Supply Chain Management in the Dry Bulk Shipping Industry

by

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B.S., Marine Engineering and Shipyard Management (2005)

United States Merchant Marine Academy

Submitted to the Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Ocean Systems Management

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ABSTRACT:

This paper is intended to show the importance of supply chain management in the dry-bulk shipping industry. A hypothetical company, the Texas Grain and Bakery Corporation, was created. The values and calculations used are artificial but representative of the industry. A well defined fleet analysis of Texas Intercoastal Transport's vessels and supply chain infrastructure show that an increase in productivity and profitability are possible with proper implementation. A systems approach of tying together the subsidiaries of Texas Grain and Bakery is used. This analysis is broken into seven sections:

(1) Overview of the Systems Approach, which breaks down the seven step process.
(2) Establishing a Baseline, which shows an annualized view of cargo movement of the core trade based on the first half of 2005.
(3) Analysis of "Ideal" Allocation of Current Fleet, which defines assumptions used in the model and proposes a core trade fleet.
(4) Analysis of Intermediate Fleet Allocation, which is a fleet analysis executable within the next 18 months.
(5) Analysis of Long-Term Fleet Allocation, which is a fleet analysis executable around 2009. Two new-build vessels are added into the core trade along with sharply increasing the amount of grain moved.
(6) Analysis of Delays, which goes over historical data from the Texas Intercoastal Transport fleet that warrants further future study.
(7) Conclusions and Recommendations, which summarizes the results of the seven step process and makes recommendations for implemention of results into the core trade of Texas Grain and Bakery.

The paper concludes with several findings. Conservatively, there is an estimated savings of $4 – 6 Million savings per year throughout Texas Grain and Bakery. There are certain inefficiencies that do exist in the system and cannot be remedied; they can only be minimized. Finally, additional study into mechanical delays is suggested in order to further increase fleet productivity and profitability in the future.

Thesis Supervisor: Henry S. Marcus
Title: Professor of Marine Systems

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Henry S. Marcus, for his support, guidance, and wisdom. His advice and counsel were essential in the creation of this thesis. I am forever indebted to his graciousness and willingness to help students in their quest for a higher education.

The valuable data and support provided by various shipping companies and industry professionals was pivotal in the understanding of this business. Their help and amiability will never be forgotten. I would also like to thank Bridget Downey for the countless hours of analysis support she provided. Her effort helped this thesis become a reality.

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Chapter 1: Overview of the Systems Approach

The systems approach to the Texas Grain and Bakery supply chain will be a seven step process. The most basic step will be to define the objective of a logistics system with the final outcome showing how to implement the completed analysis. The following gives a breakdown of the seven step systems approach.

1. **Define the objective of a basic logistics system**. There is a two-prong challenge that face companies dealing with supply chain management issues: maximize customer service while minimizing costs. This can also be expressed as having the right product at the right place when the customer wants it. The challenge is to make that happen at a low cost. Issues arise when there is difficulty in forecasting demand. A properly designed supply chain is focused on mitigating forecasting difficulties and increasing predictability.[1]

2. **Define the components of the Texas Grain and Bakery logistics system**. Moving grain and gypsum is a process that crosses not only subsidiary lines, but company lines as well. Texas Grain and Bakery is not a completely vertically integrated company. The company carries gypsum for an outside customer as part of its core trade. The following figures show the breakdown of the three basic manners in which cargo in the core trade is moved.

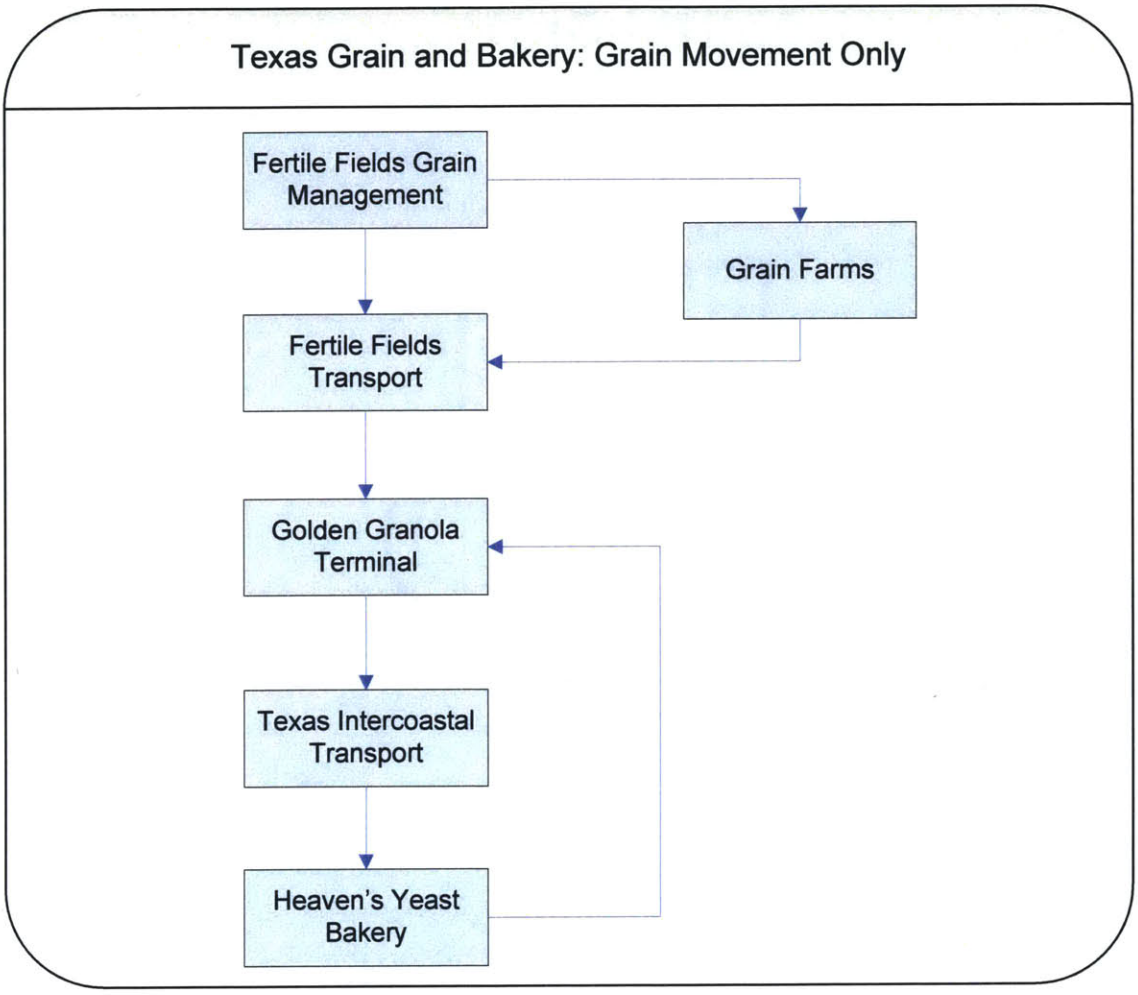

Figure 1: Core Trade Movement of Grain

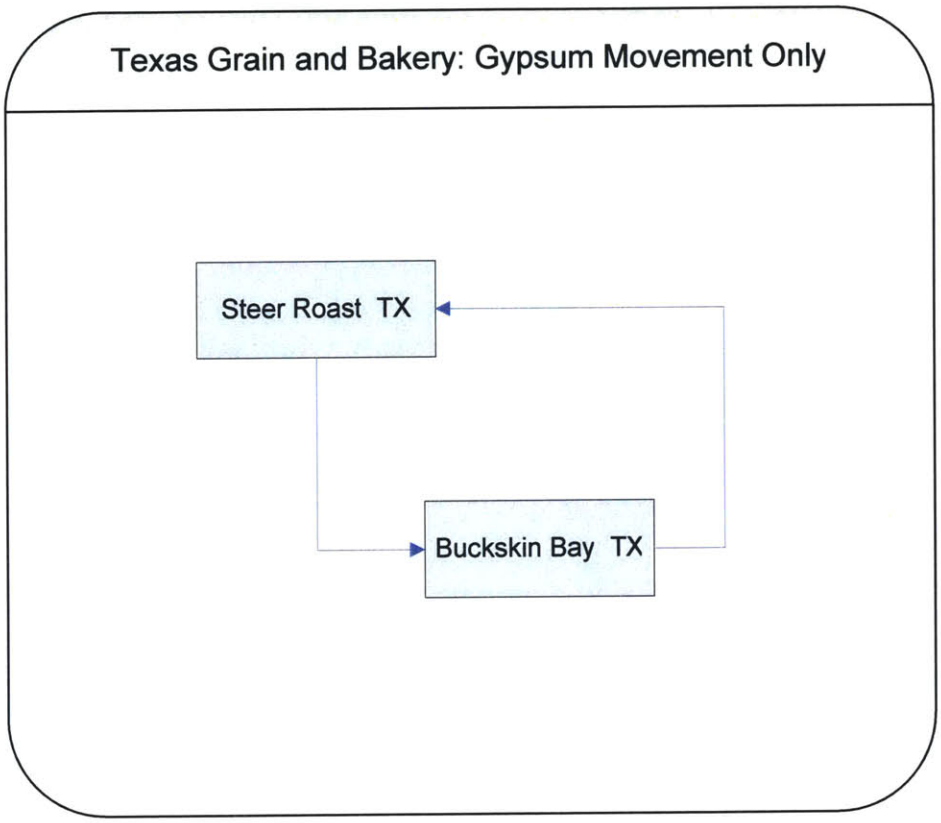

Figure 2: Core Trade Movement of Gypsum

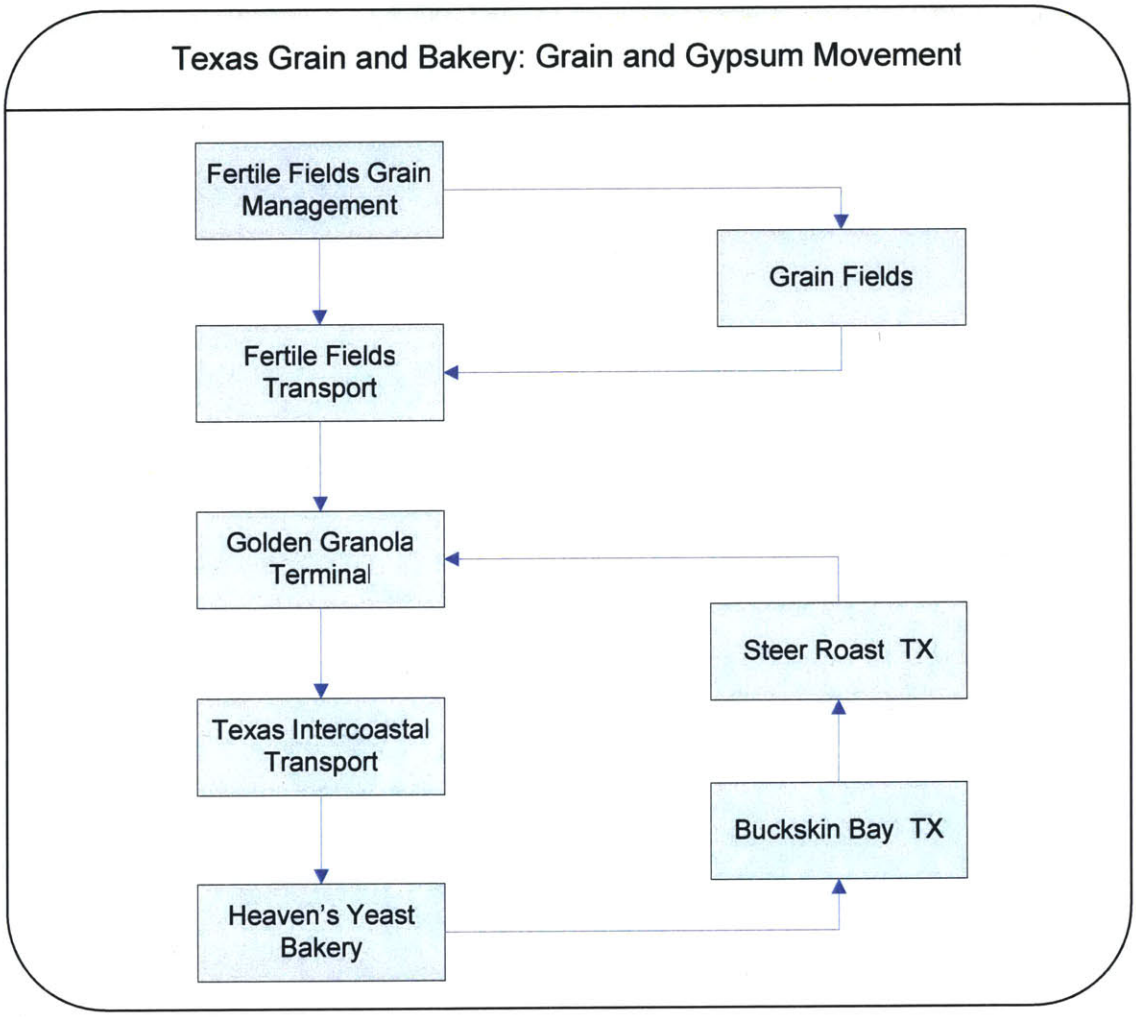

Figure 3: Core Trade Movement of Grain and Gypsum

3. **Define an area of improvement**. This is an area that appears like it has the most low-hanging fruit and largest room for improvement. In this case, ten different vessels involved in the core trade at some point during the first six months of 2005 seemed like too many.
4. **Perform a simple analysis**. A simple analysis, also known as the status quo or basic fleet analysis, must be performed to show whether a more detailed analysis is warranted.
5. **Perform a more refined analysis**. Once the simple analysis is completed, a more complete breakdown must be done in order to provide a more accurate solution by reducing the savings to a more realistic level. This is done in the form of vessel scheduling and through examination of loading rates, discharge rates, and weather and mechanical delays.
6. **Broaden the analysis**. It is important to include more parts of the overall system to get a complete view of the entire analysis. If these cannot be summed up quantitatively, they should be explained qualitatively.
7. **Develop an approach to implement the proposed infrastructure changes**. No savings is realized unless all key-players remain dedicated to the task at hand. The project must be visible and have clearly defined goals in which a solution is being actively sought by its members.

Chapter 2: Establishing a Baseline

To establish a starting point in which a comparison could be formulated, an analysis of the amount of grain and gypsum moved for the first six months of 2005 was completed. This incorporates steps three and four of the seven step process. Texas Intercoastal Transport keeps a record of each vessel voyage in the form of a Delay Sheet. The Delay Sheet provides the following information:

- Customer of the product being moved
- Name of the vessel moving the cargo
- Total amount of cargo moved in short tons
- Loading port – including total time for cargo operations
- Transit time to the port of discharge
- Discharge port – including total time for cargo operations
- Transit time to the next destination
- Total amount of maintenance and weather delays are also accounted for
- Total voyage time from loading port to loading port

Data for the grain and gypsum trades were entered into a spreadsheet where it could be analyzed. A sample line of data for a grain and gypsum trip is shown in Figures 4 and 5.

