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OPTIMAL DELIVERIES OF WHEAT IN CANADA: THE IMPACT OF CWRS WHEAT GRADE MULTIPLICITY ON TRANSPORTATION COST MINIMIZATION

by

Sandra J. Maniak

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DEDICATION

For my family; Joe, Madeleine and David.

ABSTRACT

The Transportation Problem of Linear Programming is applied to the empirical study of the Canadian Wheat Board delivery patterns for Canadian Western Red Spring Wheat from the Canadian Prairies to export positioning. The analysis is confined to the shipping costs from producing regions on the Canadian Prairie to the export terminals of Thunder Bay, Churchill, Vancouver and Prince Rupert. Transportation cost minimization as determined by the Crow's Nest Pass Freight Rates is the explicit criterion of evaluation. Three possible sources of suboptimality were investigated: the additional transportation costs associated with supporting a system of multiple grades of CWRS wheat; suboptimality arising from exclusive Canadian National and Canadian Pacific Railways service areas; and the additional transportation costs associated with short term planning at the expense of long term efficiency. Although the actual delivery patterns show a large number of crosshauls, the associated costs of this apparent inefficiency do not weigh heavily in the objective function. The optimal delivery patterns for one comprehensive grade reallocated a total of 4,568,226 tonnes of wheat to different destinations. This tonnage represents 31% of the total tonnage handled, however, contributed a saving of only 1.86% of the total shipping bill. There is no incentive for the Canadian Wheat Board to operate efficiently because the additional transportation costs associated with inefficiency

are insignificant in terms of the findings. It can be concluded that the transportation tariff structure does not reflect a significant price differential between attractive shipping routes and more costly deliveries. The tariff structure does not appear to encourage efficient use of limited transport services. The dual solution has limited significance with respect to production patterns in the producing regions because the grade of wheat produced is governed by the uncontrollable variables of environment and weather. The producer always strives to produce the highest quality of wheat, however, is constrained by the impacts of environmental and climatic variables upon the ultimate grades harvested. The dual objective function indicates that the present transportation tariff structure favours increased handling capacity at Churchill. Churchill, however, is subject to serious constraints limiting its ability to increase handling capacity. Thunder Bay represents the second most attractive destination at which to increase demands. The favourable international price differential for wheat at Vancouver outweighs the attactiveness of Thunder Bay based on the Crow Rate structure. The transportation cost matrix can be weighted to divert grain deliveries from congested ports such as Vancouver and from Churhcill which has its own unique constraints. The model does not consider international oceanic transportation tariffs, nor specific destination patterns.

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1.0 INTRODUCTION

Since the turn of the nineteenth century Canadian Western Red Spring (CWRS) wheat has served to set the international standard of quality for the most favourable milling wheats for bread flours. The Canadian wheat grading system evolved during the early decades of the twentieth century to meet the expectations of European millers and bakers who represented the predominant proportion of Canada's international wheat market. CWRS wheat remains the most important internationally traded grain in Canada accounting for approximately 80 per cent of grain traded during the 1980-1981 crop year.

The responsibility for the coordination and shipment of wheat and grains from the producing areas to export position lies with the Canadian Wheat Board (CWB), a crown corporation established in 1935. In this research the tranportation coordination efforts of the CWB are evaluated on the basis of the annual wheat delivery patterns from Prairie points from July 1980 to June 1981. Transportation cost minimization is the explicit criterion of evaluation. The transportation costs associated with the actual delivery patterns from producing regions to demanding ports are compared to the minimum cost solutions derived from the application of the Classical Transportation Problem of Linear Programming.

The Transportation Problem is applied to the pattern of shipments observed over the 1980-1981 crop year. The analysis of shipping patterns aggregated over time will demonstrate the additional transportation costs associated with the entire grain transportation system for the study period. The model assumes that the CWB has a complete knowledge of the availabilities of grain types throughout the Prairie region, allowing supplies to be drawn from the producing areas at any time to meet export contracts. This assumption allows the application of the economic man assumption of normative economics to the shipping problem, ignoring the constraints imposed by changing rail car availability, vessel arrivals, current elevator stocks and environmental conditions. Shipping schedules are organized weekly by the CWB to meet these changing circumstances. Consideration of these temporal constraints is expected to lead to moderately efficient shipping patterns required to meet the immediate export demand requirements. When the scheduling of deliveries occurs on a weekly basis, the shipping patterns become responsive to the current inventories of railcars and grain at hand at country elevators as these constraints become increasingly dominant in determining efficient shipping schedules required to meet vessel arrivals.

The existing procedures of the CWB do not forecast or anticipate demands on terminal elevator stocks, country elevator stocks, railcar availability and delivery requirements for more than one week at a time in the six week Block Shipping planning cycle. The fact that each week is treated as a separate planning problem yields short term suboptimality at the expense of long term efficiency. Recommendations have been made to emphasize the long term goals (Booz, Allen and Hamilton, IX-15) in order to increase the Wheat Board's effectiveness in meeting delivery requirements. The cost of meeting these temporal constraints on a weekly basis can be measured by determining the optimal delivery patterns over the course of the crop year required to meet the annual export demands but confounded with pure shipment inefficiency.

The delivery patterns provided by the Canadian Grain Commission (CGC) specify the annual export contract demands that must be met. The fact that availabilities vary over the year depending upon country elevator price, tax deferral programmes, environmental conditions, producer delivery preferences and elevator capacity leads to major constraints in determining shipping schedules. In order to evaluate the cost of these constraints in meeting the predetermined export demands, the overall volumes to be delivered should be utilized to assess the efficiency of the actual shipping schedules. It is therefore the objective of this study to determine the total additional shipping costs incurred by meeting the constraints imposed by changing rail car availability, vessel nomination, current elevator stocks and environmental conditions. The additional shipping costs particularly associated with grade multipicity will be addressed specifically by reorganizing grades, sub-grades, and protein segregations into alternative grading schemes. The Crow Rates governing the transport tariff structure are defined by federal statute for the grain producing areas of Western Canada. The Crc [illegible] s will be used to define transport cost minimization serving as the basis for the optimality analyses performed.

The underlying assumptions behind the CWB's railcar allocation decisions are not explicitly defined. Generally, weekly patterns emerge which seek to minimize the transportation costs associated with each of the required deliveries. Nevertheless, there is no certain objective to which the Board strives, nor any quantitative measurement available to assess the extent to which it is achieved or to what extent other objectives have been compromised (Booz, Allen and Hamilton, 1979, p.179). It is expected that suboptimality will be revealed by the analyses. Suboptimality can arise from at least three sources.

1. The Canadian National (CN) and the Canadian Pacific (CP) Railways each operate exclusive railroad service systems. This exclusiveness is characterized by the fact that each country elevator station is serviced by one railway company. Loadings at CP country elevators are delivered to the CP terminal elevators of Vancouver and Thunder Bay where CP marshalling yards are located. Because CP facilities do not exist at Prince Rupert or Churchill CP deliveries to these points are not permitted. Loadings from CN points can be delivered to any of the four terminal locations as they each have CN facilities. Therefore supplies of wheat at CP stations near Prince Rupert or Churchill must be shipped farther to Vancouver or Thunder Bay as the situation dictates. As a result, the restricted nature of the CN and CP

unloading facilities, rail lines and country loading stations is expected to cause suboptimality. The optimal shipping patterns are determined for each transportation company by using its unique network structure. Optimal patterns are also determined for the combination of the two networks in order allow flows from CP origins to exclusive CN destinations. Total shipping optimization is therefore permitted in the model to assess the additional transport costs associated with railway restrictions.

2. As suggested by the Canadian Grains Council (1978) the relationship between the number of grades and the transportation of wheat may be indirect, but nevertheless important. Essentially, each grade represents an individual commodity which must be stored, transported and processed separately. As the number of grades increases, transportation coordination becomes more difficult, perhaps leading to inefficiency.

The Canadian Grain Commission establishes the characteristics for each grade annually. Producers support the concept of a large number of grades to maximize their opportunity to receive a higher return for a marginally superior product. The producer always strives to produce the highest quality of wheat, however, enivronmental and climatic variables ultimately dictate the grade harvested. It is, therefore, difficult to alter production patterns to minimize the total shipping bill. All grain is originally graded at country elevator stations and is delivered by grade to specified terminal elevators. Misshipments occur when a different grade is delivered than that which was ordered. Tough and damp grains are not treated as specific grades during the delivery process and are substituted for requests for straight grades. Once the grain arrives at the terminal elevator, a final grade and value is determined. The grain is then blended with other grain of varying grades to prepare a product to meet the precise specifications of each vessel requirement. This fact alone undermines the rational of the country grading system. Incorrect shipments and unnecessary long cross hauls may occur in order to meet the delivery requirements of specific grades because the location of the supplies requested must be determined on a weekly basis. As indicated, this information is not always available or accurately received from country loading stations.

The optimal transportation costs will be defined for one grade encompassing all the specific grades shipped. This will serve as a yardstick against which to measure the transportation costs associated with the multiplicity of grades and the location of supplies in the system. The analysis will also be undertaken for a system free of CP and CN differentiation in order to assess the costs imposed by railway incompatibility in this context.

3. The CWB treats each each week as a separate transportation problem that may compromise short term optimality in favour of long term

efficiency. Country elevator stocks are influenced by a weekly delivery quota system, reflecting the specifications of required supplies of grain by elevator station. Quotas are set weekly by grade, setting the total number of tonnes that can be delivered to country elevators by each producer. This policy provides a system of equity whereby each producer has the opportunity to deliver the required grains to country points when requested. Whereas the quota system sets the maximum deliveries to country elevators, these are not often met by the producers, leaving elevator stocks dependent upon the variables of price and producer delivery preferences, which may not meet the requirements expected to be on hand. The CWB depends upon a weekly mail information system to maintain country elevator stock inventory. Because the CWB cannot explicitly define or determine the supplies of grain available at country elevators, shipping schedules must be organized to load grain where it is known to be available. Incorrect shipping patterns may arise from the limitations inherent in the known schedules of demand for grains and supplies available to the CWB on a weekly basis. The Transportation Problem derives the optimal shipping patterns for the entire schedule of demands and supplies on an annual basis as this is the best indication of the supplies, both elevator and on-farm, that are available.

The Classical Transportation Problem seeks the minimum cost delivery pattern of given supplies of a homogeneous commodity to demand destinations of a spatially organized system. The geographical implications of determining minimum transportation costs are of profound importance in overcoming the friction of distance and assessing the costs that spatially separate supply and demand points generate. This is especially critical in the agricultural industry where production occurs in sparsely settled regions serving concentrated points of demand. Reducing the costs of overcoming distance has important geographical implications for trade. Whereas the price of transportation directly affects the final value of the commodity, it is also critical to efficiently utilize the available supplies of shipping services. Weekly, the CWB is assigned a precise number of railway cars and locomotives with which to coordinate the delivery of grains to terminals to meet domestic and international sales contracts. However, the allocated supplies of railcars usually represents a shortfall from those required. Therefore, the movement of the largest possible volumes of supplies each week is critical. This research is important in understanding the spatial efficiency of the Canadian wheat transportation system.

For every cost minimization solution to the Classical Transportation Problem there is a corresponding maximization solution known as the dual solution. The variables known as ui and vj represent the buying price of one unit of the commodity at the origin and the selling price of the commodity at the destination. The solution to the dual problem maximizes the difference between the buying and selling prices. The difference is equal to the transportation costs. The dual variables provide a basis of economic interpretation of the primal problem whereby the relative savings or costs incurred by alternative shipping schedules can be determined. High values of ui are located at supply regions having a favourable locational advantage as reflected by the lowest shipping charges to the nearest destination. Likewise, vj represents the comparative advantage of the demand points competing for limited resources. Places with low values of vj are favourable locations at which to increase handling. Increased deliveries should occur from places with high values of ui to places with low values of vj. The conventional application of the dual solution indicates supply regions that are best located for meeting demands as defined by the transport cost. Because the final grade produced is largely determined by environmental and climatic variables, it is virtually impossible to alter production patterns to decrease shipping costs. The interpretation of the dual solution is therefore limited with respect to the producing regions. The dual solution is important in this application for identifying demand points that are attractive places at which to increase demand levels on the basis of the regional transportation cost structure.

This investigation seeks to determine a quantitative measure whereby the Canadian Wheat Board can evaluate the railcar allocation programmes in the short run. This examination of shipping patterns does not address the causes underlying the variables of railcar availability, vessel arrivals, elevator stocks and environmental conditions related to agricultural production. The goal of transportation cost minimization is the explicit criterion of evaluation as measured by the Crow Rate structure. The aggregation of grades of CWRS wheat reflects the additional transportation costs associated with a high degree of structure and multiplicity in the grading system. The significance of the potential savings derived from the simplification of the grading structure is measured. The results are presented in order to contribute to the understanding of the transportation costs associated with the wheat grading and wheat export trade in Canada.

2.0 THE WHEAT INDUSTRY OF CANADA

2.1 THE IMPORTANCE OF GRAIN EXPORTS IN CANADA

The export of grain from Western Canada is vitally important to the entire Canadian economy. The grain industry supports approximately 160,000 producers. Total Canadian production of all grains in the 1980-1981 crop year, which includes barley, oats, rye, flaxseed and rapeseed, amounted to 33.9 million tonnes. Of this yield, 56% was wheat accounting for 19.1 million tonnes. Canadian Western Red Spring Wheat, internationally renowned for its unsurpassed bread making qualities, accounted for 85.3% (16.3 million tonnes) of the Canadian wheat production. In 1980-1981 crop year 87% of CWRS wheat crop (14.2 million tonnes) was exported (Canadian Wheat Board Annual Report: 1980-1981, p. 7). In terms of foreign trade in wheat, Canada ranks second as an exporter of wheat, contributing 18% of the internationally traded tonnage. The wheat trade thus contributes 3% to the total value of international trade in Canada. Only lumber and mineral products contributed to foreign revenue in larger degrees over the study period (Canada Yearbook 1980, p. 413).

The importance of the grain trade has generated much interest in the industry. Transportation and grain handling has been the subject of numerous studies seeking practical solutions to the problems of moving grain from farms to waiting vessels to meet sales contracts. Although a wide variety of issues have been addressed by these investigations, a critical evaluation of the transportation coordination system of the CWB has yet to be undertaken in Canada. This thesis evaluates the coordination efforts of the CWB in moving CWRS wheat from country elevators to terminal port elevators and indicates the the transportation costs associated with the grade multipicity of the system. The transportation of CWRS wheat has been selected for analysis in light of Canada's unsurpassed international reputation and demand for high and consistent quality of hard red wheat.

2.2 THE IMPORTANCE OF GRAIN GRADING

The Canadian Western Red Spring wheat grading system has achieved the most distinquished reputation in international markets. This reputation is based upon the consistent adherence to established grading standards which evolved to meet the requirements and expectations of millers and bakers.

Wheat is bought in a wide range of qualities reflecting grain variety and a combination of environmental characteristics such as soil, fertilization and weather. Effective marketing of grain depends upon the known and consistent variation of quality within each grade in order for the customer to effectively assess his requirements.

The importance of dependable quality of hard spring wheats lies in the milling and baking requirements. Improvements in milling methods have been largely responsible for the fine quality of bread today, necessitating the corresponding production of suitable wheats. Hard wheats are noted for the physically hard wheat kernel, rich in protein. The desirability of protein for baking arises from its positive effect on loaf volume and texture. The gluten of protein makes the bread dough elastic enabling it to expand and hold bubbles of gas formed by the yeast. The value of protein in wheat is demonstrated by the premium paid for deliveries of protein wheat exceeding 13.5% in Canada (Canadian Grain Commission, Grain Statistics Weekly Crop year 1980/1981: 51st Week, p. 14).

2.2.1 The Importance of Wheat Grading Factors

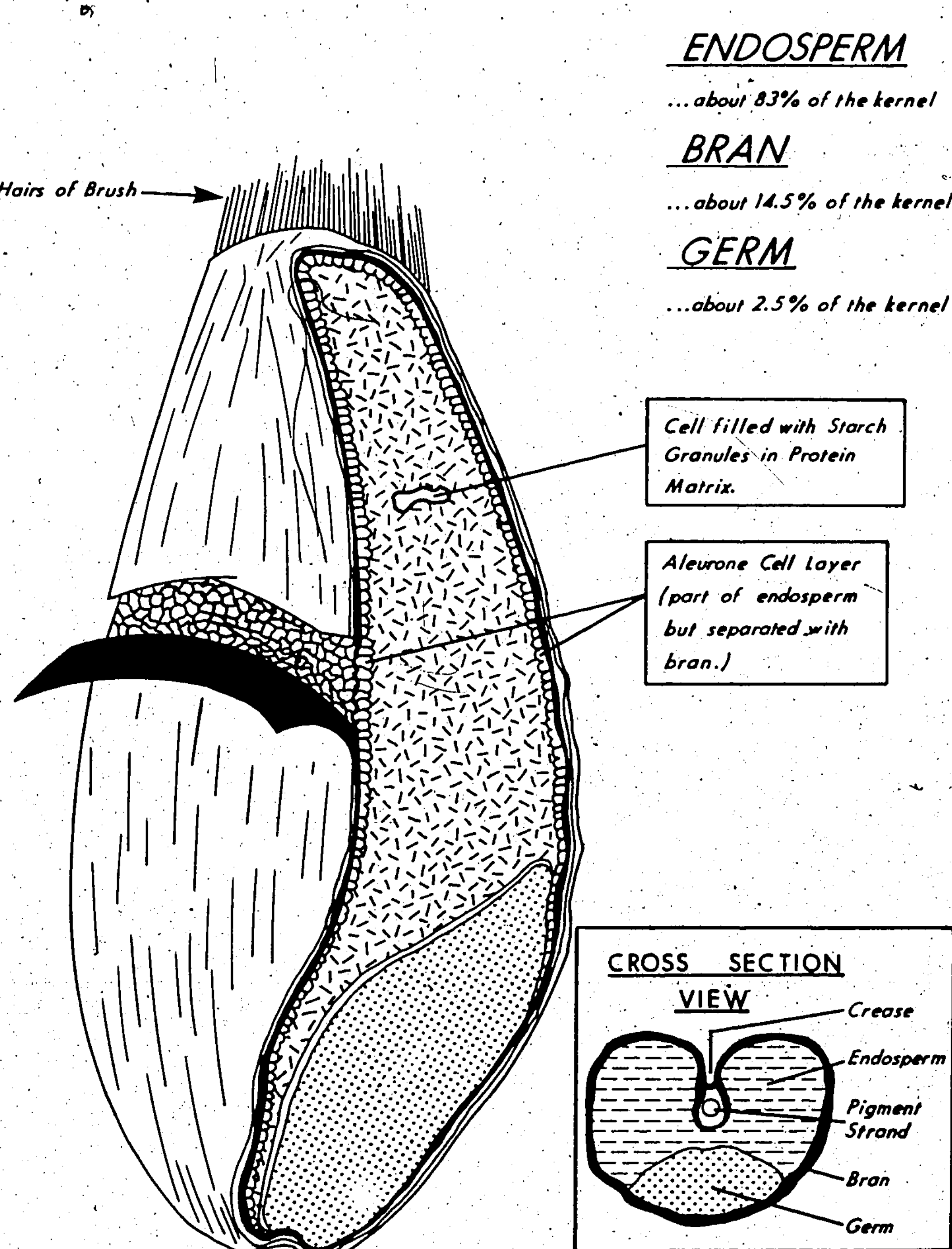
During the nineteenth century, the wheat producing regions of Canada and the United States were well suited for the cultivation of hard wheats for the European milling technology developed in Hungary. Several quality criteria were established, the most important of which were colour, hardness, vitreousness and bushel weight. Later, in recognition of additional quality criteria, protein quantity and quality became important grading factors. Canada's original grading system was organized and extended to meet these specifications of European bread making technology. These criteria have endured over time.

The grading system in Canada accommodates the flour miller who seeks a sound, clean kernel with relatively low moisture, and uniform shape which mills high yields easily when properly conditioned. The baker is also accommodated by this grading system which will produce flour having a high level of water absorption, relatively short mixing time and capable of producing bread of good quality, consistent in volume and texture. These properties should be kept uniform by the producers' grading system over time.

The wheat kernel is ovoid in shape, rounded at both ends as shown on Figure 1 on page 15. The germ is prominant at one end and a tuff of fine hair at the other. Along the ventrical side of the kernel is the crease, an infolding of the bran and all covering layers. The presence of the crease complicates any milling process which aims at separating the endosperm, the source of white flour, from the enclosing layers. The endosperm represents approximately 83% of the kernel. The maximum yield of flour obtainable from wheat kernels by milling is dependent upon the content of the endosperm and this is affected by the size and shape of the kernels and the thickness of the bran (Kent, 1966, p. 69). Up to 85% of the endosperm can be recovered by suitable milling conditions.

FIGURE 1

A KERNEL OF WHEAT



Longitudinal Section of Grain of Wheat

2.3 WHEAT GRADING FACTORS

In Canada both external and intrinsic quality criteria have been added to the wheat grading system. Today grain grading is based upon the official definitions of grades established by Schedule I of the Canadian Grain Act, amended to August 1, 1977 and from Schedule III of the Canadian Grain Regulations amended to February 1st, 1978, pertaining to grains grown in Western Canada. Maximum tolerance levels of grading factors are established annually by the Western Grain Standardization Board of the Canadian Grain Commission.

This section outlines the grading criteria for CWRS wheat in Western Canada. Although many of the factors included have infrequent applications, their discussion is included for the complete presentation of the grading system. In addition, the factors outlined below may apply to all of the Western Canadian grains (with variations of specifications) and may have only minimum application to wheat.

Official grading of Western grains by the inspectors of the Canadian Grain Commission occurs at the terminal elevators, shown on Figure 2 on page 18 at Vancouver, Prince Rupert, Thunder Bay and Churchill and at the inland terminals of Calgary, Edmonton, Lethbridge, Saskatoon and Weyburn for domestic requirements. Grain samples are cleaned of dockage prior to grading through the use of approved cleaning equipment. Dockage includes all foreign materials which can be removed from the sample of grain before grading. The percentage of dockage is assessed and noted in official grading records.

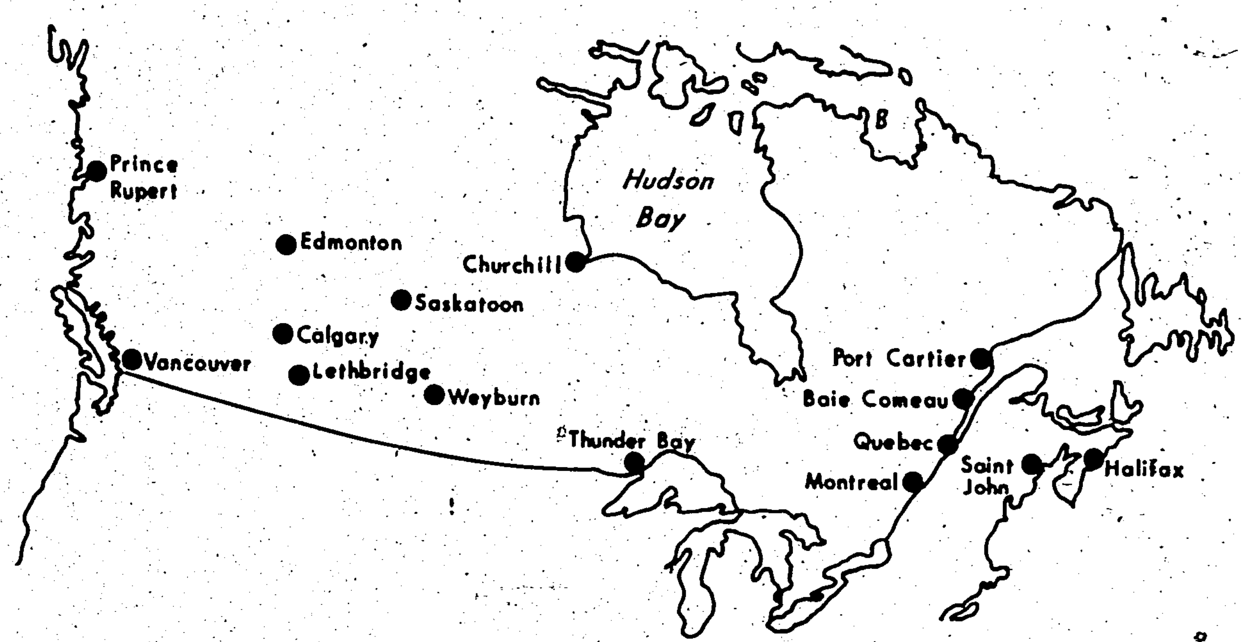
Grading specifications can be divided into two sections. The first section of criteria refer to the general standard of quality of the sample. The second set of criteria deal specifically with maximum tolerance levels of each grading factor. Maximum grading tolerances are measured by the percentage of kernels in the sample with the particular condition or the actual number of kernels or kernel pieces in 500 grams noted as variable 'K'. This necessitates an actual kernel count of the sample to determine the appropriate percentages.

The Canadian Grain Commission is responsible for maintaining quality control of wheat for domestic and export marketing purposes. During the 1981-1982 crop year the CGC established twenty-three grading factors for CWRS wheat. These factors include moisture and protein levels. The Commission has seventy-six official grade classifications for CWRS wheat produced in 1981-1982. Wheat samples that do not qualify for specific grades fall into the 'rejected' or 'sample' grade classifications. Red Spring Wheat which does not meet the expectations of CWRS grades fall into Canada Feed Wheat, Utility Wheat or Mixed Grain classifications which have less rigorous specifications.

The country elevator manager grades grain when it enters the licenced

FIGURE 2

CANADIAN WHEAT EXPORT TERMINALS AND INLAND TERMINALS



elevator system. When the grain is delivered to inland or export terminals the quality standards are checked by the CGC licenced inspector at the point of unloading. Official grading of wheat is based upon the following two types of criteria:

Standard of Quality Criteria;

a. variety
b. test weight
c. percentage of hard vitreous kernels
d. degree of soundness of the kernel

Maximum Tolerances;

a. foreign material other than wheat
b. wheat of other classes or varieties
c. sprouted kernels
d. heated kernels
e. severely binburnt kernels, including mildewed
f. fireburnt kernels
g. odour
h. dark immature kernels
i. ergot
j. sclerotinia sclerotiorium
k. shrunken or broken kernels

l. stained kernels

m. smudge

n. black point

o. stones

p. insect damage

Quality Criteria and Maximum Tolerances specifications for CWRS wheat grades are presented on Table 1 on page 21 and Table 2 on page 22 respectively. The tables indicate that as the grade changes from No. 1 through No. 3, the specifications become less strigent, thereby increasing the variation of kernel quality in the lower grades. The successful international marketing depends upon the maintenance of these quality standards.

The following descriptions outline the wheat grading factors and their raison d'etre. The information regarding grading criteria has been collected from the <u>Grain Grading Handbook for Western Canada, Effective August 1st, 1980</u>. The standards for grading factors and their importance to cereal technology is documented in Kent (1966), Spicier (1975), Pomeranz (1971, 1978) and Quisenberry (1967). These references have been utilized throughout the following descriptions as wheat is appraised throughout the world on the basis of similar characteristics pertaining to milling and bread making standards.

Figure 1: Standard of Quality Criteria for Grades of CWRS Wheat

STANDARD OF QUALITY CRITERIA	GRADE NAME No. 1 CWRS	No. 2 CWRS	No. 3 CWRS
Variety	Marquis or any variety equal to Marquis	Marquis or any variety equal to Marquis	Any variety of fair milling quality
Test Weight (minimum kg. per hectolitre)	75	72	69
Mimimum Percentage by Weight of Hard Vitreous Kernels	65	35	--
Degree of Soundness	Reasonably well matured, reasonably free from damaged kernels	Fairly well matured, may be moderately bleached or frost damaged but reasonably free from severely weather damaged kernels	Excluded from higher grades on account of frost, immature or otherwise damaged kernels

From: Grain Grading Handbook for Western Canada Effective August 1, 1980, Canadian Grain Commission, Winnipeg, Manitoba, p. 21.

TABLE 2

MAXIMUM TOLERANCES OF GRADING FACTORS FOR CWRS WHEAT

GRADING CRITERIA	GRADE NAME		
	No. 1 CWRS	No. 2 CWRS	No. 3 CWRS
Foreign Material Other than Wheat			
-matter other than cereal grains	-practically free -about 0.75%	-reasonably free -about 1.5%	-reasonably free -about 3.5%
Wheats of Other Classes or Varieties			
-durum and constrasting classes	-about 1.0%	-about 3.0%	-about 5.0%
-total, including durum and other varieties	-about 3.0%	-about 6.0%	-10%
Sprouted	0.5%	1.5%	5.0%
Heated, including Severely Binburnt	0.1%	0.75%	2.0%
Severely Binburnt, including Mildewed Kernels	2 K	5 K	10 K
Fireburnt	Nil	Nil	Nil
Dark Immature Kernels	1.0%	2.5%	10%
Ergot	3 K	6 K	24 K
Sclerotina Sclerotiorium	3 K	6 K	24 K
Shrunken and Broken (Total)	7.0%	11.0%	---
Shrunken	6.0%	10.0%	15.0%
Broken	6.0%	10.0%	---
Stained - Natural	0.5%	2.0%	5.0%
- Grass Green	0.75%	2.0%	10.0%
- Pink	1.5%	5.0%	10.0%
- Artificial	Nil	5 K	10 K
Blackpoint	10%	15%	35%
Smudge	30 K	1.0%	5.0%
Stones	3 K	3 K	5 K
Insect Damage			
Sawfly and Midge	2.0%	8.0%	25.0%
Grasshopper/Army Worm	1.0%	3.0%	8.0%

From: Grain Grading Handbook for Western Canada Effective August 1, 1980. Canadian Grain Commission, Winnipeg, Manitoba, pp. 21, 23, 24, 26.

2.3.1 Standard of Quality Criteria

a. Variety

The variety of wheat is an important grading factor. The physically hard red spring wheat kernels are most suitable for high quality bread making because they yield a strong flour, rich in gluten and proteins. The highest grades must be equal to or superior to the qualities of the Marquis wheat. For seven decades, Marquis wheat has been producing the highest quality of bread making flour. It continues to be the international standard for milling and baking requirements. Marquis wheat has been replaced over the years by higher yielding, earlier maturing, rust resistent varieties. This variety, however, continues to set the international standard for hard red spring wheat due to its exceptional milling and baking characteristics.

Degrading occurs if the sample contains excessive amounts of other classes of varieties of wheat. Table 1 on page 21 indicates that No. 3 CWRS wheat may be any red spring wheat of fair milling quality, while Marquis or a comparable variety is specified for No. 1 and 2.

b. Test Weight

The test weight of wheat per hectolitre of kernels estimates the weight of a fixed volume of grain and gives a rough indication of kernel size and shape. Wheats of a high test weight are usually considered to mill more easily and have higher flour yields, thus explaining the highest test weight for CWRS No.1 on Table 1 on page 21. The high test weight reflects a low moisture level in the sample of whole, unshruken kernels. Low moisture content in milling wheats is most favourable for both storage and bread making activities. Nevertheless, these measurements can be misleading as weak, mealy wheats have high test weights.

c. Percentage of Hard Vitreous Kernels

The hardness and softness of a kernel refers to the way in which the endosperm breaks down in the milling process. Vitreous kernels are whole, reasonably sound kernels showing clear evidence of hardiness. Natural vitreousity, or hardiness, refers to the reddish covering of the kernel which indicates hardiness without disection of the kernel.

If the surface of the wheat kernel is moistened lightly and uniformly during an abrasive process in milling known as pearling, the outer layer of the bran quickly absorbs moisture. The seed coat is relatively impervious and hinders the diffusion process of moisture from the bran to the endosperm, except in the vicinity of the germ. When the kernels are allowed to dry, a pattern of cracks appears following the lines of the endosperm cell boundaries. Hardness affects the ease of the detachment of the endosperm from the cracked layer of bran. The endosperm cells of hard wheat can be removed more easily and remain more intact than those of softer wheats.

Hardness also refers to the way in which the endosperm fractures during the milling process. A hard wheat kernel fractures into regularly shaped, free flowing particles which sieve easily. Sieving occurs before grinding or reduction of the endosperm in order to separate the bran from the endosperm. At the initial stages of the milling process, roller mills with fluted rolls open the kernel to expose the endosperm. The percentage of endosperm recovery depends upon the individual kernel. The endosperm of hard vitreous kernels is easily and most completely recovered. The top grade specifies the highest levels of vitreous kernels as noted on Table 1 on page 21.

Non-vitreous kernels are relatively high in starch, as indicated by the pale starch spot in the kernel, visible through the bran. High starch content increases the water absorption rate of the flour in bread making. The net effect is low bread yields. Non-vitreous kernels also include broken and badly damaged kernels and all kernels of contrasting classes. Broken and damaged kernels affect the removal of the germ and moisture absorption during pearling. The exposed endosperm of a broken kernel absorbs the pearling liquid and becomes damp. The endosperm, however, should retain its low moisture level for milling. In addition, if the germ is not completely removed the flour colour and quality is compromised. There is no minimum specification for vitreous kernels for No. 3 CWRS, suggesting that the kernels are non-vitreous and possess less desirable characteristics.

d. Degree of Soundness

Degree of soundness refers to the maturity and condition of the kernel. Proper maturity of the kernel ensures the expected protein level. Mature kernels are the most suitable for milling high yields of flour while protein affects the yield of the flour in bread making. The highest grade specifies the well matured and damage free characteristics.

Bleached kernels result from a variety of conditions. Bleached kernels affect the colour of the flour. Frost and weather damage are also considered in assessing the overall soundness of the sample.

The grading factors included in determining the general degree of soundness specifications are detailed further under the maximum tolerance levels in order to determine the most suitable grade.

2.3.2 Maximum Tolerances of Grading Factors

Table 2 on page 22 specifies the maximum tolerances for the remaining grading factors. Below, each factor is explained further.

a. Foreign Material other than Wheat

Foreign material is all material in the sample other than the same class of wheat remaining in the sample after dockage has been removed. Foreign material is classified into two categories:

- matter other than cereal grains in the grade definition includes large seeds and seeds of other grains such as domestic buckwheat, peas, corn, beans and weed seeds.

- cereal grains other than wheat refer to rye, barley and oats.

Table 2 on page 22 indicates that the highest quality grades of wheat are virtually void of other materials. Specific tolerances of these factors vary for the lower grades, to a maximum of 3.5% of cereal grains other than wheat based on the weight (per 500 grams) of the sample.

b. Wheats of Other Classes or Varieties

Standard of quality criteria indicate the varieties of wheat which can be considered for each grade as shown on Table 2 on page 22. Kernels which are considered wheats of contrasting classes are counted and indicated as a percentage of the sample. Constrasting varieties are not a serious degrading factor, however, kernels of other varieties are noted in the grade specification. In addition there are contrasting classes such as Red Winter, Soft White Spring, Ambur Durum, Utility and Canada Feed Wheats. This specification ensures the reliability of the buyer's expectation of each grade.

c. Sprouted Kernels

Kernels are classed as sprouted where there is clear evidence of germination activity within the kernel. The bran becomes split due to growth. Discolouration of the endosperm occurs during sprouting, affecting flour colour. The sprouting activity of germination also alters the emzymes of the endosperm creating a sticky dough negatively affecting bread making qualities. Table 2 on page 22 notes the maximum tolerances of sprouted kernels in No. 1 CWRS is 0.5%, ranging to 5.0% for No.3 CWRS. Kernels with slightly swollen germs or with a split bran without apparent sprouting activity are not considered as sprouted.

d. Heated Kernels, including Severely Binburnt Kernels

Heated kernels have the typical colour, taste and odour of wheat that has been heated in storage. Heated kernels may include rotted, mouldy or badly mildewed kernels. Rotted and mouldy kernels are recognized by their dark colour and objectionable odour. In addition, bacteria alter the chemical constitution of the endosperm. If rotted kernels are in excess of 10% of the sample the term 'rotted kernels' is applied to the name for grading purposes. Heated kernels tend to have a toughening affect on the gluten, reducing yields and producing poor crumb texture. Heated kernels have tolerances ranging from 0.1% for No. 1 to 2.0% for No. 3 CWRS.

The grading tolerances for heated kernels can include severely binburnt kernels and are included in the tolerance specifications. Severely binburnt kernels have specifications ranging from 2K to 10K. The severely binburnt classification applies when binburnt kernels are in combination with heated kernels in excess of 10%.

e. Severely Binburnt Kernels, including Mildewed Kernels

Binburnt kernels have been heated in storage. This generally occurs from the heat generated from the metal storage drums. Rotted, mouldy and badly mildewed kernels blackened throughout are classed as binburnt. Unfavourable taste and odour result in addition to discolouration, compromising flour quality.

