	44,513	169,652	513,087	618,956	32,188	54,082	597,062	96.37	16.95	15.28	98.05	0.66
290	380	115,342	11,893	56,978	172,320	274,715	14,286	24,004	264,997	42.77	7.52	6.78	43.52	0.29
290	400	60,034	57,612	29,656	89,690	184,073	9,572	16,084	177,562	28.66	5.04	4.54	29.16	0.20
290	470	1,791	.	884	2,675	8,921	464	780	8,606	1.39	0.24	0.22	1.41	0.01
290	500	4,748	4,748	2,346	7,094	26,908	1,399	2,351	25,957	4.19	0.74	0.66	4.26	0.03
290	530	2,949	.	1,457	4,406	19,538	1,016	1,707	18,847	3.04	0.54	0.48	3.10	0.02
290	550	53,675	3,958	54,879	108,554	384,818	41,421	45,518	380,721	59.92	21.82	12.86	68.88	0.41
290	650	1,437	1,437	1,470	2,907	14,245	1,533	1,685	14,093	2.22	0.81	0.48	2.55	0.02
310	350	3,076	.	1,520	4,596	3,790	197	331	3,656	0.59	0.10	0.09	0.60	0.00
310	360	26,150	.	12,918	39,068	35,795	1,861	3,128	34,529	5.57	0.98	0.88	5.67	0.04
350	1	3,810,188	1,473,189	4,935,202	8,745,390	34,222,449	8,115,480	6,510,114	35,827,815	5,328.46	4,274.57	1,838.73	7,764.29	36.32
350	280	610,072	294,339	301,367	911,439	1,201,109	62,462	104,949	1,158,623	187.01	32.90	29.64	190.27	1.27
350	290	183,054	50,000	90,426	273,480	310,702	16,158	27,148	299,712	48.38	8.51	7.67	49.22	0.33
360	1	984,471	343,089	1,686,891	2,671,362	11,832,303	3,253,879	2,499,728	12,586,454	1,842.30	1,713.88	706.03	2,850.14	12.56
360	280	391,679	234,891	193,484	585,163	807,883	42,013	70,590	779,306	125.79	22.13	19.94	127.98	0.86
360	290	49,940	25,609	24,670	74,610	91,484	4,757	7,994	88,248	14.24	2.51	2.26	14.49	0.10
380	1	128,543	92,136	207,913	336,456	1,763,302	360,929	303,644	1,820,588	274.55	190.11	85.76	378.89	1.87
380	280	28,935	15,971	14,293	43,228	79,971	4,159	6,988	77,142	12.45	2.19	1.97	12.67	0.08
400	1	462,667	430,241	710,364	1,173,031	4,791,832	1,150,309	919,313	5,022,828	746.09	605.89	259.65	1,092.33	5.09
400	280	43,226	39,123	21,353	64,579	150,689	7,836	13,167	145,359	23.46	4.13	3.72	23.87	0.16
400	290	21,394	20,430	10,568	31,962	65,596	3,411	5,732	63,276	10.21	1.80	1.62	10.39	0.07

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

DETAILED ANALYSIS OF AFFECTED TONNAGE
LOW END OF TON-MILES EFFICIENCY
Break Point 319-325 / High Island

ORIGIN	DESTINATION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
410	1	117,043	2,063	127,193	244,236	1,326,485	164,825	169,150	1,322,160	206.53	86.82	47.78	245.58	1.41
410	280	862	862	426	1,288	2,950	153	258	2,846	0.46	0.08	0.07	0.47	0.00
450	1	676	.	692	1,368	6,352	684	751	6,284	0.99	0.36	0.21	1.14	0.01
470	1	118,616	115,662	553,954	672,570	2,506,983	1,350,869	897,105	2,960,747	390.34	711.53	253.38	848.48	2.66
470	290	25,226	.	12,462	37,688	124,309	6,465	10,862	119,912	19.36	3.40	3.07	19.69	0.13
500	1	44,204	41,011	91,451	135,655	601,180	202,684	147,762	656,101	93.60	106.76	41.73	158.63	0.64
500	280	104,890	29,123	51,815	156,705	629,486	32,736	55,002	607,219	98.01	17.24	15.53	99.72	0.67
500	290	16,979	16,979	8,387	25,366	95,287	4,955	8,326	91,916	14.84	2.61	2.35	15.09	0.10
550	1	785,527	479,923	2,243,198	3,028,725	12,477,470	4,721,552	3,352,834	13,846,188	1,942.75	2,486.92	946.98	3,482.69	13.24
550	280	390,253	185,422	399,014	789,267	2,885,010	310,534	341,250	2,854,295	449.20	163.56	96.38	516.38	3.06
550	290	83,885	12,600	85,769	169,654	601,675	64,762	71,168	595,269	93.68	34.11	20.10	107.69	0.64
650	1	32,457	884	72,464	104,921	567,665	135,787	108,637	594,814	88.39	71.52	30.68	129.22	0.60
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		20,212,016	7,373,965	21,356,104	41,568,120	150,887,698	29,761,388	25,358,833	155,290,253	23,493.31	15,675.85	7,162.42	32,006.74	160.14

