THE IMPACTS
OF THE GARRISON DIVERSION UNIT
ON CANADA

VOLUME II of

A SCIENTIFIC AND POLICY REVIEW
OF THE
FINAL ENVIRONMENTAL STATEMENT
FOR THE
INITIAL STAGE, GARRISON DIVERSION UNIT

Prepared by
D.H. Boyd
Natural Resource Institute, University of Manitoba
with the cooperation of
the Agassiz Centre for Water Studies,
University of Manitoba

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A SCIENTIFIC AND POLICY REVIEW OF THE FINAL ENVIRONMENTAL

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by

D. H. BOYD

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCE MANAGEMENT

ABSTRACT

The Garrison Diversion Unit, a U.S. Bureau of Reclamation project located in the south-eastern and north-central area of the state of North Dakota, involves the transfer of Missouri River water from Lake Sakakawea to these areas to irrigate 250,000 acres of land and provide municipal and industrial water, fish and wildlife conservation and enhancement, recreation, and flood control.

Impacts of the project on Canada will be many and varied. Changes in water quality in Canadian water bodies, caused by accruals of irrigation return flows and seepage and operational losses from the Garrison Diversion Unit, may have impacts on municipal and industrial, agricultural, and recreational uses of water as well as on aquatic ecosystems and aesthetic amenities. Increased flows in Canadian rivers may cause flooding or may necessitate channelization of these rivers. Losses of waterfowl habitat and increases in botulism in waterfowl in North Dakota could mean a reduction in waterfowl populations in Canada. Exotic species, which may enter the Red River drainage basin when it is linked with the Missouri River drainage basin may have detrimental effects on the aquatic environment of Canadian rivers and lakes.

Using information pertaining to the environmental impacts of the project on Canada supplied by the Bureau of Reclamation, this study assesses the probable impacts of the project on Canada and the adequacy of this information.

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I.A HISTORY OF THE PROJECT

A letter written by Reverend Lyle Lutz, the Secretary-Treasurer of the Committee to Save North Dakota Incorporated, provides the early scenario for a gigantic irrigation project in the state of North Dakota, a project which affects the economy, social fabric, and the ecology of vast areas of that state as well as the ecology and economy of areas in Manitoba.

Reverend Lutz (1973) states:

> "The dream of copious supplies of water is entirely understandable in our semi-arid prairie region. A century ago this 'great American desert' was bypassed for several decades as unfit for agriculture. The vision was already present when statehood came to the Dakotas in 1889, and it persisted while generations of immigrant farmers painfully learned to adapt agriculture to these grasslands. And it was bolstered by the series of dry years summed up in the phrase 'dirty thirties', as well as by the slow but steady population decline from around 700,000 people in 1930 to 1970's census of around 600,000."

In 1887, a constitutional convention which preceeded the formation of the state of North Dakota, requested the U.S. Congress to consider the construction of a canal from the Missouri River in Montana to divert water across the length of North Dakota (Mudry 1973). In 1943, Congress authorized the U.S. Army Corps of Engineers to construct a series of dams on the Missouri River, while the Department of the Interior's Bureau of Reclamation was awarded the Garrison Diversion Unit (Lutz 1973). Plans drawn up by the two agencies conflicted and in 1944 a compromise was effected by the 1944 Flood Control Act (Mudry 1973). The Corps of Engineers began the construction of the Garrison Dam on the Missouri River in 1947. This dam was completed in 1956 at a cost of approximately $300 million, inundating 368,000 acres of "fertile valley bottom land, hundreds of historic sites and large areas of valuable wildlife habitat" (Mudry 1973, Bureau of Reclamation 1974a: I-5).

In 1957, the Bureau of Reclamation proposed a general plan for irrigating 1,007,000 acres of land in the state of North Dakota. This plan was submitted to Congress as was a similar plan in 1959. However, both plans failed to "demonstrate adequate agricultural cost-benefit ratios under close congressional scrutiny" (Lutz 1973). In 1965, a modified version of this plan was proposed, providing for the irrigation of only 250,000 acres, but citing such benefits as municipal and industrial water supplies, fish and wildlife conservation and enhancement, recreation, flood control, and other project purposes (Bureau of Reclamation 1974a: 1-1).

The project costs cited in 1965 were $212 million. When the Bureau's Final Environmental Statement was released in January 1974, in compliance with the National Environmental Policy Act of 1969, project costs had risen to $340 million over a 25-year construction period (Bureau of Reclamation 1974a: 1-3). In a recent letter to Henry S. Reuss, Chairman of the Conservation and Natural Resources Subcommittee, from the U.S. Comptroller General, project costs were cited to range from $405 million to $460 million (Comptroller General of the U.S. 1974).

The planned 25-year construction period began in July 1968, when work started on the Snake Creek Pumping Plant. Construction on the McClusky Canal, the principal waterway, was initiated in March 1970 (Bureau of Reclamation 1974a: 1-3).

I.B PROJECT DESCRIPTION

I.B.1 Introduction

The initial stage of the Garrison Diversion Unit is located in the southeastern and north-central area of the state of North Dakota (see Fig. 1.). The project involves the transfer of Missouri River water to these areas to irrigate 250,000 acres of land and provide municipal and industrial water, fish and wildlife conservation and enhancement, recreation, and flood control. The project will require 871,000 acre-feet[1] of water per year from the Missouri River. Much of this water will be transferred to the Souris River, James River, Sheyenne River, Wild Rice River, and Devils Lake (Bureau of Reclamation 1974a: 1-4).

The Garrison Dam (described earlier) flooded 368,000 acres creating Lake Sakakawea which has a storage capacity of 22,635,000 acre-feet of water. The Garrison Dam project was authorized for irrigation, hydro-electric power generation, flood control, fish and wildlife, and recreation purposes. Audubon Lake, a sub-impoundment of Lake Sakakawea, was developed by the Army Corps of Engineers to serve as the head-waters of the McClusky Canal of the Garrison Diversion Unit (Bureau of Reclamation 1974a: 1-9).

I.B.2 Principal Supply Works

The Snake Creek pumping plant will pump water from Lake Sakakawea to Audubon Lake to increase the elevation of that lake from 1,835 to 1,850 feet above sea level so that water will flow by gravity into the McClusky Canal. The surface area of Audubon Lake will be increased from 11,200 acres to 20,600 acres (Bureau of Reclamation 1974a: 1-5).

The 871,000 acre-feet per year of water, which will come from Audubon Lake, will flow eastward down the 73.7-mile-long McClusky Canal to the Lonetree Reservoir, the principal storage and regulation reservoir for the Garrison Diversion Unit. The Lonetree Reservoir, with a surface area of 20,300 acres, will have a storage capacity of 280,000 acre-feet. Water from the Lonetree Reservoir

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1 One acre-foot is equivalent to one acre of water to a depth of one foot.

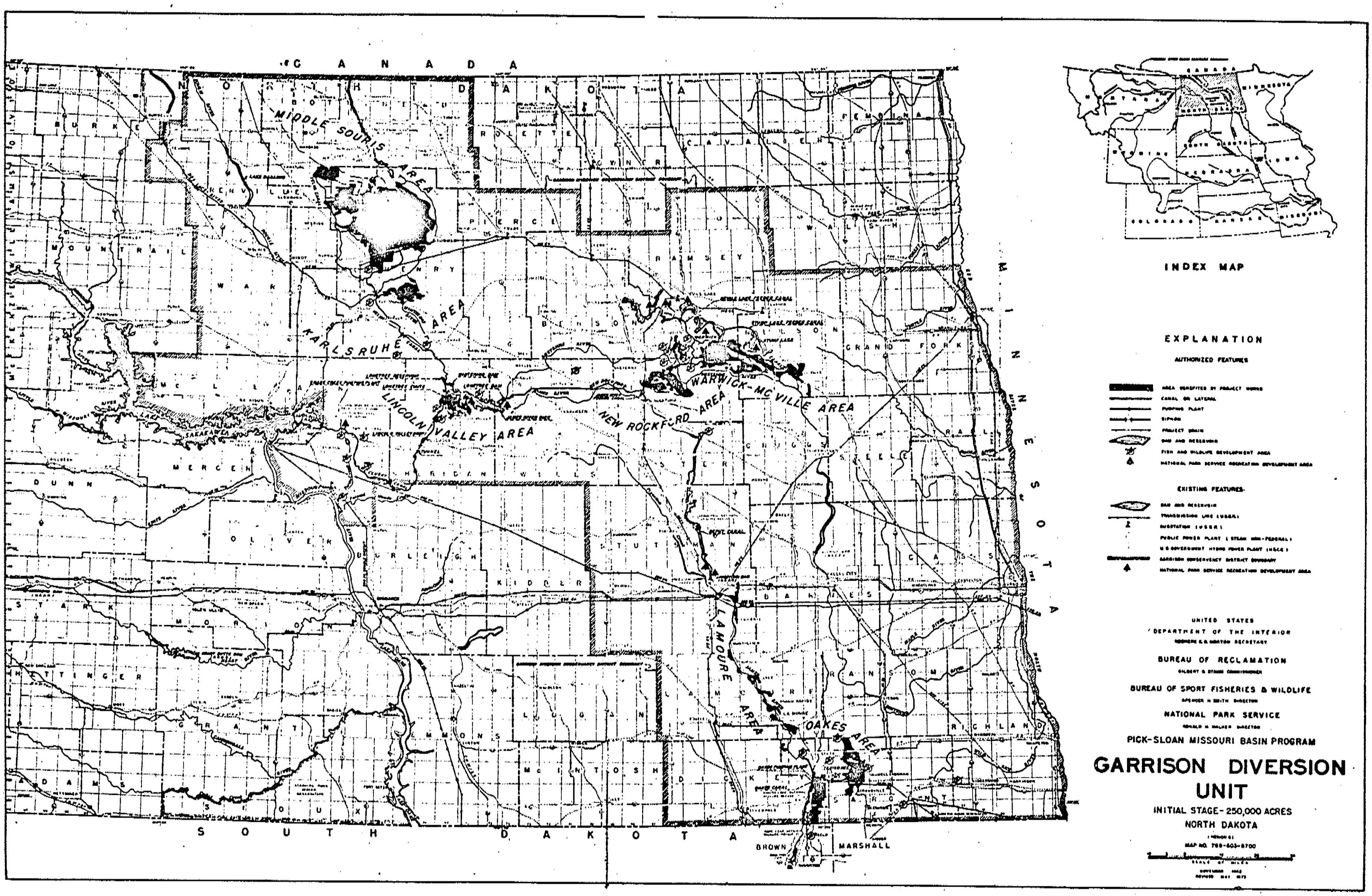


FIG. 1 Project map - Garrison Diversion Unit (from Bureau of Reclamation 1974a).

will flow eastwards along the New Rockford Canal and northwards along the Velva Canal. This flow will be regulated by the Lonetree Dam and the Wintering Dam at the outlets of the Lonetree Reservoir (Bureau of Reclamation 1974a: 1-9).

I.B.3 Northern Irrigation Areas

The 84.3 mile-long Velva Canal is the water supply feature for the northern part of the Garrison Diversion Unit. It supplies the 12,200-acre Karlsruhe and the 103,800-acre Middle Souris irrigation areas. Return flows from these irrigation areas will drain into the Souris River (Bureau of Reclamation 1974a: 1-12).

I.B.4 Eastern Irrigation Areas

The 52.3-mile-long New Rockford Canal will supply water to the 20,935-acre New Rockford irrigation area, the 47,220-acre Warwick-McVille irrigation area, the 13, 350-acre LaMoure irrigation area, the 45,480-acre Oakes irrigation area, and for the restoration (supply of fresh water) of Devils Lake. The 3-mile-long James River feeder canal, originating at the end of the New Rockford Canal, supplies water to the James River for service to the LaMoure and Oakes irrigation areas (Bureau of Reclamation 1974a: 1-13).

Water for the LaMoure irrigation area will be pumped directly from the James River. Water for the Oakes irrigation area will be pumped from the James River into the 11.3-mile-long Oakes Canal. The Taayer Reservoir, with a storage capacity of 28,500 acre-feet and a surface area of 1,440 acres, will receive water from the Oakes Canal and regulate water deliveries to the Oakes irrigation area. The 55.1-mile-long Warwick Canal (originating at the end of the New Rockford Canal) will provide water service for the Warwick-McVille irrigation area and Devils Lake (Bureau of Reclamation 1974a: 1-14, 1-17).

Return flows from the LaMoure irrigation area drain into the James River. Return flows from the New Rockford and Warwick-McVille irrigation areas drain into the Sheyenne River which drains into the Red River. The Oakes irrigation area may be broken into two sub-areas: the 26,210-acre East Oakes area and the 19,770-acre West Oakes area. Return flows from the West Oakes area drain into the James River and return flows from the East Oakes area drain into the Wild Rice River which drains into the Red River.

I.B.5 Other Irrigation Areas

An additional proposed irrigation area is the 6,515-acre Lincoln Valley irrigation area. Water service for this area will be provided from the McClusky Canal. Return flows will drain into the Lonetree Reservoir (Bureau of Reclamation 1974a: 1-13).