Mildewed kernels usually have dark grey streaks on the sides of the kernel toward the brush end. Mildew is a very slow growing, harmless mould. Its degrading factor is based upon the kernel appearance. Samples containing mildewed kernels will be degraded on the incidence and severity of kernel damage by mildew. Severely mildewed kernels, blackened throughout, are graded as severely binburnt.

f. Fireburnt Kernels

Kernels scorched by fire are classed as fireburnt. Such kernels are noticeably black with objectionable odour. Because it is not possible to separate all the kernels affected by smoke or heat in wheat which has been damaged by fire, all regular grades of wheat must be free from all fireburnt odour and kernels.

g. Odour

Wheat that has a distinct odour other than that associated with heated or fireburnt kernels will be graded 'rejected', account of odour. Top grades of wheat are virtually free from any kernels having unnatural or objectionable odours. Samples having a smutty odour are classed under this grading factor.

h. Dark Immature Kernels

The term 'dark immature' is used to describe darkened kernels which are also referred to as 'swath heated' kernels. These kernels are similar in appearance to heated kernels, however, they are sound throughout without the associated heated taste and odour. The immature nature of the kernels and their colour affect milling and bread colour and quality. The tolerances for dark immature kernels range from 1.0% to 2.5% for No. 1 CWRS and No. 3 CWRS, respectively.

i. Ergot

Ergot is a minor disease in wheat. It is, however, poisonous to man and domestic animals. Therefore, kernels affected by ergot degrade a sample appreciatively for medical reasons. Maximum tolerances are expressed by percentage or by the number of kernel size pieces of ergot in 500 grams. For No. 3 CWRS the maximum is 24K or 0.25%.

j. Sclerotinia Sclerotiorium

Sclerotinia sclerotiorium is a disease, similar to ergot, which produces fungous bodies. Its bacteria leads to digestive disorders in livestock and humans. Natural immunization from this bacteria is common, however, not international. Therefore, international distribution of this condition is minimized. As with ergot, similar tolerances are applied, a maximum limit of 0.25% or 24 K for No. 3 CWRS.

k. Shrunken and Broken Kernels

Shrunken kernels are whole kernels that are otherwise reasonably sound. Broken kernels inhibit the proper completion of the tempering process where the germ is removed from the endosperm before milling. Shrunken kernels also affect this process as the wrinkled nature of the bran inhibits the affect of tempering or pearling. Shrunken and broken kernels are, therefore, less suitable for milling than whole, sound kernels. Maximum limits for No. 1 CWRS is 6.0%, No. 2 CWRS is 10.0% and 15.0% for No. 3 CWRS.

1. Stained Kernels

Kernels can become naturally stained by coming in contact with foreign substances such as weed stain. A stained appearance of a kernel occurs when wheat comes in contact with the sap from green foliage of a variety of plants. Naturally stained kernels must meet the maximum tolerances limits ranging from 0.5% for No. 1 CWRS to 5.0% for No. 3 CWRS. Up to 2.5% of Grass Green and Pink kernels may be removed and assessed as dockage to improve the sample. Remaining material must meet maximum tolerances noted on Table 2 on page 22.

Other types of staining occur when kernels are in contact with oil, grease, paint, soil and soot. It is a degrading factor known as 'artifical' as staining affects flour colour.

m. Smudge

Smudge refers to a black or dark brown discolouration or stain similar to blackpoint, however, extending beyond the germ area of the kernel. It can also be identified by the reddish identification associated with some plant diseases. Maximum tolerances specified for smudge, including blackpoint range from 10% to 35%.

Penetrating smudge is discolouration extending throughout the endosperm. This is usually caused by a serious infestation of fungous plant diseases.

n. Blackpoint, Including Smudge

Blackpoint is a dark brown or black discolouration caused by plant diseases (helminthosperium sativa). Maximum tolerances apply to a moderate degree of discolouration confined to the germ end. Tolerances may be reduced according to the severity of the stain and in consideration of the overall quality of the sample.

o. Stones

Stones include hard shale, coal, hard earth pellets or other material of similar consistency excepting fertilizer pellets. Any material that is readily removed by ordinary cleaning methods may be assessed as dockage. Grade tolerances for material classed as stones are established for material that is not readily separable. Tolerances are expressed in number of stones per 500 grams, ranging from 3K for No. 1 CWRS to 5K for No. 3 CWRS wheat. Where it is not practical to use count, quantity of stones is expressed by percentage weight.

p. Insect Damage

Insect damage can include Sawfly, Midge, Grasshopper or Army Worm infestations. Sawfly and Midge damage is characterized by shrivelled or distorted kernels. Grasshopper and Army Worm damage is characterized by kernels that are chewed, usually on the sides. The tolerances noted on Table 2 on page 22 are not absolute maximum tolerances. The assigned grade takes into account the varying degree of damage and the overall quality of the sample.

2.3.3 'Rejected' and 'Sample' Grades

A wheat sample may seem to qualify for a particular grade, however, there may be unfavourable characteristics that will excessively degrade the sample. In this circumstance the term 'rejected' is added to the grade name for which it would otherwise qualify with a notation of the associated degrading factor. Such grades can be further cleaned or blended with other wheat in order to standardize quality. The term 'rejected' is made part of the grade name to indicate an 'Off-grade' or 'Class III' grade because of inseparable mixture or condition other than moisture that is not permitted in Class I (Statutory Grades) or Class II (Special) grades.

Wheat that does not qualify for any grade, including a 'rejected' grade is graded 'sample'. The term 'sample' is added to the grade name in addition to the major degrading factor. When a shipment of grain has reason to be classed 'sample' in addition to reasons for which it could be termed 'rejected' the wheat assumes the classification of 'sample'.

A precise order of precedence is given by the CGC in order to determine the primary and secondary degrading factors. The order of precedence is as follows:

Salvaged wheat

Fireburnt

Excreta

Ergot

Odour

Rotted Kernels

Heated Kernels

Mildewed Kernels

Damaged Kerrnels

Stained Kernels

Sprouted Kernels

Dried Kernels

Admixture

Stones

When there are two or more reasons for classifying wheat 'rejected' or 'sample' only the primary factor is included in the grade name. Secondary reasons are noted.

2.3.4 Moisture Testing

Moisture content affects both the grinding and sifting operations of milling. Generally, as the moisture content of the kernel increases, the bran becomes tough and less brittle while the endosperm becomes mellow and more friable. However, the cohesion between the bran and the endosperm becomes stronger, so that the endosperm is more difficult to remove from the bran. As moisture level increases, the separation of the particles by sieving also becomes more difficult.

Moisture testing is performed in accordance with the CGC inspection guidelines. Official moisture meters are used to determine the percentage of moisture in the sample. When wheat contains excessive moisture, an appropriate term is added to the grade for which it qualifies. Samples are graded 'tough' when moisture content ranges between 14.6% and 17.0%. 'Damp' samples have an excess of 17.0% moisture content.

There are natural and artifical processes utilized to reduce moisture levels for storage and milling purposes. Natural heating is achieved when dry wheat is mixed with kernels of high moisture content and stored. The sample moisture level is reduced over time. The endosperm is not effected by this drying purpose. Mechanical dryers can also be used to dry wheat. Although damage can result from this process, it is infrequent. The 'rejected' and 'sample' degrading factor termed 'dried' refers to damage caused by artifical drying procedures. Less elastic and extensible bread dough is caused by severe heat treatment of wheat which tends to make the glutten harsher and tougher. Flour yield and crumb texture are therefore affected.

2.3.5 Protein Testing

Protein level is not defined as a grading factor, however, it is assessed because of premium prices paid for high protein wheat. Protein is not a factor determining milling quality except insofar as the protein content tends to be higher in vitreous kernels. The strength of the flour refers to the baking character and is highly dependent upon the protein level of the flour.

Flour protein content is an extremely important baking property because all other properties are a function of protein quality. These properties include water absorption, mixing requirements, dough handling, loaf volume and bread crumb. Bread quality is measured by the water absorption capacity of the flour and the power of the flour to produce large well shaped loaves. The production of well shaped loaves depends upon the gas production, gas retention and the physical extensibility and resistence of the gluten.

When wheaten flour, water, yeast and salt are combined in the bread making process, the protein in the flour begins to absorb the water to form gluten. Starch also absorbs water. The amount of water absorbed to make a dough of standard consistency increases in proportion to the content of protein and damaged starch present. Only damaged or broken starch cells can absorb water. Damage to the starch cells occurs during the grinding process of milling. Flour emzymes are able to attack only the damaged starch. It is, therefore, essential that the flour contain adequate damaged starch to supply sugar during fermentation. Severe over grinding during the milling process causes excessive starch damage. This has the effect of reducing bread volume because of excessive water absorption.

The protein in the flour combines with water to form the extensible gluten. The action of glucose and fructose emzymes of flour on the water and starch produces carbon dioxide which aerates the dough. The amount of gas produced depends upon the quantity of soluble sugars in the flour. If there are not enough damaged starch cells, emzymes cannot generate enough gas for quality yield and texture. Gluten, while being sufficiently extensible to allow the loaf to rise, must be strong enough to prevent gas from escaping too readily as this would lead to loaf collapse. Therefore, adequate but not excessive gas must be produced during fermentation, otherwise, the loaf will not inflate sufficiently. The value of high protein wheats is reflected by the higher prices received at the Winnipeg Commodity Exchange. CWRS is sold at protein levels of 11.5%, 12.5% and 13.5% (Grain Statistics Weekly: Crop Year 1980-1981, 51st Week, p. 14). Extra No. 1 and Extra No. 2 CWRS wheat grades were established for the crop year under study for wheat in excess of 13.5% protein content.

2.4 CONCLUSION

Canada's reputation as a dependable and consistent producer of the highest quality of CWRS wheat is derived from the rigid adherence to the grading criteria and specifications established by the CGC. The many criteria considered in determining the appropriate assignment of wheat produces grades with consistent quality and a high level of uniformity existing within each grade.

During the mid-nineteenth century the steam powered rollermilling method was developed for grinding grain between rollers. This method was particularly suited to the milling of hard wheat varieties, capable of producing high quality leavened bread. The process was successfully developed in Hungary and by the end of the century had been established throughout North America.

Flours produced in milling are classified as 'strong' or 'weak' depending upon the nature of the wheat from which they are milled. A strong flour has the capacity to produce large porous loaves of fine and even texture. High strength in flour is related to high gluten content, providing high elasticity and high tensile strength (Petersen, 1969, p. 113). Strong wheats are usually from the hard endosperm varieties, however, not all hard wheats have strong flour. Strong wheats with strong gluten are particularly suited to the production of high quality leavened bread. Canadian grain marketing efforts are based upon the production technology for high quality wheaten bread. This emphasis is responsible for the present grading system for hard red spring wheat. Any of the factors taken by itself gives a guarantee or assurance of either milling quality of the wheat or the baking quality of the flour. Overall, however, these criteria establish grades that are highly favourable for bread making. The importance of the high protein level and the strong gluten content is critical for the successful marketing of CWRS wheat to specialized international markets.

The bread loaf size and texture is related to the number of damaged starch cells in the flour. Starch granules which are detached from the protein of the kernel are extremely difficult to damage mechanically. Hard wheat kernels are initially split along the cell walls. The increased pressure of the rollermills cracks the starch granules, thereby creating the damaged starch cells necessary for the production of leavened bread. In contrast, the starch granules of the cells of a soft endosperm are not damaged by rollermilling action. The harder wheats can produce the most desirable amount of damaged starch cells, thereby regulating the water absorption rate of the flour for the production of a specific loaf shape and size.

Since the 1950's and paricularly since the mid 1960's the export market for CWRS wheat has changed quite noticeably (Tipples, 1976, p. 485). Total export trade has been increasing, especially trade with Asian countries. European trade, however, has declined. The international production of soft wheat is steadily increasing, meeting the demands for wheaten products in developing nations. While the importance of bread in total food consumption in developing nations is increasing it is a decreasing component in European and North American diets which have historically formed the traditional Canadian export markets.

Canada's major international trading partners for the soft wheats used for cake and cookie production include developing nations. Production and trade in the softer wheats is increasing worldwide. This is directly associated with the changes in wheat technology over the past twenty years. The recent development of Chorleywood bread making process requires less hard wheat and a corresponding increase in the proportion of soft, weaker wheats of lower protein. Soft wheats are domestically produced in many of countries which import hard wheat. Despite this change in technology, Canada has opted to continue its emphasis on the production of hard wheats, which, when blended with weak flour, has the capacity to produce porous loaves of satisfactory volume, with even and fine crumb texture. Canadian CWRS wheat was formally used predominantly in European markets, usually in blends with weaker wheats for bread production (Tipples, 1976, p. 485).

This analysis measures the cost associated with the grain transportation system in Canada. The quantitative measurements are compared to the costs associated with aggregated grading system. Aggregration of the number of grades is expected to decrease total costs associated with the delivery patterns. However, the relative savings must be identified as significant in order for the present grading system to be criticized on the basis of the analysis presented in this investigation.

3.0 THE WHEAT TRANSPORTATION SYSTEM IN CANADA

3.1 SYSTEM OVERVIEW

The wheat transportation system represents a process whereby grain is harvested by producers, delivered to country elevators by means of producer delivery quotas imposed by the CWB and forwarded, via regional railway networks, to export terminals, where it is cleaned and loaded onto vessels. The Block Shipping System is the mechanism utilized to implement the positioning of grain for loading onto vessels at export terminals.

During the 1969-1970 crop year the Block Shipping System was introduced to provide a method of allocating empty railcars and hopper cars among spatially separated producing regions and grain companies whereby train runs could be scheduled to efficiently deliver grain to export terminals. Hence the grain producing areas of the Prairies were divided into forty-nine 'blocks', each of which services approximately four hundred miles of track of one railway company and one hundred country elevators among forty delivery points.

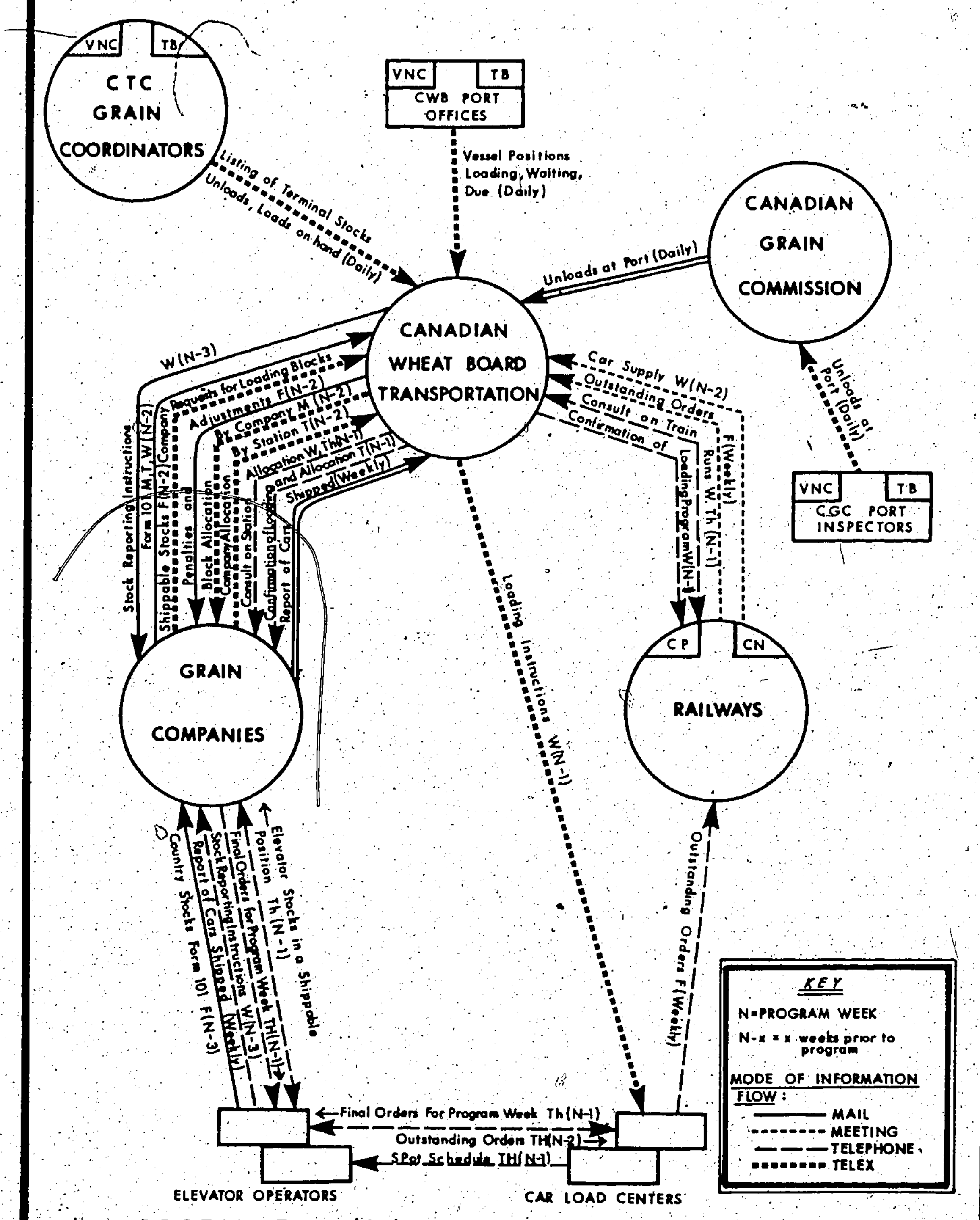
The 'block' is based upon the railway's train schedules by subdivision so that the railway company can provide flexible service on a weekly basis to the entire sub-network. The block shipping system results in the weekly allocation of railcars to shipping blocks and to grain companies for delivery to specified ports. The CWB is responsible for implementing the six week planning cycle of the coordinating program. Programs for successive weeks evolve simultaneously so that the railways, the CWB and the grain companies are continuously engaged in several stages of the process at any particular time. Figure 3 on page 45 represents the information flows that are involved in the car allocation process. Each week of the crop year is identified by its chronological week number, from one to fifty-two. The first week in August is Week 1 of the crop year. The timing of events which occur in order to meet the requirements of the program week are included on the Figure (Booz, Allen and Hamilton, 1979, App. N).

The inital step in the planning cycle is to ascertain the demand for Board, Non-Board and Off-Board grains. Statutory grades, listed in Schedule I of the Canadian Grain Act are known as Board Grains, traded only by CWB subject to the Crow Rate freight structure. Off-Grades apply to grain that cannot be graded into Statutory Grades because of condition or admixture. Non-Board grains are those grains that are traded independently and free from the CWB. The demand for Board grains is estimated by grade and type on the basis of the export sales programs agreed upon. Refinements to the estimates are made for the ports of Vancouver, Thunder Bay, Churchill and Prince Rupert.

Once the demand has been formulated, the potential stocks expected to be in export position during Week 6 are determined. Information regarding

FIGURE 3

INFORMATION FLOW FOR IMPLEMENTING THE ALLOCATION SCHEDULE



From: BOOZ, ALLEN and HAMILTON, 1978

terminal stocks, unloads, cars on hand, cars en route, country loadings and cars ordered are considered. The shortfalls between the expected demand and the expected stocks at the terminal elevators represent the quantities of grains by type and grade that must be delivered to meet the expectations of Week 6.

During Week 2 preliminary estimates are made of the quantities of grain that will be drawn from each of the forty-nine shipping blocks to determine the number of cars necessary to deliver the required grains from the country to terminal position. The instructions regarding the block, type and grade of grain to be loaded for delivery during Week 5 are prepared for distribution to the railways, elevator companies and elevator agents. These decisions are based upon the elevators managers' reports of shipable stocks by type and grade mailed weekly to the CWB.

During Week 3 a final position statement is prepared of the required cars at each destination in Week 6 by type, grade and protein level. The Grain Transportation Authority meets with the railway representatives to negotiate the car supply that will be made available for the transportation of Board and Non-Board grains. The CWB then allocates all cars handling Board grains and Non-Board grains to elevator companies. The type of grain, Board or Non-Board, is specified for each delivery. Each elevator company determines which blocks Non-Board grain cars will be spotted and at which primary elevators. In the case of Board grains the CWB has the responsibility to allocate the available railcars to elevator companies by specific shipping block. In order to perform this responsibility, however, the CWB is dependent upon the grain companies to provide current information on stock positions, to allocate cars to their elevators for the purposes of shipping a specified grain grade and to comply with the allocation once ordered.

The members of the CWB Transportation staff meet with railway representatives to determine the spotting of cars by block which will minimize the railways overall costs. Where possible the reassignment of crews to other subdivisions and the running of extra trains runs are avoided.

Once the bulk allocations of railcar are determined for each shipping block, the CWB and the railway companies determine the bulk allocation of cars to elevator companies. The Bracken formula is used to allocate the railway car supply among the elevator companies in each block. The formula is based upon the company's share of business of Board grains in the block over the previous year.

During Week 4 the elevator managers are informed of the authorized number and type of shipments to be made the following week. The railways are informed of the spotting instructions by type and grade, and the destination of the grain to be loaded. The spotting and loading of cars at primary elevators occurs during Week 5. The shipment of grain to port terminals is to be completed during Week 6.

Despite this planning program, this study presents an annual analysis of the overall transportation coordination efficiency because a 1978 survey over three months of grain unloads indicated that only 38% of grain ordered was unloaded within the six week planning cycle period. Booz Allen and Hamilton (1978, IX-2) suggest that orders are filled usually over a period of eleven to twelve weeks, 27% of orders arriving in the seventh week, 16% arriving in the eighth week, 8% arriving in the ninth week and 11% arriving during the tenth week or later. This makes the analysis of transportation coordination difficult and for this reason the annual availabilities and requirements are addressed in this analysis.

In order to apply the Transportation Problem to the delivery of CWRS wheat, the system must be represented as a set of supplies, demand and shipping costs. These three input parameters define the system and enable the Classical Transportation Problem model to derive the minimum cost solution while fulfilling the shipment requirements.

3.2 ORIGINS

The CWB has organized the Western Canadian railway network into a set of forty-nine geographical areas known as 'blocks'. These forty-nine blocks are utilized to coordinate the transportation of grain to export terminals. Each block represents the geographical area serviced exclusively by one of the operating railways. The Canadian National network is presented on Figure 4 on page 50. The Canadian Pacific network is presented on Figure 5 on page 51. In 1981 the Northern Alberta Railway, which includes blocks 90, 95, 97 and 98, became part of Canadian National Railways allowing access to Prince Rupert. These figures show the CN and CP blocks on different maps as the regions served overlap where the competing railways are nearby each other. The rail lines that form each of the forty-nine blocks were identified (Grain Deliveries from Prairie Points: Crop Year 1980/1981).

The block system represents a logical and practical system to utilize in this analysis as railcars are initially allocated for loading by block. The distribution of railcars among elevators within blocks is determined by elevator companies, which represent decisions made external to the CWB and to the system presently under investigation.

Although the origins of commodities may actually constitute regions, they must be represented by points in the framework for analysis. The shipping costs between each origin and destination pair must be a single value. This eliminates any variation in costs which may exist among the country elevator points within the region represented by a particular block.

Each block was assigned a centroid, which identifies the mid-point of the network it represents. The midpoint was selected by measuring the rail

FIGURE 4

CN SHIPPING BLOCKS

BLOCKS ON CN LINES

BLK. No.	BLK. NAME	BLK. No.	BLK. NAME
1	WINNIPEG N.	27	PRINCE ALBERT S.
3	WINNIPEG S.	29	PRINCE ALBERT W.
5	WINNIPEG W.	31	SASKATOON E.
7	BRANDON N.	33	REGINA S.
9	BRANDON W.	35	REGINA W.
11	MELVILLE	37	BIGGAR N.
13	DAUPHIN	39	BIGGAR W.
15	KAMSACK	41	EDMONTON N.
17	SASKATOON MAIN	43	EDMONTON S.
19	SASKATOON S.	45	EDMONTON W.
21	SASKATOON W.	47	HANNA S.
23	SASKATOON N.	49	HANNA W.
25	PRINCE ALBERT E.	90	NOR. ALTA. RLY. WEST
		98	GREAT SLAVE RLY.

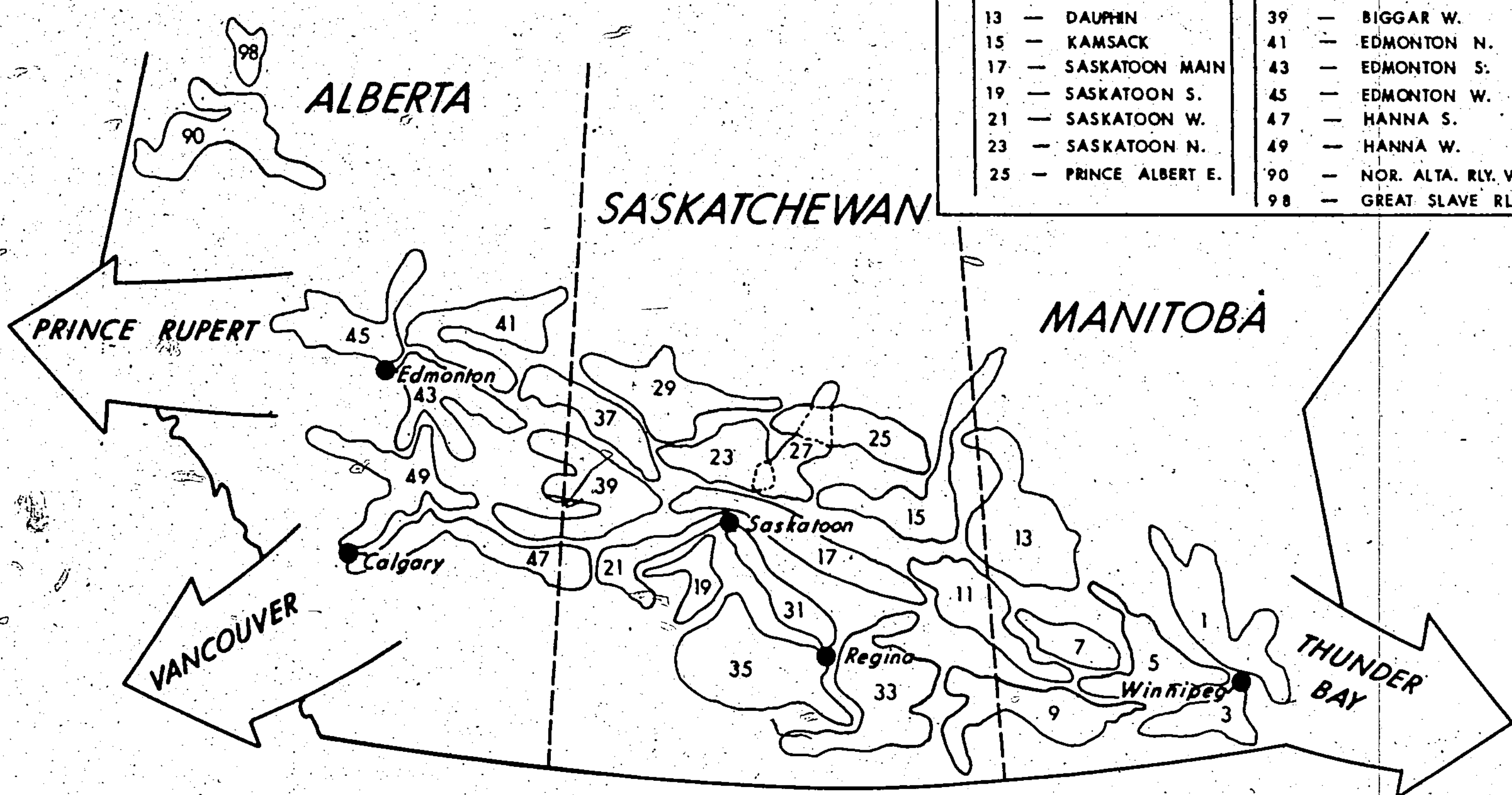
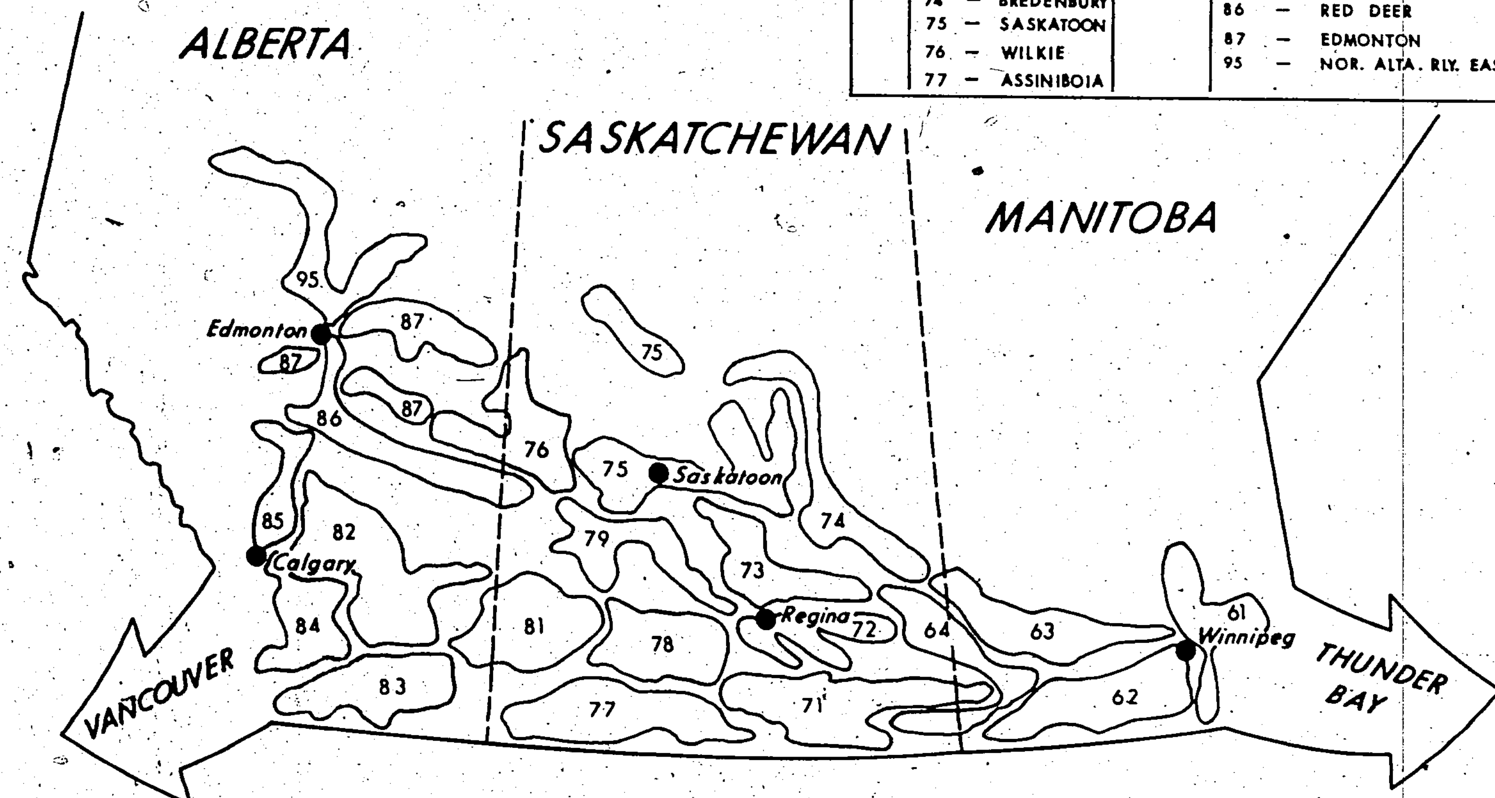


FIGURE 5

CP SHIPPING BLOCKS

BLOCKS ON CP RAIL LINES

BLK. No.	BLK. NAME	BLK. No.	BLK. NAME
61	KEEWATIN	78	SWIFT CURRENT
62	LA RIVIERE	79	OUTLOOK
63	CARBERRY	81	MEDICINE HAT
64	BRANDON	82	BROOKS
71	WEYBURN	83	LETHBRIDGE
72	PASQUA	84	VULCAN
73	BULYEA	85	CALGARY
74	BREDENBURY	86	RED DEER
75	SASKATOON	87	EDMONTON
76	WILKIE	95	NOR. ALTA. RLY. EAST
77	ASSINIBOIA		



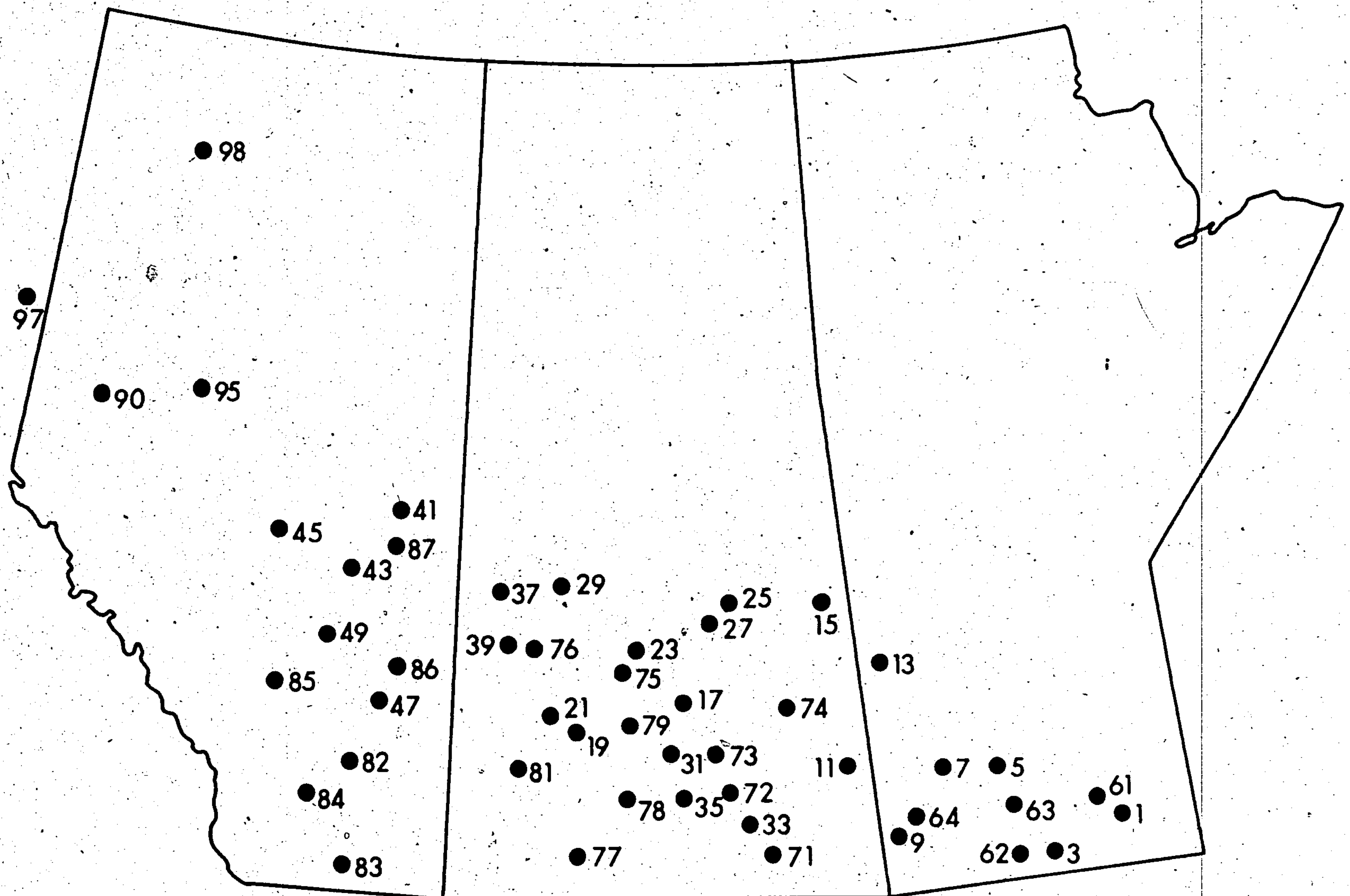
lines within each block (Guy Tombs, 1971). The resultin set of 49 centroids, as shown on Figure 6 on page 53 represent the 49 shipping origins.

The availabilities of supplies at origin points is determined by the delivery quota system, the primary instrument utilized by the CWB through which required grains are delivered from farm storage to country elevators. The system was designed to provide an orderly flow of required types and grades of grain to meet sales commitments and to provide equity of delivery opportunities to all producers.