Figure 4: Sample Grain Trip

Sample Grain Trip	
Vessel:	Vessel 1
Date:	5/4/2005
Voyage Number:	5024
Number of Tons:	29500
Loading Dock:	GGT
Loading Time:	13.65
Delay:	2.50
Actual Loading TPH:	2161.17
TIT Loading TPH:	1826.62
Transit To:	40.75
Delay:	0
Discharge Dock:	HYB
Discharge Time:	17.80
Delay:	0
Actual Discharge TPH:	1657.30
TIT Discharge TPH:	1657.30
Return Transit:	39.70
Delays:	0
Return Dock:	GGT
Total Weather Delays:	0
Total Mechanical Delays:	0
Total WOB Delays:	2.50
Total Other Delays:	0
Total Time:	111.9
Total Time Including Delays:	114.4
Customer:	TGB
Cargo Type:	Grain

Actual Loading TPH: Defined as the Number of Tons divided by the Loading Time expressed in tons per hour (TPH).

TIT Loading TPH: Defined as the Number of Tons divided by the Loading Time and Delay for that leg of the voyage expressed in tons per hour (TPH).

Actual Discharge TPH: Defined as the Number of Tons divided by the Discharge Time expressed in tons per hour (TPH).

TIT Discharge TPH: Defined as the Number of Tons divided by the Discharge Time and Delay for that leg of the voyage expressed in tons per hour (TPH).

WOB: Defined as Waiting on Berth.

Figure 5: Sample Gypsum Trip

Sample Gypsum Trip	
Vessel:	Vessel 4
Date:	8/11/2005
Voyage Number:	5021
Number of Tons:	24184.94
Loading Dock:	Steer Roast
Loading Time:	8.63
Delay:	8.60
Actual Loading TPH:	2802.42
TIT Loading TPH:	1403.65
Transit To:	64.60
Delay:	0
Discharge Dock:	Buckskin
Discharge Time:	41.10
Delay:	13.40
Actual Discharge TPH:	588.44
TIT Discharge TPH:	443.76
Return Transit:	56.10
Delays:	0
Return Dock:	Steer Roast
Total Weather Delays:	0
Total Mechanical Delays:	22
Total WOB Delays:	0
Total Other Delays:	0
Total Time:	170.43
Total Time Including Delays:	192.43
Customer:	Gesso Gypsum
Cargo Type:	Gypsum

Actual Loading TPH: Defined as the Number of Tons divided by the Loading Time expressed in tons per hour (TPH).

TIT Loading TPH: Defined as the Number of Tons divided by the Loading Time and Delay for that leg of the voyage expressed in tons per hour (TPH).

Actual Discharge TPH: Defined as the Number of Tons divided by the Discharge Time expressed in tons per hour (TPH).

TIT Discharge TPH: Defined as the Number of Tons divided by the Discharge Time and Delay for that leg of the voyage expressed in tons per hour (TPH).

WOB: Defined as Waiting on Berth.

The above data shown in Figures 4 and 5 were compiled for each grain and gypsum trip for the first six months of 2005. Once this was done, the sum of grain and gypsum was doubled to represent an annualized amount of cargo movement. During the first six months, there were ten vessels involved in the grain and gypsum trade for Texas Intercoastal Transport.

The following figure shows the total amount of cargo moved in the core trade based on annualized data for 2005. This will henceforth be known as the "status quo."

Annual Cargo Moved (Based on First 6 months of 2005)

Grain Moved (tons):	**4.4 Million**
Gypsum Moved (tons):	**2.7 Million**
Vessel Days:	**1524 Days**
Average Tons/Vessel-Day:	**4652 Tons**
Total Waiting on Berth:	**154 Vessel-Days**

Figure 6: 2005 Annualized Data

Chapter 3: Analysis of "Ideal" Allocation of Current Fleet

Next, a simple and uncomplicated analysis is completed to determine how much can be saved with an "ideal" allocation of the current fleet. This is step five of the seven step process. These calculations will show whether additional analysis is warranted for further investigation of improvement. Now that a status quo has been established in Chapter 2, general assumptions must be made and another analysis performed. Focus is placed on moving the maximum amount of cargo in the least amount of vessel-days using no more than three vessels. This will not only increase the productivity and efficiency of the shipping fleet, it will also free up vessel-days to use in other trades. The extra days not previously available will be quantified using an opportunity cost of capital of $14,400 per vessel-day (the least expensive amount of any of the Texas Intercoastal Transport vessels).

First, the loading and discharge rates, including delays, must be determined. Figures 7 through 10 show the loading and discharge rates for the docks in the core trade. The 80th percentile was taken from each graph to use as a loading or discharge rate regardless of the vessel. The 80th percentile is defined as the point at which 20% of the data exceeded the selected number and the remaining 80% was below the selected number. Further, 80th percentile assumptions are as follows based on annualized data from 2005:

- Tons of Grain Loaded (based on individual vessel loadings)
- Tons of Gypsum Loaded (based on individual vessel loadings)
- Transit Times (based on individual vessel transits)

- Empty Return Transits (based on individual vessel transits)

If a vessel made a transfer from one berth to another, the value of the time for such a transfer throughout the fleet is as follows:

- Transfer from Heaven's Yeast Bakery to Steer Roast, TX – 1 hour
- Transfer from Buckskin Bay, TX to Golden Granola Terminal – 8 hours

Please refer to Appendix 1 which shows the round-trip voyage times along with the amount of each cargo moved based upon the above assumptions. Each table also displays the theoretical amount of cargo that each vessel can move if it were to operate 365 days per year.