I.B.6 Distribution Systems and Drains

A sprinkler irrigation system is planned for all of the 250,000 irrigation acres. Water will be distributed from the canals and reservoirs to the irrigated acres by a combined system of open laterals and buried pipelines. Approximately 187 miles of open laterals and 495 miles of buried pipe will be constructed for the seven proposed irrigation areas. Drainage works will include open channels and buried pipes. Approximately 327 miles of open-channel drains and 1,700 miles of buried-pipe drains are planned (Bureau of Reclamation 1974a: 1-19, 1-20). The mileage of distribution and drainage channels and buried pipes for each of the proposed irrigation areas is given in Table 2.

Water will seep from canals, distribution laterals and drains, mix with the ground water, and drain into the rivers along with irrigation return flows in the irrigation areas. In addition, water will be discharged into surface drains directly into those rivers when there is excess capacity in the canals or distribution laterals. This discharge is referred to as operational waste.

I.B.7 Stream Channelization

Total channelization on the Garrison Diversion Unit will be about 83 miles and will be concentrated in the Middle Souris irrigation area and in the eastern part of the Oakes irrigation area on the Wild Rice River. Channelization in the Middle Souris area will "include channelization of some of the upper reaches of the natural drainages that are intermittent creeks or dry coulees." Four streams in the Middle Souris area will be channelized for a total distance of 78 miles to increase their capacity by 130-480 cubic feet per second (cfs). Channelization in the East Oakes area will involve the modification of an existing drain which will be extended through the upper 5 miles of the Wild Rice River. The capacity of this drain will be increased by 350 cfs (Bureau of Reclamation 1974a: 1-21).

I.B.8 Restoration of Devils Lake

Water from the 9.4-mile-long Devils Lake feeder canal, which originates at the Warwick Canal, will be used to raise and maintain the water surface in the main body of Devils Lake. The purpose of this development will be to freshen the saline waters of Devils Lake. East Stump Lake, part of the Devils Lake chain, will collect waters flushed from the other lakes in the chain, via the 9.5-mile-long Stump Lake feeder canal (Bureau of Reclamation 1974a: 1-14, 1-15).

I.B.9 Fish and Wildlife

A total of 36 major fish and wildlife areas and several minor areas will be developed as a part of the Garrison Diversion project. Water supply to about 29,000 acres of existing water and marsh and 27,000 acres of new marsh will be 100,000 to 165,000 acre-feet per year. Of the expenditures for fish and wildlife developments, 62% is for mitigation of fish and wildlife losses (caused by drainage of natural wetlands and destruction of habitat) and 38% is for enhancement of fish and wildlife benefits (Bureau of Reclamation 1974a: 1-22).

I.B.10 Recreation Features

Nine new recreation developments, totalling 4,795 acres, have been planned as part of the Garrison Diversion Unit. The McClusky Canal, Taayer Reservoir, and Stump Lake will each have one recreation area. The Lonetree Reservoir will have two recreation areas and Devils Lake will have four recreation areas (Bureau of Reclamation 1974a: 1-33).

I.B.11 Municipal and Industrial Water

Plans for the Garrison Diversion Unit indicate that 40,000 acre-feet of water per year could be used for municipal and industrial purposes. The City of Minot is scheduled to receive 22,900 acre-feet of water per year from the Velva Canal for municipal use. Provision of water for municipal and industrial uses in 14 additional communities could require 2,100 acre-feet of water per year, and 15,000 acre-feet per year is set aside for "as yet unidentified future municipal and industrial use" (Bureau of Reclamation 1974a: 1-44).

I.B.12 Summary

A summary of the various project features is provided by Tables 1 and 2.

Table 1. Canals and Reservoirs.[1]

Name of Project Feature	Capacity	Length or Surface Area	Source of Water	Construction Period
McClusky Canal	1,950 cfs	73.7 miles	Audubon Lake	1970-1978
Lonetree Reservoir	280,000 acre-feet	20,309 acres	McClusky Canal	1970-1979
Velva Canal	2,000 to 160 cfs	84.3 miles	Lonetree Reservoir	1981-1987
New Rockford Canal	1,600 to 1,100 cfs	52.3 miles	Lonetree Reservoir	1976-1982
James River Feeder Canal	450 cfs	3 miles	New Rockford Canal	1976-1979
Oakes Canal	320 cfs	11.3 miles	James River	-
Taayer Reservoir	28,500 acre-feet	1,440 acres	Oakes Canal	1976-1980
Warwick Canal	770 to 75 cfs	55.1 miles	New Rockford Canal	-
Devils Lake Feeder Canal	400 cfs	9.4 miles	Warwick Canal	1978-1983
Stump Lake Feeder Canal	310 cfs	9.5 miles	Devils Lake	1978-1983

[1]Data from Bureau of Reclamation (1974a).

Note: cfs = cubic feet per second

Table 2 Irrigation Areas.[1]

Name of Area	Area (acres)	Source of Water Supply	Return flows will accrue to	Distribution Laterals Open (miles)	Distribution Laterals Pipe (miles)	Drains Open (miles)	Drains Pipe (miles)	Construction Period
Karlsruhe	12,200	Velva Canal	Souris River	16	23	9	52	1982-1990
Middle Souris	103,800	Velva Canal	Souris River	83	196	189	835	1981-1989
Warwick-McVille	47,220	Warwick Canal	Sheyenne River	37	110	24	314	1977-1988
LaMoure	13,350	James River	James River	-	39	5	63	1976-1984
New Rockford	20,935	New Rockford Canal	Sheyenne River	16	37	30	140	1978-1983
Oakes East	26,210	Taayer Reservoir	Wild Rice River	35	68	62	232	1974-1980
Oakes West	19,770	Taayer Reservoir	James River					1974-1980
Lincoln Valley	6,515	New Rockford Canal	Lonetree Reservoir	0	22	5	87	1980-1983

[1] Data are from Bureau of Reclamation (1974a).

I.C Impacts on Canada

The impacts which the Garrison Diversion Unit may have on Canada cover a wide range of areas. Changes in water quality of Canadian rivers and lakes will result when irrigation return flows, canal seepage, and operational wastes are added to the Souris and Red Rivers which flow into Canada. This may affect domestic, industrial, and agricultural water supply as well as the aquatic ecology of Canadian lakes, rivers and marshes. Additions of water to the Souris and Red Rivers will increase the potential for flooding along those rivers. It will also provide additional water for beneficial uses in Canada such as municipal water supplies and generation of additional hydro-electric power. The loss of wetlands and increased incidence of botulism in waterfowl in North Dakota may reduce waterfowl populations in Canada. Exotic species of fish, plants, aquatic invertebrates, bacteria, and viruses which may enter the Red River drainage basin when the historically separated Red and Missouri River basins are joined may have detrimental impacts on fish and other aquatic organisms in the Red River basin.

These potential impacts will be examined in the following chapters. Chapter II discusses the impact on water quality, Chapter III assesses the probability and impact of flooding, and Chapter IV examines the impact on fish and wildlife.

I.D Scope and Objectives of Study

This study was conducted in response to a lack of information concerning the impacts of the Garrison Diversion project on Canada. This lack of information hindered government officials, academics, concerned citizens groups, and the public who were trying to decide what action and/or stance which they would take on the project.

This study utilizes information provided by the Bureau of Reclamation on project details and on the environmental impacts of the project on Canada. Where supplemented information was available from other U.S. Government agencies, from Canada and Manitoba Government departments, and from other sources, it was also utilized.

The objectives of this study are twofold. The first objective is to attempt to assess the impact which the Garrison Diversion project will have on Canada, using all available information. The second is to assess the adequacy of the information provided by the Bureau of Reclamation concerning the impacts which the project will have on Canada. Following from the second objective, areas where further information should be provided by the Bureau as well as areas where further studies or research are needed are identified.

This study does not attempt to recommend whether or not the project should continue or whether the project should be modified. Such a decision would require an economic analysis of the project's costs and benefits, an analysis of the social impacts of the project, and an evaluation of the environmental impact of the project in North Dakota as well as an analysis of the various political and legal factors. All of these are beyond the scope of this study.

CHAPTER II

WATER QUALITY

- INTRODUCTION
- DISSOLVED SALTS
- SUSPENDED SEDIMENTS
- NUTRIENTS
- PESTICIDES
- TRACE ELEMENTS
- TEMPERATURE

II.A INTRODUCTION

Irrigation return flows, canal seepage losses, and operational wastes will accrue to the Souris River from the irrigated lands, canals, laterals, and drains in the Karlsruhe and Middle Souris irrigation areas and to the Red River from irrigated lands, canals, laterals, and drains in the Warwick-McVille and New Rockford irrigation areas, via the Sheyenne River, and in the East Oakes irrigation area, via the Wild Rice River (see Table 2).

In general, these flows which will accrue to the Souris and Red Rivers will have different dissolved salt, suspended sediment, nutrient, pesticide, and trace element concentrations and different temperatures than the Souris and Red Rivers, resulting in changes in water quality in these two rivers. Changes will also occur in the Assiniboine River (into which the Souris River drains), Lake Winnipeg (into which the Red, Souris and Assiniboine Rivers drain), and to a much lesser extent in Lake Manitoba (where part of the flow of the Assiniboine River is diverted through the Portage Diversion during the spring flooding periods on the Assiniboine River). The Red, Assiniboine, and Souris Rivers are all part of the Red River drainage basin, shown in Figure 2.

Changes in the above water quality parameters will have impacts on the following uses of water by Canadians:

1) Municipal water supply for the town of Souris (which draws its water from the Souris River), the town of Portage la Prairie (which draws its water from the Assiniboine River), and the towns of Emerson, Morris, and St. Jean (which draw their water supplies from the Red River). Table 3 provides information on the population of these towns as well as those industries which could be affected by changes in the quality of the municipal water supply;

2) domestic water supplies to towns and to individual landowners who have wells near one of the affected rivers. The quality of the water supply from wells may be affected if river water infiltrates the ground water in the area. Towns along or near the Souris River, which use wells for their municipal water supply (with their 1971 population) are: Hartney (579), Melita (1,135), and Wawanesa (550);

3) water supplies for irrigation and livestock watering which are drawn from the Souris, Assiniboine, and Red Rivers;

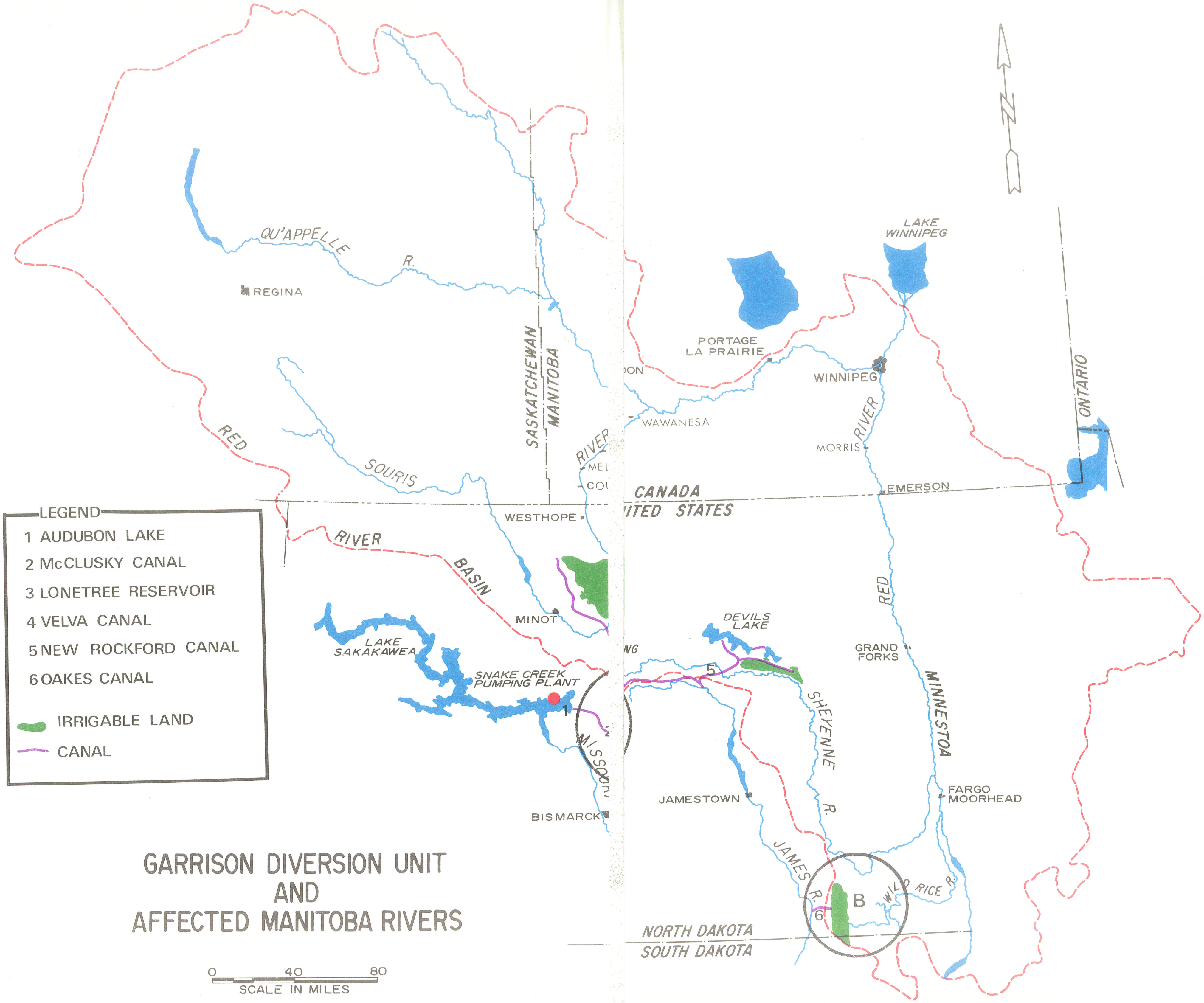
Table 3. Municipal Data[1].