Delivery quotas are set weekly by type of grain and grade in each block according to the CWB's knowledge of availabilities of grains and upcoming sales contracts. Once the overall demand for grains has been established, the CWB must determine where it can collect and deliver the necessary tonnages. Delivery quotas are then set based upon a tonnage per acre per producer for specific grains. The block shipping system is utilized at this point to allocate railcars to the elevators companies by block, specifying the grain type, grade and final destination. The railcars are then allocated to country elevators within the block, assuming that the delivery quotas will be met at each primary elevator. Those elevators that will be loading railcars receive deliveries from producers based upon the delivery quotas set for the week. The railcars are then loaded with the specified grade and forwarded to the pre-arranged destination.

FIGURE 6

ORIGIN POINTS OF DELIVERY OF CWRS WHEAT



3.3 DESTINATIONS

Four destinations are used in this study: the export terminals of Vancouver, Prince Rupert, Churchill and Thunder Bay, as shown on Figure 2 on page 18.

The demand for Board grain to be delivered to these ports is initially estimated on the basis of monthly sales programs. The demands at Vancouver, Prince Rupert and Churchill are defined in terms of vessel nominations. Therefore, the CWB must organize its delivery patterns to meet the ship arrivals estimated at these ports.

Vessel nominations are not a significant factor in determining demand at Thunder Bay, as demands are highly dependent upon the requirements set at the St. Lawrence ports (Montreal, Quebec, Baie Comeau, Port Cartier) and the Atlantic ports (Saint John and Halifax) during the winter months. The transloading characteristics of Thunder Bay increases the planning cycle by two weeks to account for

1. the off-loading of grain from railcars to lakers at Thunder Bay;

2. transit time from Thunder Bay to St. Lawrence ports;

3. the discharge and distribution of grain among river port elevators;

4. the offloads of grain from lakers to alternative vessels at river ports.

Defining the demand for grains at all ports is dependent upon the information on the available stocks, unloads, cars en route, country loadings and cars ordered. Stock information is available from the following sources;

1. Terminal Stocks are available from the Canadian Transport Commission Coordinator and the Grain Commissioner;

2. Unloads are available from the railway companies and the Canadian Transport Commission Coordinator;

3. Cars en Route are available from the railway companies and the Canadian Transport Commission Coordinator;

4. Country Loadings are available from the grain companies and railway companies;

5. Cars Ordered are available from the Canadian Wheat Board.

The available stocks, potential stocks and estimate stocks are compared to the demand formulated for each of the port destinations: Vancouver, Prince Rupert, Churchill and Thunder Bay. The shortfall between the stocks expected to be in vessel loading position and the required stocks is determined. The CWB then sets delivery quotas in order to move the required grains to points of loading for transportation to terminal ports. These demands form the basis for determining the deliveries from country elevators.

3.4 TRANSPORTATION COSTS

During the 1980-1981 crop season, the transportation costs of shipping grain for export was regulated by the Crow's Nest Pass Freight Rates. These Crow Rates are used to determine the minimum cost solution to the transportation problem. The Crow Rates from each block were collected from the series of maps presenting the Crow shipping charges from CN and CP lines to the export terminals available from Transport Canada (1967). The average rate in each block was obtained and tabulated to represent cents per tonne of grain. Table 3 on page 57 lists the rates from all CN origins to the four terminal ports and from CP origins to Thunder Bay and Vancouver. Rail service is not provided from CP origins to Prince Rupert and Churchill under the Crow Rate freight structure. This table is the transportation cost matrix utilized in the Transportation Problem model.

It is generally accepted that the Crow Rates, established by the Federal

TABLE 3
CROWSNEST PASS FREIGHT RATES FROM PRAIRIE POINTS TO EXPORT TERMINALS
(dollars per metric tonne)

Origin	Block	Block Name	Thunder Bay	Churchill	Vancouver	Prince Rupert
01	01	Winnipeg North	3.41	5.18	7.39	7.39
02	03	Winnipeg South	3.31	5.18	7.61	7.61
03	05	Winnipeg West	3.53	4.96	7.28	7.28
04	07	Brandon North	3.57	4.74	6.83	6.83
05	09	Brandon West	3.86	5.07	6.83	6.83
06	11	Melville	4.08	4.30	6.72	6.72
07	13	Dauphin	4.30	4.30	6.72	6.72
08	15	Kamsack	4.63	4.07	6.61	6.61
09	17	Saskatoon Main	4.74	4.74	5.73	5.73
10	19	Saskatoon South	5.07	4.96	5.62	5.62
11	21	Saskatoon West	5.18	4.96	5.40	5.40
12	23	Saskatoon North	4.96	4.63	5.40	5.40
13	25	Prince Albert East	4.85	4.18	5.95	5.95
14	27	Prince Albert South	4.89	4.41	5.62	5.62
15	29	Prince Albert West	5.34	4.74	5.40	5.40
16	31	Saskatoon East	4.63	4.85	5.95	5.95
17	33	Regina South	4.30	4.85	6.28	6.28
18	35	Regina West	4.63	5.07	6.17	6.17
19	37	Biggar North	5.29	4.96	5.18	5.18
20	39	Biggar West	5.29	5.07	5.29	5.29
21	41	Edmonton North	6.39	5.84	4.63	4.63
22	43	Edmonton South	5.62	5.51	4.63	4.63
23	45	Edmonton West	6.17	5.73	4.52	4.52
24	47	Hanna South	5.40	5.40	4.74	4.74
25	49	Hanna West	5.84	5.62	4.74	4.74
26	61	Keewatin	3.31		7.83	
27	62	La Riviere	3.53		7.39	
28	63	Carberry	3.64		7.39	
29	64	Brandon	3.97		6.72	
30	71	Weyburn	4.30		6.50	
31	72	Pasqua	4.18		6.06	
32	73	Bulyea	4.52		6.17	
33	74	Bredenbury	4.52		6.61	
34	75	Saskatoon	4.85		6.06	
35	76	Wilkie	5.29		5.29	
36	77	Assiniboia	4.96		5.62	
37	78	Swift Current	4.74		5.95	
38	79	Outlook	4.96		5.51	
39	81	Medicine Hat	5.18		5.18	
40	82	Brooks	5.62		4.74	
41	83	Lethbridge	5.51		4.96	
42	84	Vulcan	5.73		4.63	
43	85	Calgary	6.17		4.63	
44	86	Red Deer	5.84		4.63	
45	87	Edmonton	5.84		4.85	
46	90	N. Alberta R.R. West	5.95		5.07	
47	95	N. Alberta R.R. East	5.95		5.07	
48	97	British Columbia R.R.	5.95		5.07	
49	98	Great Slave R.R.	5.95		5.07	

statute entitled the Crow's Nest Pass Agreement of 1897, no longer compensate the railways for the actual shipping costs associated with the provision of service. Repeated studies, including the Macpherson Commission (1960), Snavely Commission (1974, 1977, 1980) and the Hall Commission (1977), have concluded that the Crow Rates do not reflect the actual costs of providing rail service from Prairie points to terminal elevators. The Snavely and Hall Commissions conclude that the Crow rates represent approximately 20% of the actual cost of providing the transportation service. Nevertheless, the railways charge these rates to the grain companies for grain delivery and they are used in this study to demonstrate the actual costs of flows in the transportation system. It is interesting to note, however, the association of the Crow Rates between origin and destination pairs and the minimum rail line distances.

Pearsons Product Moment Correlation test was applied to the Crow Rates per tonne of wheat and the rail distances between supply and demand points. The distances between all origins and all destinations were determined by calculating the shortest path railway mileages between each origin and destination. The rail lines included in the network shown on Figure 7 on page 60 are those identified as the Basic Network by the Hall Commission (1977). These links include both CN and CP lines. The connectors in the link data represent the junctions of the CN and CP rail networks. Through the use of a computer program employing the Cascade algorithm, the shortest paths were generated (Farbey, B.A., et. al.). No distinction exists between CP and CN in determining the shortest paths. Table 4 on page 61 presents the shortest rail line distances generated between origins and destinations.

The relationships between Crow Rates and the actual railway distances were investigated for all origins (both CN and CP) and exclusively for the CN destinations of Churchill and Prince Rupert. Rates from CN and CP origins to Thunder Bay generated a correlation coefficient of 0.9123. Rates from CN and CP origins to Vancouver generated a result of 0.9053. The results, presented on Table 5 on page 62 demonstrate that rate schedules on both CN and CP lines to all export teminals are highly associated with the rail line distances and explain approximately 80% of the variability. Therefore, it can be concluded that the Crow Rates are highly reflective of the delivery distances required to bring wheat to export terminals.

Although the coefficient varies with the origin/destination set under investigation there is no significant favourable bias indicated towards any of the export terminals or the railway compaines for shipping rates. The highest regression coefficients were generated for CP origins to Thunder Bay (0.99) and CN origins to Thunder Bay (0.9873). The coefficient of 0.8649 was generated for all origin to all destination pairs.

The results of this regression analysis indicates that the Crow rates probably represent some of the shipping costs related to length of haul. Yet, there are other variables to be considered in railway costing.

FIGURE 7

RAILWAY LINKS INCLUDED IN THE HALL BASIC RAILWAY NETWORK

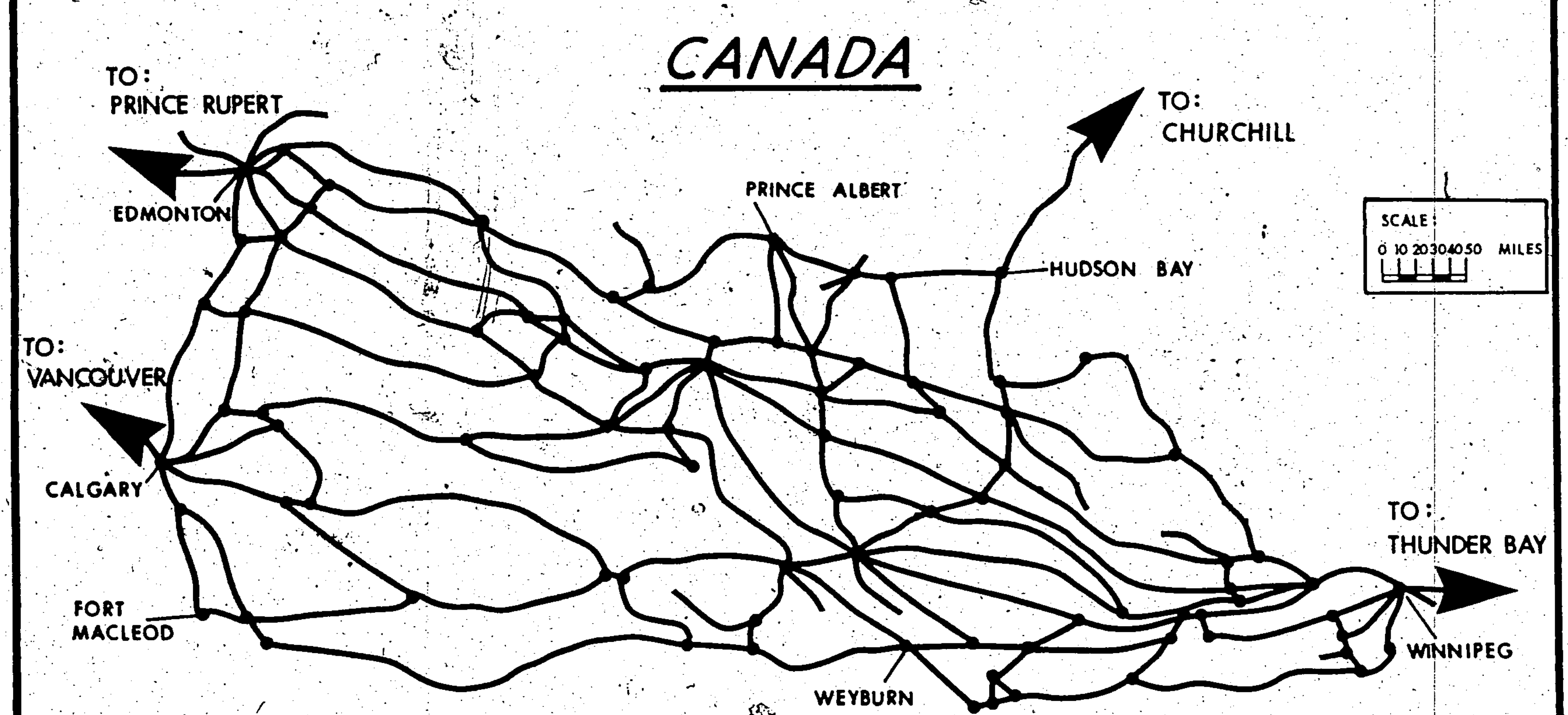


TABLE 4

SHORTEST PATH DISTANCES BETWEEN ORIGINS AND DESTINATIONS

(Distance in miles)

Origin	Block	Block Name	Thunder Bay	Churchill	Vancouver	Prince Rupert
01	01	Winnipeg North	433	1010	1483	1796
02	03	Winnipeg South	487	1002	1435	1754
03	05	Winnipeg West	521	888	1437	1707
04	07	Brandon North	583	840	1389	1659
05	09	Brandon West	623	976	1259	1620
06	11	Melville	666	777	1237	1529
07	13	Dauphin	693	737	1130	1600
08	15	Kamsack	811	598	1276	1531
09	17	Saskatoon Main	823	823	1102	1372
10	19	Saskatoon South	991	942	987	1372
11	21	Saskatoon West	970	919	955	1310
12	23	Saskatoon North	892	816	1058	1324
13	25	Prince Albert East	866	704	1188	1443
14	27	Prince Albert South	871	709	1193	1448
15	29	Prince Albert West	1035	910	1138	1331
16	31	Saskatoon East	844	920	1129	1399
17	33	Regina South	751	891	1159	1520
18	35	Regina West	811	887	1071	1448
19	37	Biggar North	1025	938	998	1191
20	39	Biggar West	999	948	997	1196
21	41	Edmonton North	1320	1254	967	1099
22	43	Edmonton South	1168	1105	855	1027
23	45	Edmonton West	1250	1184	897	1029
24	47	Hanna South	1148	1097	777	1212
25	49	Hanna West	1216	1165	770	1088
26	61	Keewatin	416	993	1466	1779
27	62	La Riviere	534	1062	1419	1795
28	63	Carberry	493	944	1389	1702
29	64	Brandon	595	933	1289	1646
30	71	Weyburn	732	929	1163	1540
31	72	Pasqua	769	845	1113	1474
32	73	Bulyea	789	838	1157	1433
33	74	Bredenbury	742	760	1157	1464
34	75	Saskatoon	885	834	1040	1310
35	76	Wilkie	981	930	1006	1217
36	77	Assiniboia	961	1037	1029	1589
37	78	Swift Current	856	932	1026	1493
38	79	Outlook	908	921	1036	1351
39	81	Medicine Hat	982	1058	942	1399
40	82	Brooks	1157	1233	725	1285
41	83	Lethbridge	1191	1267	787	1347
42	84	Vulcan	1230	1302	710	1270
43	85	Calgary	1299	1258	699	1143
44	86	Red Deer	1142	1091	832	1162
45	87	Edmonton	1664	1060	942	1074
46	90	N. Alberta R.R. West	1664	1060	942	936
47	95	N. Alberta R.R. East	1448	1598	1095	1152
48	97	British Columbia R.R.	1871	1805	728	729
49	98	Great Slave R.R.	1756	1690	1217	1218

TABLE 5

PRODUCT MOMENT TESTS OF ASSOCIATION BETWEEN CROW RATES AND RAILROAD DISTANCES

Set of Origin Points	Destination	Correlation Coefficient
CN Blocks	Churchill	0.973
CN Blocks	Prince Rupert	0.977
CN and CP Blocks	Thunder Bay	0.987
CN and CP Blocks	Vancouver	0.938
CN Blocks	Thunder Bay	0.987
CP Blocks	Thunder Bay	0.990
CN Blocks	Vancouver	0.938
CP Blocks	Vancouver	0.979

Costing studies have been carried out by the Northern Alberta Railway, CN and CP Railways as submissions to royal commissions dealing with railway costing and pricing. There is a common tendency to aggregate the costs to the system wide level, without dealing with line related costs in a comprehensive manner. The concern with branch line abandonment has generated costing research on grain dependent lines, however, there has been no differentiation established between the costs associated with differences in terrain, grade, the capacity of links or the multiple-use and shared costs of other lines which can be applied to specific links in the network. These characteristics of the costing studies of the Canadian wheat transportation industry eliminate the possibility of determining the actual costs of a delivery for the purposes of this analysis. Indeed, the problem of the adequacy of this field of research is recognized. Because of the unique nature of the Canadian system, further research must evolve from Canadian interest. Application of railway costing from other grain producing regions is highly discouraged (Hall, 1977).

The Crow Rates vary directly with tonnage shipped. In addition, the rates do not distinguish between the type, grade or value of grains. Therefore, all grains are moved at the same rate, dependent upon weight, eliminating the need to vary the rates for commodities of varying value. This fact is important in assessing the importance of shipping costs to the export trade of wheat.

The CWB operates its delivery programs with a fixed supply of railcars allocated by the Grain Transportation Authority. The number of cars allocated usually represents a shortfall from the total number requested. In light of this fact, it is particularly important for the CWB to efficiently program its deliveries. Long cross-hauls are therefore particularly costly to the CWB because rolling stock is not being used effectively.

3.5 EXCLUSIVE RAILWAY SERVICE AREAS

The Canadian National Railway and the Canadian Pacific Railway are the two firms handling the rail transportation of grain for export. The block shipping system is organized about mutually exclusive service areas. The impacts of this exclusiveness result in the restricted use of the ports of Churchill and Prince Rupert by CN only. These restricted deliveries are known as direct non-reciprocal shipments. Producers, therefore must operate through CN elevator points in order to have their grain shipped out of Churchill and Prince Rupert. Deliveries to elevators on CP lines do not, in normal circumstances, deliver to Churchill or Prince Rupert regardless of the contract demands or proximity to these terminal ports. In fact, direct non-reciprocal traffic accounted for 93.9% of statutory grain unloadings in 1980.

During the study period of 1980-1981 the railways transported grain under three other shipment categories. In 1977 the railroads began to transport grain under reciprocal agreements. Such grain is interchanged between CN and CP lines for movement to statutory rate destinations. Approximately one-half of the reciprocal traffic is loaded in CN cars at country elevator points on CP lines or the Northern Alberta Railway (NAR) and interchanged at Edmonton for delivery to Vancouver or Prince Rupert. The remaining one-half is loaded on CP cars at CN points and interchanged with CP at Calgary for delivery to Vancouver. This type of traffic accounted for 998,607 tonnes or 3.7% of the total statutory grain tonnage in 1980. The transit traffic category describes grain that is stopped and unloaded at intermediate points for cleaning, storage or processing and reloaded for movement to the terminal elevator. In 1980 transit traffic accounted for 519,711 tonnes or 1.9% of statutory grain delivered. In 1980 the Churchill Agreement took effect to facilitate the movement of grain from the Saskatoon area to Churchill. Under this agreement, CN cars were loaded by CP at CP elevator stations and delivered to Churchill. This traffic amounted to 137,098 tons, representing 0.5% of total 1980 tonnage and 41.8% of the Churchill tonnage (Snavely, 1982, p.23). That this program has not been extended and will probably never be repeated indicates that CN/CP railway service exclusiveness will continue. The costs of maintaining this situation will be addressed using the Transportation Problem.

3.6 CONCLUSIONS

Despite the complex and rigorous structure of the grain grading and transportation system described, there is room for a considerable degree of competition between delivery points and among elevator agents at delivery points where more than one company is represented (Key Issues in Canadian Grain Transportation, p. 53 and Booz-Allen, and Hamilton, 1979, Appendix S).

In effect, the result is that the factors defined as standard criteria for grading may be interpreted differently among elevator companies and elevator agents. The Canadian Grain Commission applies the most consistent criteria to grain grading at terminal elevators at the time of official grading. The rigid application of specifications as set forth in the annual publication Grain Grading Handbook for Western Canada by the Western Grain Stabilization Board of the CGC can result in the renaming of the grain grade from the initial grade assigned by individual country elevator agents. The variance in grade definition between grading at country elevators and the offical grading at terminal elevators is supported by the evidence provided by Booz Allen that 31% of the unloads over a 12 week period were either one grade (17%) or two grades (3%) different from that ordered or a totally different type of grain (1%) (Booz Allen, p. VI-16).

The initial visual appearance of the grain sample, in addition to the test weight constitutes the overall extent of the grading at country elevators. Protein testing is not universal among elevators and producers and is therefore not explicitly incorporated into the transportation system coordination system. Moisture levels are important for storage arrangements but requests for deliveries of grains are not subject to moisture considerations. Penalities are assessed by the CWB in the form of decreased rail car allocation if the grade unloaded does not meet the grade requested. Shipments of tough or damp grains are not penalized when unloaded at terminal ports expecting to be at normal moisture levels.

The transportation system has been represented as a set of origins and destinations, with a unique cost associated with the origin-destination transportation patterns. These three input parameters are utilized by the transportation problem to determine the minimum cost delivery patterns for the given supplies and demands.

The transportation system is well represented for application to the Transportation Problem for several reasons. The forty-nine shipping blocks and the four terminal ports represent the actual organization of the grain transportation system. The transportation costs, varying with tonnage shipped, are fixed between all origin-destination pairs. The delivery patterns are subject to time constraints in order to meet sales contracts. These characteristics of the coordination and transporation system may provide evidence to consolidate and aggregate the grading system to fewer grades.

For demonstrative purposes, it will be assumed that all grades can be categorized into one homogeneous commodity. The Transportation Problem can provide the miminim shipping patterns for this aggregated system. Total shipping costs are expected to be lower for an aggregated grading system, reflecting the transportation costs associated with the present grading system and the limitations of the transportation coordination system. The additional shipping costs attributed to the cost of supporting the grading structure must be evaluated against the benefits of maintaining this rigorous system. The CNR/CPR incompatibility problem is an additional component to consider in this analysis of transportation cost efficiency.

4.0 THE CLASSICAL TRANSPORTATION PROBLEM OF LINEAR PROGRAMMING

The Classical Transportation Problem of Linear Programming has been attributed to Hitchcock (1941) and Koopmans (1949). Berge (1962) indicated that Monge had developed the framework in 1791. An approach is also given by Kantorovich (1958) as discussed by Gass (1975). Hitchcock formulated the problem to determine the minimum transportation cost of shipping a homogeneous commodity from several spatially separated sources to several spatially separated markets. The solution of a series of linear equations demonstrated a technique for determining the least cost delivery pattern. Koopmans applied the Transportation Problem framework to the principle of marginal cost transport pricing in order to maximize the amount of transportation performed for a given cost. Minimizing the cost of a required set of deliveries leads to the best use of the transportation services available. The Transportation Problem framework has become known as the Hitchcock-Koopmans problem incorporating both the minimization and maximization principles.

The Transportation Problem is presented as a Linear Program. The primal problem of the Transportation Problem minimizes the total transportation costs. Associated with every primal linear programming formulation there is a corresponding maximization problem called the dual problem. The dual problem formulation seeks the minimum buying price of the resource at the supply region and the maximum selling price at demand points within a spatial system. In this context, maximizing the return for the commodity at the point of export is accomplished by minimizing the transportation charges for shipping the commodity. Because transportation costs are the only variables under investigation, transportation cost minimization is the explicit criterion of evaluation. A trader's profits are measured by the greatest difference between the buying price and the selling price. Profits do not, therefore, result when the difference between the buying and selling price are exactly equal to the transportation costs. By a fundamental theorem of Linear Programming, the maximization of the dual problem will be equal to the minimization of the primal problem and profits will not result from shipping the commodity. Nevertheless, the attempt to profit from providing transportation services leads to the optimal solution of both the primal and dual problems.

4.1 THE PRIMAL PROBLEM

Mathematically the the transportation problem minimizes a linear function

$$(1) \qquad \text{MIN:} \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} \cdot C_{ij}$$

where

Z is the objective function representing total transportation costs,

m is the number of supply points,

n is the number of demand points,

Xij is the solution variable determining the amount of commodity x shipped from origin i to destination j,

Cij is the transportation cost of shipping one unit of the commodity from origin i to destination j.

The minimization is subject to the following constraints;

$$(2) \quad \sum_{i=1}^{m} Xij \leq Si \qquad (i=1...m)$$

which specifies that the total amount of the commodity shipped from origin i must not exceed the supply of the commodity at the source;

$$(3) \quad \sum_{j=1}^{n} Xij \geq Dj \qquad (j=1...n)$$

which specifies that the total amount of the commodity shipped to destination j must at least meet the demand for the commodity at j. The problem also specifies that no negative shipments are allowed;

$$(4) \quad Xij \geq 0 \qquad \text{for all } i, j.$$

The solution to the primal problem provides the least cost pattern of shipments required to meet the demand constraints subject to available supply. The optimal pattern leads to the minimum value of the objective funtion, Z, which indicates the total cost of distribution. The measure used to determine costs depends upon the application or the type of data available. Distance, actual production and transportation costs and freight rates can be used. In this application the goal is to minimize the total shipping bill and therefore the transportation tariffs charged by the railway companies (the Crow Rates) are used to determine the minimum cost solution.

In order to apply the Transportation Problem the system must be represented by a set of supplies, demands and shipping costs. These three sets of input parameters define the system and enable the Classical Transportation Problem model to derive the minimum cost solution while fulfilling the shipment requirements. The employment of parameters to define the Transportation Problem framework requries a number of simplifying assumptions.

Although origins and destinations of commodities may constitute regions, they must be represented by points in the framework. Therefore, the shipping cost between each origin-destination pair is a single value. For this application this eliminates any variation in costs which may exist among the country elevator points within the region represented by origin i. The forty-nine shipping blocks and the four terminal ports of

Vancouver, Prince Rupert, Churchill and Thunder Bay represent the m origins and the n destinations respectively.

The model assumes that any one unit of the commodity may be substituted for any other unit of the commodity regardless of the supplying region or the source (i.e. homogenous commodity). In this application, each grade of CWRS wheat is treated as a separate commodity and hence requires solution of a separate Transportation Problem.

In the Transportation Problem, the transportation costs per unit of the commodity must be constant with respect to quantity shipped thereby establishing a linear minimization function. This assumption does not allow for production economies of scale, hence ignoring the advantage of shipping a full truck or rail car. Since the Crow Rates represent a fee schedule which is a linear function of tonnes shipped this assumption is quite realistic in the Canadian transport context. This rate structure will comprise the cost matrix input into the Transportation Problem model.

The Transportation Problem model is useful in seeking to minimize the transportation costs for shipping requirements. The coordinating agency, the Canadian Wheat Board, is free to ship a commodity from any supply point to any demand point, in order to minimize the transportation costs and optimize the system as a whole. Therefore, their problem is to determine the shipment pattern from origins to destinations which minimize total transportation costs. Theoretically, the railcar allocation of the Canadian Wheat Board is determined on the basis of a complete knowledge of the system, as the assumption implies. The application of the Transportation Problem will determine how well the CWB achieves this transportation cost minimization standard.

4.2 THE DUAL PROBLEM

The function of the dual problem is to set commodity prices at sources and destinations so as to maximize the rent obtained from transportation services performed while not creating price differentials along any routes which exceed transportation costs. The duality theorem of linear programming states that the optimum value of the dual occurs when the pattern of shipments is optimal with respect to the transportation costs. The minimum value of the primal problem is therefore equal to the maximum value of the dual problem. The dual problem provides a useful tool for analysing the primal solution. The dual is generally used for the economic interpretation of the primal problem. The dual variables are used to evaluate the cost of altering the resource allocations between supply and demand points within a spatial system as reflected by the transportation costs.

Mathematically, the dual of the transportation problem maximizes the linear function

$$(5) \quad \text{Max: } Z' = \sum_{j=1}^{n} vj.Dj - \sum_{i=1}^{m} ui.Si$$

where

- Z' is the value of the dual objective function,
- vj represents the selling price of the commodity x at destination j reflecting the increased cost in the objective function resulting from an increase of one unit of demand at destination j,
- Dj is the total amount of the commodity shipped to destination j,
- ui represents the buying price of commodity x at origin i reflecting the reduced cost to the objective function resulting from an increase of one unit of supply at origin i,
- Si is the availability of the commodity at origin i.

Conventionally the dual problem is subject to the inequality constraints

$$(6) \quad vj - ui \leq Cij \qquad (i=1...m \text{ and } j=1...n)$$

where Cij is the total cost of a delivery of one additional unit of resource from i to j, and

v_j and $u_i \geq 0$ $\qquad$ ($i=1...m$ and $j=1...n$)

The dual variable u_i represents the comparative advantage of producing in region i resulting from spatial competition derived from its proximity to demand points. Likewise, v_j measures the comparative cost of demand points competing for limited resources. In general u_i can be considered as the marginal value and v_j the marginal cost associated with an additional unit coming out of origin i and into destination j. A high value of u_i is associated with supply regions located in close proximity to a demand point. Places with high values of u_i are subject to low tranportation charges to the optimal demand point. The farthest supply points have relatively low values of u_i reflecting the relatively low level of locational advantage compared to the cl[illegible] supplying regions. These remote areas are subject to the highest transportation charges. The relative attractiveness of market points is determined through the evaluation of v_j. The value of v_j reflects the increased cost to the objective function of shipping an additional unit of supply to demand point j. A low value of v_j indicates that increased deliveries to the destination are most favourable because low values of v_j are less costly to the entire system than deliveries to places of higher values of v_j. The relative costs of changing the demand capacities among destinations can be determined by calculating the differences between the v_j values of destinations under consideration.

The constraints of the dual problem assess the desirability of the delivery of an additional unit of resource from i to j. If an extra unit of supply is added into the resource allocation and a unit is shipped from i to j, then there will be an additional transportation cost per unit, Cij. However, this will reduce the need to both ship that unit out of source i, saving ui in cost, and to ship that unit to destination j, saving vj. The net change in cost is

(7) Cij - (vj - ui).

The constraint expressed in equation (6) states that if this change is negative then the direct shipment from i to j is attractive and can be added to the solution.

Supply regions with high values of ui are more favourably located for production in terms of the cost of sending the product to market than the regions with low values. This transportation cost advantage is undermined, however, by the lack of additional capacity production available in a spatially organized agricultural system. The producing areas located nearest the market are the most desireable lands and therefore the most costly. The land is cultivated to achieve the highest yields thereby maximizing the benefit of the locational advantage. The difference between the values of ui at two spatially separated supply regions indicates the transportation cost or savings of shipping an additional unit from one origin rather than the alternative source.

The value of ui and vj are generated from the transport cost structure. The difference between the value of ui and vj in the optimal solution is equal to the transportation costs between i and j. The constraints of the model specify that the value of ui and vj cannot exceed the transport costs from i to j. The value of ui is highest at the supply region with the most favourable locational advantage because it is subject to the lowest transportation costs, hence the highest location rent. If an additional unit of supply was shipped from ui the impact on the objective function would be the smallest. The farthest location is subject to the poorest locational advantage, having the highest shipping costs, hence a corresponding low value of ui reflecting a low value of location rent. In the event of an additional unit of supply shipped from that location, the additional cost to the objective function would be relatively large. The most attractive regions for increased production are situated at places with high values of ui relfecting high location rent and relatively low transport costs to market.

Although the formulation of the general Linear Programming model assumes that resource availabilities are constant, there is frequently flexibility in the resource allocation. The relative costs or savings resulting from changing the resource availabilities and demand capacities among destinations can be evaluated in a spatial context. The dual variables can be utilized in sensitivity analyses.

Location rent surfaces can be generated (Steven, 1960) in order to easily identify favourable production and consumption regions. Supplies should be increased in areas of high values of ui because transportation costs will be less than increased production in other regions. Similarly, demands at points with low values of vj should be increased because it is least costly to the entire system. The delivery from supplying regions of high ui to destinations of low vj are most attractive for maximizing the dual objective function.

The interpretation of the dual variables allows a comparison with the dual price structure to determine the extent to which the actual transportation costs diverge from the ideal rate structure in a perfectly competitive market (Koopmans, 1948). If the rates do not reflect marginal differences in costs created by spatial disadvantages, then there is no incentive for the shipper to operate with spatial efficiency. Generally, location rents are critical to the analysis of spatial economies. Although they are dependent upon the actual transportation costs determined by the entire structure of demand and supplies, they are useful for evaluating the relative costs of overcoming the friction of distance in support of inter-regional trade.

4.3 SOLVING THE TRANSPORTATION PROBLEM

The Transportation Problem of Linear Programming can be solved by manual or computer methods. In each case an initial feasible solution is determined and then evaluated. While several solution methods have been developed, the UV Algorithm is used in this research to obtain the primal and dual solutions to the problem at hand. The mathematical computational package used in this study known as *LPTRNS was developed by Smillie (1971). It utilizes the dual solution to solve the Transportation Problem in equality form. The constraints of the problem specify that total supplies must equal total demands.

The UV algorithm maximizes the dual objective function after an initial feasible solution is generated. Other solution algorithms minimize the primal function of the problem to determine the least cost shipping patterns. Both types of solution methods operate on an iterative basis until the function is minimized or maximized.

4.3.1 Solution Theory

The general Linear Programming simplex tableau for the Transportation Problem has m+n-1 rows and mn+m+n+1 columns (Hadley, p. 284). The Transportation Problem, however, is a special application of Linear Programming. As such the supply and demand specifications derived from the origin and demand constraints produces a s[illegible]rce matrix containing only m x n cells. Hadley (1965) discusses th[illegible] algebra theory behind this unique matrix, known as A, which [illegible]ed the development of efficient algorithms to solve the Transportation Problem. The results of this approach simplifies the Transportation Problem to a matrix of m origins and n destinations rather than the simplex tableau of m+n-1 rows and mn+m+n-1 columns. The matrix of m origins and n destinations is known as the Transportation Tableau as presented on Figure 8 on page 82.

The total number of variables, N, in a linear programming formulation of the t[illegible]ion problem is equal to the product of m x n, where m is the number [illegible]ces and n is the number of destinations. M represents the number of linearly indepe[illegible] constraints equal to m+n-1. While each source and destination has its own constraints, the solution of the m+n-1 equations specifies the solution of the final equation. The final equation is a linear combination of the other equations and therefore redundant to the system of linear equations.

Any solution to the problem consists of both basic and non-basic variables. The difference between the basic and non-basic variables are best described in the context of the [illegible]ortation Tableau representing the origin-destination matrix. Basic variables represent allocations between the corresponding supply and demand points and are usually greater than zero. Non-basic variables are set equal to zero, indicating that allocations between the i and j pair are not being considered in the

FIGURE 8

THE GENERAL TRANSPORTATION PROBLEM TABLEAU

	D_1	D_2		D_j		D_n	a_i
O_1	c_{11} x_{11}	c_{12} x_{12}	. . .	c_{1j} x_{1j}	. . .	c_{1n} x_{1n}	a_1
O_2	c_{21} x_{21}	c_{22} x_{22}	. . .	c_{2j} x_{2j}	. . .	c_{2n} x_{2n}	a_2
	⋮	⋮	. . .	⋮	. . .		⋮
O_i	c_{i1} x_{i1}	c_{i2} x_{i2}	. . .	c_{ij} x_{ij}	. . .	c_{in} x_{in}	a_i
	⋮	⋮	. . .	⋮	. . .	⋮	⋮
O_m	c_{m1} x_{m1}	c_{m2} x_{m2}	. . .	c_{mj} x_{mj}	. . .	c_{mn} x_{mn}	a_m
b_j	$b1$	$b2$	. . .	b_j	. . .	bn	$\sum ai = \sum bj$

O_i = origin i

D_j = destination j

C_{ij} = transportation cost of one unit between i and j

a_i = supplies at i

b_j = demands at j

X_{ij} = units of the commodity required to be shipped from i to j

From : HADLEY, pg. 285.

current solution.

In this application of the transportation problem there are forty-nine origins and four destinations, the total number of variables in the model, N, equals

$$N = m \times n = 49 \times 4 = 196.$$

The total number of linearly independent constraints equal to m is

$$M = m + n - 1 = 49 + 4 - 1 = 52.$$

A basic solution to the general transportation problem is obtained by setting N-M variables (196 - 52 = 144) equal to zero and solving for the remaining M variables (m + n - 1 = 52). The fifty-two variables referred to as the vector M are known as the basic variables, forming the solution basis. Each variable of the basis provides the origin-destination allocation of the resource.

An initial basic feasible solution consisting of m+n-1 positive Xij's can be determined by several methods especially adapted to the Transportation Tableau. The Northwest Corner rule has been discussed by Charnes (1961), Dantzig (1963) and Hillier and Leiberman (1967). The procedure begins at the northwest corner of the transportation tableau. An allocation is assigned to the first cell satisfying an origin or demand requirement.

The 'rims' of the Transportation Tableau specify the total supplies available at each origin and demands required at each destination. The value assigned to any cell will contribute to satisfying the constraints but never exceed the rim requirements. The final allocation, which is dependent upon the prior assignments meets the entire system of availability and capacity constraints with exactly m+n-1 positive shipments.