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

DETAILED ANALYSIS OF AFFECTED TONNAGE
HIGH END OF TON-MILES EFFICIENCY
Break Point 319-325 / High Island

ORIGIN	DESTINA-TION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
1	350	5,351,468	1,463,894	5,066,607	10,418,075	28,914,276	4,835,856	5,272,435	28,477,698	4,501.97	2,547.13	1,489.16	5,559.94	46.03
1	360	1,189,583	159,454	956,425	2,146,008	5,596,116	835,541	957,441	5,474,217	871.32	440.09	270.42	1,040.99	8.91
1	380	274,920	253,641	215,664	490,584	1,464,984	182,900	228,161	1,419,723	228.10	96.34	64.44	259.99	2.33
1	390	572	572	585	1,157	3,832	483	600	3,715	0.60	0.25	0.17	0.68	0.01
1	400	524,054	338,096	533,093	1,057,147	3,155,087	448,609	525,706	3,077,990	491.25	236.29	148.48	579.06	5.02
1	450	963	.	1,268	2,231	5,130	1,160	1,125	5,165	0.80	0.61	0.32	1.09	0.01
1	470	116,950	58,298	121,717	238,667	820,776	105,912	129,989	796,700	127.80	55.79	36.71	146.87	1.31
1	480	302	302	308	610	2,279	287	357	2,210	0.35	0.15	0.10	0.41	0.00
1	500	143,824	114,235	147,864	291,688	1,044,039	133,102	164,331	1,012,810	162.56	70.11	46.41	186.25	1.66
1	540	10,271	5,289	17,909	28,180	91,279	21,152	20,337	92,093	14.21	11.14	5.74	19.61	0.15
1	550	231,416	73,213	393,697	625,113	1,930,444	578,230	512,241	1,996,433	300.57	304.56	144.68	460.46	3.07
1	560	0	.	500	500	0	1,312	823	489	0.00	0.69	0.23	0.46	0.00
1	650	9,350	.	19,910	29,260	96,976	25,477	23,492	98,960	15.10	13.42	6.64	21.88	0.15
1	670	12,615	.	26,864	39,479	134,667	35,378	32,622	137,423	20.97	18.63	9.21	30.39	0.21
280	350	1,437,464	457,500	710,088	2,147,552	1,844,051	112,380	213,256	1,743,175	287.12	59.19	60.23	286.08	2.94
280	360	317,344	69,204	156,763	474,107	436,288	26,588	50,455	412,422	67.93	14.00	14.25	67.68	0.69
280	380	62,247	21,884	30,749	92,996	110,749	6,749	12,808	104,691	17.24	3.55	3.62	17.18	0.18
280	400	41,836	35,319	20,666	62,502	91,624	5,584	10,596	86,612	14.27	2.94	2.99	14.21	0.15
280	410	5,134	.	2,536	7,670	11,712	714	1,354	11,072	1.82	0.38	0.38	1.82	0.02
280	500	135,355	135,355	66,863	202,218	538,072	32,791	62,225	508,638	83.78	17.27	17.58	83.47	0.86
280	550	93,219	13,942	95,311	188,530	459,521	57,963	71,939	445,544	71.55	30.53	20.32	81.76	0.73