Town	Municipal Water Supply Source	Population (1971)	Industries Sensitive to Changes in Water Quality	Employment by Industry
Souris	Souris River	1,674	Superior Cheese Canada Limited	16
Portage la Prairie	Assiniboine River	12,950	Campbell Soup Company Limited	250
Emerson	Red River	830		
Morris	Red River	1,399	Valley Rouge Wines Limited	13

[1] Data are from Manitoba Department of Industry and Commerce (1973).

4) recreational and aesthetic uses of the affected water bodies;

5) aquatic ecosystems, as well as waterfowl and wildlife populations around affected water bodies.



MAP PREPARED BY WATER RESOURCES BRANCH
DEPT. OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
PROVINCE OF MANITOBA

Fig. 2 R DRAINAGE BASIN (locations A and B are the two areas Missouri and Red River Watersheds will be joined)

II.B DISSOLVED SALTS

II.B.1 Introduction

> "In irrigation, pure water is extracted by the plants from the water supply resulting in an inevitable concentration of those dissolved solids which are characteristic of all natural water supply. Other uses add something to the water, but irrigation takes some of the water away, concentrating the residual salts"
>
> (U.S. Department of Interior 1969: 1).

This excerpt from the report, Characteristics and Pollution Problems of Irrigation Return Flow, explains how salts become concentrated in irrigation water, and why dissolved salt concentrations tend to be high in irrigation return flows.

The Bureau of Reclamation states that water applied to the land for the purpose of irrigating crops must be applied in some amount in excess of that required for evapotranspiration (evaporation from the soil and transpiration from the plants into the atmosphere) and allowed to flow through the root zone. These flows percolate through the soil and carry the residual dissolved solids of the irrigation water, some soluble nutrients, and any other materials which would be dissolved from the more soluble components of the soil. The major constituents of this drain effluent are sodium, calcium, magnesium, sulphate, bicarbonate, chloride and nitrate ions (Bureau of Reclamation 1974b: 4-5).

When irrigation water is first applied to the soil an initial leaching process occurs where the excess soluble minerals of the soil are dissolved and drain into the ground-water system along with minerals contained in the irrigation water. After this initial leaching period, an equilibrium condition is reached where substantial leaching of soluble minerals from the soil no longer occurs, and where the quantity of dissolved solids removed by the return flow is equal to the quantity - not concentration - of dissolved solids applied by the irrigation water (Bureau of Reclamation 1972: 21) - this is called the equilibrium period.

Dissolved salt loads will accrue to waters flowing into Canada from proposed irrigation areas of the Garrison Diversion Unit in North Dakota. These salt loads will be carried by irrigation return flows and to a lesser extent by canal seepage and operational losses.

II.B.2 Changes in Dissolved Salt Concentrations in Canadian Rivers

a) Souris River

Return flows from the Middle Souris and Karlsruhe irrigation areas, and canal seepage and operational losses from the Velva Canal and the distribution laterals and drains in these irrigation areas will accrue to the Souris River.

In the Final Environmental Statement, the Bureau claims that total dissolved solids (TDS) levels in irrigation return flows will average 1,746 milligrams per litre (mg/l) during the initial 20-year leaching period, and 1,520 mg/l under equilibrium conditions. The TDS concentration in the Souris River would be increased by 66% from its historic average value of 796 mg/l to 1,320 mg/l under equilibrium conditions (Bureau of Reclamation 1974a: III-21). During the leaching period, the average TDS level in the Souris River would be higher than 1,320 mg/l. These projections are derived from a Bureau computer study which was summarized in a report entitled Report on Water Quality and Return Flow Study for the Souris Loop Area of the Initial Stage of the Garrison Diverion Unit (Bureau of Reclamation 1972). Revisions which the Bureau has made since the report, render data on projected concentrations of dissolved salts in the Souris River found in that study and in the Final Environmental Statement inaccurate.

These revisions, which are described in the Bureau's latest report Irrigation Return Flows to the Souris River and Canada (Bureau of Reclamation 1974b), are:

1) The elimination of two extremely saline land forms from the proposed irrigation areas and their replacement with less saline areas.

2) Allowing a 10-year development period for irrigation in the Souris Loop Area which would extend the leaching period to 25-30 years, but would reduce the average salt concentration in return flows during the leaching period.

3) The addition of canal seepage and operational losses to the Souris River which would dilute the saline return flows. The Bureau had not previously accounted for either canal seepage or operational losses in any of their studies.

The methodology which the Bureau used in its revised computer study is as follows:

1) Missouri River water which is delivered to the Souris Loop for irrigation is assumed to have the following water quality parameters (Bureau of Reclamation 1974b: 30):

TDS	-	540 mg/l	Sulphate	-	188 mg/l
Sodium	-	60 mg/l	Bicarbonate	-	200 mg/l
Calcium	-	60 mg/l	Chloride	-	10 mg/l
Magnesium	-	20 mg/l			

2) A computer model which allows for treatment of unsaturated and saturated flow hydraulics of irrigation water in the soil column and balancing of the chemical reactions and transformation (including solution, precipitation, ion exchange and ion pairing) in the ground water system was used to give quantity and quality of irrigation return flow at accrual points to drains from irrigated areas (Bureau of Reclamation 1974b: 21). Levels of TDS, sodium, calcium, magnesium, sulphate, bicarbonate, chloride, and nitrate in irrigation return flows are provided by the Bureau in a volume of supporting data (Bureau of Reclamation 1974c). A monthly breakdown is provided for the value of the return flow and for concentrations of each of the dissolved salts (listed above) for a 19-year simulation period. A monthly breakdown is also provided for the average flow and for average values of each of the dissolved salts for the entire 19-year leaching period. These 19-year averages are referred to by the Bureau as leaching period values. The equilibrium values, which are most frequently cited by the Bureau are assumed to be the values for the final year of this 19-year simulation period.

3) The quality of canal seepage and operational losses which accrue to the Souris River is assumed to be the same as the quality of Garrison Diversion Unit water which is applied to the irrigated lands. The Bureau states:

> "The water lost from the Velva Canal and lateral system through seepage and operational wastes will be of about the same quality as the water diverted from the Missouri River which contains about 540 mg/l total dissolved solids ...... Following an initial ground water mounding and leaching period, most of the seepage water will mix with the ground water which has an average salinity level of 2,000 mg/l in the basin. Little influence from this water is expected on accruals to the river because the ground water now contributes to the base flow of the river."

(Bureau of Reclamation 1974b: 25b).

Monthly breakdowns for the 19-year simulation period are provided by the Bureau for the quantity of seepage and operational losses. Only yearly averages are provided for dissolved salt levels in seepage and operational losses. No breakdown is provided for dissolved salt levels during the 19-year leaching period. The yearly values used are derived from historic yearly average values for Missouri River water, with a small allowance made for evaporation in the canals - a process which increases salt concentrations in water.

4) Monthly values for return flows are combined with seepage and operational losses which are, in turn, combined with historic monthly flows in the Souris River for a 19-year period (1952-1970). Monthly concentrations of dissolved salts in return flows are combined with average annual concentrations of dissolved salts in the Souris River for the same 19-year period. Historic values of flow and dissolved salt concentrations were obtained from a monitoring station at Westhope, North Dakota, near the U.S.- Canada border (see Fig. 2).

The results of this mixing study described in the Bureau's main report (Bureau of Reclamation 1974b) are difficult to understand when examined together with the volume of supporting data (Bureau of Reclamation 1974c). The Bureau provides two tables presenting the resultant Souris River dissolved salts concentrations when (a) return flow concentrations only are mixed with historic concentrations and (b) when return flows and seepage and operational losses concentrations are mixed with historic concentrations. These tables are reproduced here as Tables 4 and 5. Examining the volume of supporting data from which these tables are derived, it is apparent that column two of both tables refers to values during the final year of the 19-year simulation period. However, since the Bureau combines the simulation period values with the historic period values, it is difficult to understand how meaningful resultant equilibrium concentrations can be obtained. The Bureau apparently uses the average resultant concentration for the 19 years over which the mixing model was run. However, since this 19-year period is essentially the leaching period, the resultant values provided by the Bureau in column three of Tables 4 and 5 can more accurately be called average, leaching-period values, rather than equilibrium values. Because the Bureau's mixing study has combined historic and leaching period concentrations on a year by year basis for the 19-year period of the model run[1] no equilibrium concentrations can be determined from the Bureau's results.

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[1] For example flows and concentrations for year 1 of the leaching period were mixed with flows and concentrations for the year 1952; likewise year 2 values were mixed with historic 1953 values, year 3 with 1954 etc.

Table 4. Constituent concentrations - Souris River (with return flows only).[1]

Constituent	Historic Average Souris River (mg/l)	Return Flow[2] Equilibrium Condition (mg/l)	Souris River Resultant (mg/l)
Calcium	60	122	103
Sodium	135	106	109
Magnesium	44	72	66
Bicarbonate	441	355	365
Chloride	36	18	28
Sulphate	220	480	411
TDS	796	1,150	1,035

[1]Data are from Bureau of Reclamation(1974b: 24).

[2]This column does not include seepage or operational losses.

Table 5. Constituent concentrations - Souris River (with return flows and seepage and operational losses)[1]

Constituent	Historic Average Souris River (mg/l)	Return Flow[2] Equilibrium Condition (mg/l)	Souris River Resultant (mg/l)
Calcium	60	110	89
Sodium	135	87	95
Magnesium	44	54	52
Bicarbonate	441	293	320
Chloride	36	15	23
Sulphate	220	360	340
TDS	796	980	885

[1]Data are from Bureau of Reclamation (1974b: 28).

[2]This column includes return flows and seepage and operational losses.

It is apparent that the Bureau's mixing model and the summary of results (Bureau of Reclamation 1974b) do not provide reliable data for projected concentrations of dissolved salts in the Souris River as a result of the Garrison Diversion Unit. For this reason, an independent computer model was developed to use base data provided by the Bureau and to compute the resultant dissolved salt concentrations in the Souris River. This model is described later.

In addition to the inadequacy of the mixing model, some other questions have been raised concerning the validity of the Bureau's salinity study. The Bureau states that 17 master sites were used for which soil profile data, detailed soil analyses, ground-water levels, and ground-water chemical analyses were obtained (Bureau of Reclamation 1974b: 20). These 17 sites, chosen for the Bureau's 1972 salinity study (Bureau of Reclamation 1972), were all on the 68,000-acre Middle Souris irrigation area. Extrapolations were then made to the 35,800-acre Mouse River[1] and the 12,200-acre Karlsruhe irrigation areas. The U.S. Environmental Protection Agency (1974a: 5) questions the validity of this extrapolation:

> "Are we to assume that detailed land classification studies have not been completed for the Mouse River Irrigation District and the Karlsruhe areas. Without such studies, how was extrapolation of data needed for the return flow analysis justified?"

Furthermore, the Bureau does not indicate whether the change in land forms which differentiates the 1974 salinity studies from the 1972 studies results in a change in the location or number of test sites. D. E. McMichael (1974), a Pollution Control Specialist with the State of Minnesota Pollution Control Agency concludes that: "It is doubtful, therefore, that the Bureau can make firm conclusions or predictions at this time." He states that: "The Bureau has done extensive soil profile analysis, and I find that their intentions are sound; however, their data and methods are questionable." McMichael (1974) cites many "holes" in the data base which have been filled in through correlation and interpolation. He notes that in some cases the correlation was poor, affecting the reliability of the data base used.

The Bureau does not provide adequate information on its computer methodology, nor on the assumptions used in constructing its computer models. The Environmental Protection Agency (1974a) argues that any assumptions which were used in applying the computer model to the return flows as well as assumptions

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1 On Fig. 2 and in Table 2, the Mouse River Irrigation District has been classified as part of the Middle Souris Irrigation Area.

on the effectiveness of irrigation management techniques should be stated.

Another criticism of the Bureau's 1974 salinity study concerns the constituent concentrations projected for seepage losses. The Bureau states that "...most of the seepage water will mix with the ground-water which has an average salinity level of 2,000 mg/l..." However, the Bureau concludes that: "Little influence from this water is expected on accruals to the river because the ground-water now contributes to the base-flow of the river" (Bureau of Reclamation 1974b: 25b). The Environmental Protection Agency argues that there is no information to support this assertion that seepage water will not become contaminated as it seeks its way to the Souris River. For example, if salt concentrations in seepage water increased by 50% due to mixing with saline ground water, average salt concentrations in the Souris River would increase by approximately 8%. The Bureau does state that there will be an initial "ground-water mounding and leaching period" (Bureau of Reclamation 1974b: 25b) but no information is provided on the length of this period or on dissolved salt concentrations during this period. There is no reason to assume that this leaching period for seepage will not be as long as the 19-year leaching period for return flows. In summary, the failure to adequately evaluate dissolved salt concentrations in seepage losses and to simply assume that these concentrations will be equal to concentrations of Missouri River water being deliver to the Souris Loop Area may be considered a major fault of the Bureau's salinity study.