The Northwest Corner procedure is a fast method to obtain an initial feasible solution, however, the allocations can be far from optimal. Other methods of selecting a less costly initial feasible solution are dependent upon intuition and an evaluation of shipping costs. The actual shipping pattern may be incorporated into the initial feasible solution. Intuitive evaluations and computational problems associated with large Transportation Problems render these techniques less efficient when large computers are available and are utilized to quickly and cheaply determine the minimum shipping cost solution from an initial feasible solution that may be far from optimal.

4.3.2 The UV Algorithm for Solving the Maximization Function

The Stepping-Stone solution algorithm was introduced by Charnes and

Cooper (1954) to determine the solution to the Transportation Problem. It solves the primal problem of the Transportation Problem and is based upon the reduced Transportation Tableau. The Stepping-Stone algorithm is a simple, manual solution method involving the addition and subtraction of allocations among cells given an initial feasible solution. It is derived from the general simplex method applicable to the solution of the general Linear Programming problems, incorporating the simplified nature of the Transportation Tableau.

Dantzig (1951) presented a method, the UV algorithm, for determining the optimal solution which is simpler than the Stepping-Stone technique. It is based upon the consideration of the m+n equations of the transportation problem tableau and the set of m+n dual variables. The dual variables, represented by the row vector D = (ui,u2,...um,vi,v2,...vn), are associated with each row and column of the tableau. Smillie's (1971) version of the UV Algorithm is based upon the equality formulation of the Transportation Problem. The procedures used to the solve the problem are presented by Hadley (1962) and Gass (1975).

Once the Northwest Corner procedure has determined an initial feasible solution the UV algorithm is used to test whether the solution is optimal. The procedure is based upon the dual constraint of the equality formulation of the linear programming problem

(8) $ui + vj - cij \leq 0$

The value of the first ui, u1, in the initial feasible solution is set to zero. Because Cij are known for all the cells, the value of vj can be determined to meet the constraint u1+vj=C1j for cells in the basic solution. These known values are then substituted in the equation ui+vj=Cij to solve sequentially for the ui and vj corresponding to the cells in the basis.

The next step is to calculate the indirect costs by calculating ui+vj-Cij for each cell not in the initial feasible solution. If all these indirect costs, ui+vj-Cij, are less than zero then the solution is optimal and the procedure terminates. If one or more indirect costs are equal to or greater than zero a better solution exists. The indirect cost indicates which cell is the best to bring into the basic solution. The largest value of ui+vj-Cij is identified as the pivot, the cell to enter the solution. The row and column of the attractive cell idenitifies the pivot row and the pivot column. If it attractive to ship one unit of the commodity between the origin and destination, then it is profitable to ship as much as possible over the attractive route.

The value of Xij to enter the allocation is chosen by determining the smallest variable which appears in the pivot row and column. This cell will leave the allocation by losing the value of Xij thereby driving the variable to zero. In order to maintain the rim requirements, the value of Xij must be added to an allocation in either the corresponding row or column. The value of Xij is added and subtracted to each cell in the loop maintaining the rim requirements until it is added to the cell which is to enter the allocation. Hadley (1962) discusses the linear independence of the loop which results in the reallocation of Xij to obtain a better solution of m+n-1 allocations while maintaining the rim requirements.

Once the improved solution has been determined, the values of all the ui and vj are again calculated for each cell not in the basic solution. The first value of ui is again set to zero and the procedure to solve for the remaining ui and vj values continues until completed. The values of the indirect costs, ui+vj-Cij, are then calculated for all cells not in the solution. If all ui+vj-Cij<0 the solution is optimal and the process terminates. Otherwise, the procedure repeats itself until all ui+vj-Cij<0. The resulting allocation provides the optimal solution to both the primal and dual problems. For all allocations in the optimal solution vj-ui=Cij indicating that the difference between the buying price at the origin and the selling price at the destination is exactly equal to shipping costs.

In the equality formulation of the Transportation Problem ui represents the increase in cost to the entire system in the event of an increase in supplies at i and vj represents the increase in cost to the entire system in the event of an increase of demand at destination j. Conventionally the UV algorithm is solved by evaluating the costs associated with the capacity constraints, ui, and the savings associated with increasing demand at destinations considered attractive by virtue of the corresponding transportation rates. This interpretation is based upon the inequality formulation of the Transportation Problem. Because the interpretation of the dual variables subject to equality constraints is different from the interpretation based upon the inequality formulation of the problem the dual varibles determined by the algorithm used in this study were arithmetically altered to allow conventional interpretation. In the inequality formulation of the supply constraint is multiplied by -1 to reverse the inequality sign to be consistent with the balance of the constraints. This results in ui being the reduced cost to the objective function in the event of an increase in Si. In order to reflect this in the equality formulation of the model the values of ui were multiplied by -1. The smallest value of ui (the most negative value) was then added to each value of ui and vj so that the relative values remain constant and that all values are positive. The resulting set of dual variables are consist with Stevens (1961) explanation of the interpretation of the dual solution where the highest value of ui is located nearest the optimal demand point and the lowest value of ui is located at the farthest supply point required to meet the specified demands. The conventional interpretation of the dual solution is therefore possible.

4.4 EMPIRICAL APPLICATIONS OF THE TRANSPORTATION PROBLEM

The Classical Transportation Problem represents an entire class of Linear Programming problems pertaining to a variety of economic applications. Its relevance to the geographer is its capacity to evaluate locational limitations of production capacity, distribution allocation schedules, network designs, cost tariffs and the effect of the multiplicity of commodities on increased transportation costs. The Transportation Problem has been applied to a wide variety of coordination issues involving a large amount of transportation required to ship products to market and where the cost of shipping is an important component of market value. The Transportation Problem is particularly relevant to geographers because it focuses entirely upon the costs associated with overcoming the friction of distance in pursuit of interregional trade.

The Classical Transportation Problem can be extended by a variety of methods to improve the model's representation of actual circumstances. It can be modified to include many commodities or a variety of transport modes. Each of these expansions can incorporate transport capacity on a link basis. Varying production costs can be included in the model to assess the impacts of transportation and production cost relationships in a spatial system. The following review of applications of the general problem highlight the model's utility in assessing a variety of transportation issues.

The dual solution of the Tranportation Problem has been used to identify regions which should change their production levels in order to take advantage of favourable transport tariffs thereby increasing spatial efficiency in meeting demands. Goldman (1958) investigated the least cost transportation requirements for the production and distribution of steel in the northeastern region of the United States. Changing the geographical distribution of steel production has the effect of reducing the number of empty coal freight car movements while producing the final product closer to the markets. The net effect is the production and distribution of more steel with the same amount of transportation equipment through the improved utilization of rolling stock. Ghosh (1965) studied the dispersal of the Indian cement industry in order to identify regions which should increase their production capacity to reduce long distance hauls. The present production areas located near well established economic activity was detrimental to the national economy because of the associated excessive transportation costs. Dispersion of the industry was recommended.

The Transportation Problem can be used to model potential market catchments. Spatial equilibrium prices are determined by the dual solution whereby attractive market regions are defined. The production and transport costs are incorporated into these models. Judge and Wallace (1958) applied the model to beef prices in the United States to demonstrate how changes in transportation costs, the geographic distribution of the population, regional income and beef supply alter prices and thereby the market. Koch and Snodgrass (1959) applied the model to the tomato processing industry in the United States. The changing production capacities of the three main processing regions had increased total processing and transportation costs of delivering the finished products to the domestic markets. Their conclusions indicate which producing regions should increase capacity in order to minimize the aggregate costs of meeting demands. Boehm and Conner (1977) attempted to determine delivery patterns of raw milk from production locations that would minimize the combined costs of assembling and processing raw milk produced in each geographic region in the United States. The results indicated a necessary trade-off between a large number of small production plants operating at high cost and fewer plants associated with higher transportation costs.

The Transportation Problem can be utilized to simulate distribution patterns under alternative shipping tariff schedules. Morrill and Garrison (1960) applied the model to wheat and flour distribution in the United States. Assuming that the location of the market did not influence location of production, the dual variables were used to indicate how transport pricing affects interregional distribution patterns. Fedler and Heady (1976) also applied the Transportation Problem to interregional grain transportation in the United States. The least cost configuration of transportation and production costs under alternative transport networks and distribution systems were emphasized. Actual costs of transportation, rather than freight rates charged were used to indicate the impact of alternative rate structures on interregional flows.

Probably the most popular application of the Classical Transportation Problem is the evaluation of shipping programmes. Barr (1970) applied the model to the interregional distribution patterns of lumber and roundwood in the Soviet Union. The centrally controlled transportation administrative organization was shown to be inefficient in coordinating the shipment of commodities. Barr concluded that other location factors, in addition to shipping costs, such as regional economic development programmes explain the spatial location of the Soviet wood processing industry. Dent (1966) investigated the actual flows of wool from growers to markets in Australia. Transport costs, a significant component of wool marketing costs, were determined by road and railway. Discrepancies between minimum cost patterns and the cost of the actual shipping patterns may be regarded as a measure of the influence of other criteria such as backhaul rates, family tradition and personal preference.

There have been several applications to the agricultural industry. Kondor (1966) studied the processing and distribution patterns of sugar beets in Hungary. The results indicate that significant transportation savings could accrue to the improved coordination of railcar allocation. Haaland (1977) applied the Transportation Problem to distribution of grain stocks subsequent to a nuclear attack in the United States. The solution to the hypothetical problem can be infeasible because the precise location and degree of damage to the transportation network is unpredictable.

Stewart and Ittman (1979) investigated the production and distribution patterns of maize in South Africa. The application of the Transportation Problem resulted in a large number of solutions where rail costs are minimized. Monanu (1980) applied the Transportation Problem to the shipment of cocoa and palm kernels in Nigeria to export ports. The results indicated that transportation utilization could be reduced if actual deliveries were altered to represent the least cost pattern. In Canada, Tychniewicz and Tosterud (1973) investigated the impact of railway branch line abandonment and grain elevator rationalization on minimizing the total cost of collecting, handling and shipping grain to Thunder Bay from the Boissevain region of Manitoba. The actual flows indicated that farmers chose delivery points for reasons other than minimum transport cost considerations. Nevertheless, the results indicate that railways could realize savings in a rationalized system.

Dunbar and Mehring (1978) applied the Transportation Problem to the costs associated with supplying coal to coal-burning plants in the United States. The model was equipped to satisfy demands shifting between fuels. The transportation cost structures were altered to determine optimality under various schedules. Henderson (1958) investigated shipment of coal from producing regions to markets in Great Britain. Because particular supplying regions maintained underutilized capacity, transportation costs were more expensive than necessary. Land (1957) investigated the transportation costs associated with supplying a homogeneous grade of coking-coal to coke ovens in England and Scotland. The results indicate that significant savings could result from altering the distribution patterns. Land suggests, however, that the simplifying assumptions may be responsible for over-estimating the potential savings, the most serious of which is expected to be the assumption of homogeneity of the resource.

As Land's research suggests, the assumption of homogeneity of the commodity must be addressed in transportation coordination modelling. Commodities may represent distinct categories or may be amalgamated into one classification. The impact of grade multiplicity is particularly important for low value, high bulk resources. Abouchar (1971) investigated the transportation and production costs associated with the seventeen grades of cement processed in the Soviet Union. The shipping patterns departed slightly from the least cost pattern. He combined the seventeen grades of cement into one high quality grade and applied the transportation problem to the set of associated production and transportation costs. The results indicated a significant savings in both production costs and transportation utilization.

The present research investigates the short term efficiency of the Canadian Wheat Board's rail car allocation schedules for the delivery of Canadian Western Red Spring wheat to the export terminals of Thunder Bay, Churchill, Prince Rupert and Vancouver. This investigation is not a scheduling problem per se, constrained by train size, railway link capacity or payload tonnages. Rather, this is an evaluation of the general level of efficiency achieved by the CWB over a study period. The transportation of wheat is internally constrained by the system's operational characteristics such as the number of railcars, locomotives, elevator handling capacity, contractual commitments and agricultural production levels. The transport rates per tonnage shipped are governed by the Crow rate structure as they apply to exclusive Canadian National and Canadian Pacific service areas.

The goal is to minimize the total transportation costs thereby maximizing the amount of transportation service provided for the given supply of railway cars. The relationship between the number of grades shipped and the additional transportation costs associated with grade multiplicity are determined. Increased production should be encouraged in regions closest to demand points as this would result in the lowest shipping charge required to meet increased demand. Similarly, increasing demand at points with high values of vj would result in the greatest savings in transportation charges. In the event of increased supplies the most attractive delivery schedules are between origins of high values of ui and low values of vj.

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TABLE 6

GRADES OF CWRS WHEAT UNLOADED AT TERMINAL ELEVATORS

Official Grade Code	Canadian Grain Commission Description	Number of Unloads 80.07.01 to 81.06.31	Total Tonnage Handled
10	Extra No. 1 CWRS +13.5%	452	7,620,330
20	Extra No. 2 CWRS +13.5%	14	930,125
100	No. 1 CWRS	2	141,860
115	No. 1 CWRS +11.5%	254	14,741,875
125	No. 1 CWRS +12.5%	21,767	1,445,723,995
135	No. 1 CWRS +13.5%	63,977	4,260,219,980
145	No. 1 CWRS +14.5%	8,041	541,192,150
200	No. 2 CWRS	1	54,740
215	No. 2 CWRS 11.5%	6,815	407,906,825
225	No. 2 CWRS 12.5%	23,798	1,581,478,685
235	No. 2 CWRS 13.5%	28,242	1,896,919,785
300	No. 3 CWRS	67,175	4,367,374,460
1010	Tough Extra No. 1 CWRS +13.5%	1	56,790
1125	Tough No. 1 CWRS +12.5%	32	2,064,345
1135	Tough No. 1 CWRS +13.5%	24	1,503,340
1145	Tough No. 1 CWRS +14.5%	2	158,415
1215	Tough No. 2 CWRS 11.5%	50	2,969,295
1225	Tough No. 2 CWRS 12.5%	162	10,517,825
1235	Tough No. 2 CWRS 13.5	261	16,680,680
1300	Tough No. 3 CWRS	2,430	156,130,705
5125	Damp No. 1 CWRS 12.5%	1	56,165
5225	Damp No. 2 CWRS 12.5%	3	245,470
5235	Damp No. 2 CWRS 13.5%	11	723,270
5300	Damp No. 3 CWRS	303	19,363,480
8100	Rejected No. 1 CWRS (Stones)	1	59,790
8135	Rejected No. 1 CWRS (Stones) 13.5%	1	61,780
8145	Rejected No. 1 CWRS (Stones) 14.5%	1	55,420
8225	Rejected No. 2 CWRS (Stones) 12.5%	1	60,695
8235	Rejected No. 2 CWRS (Stones) 13.5%	2	136,965
8300	Rejected No. 3 CWRS (Stones)	5	290,970

5.1 WHEAT GRADE AGGREGATION AND REORGANIZATION

Grain grading activities at country elevators operate independently from the official grading procedures at terminal elevators. Due to space limitations related to the diverse utility of country elevators, CWRS wheat is stored in bins differentiated on the following basis;

a. CWRS Extra No. 1

b. CWRS Extra No. 2

c. CWRS No. 1

d. CWRS No. 2

e. CWRS No. 3

f. Canada Utility

g. Canada Feed

Canada Feed and Utility grades are usually admixtures of other grains and varities and are not included in this analysis. The emphasis of this study is on the straight grades of CWRS, listed above as the first five categories.

At the point of unloading a sample of the delivery is assessed by the official inspectors of the CGC. It is at this point that the thirty grades are differentiated from the original five grades shipped from country elevators. The thirty grades established allow the CWB to blend grains to meet specific export commitments. Country elevators are not equipped nor adequately informed of requirements to undertake this level of differentiation.

For this analysis the thirty grades are aggregated into one CWRS grade. This aggregation will demonstrate the additional transportation costs associated with grade multiplicity. This extreme grade aggregation may or may not be a practical marketing solution. To this end the official thirty grades are regrouped into the three main grades traded internationally, namely CWRS No. 1, No. 2 and No. 3, as presented on Table 7 on page 102. The aggregation of grades into the main grades marketed internationally was conducted to determine the optimal shipping costs for a set of three types of grain drawn from the producing areas. It is expected that the transportation costs required to support a system of thirty grades will be more expensive than that required for a system of three grades. Once the thirty grades arrive at their destinations they are mixed with other wheat in its grade and with wheats of other grades to blend the grade down in standard or up in standard as required by the specific sales contract. The analysis may be to determine the transportation costs associated with maintaining a strict grading regime in the producing areas that ultimately faces blending at terminal elevators. Since the 1980-1981 crop year Extra No. 1 and Extra No. 2 have been eliminated from the grading structure and replaced with a premuim payment on country deliveries of wheat in excess of 13.5% protein. As a result, CWRS Extra No. 1 and CWRS Extra No. 2 have been absorbed by CWRS No. 1 and CWRS No. 2 respectively.

The component grades of each of the three new classifications are based upon the standard of quality criteria specified on Table 1 on page 21. The official grades in each of the new categories are distinquished by protein and moisture levels. Protein levels are not universally ascertained at country elevators because of the costs involved in the acquistion of testing equipment and the subsequent requirement for an additional number of storage bins in the elevators. Tough and damp grains, on the other hand, are tested at country elevators. Presently, however, the grain transportation system does not distinquish between ordered moisture levels and the delivered load. In fact, if the CWB orders grain to meet export contracts, it may receive unloads of all tough and damp grades that must be dried before vessel loading. Besides the protein and moisture level differentiation, only eleven rail car unloads were graded 'rejected' on account of excessive stone content. Stone content can be reduced by appropriate sieving to meet the straight grades, eliminating the term 'rejected' from the grade name. The resulting three categories of grades represent a practical disaggregation of CWRS wheat

TABLE 7

RECLASSIFICATION OF OFFICIAL GRADES OF CWRS WHEAT

Grading Scheme Used in the Analyses	Official C.G.C. grading Scheme and Description	
CWRS New No. 1	10	Extra No. 1 CWRS +13.5%
	100	No. 1 CWRS
	115	No. 1 CWRS +11.5%
	125	No. 1 CWRS +12.5%
	135	No. 1 CWRS +13.5%
	145	No. 1 CWRS +14.5%
	1010	Tough Extra No. 1 CWRS +13.5%
	1125	Tough No. 1 CWRS +12.5%
	1135	Tough No. 1 CWRS +13.5%
	1145	Tough No. 1 CWRS +14.5%
	5125	Damp No. 1 CWRS 12.5%
	8100	Rejected No. 1 CWRS (Stones)
	8135	Rejected No. 1 CWRS (Stones) 13.5%
	8145	Rejected No. 1 CWRS (Stones) 14.5%
CWRS New No. 2	20	Extra No. 2 CWRS +13.5%
	200	No. 2 CWRS
	215	No. 2 CWRS 11.5%
	225	No. 2 CWRS 12.5%
	235	No. 2 CWRS 13.5%
	1215	Tough No. 2 CWRS 11.5%
	1225	Tough No. 2 CWRS 12.5%
	1235	Tough No. 2 CWRS 13.5
	5225	Damp No. 2 CWRS 12.5%
	5235	Damp No. 2 CWRS 13.5%
	8225	Rejected No. 2 CWRS (Stones) 12.5%
	8235	Rejected No. 2 CWRS (Stones) 13.5%
CWRS New No. 3	300	No. 3 CWRS
	1300	Tough No. 3 CWRS
	5300	Damp No. 3 CWRS
	8300	Rejected No. 3 CWRS (Stones)
One Grade		All Above Grades

necessary to meet export requirements.

5.2 SUPPLIES AND DEMANDS

In this application of the Transportation Problem the total supply of CWRS wheat is equal to the total demand as determined by export contracts. Supplies that are not shipped do not enter this data base of the CGC and therefore represent carry-over stocks not addressed in this study. The producers were able to deliver all the CWRS wheat they wished during the study year (CWB Annual Report 1980/1981, p. 14).

The annual tonnages of each of the thirty grades delivered from each origin block were calculated. Likewise, the tonnages of each grade delivered to each of the four terminal elevators were calculated for the entire crop year. These availabilities and demands for each of the thirty official grades represent the raw data input into the Transportation Problem. The tonnages of each of the thirty grades can be reorganized into the grading schemes addressed.

In order to evaluate the actual transportation patterns against the optimal solutions, origin and destination matrices were constructed for each grade. These matrices can be combined to evaluate savings accruing from grade aggregation. Each element of the tonnage matrix is multiplied by the corresponding element of the cost matrix to ascertain the total actual costs of the delivery programs.

In this application of the Transportation Problem mathematical problems relating to the maximum dimensions of the model and the significance level have arisen. In terms of the dimensions, the resource availabilities and demands must be specified as integers. Therefore the maximum number of kilograms allowed as input must be less than 2**32 or 4.295E9. Because of the high bulk nature of the grain transportation industry and the use of cents for transportation tariffs instead of dollar decimal notation, this maximum value has been found to occur in many cases particularly for the grade aggregation analysis. In addition, the algorithm used in this analysis requires that total supplies must equal total demands.

These restrictions resulted in some changes to the model to allow for storage and manipulation of the data. For the cases of CWRS No. 3 and No. 1 at 13.5% protein (Grades 300 and 135, respectively) and for each of the aggregated grades (All Grades, New No. 1, New No. 2 and New No. 3) a minor adjustment had to be made. The model is equipped to read a series of origin-destination matrices derived from the CGC computer tape of deliveries. The inputed sums of the availabilities and the demands were divided by ten in each of these identified cases. This resulted in the sum of the demands exceeding the sum of the supplies due to rounding error in the cases presented on Table 8 on page 106. This fact is contrary to the specifications of the general Transportation Problem as the demand constraints can never be met thereby terminating the models functions.

To solve this problem the difference between the sum of the demands and the sum of the supplies were determined. This difference had to be subtracted from each of the demand constraints. To achieve this, the proportion of the total tonnage handled at each of the terminals was calculated. The appropriate percentages of the calculated difference was subsequently subtracted from each of the demand constraints. This resulted in a set of input parameters that would meet the specifications of the model and allow it to preform. The magnitude of these distortions relative to the total tonnages handled are not expected to be significant in the solution representing a very small proportion of the total tonnages handled. In addition the exponential notation, significant to seven digits, used to calculate the total cost as determined by the Transportation Problem tends to minimize the effect of small differences. The use of exponential notation eliminates the possibility of determining small differences in transportation shipping patterns. This is especially critical for the evaluation of optimal patterns derived from the exclusive CN and CP networks and the combined network. In essence, the use of exponential notation directs one's attention to somewhat significant differences.

Demand points not receiving deliveries were assigned a demand of one in order for the algorithm to assign a value of the dual variable vj for

TABLE 8

GRADES AFFECTED BY

DIMENSION AND ROUNDING ERRORS

Grade	Tonnes Subtracted From the Total to Match Availabilities and Requirements	Total Tonnages Handled
135	1.102	4,260,221
300	1.565	4,367,376
New No. 1	2.967	6,287,567
New No. 2	3.110	3,918,624
New No. 3	2.590	4,543,161
One Grade	8.667	14,749,442

evaluating the solutions. The closest supply was increased by one unit to meet the increased demand. The additional transport costs to the primal objective function were subtracted from the total cost of the allocation and the allocations disregarded from the analysis of actual patterns. However, the value of vj assigned to the destinations provide a measure to evaluate alternative demand patterns. The transportation costs to Prince Rupert are the same as the costs to Vancouver. The difference in values of vj reflect the attraction of the non-utilized port for increased business. The value of vj at destinations without any actual demand are equal to the transportation costs from the origin supplying the one unit of demand.

5.3 SHIPPING COSTS

The Crow Rate structure is utilized to derive the minimum cost shipping pattern of grain deliveries by rail in Western Canada. Grain freight rates are established by federal government statute. Crow Rates to Churchill and Prince Rupert are established only for deliveries from CN elevator points. Therefore, CN monopolizes all grain deliveries to Churchill and Prince Rupert.

To determine the efficiency of the actual delivery pattern the costs associated with the restricted links from CP shipping blocks to Churchill and Prince Rupert are set at a very high rate per weight. A high cost will force the solution algorithm to seek a lesser cost route to solve the pertaining supply and demand constraints. The cost matrix applied to the delivery of CWRS wheat for export representing exclusive railway service areas, hereby referred to as the EXCLUSIVE transportation cost matrix, is presented on Table 9 on page 109.

Nevertheless, examination of the Transport Canada Crow Rate maps can provide a basis for reasonably accurate estimates applicable to a theoretical analysis. In order to perform CN and CP rail line compatibility analyses Crow Rates from CP elevator points to Churchill were drawn from the Transport Canada map of Crow Rates to Churchill. These rates represent a close approximation of the expected rates, as CP elevator points are not included on Transport Canada's graphic presentation of rates. Freight rates to Prince Rupert, however, are similar to the rates from all Prairie points to all Pacific terminals. The transportation cost matrix from all shipping blocks to all terminal ports based upon Crow Rate structure, hereby referred to as the COMBINED transportation cost matrix is presented on Table 10 on page 110.

Despite the exclusive service areas operated by the two railroads, the shipment categories addressed above allow divergence from strict adherence to the system. Direct shipment, non-reciprocal deliveries are by far the dominant types of deliveries, shipping grain from CP lines to

TABLE 9: EXCLUSIVE TRANSPORTATION COST MATRIX
(cents per metric tonne)

Origin	Block	Block Name	Thunder Bay	Churchill	Vancouver	Prince Rupert
01	01	Winnipeg North	341	518	739	739
02	03	Winnipeg South	331	518	761	761
03	05	Winnipeg West	353	496	728	728
04	07	Brandon North	357	474	683	683
05	09	Brandon West	386	507	683	683
06	11	Melville	408	430	672	672
07	13	Dauphin	430	430	672	672
08	15	Kamsack	463	407	661	661
09	17	Saskatoon Main	474	474	573	573
10	19	Saskatoon South	507	496	562	562
11	21	Saskatoon West	518	496	540	540
12	23	Saskatoon North	496	463	540	540
13	25	Prince Albert East	485	418	595	595
14	27	Prince Albert South	489	441	562	562
15	29	Prince Albert West	534	474	540	540
16	31	Saskatoon East	463	485	595	595
17	33	Regina South	430	485	628	628
18	35	Regina West	463	507	617	617
19	37	Biggar North	529	496	518	518
20	39	Biggar West	529	507	529	529
21	41	Edmonton North	639	584	463	463
22	43	Edmonton South	562	551	463	463
23	45	Edmonton West	617	573	452	452
24	47	Hanna South	540	540	474	474
25	49	Hanna West	584	562	474	474
26	61	Keewatin	331		783	
27	62	La Riviere	353		739	
28	63	Carberry	364		739	
29	64	Brandon	397		672	
30	71	Weyburn	430		650	
31	72	Pasqua	418		606	
32	73	Bulyea	452		617	
33	74	Bredenbury	452		661	
34	75	Saskatoon	485		606	
35	76	Wilkie	529		529	
36	77	Assiniboia	496		562	
37	78	Swift Current	474		595	
38	79	Outlook	496		551	
39	81	Medicine Hat	518		518	
40	82	Brooks	562		474	
41	83	Lethbridge	551		496	
42	84	Vulcan	573		463	
43	85	Calgary	617		463	
44	86	Red Deer	584		463	
45	87	Edmonton	584		485	
46	90	N. Alberta R.R. West	595		507	
47	95	N. Alberta R.R. East	595		507	
48	97	British Columbia R.R.	595		507	
49	98	Great Slave R.R.	595		507	

TABLE 10: COMBINED TRANSPORTATION COST MATRIX
(cents per metric tonne)

Origin	Block	Block Name	Thunder Bay	Churchill	Vancouver	Prince Rupert
01	01	Winnipeg North	341	518	739	739
02	03	Winnipeg South	331	518	761	761
03	05	Winnipeg West	353	496	728	728
04	07	Brandon North	357	474	683	683
05	09	Brandon West	386	507	683	683
06	11	Melville	408	430	672	672
07	13	Dauphin	430	430	672	672
08	15	Kamsack	463	407	661	661
09	17	Saskatoon Main	474	474	573	573
10	19	Saskatoon South	507	496	562	562
11	21	Saskatoon West	518	496	540	540
12	23	Saskatoon North	496	463	540	540
13	25	Prince Albert East	485	418	595	595
14	27	Prince Albert South	489	441	562	562
15	29	Prince Albert West	534	474	540	540
16	31	Saskatoon East	463	485	595	595
17	33	Regina South	430	485	628	628
18	35	Regina West	463	507	617	617
19	37	Biggar North	529	496	518	518
20	39	Biggar West	529	507	529	529
21	41	Edmonton North	639	584	463	463
22	43	Edmonton South	562	551	463	463
23	45	Edmonton West	617	573	452	452
24	47	Hanna South	540	540	474	474
25	49	Hanna West	584	562	474	474
26	61	Keewatin	331	533	783	783
27	62	La Riviere	353	533	739	739
28	63	Carberry	364	489	739	739
29	64	Brandon	397	467	672	672
30	71	Weyburn	430	511	650	650
31	72	Pasqua	418	489	606	606
32	73	Bulyea	452	489	617	617
33	74	Bredenbury	452	444	661	606
34	75	Saskatoon	485	467	606	606
35	76	Wilkie	529	511	529	529
36	77	Assiniboia	496	533	562	562
37	78	Swift Current	474	511	595	595
38	79	Outlook	496	489	551	551
39	81	Medicine Hat	518	533	518	518
40	82	Brooks	562	578	474	474
41	83	Lethbridge	551	600	496	496
42	84	Vulcan	573	578	463	463
43	85	Calgary	617	600	463	463
44	86	Red Deer	584	578	463	463
45	87	Edmonton	584	578	485	485
46	90	N. Alberta R.R. West	595	595	507	507
47	95	N. Alberta R.R. East	595	595	507	507
48	97	British Columbia R.R.	[illegible]	595	507	507
49	98	Great Slave R.R.	595	595	507	507

CP port facilities and similarly for CN. However, the other categories of deliveries, namely direct shipment reciprocal, direct shipment to Churchill and transit traffic result in deliveries from CP blocks to the ports of Prince Rupert and Churchill. It is important to remember, however, that in 1981 the Northern Alberta Railway became part of Canadian Nation Railways. The total of 204,318 tonnes of these irregular shipments represents 1.3% of the total tonnages under current investigation. These deliveries interfere with the analysis comparing the costs associated with the exclusive railway networks to the competitive network. The existence of this problem is mentioned where this situation becomes apparent. The tonnages delivered from CP blocks to CN terminal elevators are presented on Table 11 on page 112.

The transportation tariffs do not vary among commodities despite the varying value of different grains and grades. Therefore, CWRS No. 3 wheat is shipped a the same rate as Extra CWRS No. 1 which has a higher market value. This type of service is convenient for the purposes of this investigation. The transportation tariffs contained in the matrices represent cents per 1000 kilograms. The model requires integer input necessitating a manual adjustment to determine the optimal costs and potential savings.

TABLE 11

DELIVERIES FROM CP ORIGINS TO THE CN DESTINATIONS OF PRINCE RUPERT AND CHURCHILL

Origin	Destination	Grade	Tonnage
74	Churchill	125	2,244
75	Churchill	125	6,147
76	Churchill	125	21,437
86	Prince Rupert	215	454
87	Prince Rupert	215	4,185
74	Churchill	225	12,525
75	Churchill	225	12,185
76	Churchill	225	22,382
74	Churchill	300	19,283
75	Churchill	300	11,770
76	Churchill	300	9,018
82	Prince Rupert	300	164
86	Prince Rupert	300	6,208
87	Prince Rupert	300	75,839
74	Churchill	1300	59
86	Prince Rupert	1300	117
87	Prince Rupert	1300	221

Total To Churchill	117,050
Total To Prince Rupert	87,259
TOTAL	204,309

5.4 ANALYSES

The efficiency of the Canadian grain transportation system will be determined by comparing the empirical total shipping costs to the results obtained by performing the Transportation Problem of Linear Programming on the data base. The comparisions will be completed for the year as a total. The analyses, therefore, necessitate the following applications of the Transportation Problem;

a. Total tonnage delivered over the study year classed as one commodity type charged Crow Rates as they apply to railway company exclusive service areas.

b. Total tonnages delivered over the study year classed as one commodity type charged according to shipping rates as they would apply to a competitive railway transportation network.

c. Delivered tonnages by grade over the study year charged Crow Rates as they apply to railway company exclusive service areas.

d. Delivered tonnages by grade over the study year charged shipping rates as they would apply to a competitive railway transportation network.

The data parameters utilized in this study are therefore, commodity type, supplies, demands and transportation costs. These data parameters are used to determine the efficiency of the delivery patterns based upon the premise that sub-optimality arises from the following sources:

1. Exclusive Canadian National and Canadian Pacific railway service areas and service networks.

2. The additional costs of transportation resulting from the grade multiplicity.

3. The cost of short term suboptimal planning in response to operational constraints of the transportation and handling system at the expense of long term efficiency.

The causes of suboptimality are discussed in Chapter One. The analysis and the occurance of suboptimality arising from these causes is presented in the following chapter.

6.0 TRANSPORTATION PROBLEM ANALYSIS

The Transportation Problem of of Linear Programming as been applied to the set of given supply and demand constraints to detemine the pattern of shipments between origins and destinations that minimizes the total transportation bill in such a way that contractual commitments are met. The Transportation Problem derives an efficient result by specifying that the prescribed set of demands, as given by the Canadian Grain Commission in this case, cannot be met at a lower total cost. The efficient patterns determined by the Transportation Problem are compared to the actual shipment patterns as provided by the Canadian Grain Commission for the 1980-1981 study year. The actual and optimal patterns for each of the grades of wheat discussed below are presented on origin-destination matrices in Appendix A.

6.1 ACTUAL TRANSPORTATION COSTS.

Actual transportation costs for shipping CWRS wheat to export terminals was determined by multiplying each element of the origin-destination tonnage matrix by the corresponding element of the Crow Rate cost matrix that is presented in the previous chapter. The actual shipping charges for the delivery of each grade, and the grade aggregation systems are presented on Table 12 on page 117. The total cost of transporting 14.7 million tonnes of CWRS wheat was $70,130,875. The following analyses will demonstrate how this cost can be reduced by efficient shipping schedules, grade aggregation and unrestricted commodity flows from all origins to all destinations.

6.2 PRIMAL SOLUTIONS TO THE TRANSPORTATION PROBLEM

The optimal separate costs of transportation as determined by by the COMBINED transportation cost matrix for each of the thirty commodity grades yields a total minimum cost, represented as Z1, of $68,848,586. This represents a saving of $1,282,289 (1.83%) from the actual shipping pattern.

The optimal minimum cost for shipping one comprehensive grade, Z3, which includes the aggregation of all thirty grades is $68,562,410. This represents a saving of $286,176 or 0.42% from the optimum costs of shipping thirty different grades. The minimum cost resulting from complete grade aggregation is 2.2% less than the actual shipping costs

Table 12 : Primal Solutions to the Transportation Problem

Grade	Actual Cost of Deliveries	Optimal Cost COMBINED	Cost Difference (Possible Savings)	% Difference in Cost (Actual/ Optimal)	Difference as a % of Total Cost	Actual Cost as a % of Total Cost	Savings as a % of Total Savings Possble	Total Tonnage Handled	% of Total Tonnage Handled
10	150,330	150,008	322	0.21	.0005	00.2	.0025	31,620	0.2
20	3,722	3,722	0	0.0	0	00.005	0	930	0.006
100	704	704	0	0.0	0	00.001	0	142	0.001
115	78,969	78,946	23	0.029	.00003	00.11	0.002	14,742	0.1
125	6,952,061	6,916,984	35,077	0.507	.05	9.9	2.74	1,445,724	9.8
135	20,920,365	20,537,530	382,835	1.86	.6	29.8	29.9	4,260,220	28.9
145	2,595,399	2,555,823	39,576	1.55	.06	3.7	3.09	531,192	3.6
200	326	326	0	0	0	00.0005	0	55	00.0004
215	2,205,743	2,195,997	9,746	0.44	.014	3.1	8.76	407,907	2.8
225	7,604,147	7,454,994	149,153	2.0	.21	10.8	11.63	1,581,479	10.7
235	8,307,083	8,307,083	0	0	0	11.8	0	1,896,920	12.9
300	20,181,870	19,742,740	439,130	2.22	.63	28.8	34.25	4,367,374	29.6
1010	275	275	0	0	0	00.0004	0	57	00.0004
1125	7,950	7,950	0	0	0	00.011	0	2,064	00.014
1135	6,626	6,626	0	0	0	00.01	0	1,503	00.01
1145	768	768	0	0	0	00.001	0	158	00.001
1215	14,311	14,311	0	0	0	00.02	0	2,969	00.02
1225	47,248	47,118	130	00.28	.00002	00.067	.01	10,518	00.072
1235	70,086	70,086	0	0	0	00.0	0	16,681	00.11
1300	888,205	663,319	224,886	33.9	.32	1.27	17.54	156,131	1.06
5125	254	254	0	0	0	00.0004	0	56	00.0004
5225	1,352	1,352	0	0	0	00.002	0	245	00.002
5235	3,377	3,377	0	0	0	00.005	0	723	00.005
5300	85,459	85,166	1,293	1.52	.002	00.10	.1	19,363	00.13
1800	297	297	0	0	0	00.0004	0	60	00.0004
8135	265	265	0	0	0	00.0004	0	62	00.0004
8145	342	342	0	0	0	00.0005	0	55	00.0004
8225	281	281	0	0	0	00.0004	0	61	00.0004
8235	602	602	0	0	0	00.0009	0	137	00.0009
8300	1,457	1,339	118	8.81	.0002	00.002	.009	291	00.002
Z1	70,130,875	68,848,586	1,282,289		1.83			14,749,439	100
New No. 1	30,714,006	30,221,790	492,816	1.63	0.7	43.8	32.7	6,287,567	42.6
New No. 2	18,258,278	17,913,210	345,068	1.93	0.49	26.0	22.9	3,918,624	26.5
New No. 3	21,157,991	20,488,490	669,501	3.27	0.95	30.2	44.4	4,543,161	30.9
Z2	70,130,875	68,623,490	1,507,385		2.15			14,749,439	100
Z3	70,130,875	68,562,410	1,568,465		2.29			14,749,439	100

realized. A total of 4.568 million tonnes of wheat (31% of total tonnes handled) were reallocated to optimal destinations. The magnitude of this reallocation based upon the COMBINED cost matrix does not appear to be reflected in the objective function.