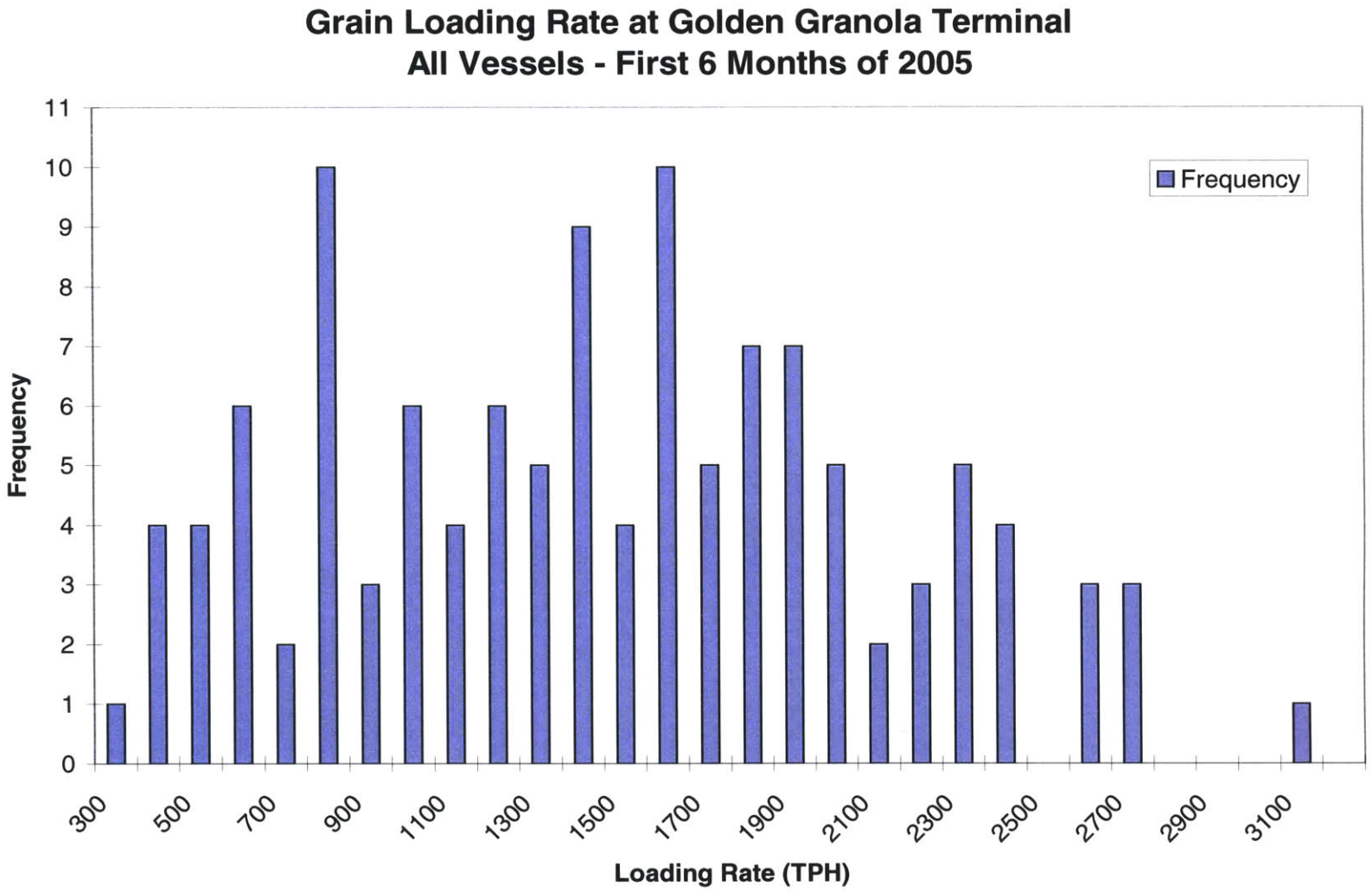

Figure 7: Grain Loading Rate at Golden Granola Terminal

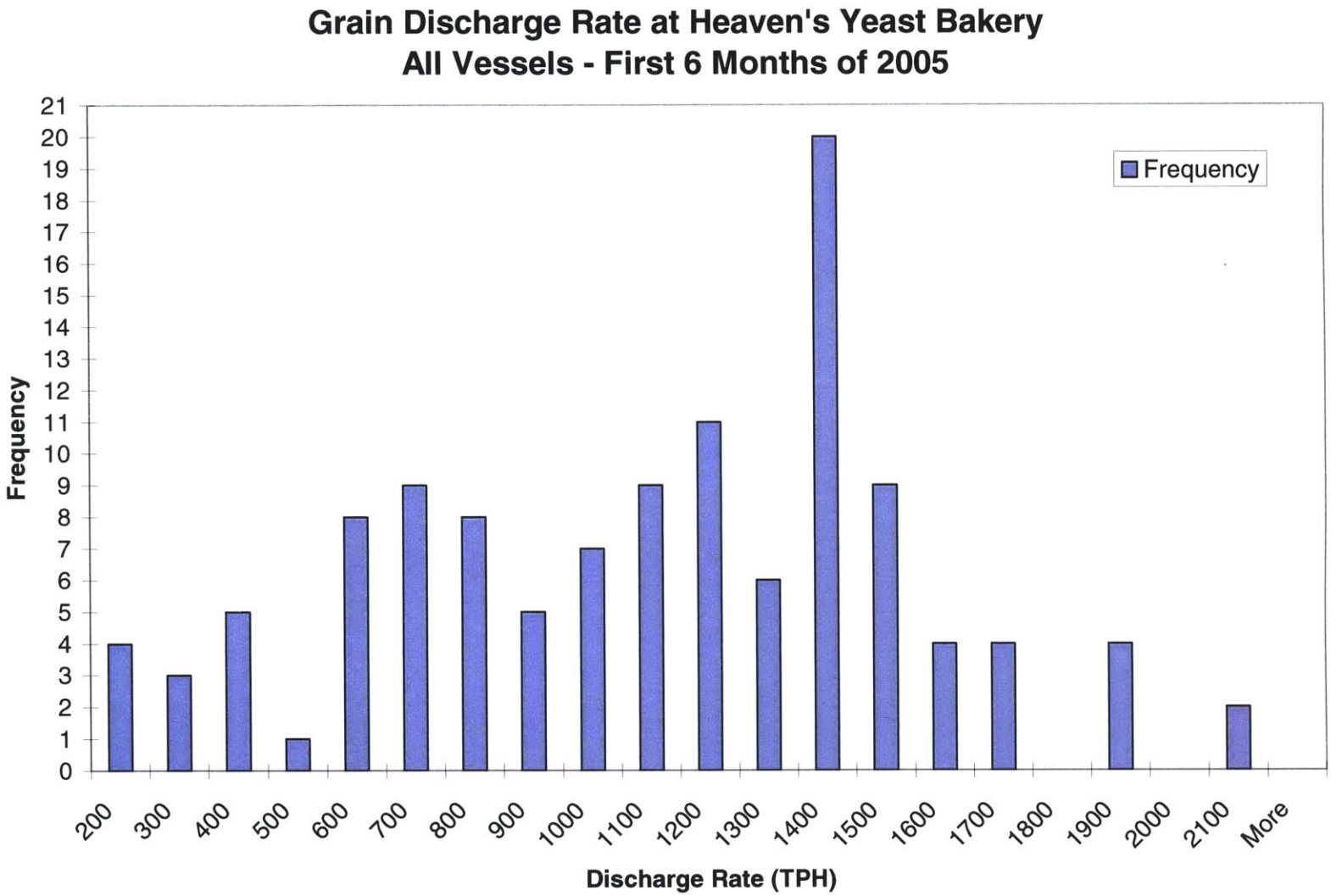

Figure 8: Grain Discharge Rate at Heaven's Yeast Bakery

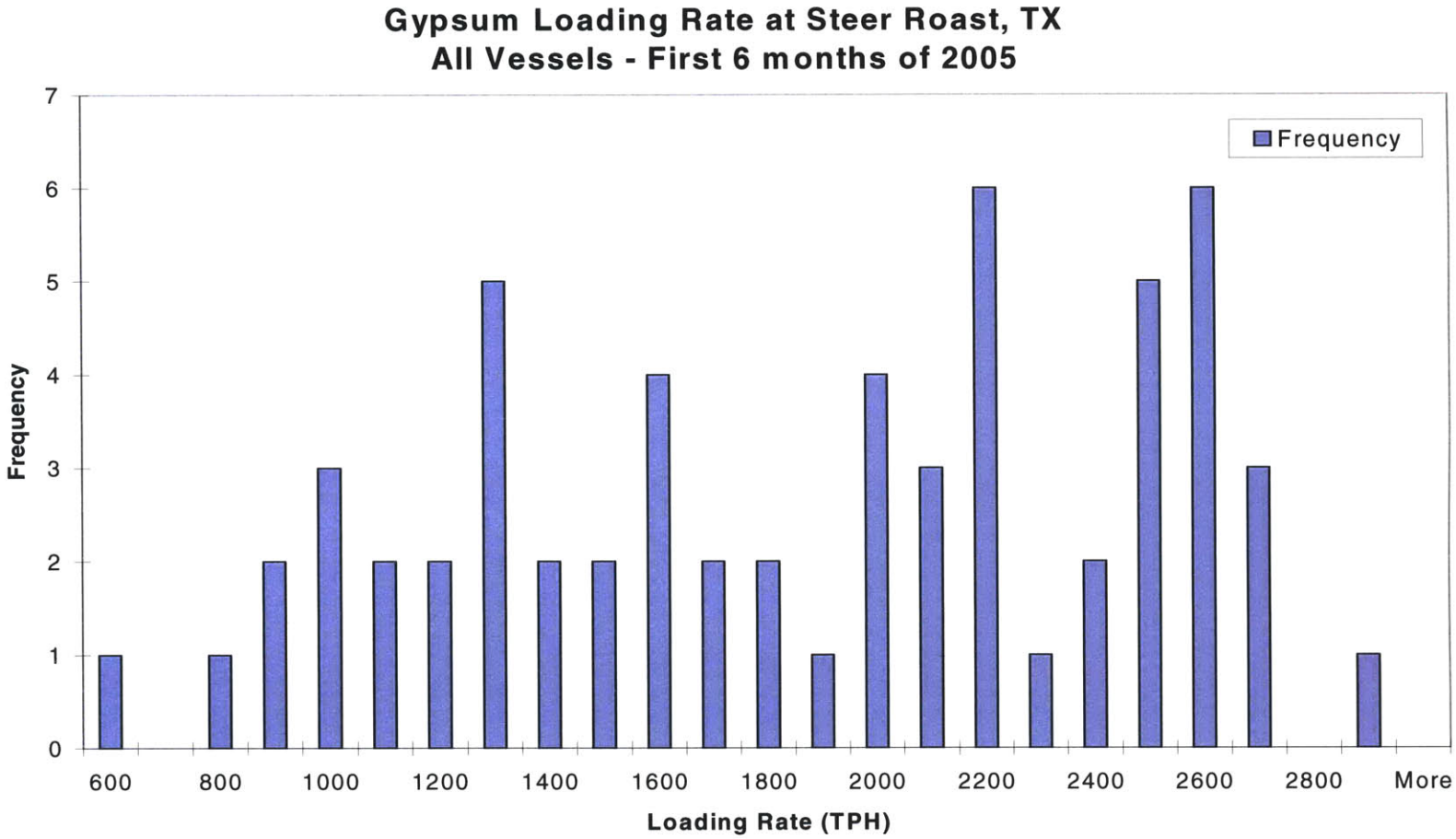

Figure 9: Gypsum Loading Rate at Steer Roast, TX

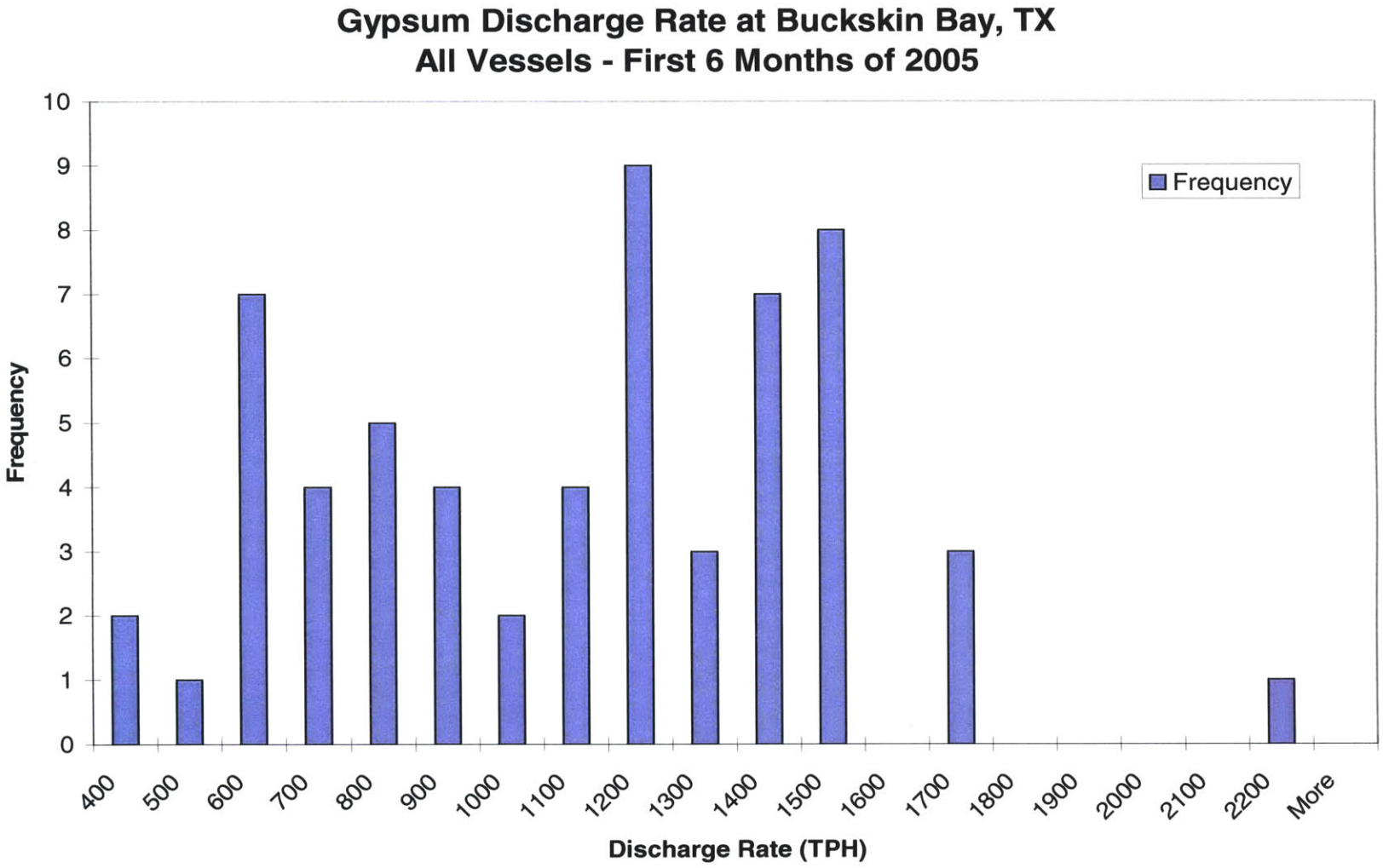

Figure 10: Gypsum Discharge Rate at Buckskin Bay, TX

Moving the estimated 4.4 million tons of grain and 2.7 million tons of gypsum can be accomplished by using a combination of three vessels:

- Vessel 1
- Vessel 2
- Vessel 3

The calculations based on the numbers in Appendix 1 assume that there will be immediate berth availability whenever a ship arrives. Shown below are the calculations used to move the allotted amount of cargo:

Vessel 2 – Year-round service moving grain and gypsum

Gypsum Moved: 1,824,412 tons

Grain Moved: 1,268,809 tons

Days of Utilization: 365 vessel-days

Vessel 3 – 48 round trips of grain and gypsum

Gypsum moved: (48 trips)(18,551 tons) = 890,448 tons

Grain Moved: (48 trips)(18,274 tons) = 877,152 tons

Days of Utilization: (7.42 days)(48 trips) = 356.16 vessel-days

Vessel 1 – 75 round trips of grain only

Grain moved: (75 trips)(30,363 tons) = 2,277,225 tons

Days of Utilization: (4.86 days)(75 trips) = 364.5 vessel-days

Total Amounts:

Grain Moved: 4,423,186 tons

Gypsum Moved: 2,714,860 tons

Days of Utilization: 1086 vessel-days

Based upon assumptions explained above and using the status quo baseline presented in Chapter 2, an estimated savings per year based on opportunity cost can be quantified:

	Status Quo	**"Ideal" Analysis**	**Savings**
Vessel-Days:	1524	1086	438
Savings:	($14,400)(438 vessel-days) = **$6.3 Million**		

Savings of this magnitude justify that further study is warranted to complete a more rigorous analysis and breakdown of possible savings for Texas Intercoastal Transport.

3.1 – Ideal Fleet and Cargo Movement

Due to changes in the fleet status at Texas Intercoastal Transport, the short-term analysis was slightly changed. The following vessels will be used in the rigorous analysis as part of step five of the seven step process:

- Vessel 4 – movement of gypsum only
- Vessel 2 – movement of grain and gypsum
- Vessel 1 – movement of grain only
- Vessel 5 – movement of grain only

The changes to the fleet were due to the fact that Vessel 3 was permanently laid up. Vessel 4 will only move gypsum due to physical limitations. In this analysis, 5.5 years of historical data was analyzed for each vessel excluding Vessel 5. This allows for a more accurate determination of loading, discharge, and transit times along with vessel cargo capacities. Instead of taking the 80^{th} percentile for the entire fleet, it is now done for each individual vessel resulting in a more precise analysis. The results used in calculating the vessel voyages are shown in Appendix 2.

Moving the estimated 4.4 million tons of grain and 2.7 million tons of gypsum can now be accomplished by using a combination of the four vessels listed above. The calculations are based on the numbers in Appendix 2 and assume that there will be immediate berth availability whenever a vessel arrives. Shown below are the calculations used to move the allotted amount of cargo:

Vessel 4 – Year-round service moving gypsum only

Gypsum Moved: 1,353,948 tons

Days of Utilization: 365 vessel-days

Vessel 2 – 35 round trips moving grain and gypsum, 15 round trips of grain only

Gypsum Moved: (35 trips)(39,507 tons) = 1,382,745 tons

Grain Moved: (50 trips)(28,861 tons) = 1,443,050 tons

Days of Utilization: 360 vessel-days

Vessel 1 – Year-round service moving grain only

Grain moved: 2,323,526 tons

Days of Utilization: 365 vessel-days

Vessel 5 – 19 round trips of grain only

Grain moved: (19 trips)(33,900 tons) = 644,100 tons

Days of Utilization: 110 vessel-days

Total Amounts:

Grain Moved: 4,410,676 tons

Gypsum Moved: 2,736,693 tons

Days of Utilization: 1200 vessel-days

Based upon assumptions explained above and using the status quo baseline presented in Chapter 2, an estimated savings per year based on opportunity cost can be quantified using this new fleet of existing self-unloaders:

	Status Quo	**Revised "Ideal" Analysis**	**Savings**
Vessel-Days:	1524	1200	324
Savings:	($14,400)(324 vessel-days) = **$4.7 Million**		

It should be noted that this fleet simulation has significant savings over the status quo even though most vessels are not used for the dual purpose of moving grain and gypsum. Only 35 round-trip voyages on the Vessel 2 had gypsum as a backhaul cargo. The other 165 trips carried a cargo one-way and returned to its loading port empty. If more backhaul cargo could be carried on vessels that transported grain, the increase in savings could be significant and would much more closely resemble the $6.3 million savings presented in the previous analysis.

3.2 – Incorporation of Vessel Scheduling

To further refine the $4.7 million savings into a more true value, the physical limitations of the vessels and berths must be accounted for. This is step five of the seven step process. In the previous analysis, it was assumed that there was unlimited berth availability at each loading and discharge facility. Now, vessel scheduling for the entire year was performed taking into account the following assumptions:

- No more than one Texas Intercoastal Transport vessel at any dock throughout the entire core trade.
- There is a 24 hour window between arriving vessels at Golden Granola Terminal. This means that if a vessel arrives on a Monday at 0900, then the next vessel may not berth at the dock until at least Tuesday at 0900 if the berth is empty at the end of the 24 hour period.
- At all other docks, one vessel will immediately move to the available berth as soon as another one leaves.
- The vessel next in line at a dock is considered "Waiting on Berth." In actuality, the vessel may not actually be anchored; it would reduce sea speed in order to coincide with the departure of the vessel currently at the dock.

The discharge rate, and subsequently the discharge time, at Heaven's Yeast Bakery were changed to reflect a completely self unloading fleet. The discharge rate used was derived for each vessel using the following graphs shown below.