To more accurately predict resultant flows and dissolved salt concentrations in the Souris River, an independent computer model was developed as follows:

1) A monthly breakdown for the following components was used as input data to the model:

a) Nineteen-year historic average dissolved salt concentrations and flows for the Souris River at Westhope, North Dakota;

b) dissolved salt concentrations and their associated flows for years which had the highest and lowest salt concentrations in the Souris River;

c) dissolved salt concentrations and their associated flows for return flows for the year during the 19-year leaching period where salt concentrations are the highest, for the average concentration during the leaching period, and for the equilibrium concentrations; and

d) dissolved salt concentrations, and their associated flows, which are provided by the Bureau for seepage and operational losses (Bureau of Reclamation 1974a).

The input data to the model is presented in Appendix A.

2) Historical input data for the Souris River is mixed with data for return flows and seepage and operational losses to give the resultant dissolved salt concentrations for average, high-salt year, and low-salt year conditions in the Souris River. A summary of the output from the computer mixing model is provided in Table 6. The computer program used, along with the computer output for the various cases is found in Appendix A.

The new salt concentrations, which are calculated for the Souris River at Westhope, North Dakota will approximate the new levels along the Souris River from the border to the Town of Souris. Along this reach of the river, four streams enter the Souris: The Antler River, Gainsborough Creek, Graham Creek and Jackson Creek. The flow of the first three streams in 1971 totalled 7,730 acre-feet; 2,330 acre-feet and 576 acre-feet respectively (Environment Canada 1972). There is no monitoring station on Jackson Creek. The total accrual into the Souris River measured by 3 stations was 10,636, or approximately 5% of the 208,000 acre-feet (Environment Canada 1972) flow in 1971 at Westhope. Thus, dilution from streams entering the river from the border to the town of Souris will be very minimal. Some dilution may occur between the town of Souris and the point at which the Souris River drains into the Assiniboine River due to additional flow from Plum Creek, which enters the Souris River just below the town of Souris. The total flow for Plum Creek in 1971 was 23,600 acre-feet (Environment Canada 1972) or approximately 11% of the 208,000 acre-feet flow at Westhope.

b) Assiniboine River

The Bureau does not examine changes in dissolved salts concentrations in the Assiniboine River. The independent computer study previously outlined therefore includes an evaluation of resultant flows and dissolved salt concentrations for the Assiniboine River. Historic data were provided by Environment Canada for the period 1953 to 1970 for the Assiniboine River at Portage la Prairie (Environment Canada n.d.). Because of the limited nature of the data, only average dissolved salt concentrations were used for the Assiniboine River. Accurate values for high-salt and low-salt year concentrations could not be obtained.

Table 6. Summary of results - Souris River.

Constituent	Historic Average Concentration (mg/l)	Concentration Under Leaching Period - High Salt Year Conditions (mg/l)	(% inc.)	Concentration Under Leaching Period - Average Conditions (mg/l)	(% inc.)	Concentration Under Equilibrium Conditions (mg/l)	(% inc.)
TDS	796	923	16%	877	10%	830	4%
Sodium	135	113	-16%	105	-22%	101	-25%
Calcium	60	87	45%	82	37%	79	32%
Magnesium	44	53	20%	51	16%	47	7%
Sulphate	220	352	60%	323	47%	298	35%
Bicarbonate	441	352	-20%	338	-23%	333	-24%
Chloride	36	38	6%	27	-25%	21	-42%
Hardness	333	435	31%	415	25%	392	18%

Input/output data for the Assiniboine River computer study are presented in Appendix A. Table 7 provides a summary of output. These values should be valid for the reach of the Assiniboine River from the confluence of the Cypress River near Holland to the mouth of the Assiniboine River in Winnipeg. The total flow near Holland in 1971 was 1,370,000 acre-feet, at Portage la Prairie 1,300,000, and at Headingly (near Winnipeg) 1,300,000 acre-feet (Environment Canada 1972) for a variance of approximately 5%. Salt concentrations in the Assiniboine from the mouth of the Souris River near Treesbank to the mouth of the Cypress River will be slightly greater than those projected by the computer mixing model due to the lower flow of the Assiniboine River in this reach.

Another assumption is that the total salt load from the Garrison Diversion Unit in the Souris Loop Area will remain constant in the Souris and Assiniboine Rivers. This assumes that the salts will not be adsorbed to sediments or taken up by aquatic organisms, which is a reasonable assumption considering the nature of the constituents.

c) Red River

The Red River will receive irrigation return flows and seepage and operational losses from irrigated lands, canals, and laterals in the Warwick-McVille and New Rockford irrigation areas, whose return flows accrue to the Sheyenne River, and in the East Oakes irrigation area, whose return flows accrue to the Wild Rice River. Both the Sheyenee and Wild Rice Rivers drain into the Red River.

The Bureau has done no specific studies on resultant salinity levels in the Red River. The only reference to increased salinity in the Red River is found in the Final Environmental Statement in which the Bureau concludes that under equilibrium conditions TDS levels in the Red River will increase from an historic average of 350 mg/l to 400 mg/l - an increase of approximately 14% - at the U.S. - Canada border (Bureau of Reclamation 1974a: III-22). Without baseline data of the type provided for the Souris Loop Area, no projections can be made for changes in salinity levels in the Red River.

II.B.3 Environmental Impacts of Changes in Salinity Levels

a) Municipal and Industrial Water

The assessment of environmental impacts of changes in salinity levels in

Table 7. Summary of results - Assiniboine River.

Constituent	Historic Average Concentration (mg/l)	Concentration Under Leaching Period - High Salt Year Conditions (mg/l)	(% inc.)	Concentration Under Leaching Period - Average Conditions (mg/l)	(% inc.)	Concentration Under Equilibrium Conditions (mg/l)	(% inc.)
TDS	648	704	9%	694	7%	683	5%
Sodium	55	62	13%	60	9%	59	7%
Calcium	82	86	5%	85	4%	84	2%
Magnesium	36	39	8%	39	8%	38	6%
Sulphate	180	215	19%	212	19%	206	14%
Bicarbonate	317	315	-1%	311	-2%	310	-2%
Chloride	24	27	13%	24	0	23	-4%
Hardness	353	375	6%	372	5%	366	4%

Canadian water-bodies is primarily based on the results of the independent computer study outlined above. The input to this computer study was necessarily based on data provided by the Bureau for dissolved salt concentrations of return flows and seepage and operational losses. Thus, if some of the concerns noted above concerning the inadequacy of the Bureau's data are true, then the output data of the independent computer study will be inaccurate. The indepedent computer study developed herein has only improved upon the Bureau's final mixing model.

(1) TDS

Environment Canada's Inland Waters Branch (1972: 31) lists the objective level for TDS in public water supplies as less than 500 mg/l and the acceptable level as 1,000 mg/l. The United States Public Health Service lists the permissible concentration of TDS in drinking water at 500 mg/l (U.S. Department of Interior 1969: 93). Concentrations above 500 mg/l may not be acceptable on the grounds of undesirable taste and laxative effects. TDS is unaffected by conventional water treatment.

Inland Waters Branch (1972: 74) lists TDS levels of 1,500 mg/l as the maximum acceptable level for brewing industry water, less than 500 mg/l for dairy industry water, and 850 mg/l for food processing industry water.

Historic TDS levels in both the Souris and Assiniboine Rivers 796 mg/l and 648 mg/l respectively, already exceed some drinking water criteria and some industrial process water standards. As a result of the Garrison Diversion Unit, average annual TDS levels will increase from 4% to 16% in the Souris River and from 5% to 9% in the Assiniboine River (Tables 6 and 7). In general, under equilibrium conditions, TDS levels in the Souris will be decreased from December to March and increased from April to November. During the initial 19-year leaching period, average TDS levels will be decreased during the month of February only and will be increased during all other months (Appendix A). TDS levels will be increased in the Assiniboine River for all months for both the equilibrium and leaching period (Appendix A). Although no monthly breakdowns are provided, the most recent information provided by the Bureau on salt levels in the Red River indicates that under equilibrium conditions TDS levels in the Red River will increase by 14% from 350 mg/l to 400 mg/l (Bureau of Reclamation 1974a: III-22). This increase will be greater during the initial leaching period.

In general any reduction in TDS levels would be beneficial for industrial and municipal uses of water, especially for the Souris and Assiniboine Rivers; however, any increase would cause a negative impact.

In the Final Environmental Statement, the Bureau of Reclamation (1974a: III-17) claims:

> "The concentration of total dissolved solids in these streams will be increased as a result of the project, but they will still be suitable for most uses without treatment for increased salinity. For domestic use, the total dissolved solids (TDS) of the Souris, Sheyenne, and James Rivers may exceed the public drinking water standard of 500 mg/l (recommended) and 1,000 mg/l (adequate) but salt concentrations will still be lower than many public water supplies in North Dakota".

A recommendation in the Bureau's 1972 Souris Loop return flow study reads:

> "Should the State of North Dakota determine that irrigation return flows to the Souris River would violate the State water quality standards, these standards should be revised to allow development of lands in the area" (Bureau of Reclamation 1972: 26).

Such statements do nothing to alleviate Canadian concerns over increased salinity of Canadian rivers as a result of the Garrison Diversion Unit.

(2) Hardness

Inland Waters Branch (1972: 31) cites less than 250 mg/l as the objective guideline for total hardness (as $CaCO_3$) in public water supplies. The United States Public Health Service recommends that a total hardness of 150-200 mg/l can be tolerated in municipal water supplies. If total hardness exceeds 200 mg/l, the water should be softened, as a process which involves the removal of calcium and magensium ions. For industrial process water, Inland Waters Branch (1972: 74), cites 250 mg/l as the maximum permissible concentration in brewing industry water. The average total hardness of the Souris and Assiniboine Rivers, 333 mg/l and 353 mg/l, exceeds drinking and industrial process water criteria and the towns of Souris and Portage la Prairie soften their water. The Garrison Diversion Unit, which will increase hardness in the Souris River by 18% to 31% and in the Assiniboine River by 4% to 6% (Tables 6 and 7), will result in additional water treatment costs for these two towns.

The town of Souris uses a zeolite softening process whereby calcium and magnesium ions are replaced by sodium ions. Presently the Souris water treatment plant consumes $4,256 in salt annually (L.E. Dane[1], personal communication). With an 18 - 31% increase in total hardness in the Souris River, the town of Souris would be faced with an annual additional salt cost ranging from $766 to $1,319, depending on return flow conditions.

The town of Portage la Prairie employs a water softening process called solids contact softening whereby calcium and magnesium ions are removed by the addition of lime. Based on operating data for the period April 1 to April 30, 1974 (D.G. Rodger[2], personal communication) during which the total hardness of Assiniboine River water was 295 mg/l, the Portage la Prairie water treatment plant can be expected to consume $35,844.00 worth of lime for an average year where the average total hardness is 353 mg/l. As a result of the Garrison Diversion Unit, Portage la Prairie would incur annual additional lime costs of $1,434 to $2,151, depending upon the condition of the return flow, to treat the 4% to 6% increase in total carbonate hardness in the Assiniboine River. However, this does not remove non-carbonate (sulphate) hardness which will increase by 14% to 19% in the Assiniboine River (Table 7). Portage la Prairie uses soda ash[3] periodically to remove non-carbonate hardness. With the increase in non-carbonate hardness caused by the Garrison Diversion Unit soda ash could be used continuously, resulting in significant increases in water treatment costs above the increases cited above.

The additional cost of salt to the town of Souris and lime and soda ash to Portage la Prairie are the minimum increases which these towns could incur. Other chemical costs will probably be increased as well, but these costs cannot be quantified at this time. The town of Souris may be forced to install an additional water softening unit, which would result in a substantial capital investment. In addition to increased chemical costs, cost of disposal of waste chemicals from water treatment plants as well as problems associated with disposal will be increased.

(3) Chloride

High concentrations of chlorides in municipal and industrial water are

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1 Mr. Dane is the Secretary-Treasurer for the town of Souris.

2 Mr. Rodger is Secretary-Treasurer for the town of Portage la Prairie.

3 Soda Ash is equivalent to sodium carbonate.

objectionable as they impart objectionable tastes to the water. Inland Waters Branch (1972: 31) cites less than 250 mg/l as the objective and 250 mg/l as the acceptable guideline for concentration of chloride (as Cl) in drinking water. The United States Public Health Service recommends 250 mg/l as the maximum concentration of chloride in municipal water supplies (U.S. Department of Interior 1969: 94). Chloride ions may impart a taste to the water in concentrations as low as 100 mg/l (McKee and Wolf 1973: 160). For industrial process water, Inland Waters Branch (1972: 74) cites maximum permissible chloride levels of 60-100 mg/l for brewing industry water, less than 30 mg/l for dairy industry water, and 250 mg/l for food processing industry water. Chloride cannot be removed by conventional water treatment systems, such as those of Souris and Portage la Prairie. Chloride concentrations are presently well below most criteria in both the Souris and Assiniboine Rivers, averaging 36 mg/l and 24 mg/l respectively (Table 6 and 7).

In general, chloride concentrations in both the Assiniboine and Souris Rivers will initially be increased during the first few years of the leaching period and then decreased during the equilibrium period, as a result of the Garrison Diversion Unit (Table 6 and 7). Concentrations during the first few leaching years should not be increased substantially and no adverse impacts are expected.