The optimal minimum costs resulting from an aggregation of the thirty grades into three major commodity groups yields a total minimum cost, represented as Z2, of $68,623,490. This represents a saving of 2.15% from the actual shipping costs or $1,507,385. This level of aggregation leads to a 0.33% saving ($225,096) over the optimal allocation of the system of thirty grades. Alternatively, three grades of the commodity result in an additional cost of $61,080 or 0.09% over the system of one grade.

A high level of efficiency has been shown to exist in the transportation coordination programmes of the Canadian Wheat Board. Efficiency can be attributed to the following reasons;

1. An intuitive understanding of the location of supplies of grain grades gathered by historical precedent and the application of this intuitive knowledge to the allocation schedules.

2. The objective of the CWB is to coordinate transportation to move grain from the nearest supplying region from the demanding terminal (Booz Allen, 1979). This objective appears to be achieved on a consistent basis.

3. The transportation costs from all points on the Prairie are equal to both Vancouver and to Prince Rupert. Therefore, the locational advantage of supplying grain nearby Prince Rupert may be undermined when grain is shipped to the farther port of Vancouver at the same cost to the CWB. Inefficiencies in operations are not, therefore, consistently or appropriately manifested in monetary terms to the CWB and to the transportation system as a whole.

4. The Crow Rates do not effectively indicate the real costs of providing the transportation service. The small difference between the least expensive rate and the highest rate may lead to a large number of inefficient deliveries resulting in only small overall additional costs to the system as a whole.

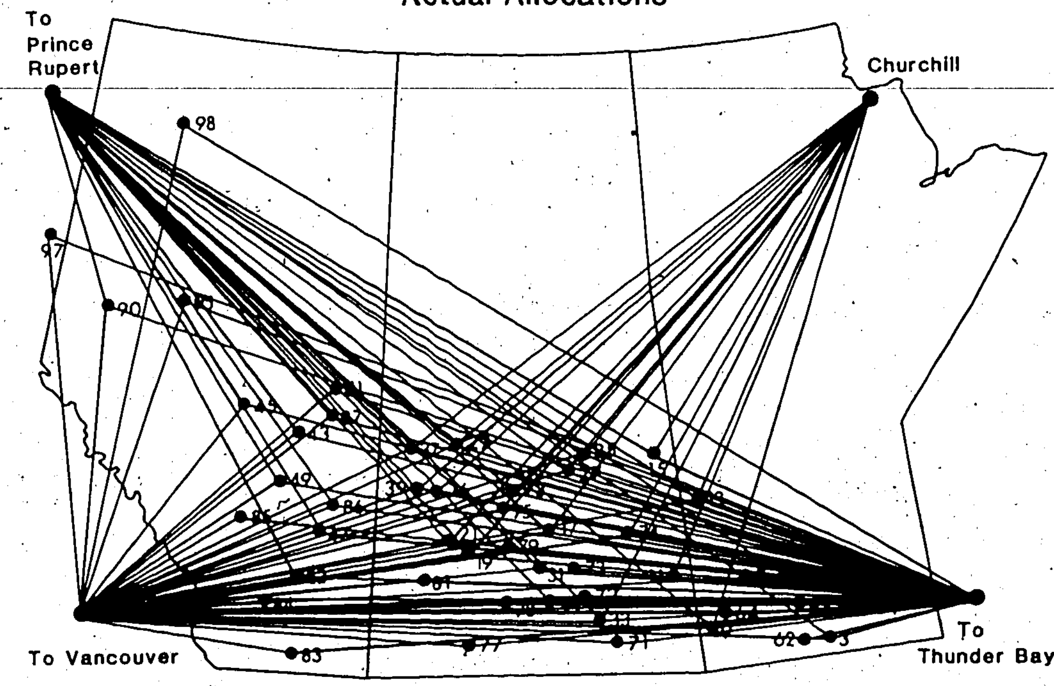
While there appears to be only minor inefficiencies in the actual shipping patterns as measured by the total shipping cost, the allocations given by the Transportation Problem appear to be much more efficient. Delivery patterns can be represented as desirelines on maps indicating inefficiencies of shipping schedules highlighted by the crossovers of desirelines. Although desirelines do not show volumes they indicate that all supplies are shipped. Actual shipment patterns can be compared to the optimal patterns represented as desirelines. The suboptimal shipping patterns can be easily identified by comparing corresponding maps. In most cases the actual shipping patterns are efficient for each of the thirty grades in su a way that the Transportation Problem could not generate a lesser cost solution. In these situations the total tonnage handled is small and therefore the opportunity to achieve efficiency is maximized.

Figure 9 on page 121 represents the actual delivery patterns under a system of one grade. The map showing the desirelines for the actual patterns was generated by noting all deliveries from all supply points. The multiple crossovers of desirelines indicate inefficiency. The optimal allocations clearly define supplying regions that represent commodity hinterlands dependent upon tariff structures to export ports. Origins 39, 76 and 81 represent supply regions having equal transportation costs to Thunder Bay, Vancouver and Prince Rupert with lower rates to Churchill. Therefore, the Pacific Coast can only realistically expect to handle the grain from Alberta and perhaps the most Western points of Saskatchewan based upon the given demand structure and transportation cost structure.

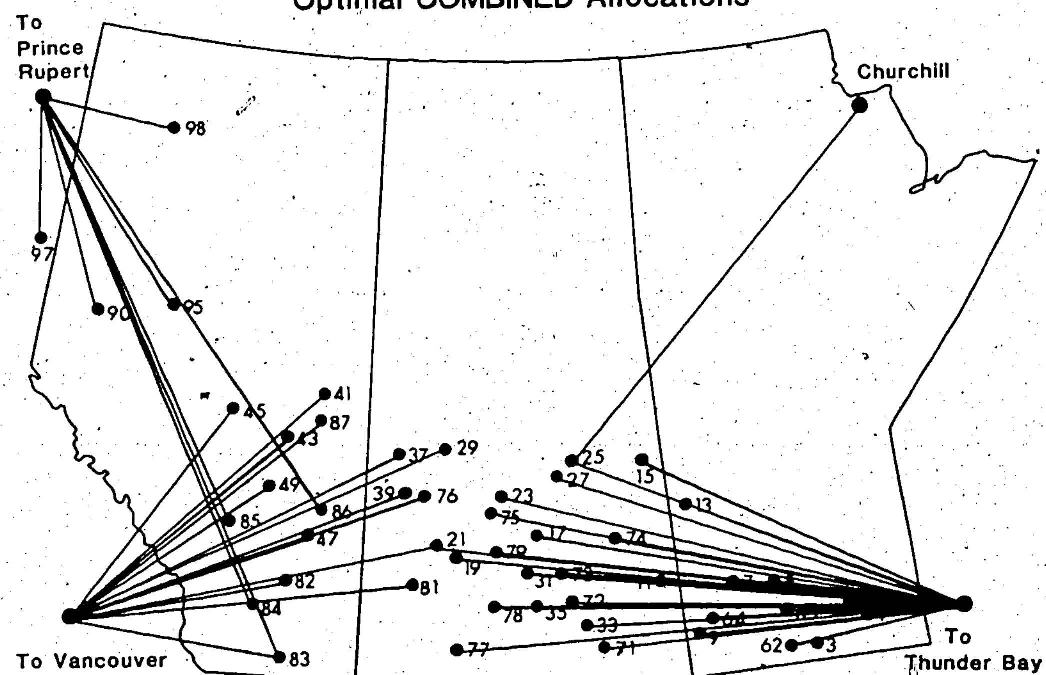
Actual hauling costs relative to each delivery route may suggest alternative supplying regions. The actual hauling costs should be used to determine the best origin-destination patterns of delivery. On the basis of actual costs the CWB could attempt to minimize the overall costs to the railways and to the entire system as a whole rather than minimizing the losses to the CWB as reflected and measured by the Crow Rates charged to the Board as compensation for transportation services. Canadian railway costing systems do not provide line-related costs for grain

FIGURE 9 ONE COMPREHENSIVE GRADE

Actual Allocations



Optimal COMBINED Allocations



transportation except on grain dependent spur lines.

There are cases where the CWB clearly does not follow the guidelines promoting efficiency where grains are shipped to the closest port. In the cases of CWRS No. 2 at 13.5% protein (Grade 235), for example, deliveries are made from across the Prairies to Thunder Bay as shown on Figure 10 on page 123. Savings cannot be generated by an improved allocation schedule because Thunder Bay is the only demand point, rendering the problem trival. The total tonnage of CWRS No. 2 at 13.5% protein wheat handled represents 11.8% of the total shipping costs and 12.9% of the total tonnage handled.

Similarly in the case of CWRS No. 1 at 11.5% protein (Grade 115) all shipments are destined for Prince Rupert except for one shipment to Thunder Bay as shown on Figure 11 on page 124. The savings of $23.00 results from shipping from origin 33 to Thunder Bay rather than from origin 35 to Thunder Bay.

CWRS No. 1 at 13.5% protein (Grade 135) represents the largest cost to the system in terms of transportation charges at 29.8% of the total actual costs. The pattern of actual deliveries suggests an opportunity to increase efficiency as shown on Figure 12 on page 126. In fact, the optimal delivery patterns would result in a saving of 1.86% from the actual costs of shipping this grade representing a decrease in costs of $382,835. This grade contributes 28.9% of the total tonnage handled over

FIGURE 10

CWRS No. 2, 13.5% PROTEIN (Grade 235)

Actual and Optimal COMBINED Allocations

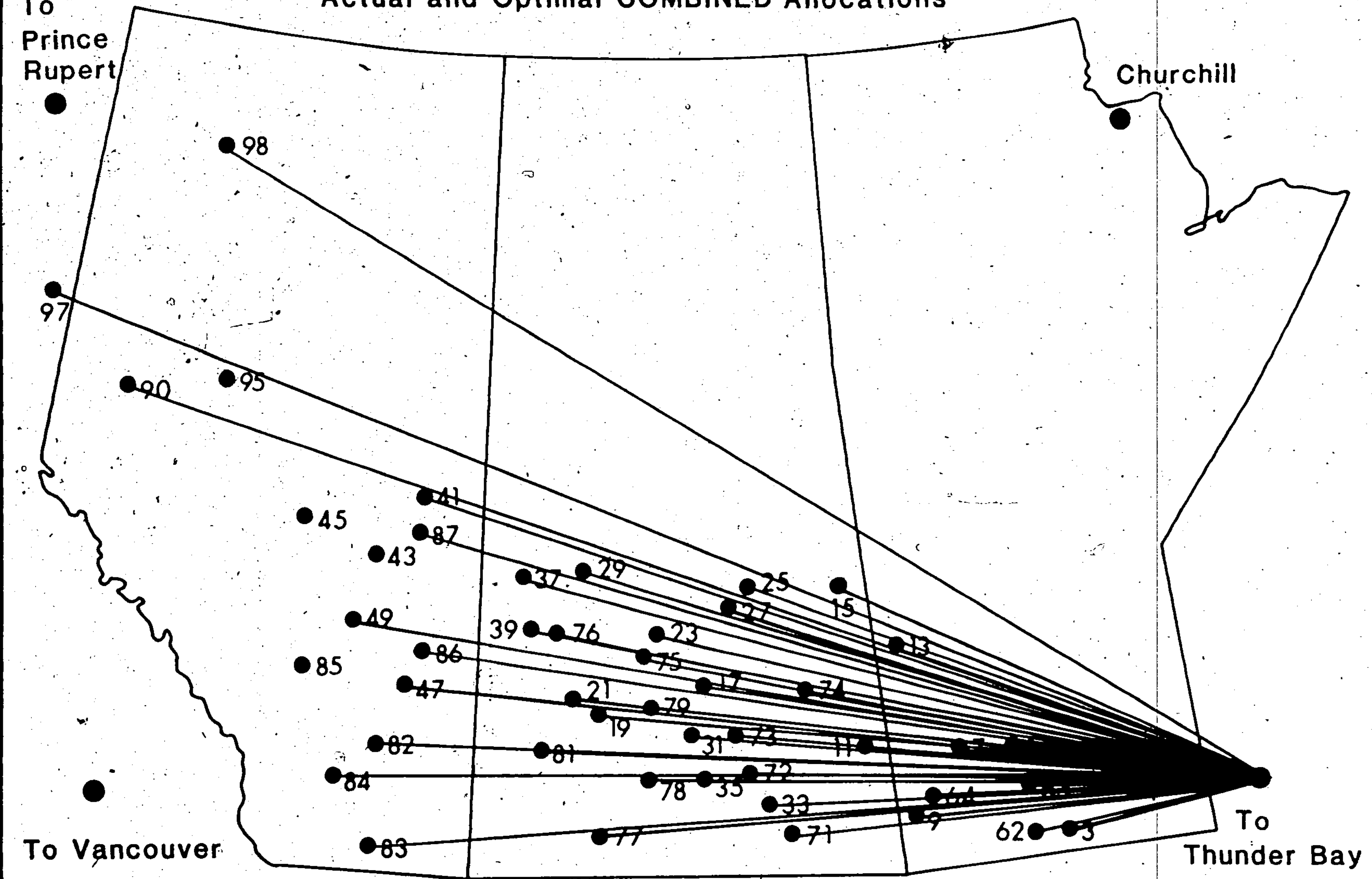
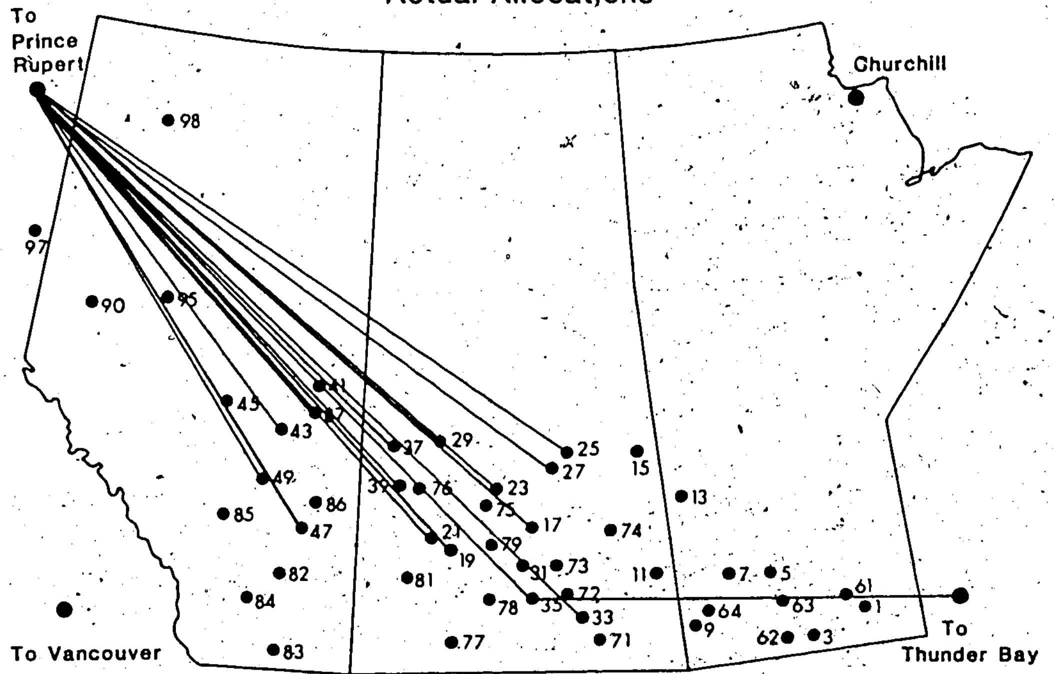
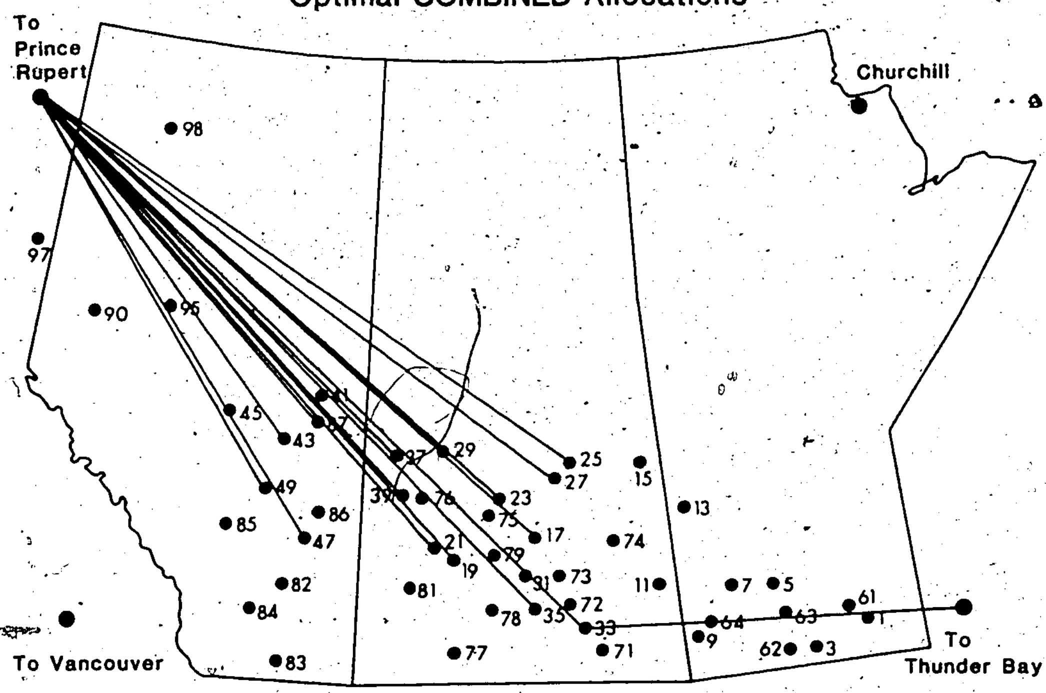


FIGURE 11 CWRS No. 1, 11.5% PROTEIN (Grade 115)

Actual Allocations



Optimal COMBINED Allocations



the study period. Possible cost savings for this grade represent 29.9% of the total possible savings under a system of thirty grades. In terms of market value, CWRS No. 1 at 13.5% protein generates the highest return of all Canadian wheats traded internationally. It is interesting to note that possible savings in the delivery allocations of this grade represent the most inefficient scheduling with the exception of CWRS No. 3 which is marketed at a lower price.

CWRS No. 3 (Grade 300) represents the lowest grade of red spring wheat in Canada and is often marketed as a feed or utility wheat or for blending own higher quality grades. It has, therefore, a correspondingly lower market value. Nevertheless it represents 29.6% of the tonnage traded over the study year and 28.8% of the total actual transportation costs. Because the Crow Rates are applied to all commodities on a tonnage basis, transportation costs represent a relatively higher proportion of the total market value of CWRS No. 3 wheat. In addition this grade is characterized by the poorest allocation schedule as evident on Figure 13 on page 127. Inefficiencies in shipping CWRS No. 3 wheat account for 34.25% of the possible savings in a system of thirty grades. As a result, transportation costs represent an even larger proportion of the value of this commodity. Optimal shipment patterns could reduce the total shipping bill by 2.2% at a saving of $439,130. This would lead to a total optimal cost of shipping this grade of $19,742,740.

The shipment pattern of Tough CWRS No. 3 (Grade 1300) represents the third

FIGURE 12 CWRS No. 1, 13.5% PROTEIN (Grade 135)

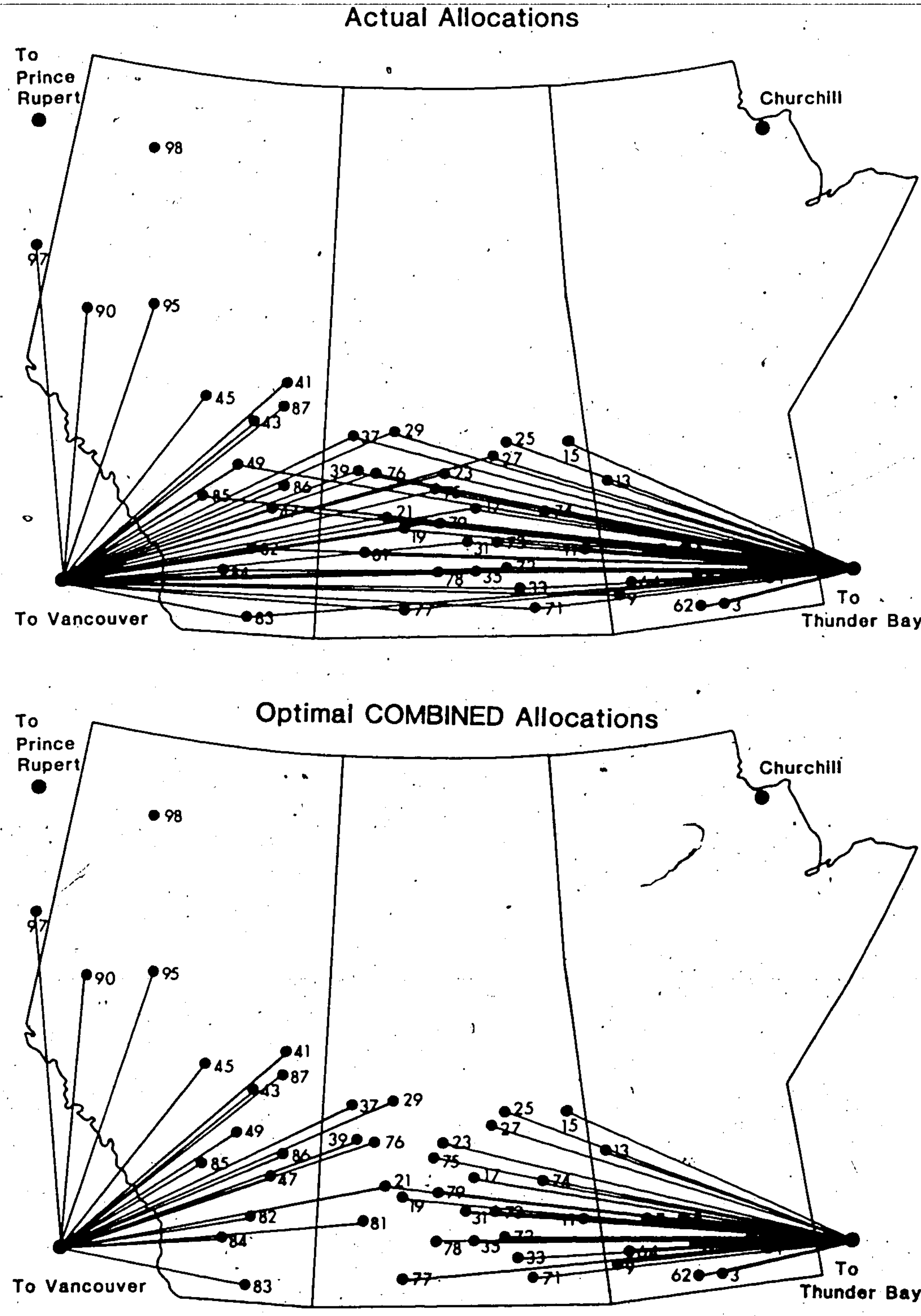
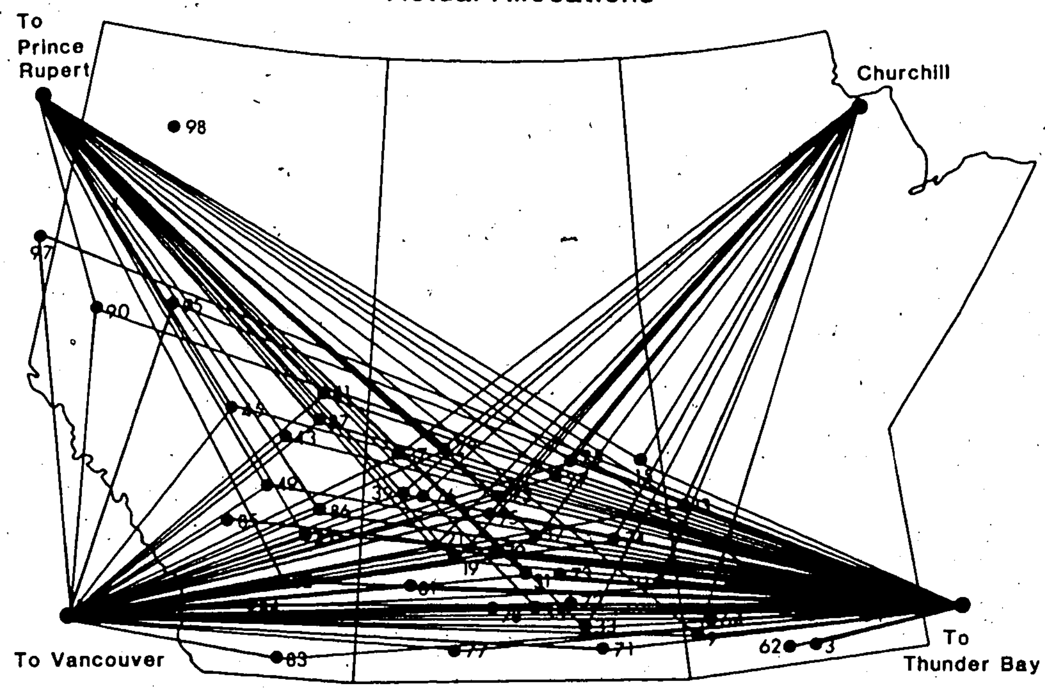
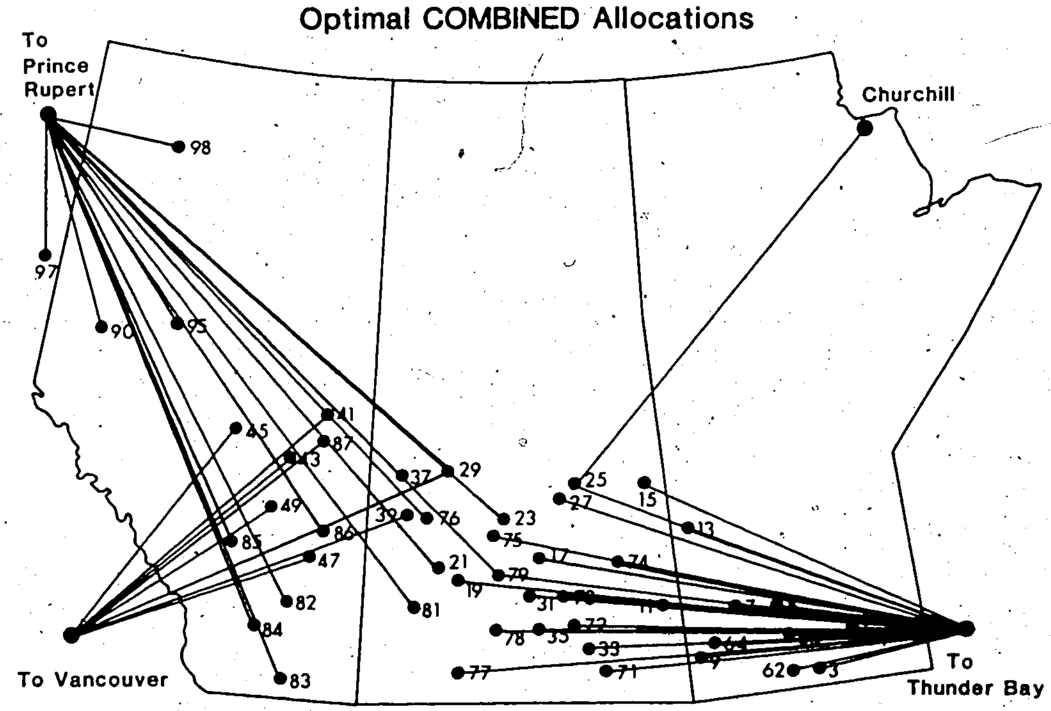


FIGURE 13 CWRS No. 3 (Grade 300)

Actual Allocations



Optimal COMBINED Allocations



largest opportunity for cost reductions under optimal delivery scheduling as shown on Figure 14 on page 129. The actual cost of delivery could be reduced by 33.9% or $224,886. Possible savings from the efficient delivery of this grade account for 17.54% of the total savings in a system of thirty grades. This grade, however, does not represent a large contribution to the total costs of the transportation system despite the opportunity for a significant reduction in transportation costs.

Wheat classed as Tough CWRS No. 1 at 12.5% protein (Grade 1125) demonstrates the CWB's success in optimizing its shipment scheduling as shown on Figure 15 on page 130. Transportation costs to Thunder Bay are the same from the origins of 19 and 79, however, there are greatest savings from shipping supplies from origin 79 to Vancouver rather than from origin 19. This situation illustrates the problems of utilizing points to represent supplying regions. Origin 19 is west of origin 79 yet the average transportation cost from 19 are less than the average from the area represented by origin 79.

6.3 EXCLUSIVE RAILWAY SERVICE AREAS

The Transportation Problem was applied to the supply and demand constraints using both the EXCLUSIVE and COMBINED cost matrices to

FIGURE 14 TOUGH CWRS No. 3 (Grade 1300)

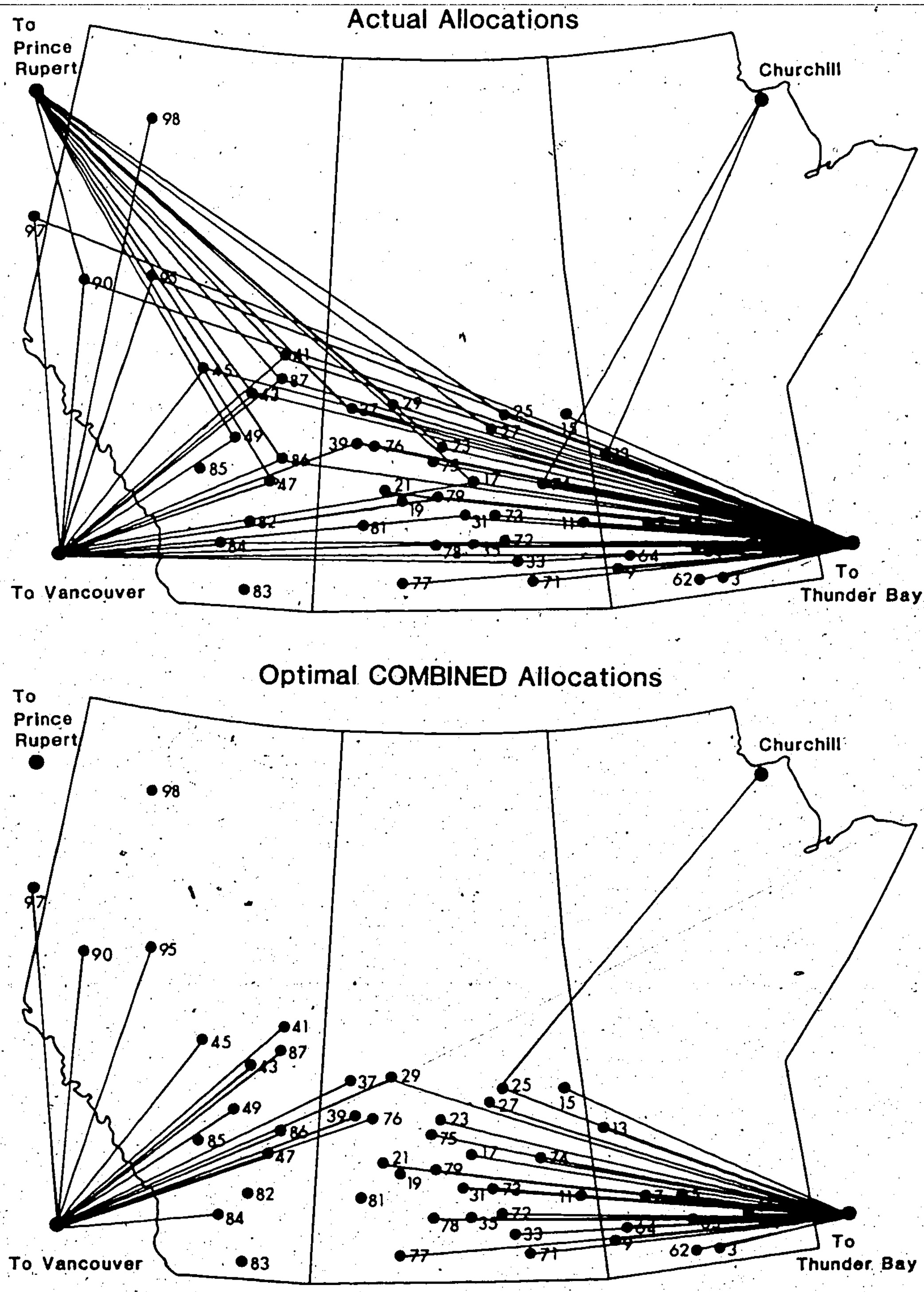
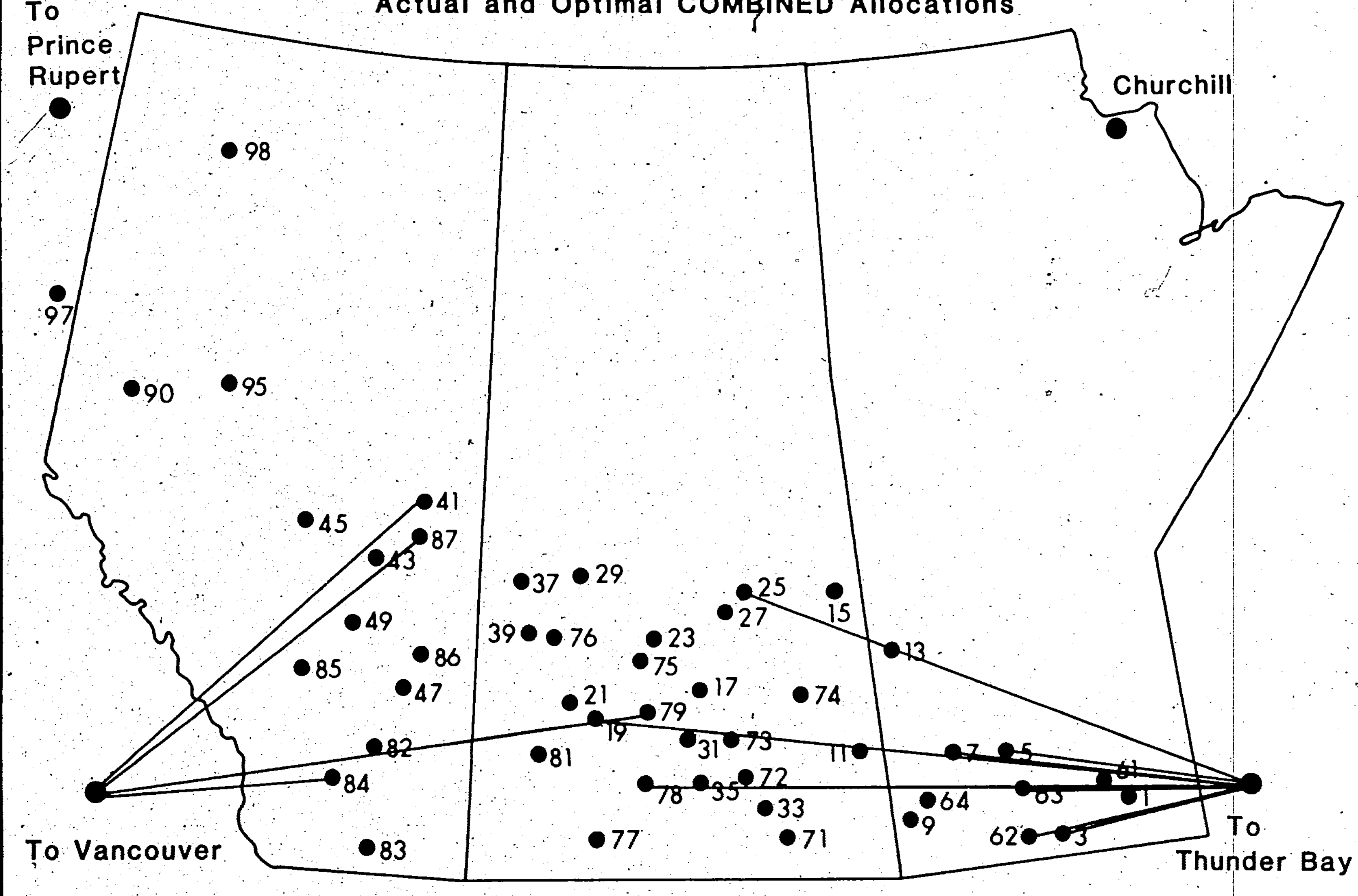