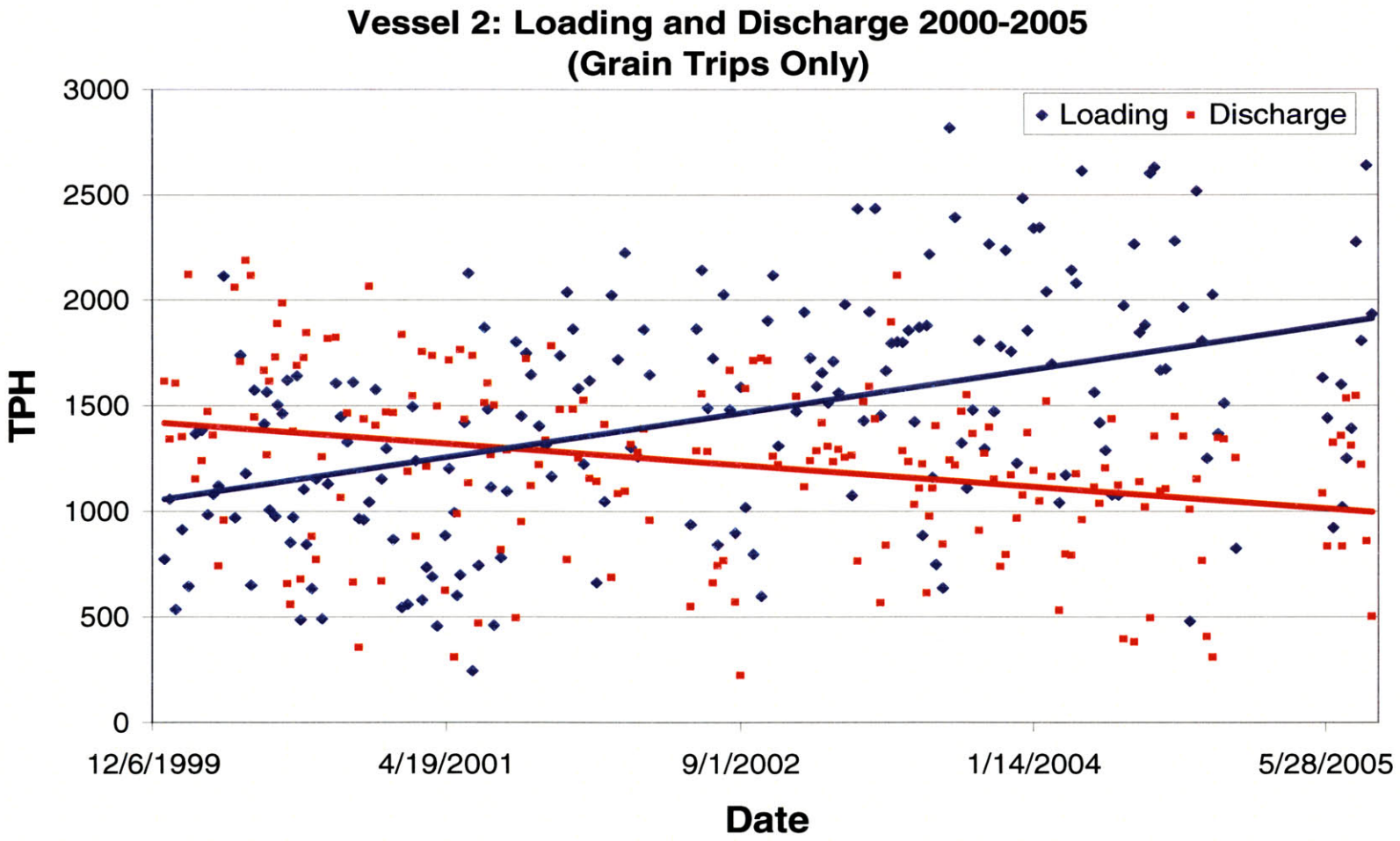

Figure 11: Vessel 2 Grain Loading and Discharge Rates

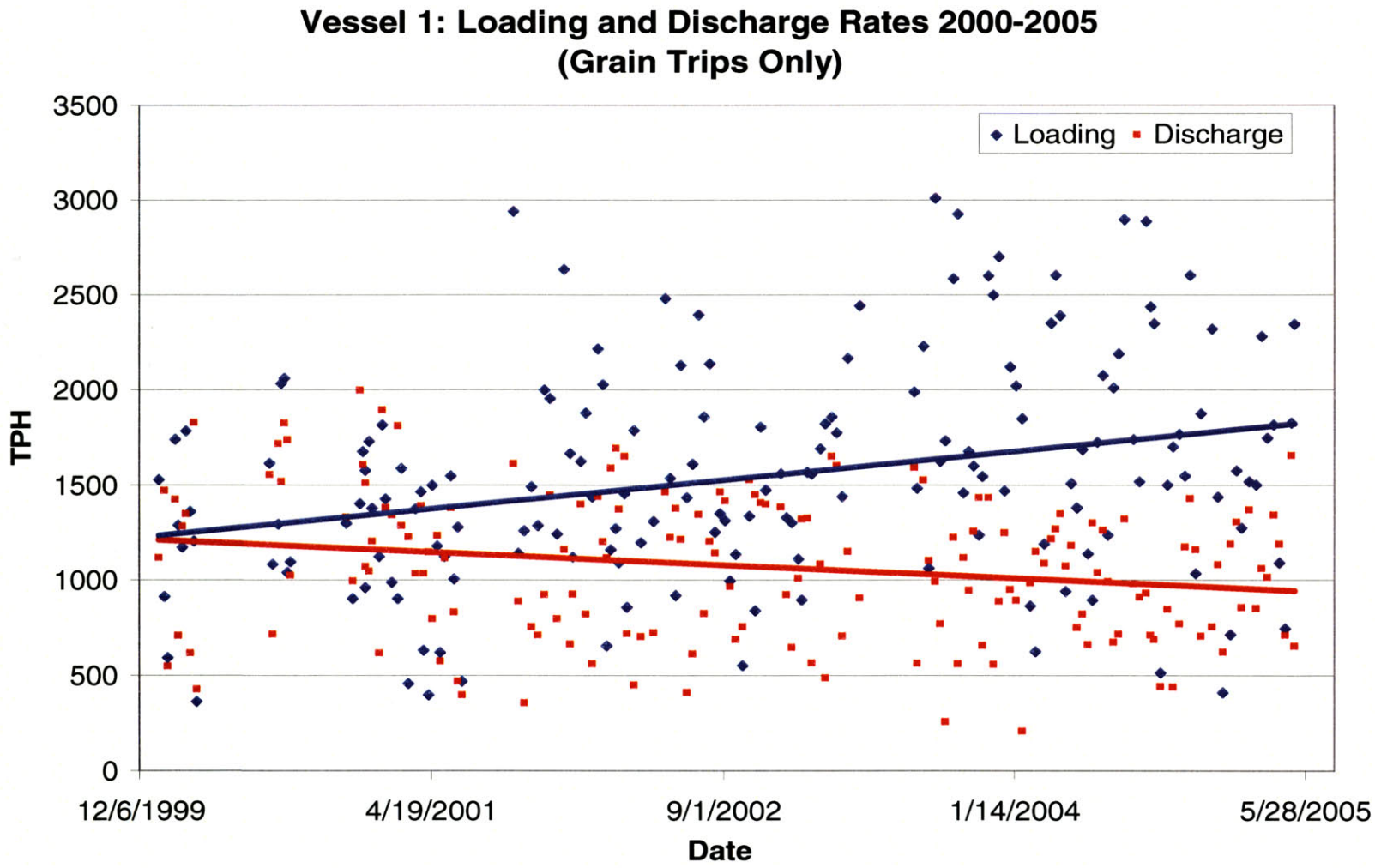

Figure 12: Vessel 1 Grain Loading and Discharge Rates

The trend over the past five years shows that the loading rate at Golden Granola Terminal has been steadily increasing while there has been a decrease in the discharge rate at Heaven's Yeast Bakery. In this new analysis, the discharge rate has been increased to the maximum point of the least squares line on the Golden Granola Terminal loading rate. The new calculation for the amount of cargo moved by each vessel in the core trade is shown in Appendix 3. Note that there was no analysis done for Vessel 5; therefore, her new discharge rate was increased to 1500 tons per hour which is inline with her loading rate at Golden Granola Terminal.

Vessel scheduling is done by taking a vessel's voyage and splitting it up into its distinct parts: transits, loading, and discharge. This is done on an hourly basis for an entire year. The voyages are then lined up consecutively for the year. In the next column over, the same process is repeated for another vessel. Each leg of the voyage is color coded as followed:

- Light Yellow – Any vessel transit
- Green – Loading of Gypsum at Steer Roast, TX
- Orange – Discharging of Gypsum at Buckskin Bay, TX
- Blue – Loading of Grain at Golden Granola Terminal
- Purple – Discharging of Grain at Heaven's Yeast Bakery

The vessels start the year at a loading dock depending on the cargo they are specified to move. Each vessel is allowed to operate at its pre-determined schedule until there are any identical colors that overlap each other except for the transits (light yellow). Once and overlap occurs, or the 24 hour arrival window is breached at Golden Granola

Terminal, the vessel arriving second is deemed as "waiting on berth" in which this time frame is denoted by black colored cells. The vessel's successive voyages are then adjusted for the rest of the year to accommodate the changes. A snapshot of the vessel scheduling is shown in Figure 13.

Note that in this process we are also broadening our analysis to account for other stakeholders in the Texas Grain and Bakery logistics system (i.e. step 6). The 24 hour waiting time described above is included to assist Golden Granola Terminal in its operations. This time will allow the terminal to plan for maintenance and repair activities. This waiting time will also allow Fertile Fields Transport to have less waiting on berth delays because of the greater predictability involved. In addition, Fertile Fields Transport considered other benefits that could be obtained by decreasing the number of high-cost loading docks that they serve. In the following analysis, we only consider the additional cost of the 24 hour waiting time; we do not consider any other benefits involved.

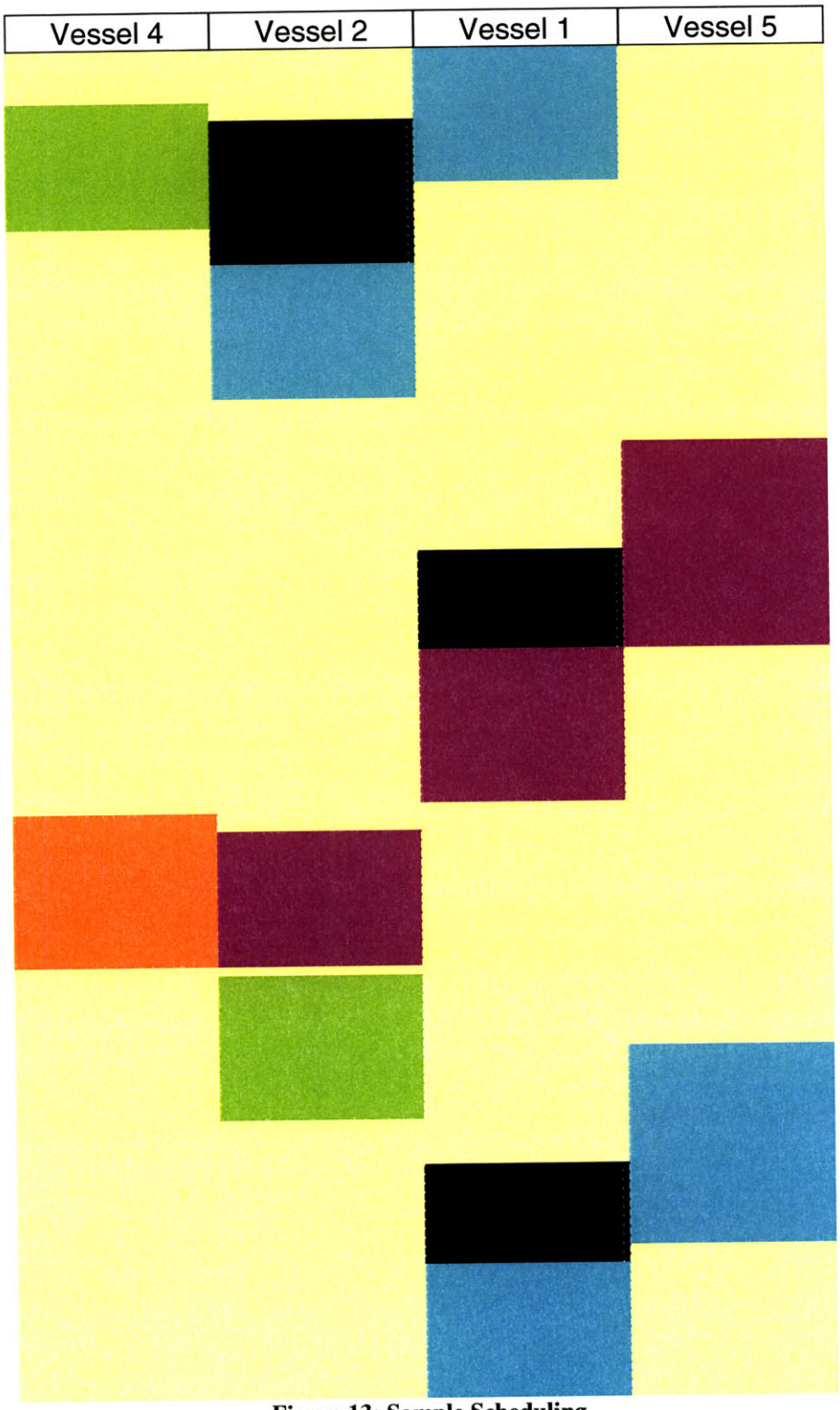

Figure 13: Sample Scheduling

Once the vessel scheduling was completed, it became obvious that due to waiting on berth, extra voyages were needed to account for the lost time. The following is a breakdown of the waiting on berth per year for each of the vessels

	Waiting on Berth Delays				
	Vessel 4	Vessel 2	Vessel 1	Vessel 5	**Total**
Days/year	2.8	9.1	30.5	1.1	**43.5**

Because of the excessive waiting on berth for Vessel 1 and Vessel 2, eight additional grain trips need to be made on Vessel 5 to account for the difference in the amount of grain that would be moved from the ideal scenario. The new calculations to move the estimated 4.4 million tons of grain and 2.7 million tons of gypsum are shown below. The calculations are based on the numbers in Appendix 3 and take into account both the faster discharge rate and additional trips needed to make up for the waiting on berth.

Vessel 4 – 55 round trips of gypsum only

Gypsum Moved: (55 trips)(24,538 tons) = 1,349,590 tons

Total Waiting on Berth: 2.8 days

Days of Utilization: 365 vessel-days

Vessel 2 – 35 round trips moving grain and gypsum, 15 round trips of grain only

Gypsum Moved: (35 trips)(39,507 tons) = 1,382,745 tons

Grain Moved: (50 trips)(28,861 tons) = 1,443,050 tons

Total Waiting on Berth: 9.2 days

Days of Utilization: 365 vessel-days

Vessel 1 – 70 round trips of grain only

Grain moved: (70 trips)(30,925 tons) = 2,164,750 tons

Total Waiting on Berth: 30.5 days

Days of Utilization: 361 vessel-days

Vessel 5 – 24 round trips of grain only

Grain moved: (24 trips)(33,900 tons) = 811,200 tons

Total Waiting on Berth: 1.1 days

Days of Utilization: 143 vessel-days

Total Amounts:

Grain Moved: 4,419,000 tons

Gypsum Moved: 2,732,335 tons

Waiting on Berth: 44 days

Days of Utilization: 1234 vessel-days

The comparison between the ideal fleet versus the refined fleet that has been scheduled and had an increased discharge rate at Heaven's Yeast Bakery is interesting to look at from a few standpoints. The first is to look at the savings versus the status quo.

	Status Quo	Scheduled Fleet	Savings
Vessel-Days:	1524	1234	290
Savings:	($14,400)(290 vessel-days) = $4.2 Million		

A second comparison is to look at the monetary impact that the waiting on berth has on the fleet when compared to the ideal fleet. The difference is shown below.

	Ideal Fleet	Scheduled Fleet	Savings
Vessel-Days:	1200	1234	-34
Savings:	($14,400)(-34 vessel-days) = -$489,600		

One major factor that cannot be underestimated or ignored is the fact that the discharge time at Heaven's Yeast Bakery was increased. The table below shows the difference in the number of voyages each vessel makes in the two scenarios.

	Ideal vs. Scheduled Fleet (number of voyages/year)					
	Vessel 4	Vessel 2 (grain only)	Vessel 2 (combined)	Vessel 1	Vessel 5	**Total**
Ideal	55	15	35	77	19	**201**
Scheduled	55	15	35	70	26	**201**

Theoretically, the table illustrates that the increased discharge rate at Heaven's Yeast Bakery in a fully self-discharging scenario makes up for the trips lost due to waiting on berth for Vessel 2. Unfortunately, the waiting on berth time for Vessel 1 is so extreme that voyages must be added onto Vessel 5 to ensure all 4.4 million tons of grain is moved.

Chapter 4: Analysis of Intermediate Fleet Allocation

An intermediate fleet scenario with the possibility of execution within the next 18 months was analyzed based on information provided by Texas Intercoastal Transport. Specifications of four vessels were provided as follows:

- Vessel 2 currently in the Texas Intercoastal Transport fleet (denoted as Vessel 2)
- One existing vessel which Texas Intercoastal Transport may purchase from an unnamed source (denoted as Vessel 6)
- The conversion of one vessel to be used in the core trade (denoted as Vessel 7)
- A tanker converted into a self-unloading dry bulk carrier (denoted as Vessel 8)

This fleet of vessels would be completely self-discharging and includes the use of Vessel 2 in combination with the purchased vessels or either Vessels 6 through 8 above. The fleet will be optimized to move 4.5 million tons of grain and 3.4 million tons of gypsum minimizing vessel-days and the number of vessels. Below is a list of assumptions used in the calculations:

- Vessels are utilized for a maximum of 355 days/year. This allows 10 days/year for out of service maintenance, inspections, and repairs. This number was provided by Texas Intercoastal Transport. A vessel-year in the results, therefore, refers to 355 days.
- If a vessel returns empty to the loading port, the return transit is 2 hours less than the fully loaded transit time.
- All grain movements are from Golden Granola Terminal to Heaven's Yeast Bakery.
- All gypsum movements are from Steer Roast, TX to Buckskin Bay, TX.

The calculations based on the numbers in Appendix 4 assume that there will be immediate berth availability whenever a vessel arrives. Three different options for ideal fleet allocations are shown below as part of step four of the seven step process.