290	330	677	.	334	1,011	519	32	60	490	0.08	0.02	0.02	0.08	0.00
290	350	1,205,027	146,057	595,268	1,800,295	1,363,425	83,090	157,674	1,288,841	212.29	43.76	44.53	211.52	2.17
290	360	343,435	44,513	169,652	513,087	412,637	25,147	47,720	390,065	64.25	13.25	13.48	64.02	0.66
290	380	115,342	11,893	56,978	172,320	183,143	11,161	21,180	173,125	28.52	5.88	5.98	28.41	0.29
290	400	60,034	57,612	29,656	89,690	122,715	7,479	14,191	116,002	19.11	3.94	4.01	19.04	0.20
290	470	1,791	.	884	2,675	5,947	362	688	5,622	0.93	0.19	0.19	0.92	0.01
290	500	4,748	4,748	2,346	7,094	17,939	1,093	2,075	16,958	2.79	0.58	0.59	2.78	0.03
290	530	2,949	.	1,457	4,406	13,026	794	1,506	12,313	2.03	0.42	0.43	2.02	0.02
290	550	53,675	3,958	54,879	108,554	256,545	32,360	40,163	248,742	39.94	17.04	11.34	45.65	0.41
290	650	1,437	1,437	1,470	2,907	9,496	1,198	1,487	9,208	1.48	0.63	0.42	1.69	0.02
310	350	3,076	.	1,520	4,596	2,527	154	292	2,388	0.39	0.08	0.08	0.39	0.00
310	360	26,150	.	12,918	39,068	23,863	1,454	2,760	22,558	3.72	0.77	0.78	3.70	0.04
350	1	3,810,188	1,473,189	4,935,202	8,745,390	22,814,966	6,340,219	5,744,218	23,410,966	3,552.31	3,339.50	1,622.41	5,269.40	36.32
350	280	610,072	294,339	301,367	911,439	800,739	48,799	92,602	756,936	124.68	25.70	26.15	124.22	1.27
350	290	183,054	50,000	90,426	273,480	207,135	12,623	23,954	195,804	32.25	6.65	6.77	32.13	0.33
360	1	984,471	343,089	1,686,891	2,671,362	7,888,202	2,542,093	2,205,642	8,224,653	1,228.20	1,338.97	622.97	1,944.20	12.56
360	280	391,679	234,891	193,484	585,163	538,589	32,823	62,285	509,126	83.86	17.29	17.59	83.55	0.86
360	290	49,940	25,609	24,670	74,610	60,989	3,717	7,053	57,653	9.50	1.96	1.99	9.46	0.10
380	1	128,543	92,136	207,913	336,456	1,175,535	281,976	267,921	1,189,590	183.03	148.52	75.67	255.88	1.87
380	280	28,935	15,971	14,293	43,228	53,314	3,249	6,166	50,398	8.30	1.71	1.74	8.27	0.08
400	1	462,667	430,241	710,364	1,173,031	3,194,554	898,679	811,158	3,282,075	497.39	473.35	229.11	741.64	5.09
400	280	43,226	39,123	21,353	64,579	100,460	6,122	11,618	94,964	15.64	3.22	3.28	15.58	0.16
400	290	21,394	20,430	10,568	31,962	43,731	2,665	5,057	41,339	6.81	1.40	1.43	6.78	0.07