FIGURE 15

TOUGH CWRS No. 1, 12.5% PROTEIN (Grade 1125)

Actual and Optimal COMBINED Allocations

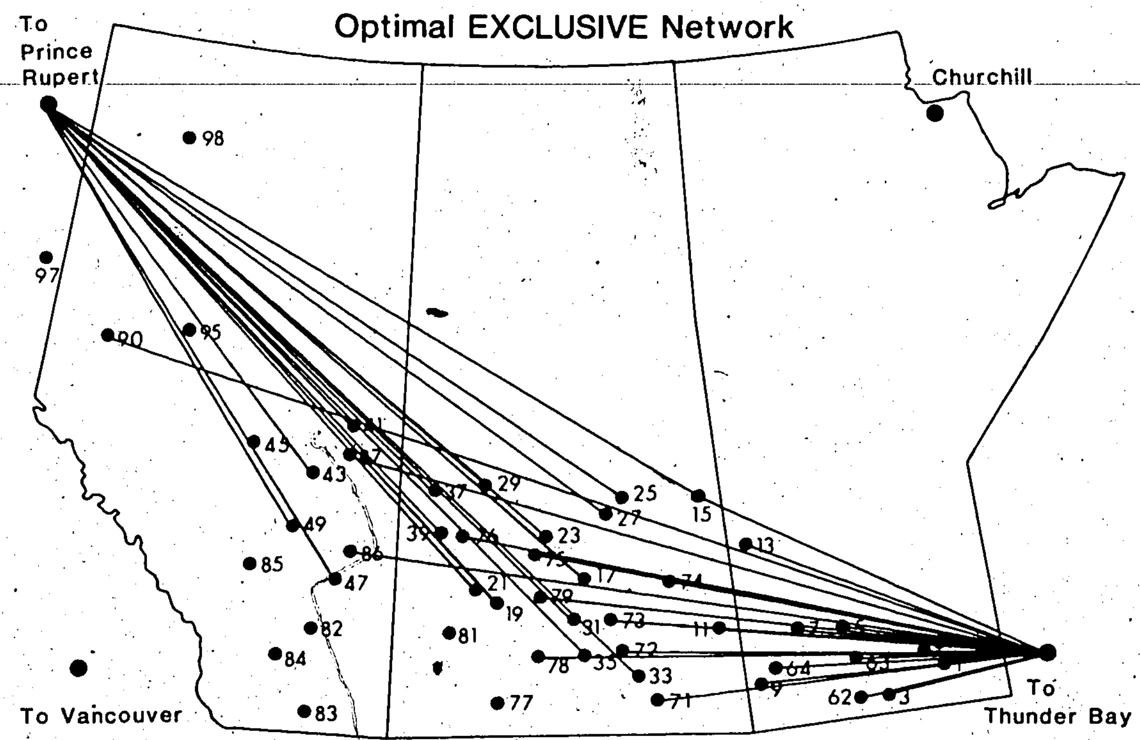


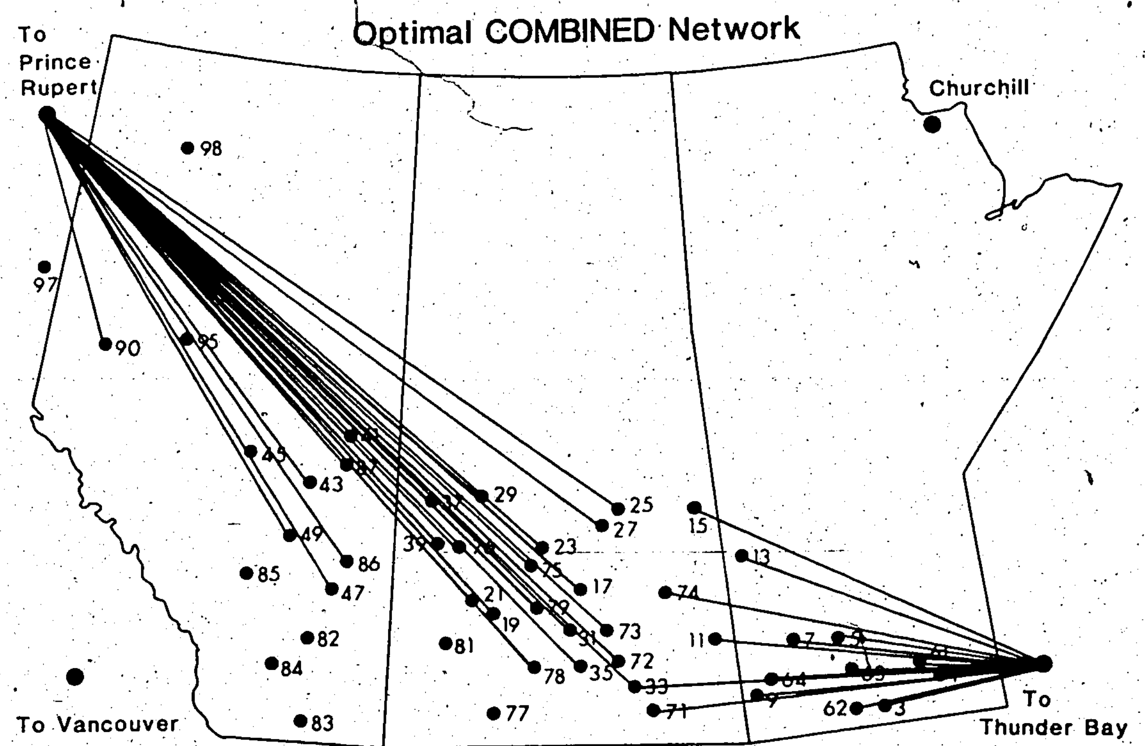
determine the additional shipping costs associated with the use of exclusive railway networks. The EXCLUSIVE transportation cost matrix represents the possibilities of deliveries within the context of the exclusive CN and CP networks. Operationally this suggests that loadings from CN origins can be delievered to any of the four terminal elevators and that loadings at CP origins may proceed only to Thunder Bay or Vancouver. The COMBINED transportation cost matrix allows deliveries between all origins and all destinations. Possible cost savings would suggest that inefficiency results because grain from CP points must be delivered to the farther ports of Vancouver and Thunder Bay requiring higher transportation charges than deliveries to closer places.

In all but two cases the results of the Transportation Problem indicate that savings would not result from a combination of two railway facilities on the basis of the given transportation tariffs. One case refers to CWRS No. 2 shipments of 11.5% protein (Grade 215)as presented on Figure 16 on page 132.

The actual shipping costs for CWRS No. 2 at 11.5% protein level was $2,205,742. This included the delivery of 4720 tonnes from CP origins to Prince Rupert. Under the restricted EXCLUSIVE network deliveries from CP origins were optimally shipped to Thunder Bay at a total cost of $2,216,207 representing $10,785 in additional transportation costs. In the optimal solution of the COMBINED network, wheat from CP origins is best shipped to Prince Rupert to minimize the total delivery costs.

FIGURE 16 AFFECT OF EXCLUSIVE NETWORK
CWRS No. 2, 11.5% PROTEIN (Grade 215)



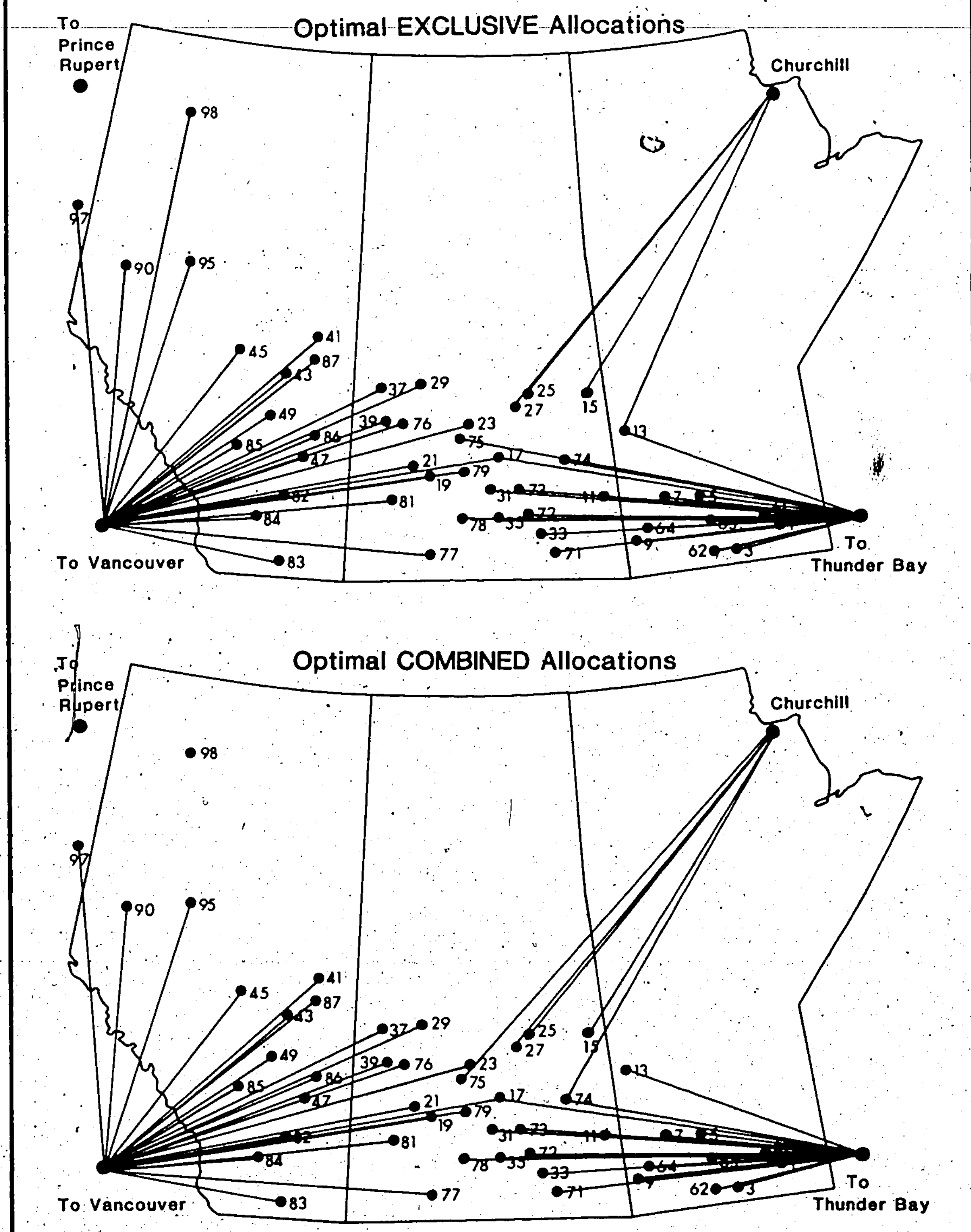


Savings of $9,745 result from the efficient utilization of the COMBINED network bringing the total transportation costs for this grade to $2,195,997.

Similarly, the actual delivery patterns of CWRS No. 2 at 12.5% protein level are characterized by shipments from CP origins to Churchill as shown on Figure 17 on page 134. The actual shipping costs were $7,604,146. An improved efficiency using the restriced EXCLUSIVE network could reduce the total shipping bill by $143,147 to $7,460,999. Such an allocation does not include the delivery of grain from CP origins to Churchill as alternative supplies are available at an overall lower total cost. The use of the COMBINED network brings the cost of delivery to $7,454,994 indicating a further reduction of $6,005 by allowing the deliveries from CP origins to Churchill.

Of the thirty grades, the four grades of CWRS No. 1 at 11.5%, 12.5% protein, CWRS No. 3 and Tough CWRS No. 3 (Grades 115, 125, 300, 1300 respectively) had deliveries from CP origins to CN destinations. In each case the EXCLUSIVE network was able to efficiently reallocate the deliveries from CP origins to Vancouver or Thunder Bay at an optimal cost less than the actual costs. In each of these four cases the use of the COMBINED network instead of the EXCLUSIVE network did not result in further savings in transportation costs.

FIGURE 17 AFFECT OF EXCLUSIVE NETWORK
CWRS No. 2, 12.5% PROTEIN (Grade 225)



6.4 INTERPRETATION OF THE DUAL SOLUTIONS

The dual variables associated with each origin (ui) and each destination (vj) provide a method to evaluate the relative costs of shipping a unit of the commodity between alternative supply-demand pairs. It is the difference between the ui and vj values of the origin-destination route under review relative to the actual transportation costs from i to j that is important in determining how supplies can meet demands at least cost in a spatial system.

Smillie (1971) has solved the LPTRNS equality formulation of the Transportation Problem using the UV algorithm. The redundant ui constraint of the system of linear equations is set to zero to determine the remaining ui's and vj's. As the discussion of the dual model indicates, the ui's and vj's can be altered to provide a system of variables easily interpreted on the bases of the inequality formulation of the model by multiplying all the ui variables by -1 and subtracting the smallest value of ui from all the ui's and adding the smallest value of ui to all of the vj's. The results of this manipulation indicate that the supply regions with high values of ui are more favourably located for production than regions with low values of ui. Increased production should occur in regions having a high ui value as this would result in the lowest shipping charge required to meet increased demand. Similarly, increasing demand at points with low values of vj would result in the lowest additional costs for transportation charges to the entire system. Increased supplies of the commodity are best delivered between origins with high values of ui and low values of vj. This interpretation is consistent with Stevens (1960) approach to the dual variables.

The economic implications of the dual solutions can only be interpreted from the COMBINED solutions of the Transportation Problem. The EXCLUSIVE cost matrix has extraordinarily high rates from CP origins to Prince Rupert and Churchill so that the algorithm will find a lower cost route to bring the supplies to market. The solution to the dual provides very low values of ui at CP origins and high values of vj at Prince Rupert and Churchill thereby discouraging shipments between these origin-destination pairs. The unreasonably high transportation costs affect the dual variables in such a way that their interpretation is limited.

Demand points not receiving deliveries were assigned a demand of one in order for the algorithm to assign a value of vj for evaluating the solutions. The closest supply was increased by one unit to meet the increased demand. The additional transport costs to the primal objective function was subtracted from the total cost of the allocation and the allocations disregarded from the analysis of actual patterns. However, the value of vj assigned to the destinations provide a measure to evaluate alternative demand patterns. The transportation costs to Prince Rupert are the same as the costs to Vancouver. The difference in values of vj reflect the attraction of the non-utilized port for increased business.

The value of vj at destinations without any actual demand are equal to the transportation costs from the origin supplying the one unit of demand.

The occasional delivery from CP origins to the CN ports of Churchill and Prince Rupert that are included in the optimal solutions of the EXCLUSIVE network distort the dual solutions further as alternative CP terminals are not available. Because each of the thirty grades represents only a proportion of the system as a whole, the dual solutions do not provide a valuable contribution to the entire system. However, solutions for each of the thirty grades and the alternative grading options can be used to indicate favourable delivery routes. The usual interpretation of the dual variables are, however, subject to two major constraints in this study.

Firstly, the supplies of different grades are primarily subject to environmental conditions that determine the type of grain produced and the yield harvested. The region of Southern Saskatchewan known as the Palliser Triangle is best suited for the production of No. 1 CWRS wheat of high protein because of the favourable soil and climatic conditions. The quality and protein level of wheat generally declines with distance away from the Palliser Triangle. The production of particular grades in specific areas is therefore difficult to achieve. In general, producers strive to cultivate the highest quality of CWRS wheat. The final grades harvested are usually a result of poor environmental conditions rather than an explicit intention. The production of grain grades in Western Canada is not affected by transportation rates because producers are financially protected by price supports and the guarantee of equal opportunity for producers to sell their harvest to the CWB for export. The environmental effects on grain production represent the most fundamental concern of the producer rather than the transportation costs of moving the commodity to market. Further, the Crow Rates apply to all grain on a tonnage basis regardless of grain grade or protein level.

A long drought affected production during the study year. Although Alberta received above average precipitation during the spring, Saskatchewan and Manitoba received below average precipitation. The net results were that Saskatchewan and Manitoba produced yields below the previous ten year average but higher than expected. Yields in Alberta were close to record levels. The overall quality of the crop was considerably lower than the 1979-1980 crop, however, the average protein content of 13.9% was higher than the 13.4% average in 1979-1980 crop year (CWB Annual Report 1980-1981, pp. 19-20). Because of changing production patterns the value of ui's and vj's for each grade cannot effectively suggest production trends. The Transportation Problem has been used in other applications to direct production in areas best suited for the activity.

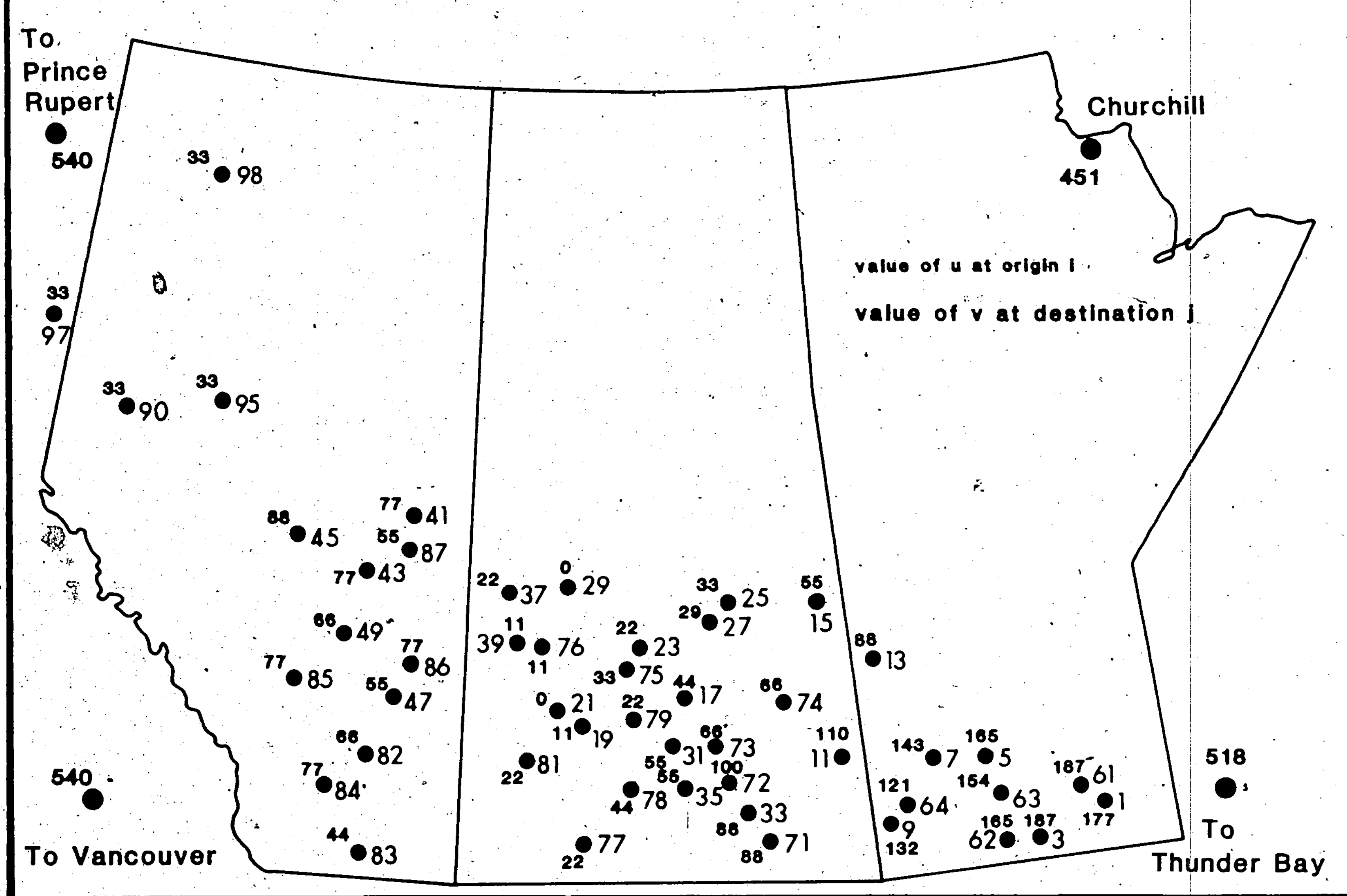
The second factor that affects the interpretation of the dual solution in this application is the fact that demand for wheat at export terminals is generated by factors external to the Canadian grain producer and the spatial system under investigation. The dual solution provided by this analysis can only be interpreted within the Canadian Prairie context as transport rates for grain are f.o.b. West Coast, Churchill and Thunder Bay. Because grain is subject to a number of additional costs before reaching the final destination the value of the vj's cannot be effectively utilized to determine the best locations at which to increase demand. Terminal handling costs, dockage, demurrage, St. Lawrence and other canals, trans-oceanic and unloading costs must also be considered in assessing the most desirable locations at which to increase demand. The fact that demands are exogenous to the system under investigation and indeed to the Canadian grain producer undermines the use of the values of vj derived from the regional Canadian transportation tariff structures. Nevertheless, with the nature of these constraints identified, the dual solution can provide the basis for interpreting the nature of the grain transportation system in Canada.

Assuming that the distribution of wheat production for the study year represents an average situation, the dual variables may be meaningfully interpreted. The structure of the capacity constraints at the supplying regions are for the most part similar for all grades under review. This similarity suggests common characteristics of the grain transportation system. The dual solution for one comprehensive grade on the basis of the entire shipping schedule is presented on Figure 18 on page 140.

In general the highest values of ui occur nearest the demand points. Usually the highest values occur in eastern Manitoba, as in this example,

FIGURE 18

OPTIMAL DUAL SOLUTION FOR ONE COMPREHENSIVE GRADE

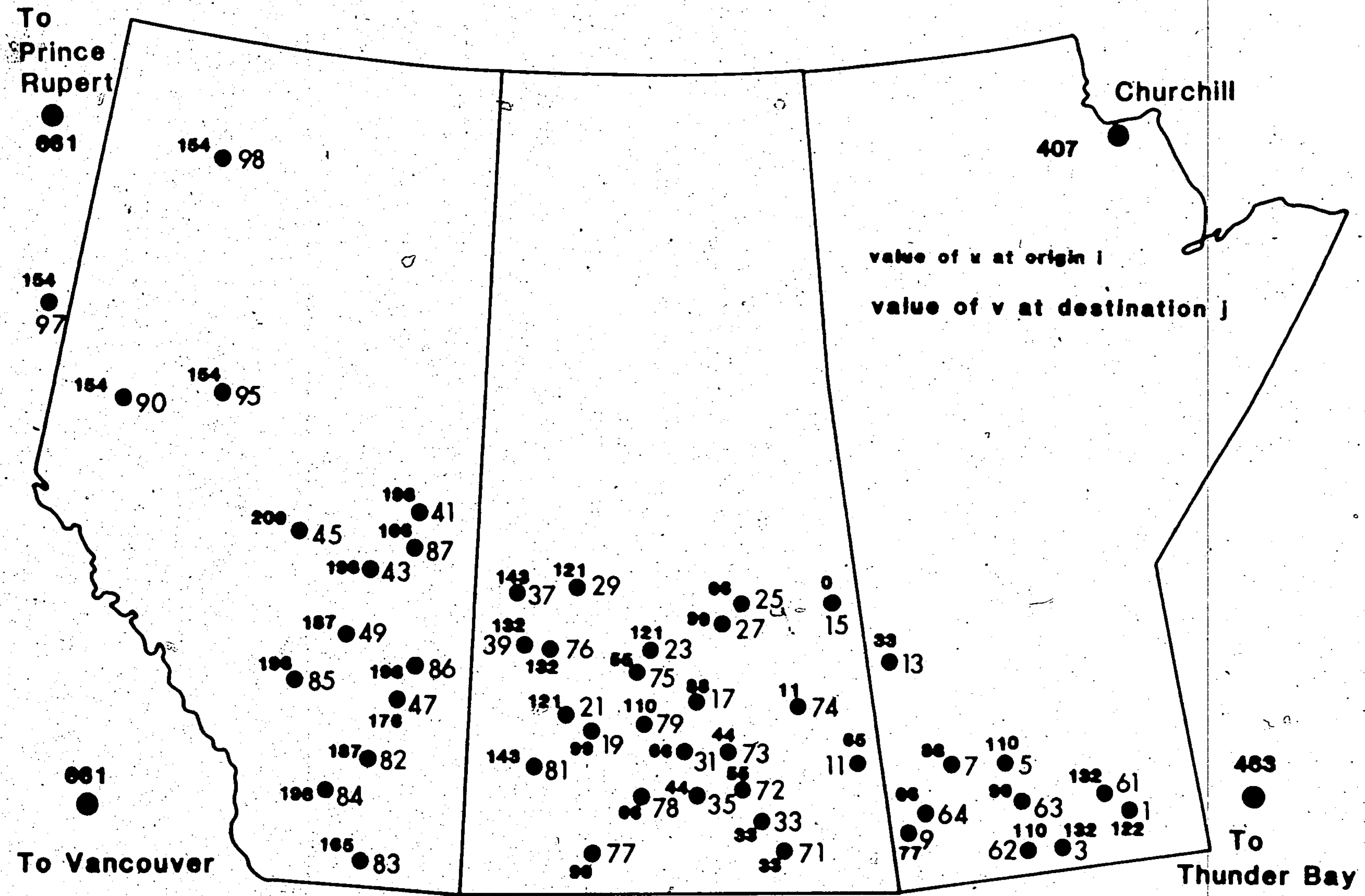


as the largest demand for all grades is concentrated at Thunder Bay. The value of ui at orgins 3 and 61 is the highest in the solution at 187. This indicates that the transportation cost from origins 61 and 3 to Thunder Bay are vj-ui=518-187=331. In fact the cost matrix sets the cost of shipping between these origins and Thunder Bay at $3.31 per tonne. The calculation of this cost is derived from the constraint specifications of the optimum dual solution Cij=vj-ui. The capacity constraint at origin 61 is calculated as the difference between the values of ui at alternative supply points in the primal solution. For example, the additional costs incurred by shipping grain from origin 21 to Thunder Bay is u3-u21=187. The costs or savings associated with alternative supply points in the optimal allocation schedule can be determined in this manner. Relative costs of shipping to one destination from any supply point can be determined by solving Cij-(vj-ui). If the sum of the dual variables (vj-ui) for the route under investigation is greater than the cost Cij then the result is negative and the delivery is attractive.

In the case of CWRS No. 2 at 11.5% protein (Grade 215), the highest values of ui occur nearest Prince Rupert as shown on Figure 19 on page 142 where 94% of the total tonnage of this grade is handled. The remaining 6% is handled at Thunder Bay. The high level of demand at Prince Rupert causes the high values of ui near this port because of the necessity to ship wheat from as far away as eastern Saskatchewan to meet demand requirements at Prince Rupert.

FIGURE 19

OPTIMAL DUAL SOLUTION FOR CWRS No. 2, 11.5% PROTEIN (Grade 215)



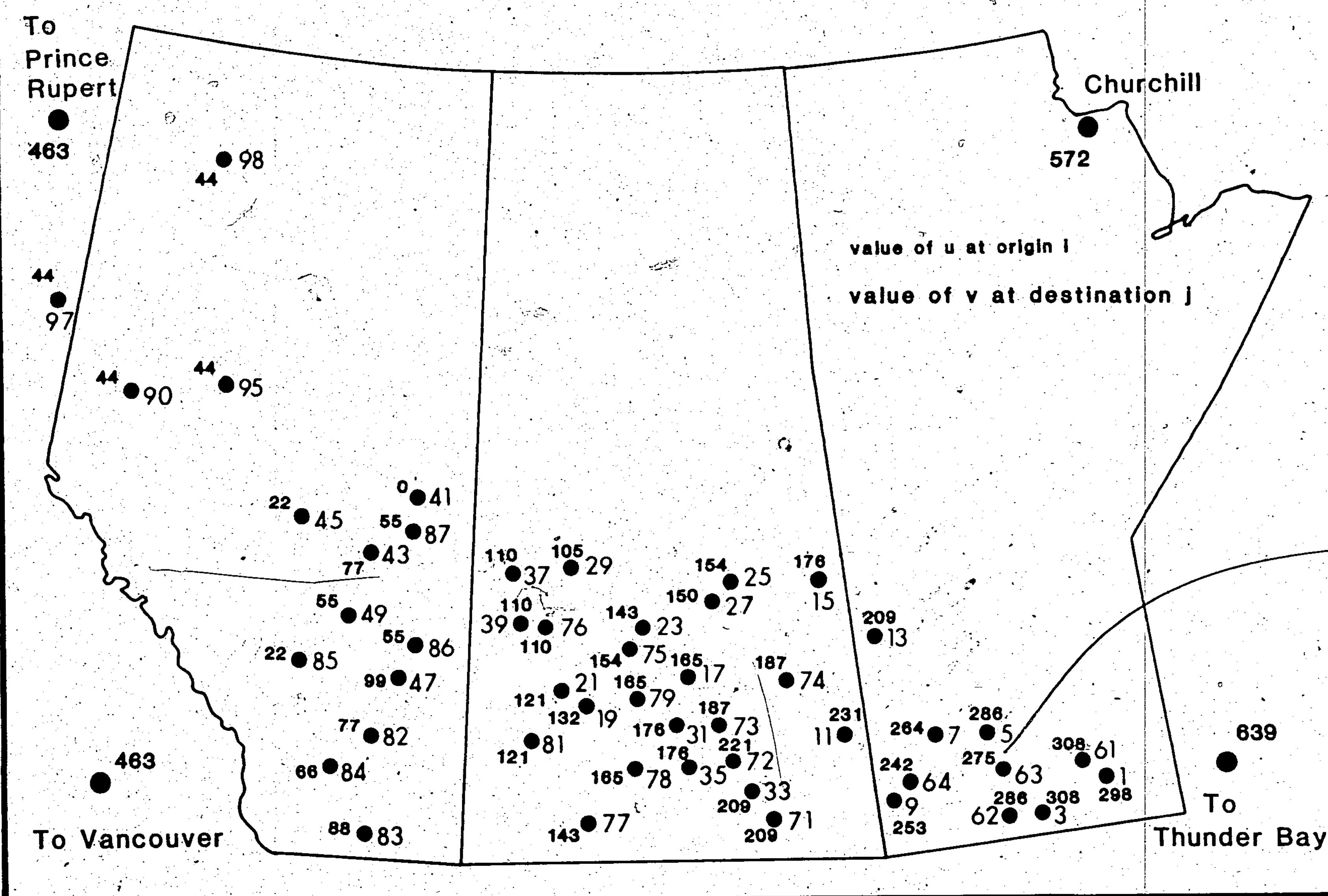
In the case of CWRS No. 2 at 13.5% (Grade 235), all shipments are made to Thunder Bay as shown on Figure 20 on page 144. The lowest value of ui is located at origin 41 from which transportation costs to Thunder Bay are the highest. The value of ui near the demand point represents a high cost associated with the capacity constraints at the supply regions necessitating the shipment of wheat from farther place at higher transportation costs to meet the prescribed demands.

In the case where wheat is demanded at all destinations, the values of ui decrease towards Saskatchewan where transport costs to all ports are highest. Saskatchewan represents the most unattractive supply region from which to ship grain because the region is subject to the highest transportation costs to meet increased demand requirements. This holds for increased demands at all ports. Where demands are concentrated at one port the lowest values of ui are located in the areas most remote from the demand point as in the case of CWRS No. 2 at 13.5%.

Although grain is subject to environmental constraints and demands generated external to the system there are notable trends to identify. Each of the four terminal ports handle all of the three major grades known as CWRS No. 1, No. 2 and No. 3. Prince Rupert is characterized by the highest level of speciality by wheat grade. Almost 70% (922,009 tonnes) of the total tonnage handled at in Prince Rupert (1,323,451 tonnes) is CWRS No. 3. This represents 20% of the total tonnage of CWRS No. 3 traded over the study period. Its proportion of the overall tonnage handled is

FIGURE 20

OPTIMAL DUAL SOLUTION FOR CWRS No. 2, 13.5% PROTEIN (Grade 235)



small at 6%. Low grades of grain exported to the Peoples' Republic of China are delivered to Prince Rupert in order to maintain trade strictly between governments without involment of intermediaries. The concentration of trade at this port is governed by political considerations and therefore the capacity constraints of the supplying regions nearest Prince Rupert are subject to changing political attitudes and decisions especially in light of the fact that the terminal at Prince Rupert has been recently purchased from the Canadian Government by a conglomeration of international grain trading companies.

Of the total tonnage of grain handled at Vancouver, 53% was CWRS No. 1, representing 16% of the total tonnage handled during the study period. Vancouver's remaining tonnage is divided equaly between CWRS No. 2 and No. 3. Japanese requirements for CWRS No. 1 account for the level of concentration in a large measure. Thunder Bay handles all grades in significant proportion. CWRS No. 1 comprises 45% (3,893,668 tonnes) of the total tonnage handled (8,741,869 tonnes) while CWRS No. 2 and No. 3 represent 27% and 28% of the port tonnage respectively. This is a result of the fact that Thunder Bay handles almost 60% of all CWRS wheat exported to a wide variety of buyers and markets. Churchill's major grade is CWRS No. 2 at 44% with 42% CWRS No. 3 and 14% CWRS No. 1. Churchill, however, handles less than 7% of the total tonnage handled over the study period.

The nature of the generalized demand constraints suggests that there is a lack of an obvious demand pattern evident from the shipping patterns that can stimulate changing production patterns if this were indeed possible. The fact that Vancouver handles 99% of the CWRS No. 1 required on the West Coast is the only unique characteristic of the delivery patterns. The low grades delivered to Prince Rupert are, as suggested, subject to change in the future.

The relative attractiveness of alternative destinations is indicated by the values of vj for each port. A low value of vj is most attractive reflecting the lowest increased cost to the objective function resulting from shipping an additional unit of the commodity into the destination j. Alternatively, the highest value of vj represents the costliest destination at which to increase demands. The highest values of vj (540) occur at Prince Rupert and Vancouver. These are followed by Thunder Bay (518) and finally by Churchill (451). The West Coast terminals have high values of vj suggesting that Vancouver and Prince Rupert are the least attractive destinations at which to increase demands because increased transportation costs to these destinations would be most costly to the entire system.

Churchill has the lowest value of vj indicating that this is the most favourable point at which to increase demand. Increased supplies can be delivered to Churchill at least cost to the objective function. In the optimal allocation, deliveries between the CN origins of 15, 19, 21, 23, 25, 29, 35, 37, and 39 and between the CP origins 74, 75, 76 and 79 to Churchill have the most favourable rate. Unfortunately, the volume of trade at Churchill prevents the best use of the faciltiy as determined by shipping charges. The relatively low transportation costs to Churchill suggests that its demand constraints are most costly to the system.

There are problems associated with expanding the volume of business at Churchill. These concerns are specifically related to the three month shipping season (August, September and October), the restricted marketing opportunities, the lack of adequate backhaul shipping, the poor railway bed conditions preventing the use of covered hopper cars, excessive marine insurance and the requirements of marine technology due to the hazardous weather conditions (Booz, Allen and Hamilton, 1979, p. VII).