Option 1

Vessel 2 – Year-round service moving grain and gypsum

Gypsum Moved: 1,527,168 tons

Grain Moved: 1,125,281 tons

Days of Utilization: 355 vessel-days

Vessel 6 – 45 round trips of grain and gypsum, 5 round trips of grain only

Gypsum moved: (45 trips)(42,000 tons) = 1,890,000 tons

Grain Moved: (50 trips)(36,000 tons) = 1,800,000 tons

Days of Utilization: (7.33 days)(45 trips) + (4.62 days)(5 trips) = 352.95 vessel-days

Vessel 8 – 47 round trips of grain only

Grain moved: (47 trips)(34,000 tons) = 1,598,000 tons

Days of Utilization: (5.42 days)(47 trips) = 254.74 vessel-days

Total Amounts:

Grain Moved: 4,523,281 tons

Gypsum Moved: 3,417,166 tons

Days of Utilization: 962.69 vessel-days

Option 2

Vessel 6 – Year-round service moving grain and gypsum

Gypsum Moved: 2,033,183 tons

Grain Moved: 1,742,728 tons

Days of Utilization: 355 vessel-days

Vessel 2 – 36 round trips of grain and gypsum

Gypsum moved: (36 trips)(38,000 tons) = 1,368,000 tons

Grain Moved: (36 trips)(28,000 tons) = 1,008,000 tons

Days of Utilization: (8.83 days)(36 trips) = 317.88 vessel-days

Vessel 8 – 52 round trips of grain only

Grain Moved: (52 trips)(34,000 tons) = 1,768,000 tons

Days of Utilization: (5.42 days)(52 trips) = 281.84 vessel-days

Total Amounts:

Grain Moved: 4,518,728 tons

Gypsum Moved: 3,401,183 tons

Days of Utilization: 954.72 vessel-days

Option 3

Vessel 2 – Year-round service moving grain and gypsum

Gypsum Moved: 1,527,168 tons

Grain Moved: 1,125,281 tons

Days of Utilization: 355 vessel-days

Vessel 6 – 45 round trips of grain and gypsum, 5 round trips of grain only

Gypsum moved: (45 trips)(42,000 tons) = 1,890,000 tons

Grain Moved: (50 trips)(36,000 tons) = 1,800,000 tons

Days of Utilization: (7.33 days)(45 trips) + (4.62 days)(5 trips) = 352.95 vessel-days

Vessel 7 – 50 round trips of grain only

Grain Moved: (50 trips)(32,000 tons) = 1,600,000 tons

Days of Utilization: (5.83 days)(50 trips) = 291.5 vessel-days

Total Amounts:

Grain Moved: 4,525,281 tons

Gypsum Moved: 3,417,166 tons

Days of Utilization: 999.45 vessel-days

On an ideal basis, Option 2 had the least number of vessel-days to move the specified 4.5 million tons of grain and 3.4 million tons of gypsum. Once again, vessel scheduling must be done in order to get the most accurate results. The same method of scheduling the vessels previously used was repeated. This is step five of the seven step process although including the 24 hour vessel window at Golden Granola Terminal is part of step six. The voyages were color coded as follows:

- Light Yellow – Any vessel transit
- Green – Loading of Gypsum at Steer Roast, TX
- Orange – Discharging of Gypsum at Buckskin Bay, TX
- Blue – Loading of Grain at Golden Granola Terminal
- Purple – Discharging of Grain at Heaven's Yeast Bakery

The vessels start the year at a loading dock depending on the cargo they are specified to move. Each vessel is allowed to operate at its pre-determined schedule until there are any identical colors that overlap each other except for the transits (light yellow). Once an overlap occurs, or the 24 hour arrival window is breached at Golden Granola Terminal, the vessel arriving second is deemed as "waiting on berth" in which this time frame is denoted by black colored cells. The vessel's successive voyages are then adjusted for the rest of the year to accommodate the changes. A snapshot of the vessel scheduling is shown in Figure 14.

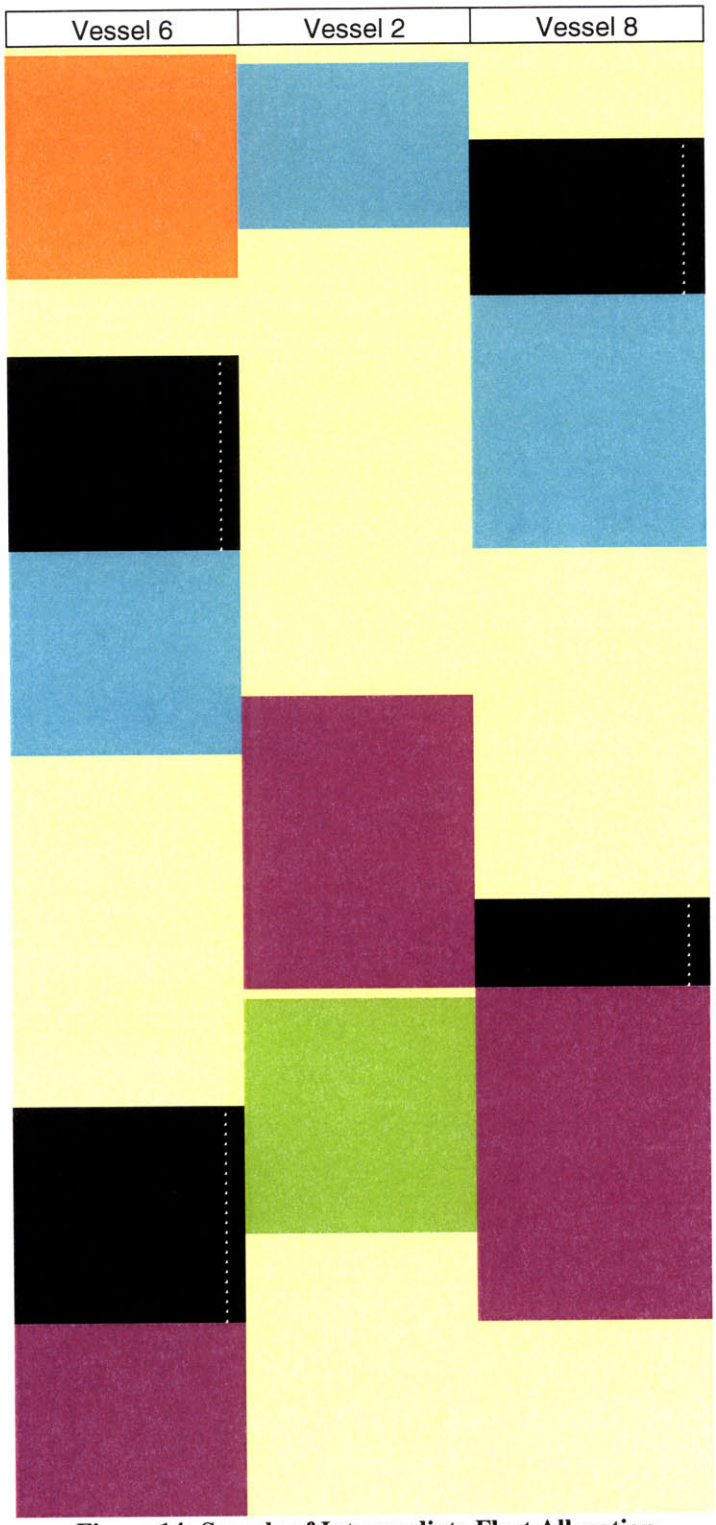

Figure 14: Sample of Intermediate Fleet Allocation

Once vessel scheduling was completed, extra voyages were again needed to account for the lost time because of waiting on berth. The following is a breakdown of the waiting on berth per year for each of the vessels:

	Waiting on Berth Delays			
	Vessel 6	Vessel 2	Vessel 8	**Total**
Days/year	34.3	19.1	24.5	**77.9**

Because there are almost 78 days of lost time due to waiting on berth, additional voyages are needed to makeup for the difference in the amount of grain and gypsum that would be moved from the ideal scenario. The calculations to move the estimated 4.5 million tons of grain and 3.4 million tons of gypsum are shown below. The calculations are based on the numbers in Appendix 4 and take into account the additional trips needed to make up for the waiting on berth.

Vessel 6 – 43 round trips of grain and gypsum

Gypsum Moved: (43 trips)(42,000 tons) = 1,806,000 tons

Grain Moved: (43 trips)(36,000 tons) = 1,548,000 tons

Days of Utilization: (8.83 days)(43 trips) + 34.3 vessel-days of waiting on berth = 349.5 vessel days

Vessel 2 – 37 round trips of grain and gypsum

Gypsum moved: (37 trips)(38,000 tons) = 1,406,000 tons

Grain Moved: (37 trips)(28,000 tons) = 1,036,000 tons

Days of Utilization: (8.83 days)(36 trips) + 19.1 vessel-days of waiting on berth = 345.8 vessel-days

Vessel 8 – 52 round trips of grain only and 5 round trips of grain and gypsum

Gypsum moved: (5 trips)(40,000 tons) = 200,000 tons

Grain Moved: (57 trips)(34,000 tons) = 1,938,000 tons

Days of Utilization: (5.42 days)(52 trips) + (8.17 days)(5 trips) + 24.5 vessel-days of waiting on berth = 347.2 vessel-days

Total Amounts:

Grain Moved: 4,522,000 tons

Gypsum Moved: 3,412,000 tons

Waiting on Berth: 77.9 vessel-days

Days of Utilization: 1043 vessel-days

To keep numbers equivalent when looking at all the scenarios, an extra thirty vessels-days have been added to the table below. This is because the "current fleet analysis" in Chapter 3 used 365 operating vessel-days per year while the intermediate scenario only uses 355 operating vessel-days. The savings versus the status quo is quantified below:

	Status Quo	Scheduled Fleet	Savings
Vessel-Days:	1524	1073	451
Savings:	($14,400)(451 vessel-days) = $6.5 Million		

There are a few reasons why the intermediate scenario has a much larger savings over the status quo. For one, the gypsum trips are all backhaul cargo. This means that

the vessels can be used for a dual purpose unlike the status quo in which Vessel 4 could only carry gypsum and nothing else. Also, Vessel 6 and Vessel 8 can carry more cargo than the vessels they replaced. Because of this, more tonnage can be moved on a per day basis. This results in fewer voyages needed in a year and significantly reduces the number of vessels-days to move the allotted cargo amounts. This becomes especially evident when it is noted that the intermediate fleet moves an additional 700,000 tons of gypsum and 100,000 tons of grain per year.

Chapter 5: Analysis of Long-Term Fleet Allocation

A long-term fleet scenario with the possibility of execution no earlier than 2009 was analyzed based on information provided by Texas Intercoastal Transport. Specifications of the vessels to be used in this trade were provided as follows:

- Vessel 1 currently in the Texas Intercoastal Transport fleet (denoted as Vessel 1)
- One existing vessel which Texas Intercoastal Transport may purchase from an unnamed source (denoted as Vessel 6)
- The conversion of one vessel to be used in the core trade (denoted as Vessel 7)
- A tanker converted into a self-unloading dry bulk carrier (denoted as Vessel 8)
- The possibility of two new-build vessels (denoted as Vessel 9 and Vessel 10)

This fleet of vessels would be completely self-discharging in which one option would not include any new builds. The fleet will be optimized to move 7.0 million tons of grain and 3.4 million tons of gypsum minimizing vessel-days and the number of vessels. Below is a list of assumptions used in the calculations:

- Vessels are utilized for a maximum of 355 days/year. This allows 10 days/year for out of service maintenance, inspections, and repairs. This number was provided by Texas Intercoastal Transport. A vessel-year in the results, therefore, refers to 355 days.
- If a vessel returns empty to the loading port, the return transit is 2 hours less than the fully loaded transit time.
- The data used for Vessel 1 is based on the 80^{th} percentile from historical information.

- All grain movements are from Golden Granola Terminal to Heaven's Yeast Bakery
- All gypsum movements are from Steer Roast, TX to Buckskin Bay, TX.

The calculations based on the numbers in Appendix 4 assume that there will be immediate berth availability whenever a vessel arrives. This is step four of the seven step process. Three different options for ideal fleet allocations are shown below.

Option 1

Vessel 9 – Year-round service moving grain and gypsum

Gypsum Moved: 2,078,047 tons

Grain Moved: 1,870,243 tons

Days of Utilization: 355 vessel-days

Vessel 10 – 27 round trips of grain and gypsum, 23 round trips of grain only

Gypsum moved: (27 trips)(50,000 tons) = 1,350,000 tons

Grain Moved: (50 trips)(45,000 tons) = 2,250,000 tons

Days of Utilization: (8.54 days)(27 trips) + (5.25 days)(23 trips) = 351.33 vessel-days

Vessel 6 – Year-round service moving grain only

Grain Moved: 2,763,244 tons

Days of Utilization: 355 vessel-days

Vessel 8 – 4 round trips of grain only

Grain Moved: (4 trips)(34,000 tons) = 136,000 tons

Days of Utilization: (5.42 days)(4 trips) = 21.68 vessel-days

Total Amounts:

Grain Moved: 7,019,487 tons

Gypsum Moved: 3,428,047 tons

Days of Utilization: 1083.01 vessel-days

Option 2

Vessel 9 – Year-round service moving grain and gypsum

Gypsum Moved: 2,078,047 tons

Grain Moved: 1,870,243 tons

Days of Utilization: 355 vessel-days

Vessel 6 – 32 round trips of grain and gypsum, 26 round trips of grain only

Gypsum moved: (32 trips)(42,000 tons) = 1,344,000 tons

Grain Moved: (58 trips)(36,000 tons) = 2,088,000 tons

Days of Utilization: (7.33 days)(32 trips) + (4.62 days)(26 trips) = 354.68 vessel-days

Vessel 8 – Year-round service moving grain only

Grain Moved: 2,228,306 tons

Days of Utilization: 355 vessel-days

Vessel 7 – 26 round trips of grain only

Grain Moved: (26 trips)(32,000 tons) = 832,000 tons

Days of Utilization: (5.83 days)(26 trips) = 151.58 days

Total Amounts:

Grain Moved: 7,018,549 tons

Gypsum Moved: 3,422,047 tons

Days of Utilization: 1216.26 vessel-days

Option 3

Vessel 6 – Year-round service moving grain and gypsum

Gypsum Moved: 2,033,183 tons

Grain Moved: 1,742,728 tons

Days of Utilization: 355 vessel-days

Vessel 8 – 35 round trips of grain and gypsum, 12 round trips of grain only

Gypsum moved: (35 trips)(40,000 tons) = 1,400,000 tons

Grain Moved: (47 trips)(34,000 tons) = 1,598,000 tons

Days of Utilization: (8.17 days)(35 trips) + (5.42 days)(12 trips) = 350.99 vessel-days

Vessel 1 – Year-round service moving grain only

Grain Moved: 2,259,868 tons

Days of Utilization: 355 vessel-days

Vessel 7 – 44 round trips of grain only

Grain Moved: (44 trips)(32,000 tons) = 1,408,000 tons

Days of Utilization: (5.83 days)(44 trips) = 256.52 days

Total Amounts:

Grain Moved: 7,008,596 tons

Gypsum Moved: 3,433,183 tons

Days of Utilization: 1317.51 vessel-days

On an ideal basis, Option 1 had the least number of vessel-days to move the specified 7.0 million tons of grain and 3.4 million tons of gypsum. Once again, vessel scheduling must be done in order to get the most accurate results. The same method of scheduling the vessels previously used was repeated. This is step five and six of the seven step process. The voyages were color coded as follows:

- Light Yellow – Any vessel transit
- Green – Loading of Gypsum at Steer Roast, TX
- Orange – Discharging of Gypsum at Buckskin Bay, TX
- Blue – Loading of Grain at Golden Granola Terminal
- Purple – Discharging of Grain at Heaven's Yeast Bakery