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

DETAILED ANALYSIS OF AFFECTED TONNAGE
HIGH END OF TON-MILES EFFICIENCY
Break Point 319-325 / High Island

ORIGIN	DESTINATION	AFFECTED TONS (TRUCK)	HAZARD TONS (TRUCK)	AFFECTED TONS (RAIL)	AFFECTED TONS (BARGE)	COST OF FUEL (TRUCK)	COST OF FUEL (RAIL)	COST OF FUEL (BARGE)	NET COST	EMISSION TRUCK (TONS)	EMISSION RAIL (TONS)	EMISSION BARGE (TONS)	NET EMISSION	ACCIDENT
410	1	117,043	2,063	127,193	244,236	884,323	128,770	149,250	863,843	137.69	67.83	42.15	163.36	1.41
410	280	862	862	426	1,288	1,967	120	227	1,859	0.31	0.06	0.06	0.31	0.00
450	1	676	.	692	1,368	4,234	534	663	4,106	0.66	0.28	0.19	0.75	0.01
470	1	118,616	115,662	553,954	672,570	1,671,322	1,055,366	791,563	1,935,125	260.23	555.88	223.57	592.53	2.66
470	290	25,226	.	12,462	37,688	82,873	5,050	9,584	78,339	12.90	2.66	2.71	12.86	0.13
500	1	44,204	41,011	91,451	135,655	400,787	158,347	130,379	428,755	62.40	83.40	36.82	108.98	0.64
500	280	104,890	29,123	51,815	156,705	419,657	25,575	48,531	396,701	65.34	13.47	13.71	65.10	0.67
500	290	16,979	16,979	8,387	25,366	63,525	3,871	7,346	60,050	9.89	2.04	2.07	9.85	0.10
550	1	785,527	479,923	2,243,198	3,028,725	8,318,313	3,688,713	2,958,383	9,048,643	1,295.17	1,942.91	835.57	2,402.50	13.24
550	280	390,253	185,422	399,014	789,267	1,923,340	242,605	301,103	1,864,842	299.47	127.78	85.04	342.21	3.06
550	290	83,885	12,600	85,769	169,654	401,116	50,596	62,796	388,917	62.45	26.65	17.74	71.37	0.64
650	1	32,457	884	72,464	104,921	378,443	106,083	95,856	388,670	58.92	55.88	27.07	87.73	0.60
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		20,212,016	7,373,965	21,356,104	41,568,120	100,591,799	23,251,085	22,375,441	101,467,442	15,662.21	12,246.75	6,319.78	21,589.18	160.14