(4) Sulphate

At levels of 250 mg/l sulphate ions cause objectionable taste in water and at concentrations of 600 mg/l a threshold laxative effect is reported. Sulphate along with chloride are reported to be the two most troublesome salts in drinking water (EPA 1973: 219). Inland Waters Branch (1972: 31) cites less than 250 mg/l as the objective and 500 mg/l as the acceptable guidelines for sulphate (as SO_4) in drinking water. Waters with sulphate concentrations in excess of 500 mg/l should not be used for drinking purposes as gastrointestinal irritation, catharsis (purgation of the alimentary canal), and objectionable tastes may occur (Canada Department of Health and National Welfare 1968: 29). For industrial process water, Inland Waters Branch (1972: 74) cites less than 60 mg/l as the maximum permissible sulphate level in dairy industry water, and 250 mg/l in food processing water. Sulphate ions cannot be removed by conventional water treatment procedures.

Historic average levels of sulphate in the Souris and Assiniboine Rivers, 220 mg/l and 180 mg/l respectively, are high in relation to the previously cited standards. As a result of the Garrison Diversion Unit, average sulphate concentrations in the Souris River will be increased by 35% to 60% to levels of 298 mg/l to 352 mg/l respectively (Table 6); in the Assiniboine River by 14% to 19% to 206 mg/l to 215 mg/l respectively (Table 7). This increase places Souris River water within the range where noticeable objectionable tastes occur which may affect the quality of the drinking water of the town of Souris and the quality of the cheese being produced by Superior Cheese Canada Limited, which uses the town's water supply. In some months, during the leaching period, sulphate levels in the Souris River will be raised above 500 mg/l (Appendix A), the level above which adverse human physiological effects are possible. The sulphate concentrations in the Assiniboine River will be increased to levels close to the noticeable taste threshold. In some months, during the leaching period, sulphate concentrations will be increased to levels above the noticeable taste threshold (Appendix A). This may adversely affect the water supply of the town of Portage la Prairie and the quality of product produced by Campbell Soup Company Limited.

No evaluation of changes of sulphate concentrations in the Red River are possible as no data are provided by the Bureau. However, if sulphate concentrations were raised above the noticeable taste threshold, a negative impact could be felt by Valley Rouge Wines Limited, in Morris.

(5) Sodium

The town of Souris, in the process of softening water, replaces calcium and magnesium ions with sodium ions. As a result of increased treatment made necessary by increased total hardness in the Souris River, more sodium ions will be added to the water. In its latest report, Irrigation Return Flows to the Souris River and Canada, the Bureau of Reclamation (1974b: 59) claims this will create a potential health problem for people on salt free diets, such as people suffering from cardiac, renal, or circulatory diseases. However, the Bureau claims that for the Souris River this increase will be neutralized by a reduction in sodium concentration which will result from addition of seepage and operational losses from the Garrison Diversion Unit, a conclusion which is verified in summary Table 6. Sodium concentrations in the Assiniboine River will, however, increase by 7% to 13%, as a result of the Garrison Diversion Unit (Table 7).

(6) General

As indicated previously, salt concentrations projected by the independent computer mixing program, which are used to assess the impacts listed above, are only as reliable as the data provided by the Bureau. It is possible that salt concentrations will be greater than projected values, a result which would intensify any adverse impacts cited above.

It should also be noted that impacts are cited mainly for the town of Souris which uses the Souris River as its municipal water supply and for the town of Portage la Prairie, which uses the Assiniboine River as its municipal water supply. Impacts will also be felt by any landowners who use the water from the river directly for domestic purposes, and possibly for landowners and for towns such as Hartney, Melita, and Wawanesa whose wells may be contaminated by increased salinity in the river.

No impacts for the Red River can be cited, as no data is provided by the Bureau on changes in salt concentrations in the Red River. However, increased salinity in the Red River would affect the water supply of the towns of Emerson, Morris, and St. Jean and Valley Rouge Wines Limited in Morris. In addition, many farmers along the west side of the Red River haul water from Emerson, Morris, and St. Jean, as ground water supplies west of the Red River are virtually non-existant. These farmers would also be affected if salinity levels in the Red River were to increase significantly.

b) Irrigation Water

In the report, Characteristics and Pollution Problems of Irrigation Return Flow, the U.S. Department of Interior (1969: 25) concludes that:

> "the use of saline waters for irrigation imposes extra burdens on the irrigation farmer. Salinity generally reduces growth and yield. It may restrict production to the more tolerant crops ... The farmer using low quality water may be restricted in his irrigation methods, or he may have to adopt special practices to obtain germination.... Sprinkling may not be practical because of accumulation of salts, especially chlorides, on the leaves, and the resulting leaf burn or defoliation."

The National Technical Advisory Committee of the U.S. states that TDS levels of 500-1,000 mg/l may have detrimental effects on sensitive crops, while levels of 1,000-2,000 mg/l may have adverse effects on many crops.

Any increase in salinity of the Souris, Assiniboine, and Red Rivers may result in adverse impacts for farmers who use water from these rivers to irrigate crops. In particular, market vegetable gardeners around Portage la Prairie and Winnipeg who use the Assiniboine and Red Rivers for their water supply may be adversely impacted.

A plan has been proposed to divert water from the Assiniboine River to the Morden-Winkler-Altona area of Manitoba to build an irrigation system in that area. Any increase in the salinity of the Assiniboine River due to the Garrison Diversion Unit may threaten the viability of that project.

c) Aquatic Ecosystems

According to the Environmental Protection Agency (1973: 137):

> "The quantity and quality of dissolved solids are major factors determining the variety and abundance of plant and animal life in an aquatic ecosystem. They serve as nutrients in productivity and as agents in osmotic stress and direct toxicity. Major changes in quantity or composition of total dissolved solids have the effect of causing attendant changes in the structure and function of aquatic ecosystems."

While the levels of salts in the Souris and Assiniboine Rivers are well below toxic levels to aquatic organisms, major changes in species composition may occur as species which are better equipped to adapt to the new salt levels dominate over those that are not. For example, while salt concentrations of less than 1,000 mg/l have little direct effect on fish and wildlife, changes as small as 20 mg/l limit the growth of certain plant species (U.S. Department of Interior 1969: 107).

Other indirect impacts on aquatic ecosystems result from increases in concentrations of certain salts. Increases in calcium concentrations in water may affect the essential carbonate buffer system, resulting in pH changes. Rapid changes in pH may cause losses of the eggs and fry of fish (U.S. Department of Interior 1969: 104). As summary Table 6 indicates, calcium concentrations in the Souris River will be increased by 32% to 45% as a result of the Garrison Diversion Unit. In addition, the toxicity to fish of such trace elements as boron, copper, zinc, and other heavy metals is affected by calcium and magnesium concentrations.

Another aspect of increased salt levels in Canadian waters as a result of the Garrison Diversion Unit is the accrual of most of this increased salt load to Lake Winnipeg. While the Bureau, in their latest study on the Souris Loop Area, projects an increased salt load of 142,000 tons per year in the Souris River (Bureau of Reclamation 1974b: 29) under equilibrium conditions, the impact on Lake Winnipeg is dismissed by the comment: "It appears that the Lake Winnipeg watershed will be little affected by the increased loading of dissolved solids from the Garrison Diversion Unit since the Souris River makes only a relatively small contribution to the total runoff" (Bureau of Reclamation 1974b: 59). No supporting data or analysis is provided to substantiate this claim.

II.C SUSPENDED SEDIMENTS

II.C.1 Introduction

Turbidity, or suspended sediment load, may increase in Canadian waters as a result of the Garrison Diversion project. There are several ways this may happen:

1) Flows in rivers entering Canada will be increased as irrigation return flows and seepage and operational losses are added to them. Increased flow in a river may result in the erosion of riverbanks.

2) Surface runoff from irrigated croplands in North Dakota may be increased, due to the greater moisture content in the soil as a result of irrigation. The likelihood of increased surface runoff is less for sprinkler irrigation (which will be used on Garrison irrigation lands) than for other forms of irrigation, but the possibility still exists for increases in surface runoff. Any increased surface runoff would ultimately carry an increased sediment load into Canadian rivers.

3) Erosion of canals, laterals, and drains; stream channelization; and the cleaning of canals, laterals, and drains may cause increases in the sediment load in those water courses, which may lead to increased sediment loads in Canadian rivers.

II.C.2 Changes in Suspended Sediment Loads in Canadian Rivers

a) Increased Flows

Flows in the Souris River will be increased from their present 20-year average level of 164,400 acre-feet per year at Westhope, North Dakota (near the U.S.-Canada border) (Bureau of Reclamation 1974c: 8) to 272,100 acre-feet per year, with the addition of 107,700 acre-feet per year (Bureau of Reclamation 1974b: 28) due to irrigation return flows, canal seepage and operational losses in the Souris Loop area. The increase of flows in the Souris will range from 14.7% in April to 500.0% in December, with an average annual increase of 65.5% (Table 8).

In the <u>Final Environmental Statement</u>, the Bureau of Reclamation claims that 50,000 acre-feet per year of irrigation return flow will be added to the Sheyenne River and the Wild Rice River, both of which drain into the Red River. The Sheyenne River will receive 33,000 acre-feet of irrigation return flow annually from the Warwick-McVille and New Rockford irrigation areas. The Wild Rice River will receive 17,000 acre-feet of water annually from the East

Table 8. Flows in the Souris River .

Flows (1,000 acre-feet)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Historic Flows[1]	1.6	1.3	2.2	33.4	49.6	33.0	19.5	10.4	4.0	4.8	2.9	1.7	164.4
Return Flows[2]	5.0	4.2	4.3	3.9	4.5	5.1	6.1	6.5	6.7	6.2	5.6	5.5	63.7
Seepage and Operational Losses[3]	2.0	1.0	1.0	1.0	3.0	4.0	7.0	7.0	6.0	5.0	4.0	3.0	44.0
Resultant Flows	7.6	6.5	7.5	38.3	57.1	42.1	32.6	23.9	16.7	16.0	12.5	10.2	272.1
Percent Increase in Flows	375.0	400.0	240.9	14.7	15.1	27.6	67.2	129.8	317.5	233.3	331.0	500.0	65.5[4]

[1]Historic average flows 1931-1970 (Bureau of Reclamation 1974c: 8).

[2]Equilibrium period (Bureau of Reclamation 1974c: 22).

[3]Equilibrium period (Bureau of Reclamation 1974c: 24).

[4]Average annual increase.

Oakes irrigation area (Bureau of Reclamation 1974a: III-22). Average annual flows in the Red, Sheyenne, and Wild Rice Rivers are 2,246,000 acre-feet at Emerson, Manitoba, 117,000 acre-feet at Fargo, North Dakota and 51,200 acre-feet at Abercrombie, North Dakota respectively (Bureau of Reclamation 1974a: II-15 to II-17). No monthly breakdowns are provided by the Bureau, either for the historic flows of the Red River or for the irrigation return flows. Since the Final Environmental Statement was released, the Bureau has found that irrigation return flows did not include seepage and operational losses. The Bureau had initially assumed these were included in the irrigation return flows. Hence, the additional flows accruing to rivers from the irrigation areas must all be revised upwards (J. Keyes[1], personal communication). This revision has only been made for the Souris Loop area. Irrigation return flows from the Souris Loop area were initially assumed to be 63,700 acre-feet per year. Added to this were 37,000 acre-feet per year of seepage losses and 7,000 acre-feet per year of operational losses (see section II.B.2). Seepage is 58.1% of return flows and operational losses are 11.0% of return flows. These percentages were extrapolated using data describing flows accruing to the Sheyenne and Wild River Rivers to yield the revised levels of flow in the Sheyenne, Wild Rice, and Red Rivers (summarized in Table 9).

The primary concern to Canadians is the 65.5% average annual increase in flow along the Souris River (Table 8). An increase of that magnitude can be expected to cause erosion of riverbanks which would result in high sediment loads in the Souris River until the river adjusts to its new flow, a process which can take decades. Although the percent increase in flow will be the smallest during the spring flooding period, April and May, which is the most critical period in terms of riverbank erosion, the increases of 14.7% in April and 15.1% in May (Table 8) are significant when flows are already close to or above maximum channel capacities in many areas.

Erosion of river banks along the Red River should not be a major concern as the projected increase in flow of 3.8% (at Emerson) is very small (Table 9). However, any increase in flow during spring flood periods along the Red will

1 Mr. Keyes is a hydrologist for the U.S. Bureau of Reclamation.

Table 9. Increased flows in the Sheyenne, Wild Rice, and Red Rivers.

River	Historic Flow (acre-feet per year)	Irrigation Return Flows (acre-feet/year)	Canal Seepage (acre-feet/year)	Operational Losses (acre-feet/year)	Resultant Flows (acre-feet/year)	Percent Increase
Souris[1]	164,400	63,700	37,000	7,000	272,100	65.5
Sheyenne	117,000[2]	33,000[3]	19,173[4]	3,630[4]	172,803	47.7
Wild Rice	51,200[2]	17,000[3]	9,877[4]	1,870[4]	79,947	56.1
Red	2,246,000[2]	50,000[5]	29,050[5]	5,500[5]	2,330,550	3.8

[1]Data are from Table 8.

[2]Data are from Bureau of Reclamation (1974a: II-15 to II-17).

[3]Data are from Bureau of Reclamation (1974a: III-22).