The vessels start the year at a loading dock depending on the cargo they are specified to move. Each vessel is allowed to operate at its pre-determined schedule until there are any identical colors that overlap each other except for the transits (light yellow). Once and overlap occurs, or the 24 hour arrival window is breached at Golden Granola Terminal, the vessel arriving second is deemed as "waiting on berth" in which this time frame is denoted by black colored cells. In the long-term analysis, some of the vessels take longer than 24 hours to load at Golden Granola Terminal. If this happened during the scheduling, the vessel that was waiting on berth would automatically be shifted to the dock once the other one left. The vessel's successive voyages are then adjusted for the rest of the year to accommodate the changes. A snapshot of the vessel scheduling is shown below in Figure 15:

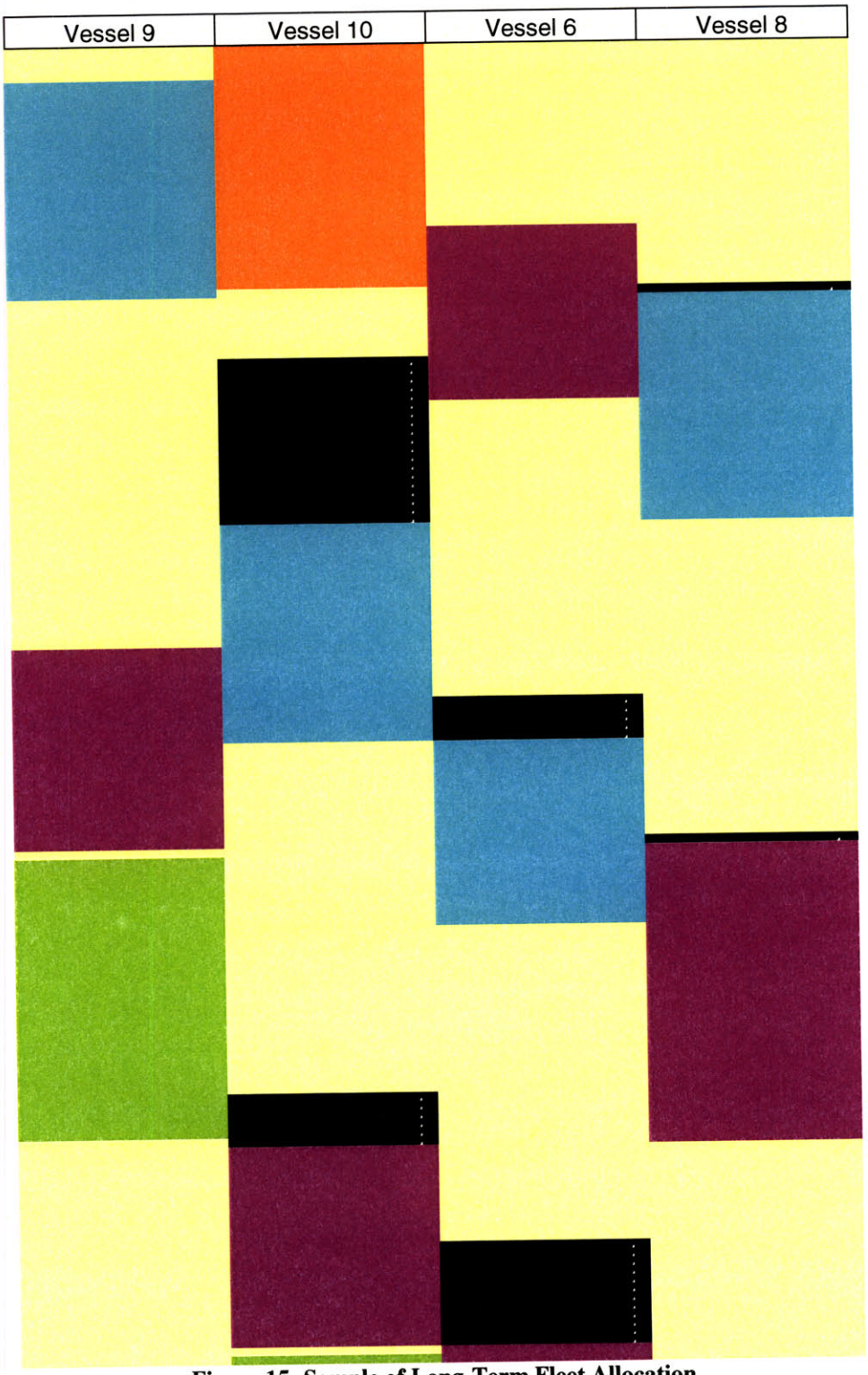

Figure 15: Sample of Long-Term Fleet Allocation

Once vessel scheduling was completed, extra voyages were again needed to account for the lost time because of waiting on berth. The following is a breakdown of the waiting on berth per year for each of the vessels:

	Waiting on Berth Delays				
	Vessel 9	Vessel 10	Vessel 6	Vessel 8	**Total**
Days/year	21.6	19.6	30.6	0.6	**72.4**

Because there are 72.4 days of lost time due to waiting on berth, additional voyages are needed to makeup for the difference in the amount of grain and gypsum that would be moved from the ideal scenario. The new calculations to move the estimated 7.0 million tons of grain and 3.4 million tons of gypsum are shown below. The calculations are based on the numbers in Appendix 4 and take into account the additional trips needed to make up for the waiting on berth.

Vessel 9 – 39 round trips of grain and gypsum combined

Gypsum Moved: (39 trips)(50,000 tons) = 1,950,000 tons

Grain Moved: (39 trips)(45,000 tons) = 1,755,000 tons

Days of Utilization: (8.54 days)(39 trips) + 21.6 vessel-days of waiting on berth = 354.7 vessel-days

Vessel 10 – 30 round trips of grain and gypsum, 14 round trips of grain only

Gypsum moved: (30 trips)(50,000 tons) = 1,500,000 tons

Grain Moved: (44 trips)(45,000 tons) = 1,980,000 tons

Days of Utilization: (8.54 days)(30 trips) + (5.25 days)(14 trips) + 19.6 vessel-days of waiting on berth = 349.3 vessel-days

Vessel 6 – 69 round trips of grain only

Grain Moved: (69 trips)(36,000 tons) = 2,484,000 tons

Days of Utilization: (4.62 days)(69 trips) + 30.6 vessel-days of waiting on berth = 349.4 vessel-days

Vessel 8 – 23 round trips of grain only

Grain Moved: (23 trips)(34,000 tons) = 782,000 tons

Days of Utilization: (5.42 days)(23 trips) + 0.6 vessel-days of waiting on berth = 125.3 vessel-days

Total Amounts:

Grain Moved: 7,001,000 tons

Gypsum Moved: 3,450,000 tons

Waiting on Berth: 72.4 vessel-days

Days of Utilization: 1179 vessel-days

To keep numbers equivalent when looking at the scenarios, an extra thirty vessels-days have been added to the table below. This is because the "current fleet analysis" in Chapter 3 used 365 operating vessel-days per year. Also, the "intermediate scenario" had an additional 30 vessel-days added as well because it used 355 operating vessel-days per year. The savings versus the status quo is quantified below:

	Status Quo	Scheduled Fleet	Savings
Vessel-Days:	1524	1209	315
Savings:	($14,400)(315 vessel-days) = $4.6 Million		

The savings represented in the long-term fleet analysis are very surprising considering the circumstances. There are going to be obvious efficiencies because all of the gypsum trips are carried as backhaul cargo. Another factor is that the newly built vessels are much larger than their predecessors. The unforeseen benefit is the fact there is still a significant savings as compared to the status quo. In this scenario, there is an additional 2.5 million tons of grain and 700,000 tons of gypsum being transported. With such a large amount in the increase of cargo, why is there still 315 vessels-days of savings? If the scheduling is closely looked at, it becomes clear that the waiting on berth is significantly less than the status quo even though there are many more trips being made. Vessel 9 and Vessel 10 are exactly the same ships; therefore, their scheduling is the same as well. They both operate a majority of the year on the same route moving grain and gypsum. Because of this, the waiting on berth is significantly decreased due to the fact that the vessels naturally start to simulate a liner-type service. An anomaly in the results is the fact that Vessel 8 has less than one vessel-day of waiting on berth for the time that she is in service. The schedule that the vessel is simulated with happens to fit

perfectly in with the other vessels and, as a result, has almost no waiting on berth for the time it is in service.

Chapter 6: Analysis of Delays

As another part of step seven of the seven step process, two major delays apparent in the Texas Intercoastal Transport fleet are weather and mechanical delays. Note that our analysis showed that vessels with identical round trip times will have no waiting on berth delays if there are no weather or mechanical delays that disrupt vessel schedules. Consequently, these delays become an important consideration. Though weather can be unpredictable at times, over long periods, trending of the delays in the fleet can help determine certain seasons or time frames in which the opportunity for optimal cargo movement is available. Figure 16 shows five and a half years of grain data for five vessels laid on top of each other. The seasons of the year are split up accordingly and the average and standard deviations for the vessels are shown. It is interesting to note that the spring season is historically the most optimal timeframe to transport grain. This is especially advantageous for Texas Grain and Bakery since the summer consumption rates are typically much higher than other times of the year. The spring season will allow for a lull in the weather in order to boost inventory levels to prepare for hurricane season service interruptions.

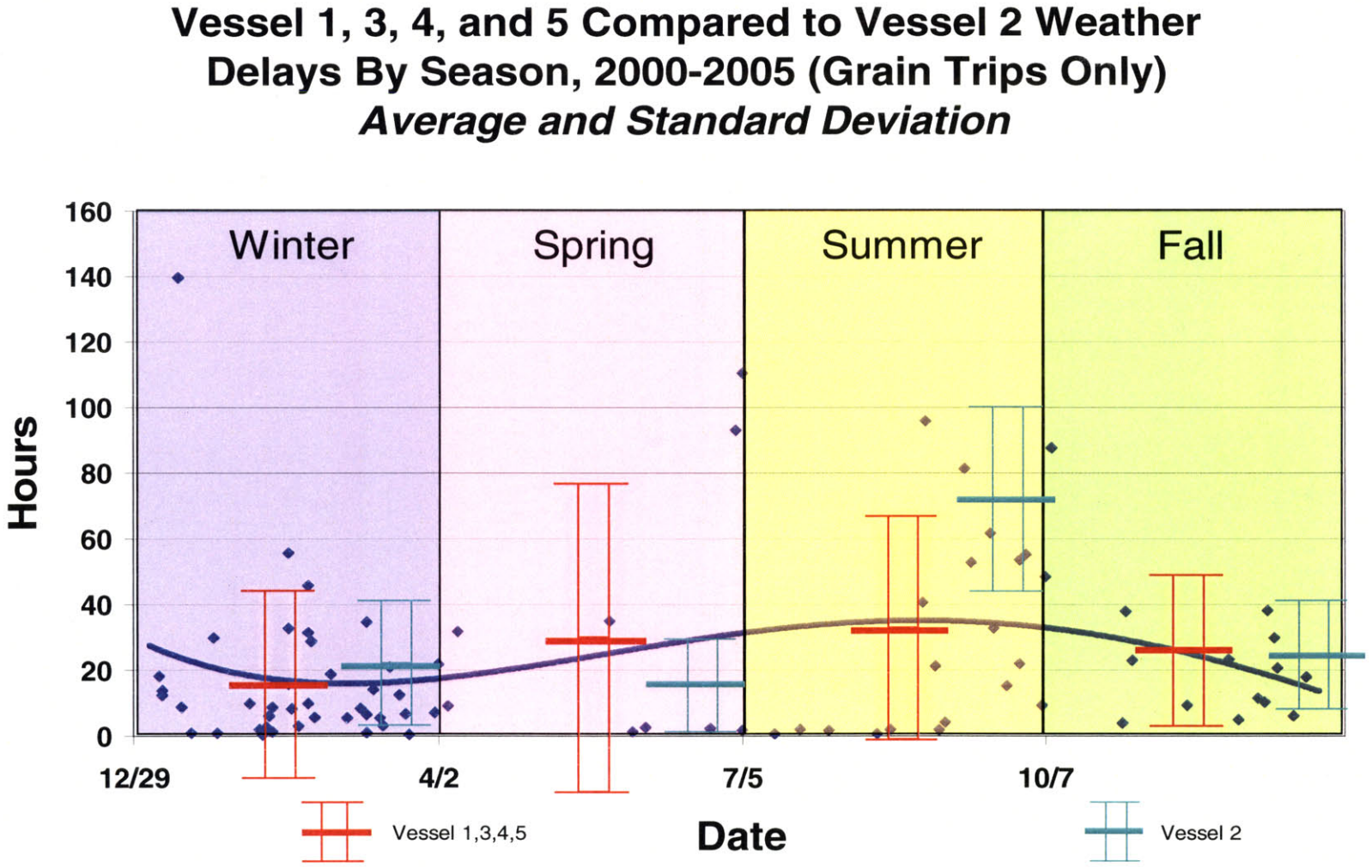

Figure 16: Grain Trip Weather Delays (2000-2005)

The cause of mechanical delays can be hard to pinpoint. In the case of Texas Intercoastal Transport's vessels, the delays could be engine room, hull, or discharge equipment related among others. The delay sheets which show the delays are denoted as "maintenance." However, maintenance should not adversely affect the scheduling of a vessel. Because the maintenance times on the delay sheet affect the vessel's voyage, they should be considered breakdowns. Figures 17 and 18 each show three important pieces of data for their specified vessel. The vertical bars are the number of delays for that year. The green line shows the frequency of the delays which is defined as the number of delays divided by the number of voyages. Finally, the red line shows the average delay in hours.

Vessel 2, shown in Figure 17, illustrates that even though the total number of delays has decreased since 2002, the frequency has gone up. Also, as the frequency of the delay has gone up, so has the average delay length in the same timeframe. Vessel 1, shown in Figure 18, has some startling details. The vessel was in the shipyard in 2003, which was one of the lowest years in terms of the number of delays, frequency, and average delay time. However, the two consecutive years following, namely 2005, show that 70% of voyages had some kind of mechanical delay.

These results need further analysis to find the cause before a solution can be proposed. However, the number of delays currently present has a negative impact on the productivity of the fleet. A delay on one vessel can theoretically impact all others waiting in the queue behind it. This ripple effect can compound significantly throughout the entire core trade.