NOTE: An Origin or Destination value of "1" indicates
a location outside GIWW milepoints 270-670

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island

------ DISTRICT=HOUSTON DISTRICT ------

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM1495	58701	1,011,568	791,142	2,342,909	20.00	5.25	73.75	3.4	6.9	3,600	3,734	112.50	120.89	0.09
FM1764	160701	489,632	131,023	4,149,703	14.52	12.58	13.36	4.5	4.8	24,000	24,065	375.00	377.03	0.27
FM1764	160702	326,421	87,348	4,149,703	20.00	17.33	13.36	3.0	3.2	24,000	24,043	750.00	752.71	0.54
FM2918	293901	123,039	2,925	4,334,935	20.00	9.03	54.84	7.0	9.9	500	516	15.63	16.64	0.01
FM360	52706	1,104,336	770,972	5,014,448	20.00	5.31	73.44	9.2	17.3	1,500	1,646	46.88	56.03	0.04
FM523	100301	120,734	97,146	1,867,826	20.00	16.70	16.48	3.2	3.4	6,625	6,641	207.03	208.03	0.15
I45	11004	457,339	122,381	12,973,790	6.95	6.80	2.16	11.4	11.5	62,000	62,061	968.75	970.65	0.44
I45	11005	402,606	107,735	5,528,218	2.18	2.15	1.41	10.0	10.1	95,667	95,720	1494.8	1496.5	0.68
I45	67508	697,823	186,734	15,422,523	12.91	12.26	4.99	17.4	17.7	26,000	26,093	406.25	409.14	0.19
S134	37602	11,696,896	3,757,808	7,009,427	20.00	4.13	79.37	6.5	14.8	15,900	17,451	496.88	593.83	0.42
S146	38905	3,435,617	947,897	2,496,949	9.75	4.42	54.68	6.2	8.8	15,700	16,156	245.31	259.55	0.19
S146	38906	3,435,617	947,897	2,496,949	10.65	4.59	56.86	7.5	11.0	11,786	12,242	184.16	198.40	0.14
S146	38912	3,435,617	947,897	2,496,949	9.98	4.47	55.26	4.8	7.0	19,700	20,156	307.81	322.05	0.23
S197	38911	588,918	157,591	3,294,557	20.00	12.24	38.81	5.4	6.7	5,833	5,911	182.28	187.16	0.13
S288	59804	541,092	444,227	2,655,275	6.85	6.11	10.85	12.2	12.7	12,600	12,672	196.88	199.12	0.14
S330	50807	8,073,046	2,544,063	2,496,949	4.54	1.96	56.89	8.0	11.6	26,000	27,071	406.25	439.71	0.31
S332	58601	306,980	247,005	2,057,202	11.46	9.98	12.98	8.1	8.5	8,767	8,808	273.97	276.51	0.20
S341	62801	652,842	174,697	4,149,703	20.00	11.59	42.04	6.0	7.6	5,100	5,187	79.69	82.39	0.06
S348	68601	1,218,639	326,101	7,909,001	19.32	15.34	20.59	11.2	12.2	14,500	14,662	453.13	463.23	0.33
S35	17801	224,179	175,073	1,764,574	5.81	5.45	6.23	5.3	5.5	21,500	21,530	335.94	336.87	0.24
S35	17802	224,179	175,073	2,342,909	10.26	9.43	8.11	6.3	6.5	13,773	13,803	215.20	216.13	0.15
S35	17803	224,179	175,073	2,342,909	13.82	12.35	10.63	7.2	7.5	8,900	8,930	139.06	139.99	0.10
S35	17901	57,689	22,589	2,342,909	10.29	10.06	2.23	10.4	10.5	8,300	8,308	129.69	129.93	0.09
S35	17902	57,689	22,589	2,342,909	10.46	10.22	2.26	10.3	10.4	8,222	8,230	256.94	257.42	0.18
S35	17903	57,689	22,589	2,342,909	13.90	13.49	2.99	10.5	10.6	6,067	6,075	189.59	190.07	0.14
S36	18705	1,110,333	771,835	2,535,398	13.80	8.94	35.21	15.1	17.7	4,600	4,747	143.75	152.95	0.11
S36	18801	1,110,333	771,835	2,535,398	11.10	7.72	30.42	8.7	10.1	9,900	10,047	309.38	318.58	0.23
S36	18802	1,110,333	771,835	2,535,398	19.72	11.10	43.72	10.2	12.9	4,750	4,897	148.44	157.64	0.11
S36	18803	1,110,333	771,835	3,516,385	20.00	12.29	38.56	10.2	12.3	6,013	6,160	187.91	197.11	0.14
S36	18804	1,110,333	771,835	3,516,385	16.53	11.36	31.27	7.4	8.6	11,367	11,514	355.22	364.42	0.26
S36	18805	1,110,333	771,835	3,516,385	20.00	11.17	44.16	8.1	10.3	6,000	6,147	187.50	196.70	0.14
S36	18806	1,110,333	771,835	3,516,385	20.00	11.55	42.24	7.7	9.6	6,820	6,967	213.13	222.33	0.16
S87	37606	3,276,451	876,760	6,504,983	20.00	5.85	70.77	9.2	16.5	5,000	5,435	156.25	183.41	0.13
US59	17707	3,474,223	2,041,626	4,149,703	2.37	2.01	15.17	6.2	6.6	106,000	106,461	1656.3	1670.6	0.76
US75	5104	3,276,451	876,760	6,011,120	10.14	6.77	33.20	6.2	7.3	36,000	36,435	562.50	576.08	0.26
US90	2801	544,199	362,117	3,715,330	12.14	10.46	13.79	7.1	7.5	16,375	16,447	255.86	258.11	0.12
US90	2802	544,199	362,117	3,715,330	20.00	15.57	22.17	7.3	8.0	8,900	8,972	139.06	141.32	0.06
US90A	2710	152,638	40,845	3,715,330	13.96	13.27	4.90	3.8	3.9	26,480	26,500	413.75	414.38	0.19