[4]Extrapolations from Souris Loop data.

[5]Summation of return flows, canal seepage, and operational losses accruing to the Sheyenne and Wild Rice Rivers.

increase the area of land flooded and thus increase the amount of soil erosion along the banks and flood plain of the Red River. Another concern is increased erosion in the Sheyenne and Wild Rice Rivers, whose flows may increase by 47.7% and 56.1%, respectively (Table 9). Any increased sediment load in these rivers could accrue to the Red River.

Although increased flows in rivers represent the primary concern in regards to increased sediment loading, the Bureau provides no assessment of this potential. In fact in their latest report, Irrigation Return Flows to the Souris River and Canada, the Bureau concludes that:

> "the only potentials for an increase in turbidity of Souris River stream flow are associated with erosion of drain ditches following storms and the higher soil moisture of irrigated lands during periods of heavy rainfall" (Bureau of Reclamation 1974b: 51).

b) Surface Runoff

The Bureau argues that no surface runoff from proposed irrigation areas is anticipated due to the use of sprinkler irrigation and to the sandy texture and relatively high water intake of the irrigated soils (Bureau of Reclamation 1974b: 51). However, irrigation will increase the moisture content of the soil which may cause increased surface runoff of water from rainstorms. Any increases in surface runoff from irrigated croplands could result in an increased sediment load in Canadian rivers.

c) Erosion of Canals, Laterals, Drains

Erosion of canals, distribution laterals, and drains which would increase sediment loading of water on these water courses, will result from normal operation, rainstorms and spring melt, and cleaning operations. The Bureau states that "...localized scour of the drain channel could produce some sediment laden flows following heavy rainfall" (Bureau of Reclamation 1974b: 51). In the case of canals and laterals, sediment loads would be carried by operational losses which accrue directly to Canadian rivers. Sediment loads in drains would also accrue directly to Canadian rivers.

The Bureau states that erosion of canals, drains, and laterals would be mitigated by the establishment of native grass and shrub cover on the banks. It seems doubtful that the Bureau will have any success with the establishment of native grasses and shrub cover on the banks of canals when canals will be cleaned every ten years and laterals and drains every five years (see below), a process which will disturb vegetation along the banks. There is already evidence that erosion of banks of canals may pose major problems. Recently a large completed section of the McClusky canal collapsed while other completed portions have shown evidence of massive erosion. Madson (1974) stated: "Sizeable portions of reach 3A of the McClusky canal stretching from northern Burleigh County into southern Sheridan County, show some of the worst evidence of bank erosion, with portions of the lower cuts now eroded to the degree where they resemble topography in North Dakota's badlands."

The frequencey of canal, lateral, and drain cleaning operations depends upon the location, capacity, depth of cut, soil type, adjacent topography, velocity, and other parameters. In general the major canals will be cleaned every 10 years; the laterals and drains every 5 years (Bureau of Reclamation 1974a: III-73). The Bureau states that during cleaning operations, the turbidity of water will be temporarily increased, some bank erosion will occur until the banks are stabilized, and aquatic plant and animal life will be destroyed or temporarily disturbed (Bureau of Reclamation 1974a: III-73). The Bureau states that to minimize turbidity downstream, cleaning operations will proceed at times when there is very low flow in the canals, laterals, and drains. They also intend to use earth dikes downstream to trap and settle turbid waters during cleaning operations (Bureau of Reclamation 1974a: IV-21). While additional sediment loading in Canadian waters as a result of cleaning operations appears to be minimal, the possibility does exist.

d) Stream Channelization

Channeliztion will occur on four creeks in the Souris Loop area which drains into the Souris River and on the Wild Rice River which drains into the Red River. Channel modifications will occur on Cut Bank Creek, Little Deep Creek, Spring Coulee, and South Egg Creek for a total of 78 miles in the Souris Loop area. Five miles of the Wild Rice River will be channelized to a depth of 6 feet, as a result of the extension of existing drains in the area into the River (Bureau of Reclamation 1974a: III-47, 48).

Stream channeliztion will result in erosion and increased sediment loads until stablization of the banks occurs. This increased sediment load may accrue to the Souris and Red Rivers. Channelization of creeks and existing drains in irrigation areas will increase drainage in these areas. Marshes which now act as natural storage reservoirs partially protecting downstream areas from spring flooding may be drained. Thus the rate of surface runoff from rainstorms and from spring melt will be increased, resulting in increases in suspended sediment loads accruing to drains in areas where channelization has occured.

II.C.3 Environmental Impacts of Increased Sediment Loads

Increased sediment loads in rivers will cause increased turbidity in the water and increased deposition of silt along river bottoms. Increased turbidity will increase water temperature which will increase evaporation thereby increasing concentrations of dissolved salts. Increased temperatures will also cause thermal stress on aquatic organisms.

a) Municipal and Industrial Water Supply

For municipal water supplies, 5 Jackson turbidity units are recommended as the maximum permissible concentration. This value is recommended by the United States Public Health Service (McKee and Wolf 1973: 89) and the Canadian Department of Health and National Welfare (1968: 3). The primary reason for this limit is an aesthetic one. Suspended sediments, which cause turbidity, may usually be removed from water by conventional water treatment. However, the Environmental Protection Agency cautions that most treatment plants were designed to remove the turbidity existing at the time the plant was constructed. Therefore, if turbidity increases in Canadian rivers, towns such as Souris - which uses Souris River water for its municipal water supply - may be forced to expand their water treatment capacity and will face increased water treatment costs. Increased turbidity will also increase water temperatures which will increase evaporation. Increased evaporation rates will mean increases in concentrations of dissolved salts.

Turbidity criteria for industrial water supplies vary greatly with the type of industry. Criteria for boiler feed water vary from 2-80 Jackson turbidity units; for processing water in the brewing industry, 10 units; in the carbonated beverage industry, 2 units; in the food processing industry, 10 units; and in the textile manufacturing industry, 0.3 units (U.S. Department of Interior 1969: 100).

No information is provided by the Bureau on projected or historic turbidity or suspended solids levels in the Red or Souris Rivers.

b) Recreation and Aesthetics

The United States Department of Interior (1969: 115-116) claims that high turbidity levels in rivers could have "potentially serious adverse effects on body contact activities and aesthetic appeal." It set 10 Jackson turbidity units as the noticeable threshold - the level at which people begin to notice turbidity and perhaps to complain - and 50 units as the limiting threshold - the level at which concentrations prohibit or seriously impair the use of water for recreation - for water contact activities, such as swimming or diving. For boating and aesthetics, the noticeable threshold is set at 20 units, and there is no defined value for the limiting threshold.

c) Aquatic Life

Suspended sediments in rivers may kill fish and shellfish by causing abrasive injuries, by clogging the gills and respiratory passages of aquatic organisms, and by blanketing the stream bottom with silt which kills eggs and young and food organisms, and which destroys spawning beds (McKee and Wolf 1973: 280). Teba observed trout egg mortality of 50% in silt covered gravel as opposed to clean gravel (U.S. Department of Interior 1968: 108). Sedimentation limits circulation of clean water around the eggs, resulting in mortality or a pathological condition. Cordane and Kelley observed 41% - 63% fewer invertebrates in silty streams than in clear streams (U.S. Department of Interior 1969: 108). Invertebrates are either smothered or destroyed by abrasive action. Larvae are prevented from attaching themselves to the bottom of silty streams and may be carried away rapidly.

Abrasive action, due to high suspended sediment concentrations, may destroy algae and rooted plants. Sediments on underwater plants may inhibit gaseous exchange with water (U.S. Department of Interior 1969: 108).

Indirectly, suspended sediments are harmful to aquatic life because they screen out light, thus disrupting the photosynthetic reaction and the production of plant materials, and because by carrying down and trapping bacteria, they promote and maintain the development of noxious conditions and oxygen depletion (McKee and Wolf 1973: 280). Suspended sediments serve as a transport mechanism for pesticides and other toxic substances which are readily adsorbed to sediment particles (EPA 1973: 140). By reducing the clarity of water, they act to increase water temperatures, thus placing thermal stress on Aquatic organisms.

The Environmental Protection Agency states that "waters with concentrations of 80 milligrams per litre of suspended solids are unlikely to support good freshwater fisheries" (EPA 1973: 140).

The LC50[1] of suspended solids for rainbow trout is 270 mg/l (McKee and Wolf 1973: 280). In the report Characteristics and Pollution Problems of Irrigation Return Flow, the U.S. Department of Interior (1969: 108) concludes: "Even low amounts of silt for short periods of time may adversely affect primary productivity of streams."

While it is very difficult to quantify any impact on aquatic life caused by increased turbidity as a result of the Garrison Diversion Unit, it is apparent that the potential for adverse impacts is significant.

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1 LC50 refers to the particular concentration of a toxic substance which kills 50% of the organisms exposed in a given period of time.

II.D. NUTRIENTS

II.D.1 Introduction

Nutrients, including nitrogen, phosphorus, and organic wastes, may accrue to rivers flowing into Canada as a result of the Garrison Diversion Unit. The potential for changes in nutrient concentrations in Canadian water bodies results from the following aspects:

1) Increased use of fertilizer on proposed irrigation areas coupled with an increase in surface runoff from rainstorms and possibly from snowmelt;

2) nutrient-laden runoff from feedlots which may be established in or near proposed irrigation areas as well as from livestock which may have access to project drains;

3) the drainage of natural wetlands in proposed irrigation areas which may carry high nutrient loads into project drains; and

4) processing wastes from potential industries, such as sugar-beet processing, dairy, meat-packing, and other agriculture-based industries, which may be established in or near proposed irrigation areas and whose nutrient-laden wastes may drain into project drains or surrounding water bodies.

II.D.2 Changes in Nutrient Loads in Canadian Water Bodies

a) Nitrogen and Phosphous from Fertilizers

Fertilizers containing nitrates are often applied directly to the soil. In addition the fertilizer nitrogen is applied to cropland as manure, anhydrous ammonia, ammonia salts, and urea. These forms of nitrogen can readily be converted to nitrate in the soil (Bureau of Reclamation 1974b : 31). Phosphorus is applied mainly as phosphate fertilizer which is adsorbed or bonded to the surface of soil particles or precipitated into the soil profile (Bureau of Reclamation 1974b: 32). The U.S. Department of Interior (1969) points out that because of the tendency of irrigation practices to leach large quantities of nutrients out of the soil, it becomes necessary to replace these through increased use of applied fertilizers.

The Bureau of Reclamation (1974b: 34) cites four variables which influence nitrate and phosphate concentrations in irrigation return flows: (1) rate and time of fertilizer applications; (2) soil and crop management practices; (3) biological activity in the soil profile; and (4) the amount of leaching from the initial nitrogen content of the soil-root zone.

Garrison Diversion Unit irrigation will lead to greater application of fertilizer to proposed irrigation lands in North Dakota. The Bureau states that the use of nitrogen is expected to increase from 44 lbs. per acre before irrigation to 116 lbs per acre with irrigation (Bureau of Reclamation 1974a: III-70). This is an increase of 72 lbs per acre or 163.3%. The use of phosphorus is expected to increase from 21 lbs per acre before irrigation to 52 lbs per acre with irrigation (Bureau of Reclamation 1974a: III-70). This is an increase of 31 lbs per acre or 147.6%. Data on the use of nitrates and phosphates on proposed irrigation areas whose return flows accrue to Canadian waters, both before and with irrigation, is given in Table 10. An annual increase of 8,352,000 lbs of nitrate and 3,596,000 lbs of phosphate will be applied to land whose return flows accrue to the Souris River; an annual increase of 6,794,280 lbs of nitrate and 2,925,315 lbs of phosphate will be applied to lands whose return flows accrue to the Red River.

With irrigation there will be higher potential for these increased amounts of nitrates and phosphates to be leached through the soil profile into subsurface drainage flows. In addition, as previously indicated, a high soil moisture content as a result of irrigation will likely result in a greater rate of runoff from both rainstorms and possibly from spring melt. This increases the possibility for these increased amounts of nitrates and phosphates applied to be carried away in surface runoff water.

The Department of Interior (1969:64) cites eight sources of nitrogen (N) in drainage water: (1) dissolved N in rainfall; (2) N adsorbed to dust and soil particles; (3) N incorporated in organic matter; (4) manure; (5) N which has accumulated in soils prior to irrigation and which is initially leached out; (6) fixation by aquatic micro-organisms; (7) N from fertilizers; and (8) N in urban and industrial wastes. All of the above sources, with the exception of (8) may be influenced by increased use of fertilizers or increased surface funoff resulting from the Garrison Diversion Unit.

The Department of Interior (1969: 66) cites four ways by which phosphorus fertilizer may increase the phosphorus content of drainage water:

1) Percolating water passing through heavily fertilized sandy soil low in fixing capacity will carry soluble phosphorus into the drains.

Table 10. Changes in fertilizer application.