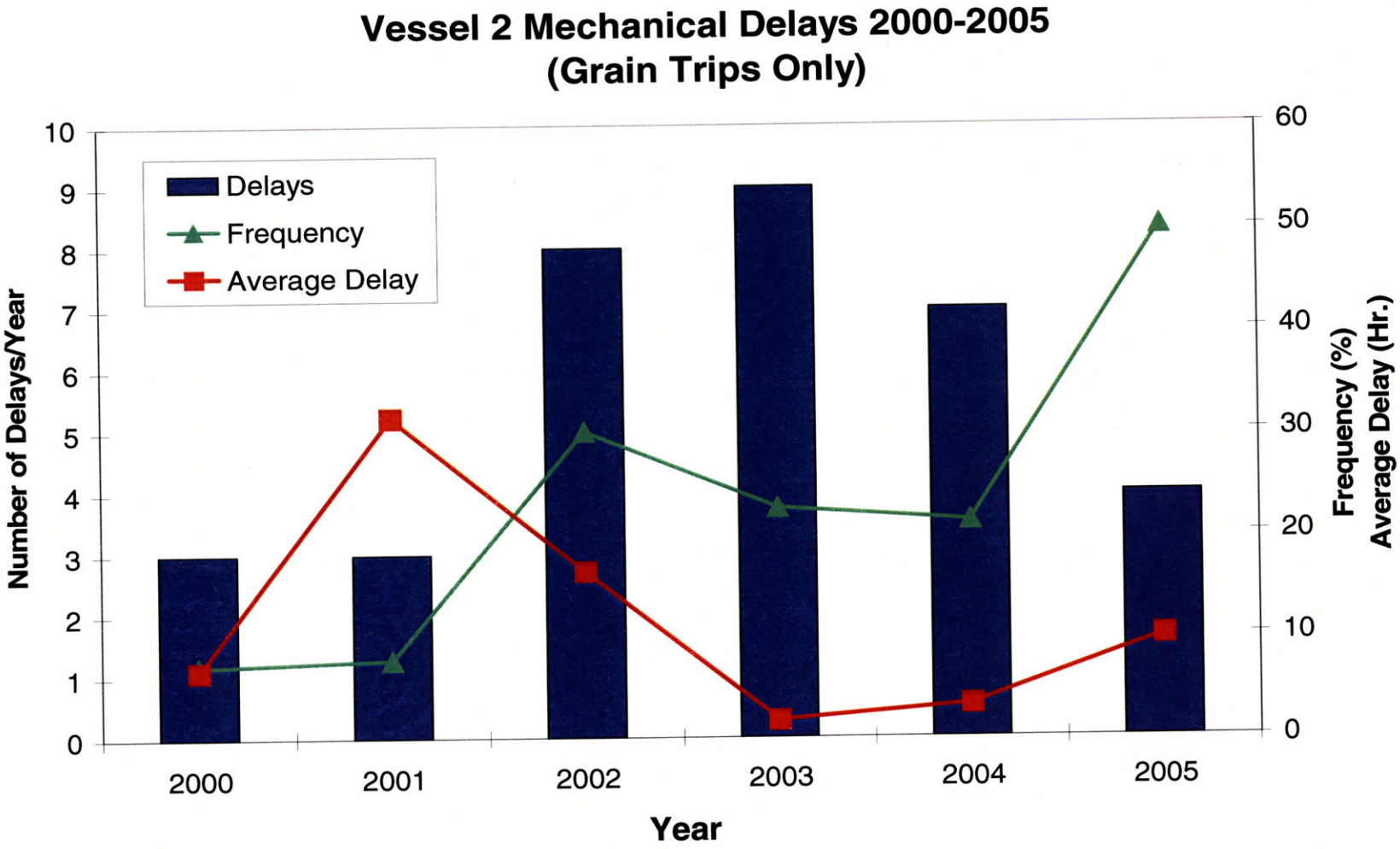

Figure 17: Vessel 2 Grain Trip Mechanical Delays (2000-2005)

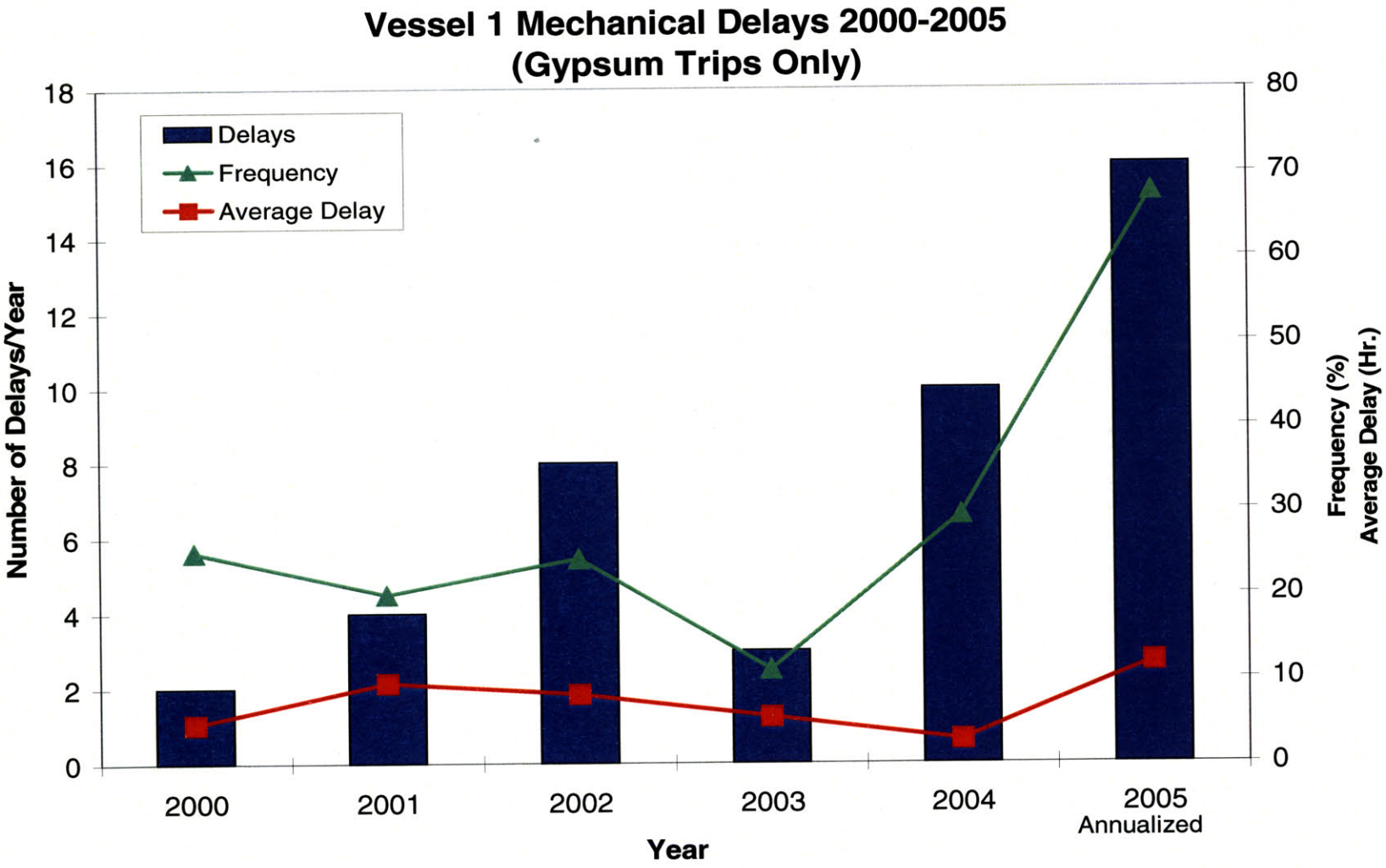

Figure 18: Vessel 1 Gypsum Trip Mechanical Delays (2000-2005)

Chapter 7: Conclusions and Recommendations

After completing the seven step process as outlined in Chapter 1, there are many conclusions that can be drawn. The basic conclusions are as follows:

- Dedicated vessels will improve productivity in the core trade.
- A self-unloading fleet will increase productivity and predictability.
- Vessels with similar round trip times, on a scheduled service, are the key to avoiding waiting on berth delays.
- Effectively eliminating mechanical delays and better planning for weather delays will increase fleet productivity.

The following table shows a breakdown of the results of each analysis performed:

	2005 Annualized (Status Quo)	Current Fleet	Intermediate Fleet	Long Term
Grain (M Tons)	4.4	4.4	4.5	7.0
Gypsum (M Tons)	2.7	2.7	3.4	3.4
Total (M Tons)	7.1	7.1	7.9	10.4
Vessel-Days	1524	1234	1073	1209
Tons/Vessel-Day	4659	5754	7363	8602
Waiting on Berth (days)	154	44	78	72
Opportunity Cost of WOB Delays	$4.4 M	$1.3 M	$2.2 M	$2.1 M
Savings vs. Status Quo	$0.0 M	$4.2 M	$6.5 M	$4.6 M

Figure 19: Results of Analysis

Each of the above fleets simulated minimized the number of vessels and vessel-days in order to make the system as predictable and productive as possible. There were ten different vessels used in the 2005 annualized timeframe. Because so many vessels

went in and out of the core trade, excessive amounts of waiting on berth became an inherent part of the system. By dedicating vessels that will operate exclusively in the core trade, waiting on berth can be minimized. It is important to note that 136 of the vessel-days that are saved when comparing the 2005 Annualized Fleet (status quo) to the Current Fleet are not due to waiting on berth. They are strictly due to gains in fleet productivity as there is a 23% increase in the tons moved per vessel-day. The gains also assume that the fleet will meet the 80^{th} percentile rates defined in the analysis. Hidden in such an analysis is the fact that vessels slowed down when it was known they would be waiting on berth. Consequently, some of the waiting on berth time was transferred to the transit time category.

Looking at the Intermediate Fleet, the importance of larger vessels and a self-discharging capability become more evident. In this scenario, all gypsum carried is done as a backhaul. Also, Vessel 6 and Vessel 8 replace vessels that are less productive. These efficiencies allow the number of vessels in the core trade to be reduced from four to three. There is also more grain and gypsum being moved in the same amount of time. Even with this additional cargo, the savings over the status quo equates to $6.5 Million per year.

The Long-Term Fleet presents a much different case in which there will be a total of 10.4 million tons of cargo moved in the core trade. This differs greatly from the 7.1 million tons transported in the 2005 annualized data (status quo). The introduction of two new-build vessels along with Vessel 6 and Vessel 8 make up this fleet. Even with the greatly increased cargo amounts, a savings of $4.6 Million per year is possible due to larger vessels, and the two new-builds being identical which aid in scheduling.

It should be noted that even though there is a lot of money to be saved, inefficiencies are an inherent part of the system. Waiting on berth is not something that can be easily vanquished. One vessel will being moving just gypsum or grain for the entire year while a different vessel will only move gypsum as a backhaul for part of the year before switching over to moving grain only. This changes vessel trip times and berth availability through the entire system. The different trip durations along with vessels not being similar to each other add even more inefficiencies to the system. There never really is any uniformity until the two new-build vessels are added in the Long Term Fleet.

Mechanical delays are an area where further study is warranted. In actuality, the number of mechanical delays should be a statistical anomaly rather than an accepted drag on the productivity of the core trade. A proper maintenance management program coupled with tight specifications for shipyard drydockings will greatly reduce the number of delays.

In conclusion, the setting of overall supply chain goals and the implementation of a maintenance management system, when combined with minimal mechanical delays will allow Texas Grain and Bakery to obtain several million dollars of savings even with significant growth in cargo movements.

Appendix:

Appendix 1: Simple Analysis Core Trade Vessel Specifications

Vessels Moving Grain Only

Vessel:	Vessel 1
Load Rate at GGT (TPH):	2,100.00
Discharge Rate at HYB (TPH):	1,500.00
Tons Loaded Grain:	30,363.00
Loading Time at GGT (hours):	14.46
Transit GGT to HYB (hours):	40.90
Discharge Time at HYB (hours):	20.24
Transit HYB to GGT (hours):	41.00
Round Trip (hours):	116.60
Round Trip (days):	4.86
Trips/year	75.13
Tons moved/day (tons)	6,249.64
Tons moved/yr (tons)	2,281,119.87

Appendix 1: Simple Analysis Core Trade Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 2
Load Rate at GGT (TPH):	2,100.00
Discharge Rate at HYB (TPH):	1,500.00
Load Rate at Steer Roast (TPH):	2,500.00
Discharge Rate at Buckskin (TPH):	1,500.00
Tons Loaded Grain	28,000.00
Tons Loaded Gypsum	40,261.00
Loading Time at GGT (hours):	13.33
Transit GGT to HYB (hours):	47.07
Discharge Time at HYB (hours):	18.67
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	16.10
Transit Steer Roast to Buckskin (hours):	62.30
Discharge Time at Buckskin Bay, TX	26.84
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	193.32
Round Trip (days):	8.05
Trips/year	45.31
Grain Moved/day (tons)	3,476.19
Gypsum Moved/day (tons)	4,998.39
Tons moved/yr (grain)	1,268,809.54
Tons moved/yr (gypsum)	1,824,412.17

Appendix 1: Simple Analysis Core Trade Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 3
Load Rate at GGT (TPH):	2,100.00
Discharge Rate at HYB (TPH):	1,500.00
Load Rate at Steer Roast (TPH):	2,500.00
Discharge Rate at Buckskin (TPH):	1,500.00
Tons Loaded Grain	18,274.00
Tons Loaded Gypsum	18,551.00
Loading Time at GGT (hours):	8.70
Transit GGT to HYB (hours):	61.17
Discharge Time at HYB (hours):	12.18
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	7.42
Transit Steer Roast to Buckskin (hours):	67.30
Discharge Time at Buckskin Bay, TX	12.37
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	178.14
Round Trip (days):	7.42
Trips/year	49.17
Grain Moved/day (tons)	2,461.94
Gypsum Moved/day (tons)	2,499.26
Tons moved/yr (grain)	898,608.78
Tons moved/yr (gypsum)	912,230.03

Appendix 2: Refined "Ideal" Core Trade Vessel Specifications

Vessels Moving Gypsum Only

Vessel:	Vessel 4
Load Rate at Steer Roast (TPH):	1,714.00
Discharge Rate at Buckskin (TPH):	1,423.00
Tons Loaded	24,538.00
Loading Time (hours):	14.32
Transit Steer Roast to Buckskin (hours):	64.60
Discharge Time (hours):	17.24
Transit Buckskin to Steer Roast (hours):	62.60
Round Trip (hours):	158.76
Round Trip (days):	6.62
Trips per Year	55.18
Tons moved/day (tons)	3,709.45
Tons moved/yr (tons)	1,353,948.00

Vessels Moving Grain Only

Vessel:	Vessel 2
Load Rate at GGT (TPH):	1,881.00
Discharge Rate at HYB (TPH):	1,667.00
Tons Loaded	28,861.00
Loading Time (hours):	15.34
Transit GGT to HYB (hours):	47.70
Discharge Time (hours):	17.31
Transit HYB to GGT (hours):	45.70
Round Trip (hours):	126.06
Round Trip (days):	5.25
Trips per year	69.49
Tons moved/day (tons)	5,494.87
Tons moved/yr (tons)	2,005,626.18

Appendix 2: Refined "Ideal" Core Trade Vessel Specifications (continued)

Vessels Moving Grain Only

Vessel:	Vessel 1
Load Rate at GGT (TPH):	2,078.00
Discharge Rate at HYB (TPH):	1,465.00
Tons Loaded	30,925.00
Loading Time (hours):	14.88
Transit GGT to HYB (hours):	41.30
Discharge Time (hours):	21.11
Transit HYB to GGT (hours):	39.30
Round Trip (hours):	116.59
Round Trip (days):	4.86
Trips per year	75.13
Tons moved/day (tons)	6,365.83
Tons moved/yr (tons)	2,323,526.45

Vessel:	Vessel 5
Load Rate at GGT (TPH):	1,546.00
Discharge Rate at HYB (TPH):	1,177.00
Tons Loaded	33,800.00
Loading Time (hours):	21.86
Transit GGT to HYB (hours):	46.00
Discharge Time (hours):	28.72
Transit HYB to GGT (hours):	44.00
Round Trip (hours):	140.58
Round Trip (days):	5.86
Trips per year	62.31
Tons moved/day (tons)	5,770.38
Tons moved/yr (tons)	2,106,189.41