CONTROL & SECTION NUMBERS AFFECTED BY BREAK IN GIWW
BREAK POINT 319-325 / High Island

DISTRICT=YOAKUM DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM2031	60401	1,640	.	1,252,801	20.00	19.79	1.07	7.9	7.9	660	660	20.63	20.64	0.01
FM2717	271401	119,191	79,009	2,094,784	20.00	6.29	68.53	7.9	13.6	240	256	7.50	8.49	0.01
FM2760	271403	143,694	95,252	2,568,860	20.00	11.16	44.19	9.5	12.0	660	679	20.63	21.82	0.02
S316	58001	262,885	174,261	1,642,425	20.00	5.69	71.56	4.8	9.1	740	775	23.13	25.30	0.02
S35	17904	51,693	21,727	2,276,676	7.94	7.82	1.60	10.5	10.6	10,317	10,324	161.20	161.42	0.12
S35	17906	51,693	21,727	2,276,676	11.85	11.57	2.36	11.8	11.9	6,150	6,157	96.09	96.31	0.07
S35	17907	51,693	21,727	2,276,676	15.25	14.79	3.02	16.4	16.6	3,430	3,437	107.19	107.62	0.08
S35	17908	51,693	21,727	2,276,676	20.00	18.11	9.45	6.4	6.6	2,638	2,645	82.44	82.87	0.06
S35	17909	51,693	21,727	2,276,676	18.12	17.47	3.57	15.3	15.5	3,100	3,107	96.88	97.30	0.07
S35	17910	51,693	21,727	1,795,577	8.02	7.86	2.03	10.0	10.0	8,500	8,507	132.81	133.03	0.10
S35	18001	24,676	21,727	1,795,577	6.49	6.44	0.80	13.1	13.2	7,964	7,967	248.88	249.08	0.18
S60	24101	1,640	.	1,952,424	16.05	16.03	0.12	10.8	10.8	4,260	4,260	133.13	133.14	0.10
S60	24102	1,640	.	2,276,676	15.73	15.71	0.10	8.7	8.7	6,325	6,325	98.83	98.83	0.07
S60	24103	1,640	.	2,276,676	20.00	19.95	0.27	3.6	3.6	5,800	5,800	90.63	90.63	0.06
S60	24104	1,640	.	2,276,676	20.00	19.93	0.34	6.9	6.9	2,400	2,400	75.00	75.01	0.05
US59	8905	2,368,247	1,270,653	2,112,832	2.78	2.17	21.88	21.1	22.9	13,600	13,914	212.50	222.32	0.10
US59	8904	2,368,247	1,270,653	2,112,832	2.78	2.17	21.91	21.4	23.2	13,400	13,714	209.38	219.19	0.10
US59	8903	2,368,247	1,270,653	2,112,832	2.39	1.92	19.40	21.8	23.4	15,350	15,664	239.84	249.66	0.11
US59	8901	2,368,247	1,270,653	5,841,189	11.03	7.87	28.69	13.6	15.4	14,767	15,081	230.73	240.55	0.11
US59	8804	1,704,407	776,969	5,841,189	11.42	8.79	23.06	15.0	16.5	12,867	13,093	201.05	208.11	0.09
US87	14306	235,868	174,261	5,841,189	20.00	15.32	23.42	9.2	10.2	2,850	2,881	89.06	91.02	0.04
US87	14307	235,868	174,261	5,841,189	20.00	13.22	33.90	9.2	10.8	1,700	1,731	53.13	55.08	0.03
US87	14308	235,868	174,261	8,872,292	20.00	17.47	12.65	9.2	9.7	6,020	6,051	188.13	190.08	0.09
US87	14309	235,868	174,261	8,872,292	20.00	17.55	12.24	10.1	10.6	5,667	5,698	177.09	179.05	0.08
US87	14310	235,868	174,261	5,009,267	19.39	17.92	7.59	11.8	12.1	8,280	8,311	258.75	260.71	0.12
US87	14401	235,868	174,261	5,009,267	20.00	16.85	15.74	6.7	7.2	6,363	6,394	198.84	200.80	0.09
US87	14403	235,868	174,261	2,276,676	20.00	16.36	18.22	7.5	8.1	4,800	4,831	150.00	151.96	0.07

DISTRICT=CORPUS CHRISTI DISTRICT

HIGHWAY	CONTROL/ SECTION	ADD TONS	HAZARD TONS	18K ESALS BEFORE FAILURE	YEARS TO FAILURE BEFORE BREAK	YEARS TO FAILURE AFTER BREAK	MAINT COST INCREASE %	% TRUCKS BEFORE BREAK	% TRUCKS AFTER BREAK	AADT BEFORE BREAK	AADT AFTER BREAK	CURRENT CONGEST FACTOR	NEW CONGEST FACTOR	CRITICAL
FM1069	154904	4,766	2,454	3,436,383	20.00	19.89	0.55	5.8	5.8	5,100	5,101	79.69	79.71	0.06
FM2725	275601	5,505	2,835	3,074,361	20.00	19.72	1.40	6.7	6.7	2,000	2,001	62.50	62.55	0.04
S35	18003	2,949	.	1,791,737	15.08	15.05	0.22	14.0	14.0	3,200	3,200	100.00	100.02	0.07
S35	18004	2,949	.	1,791,737	6.71	6.71	0.10	9.5	9.5	10,592	10,592	331.00	331.02	0.24
S35	18005	2,949	.	1,791,737	7.71	7.70	0.11	9.9	9.9	8,867	8,867	277.09	277.12	0.20
S358	61701	1,637,975	769,057	2,810,157	5.12	4.04	21.00	4.3	4.8	48,638	48,855	506.65	511.17	0.37
S361	18010	10,271	5,289	1,470,362	9.81	9.75	0.61	10.3	10.3	5,500	5,501	171.88	171.96	0.12