Irrigation Area	Area (acres)	Total Nitrate Fertilizer Used[1]: Before Irrigation (lbs)	Total Nitrate Fertilizer Used[1]: With Irrigation (lbs)	Total Phosphate Fertilizer Used[2]: Before Irrigation (lbs)	Total Phosphate Fertilizer Used[2]: With Irrigation (lbs)	Return Flows Accrue to:
Karlsruhe	12,200	536,800	1,415,000	256,200	634,400	Souris River
Middle Souris	103,800	4,567,200	12,040,800	2,179,800	5,397,600	Souris River
Warwick - McVille	47,200	2,077,680	5,477,520	991,620	2,455,440	Sheyenne River (Red River)
New Rockford	20,935	921,140	2,428,460	439,635	1,088,620	Sheyenne River (Red River)
Oakes East	26,210	1,153,240	3,040,360	550,410	1,362,920	Wild Rice River (Red River)
TOTALS	210,365	9,256,060	24,402,340	4,417,665	10,938,980	Red River Drainage Basin

[1]Based on a pre-irrigation application rate of 44 lbs/acre and a post-irrigation rate of 116 lbs/acre (Bureau of Reclamation 1974a: III-70).

[2]Based on a pre-irrigation application rate of 21 lbs/acre and a post-irrigation rate of 52 lbs/acre (Bureau of Reclamation 1974a: III-70).

2) Fertilizers applied to the surface of soils are readily adsorbed and stay near the surface. When the surface particulate matter is eroded by wind or carried in surface runoff, adsorbed phosphorus is carried with sediments into drainage water. Here, the phosphorus adsorbed to sediments equilibrates with the dissolved phosphorus in the drainage water and will increase the concentration of phosphorus in the drainage water unless it is already at or above the equilibrium concentration.

3) Biggar and Corey (1967, cited in U.S. Department of Interior 1969: 66) speculate that runoff water in contact with fertile soils can pick up soluble phosphorus as it moves over the surface of the land and that the concentration in runoff water might range up to a few tenths of a mg/l.

4) Phosphorus fertilizer is likely to stimulate plant growth. Parts of these plants, such as dried leaves, are carried away by wind or water into the drainage water where plant material is mineralized by micro-organisms, resulting in the accumulation of soluble inorganic phosphorus in water.

The U.S. Department of Interior (1969: 24-25) found that while nitrogen and phosphorus levels are highly variable in surface runoff from irrigated cropland, the nitrogen content in subsurface drainage water will be less than that of applied irrigation water if the irrigation water was initially high in nitrogen. Conversely, the nitrogen content of drainage water will be greater if applied irrigation water contained little or no nitrogen. The phosphorus content in subsurface drainage water is generally reduced unless the applied irrigation water contained little or no phosphorus.

Timmons et al. (1968, cited in Holt 1973: 565) investigated the nitrogen and phosphorus content of runoff water from small plots as a function of different cropping and fertilization practices. Their results are summarized in Table 11. Nitrogen loss to runoff water was highest for fallow plots (3.48 lb/acre/year where no fertilizer was applied) and for rotation hay plots (3.10 lb/acre/year where 22 lb/acre/year of fertilizer was applied); phosphorus loss to runoff water was highest for rotation hay plots (0.21 lb/acre/year where 18 lb/acre/year of fertilizer was applied). However, these results are not valid for N and P which are adsorbed to soil particles and carried with surface runoff water, for N and P incorporated into organic matter, or for N and P which are leached into the subsurface drainage water. Holt (1973: 566) concluded that loss of nutrients adsorbed to soil particles was the major pathway by which

Table 11. Dissolved total nitrogen and inorganic phosphorus in runoff water.[1]

Cropping treatment	Fertilizer N applied (lb per a per yr)[2]	Average total dissolved N (lb per a per yr)	Fertilizer P applied (lb per a per yr)	Average dissolved inorganic phosphorus (ortho) (lb per a per yr)
Fallow	0	3.48	0	0.05
Continuous corn	100	0.70	26	0.06
Rotation corn	22	1.08	18	0.07
Rotation oats	22	0.67	18	0.01
Rotation hay	22	3.10	18	0.21

[1]Adapted from Timmons et. al. (1968, cited in Holt 1973: 565).

[2]lb per a per yr: lbs. per acre per year.

N and P were transported away from agricultural land. The results of Timmons et al. (listed in Table 11) are partially explained by laboratory studies (Timmons et al. 1970, cited in Holt 1973: 566) which indicated that dessication of plant materials by freezing or drying released appreciable amounts of water soluble nitrogen and phosphorus. This explains the high contribution of N and P to runoff water from rotation hay plots.

Biggar and Corey (1969, cited in Holt 1973: 565) cite studies conducted at Morris, Minnesota which indicated that the first rain will sweep nitrates, applied as fertilizer, into the soil and that runoff water will be low in nitrates compared to water percolating through the soil, due to the high solubility of nitrate. As data in Table 11 indicate, fertilizers will not directly affect the nitrogen content of surface runoff as nitrates are highly soluble. They may, however, indirectly affect the nitrogen content of surface waters through incorporation of nitrates into plant tissues. If these plant tissues are not plowed into the soil they will be dessicated and nitrogen will be released. This conclusion is verified by the high dissolved N level for rotation hay plots (see table 11) and by a U.S. Department of Agriculture (cited by Garman 1973: 14) study which showed that soluble nutrients were carried in runoff water from corn and soybean stubble when heavy spring runoff occurred. Thus, nitrates that are leached from the soil and nitrates which are incorporated into plant tissues and which are carried by runoff upon dessication of these plant tissues are two important mechanisms by which nitrogen levels in water bodies could increase as a result of the Garrison Diversion Unit.

Phosphorus has different solubility characteristics than nitrogen. Zubriski et al. (1971, cited in Bureau of Reclamation 1974b: 35) found that one of the most striking characteristics of native soil phosphorus and fertilizer phosphate is immobility. Phosphous adsorption by soil particles and uptake by plants and micro-organisms tend to restrict the downward movement of phosphorus in percolating water. This is confirmed by studies conducted by the U.S. Agricultural Research Service on an irrigation project in Idaho (cited in Bureau of Reclamation 1974b: 35) which indicated that the concentration of phosphates in irrigation return flows was less than the concentration of phosphates in irrigation water applied to the land.

Zubriski et al. (1971: 41) found that practically all phosphorus applied in soluble form is converted to water insoluble compounds in a few days and that surface runoff is the major mechanism by which phosphorus is transported from the land. Runoff phosphorus, although it may exist in a dissolved state, is more likely to be adsorbed to suspended particles which will eventually become part of stream or lake sediments. Taylor (1967, cited in Holt 1973: 363) confirmed that the principal transport mechanism for phosphate from agricultural land is through erosion of surface soil on which it is adsorbed. Holt et al. (1970: 82) noted that continuous application of fertilizer phosphorus will result in high concentrations in surface soils where it is extremely vulnerable to loss by erosion. Scarseth and Chandler (1968, cited in Holt et al. 1970: 782) found that 60% of phosphate applied over a 26-year period to a nearly level loamy sand in a cotton, oats, and corn rotation was lost by erosion. Ensminger (1952, cited in Holt et al. 1970: 783) found that 63% of phosphous applied was lost from a Hartsell fine sandy loam under a corn and cotton rotation. Taylor (1967, cited in Holt et al. 1970: 783) estimated that fertilizer and soil phosphorus contained in eroded soil may contribute 1-5 lb/acre per year of readily available phosphorus to surface water. He assumed that 10% of the total phosphorus in eroded soils would be available for aquatic plant growth.

As with nitrate, phosphates applied to the land, which are incorporated into plant tissue, can be carried along with surface runoff waters when these plant tissues are dessicated. Timmons (1969, cited in Holt et al. 1970: 783) has demonstrated, in laboratory leaching studies of fresh frozen hay samples, that virtually all plant phosphorus can be leached with water and over 70% is in the inorganic (orthophosphate) form. Timmons et al. (cited in Zubriski et al. 1971: 41) found that annual phosphorus losses in runoff water from Barnes loam soils in Morris, Minnesota were highest for rotation corn and hay plots. Phosphorus losses in sediments were highest from fallow plots (103 lbs/acre from snowmelt; 42 lbs/acre from rainfall).

There is one additional indirect way in which the application of phosphate fertilizers can cause increases in phosphate levels in surrounding water bodies. The U.S. Bureau of Sport Fisheries and Wildlife (1974: 7) claims that while phosphate fertilizers are relatively immobile, phosphorus incorporated into plant material which in turn is fed to cattle is mobile. One impact of an irrigation project is an increase in livestock access to water on project drains. Thus, there are areas where enrichment of surface water with phosphorus can be expected.

Phosphorus can exist in water in at least 5 forms: soluble orthophosphates; soluble organics; insoluble organics; adsorbed on suspended materials; and as a component of suspended minerals and organic matter (U.S. Department of Interior 1969: 19). As a result of the Garrison Diversion Unit, a major mechanism for increases in phosphorus levels in water bodies would be from phosphorus adsorbed on suspended materials. Other mechanisms would be when phosphorus as a component of organic matter is transported to water bodies as dead and decaying organic matter is eroded from the land or when cattle have access to project drains in the proposed irrigation areas. Some soluble orthophosphates may be carried into water bodies with the dessication of plant tissue in irrigated croplands. However, most of the increased phosphorus load in water bodies would be adsorbed to soil particles. Holt (1973: 560) argues that the availability of phosphorus which could be supplied to aquatic organisms by desorption from soil particles - either suspended or settled - is still largely a matter of conjecture. Zubriski et al. (1971: 42) claim that runoff soil particles - regardless of origin - may add or remove phosphorus from runoff waters, depending on a number of variables including the phosphorus content of the water and the nature of the phosphorus. Data compiled for North Dakota soils by Torkelson and Dahnke and by Zubriski (cited in Zubriski et al. 1971: 43) indicated that when the phosphorus concentration in solution was in excess of 0.1-0.2 mg/l, sediments from low and very low phosphorus soils did not add phosphorus to the solution while sediments from medium and high phosphous soils add phosphorus to the solution to bring the concentration up to 0.3 mg/l

Latterel et al. (1969, cited in Holt et al. 1970: 783) indicated that lake-bottom sediments have a high capacity to remove orthophosphate from solution. Rigler (1964, cited in Holt et al. 1970: 783) documented the turnover rate of soluble inorganic phosphorus to organic forms in a number of hard and soft-water lakes in Canada to be less than 10 minutes. Holt et al. (1970: 783) noted a difficulty in separating the phosphorus adsorbed or precipitated by the lake sediments and that which is added through the biosystem:

> "Because of the rapid turnover of inorganic phosphorus due primarily to the rapid incorporation of phosphate into the biosystem of lakes, it is difficult to assess the contribution that sediment makes to the phosphate levels of surface waters. In general, the eroded soil material might have

considerable potential to remove dissolved phosphorus from waters, but at the same time might act as a reservoir of phosphorus when the concentration in the water is sufficiently low and equilibrium between water and sediment is attained."

In the Final Environmental Statement the Bureau of Reclamation (1974a: IV-25) does not provide specific data on the potential concentrations of nitrates in irrigation return flows. Instead, the Bureau cites various reports which conclude:

1) Fertilizer nutrients are lost by soil erosion rather than by leaching.

2) The loss of nitrates appears to be small in the presence of a growing crop due to rapid uptake of nitrate ions by plants and due to uptake of water by plants resulting in less free water in the soil.

3) The total amount of nitrogen leached from a soil in fallow is considerably greater than from a soil with growing plants and depends on the crop grown.

4) Sprinkler irrigation will minimize soil erosion and deep percolation, thereby reducing the movement of nitrogen into ground water. It also allows additional time for soil bacteria to act upon agricultural chemicals.

5) Results of irrigation field trials, conducted on sandy loam soils at Oakes, North Dakota, showed little nitrate leached below a depth of 5 feet during a period of 13 months for any fertilizer treatment.

The Bureau (1974a: IV-32) concludes:

"Since the movement of nitrate-nitrogen in the soil is dependent upon water movement, various rates of water application would result in varied amounts of nitrate leaching. Increased applications of nitrogen, which result from irrigation will tend to increase the possibility of nitrogen reaching the groundwater reservoir and return flow systems. Only through controlled management of sprinkler irrigation will nitrification of ground water supplies be held to a minimum."

In its most recent study, Irrigation Return Flows to the Souris River and Canada, the Bureau cites a computer study which projected nitrate levels in irrigation return flows from proposed irrigation areas in the Souris Loop area. In this study, the Bureau states that some nitrates will be carried in return flows because sufficient leaching at the root zone is necessary to maintain a salt balance for continued productivity of irrigated lands (Bureau of Reclamation 1974b: 34).

The Bureau's computer study included the processes of mineralization, immobilization, nitrification, urea hydrolysis, nitrogen uptake by the crops, crop root and residue decay, cation exchange, dispersion and convective tranport. The routing and mixing phase of the model, whereby return flows are routed into and mixed with water in the Souris River, was incorporated into the Bureaus' dissolved salts computer study (described in section II.B). The results of this study indictate that the average nitrate (NO_3) concentration in return flows and seepage and operational losses in the Souris Loop area will be 5 milligrams per litre (mg/l). The Missouri River water to be applied to proposed irrigation areas has an historic average nitrate concentration of 2 mg/l, while the historic average for the Souris River is 7 mg/l (Bureau of Reclamation 1974b: 33). While irrigation return flows will have an average nitrate concentration about 2.5 times that in water being applied to the land, this concentration will be less than the historic average in the Souris River. Nitrate levels in the past have fluctuated between 0 and 24 mg/l in the Souris River with long periods of high concentration. The Bureau concludes that these wide fluctuations would be stabilized with the addition of return flows to the Souris River (Bureau of Reclamation 1974b: 33).