Appendix 2: Refined "Ideal" Core Trade Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 2
Load Rate at GGT (TPH):	1,881.00
Discharge Rate at HYB (TPH):	1,667.00
Load Rate at Steer Roast (TPH):	2,414.00
Discharge Rate at Buckskin (TPH):	1,588.00
Tons Loaded Grain	28,861.00
Tons Loaded Gypsum	39,507.00
Loading Time at GGT (hours):	15.34
Transit GGT to HYB (hours):	47.70
Discharge Time at HYB (hours):	17.31
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	16.37
Transit Steer Roast to Buckskin (hours):	63.10
Discharge Time at Buckskin Bay, TX	24.88
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	193.70
Round Trip (days):	8.07
Trips/year	45.22
Grain Moved/day (tons)	3,575.95
Gypsum Moved/day (tons)	4,895.01
Tons moved/yr (grain)	1,305,220.92
Tons moved/yr (gypsum)	1,786,679.70

Appendix 3: Increased Discharge Rate Vessel Specifications

Vessels Moving Grain Only

Vessel:	Vessel 2
Load Rate at GGT (TPH):	1,881.00
Discharge Rate at HYB (TPH):	1,900.00
Tons Loaded	28,861.00
Loading Time (hours):	15.34
Transit GGT to HYB (hours):	47.70
Discharge Time (hours):	15.19
Transit HYB to GGT (hours):	45.70
Round Trip (hours):	123.93
Round Trip (days):	5.16
Trips per year	70.68
Tons moved/day (tons)	5,589.00
Tons moved/yr (tons)	2,039,985.10

Vessel:	Vessel 1
Load Rate at GGT (TPH):	2,078.00
Discharge Rate at HYB (TPH):	1,825.00
Tons Loaded	30,925.00
Loading Time (hours):	14.88
Transit GGT to HYB (hours):	41.30
Discharge Time (hours):	16.95
Transit HYB to GGT (hours):	39.30
Round Trip (hours):	112.43
Round Trip (days):	4.68
Trips per year	77.92
Tons moved/day (tons)	6,601.60
Tons moved/yr (tons)	2,409,583.72

Appendix 3: Increased Discharge Rate Vessel Specifications (continued)

Vessels Moving Grain Only

Vessel:	Vessel 5
Load Rate at GGT (TPH):	1,546.00
Discharge Rate at HYB (TPH):	1,500.00
Tons Loaded	33,800.00
Loading Time (hours):	21.86
Transit GGT to HYB (hours):	46.00
Discharge Time (hours):	22.53
Transit HYB to GGT (hours):	44.00
Round Trip (hours):	134.40
Round Trip (days):	5.60
Trips per year	65.18
Tons moved/day (tons)	6,035.88
Tons moved/yr (tons)	2,203,097.92

Vessels Moving Gypsum Only

Vessel:	Vessel 4
Load Rate at Steer Roast (TPH):	1,714.00
Discharge Rate at Buckskin (TPH):	1,423.00
Tons Loaded	24,538.00
Loading Time (hours):	14.32
Transit Steer Roast to Buckskin (hours):	64.60
Discharge Time (hours):	17.24
Transit Buckskin to Steer Roast (hours):	62.60
Round Trip (hours):	158.76
Round Trip (days):	6.62
Trips per Year	55.18
Tons moved/day (tons)	3,709.45
Tons moved/yr (tons)	1,353,948.00

Appendix 3: Increased Discharge Rate Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 2
Load Rate at GGT (TPH):	1,881.00
Discharge Rate at HYB (TPH):	1,900.00
Load Rate at Steer Roast (TPH):	2,414.00
Discharge Rate at Buckskin (TPH):	1,588.00
Tons Loaded Grain	28,861.00
Tons Loaded Gypsum	39,507.00
Loading Time at GGT (hours):	15.34
Transit GGT to HYB (hours):	47.70
Discharge Time at HYB (hours):	15.19
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	16.37
Transit Steer Roast to Buckskin (hours):	63.10
Discharge Time at Buckskin Bay, TX	24.88
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	191.58
Round Trip (days):	7.98
Trips/year	45.73
Grain Moved/day (tons)	3,615.58
Gypsum Moved/day (tons)	4,949.26
Tons moved/yr (grain)	1,319,685.88
Tons moved/yr (gypsum)	1,806,480.37

Appendix 4: Intermediate and Long-Term Vessel Specifications

Vessels Moving Grain Only

Vessel:	Vessel 6
Load Rate at GGT (TPH):	1,714.29
Discharge Rate at HYB (TPH):	1,800.00
Tons Loaded	36,000.00
Loading Time (hours):	21.00
Transit GGT to HYB (hours):	36.00
Discharge Time (hours):	20.00
Transit HYB to GGT (hours):	34.00
Round Trip (hours):	111.00
Round Trip (days):	4.62
Trips per year	76.76
Tons moved/day (tons)	7,783.79
Tons moved/yr (tons)	2,763,244.55

Vessel:	Vessel 7
Load Rate at GGT (TPH):	1,523.81
Discharge Rate at HYB (TPH):	1,280.00
Tons Loaded	32,000.00
Loading Time (hours):	21.00
Transit GGT to HYB (hours):	48.00
Discharge Time (hours):	25.00
Transit HYB to GGT (hours):	46.00
Round Trip (hours):	140.00
Round Trip (days):	5.83
Trips per year	60.86
Tons moved/day (tons)	5,485.71
Tons moved/yr (tons)	1,947,428.66

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain Only

Vessel:	Vessel 8
Load Rate at GGT (TPH):	1,307.69
Discharge Rate at HYB (TPH):	1,000.00
Tons Loaded	34,000.00
Loading Time (hours):	26.00
Transit GGT to HYB (hours):	36.00
Discharge Time (hours):	34.00
Transit HYB to GGT (hours):	34.00
Round Trip (hours):	130.00
Round Trip (days):	5.42
Trips per year	65.54
Tons moved/day (tons)	6,276.92
Tons moved/yr (tons)	2,228,306.91

Vessel:	Vessel 2
Load Rate at GGT (TPH):	1,647.06
Discharge Rate at HYB (TPH):	933.33
Tons Loaded	28,000.00
Loading Time (hours):	17.00
Transit GGT to HYB (hours):	57.80
Discharge Time (hours):	30.00
Transit HYB to GGT (hours):	55.80
Round Trip (hours):	160.60
Round Trip (days):	6.69
Trips per year	53.05
Tons moved/day (tons)	4,184.31
Tons moved/yr (tons)	1,485,428.76

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain Only

Vessel:	Vessel 9 or 10
Load Rate at GGT (TPH):	1,800.00
Discharge Rate at HYB (TPH):	1,956.52
Tons Loaded	45,000.00
Loading Time (hours):	25.00
Transit GGT to HYB (hours):	40.00
Discharge Time (hours):	23.00
Transit HYB to GGT (hours):	38.00
Round Trip (hours):	126.00
Round Trip (days):	5.25
Trips per year	67.62
Tons moved/day (tons)	8,571.43
Tons moved/yr (tons)	3,042,856.65

Vessel:	Vessel 1
Load Rate at GGT (TPH):	2,078.00
Discharge Rate at HYB (TPH):	1,465.00
Tons Loaded	30,925.00
Loading Time (hours):	14.88
Transit GGT to HYB (hours):	41.30
Discharge Time (hours):	21.11
Transit HYB to GGT (hours):	39.30
Round Trip (hours):	116.59
Round Trip (days):	4.86
Trips per year	73.08
Tons moved/day (tons)	6,365.83
Tons moved/yr (tons)	2,259,868.19

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Gypsum Only

Vessel:	Vessel 6
Load Rate at Steer Roast (TPH):	1,826.09
Discharge Rate at Buckskin (TPH):	1,826.09
Tons Loaded	42,000.00
Loading Time (hours):	23.00
Transit Steer Roast to Buckskin (hours):	44.00
Discharge Time (hours):	23.00
Transit Buckskin to Steer Roast (hours):	42.00
Round Trip (hours):	132.00
Round Trip (days):	5.50
Trips per Year	64.55
Tons moved/day (tons)	7,636.37
Tons moved/yr (tons)	2,710,910.67

Vessel:	Vessel 7
Load Rate at Steer Roast (TPH):	1,565.22
Discharge Rate at Buckskin (TPH):	1,800.00
Tons Loaded	36,000.00
Loading Time (hours):	23.00
Transit Steer Roast to Buckskin (hours):	60.00
Discharge Time (hours):	20.00
Transit Buckskin to Steer Roast (hours):	58.00
Round Trip (hours):	161.00
Round Trip (days):	6.71
Trips per Year	52.92
Tons moved/day (tons)	5,517.63
Tons moved/yr (tons)	1,958,758.23

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Gypsum Only

Vessel:	Vessel 8
Load Rate at Steer Roast (TPH):	1,600.00
Discharge Rate at Buckskin (TPH):	1,818.18
Tons Loaded	40,000.00
Loading Time (hours):	25.00
Transit Steer Roast to Buckskin (hours):	44.00
Discharge Time (hours):	22.00
Transit Buckskin to Steer Roast (hours):	42.00
Round Trip (hours):	133.00
Round Trip (days):	5.54
Trips per Year	64.06
Tons moved/day (tons)	7,421.37
Tons moved/yr (tons)	2,634,586.03

Vessel:	Vessel 2
Load Rate at Steer Roast (TPH):	1,583.33
Discharge Rate at Buckskin (TPH):	1,583.33
Tons Loaded	38,000.00
Loading Time (hours):	24.00
Transit Steer Roast to Buckskin (hours):	60.00
Discharge Time (hours):	24.00
Transit Buckskin to Steer Roast (hours):	58.00
Round Trip (hours):	166.00
Round Trip (days):	6.92
Trips per Year	51.33
Tons moved/day (tons)	5,648.73
Tons moved/yr (tons)	2,005,299.98

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Gypsum Only

Vessel:	Vessel 9 or 10
Load Rate at Steer Roast (TPH):	1,562.50
Discharge Rate at Buckskin (TPH):	1,785.71
Tons Loaded	50,000.00
Loading Time (hours):	32.00
Transit Steer Roast to Buckskin (hours):	48.00
Discharge Time (hours):	28.00
Transit Buckskin to Steer Roast (hours):	46.00
Round Trip (hours):	154.00
Round Trip (days):	6.42
Trips per Year	55.32
Tons moved/day (tons)	8,011.70
Tons moved/yr (tons)	2,844,154.60

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 6
Load Rate at GGT (TPH):	1,714.29
Discharge Rate at HYB (TPH):	1,800.00
Load Rate at Steer Roast (TPH):	1,826.09
Discharge Rate at Buckskin (TPH):	1,826.09
Tons Loaded Grain	36,000.00
Tons Loaded Gypsum	42,000.00
Loading Time at GGT (hours):	21.00
Transit GGT to HYB (hours):	36.00
Discharge Time at HYB (hours):	20.00
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	23.00
Transit Steer Roast to Buckskin (hours):	44.00
Discharge Time at Buckskin Bay, TX	23.00
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	176.00
Round Trip (days):	7.33
Trips/year	48.41
Grain Moved/day (tons)	4,909.09
Gypsum Moved/day (tons)	5,727.28
Tons moved/yr (grain)	1,742,728.55
Tons moved/yr (gypsum)	2,033,183.31

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 7
Load Rate at GGT (TPH):	1,523.81
Discharge Rate at HYB (TPH):	1,280.00
Load Rate at Steer Roast (TPH):	1,565.22
Discharge Rate at Buckskin (TPH):	1,800.00
Tons Loaded Grain	32,000.00
Tons Loaded Gypsum	36,000.00
Loading Time at GGT (hours):	21.00
Transit GGT to HYB (hours):	48.00
Discharge Time at HYB (hours):	25.00
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	23.00
Transit Steer Roast to Buckskin (hours):	60.00
Discharge Time at Buckskin Bay, TX	20.00
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	206.00
Round Trip (days):	8.58
Trips/year	41.36
Grain Moved/day (tons)	3,728.16
Gypsum Moved/day (tons)	4,194.18
Tons moved/yr (grain)	1,323,495.43
Tons moved/yr (gypsum)	1,488,932.36

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 8
Load Rate at GGT (TPH):	1,307.69
Discharge Rate at HYB (TPH):	1,000.00
Load Rate at Steer Roast (TPH):	1,600.00
Discharge Rate at Buckskin (TPH):	1,818.18
Tons Loaded Grain	34,000.00
Tons Loaded Gypsum	40,000.00
Loading Time at GGT (hours):	26.00
Transit GGT to HYB (hours):	36.00
Discharge Time at HYB (hours):	34.00
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	25.00
Transit Steer Roast to Buckskin (hours):	44.00
Discharge Time at Buckskin Bay, TX	22.00
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	196.00
Round Trip (days):	8.17
Trips/year	43.47
Grain Moved/day (tons)	4,163.26
Gypsum Moved/day (tons)	4,897.96
Tons moved/yr (grain)	1,477,958.67
Tons moved/yr (gypsum)	1,738,774.91

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 2
Load Rate at GGT (TPH):	1,647.06
Discharge Rate at HYB (TPH):	933.33
Load Rate at Steer Roast (TPH):	1,583.33
Discharge Rate at Buckskin (TPH):	1,583.33
Tons Loaded Grain	28,000.00
Tons Loaded Gypsum	38,000.00
Loading Time at GGT (hours):	17.00
Transit GGT to HYB (hours):	48.00
Discharge Time at HYB (hours):	30.00
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	24.00
Transit Steer Roast to Buckskin (hours):	60.00
Discharge Time at Buckskin Bay, TX	24.00
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	212.00
Round Trip (days):	8.83
Trips/year	40.19
Grain Moved/day (tons)	3,169.81
Gypsum Moved/day (tons)	4,301.88
Tons moved/yr (grain)	1,125,281.98
Tons moved/yr (gypsum)	1,527,168.40

Appendix 4: Intermediate and Long-Term Vessel Specifications (continued)

Vessels Moving Grain and Gypsum

Vessel:	Vessel 9 or 10
Load Rate at GGT (TPH):	1,800.00
Discharge Rate at HYB (TPH):	1,956.52
Load Rate at Steer Roast (TPH):	1,562.50
Discharge Rate at Buckskin (TPH):	1,785.71
Tons Loaded Grain	45,000.00
Tons Loaded Gypsum	50,000.00
Loading Time at GGT (hours):	25.00
Transit GGT to HYB (hours):	40.00
Discharge Time at HYB (hours):	23.00
Transfer Time to Steer Roast	1.00
Loading Time at Steer Roast	32.00
Transit Steer Roast to Buckskin (hours):	48.00
Discharge Time at Buckskin Bay, TX	28.00
Transfer Time to GGT from Buckskin	8.00
Round Trip (hours):	205.00
Round Trip (days):	8.54
Trips/year	41.56
Grain Moved/day (tons)	5,268.29
Gypsum Moved/day (tons)	5,853.66
Tons moved/yr (grain)	1,870,243.10
Tons moved/yr (gypsum)	2,078,047.89

Endnotes

[1] Yossi Sheffi, The Resilient Enterprise, (Cambridge: The MIT Press, 2005) 78.