The problems associated with trade at Churchill can be incorporated into the model by using a weighting factor in the cost matrix to reflect the additional costs incurred from railing grain to Hudson Bay. Such a weighting system may have the effect of increasing the value of vj so that Churchill may no longer be attractive on this basis. This type of alteration can be applied to any origin/destination pair in the cost matrix. For example, a capacity cost could be added to shipments to Vancouver to direct tonnages to an otherwise more attractive terminal port. Such weightings also show their impact in the optimal allocations derived from the solution to the primal problem of the Transportation Problem.

Thunder Bay has a slightly higher value of vj which makes it a favourable place at which to increase demand levels. The most favourable points at which to increase production, because of relatively low transportation costs in the regions located in Southern Manitoba nearest Thunder Bay. The high values of ui nearest Thunder Bay indicate that Thunder Bay handles the largest tonnage and is the overall optimal demand point.

Transportation costs to the final international destination are incurred in addition to the Crow Rate for shipment of grain in Western Canada. The best transportation alternative depends upon global transportation rates. As a result the Transportation Problem cannot be used to recommend directional flows of grain on the Canadian Prairie because of the external factors affecting international shipping. The solution, however, can be used to identify a major inefficiency in the grain tranportation system.

The Canadian price for CWRS wheat is influenced by security markets and the international forces affecting market economies, however, CWRS wheat destined for export markets is not traded on commodity markets. The international price for CWRS wheat is determined c.i.f. Antwerp, Rotterdam or Amsterdam. Because the transportation rates vary between Canadian terminal elevators and the European freeports, the price of CWRS wheat varies among terminal elevators. The average 1980-1981 ocean transportation charges for wheat to Rotterdam via Pacific Coast was $15.24 per tonne compared to $22.89 for direct overseas shipments from Thunder Bay. Transhipment of grain from lakers to ocean vessels at St. Lawrence or Maritime ports increase the costs via Thunder Bay further.

Trans-Atlantic oceanic rates to Antwerp/Rotterdam via St. Lawrence ports is $10.15 per tonne, via Maritime ports is $10.06 and via Churchill is $4.42 per tonne. The rate to Japan via the West Coast is $20.58 per tonne (Canadian Grains Industry Statistical Handbook 1982, p. 192).

The transportation cost differential has the affect of setting a higher price for wheat at Vancouver than Thunder Bay. The price of CWRS No. 1, 13.5% protein on July 20th, 1981 was $225.07 at Thunder Bay and $248.81 at Vancouver (Grain Statistics Weekly, 51st week, 1981). The CWB could attempt to maximize its profits by shipping more wheat through the West Coast. Thunder Bay handles approximately 60% of all CWRS wheat traded on an annual basis because of severe capacity constraints on the volume of throughput at the Vancouver terminals. The strong attraction to sell grain at Vancouver is compromised because grain is diverted to the Thunder Bay terminals. Despite the highest values of vj at Vancouver, the difference between the values of vj at Thunder Bay and Vancouver (540-518=22) does not exceed the actual price per tonne of wheat available at Vancouver ($248.81-$225.07=$23.74). As a result, the favourable price differential at Vancouver outweighs the additional costs of transporting wheat from the producing areas to the Pacific Coast rather than Thunder Bay.

The desirability of increased demands at Vancouver can, therefore, be considered despite the values of vj. The possibility of expanded throughput at Vancouver is limited, however, by the fact that operations have almost reached the maximum potential capacity because of the system's operating characteristics. The problems that must be overcome to increase the handling capacity are various, ranging from the railway capacity through the West Coast mountain ranges to the inability of reliably estimating ship arrivals at Vancouver loading docks. The logistics of the system act as a constraint on actual sales of grain at Vancouver because of the uncertainty of being able to meet throughput requirements. The recommendations to increase throughput capacity at Prince Rupert is, therefore, a desirable and favourable policy objective supported by the results of this analysis if the difference between the values of vj and Thunder Bay at the Pacific Terminals continues to be outweighed by the international price differential.

6.5 CONCLUSIONS

The universal grading scheme has been shown to decrease the total shipping bill by 2.3% in the amount of $1,568,590 with a corresponding reallocation of 4.568 million tonnes of wheat representing 31% of the total tonnage handled over the study year. This would bring the actual cost of deliveries to $68,562,406. Optimal allocation of the sytem of thirty grades would reduce the actual costs by an additional 1.8% or $1,282,289. The system of three grades would reduce the actual costs by 2.15% or

$1,507,385. On the basis of the given transportation cost structure, it can therefore be concluded that grade multiplicity is supported at a nominal cost to the CWB. This conclusion is intuitively contrary to the expectation that as the number of grades of the commodity increases, transportation coordination becomes increasingly difficult and expensive.

A high level of efficiency has been found to exist in the transportation coordination schedules of the CWB on the basis of the transportation charges. The average additional cost per railcar accruing from inefficient delivery schedules amounts to $5.70 (total savings/total number of deliveries). The average cost per delivery is $313.32 (total actual cost/total number of deliveries). On the basis of the given Crow Rate tariff schedule possible savings resulting from efficient delivery patterns account for 1.8% of the total transportation charges per delivery. It can be concluded that the transportation tariff structure does not provide any incentive for efficient use of transportation services as the savings accruing from the optimal use of the system are nominal, and possibly outweighed by the costs to ensure least cost allocation patterns.

While the solutions to the Transportation Problem do not present major opportunities for cost savings, they present obvious supply regions in relation to each of the terminal destinations. The patterns of optimal shipments provide a useful basis upon which to efficiently utilize the railway transportation services thereby minimizing the costs to the entire system, rather than minimizing those costs charged directly to the CWB.

It has been shown that the CP and the CN exclusive railway networks do not impose any additional actual costs to the entire system. This conclusion, however, is only determined on the basis of the Crow Rates which no longer cover the real cost of providing transportation services. While it appears that future cooperation will not occur between the two railways, except for the reciprocal traffic (amounting to less than 5% of total tonnage handled in 1980), this conclusion is subject to further scrutiny. The operating characteristics of the grain traffic must be analysed before the costs to the entire system can be determined.

The dual solution indicates that Churchill is the most favourable destinations at which to increase the level of demand. However, increased handling at Churchill is subject to major problems related to its shipping season, railway accessibility and the lack of additional marketing opportunities. It is expected that westward deliveries will be increasing at a faster rate than eastbound deliveries (Booz, Allen and Hamilton, 1978, III-2). The CWB could maximize its return by selling wheat at Vancouver where the highest international prices are paid for the commodity. The dual solution suggests that this trend will be most costly to the system on the basis of the present transportation tariff structure. The international price of wheat at Vancouver outweighs the advantage of Thunder Bay as a point to increase demand as determined by the Crow Rate transportation cost schedules. Indeed, this conclusion is significant with respect to Vancouver and Prince Rupert.

The structure of the grain transportation cost tariffs in Western Canada provides a large number of alternative solutions to the primal shipping problem of Linear Programming because shipping costs to Vancouver and Prince Rupert are equal from all origins. It is expected that numerous suboptimal solutions would also be generated by the model because the resource is homogeneous and distributed throughout a region where shipping costs have a small variation. In this particular application the suboptimal solutions would be almost as good as any optimal solution. Indeed, Smillie and Bar (1972) suggest that suboptimal solutions must be considered in delivery problems because the weather, accidents and equipment failure introduce the element of uncertainty into the planning process. The inherent constraints and limitations of the coordinating group results in the scheduling of deliveries that are considered suboptimal, however, under the circumstances contribute only small increases to the overall total shipping cost. The optimal solutions for the CWB's scheduling represents a benchmark from which to ascertain the general level of efficiency. A high level of efficiency has been found to occur. Although alternative optimal solutions are probably very good they are not considered here because of the large number of alternatives to address which would not make a considerable contribution to the results already provided.

7.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Canadian Western Red Spring wheat is the most important internationally traded grain in Canada. The Canadian Wheat Board is responsible for coordinating the delivery of wheat from producing areas to export terminal ports. The transportation coordination programs of the Canadian Wheat Board have been evaluated from July 1st, 1980 to June 31st, 1981. The location of demands is determined by international customers who nominate ships to collect the wheat at a specific Canadian export terminal. Demands, therefore, are based totally upon customer preferences.

The planning programs of the Canadian Wheat Board treat each week as a separate Transportation Problem. This investigation has evaluated the programs of the fifty-two weeks in the study year as one transportation problem in order to determine the level of suboptimality realized by short term planning at the expense of long term efficiency. Transportation cost minimization is the explicit criterion of investigation.

The Transportation Problem assumes that the coordinating agency, in this case the Canadian Wheat Board, has complete knowledge of the location and level of supplies and demands upon to which to determine shipping schedules. While the version of the model used in this analysis is unconstrained with regard to network capacity, the nature of the Canadian wheat transportation and handling system indirectly imposes critical constraints.

The level of supplies at country elevators, for example, is affected by elevator price, producer delivery quotas, tax deferral programs, environmental conditions, producer delivery preference and elevator capacity. The actual supplies used in the analyses are dependent upon what is actually drawn from each origin and does not consider on-farm stocks, elevator stocks, terminal stocks and grain en route.

The analyses evaluate the transportation patterns of actual deliveries which are constrained by railcar availability, vessel arrivals, terminal elevator capacity, country elevator stocks, labour problems, environmental and physical damage to the transportation network. Demand is primarily a function of vessel arrival. The destination of wheat is constrained by the location of the vessel arrival which is the discretion of the buyer. Because misshipments occur from the producing areas, the unloads of grain at terminal elevators could be different from what was ordered to meet the requirements of the expected vessel.

As enumerated at the outset, this investigation determines the additional costs of transportation arising from three sources of suboptimality:

1. Weekly Transportation Schedules,

2. Grade Multiciplicity, and

3. Network Exclusiveness.

The actual transportation costs of the observed delivery patterns have been compared to the optimal solutions derived from the Transportation Problem. The interpretation of the dual solution is limited due to the global factors affecting the Prairie wheat production and transportation costs. The dual solution provides a system to evaluate the relative costs or savings of shipping between alternative points. The solution to the Transportation Problem modelling has provided information regarding the costs associated with the three sources of suboptimality investigated.

The actual patterns and costs of the deliveries for each of the thirty grades of CWRS wheat were determined and compared to the optimal costs and allocations. The actual and optimal patterns were mapped, indicating a high level of inefficiency associated with the actual patterns compared to the obviously efficient patterns associated with the optimal allocations. A total of 4.568 million tonnes of wheat, representing 31% of all tonnage handled were reallocated to optimal destinations. In some cases, demand for a grade of wheat at one port required deliveries from across the Prairie region. In other cases, the elevator company shipped wheat to its own terminal elevator at a higher transportation cost in order to protect any financial benefit derived from the purchase of grain from the producer. Deliveries to terminal elevators operated by other owners necessitates the sale of grain at dockside for the going price. The objective function, however, did not indicate a significant possible saving associated with improved shipping schedules. The possible savings in a system of thirty grades represents 1.83% of the actual cost.

The system of thirty grades of wheat was combined into one comprehensive grade in order to determine the additional costs of transportation resulting from the complex coordination involved with meeting specific demand requirements for each grade. Originally, the additional transportation costs associated with grade multiplicity were expected to be significant. The Transportation Problem for a system of one comprehensive grade determined an objective function that represented a 2.29% decrease in the actual total costs as measured by the Crow Rate structure. Savings from the optimal allocation of one grade represents a mere 0.46% saving over optimal delivery of thirty grades.

The optimal allocation of supplies to demand points provide clear opportunities to increase efficiency by establishing hinterlands for each specific port. The optimal allocation patterns deliver wheat to the nearest terminal capable of handling the capacity. Alberta and the far western portion of Saskatchewan are optimally serviced by Pacific terminals. The remaining areas are best serviced by Thunder Bay and there are shipments from one origin to Churchill. In effect, the least cost allocation indicates that shipments should not occur between Alberta and Thunder Bay, deliveries which are known to occur.

The actual distribution patterns indicate a high level of inefficiency by the crossover of desirelines, however, the objective function does not indicate any significant saving. The transportation costs related to the support of the grading system are not obvious or measurable from the results of the analysis. Until these costs can be ascertained, any change to the grading system may undermine the Canadian reputation for consistent and dependable high quality red spring wheat. These results suggest that the problem may be minor and that change may be detrimental from the standpoint of international wheat trading.

The fact that these costs do not weigh heavily in the objective function leads to questioning the accuracy of the cost matrix. Furthermore, the actual transportations charges do not reflect the actual costs of providing the service. Under the statutory Crow Rates, the difference between the cheapest and the most expensive transportation rates are not large. As a result the Canadian Wheat Board cannot respond to the inefficiency because the monetary costs are not obvious enough to provide incentive to reduce suboptimality. The costs associated with suboptimality are absorbed by other parties involved in the Canadian wheat transportation system, namely the railway companies and the federal government.

The Canadian National and the Canadian Pacific Railways each operate exclusive railroad service networks. The results of the Transportation Problem analyses demonstrate that under the Crow Rate structure the additional transportation costs associated with exclusive railway service systems are neglible. In fact, the actual patterns indicate that grain was moved from CP origins to exclusive CN destinations under the reciprocal traffic agreement at a higher cost than necessary under optimal delivery scheduling.

The model is subject to a major problem in investigating the costs of exclusive service systems because Crow Rates to Vancouver and Prince Rupert are equal thereby eliminating any advantage of shipping to the closest port. In addition, the tonnages handled at Churchill are small and therefore are not significant in terms of possible savings to the entire system. It is expected, however, that under a cost matrix reflecting the true costs of service that the effect of railway exclusiveness may provide more meaningful results.

The Transportation Problem model used in this analysis is an unconstrained model that does not provide any indication of network congestion. Bottleneck problems at terminal elevators, especially at Vancouver, are indirectly considered in the model because the demand at Vancouver is directly related to the handling capacity at railway marshalling yards.

The western portion of the Canadian National mainline follows an alignment through Jasper and the Yellowhead Pass meeting the Canadian Pacific line at Kamploops, British Columbia, following a similar alignment as the Canadian Pacific mainline through the Fraser River Valley to Vancouver.

From Calgary the northern CP line passes through Rodgers Pass and the southern line passes through the Crow's Nest Pass. The CP lines connect at Hope, British Columbia and proceed to Vancouver. It has been suggested that the CN and CP lines through the Fraser River Valley be coordinated to allow unidirectional flows on each line. This would result in all westbound trains using the CP line, for example, and eastbound trains using the CN line, eliminating the present bottleneck problems associated with one track for each railway and the necessity of the time-consuming siding of trains.

The interpretation of the dual solution is limited. The major finding is related to the favourable transportation costs to Churchill from several CN and CP origins. In addition, shipments are presently delivered to Thunder Bay at higher costs than deliveries to Vancouver due to the operating capacity at Vancouver. The dual solution suggests that increased capacity at the port of Churchill would result in the greastest saving to the system. Churchill, however, is subject to serious constraints limiting its ability to increase volumes handled. Thunder Bay represents the second best location at which to increase handling by virtue of the dual variables. The attractiveness of Thunder Bay is undermined by the higher price for wheat obtained at Vancouver. The favourable international price differential at Vancouver outweighs the attractiveness of Thunder Bay as a location at which to increase demand. The transportation costs through the St. Lawrence Seaway and the associated storage and transhipment charges are slightly higher that the price difference for wheat obtainable at Vancouver. For the system of one grade, Vancouver represents the most attractive location at which to increase demand, however this advantage is only marginally significant. This conclusion is important in light of the fact that wheat trade opportunities out of Vancouver are refused due to the limited handling capacity. The dual solution has limited significance with respect to the production patterns in the producing regions because the grade of wheat harvested is governed by the uncontrollable variables of environment and weather. The producer always strives to produce the highest quality of wheat, however, is constrained by the impacts of these variables. Because of the changing annual production patterns the values of ui cannot effectively suggest attractive production trends to minimize the total transportation bill.

The data provided for the analyses is on a tonnage basis, rather than by number of carloads. Each carload is subject to its unique capacity, dependent upon the type of car and the railway lines over which it will travel. Although the use of the number of carloads does not reflect the actual tonnage of the deliveries, it would be valuable to equate the improved transportation coordination programs with the number of cars necessary to complete the program. There is evidence to suggest that the grain transportation problem is complicated by far too many railcars congesting port areas, particularly Vancouver. The improved utility of rolling stock is a desirable objective, however, this analysis is unable to provide any meaningful information related to this problem.

The link capacity is not explicitly defined in this model, however, demand capacities are directly determined by line and railway capacity. The multiple commodity nature of the Canadian railways complicates the possibility of establishing link capacities for grain especially when shipments are based upon a tonnage basis rather than number of cars. The transportation of all commodities is subject to seasonal variation and international factors which are almost impossible to forecast or anticipate and therefore difficult to model.

The actual delivery schedules used in this analysis were determined by the offical grade and tonnage at the point of unloading at terminal elevators. The data does not reflect the nature or frequency of misshipments. As a result the misshipped grades may be included in the analysis of another grade than that requested. Tough and damp grades require drying at terminal elevators. An elevator company which misgrades a shipment is penalized by a reduction of one railway car for the following week's allocation. In the event that the misshipments represent a significant proportion of the deliveries it would be expected that the results of the Transportation Problem would exaggerate the level of inefficiency associated with the delivery programs.

The Transportation Problem is subject to the economic man axiom of economics. The Canadian Wheat Board must, however, reach its mandate to provide equity of opportunity to all producers as exemplified by the Braken Formula for railcar allocation. The formula gives favourable bias to country elevators reaching capacity and also requires that all producers have an equal opportunity to sell produce to the CWB. This assumption of the model is contrary to the operations of the Canadian Wheat Board, but not to the problem under investigation. Assuming that the allocation schedules for the study year reflect the CWB's ability to provide equity of opportunity to producers the Transportation Problem determines the minimum transportation cost solution associated with bringing the commodities to the market place. The Transportation Problem model also assumes that the coordinating agency has full and complete knowledge of the characteristics of the demands and supplies. It is the intention of the Board to operate with the full knowledge of the dynamics of the system. The actual delivery patterns suggest that the CWB does not operate with complete knowledge and encourages the Board to consider the annual demands on the system to lengthen the planning horizon beyond the weekly shipping schedules.

The Canadian Wheat Board has made a conscience effort to increase production of Canadian Western Red Spring Wheat for export despite the distintegration of her traditional foreign markets and the changing requirements of bread making technology favouring an increase in the softer wheats accompanied by a corresponding decrease in the tonnage of high quality hard wheat. The ever increasing marketing opportunities for softer wheats in both developing and developed nations is not available to Canadian producers because of the emphasis of hard wheat production. This marketing decision has an impact on the entire agricultural sector of the economy, in particular the costs of maintaining the CWRS grading and transportation systems for the purposes of international marketing and the constraints imposed upon other commodity types. The fact that the grades of wheat are blended at the termial elevators to meet the specific requirements of awaiting vessels questions the rational of such a rigorous grading system. The producer does, however, receive his compensation for the quality produced at the point of delivery to the country elevators. Despite the fact that this application of the Transportation Problem is unable to identify the actual costs of supporting the system, the grading system should be reviewed in light of international trends in agricultural marketing opportunities. The Canadian Wheat Board, however, continues to sell as much wheat that can reach the terminal elevators. In fact, some contracts cannot be met because of the congestion at the port of Vancouver. It is the intent of the actors in the Canadian grain transportation system to improve the throughoutput of the system to ensure that total sales rise and that all opportunities can be capitized upon.

The Transportation Problem analyses conducted in this research is subject to major theoretical and operating constraints. The original objectives to ascertain the additional transportation costs associated with three possible causes of suboptimality were severely compromised by the nature of the cost matrix which was critical for meaningful results. Although the flow diagrams provide an indication of the efficiency with which the CWB operates, the objective functions were unable to provide any meaningful measure of inefficiency in transportation coordination or in the suboptimal use of system resources. Crosshauls were found to exist in each of the three possible causes of suboptimality, however, the costs associated with these crosshauls are not significantly reflected in the objective function.

The recommendation of this thesis is to establish shipping charges that reflect the actual cost of service in order to provide a measure whereby the CWB can respond to inefficient expenditures. Any meaningful changes to the Crow Rate structure requires the advance of railway costing techinques in Canada. It has been suggested that the current proposal to abolish the Crow Rates will generate an improved efficiency from the CWB. The results of this analysis clearly support the elimination of the Crow Rates for the purposes of freight charges as they distort the economic principles of pricing and the efficient use of scarce resources.

This application of the Transportation Problem model has effectively demonstrated its utility as a tool to evaluate shipping schedules. The presentation of a complex transportation system by the parameters of the model simplify the system to a level that is possible to evaluate. The nature of the cost matrix used in this analysis demonstrates the critical influence that transportation costs have on delivery schedules and the importance of shipping rates to reflect the real costs of service.

Whereas this analysis has been restricted to the Canadian transportation system, the demand points could be altered to reflect the final destinations of Canadian grains. This could be achieved by establishing a suitable transportation cost matrix. This approch, however, is constrained by the fact that oceanic shipping is a volatile business subject to extreme flexibility in tariff structures. The transshipment version of the Transportation Problem is available for such an application.

The Transportation Problem has been used in the past to provide a method to evaluate transportation pricing in a spatial system. This model can be effectively used to evaluate any proposed freight rate structure for the transportation of grains in Western Canada or can be adapted for a similar applications. This model should be used in the future to evaluate the additional costs of transportation caused by the three sources of suboptimality under an appropiate transportation cost matrix.

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APPENDIX A

OPTIMAL AND ALLOCATIONS FOR SPECIFIC GRADES OF CWRS WHEAT

OPTIMAL ALLOCATIONS: ONE GRADE

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	66,459				66,459
03 Winnipeg South	159,594				159,594
05 Winnipeg West	172,206				172,206
07 Brandon North	99,152				99,152
09 Brandon West	269,281				269,281
11 Melville	216,260				216,260
13 Dauphin	363,913				363,913
15 Kamsack	281,568				281,569
17 Saskatoon Main	379,299				379,299
19 Saskatoon South	277,354				277,354
21 Saskatoon West	75,005		278,372		353,377
23 Saskatoon North	319,524				319,524
25 Prince Albert East	45,316	310,769			356,085
27 Prince Albert South	333,214				333,214
29 Prince Albert West			339,354		339,354
31 Saskatoon East	215,593				215,593
33 Regina South	619,195				619,195
35 Regina West	343,911				343,911
37 Biggar North			295,820		295,820
39 Biggar West			489,839		489,839
41 Edmonton North			189,542		189,542
43 Edmonton South			322,726		322,726
45 Edmonton West			22,567		22,567
47 Hanna South			515,888		515,888
49 Hanna West			261,861		261,861
61 Keewatin	155,229				155,229
62 La Riviere	273,115				273,115
63 Carberry	224,944				224,944
64 Brandon	356,501				356,501
71 Weyburn	422,567				422,567
72 P[illegible]	381,783				381,783
73 B[illegible]a	415,328				451,328
74 [illegible]enbury	331,749				331,749
75 Saskatoon	313,520				313,520
76 Wilkie			572,911		572,911
77 Assiniboia	710,832				710,832
78 Swift Current	607,230				607,230
79 Outlook	312,230				312,230
81 Medicine Hat			458,977		458,977
82 Brooks			345,454		345,454
83 Lethbridge			38,634	445,705	484,3[illegible]
84 Vulcan				384,164	384,164
85 Calgary				17,655	17,655
86 Red Deer				191,808	191,808
87 Edmonton			241,394		241,394
90 N. Alberta RR West				152,922	152,922
95 N. Alberta RR East				51,743	51,743
97 British Columbia RR				58,088	58,088
98 Great Slave RR				21,368	21,367
TOTAL DEMANDS	8,741,871	310,769	4,373,341	1,323,453	14,749,434

ACTUAL ALLOCATIONS: ONE GRADE

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	66,339		120		66,459
03 Winnipeg South	159,463		52	79	159,594
05 Winnipeg West	171,943		174	89	172,206
07 Brandon North	99,152				99,152
09 Brandon West	264,804	4,091	316	70	269,281
~~11 Melville~~	~~211,458~~	~~4,802~~			~~216,260~~
13 Dauphin	325,983	37,822	48	60	363,913
15 Kamsack	248,953	32,560		56	281,569
17 Saskatoon Main	233,546	8,402	99,527	37,824	379,299
19 Saskatoon South	220,784	248	44,244	12,078	277,354
21 Saskatoon West	252,201	7,717	85,652	7,807	353,377
23 Saskatoon North	201,446	18,684	15,076	84,318	319,524
25 Prince Albert East	108,143	33,101	1,117	213,724	356,085
27 Prince Albert South	103,247	6,446	18,200	205,320	333,213
29 Prince Albert West	116,172	19,250	16,107	187,825	339,354
31 Saskatoon East	138,410		77,005	178	215,593
33 Regina South	568,381	4,998	8,268	37,548	619,195
35 Regina West	326,539		16,321	1,051	343,911
37 Biggar North	31,437	13,030	167,078	84,275	295,820
39 Biggar West	25,775	2,464	395,440	66,160	489,839
41 Edmonton North	7,223		100,917	81,403	189,542
43 Edmonton South	4,724		176,228	141,773	322,725
45 Edmonton West	2,180		17,583	2,804	22,567
47 Hanna South	7,985		491,817	16,086	515,888
49 Hanna West	2,926		211,613	47,322	261,861
61 Keewatin	155,229				155,229
62 La Riviere	273,115				273,115
63 Carberry	222,856		88		224,944
64 Brandon	356,431		70		356,501
71 Weyburn	413,838		8,729		422,567
72 Pasqua	351,085		30,698		381,783
73 Bulyea	415,328				415,328
74 Bredenbury	297,583	34,113	53		331,749
75 Saskatoon	274,023	30,104	9,393		313,520
76 Wilkie	450,041	52,839	70,031		572,911
77 Assiniboia	665,570		45,262		710,832
78 Swift Current	512,728		94,502		607,230
79 Outlook	237,762		74,468		312,230
81 Medicine Hat	171,830		287,147		458,977
82 Brooks	9,010		336,280	164	345,454
83 Lethbridge	2,187		482,152		484,339
84 Vulcan	2,747		381,417		384,164
85 Calgary	568		17,087		17,655
86 Red Deer	4,299		180,729	6,780	191,808
87 Edmonton	7,795		153,281	80,318	241,394
90 N. Alberta RR West	9,659		135,440	7,823	152,922
95 N. Alberta RR East	5,645		46,098		51,743
97 British Columbia RR	241		57,847		58,088
98 Great Slave RR	1,075		20,293		21,368
TOTAL DEMANDS	8,741,871	310,769	4,373,341	1,323,453	14,749,434

OPTIMAL ALLOCATIONS: NEW NUMBER ONE CWRS
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	2,119				2,119
03 Winnipeg South	25,760				25,760
05 Winnipeg West	18,488				18,488
07 Brandon North	6,197				6,197
09 Brandon West	34,492				34,492
11 Melville	10,089				10,089
13 Dauphin	8,291				8,291
15 Kamsack	18,741	6,712			25,453
17 Saskatoon Main	157,723				157,723
19 Saskatoon South	231,575				231,575
21 Saskatoon West	251,280				251,280
23 Saskatoon North	102,651				102,651
25 Prince Albert East		3,420			3,420
27 Prince Albert South	41,552				41,552
29 Prince Albert West		33,372			33,372
31 Saskatoon East	176,685				176,685
33 Regina South	261,846				261,846
35 Regina West	308,833				308,833
37 Biggar North			33,478		33,478
39 Biggar We[illegible]			228,182		228,182
41 Edmonto[illegible]			692		692
43 Edmont[illegible]			9,731		9,731
45 Edmont[illegible]			200		200
47 Hanna S[illegible]			288,905		288,905
49 Hanna West			78,866		78,866
61 Keewatin	4,173				4,173
62 La Rivière	32,250				32,250
63 Carberry	12,773				12,773
64 Brandon	45,093				45,093
71 Weyburn	189,820				189,820
72 Pasqua	138,165				138,165
73 Bulyea	209,687				209,687
74 Bredenbury	23,739				23,739
75 Saskatoon	92,237				92,237
76 Wilkie	3,406		286,870		290,276
77 Assiniboia	654,123				654,123
78 Swift Current	564,732				564,732
79 Outlook	267,149				267,149
81 Medicine Hat			426,551		426,551
82 Brooks			222,265		222,265
83 Lethbridge			439,772		439,772
84 Vulcan			255,081		255,081
85 Calgary			5,323		5,323
86 Red Deer			49,560	11,524	61,084
87 Edmonton			10,315		10,315
90 N. Alberta RR West				2,383	2,383
95 N. Alberta RR East				443	443
97 British Columbia RR				340	340
98 Great Slave RR					
TOTAL DEMANDS	3,893,669	43,504	2,335,791	14,690	6,287,654

ACTUAL ALLOCATIONS: NEW NUMBER ONE CWRS

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	2,119				2,119
03 Winnipeg South	25,760				25,760
05 Winnipeg West	18,488				18,488
07 Brandon North	6,197				6,197
09 Brandon West	34,139	274	79		34,492
11 Melville	9,753	336			10,089
13 Dauphin	8,291				8,291
15 Kamsack	25,355	99			25,454
17 Saskatoon Main	112,916	2,176	41,810	821	157,723
19 Saskatoon South	190,071		40,506	998	231,575
21 Saskatoon West	192,972	117	57,900	291	251,280
23 Saskatoon North	98,377	2,465	769	1,040	102,651
25 Prince Albert East	3,055	193		172	3,420
27 Prince Albert South	37,516	727	857	2,452	41,552
29 Prince Albert West	23,841	6,074	2,447	1,010	33,372
31 Saskatoon East	114,958		61,727		176,685
33 Regina South	258,123		2,758	965	261,846
35 Regina West	292,976		15,798	59	308,833
37 Biggar North	1,788	38	29,291	2,361	33,478
39 Biggar West	11,107	1,175	213,930	1,970	228,182
41 Edmonton North			692		692
43 Edmonton South			7,665	2,066	9,731
45 Edmonton West			200		200
47 Hanna South	1,098		287,665	142	288,905
49 Hanna West	190		78,405	271	78,866
61 Keewatin	4,173				4,173
62 La Riviere	32,250				32,250
63 Carberry	12,773				12,773
64 Brandon	45,093				45,093
71 Weyburn	187,107		2,713		189,820
72 Pasqua	133,483		4,682		138,165
73 Bulyea	209,687				209,687
74 Bredenbury	21,494	2,245			23,739
75 Saskatoon	83,823	6,147	2,267		92,237
76 Wilkie	235,944	21,438	32,894		290,276
77 Assiniboia	612,036		42,086		654,123
78 Swift Current	477,490		87,242		564,732
79 Outlook	203,168		63,981		267,149
81 Medicine Hat	157,155		269,397		426,552
82 Brooks	7,188		215,078		222,266
83 Lethbridge	846		438,926		439,772
84 Vulcan	663		254,418		255,081
85 Calgary	148		5,175		5,324
86 Red Deer			61,084		61,084
87 Edmonton			10,243	72	10,315
90 N. Alberta RR West	59		2,324		2,383
95 N. Alberta RR East			443		443
97 British Columbia RR			340		340
98 Great Slave RR					
TOTAL DEMANDS	3,893,669	43,504	2,33[illegible]792	14,690	6,287,654

OPTIMAL ALLOCATIONS: NEW NUMBER TWO CWRS
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	16,108				16,108
03 Winnipeg South	49,317				49,317
05 Winnipeg West	48,771				48,771
07 Brandon North	18,886				18,886
09 Brandon West	124,006				124,006
11 Melville	86,928				86,928
13 Dauphin	93,890				93,890
15 Kamsack	98,223	42,120			140,342
17 Saskatoon Main	144,985				144,985
19 Saskatoon South	24,822				24,822
21 Saskatoon West			1,529	62,227	63,756
23 Saskatoon North	9,662		155,530		165,192
25 Prince Albert East		95,997			95,997
27 Prince Albert South	160,149				160,149
29 Prince Albert West			81,802		81,802
31 Saskatoon East	27,391				27,391
33 Regina South	247,167				247,167
35 Regina West	28,746				28,746
37 Biggar North			128,481		128,481
39 Biggar West			142,963		142,963
41 Edmonton North			41,951		41,951
43 Edmonton South			102,099		102,099
45 Edmonton West			2,265		2,265
47 Hanna South			142,565		142,565
49 Hanna West			51,963		51,963
61 Keewatin	42,665				42,665
62 La Riviere	101,872				101,872
63 Carberry	61,411				61,411
64 Brandon	143,780				143,780
71 Weyburn	155,593				155,593
72 Pasqua	152,914				152,914
73 Bulyea	140,360				140,360
74 Bredenbury	126,720				126,720
75 Saskatoon	131,900				131,900
76 Wilkie			141,288		141,288
77 Assiniboia	47,224				47,224
78 Swift Current	28,805				28,805
79 Outlook	28,253				28,253
81 Medicine Hat				26,933	26,933
82 Brooks				71,257	71,257
83 Lethbridge				38,184	38,184
84 Vulcan				102,660	102,660
85 Calgary				7,270	7,270
86 Red Deer				39,535	39,535
87 Edmonton			60,767		60,767
90 N. Alberta RR West				25,278	25,278
95 N. Alberta RR East				8,555	8,555
97 British Columbia RR				4,364	4,364
98 Great Slave RR				491	491
TOTAL DEMANDS	2,340,548	138,117	1,053,203	386,754	3,918,622

ACTUAL ALLOCATIONS: NEW NUMBER TWO CWRS

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	16,107				16,107
03 Winnipeg South	49,186		52	79	49,317
05 Winnipeg West	48,688		83		48,771
07 Brandon North	18,886				18,886
09 Brandon West	121,502	2,504			124,006
11 Melville	85,146	1,782			86,928
13 Dauphin	85,990	7,899			93,889
15 Kamsack	119,377	20,965			140,342
17 Saskatoon Main	72,428	4,865	53,103	14,589	144,985
19 Saskatoon South	16,513	188	2,380	5,741	24,822
21 Saskatoon West	31,459	5,711	25,019	1,566	63,755
23 Saskatoon North	78,968	11,811	13,284	61,130	165,193
25 Prince Albert East	35,043	13,582	419	46,953	95,997
27 Prince Albert South	47,632	2,866	15,396	94,255	160,149
29 Prince Albert West	23,062	6,043	6,290	46,407	81,802
31 Saskatoon East	15,155		11,710	526	27,391
33 Regina South	218,419	3,424	2,910	22,415	247,166
35 Regina West	27,488		373	885	28,746
37 Biggar North	12,556	8,209	80,245	27,471	128,481
39 Biggar West	8,751	1,175	120,138	12,899	142,963
41 Edmonton North	69		35,921	5,961	41,951
43 Edmonton South			65,952	36,147	102,099
45 Edmonton West			2,265		2,265
47 Hanna South	594		140,980	991	142,565
49 Hanna West	71		47,873	4,019	51,963
61 Keewatin	42,665				42,665
62 La Riviere	101,872				101,872
63 Carberry	61,411				61,411
64 Brandon	143,780				143,780
71 Weyburn	150,317		5,276		155,593
72 Pasqua	137,492		15,422		152,914
73 Bulyea	140,360				140,360
74 Bredenbury	114,195	12,525			126,720
75 Saskatoon	113,005	12,186	6,709		131,900
76 Wilkie	99,884	22,382	19,022		141,288
77 Assiniboia	44,611		2,613		47,224
78 Swift Current	23,190		5,615		28,805
79 Outlook	21,185		7,068		28,253
81 Medicine Hat	11,363		15,570		26,933
82 Brooks	669		70,588		71,257
83 Lethbridge	421		37,763		38,184
84 Vulcan	419		102,241		102,660
85 Calgary			7,271		7,271
86 Red Deer	89		38,992	454	39,535
87 Edmonton	128		56,454	4,186	60,768
90 N. Alberta RR West	271		24,927	80	25,278
95 N. Alberta RR East			8,555		8,555
97 British Columbia RR	51		4,313		4,364
98 Great Slave RR	80		410		491
TOTAL DEMANDS	2,340,548	138,117	1,053,203	386,754	3,918,624

OPTIMAL ALLOCATIONS: NEW NUMBER THREE CWRS

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	48,232				48,232
03 Winnipeg South	84,516				84,516
05 Winnipeg West	104,947				104,947
07 Brandon North	74,068				74,068
09 Brandon West	110,784				110,784
11 Melville	119,244				119,244
13 Dauphin	261,733				261,733
15 Kamsack	115,772				115,772
17 Saskatoon Main	76,591				76,591
19 Saskatoon South	20,957				20,957
21 Saskatoon West				38,341	38,341
23 Saskatoon North				51,680	51,680
25 Prince Albert East	127,520	129,148			256,668
27 Prince Albert South	131,513				131,513
29 Prince Albert West			101,992	122,188	224,180
31 Saskatoon East	11,517				11,517
33 Regina South	110,181				110,181
35 Regina West	6,333				6,333
37 Biggar North				133,861	133,861
39 Biggar West			118,694		118,694
41 Edmonton North			146,899		146,899
43 Edmonton South			210,896		210,896
45 Edmonton West			20,103		20,103
47 Hanna South			84,418		84,418
49 Hanna West			131,034		131,034
61 Keewatin	108,392				108,392
62 La Riviere	138,993				138,993
63 Carberry	150,760				150,760
64 Brandon	167,627				167,627
71 Weyburn	77,154				77,154
72 Pasqua	90,703				90,703
73 Bulyea	65,281				65,281
74 Bredenbury	181,291				181,291
75 Saskatoon	89,383				89,383
76 Wilkie				141,347	141,347
77 Assiniboia	9,485				9,485
78 Swift Current	13,693				13,693
79 Outlook	10,985			5,844	16,829
81 Medicine Hat				5,493	5,493
82 Brooks				51,932	51,932
83 Lethbridge				6,383	6,383
84 Vulcan				26,423	26,423
85 Calgary				5,061	5,061
86 Red Deer				91,189	91,189
87 Edmonton			170,312		170,312
90 N. Alberta RR West				125,261	125,261
95 N. Alberta RR East				42,746	42,746
97 British Columbia RR				53,394	53,394
98 Great Slave RR				20,877	20,877
TOTAL DEMANDS	2,507,655	129,148	984,346	922,010	4,543,158

ACTUAL ALLOCATIONS: NEW NUMBER THREE CWRS

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	48,113		120		48,233
03 Winnipeg South	84,516				84,516
05 Winnipeg West	104,767		91	89	104,947
07 Brandon North	74,068				74,068
~~09 Brandon West~~	~~109,164~~	~~1,313~~	~~237~~	~~70~~	~~110,784~~
11 Melville	116,560	2,684			119,244
13 Dauphin	231,702	29,922	49	60	261,733
15 Kamsack	104,121	11,596		56	115,773
17 Saskatoon Main	48,202	1,361	4,623	22,404	76,592
19 Saskatoon South	14,199	60	1,358	5,340	20,957
21 Saskatoon West	27,770	1,888	2,733	5,950	38,341
23 Saskatoon North	24,101	4,407	1,023	22,148	51,679
25 Prince Albert East	70,045	19,326	699	166,598	256,668
27 Prince Albert South	18,099	2,853	1,947	108,613	131,512
29 Prince Albert West	69,269	7,133	7,370	140,408	224,180
31 Saskatoon East	8,297		3,041	179	11,517
33 Regina South	91,840	1,575	2,599	14,166	110,182
35 Regina West	6,075		150	107	6,332
37 Biggar North	17,093	4,784	57,541	54,443	133,861
39 Biggar West	5,916	114	61,372	51,290	118,692
41 Edmonton North	7,154		64,303	75,441	146,900
43 Edmonton South	4,725		102,610	103,561	210,896
45 Edmonton West	2,180		15,119	2,804	20,103
47 Hanna South	6,293		63,172	14,953	84,418
49 Hanna West	2,667		85,335	43,032	131,034
61 Keewatin	108,392				108,392
62 La Riviere	138,993				138,993
63 Carberry	150,672		89		150,761
64 Brandon	167,557		70		167,627
71 Weyburn	76,414		740		77,154
72 Pasqua	80,110		10,594		90,703
73 Bulyea	65,281				65,281
74 Bredenbury	161,894	19,342	53		181,289
75 Saskatoon	77,194	11,771	417		89,382
76 Wilkie	114,214	9,019	18,115		141,348
77 Assiniboia	8,922		563		9,485
78 Swift Current	12,158		1,536		13,694
79 Outlook	13,410		3,419		16,829
81 Medicine Hat	3,313		2,180		5,493
82 Brooks	1,153		50,614	165	51,932
83 Lethbridge	920		5,463		6,383
84 Vulcan	1,665		24,758		26,423
85 Calgary	420		4,641		5,061
86 Red Deer	4,211		80,652	6,325	91,190
87 Edmonton	7,667		86,584	76,061	170,312
90 N. Alberta RR West	9,329		108,189	7,742	125,260
95 N. Alberta RR East	5,645		37,101		42,746
97 British Columbia RR	190		53,194		53,384
98 Great Slave RR	995		19,882		20,877
TOTAL DEMANDS	2,507,655	129,148	984,346	922,009	4,543,158

OPTIMAL ALLOCATIONS: CWRS NO. 1, 11.5% Protein (Grade 115)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North					
03 Winnipeg South					
05 Winnipeg West					
07 Brandon North					
09 Brandon West					
11 Melville					
13 Dauphin					
15 Kamsack					
17 Saskatoon Main				821	821
19 Saskatoon South				997	997
21 Saskatoon West				291	291
23 Saskatoon North				1,041	1,041
25 Prince Albert East				172	172
27 Prince Albert South				2,452	2,452
29 Prince Albert West				1,010	1,010
31 Saskatoon East					
33 Regina South	52			913	965
35 Regina West				111	111
37 Biggar North				2,361	2,361
39 Biggar West				1,970	1,970
41 Edmonton North					
43 Edmonton South				2,066	2,066
45 Edmonton West					
47 Hanna South				142	142
49 Hanna West				271	271
61 Keewatin					
62 La Riviere					
63 Carberry					
64 Brandon					
71 Weyburn					
72 Pasqua					
73 Bulyea					
74 Bredenbury					
75 Saskatoon					
76 Wilkie					
77 Assiniboia					
78 Swift Current					
79 Outlook					
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan					
85 Calgary					
86 Red Deer					
87 Edmonton				72	72
90 N. Alberta RR West					
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	52			14,690	14,742

ACTUAL ALLOCATIONS: CWRS NO. 1, 11.5% Protein (Grade 115)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North					
03 Winnipeg South					
05 Winnipeg West					
07 Brandon North					
09 Brandon West					
11 Melville					
13 Dauphin					
15 Kamsack					
17 Saskatoon Main				821	821
19 Saskatoon South				997	997
21 Saskatoon West				291	291
23 Saskatoon North				1,041	1,041
25 Prince Albert East				172	172
27 Prince Albert South				2,452	2,452
29 Prince Albert West				1,010	1,010
31 Saskatoon East					
33 Regina South				965	965
35 Regina West	52			59	111
37 Biggar North				2,361	2,361
39 Biggar West				1,970	1,970
41 Edmonton North					
43 Edmonton South				2,066	2,066
45 Edmonton West					
47 Hanna South				142	142
49 Hanna West				271	271
61 Keewatin					
62 La Riviere					
63 Carberry					
64 Brandon					
71 Weyburn					
72 Pasqua					
73 Bulyea					
74 Bredenbury					
75 Saskatoon					
76 Wilkie					
77 Assiniboia					
78 Swift Current					
79 Outlook					
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan					
85 Calgary					
86 Red Deer					
87 Edmonton				72	72
90 N. Alberta RR West					
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	52		14,690	14,742	

OPTIMAL ALLOCATIONS: CWRS NO. 1, 13.5% Protein (Grade 135)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	1,228				1,228
03 Winnipeg South	16,779				16,779
05 Winnipeg West	5,664				5,664
07 Brandon North	1,491				1,491
09 Brandon West	21,002				21,002
11 Melville	3,210				3,210
13 Dauphin	4,089				4,089
15 Kamsack	16,972				16,972
17 Saskatoon Main	108,546				108,546
19 Saskatoon South	127,274				127,274
21 Saskatoon West	75,865		73,315		149,180
23 Saskatoon North	34,761				34,761
25 Prince Albert East	522				522
27 Prince Albert South	11,498				11,498
29 Prince Albert West			9,937		9,937
31 Saskatoon East	117,415				117,415
33 Regina South	142,412				142,412
35 Regina West	207,418				207,418
37 Biggar North			18,952		18,952
39 Biggar West			142,137		142,137
41 Edmonton North			376		376
43 Edmonton South			4,578		4,578
45 Edmonton West			200		200
47 Hanna South			255,727		255,727
49 Hanna West			62,354		62,354
61 Keewatin	2,431				2,431
62 La Riviere	24,238				24,238
63 Carberry	3,991				3,991
64 Brandon	28,468				28,468
71 Weyburn	144,075				144,075
72 Pasqua	54,469				54,469
73 Bulyea	151,647				151,647
74 Bredenbury	14,954				14,954
75 Saskatoon	53,806				53,806
76 Wilkie			139,222		139,222
77 Assiniboia	513,046				513,046
78 Swift Current	417,519				417,519
79 Outlook	157,509				157,509
81 Medicine Hat			360,758		360,758
82 Brooks			151,259		151,259
83 Lethbridge			331,790		331,790
84 Vulcan			187,749		187,749
85 Calgary			4,387		4,387
86 Red Deer			46,808		46,808
87 Edmonton			7,157		7,157
90 N. Alberta RR West			638		638
95 N. Alberta RR East			237		237
97 British Columbia RR			340		340
98 Great Slave RR					
TOTAL DEMANDS	2,462,299		1,797,921		4,260,220

ACTUAL ALLOCATIONS: CWRS NO. 1, 13.5% Protein (Grade 135)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	1,228				1,228
03 Winnipeg South	16,779				16,779
05 Winnipeg West	5,664				5,664
07 Brandon North	1,491				1,491
09 Brandon West	20,923		79		21,002
11 Melville	3,210				3,210
13 Dauphin	4,089				4,089
15 Kamsack	16,972				16,972
17 Saskatoon Main	72,948		35,598		108,546
19 Saskatoon South	96,647		30,627		127,274
21 Saskatoon West	98,693		50,486		149,179
23 Saskatoon North	34,137		624		34,761
25 Prince Albert East	522				522
27 Prince Albert South	10,827		671		11,498
29 Prince Albert West	9,003		934		9,937
31 Saskatoon East	71,630		45,785		117,415
33 Regina South	140,384		2,028		142,412
35 Regina West	193,301		14,116		207,417
37 Biggar North	993		17,959		18,952
39 Biggar West	6,514		135,623		142,137
41 Edmonton North			376		376
43 Edmonton South			4,578		4,578
45 Edmonton West			200		200
47 Hanna South	593		255,135		255,728
49 Hanna West	72		62,282		62,354
61 Keewatin	2,431				2,431
62 La Riviere	24,239				24,239
63 Carberry	3,991				3,991
64 Brandon	28,468				28,468
71 Weyburn	142,037		2,038		144,075
72 Pasqua	51,115		3,354		54,469
73 Bulyea	151,647				151,647
74 Bredenbury	14,954				14,954
75 Saskatoon	51,873		1,933		53,806
76 Wilkie	117,408		21,814		139,222
77 Assiniboia	472,238		40,808		513,046
78 Swift Current	342,931		74,588		417,519
79 Outlook	117,306		40,203		157,509
81 Medicine Hat	128,914		231,845		360,759
82 Brooks	5,096		146,163		151,259
83 Lethbridge	396		331,394		331,790
84 Vulcan	488		187,261		187,749
85 Calgary	148		4,239		4,387
86 Red Deer			46,808		46,808
87 Edmonton			7,157		7,157
90 N. Alberta RR West			639		639
95 N. Alberta RR East			237		237
97 British Columbia RR			340		340
98 Great Slave RR					
TOTAL DEMANDS	2,462,299		1,797,921		4,260,220

OPTIMAL ALLOCATIONS: CWRS NO. 2, 11.5% Protein (Grade 215)
COMBINED Transportation Cost Matrix
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	365				365
03 Winnipeg South	79				79
05 Winnipeg West	561				561
07 Brandon North	1,449				1,449
09 Brandon West	225				225
11 Melville	827				827
13 Dauphin	1,384				1,384
15 Kamsack	2,263				2,263
17 Saskatoon Main				14,687	14,687
19 Saskatoon South				5,741	5,741
21 Saskatoon West				1,663	1,663
23 Saskatoon North				61,342	61,342
25 Prince Albert East				47,475	47,475
27 Prince Albert South				94,420	94,420
29 Prince Albert West				46,225	46,225
31 Saskatoon East				526	526
33 Regina South	9,753			12,967	22,720
35 Regina West				1,336	1,336
37 Biggar North				27,547	27,547
39 Biggar West				12,820	12,820
41 Edmonton North				5,961	5,961
43 Edmonton South				35,577	35,577
45 Edmonton West					
47 Hanna South				949	949
49 Hanna West				3,975	3,975
61 Keewatin	827				827
62 La Riviere	351				351
63 Carberry	3,815				3,815
64 Brandon	540				540
71 Weyburn	212				212
72 Pasqua				1,326	1,326
73 Bulyea				271	271
74 Bredenbury	550				550
75 Saskatoon				2,818	2,818
76 Wilkie				2,111	2,111
77 Assiniboia					
78 Swift Current				132	132
79 Outlook				117	117
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan					
85 Calgary					
86 Red Deer				454	454
87 Edmonton				4,186	4,186
90 N. Alberta RR West				80	80
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	23,201			384,706	407,907

OPTIMAL ALLOCATIONS: CWRS NO. 2, 11.5% Protein (Grade 215)
EXCLUSIVE Transportation Cost Matrix
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	365				365
03 Winnipeg South	79				79
05 Winnipeg West	561				561
07 Brandon North	1,449				1,449
09 Brandon West	225				225
11 Melville	827				827
13 Dauphin	1,384				1,384
15 Kamsack	521			1,742	2,263
17 Saskatoon Main				14,687	14,687
19 Saskatoon South				5,741	5,741
21 Saskatoon West				1,663	1,663
23 Saskatoon North				61,342	61,342
25 Prince Albert East				47,475	47,475
27 Prince Albert South				94,420	94,420
29 Prince Albert West				46,225	46,225
31 Saskatoon East				526	526
33 Regina South				22,720	22,720
35 Regina West				1,336	1,336
37 Biggar North				27,547	27,547
39 Biggar West				12,820	12,820
41 Edmonton North				5,961	5,961
43 Edmonton South				35,577	35,577
45 Edmonton West					
47 Hanna South				949	949
49 Hanna West				3,975	3,975
61 Keewatin	827				827
62 La Riviere	351				351
63 Carberry	3,815				3,815
64 Brandon	540				540
71 Weyburn	212				212
72 Pasqua	1,326				1,326
73 Bulyea	271				271
74 Bredenbury	550				550
75 Saskatoon	2,818				2,818
76 Wilkie	2,111				2,111
77 Assiniboia					
78 Swift Current	132				132
79 Outlook	117				117
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan					
85 Calgary					
86 Red Deer	454				454
87 Edmonton	4,186				4,186
90 N. Alberta RR West	80				80
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	23,201			384,706	407,907

ACTUAL ALLOCATIONS: CWRS NO. 2, 11.5% Protein (Grade 215)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	365				365
03 Winnipeg South				79	79
05 Winnipeg West	561				561
07 Brandon North	1,449				1,449
09 Brandon West	225				225
11 Melville	827				827
13 Dauphin	1,384				1,384
15 Kamsack	2,263				2,263
17 Saskatoon Main	176			14,511	14,687
19 Saskatoon South				5,741	5,741
21 Saskatoon West	96			1,567	1,663
23 Saskatoon North	439			60,903	61,342
25 Prince Albert East	877			46,598	47,475
27 Prince Albert South	371			94,049	94,420
29 Prince Albert West	223			46,002	46,225
31 Saskatoon East				526	526
33 Regina South	305			22,415	22,720
35 Regina West	451			885	1,336
37 Biggar North	119			27,428	27,547
39 Biggar West				12,820	12,820
41 Edmonton North				5,961	5,961
43 Edmonton South				35,577	35,577
45 Edmonton West					
47 Hanna South				949	949
49 Hanna West				3,975	3,975
61 Keewatin	827				827
62 La Riviere	351				351
63 Carberry	3,815				3,815
64 Brandon	540				540
71 Weyburn	212				212
72 Pasqua	1,326				1,326
73 Bulyea	271				271
74 Bredenbury	550				550
75 Saskatoon	2,818				2,818
76 Wilkie	2,111				2,111
77 Assiniboia					
78 Swift Current	132				132
79 Outlook	117				117
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan					
85 Calgary					
86 Red Deer				454	454
87 Edmonton				4,186	4,186
90 N. Alberta RR West				80	80
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	23,201			384,706	407,907

OPTIMAL ALLOCATIONS: CWRS NO. 2, 12.5% Protein (Grade 225)
COMBINED Transportation Cost Matrix
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	5,653				5,653
03 Winnipeg South	8,587				8,587
05 Winnipeg West	15,444				15,444
07 Brandon North	8,882				8,882
~~09 Brandon West~~	~~19,651~~				~~19,651~~
11 Melville	16,945				16,945
13 Dauphin	38,236				38,236
15 Kamsack		45,093			45,093
17 Saskatoon Main	61,826		3,619		65,445
19 Saskatoon South			4,336		4,336
21 Saskatoon West			35,004		35,004
23 Saskatoon North			39,821		39,821
25 Prince Albert East		28,552			28,552
27 Prince Albert South		34,519			34,519
29 Prince Albert West			19,298		19,298
31 Saskatoon East	12,041				12,041
33 Regina South	25,758				25,758
35 Regina West	4,458				4,458
37 Biggar North			91,720		91,720
39 Biggar West			121,233		121,233
41 Edmonton North			35,235		35,235
43 Edmonton South			65,561		65,561
45 Edmonton West			2,265		2,265
47 Hanna South			140,536		140,536
49 Hanna West			47,695		47,695
61 Keewatin	13,289				13,289
62 La Riviere	14,887				14,887
63 Carberry	25,555				25,555
64 Brandon	14,050				14,050
71 Weyburn	15,830				15,830
72 Pasqua	52,055				52,055
73 Bulyea	15,831				15,831
74 Bredenbury	18,271	682			18,953
75 Saskatoon		29,176			29,176
76 Wilkie			59,003		59,003
77 Assiniboia			6,606		6,606
78 Swift Current	8,454				8,454
79 Outlook			9,887		9,887
81 Medicine Hat			16,199		16,199
82 Brooks			70,469		70,469
83 Lethbridge			37,693		37,693
84 Vulcan			101,764		101,764
85 Calgary			7,271		7,271
86 Red Deer			38,992		38,992
87 Edmonton			56,279		56,279
90 N. Alberta RR West			24,801		24,801
95 N. Alberta RR East			8,497		8,497
97 British Columbia RR			3,616		3,616
98 Great Slave RR			354		354
TOTAL DEMANDS	395,703	138,022	1,047,754		1,581,479

OPTIMAL ALLOCATIONS: CWRS NO. 2, 12.5% Protein (Grade 225)
EXCLUSIVE Transportation Cost Matrix
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	5,653				5,653
03 Winnipeg South	8,587				8,587
05 Winnipeg West	15,444				15,444
07 Brandon North	8,882				8,882
09 Brandon West	19,651				19,651
11 Melville	16,945				16,945
13 Dauphin	8,378	29,858			38,236
15 Kamsack		45,093			45,093
17 Saskatoon Main	61,826		3,619		65,445
19 Saskatoon South			4,336		4,336
21 Saskatoon West			35,004		35,004
23 Saskatoon North			39,821		39,821
25 Prince Albert East		28,552			28,552
27 Prince Albert South		34,519			34,519
29 Prince Albert West			19,298		19,298
31 Saskatoon East	12,041				12,041
33 Regina South	25,758				25,758
35 Regina West	4,458				4,458
37 Biggar North			91,720		91,720
39 Biggar West			121,233		121,233
41 Edmonton North			35,235		35,235
43 Edmonton South			65,561		65,561
45 Edmonton West			2,265		2,265
47 Hanna South			140,536		140,536
49 Hanna West			47,695		47,695
61 Keewatin	13,289				13,289
62 La Riviere	14,887				14,887
63 Carberry	25,555				25,555
64 Brandon	14,050				14,050
71 Weyburn	15,830				15,830
72 Pasqua	52,055				52,055
73 Bulyea	15,831				15,831
74 Bredenbury	18,953				18,953
75 Saskatoon	29,176				29,176
76 Wilkie			59,003		59,003
77 Assiniboia			6,606		6,606
78 Swift Current	8,454				8,454
79 Outlook			9,887		9,887
81 Medicine Hat			16,199		16,199
82 Brooks			70,469		70,469
83 Lethbridge			37,693		37,693
84 Vulcan			101,764		101,764
85 Calgary			7,271		7,271
86 Red Deer			38,992		38,992
87 Edmonton			56,279		56,279
90 N. Alberta RR West			24,801		24,801
95 N. Alberta RR East			8,497		8,497
97 British Columbia RR			3,616		3,616
98 Great Slave RR			354		354
TOTAL DEMANDS	395,703	138,022	1,047,754	1,581,479	

ACTUAL ALLOCATIONS: CWRS NO. 2, 12.5% Protein (Grade 225)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	5,653				5,653
03 Winnipeg South	8,535		52		8,587
05 Winnipeg West	15,361		83		15,444
07 Brandon North	8,882				8,882
09 Brandon West	17,147	2,504			19,651
11 Melville	15,163	1,782			16,945
13 Dauphin	30,432	7,804			38,236
15 Kamsack	24,129	20,964			45,093
17 Saskatoon Main	8,767	4,865	51,813		65,445
19 Saskatoon South	1,768	188	2,380		4,336
21 Saskatoon West	4,315	5,712	24,977		35,004
23 Saskatoon North	14,726	11,811	13,284		39,821
25 Prince Albert East	14,551	13,582	419		28,552
27 Prince Albert South	16,257	2,866	15,396		34,519
29 Prince Albert West	6,965	6,043	6,290		19,298
31 Saskatoon East	329		11,710		12,041
33 Regina South	19,425	3,423	2,910		25,758
35 Regina West	4,085		373		4,458
37 Biggar North	3,266	8,210	80,246		91,721
39 Biggar West	182	1,175	119,877		121,234
41 Edmonton North			35,235		35,235
43 Edmonton South			65,561		65,561
45 Edmonton West			2,265		2,265
47 Hanna South	279		140,257		140,536
49 Hanna West			47,695		47,695
61 Keewatin	13,289				13,289
62 La Riviere	14,887				14,887
63 Carberry	25,555				25,555
64 Brandon	14,050				14,050
71 Weyburn	10,554		5,276		15,830
72 Pasqua	36,633		15,422		52,055
73 Bulyea	15,831				15,831
74 Bredenbury	6,428	12,525			18,953
75 Saskatoon	10,281	12,186	6,709		29,176
76 Wilkie	17,656	22,382	18,965		59,003
77 Assiniboia	3,993		2,613		6,606
78 Swift Current	2,839		5,615		8,454
79 Outlook	2,819		7,068		9,887
81 Medicine Hat	629		15,570		16,199
82 Brooks			70,469		70,469
83 Lethbridge			37,693		37,693
84 Vulcan			101,764		101,764
85 Calgary			7,271		7,271
86 Red Deer			38,992		38,992
87 Edmonton			56,279		56,279
90 N. Alberta RR West	42		24,759		24,801
95 N. Alberta RR East			8,497		8,497
97 British Columbia RR			3,616		3,616
98 Great Slave RR			354		354
TOTAL DEMANDS	395,703	138,022	1,047,754		1,581,479

ACTUAL AND OPTIMAL ALLOCATIONS: CWRS NO. 2, 13.5% Protein (Grade 235)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	9,632				9,632
03 Winnipeg South	38,946				38,946
05 Winnipeg West	31,572				31,572
07 Brandon North	7,673				7,673
09 Brandon West	103,849				103,849
11 Melville	67,102				67,102
13 Dauphin	49,836				49,836
15 Kamsack	90,678				90,678
17 Saskatoon Main	61,249				61,249
19 Saskatoon South	14,745				14,745
21 Saskatoon West	26,990				26,990
23 Saskatoon North	63,744				63,744
25 Prince Albert East	19,426				19,426
27 Prince Albert South	30,906				30,906
29 Prince Albert West	15,874				15,874
31 Saskatoon East	14,771				14,771
33 Regina South	198,256				198,256
35 Regina West	22,892				22,892
37 Biggar North	9,170				9,170
39 Biggar West	8,569				8,569
41 Edmonton North	69				69
43 Edmonton South					
45 Edmonton West					
47 Hanna South	315				315
49 Hanna West	71				71
61 Keewatin	26,457				26,457
62 La Riviere	85,646				85,646
63 Carberry	31,539				31,539
64 Brandon	128,891				128,891
71 Weyburn	139,254				139,254
72 Pasqua	99,473				99,473
73 Bulyea	123,373				123,373
74 Bredenbury	104,979				104,979
75 Saskatoon	99,730				99,730
76 Wilkie	79,718				79,718
77 Assiniboia	40,428				40,428
78 Swift Current	20,160				20,160
79 Outlook	18,208				18,208
81 Medicine Hat	10,734				10,734
82 Brooks	669				669
83 Lethbridge	421				421
84 Vulcan	327				327
85 Calgary					
86 Red Deer	89				89
87 Edmonton	128				128
90 N. Alberta RR West	229				229
95 N. Alberta RR East					
97 British Columbia RR	51				51
98 Great Slave RR	80				80
TOTAL DEMANDS	1,896,919				1,896,919

OPTIMAL ALLOCATIONS: CWRS NO. 3 (Grade 300)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	43,455				43,455
03 Winnipeg South	81,230				81,230
05 Winnipeg West	94,555				94,555
07 Brandon North	66,778				66,778
09 Brandon West	107,014				107,014
11 Melville	111,427				111,427
13 Dauphin	229,319				229,319
15 Kamsack	104,617				104,617
17 Saskatoon Main	68,784				68,784
19 Saskatoon South	20,759				20,759
21 Saskatoon West				37,920	37,920
23 Saskatoon North				51,277	51,277
25 Prince Albert East	124,642	128,877			253,519
27 Prince Albert South	130,079				130,079
29 Prince Albert West			93,244	126,314	219,558
31 Saskatoon East	11,350				11,350
33 Regina South	105,726				105,726
35 Regina West	6,287				6,287
37 Biggar North				133,598	133,598
39 Biggar West			118,345		118,345
41 Edmonton North			143,908		145,908
43 Edmonton South			209,082		209,082
45 Edmonton West			16,626		16,626
47 Hanna South			83,861		83,861
49 Hanna West			130,746		130,746
61 Keewatin	101,003				101,003
62 La Riviere	129,979				129,979
63 Carberry	144,288				144,288
64 Brandon	163,906				163,906
71 Weyburn	76,865				76,865
72 Pasqua	88,537				88,537
73 Bulyea	61,617				61,617
74 Bredenbury	173,244				173,244
75 Saskatoon	86,448				86,448
76 Wilkie				140,382	140,382
77 Assiniboia	9,262				9,262
78 Swift Current	13,293				13,293
79 Outlook	5,187			11,463	16,650
81 Medicine Hat				5,493	5,493
82 Brooks				51,761	51,761
83 Lethbridge				6,239	6,239
84 Vulcan				25,254	25,254
85 Calgary				5,061	5,061
86 Red Deer				89,124	89,124
87 Edmonton			168,757		168,757
90 N. Alberta RR West				121,835	121,835
95 N. Alberta RR East				41,691	41,691
97 British Columbia RR				48,153	48,153
98 Great Slave RR				18,712	18,712
TOTAL DEMANDS	2,359,651	128,877	964,569	914,277	4,367,374

ACTUAL ALLOCATIONS: CWRS NO. 3 (Grade 300)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	43,455				43,455
~~03 Winnipeg South~~	~~81,230~~				~~81,230~~
05 Winnipeg West	94,375		91	89	94,555
07 Brandon North	66,778				66,778
09 Brandon West	105,394	1,313	237	70	107,014
11 Melville	108,744	2,683			111,427
13 Dauphin	199,499	29,711	49	60	229,319
15 Kamsack	92,965	11,596		56	104,617
17 Saskatoon Main	41,434	1,361	3,787	22,202	68,784
19 Saskatoon South	14,000	60	1,358	5,340	20,758
21 Saskatoon West	27,446	1,889	2,634	5,950	37,919
23 Saskatoon North	23,833	4,407	1,023	22,014	51,277
25 Prince Albert East	68,106	19,326	699	165,388	253,519
27 Prince Albert South	17,781	2,853	1,947	107,498	130,079
29 Prince Albert West	65,706	7,134	7,370	139,348	219,558
31 Saskatoon East	8,209		2,962	179	11,350
33 Regina South	87,427	1,574	2,558	14,167	105,726
35 Regina West	6,030		150	107	6,287
37 Biggar North	16,975	4,784	57,542	54,297	133,598
39 Biggar West	5,760	113	61,181	51,291	118,345
41 Edmonton North	6,672		63,190	74,046	143,908
43 Edmonton South	4,550		101,881	102,651	209,082
45 Edmonton West	1,119		13,376	2,131	16,626
47 Hanna South	6,293		62,783	14,785	83,861
49 Hanna West	2,667		85,104	42,975	130,746
61 Keewatin	101,003				101,003
62 La Riviere	129,979				129,979
63 Carberry	144,199		89		144,288
64 Brandon	163,836		70		163,906
71 Weyburn	76,125		740		76,865
72 Pasqua	77,997		10,540		88,537
73 Bulyea	61,617				61,617
74 Bredenbury	153,907	19,284	53		173,244
75 Saskatoon	74,261	11,770	417		86,448
76 Wilkie	113,248	9,019	18,115		140,382
77 Assiniboia	8,699		563		9,262
78 Swift Current	11,757		1,536		13,293
79 Outlook	13,291		3,359		16,650
81 Medicine Hat	3,313		2,180		5,493
82 Brooks	982		50,613	166	51,761
83 Lethbridge	920		5,319		6,239
84 Vulcan	1,072		24,182		25,254
85 Calgary	420		4,641		5,061
86 Red Deer	3,885		79,030	6,209	89,124
87 Edmonton	7,161		85,757	75,839	168,757
90 N. Alberta RR West	9,063		105,353	7,419	121,835
95 N. Alberta RR East	5,332		36,359		41,691
97 British Columbia RR	140		48,013		48,153
98 Great Slave RR	994		17,718		18,712
TOTAL DEMANDS	2,359,651	128,877	964,569	914,277	4,367,374

OPTIMAL ALLOCATIONS: TOUGH CWRS NO. 1, 12.5% Protein (Grade 1125)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North					
03 Winnipeg South	361				361
05 Winnipeg West	502				502
07 Brandon North	242				242
09 Brandon West					
11 Melville					
13 Dauphin					
15 Kamsack					
17 Saskatoon Main					
19 Saskatoon South	59				59
21 Saskatoon West					
23 Saskatoon North					
25 Prince Albert East	44				44
27 Prince Albert South					
29 Prince Albert West					
31 Saskatoon East					
33 Regina South					
35 Regina West					
37 Biggar North					
39 Biggar West					
41 Edmonton North			80		80
43 Edmonton South					
45 Edmonton West					
47 Hanna South					
49 Hanna West					
61 Keewatin					
62 La Riviere	71				71
63 Carberry	409				409
64 Brandon					
71 Weyburn					
72 Pasqua					
73 Bulyea					
74 Bredenbury					
75 Saskatoon					
76 Wilkie					
77 Assiniboia					
78 Swift Current	89				89
79 Outlook			59		59
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan			58		58
85 Calgary					
86 Red Deer					
87 Edmonton			91		91
90 N. Alberta RR West					
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	1,777		288		2,065

ACTUAL ALLOCATIONS: TOUGH CWRS NO. 1, 12.5% Protein (Grade 1125)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North					
~~03 Winnipeg South~~	~~361~~				~~361~~
05 Winnipeg West	502				502
07 Brandon North	242				242
09 Brandon West					
11 Melville					
13 Dauphin					
15 Kamsack					
17 Saskatoon Main					
19 Saskatoon South	59				59
21 Saskatoon West					
23 Saskatoon North					
25 Prince Albert East	44				44
27 Prince Albert South					
29 Prince Albert West					
31 Saskatoon East					
33 Regina South					
35 Regina West					
37 Biggar North					
39 Biggar West					
41 Edmonton North			80		80
43 Edmonton South					
45 Edmonton West					
47 Hanna South					
49 Hanna West					
61 Keewatin					
62 La Riviere	71				71
63 Carberry	409				409
64 Brandon					
71 Weyburn					
72 Rasqua					
73 Bulyea					
74 Bredenbury					
75 Saskatoon					
76 Wilkie					
77 Assiniboia					
78 Swift Current	89				89
79 Outlook			59		59
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan			58		58
85 Calgary					
86 Red Deer					
87 Edmonton			91		91
90 N. Alberta RR West					
95 N. Alberta RR East					
97 British Columbia RR					
98 Great Slave RR					
TOTAL DEMANDS	1,777		288		2,065

OPTIMAL ALLOCATIONS: TOUGH CWRS No. 3 (Grade 1300)
(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	4,560				4,560
~~03 Winnipeg South~~	~~3,286~~				~~3,286~~
05 Winnipeg West	9,481				9,481
07 Brandon North	6,645				6,645
09 Brandon West	3,322				3,322
11 Melville	7,210				7,210
13 Dauphin	29,068				29,068
15 Kamsack	10,720				10,720
17 Saskatoon Main	5,814				5,814
19 Saskatoon South					
21 Saskatoon West	323				323
23 Saskatoon North	345				345
25 Prince Albert East	2,592	271			2,863
27 Prince Albert South	1,434				1,434
29 Prince Albert West	2,924		1,233		4,157
31 Saskatoon East	167				167
33 Regina South	2,758				2,758
35 Regina West	46				46
37 Biggar North			264		264
39 Biggar West			349		349
41 Edmonton North			2,750		2,750
43 Edmonton South			1,614		1,614
45 Edmonton West			1,331		1,331
47 Hanna South			557		557
49 Hanna West			287		287
61 Keewatin	7,388				7,388
62 La Riviere	8,019				8,019
63 Carberry	5,584				5,584
64 Brandon	3,205				3,205
71 Weyburn	289				289
72 Pasqua	1,996				1,996
73 Bulyea	3,085				3,085
74 Bredenbury	7,314				7,314
75 Saskatoon	2,822				2,822
76 Wilkie			965		965
77 Assiniboia	223				223
78 Swift Current	310				310
79 Outlook	178				178
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan			1,169		1,169
85 Calgary					
86 Red Deer			1,360		1,360
87 Edmonton			1,166		1,166
90 N. Alberta RR West			3,373		3,373
95 N. Alberta RR East			940		940
97 British Columbia RR			221	5,010	5,231
98 Great Slave RR				2,164	2,164
TOTAL DEMANDS	131,108	271	17,579	7,174	156,131

ACTUAL ALLOCATIONS: TOUGH CWRS NO. 3 (Grade 1300)

(metric tonnes)

Origin Name	Thunder Bay	Churchill	Vancouver	Prince Rupert	TOTAL SUPPLIES
01 Winnipeg North	4,441		119		4,560
03 Winnipeg South	3,286				3,286
05 Winnipeg West	9,481				9,481
07 Brandon North	6,645				6,645
09 Brandon West	3,322				3,322
11 Melville	7,210				7,210
13 Dauphin	28,857	211			29,068
15 Kamsack	10,720				10,720
17 Saskatoon Main	4,984		627	203	5,814
19 Saskatoon South					
21 Saskatoon West	323				323
23 Saskatoon North	211			134	345
25 Prince Albert East	1,711			1,152	2,863
27 Prince Albert South	319			1,115	1,434
29 Prince Albert West	3,097			1,060	4,157
31 Saskatoon East	88		79		167
33 Regina South	2,715		42		2,758
35 Regina West	46				46
37 Biggar North	118			146	264
39 Biggar West	157		192		349
41 Edmonton North	319		1,113	1,318	2,750
43 Edmonton South	53		651	910	1,614
45 Edmonton West	118		962	251	1,331
47 Hanna South			389	168	557
49 Hanna West			231	56	287
61 Keewatin	7,388				7,388
62 La Riviere	8,019				8,019
63 Carberry	5,584				5,584
64 Brandon	3,205				3,205
71 Weyburn	289				289
72 Pasqua	1,943		53		1,996
73 Bulyea	3,085				3,085
74 Bredenbury	7,254	60			7,314
75 Saskatoon	2,822				2,822
76 Wilkie	965				965
77 Assiniboia	223				223
78 Swift Current	310				310
79 Outlook	118		60		178
81 Medicine Hat					
82 Brooks					
83 Lethbridge					
84 Vulcan	593		576		1,169
85 Calgary					
86 Red Deer	60		1,184	116	1,360
87 Edmonton	453		492	221	1,166
90 N. Alberta RR West	211		2,838	324	3,373
95 N. Alberta RR East	314		626		940
97 British Columbia RR	51		5,180		5,231
98 Great Slave RR			2,164		2,164
TOTAL DEMANDS	131,108	271	17,578	7,174	156,131