The volume of supporting data to the Bureau's study (Bureau of Reclamation 1974c) provides a monthly breakdown of historic nitrate (NO_3) levels in the Souris River and projected nitrate levels in irrigation return flows.

Nitrate concentrations in return flows reach a maximum of 15 mg/l during the leaching period, declining to an average annual concentration of 9 mg/l during the final year of the leaching period. The average annual nitrate concentration during the 19-year leaching period is 7 mg/l, which is lower than the 9 mg/l equilibrium concentration due to the projection that nitrate levels in return flows will be zero during the first 2 years of the leaching period and very low during the following few years (Bureau of Reclamation 1974b: 50). The projection that the nitrate concentration in return flow starts at zero and gradually rises to a maximum of 15 mg/l during the eleventh year of the leaching period is the reverse of the pattern of dissolved salts in return flow which peak during the first few years of the leaching period and gradually decline to an equilibrium level. The Bureau does not explain the reason for this changed pattern for nitrates. As no explanation is provided, the very low nitrate-concentration projections made for the first few years of the leaching period are questionable.

The concerns cited in section II.B concerning the adequacy of the Bureau's computer study apply to nitrate projections as well. While the Bureau cites an average annual nitrate concentration of 5 mg/l in the Souris River - under equilibrium conditions, presumably - (Bureau of Reclamation 1974b: 33); analysis of the volume of supporting data indicates that 5 mg/l is the average concentration for the 19-year leaching period; that nitrate concentrations in the Souris vary from 2 mg/l to 9 mg/l during the leaching period; and that no equilibrium concentration can be readily determined from the data presented (Bureau of Reclamation 1974c: 52).

The independent computer mixing program, developed for this study and described in section II.B, projected nitrate (NO_3) concentrations in the Souris and Assiniboine Rivers under the various cases of operation of the Garrison Diversion Unit. Input/output data for this computer study are listed in Appendix A. A summary of average annual nitrate concentration changes in the Souris and Assiniboine Rivers is given in Table 12. These projections only account for one form of nitrogen - soluble nitrates (NO_3); they do not account for nitrogen which is incorporated into plant materials or organic wastes. These projections are valid only if there is no significant uptake of nitrates by aquatic plants along the Souris and Assiniboine Rivers. While this may be true for the Souris River which has a high historic nitrate concentration (6.42 mg/l), it may not hold true for the Assiniboine River which has a much lower historic nitrate concentration (1.37 mg/l). Nitrate-nitrogen in the Souris River is already in excess of what can be used by aquatic organisms (i.e. it is not a limiting factor for aquatic plant growth). However, additional nitrate-nitrogen in the Assiniboine River may become incorporated into aquatic plant tissues and therefore the nitrate levels for the Assiniboine may be significantly less than those projected in Table 12.

The Bureau, in its Final Environmental Statement, states that phosphorus does not leach except from extremely sandy soils. Most of the phosphorus applied to the soil becomes water insoluble or fixed within a few hours after application by the formation of insoluble iron, aluminum, or calcium compounds. The Bureau concludes that: "the amount of phosphorus removed from the irrigated area is not expected to influence our streams or rivers to any appreciable amount" (Bureau of Reclamation 1974a: III-70). The Bureau claims that phosphorus is lost mostly through surface erosion of soil particles and soil organic matter, a claim which was confirmed earlier in this section. The Bureau concludes: "As stated in many of the reports, phosphorus pollution of streams and lakes attributable to irrigation should be very low, especially due to the

Table 12. Summary of changes in nitrate (NO_3) concentrations.[1]

River	Historic Average Nitrate Concentration (mg/l)	Nitrate Concentration Under Leaching High Nitrate Year Conditions (mg/l)	(% change)	Nitrate Concentration Under Average Leaching Conditions (mg/l)	(% change)	Nitrate Concentration Under Equilirium Conditions (mg/l)	(% change)
Souris	6.42	7.71	20%	5.51	-14%	6.21	-3%
Assiniboine	1.37	2.46	80%	1.90	39%	2.08	52%

[1]Data are summarized from Appendix A.

flat nature of the terrain of the project area and to the efficiency attainable by sprinkler irrigation". (Bureau of Reclamation 1974a: IV-27).

In its most recent study, Irrigation Returns Flows to the Souris River and Canada, the Bureau (1974b: 36) cites references which confirm that "the assumption of insignificant phosphate contributions to the Souris River appears to be valid". The volume of supporting data to this study (Bureau of Reclamation 1974c) contains reprints of four papers which the Bureau found to be "especially helpful" in the study of nitrate and phosphate contributions to the Souris River for the Garrison Diversion Unit. However, all of these papers are very general; none specifically treat the problem of nutrient runoff from irrigated areas.

The Bureau limits its discussion to phosphates which leach through the soil profile. It does not consider phosphates which are carried by surface runoff, either adsorbed to soil particles, incorporated in plant tissues or organic wastes, or in soluble (orthophosphate) form, when it claims that "phosphate contributions to the Souris River will not be significant" (Bureau of Reclamation 1974b: 35). While no surface runoff is expected as a result of the normal operation of sprinkler irrigation equipment, rainstorms, spring runoff, and overuse of irrigation equipment may cause surface runoff which would carry additional loads of phosphorus. There are also concerns that sprinkler irrigation equipment will not be used properly by individual irrigators, which could result in greater surface runoff than is anticipated.

No information is provided on the addition of nitrates or phosphates to the Red River from the Warwick-McVille, New Rockford, and Oakes East irrigation areas.

b) Total Nutrient Loads due to Fertilizers

In the report Irrigation Return Flows to the Souris River and Canada, the Bureau (1974b: 36) states that return flows will contribute about 720 tons of nutrients annually to the Souris River basin, consisting mainly of nitrates and an insignificant amount of phosphates. This will increase the total nitrate-nitrogen loading of the Souris River to about 2,060 tons per year, a 50% increase over its historic average of 1,340 tons per year.

No information is provided on increases in total nitrate-nitrogen loading in the Red River. However, a crude estimate may be made by extrapolating the nitrate-nitrogen load due to irrigation return flows in the Souris Loop area to irrigation areas whose return flows accrue to the Red River. From Table 10, the total area of Souris Loop irrigation lands is 116,000 acres. This area add 720 tons of nitrate-nitrogen per year to the Souris River. The total area of irrigation lands whose return flows accrue to the Red River is 94,365 acres. Thus: $720 \times \frac{94,365}{116,000}$ or 586 tons of nitrate-nitrogen per year could accrue to the Red River, if the Bureau's estimate for the Souris River is accurate.

The total nitrate-nitrogen load added to the Red River watershed per year as a result of increased use of fertilizers on, and increased runoff from, proposed irrigation areas in North Dakota is 1306 tons (720 plus 586). It must be noted that this projection is a minimum level, as the Bureau did not account for nitrogen or phosphorus which would be carried by surface runoff water. Most of the increased nutrient load in the Red River drainage basin will accrue to Lake Winnipeg, although some will accrue to Lake Manitoba during the spring, when flows in the Assiniboine River reach flood levels and the Portage diversion, which diverts Assiniboine River water into Lake Manitoba, is opened.

c) Nutrients from Feedlots

If feedlots are established near the proposed irrigation areas as a result of the Garrison Diversion Unit, wastes draining from those feedlots could accrue to waters flowing into Canada. No information is provided by the Bureau on the possibility and location of new feedlots close to the proposed irrigation areas. In the Supplement to the Final Environmental Statement the Bureau (1974d: 5) states that adequate implementation of Environmental Protection Agency and State regulations, which do not allow discharge of wastes from feedlots into surface waters, will limit the impacts of nutrient loading from cattle feedlot operations.

The Environmental Protection Agency (1974a: 2) states that the expected proliferation of livestock feedlots will be of special importance. The Agency states:

> "The development of significant livestock-feeder economy carries with it the risk of substantially increased organic and nutrient pollutant loads to area streams. Although regulations promulgated by E.P.A. call for a "no-discharge" policy from large feedlots, this requirement is waived in the event of a large rainfall event. From the information presented in the draft report (Bureau of Reclamation 1974b), it does not appear that conclusions concerning nutrient loads to the Souris River and Canada considered this possibility".

In addition, a study of feedlots in Colorado (cited by Holt 1973: 567) indicated over half of the nitrogen excreted by livestock was lost by volatization (primarily as ammonia) and deposited again on land and water surrounding the feedlots. Thus, wastes from feedlots can be either a direct or indirect source of nutrients in the Souris and Red Rivers as a result of the Garrison Diversion Unit.

d) Other Sources of Nutrients

As indicated in the introduction to this section, there are three other potential sources of additional nutrient loading in Canadian water bodies as a result of the Garrison Diversion Unit. These are:

1) The drainage of natural wetlands in proposed irrigations areas. Drainage waters from these wetlands may carry high nutrient loads into project and natural drains and hence into surrounding water bodies during the first few years of project operation.

2) With the construction of project drains in proposed irrigation areas, livestock in these areas will have access to these drains. Thus water in project drains which empties into surrounding water bodies may pick up excrement from livestock.

3) Various potential industries, such as sugar-beet processing, dairy, meat-packing, and other agriculture-based industries may become established in or near proposed irrigation areas. Nutrient-laden wastes from these industries may accrue to surrounding water bodies, if not adeqautely treated.

The Bureau has considered none of the above sources of nutrients which could result from the Garrison Diversion Unit.

II.D.3 Environmental Impacts of Increased Nutrient Loads in Canadian Water Bodies

a) Domestic and Industrial Water Supply

Canadian guidelines for drinking water, cited in an Inland Waters Branch report entitled Guidelines for Water Quality Objectives and Standards, for nitrate plus nitrite (as N) are as follows: objective level - less than 10 mg/l; acceptable level - less than 10 mg/l; maximum permissible level - 10 mg/l (Inland Waters Branch 1972: 29). A nitrate concentration of 10 mg/l as N is equivalent to 45 mg/l as NO_3. These values are set due to the possibility of infantile nitrate poisoning or methemoglobinemia (cyanosis) which may result from N levels in excess of 10 mg/l (U.S. Department of Interior 1969: 96). Inland Waters Branch (1972: 31) guidelines for phosphates (as PO_4) are: objective level - less than 0.2 mg/l; acceptable level - 0.2 mg/l. Phosphates cause algal blooms, tastes and odours, and slime growth and may adversely affect coagulation, flocculation, and lime-soda treatment of water. A phosphate concentration in excess of 0.5-1.5 mg/l may interfere markedly with coagulation (McKee and Wolf 1973: 240). Under new proposed North Dakota State water quality standards, limits for concentration of nitrates (as N) are 4.0-5.0 mg/l and for phosphates (as PO_4) are 0.1-0.2 mg/l (Bureau of Reclamation 1974a: IV-31).

Inland Waters Branch (1972: 74) guidelines for nitrates (as NO_3) in industrial process waters are: brewing 10-30 mg/l; dairy - less than 20 mg/l; food canning and freezing 10-12 mg/l. These values should not be exceeded for acceptable industrial process water. No guidelines are provided for phosphates in industrial process waters. Both nitrates and phosphates can impart a repugnant taste to water affecting the taste of various food and beverage products (McKee and Wolf 1973: 241). Historic nitrate levels in the Souris River of 6.43 mg/l (as NO_3) are relatively high but do not exceed the previously cited criteria. Historic nitrate levels in the Assiniboine of 1.37 mg/l (as NO_3) are relatively low. The projected concentrations in nitrate levels in the Souris River range from an average value of 7.71 mg/l (as NO_3) during the high-nitrate year of the leaching period to 6.21 mg/l under equilibrium conditions. This would not raise nitrate concentrations to unacceptable levels for municipal and industrial water. Nor would nitrate levels in the Assiniboine River be raised above the previously mentioned criteria (Table 12). Thus the major concern in regard to nitrates in municipal and industrial water in the Souris and Assiniboine Rivers will be the stimulation of increased aquatic plant growth, such as algal blooms which cause tastes and odour problems. No data are available on historic or projected phosphate levels in the Souris or Assiniboine Rivers. However, in March 1974, the Town of Souris wrote to the Manitoba Department of Mines, Resources and Environmental Management, complaining that its water supply was discoloured and contained high amounts of sediment and iron. In reply, the Department noted that the iron, which is normally removed by the type of water treatment plant at Souris, was "forming complex compounds with the excessively high phosphate and bicarbonate levels and could not be removed by the treatment levels available at Souris". The only solution the Department could propose was to wait for the phosphate level to subside (Balacko 1974, cited in Smith 1974). If phosphate concentrations were increased in the Souris River as a result of the Garrison Diversion Unit, this problem would be more severe.

No data are provided on historic or projected nitrate or phosphate levels in the Red River. Therefore, no assessment of the impacts on municipal and industrial water from the Red River may be made.

b) Water for Livestock and Irrigation

The U.S. Environmental Protection Agency established a maximum permissible nitrate level as 100 mg/l (as NO_3) in water for livestock watering (EPA n.d.). McKee and Wolf (1973: 225) note that special attention should be paid to the concentration of nitrates in stock waters especially when the total salt concentration exceeds 570 to 1000 mg/l, as is the case in the Souris River. No information is available on the impacts of phosphate in livestock water. However, for both nitrates and phosphates, the major impacts of their presence in livestock water would be the stimulation of algal growths which may be toxic to livestock, rather than their direct toxicity.

Nitrate and phosphates in irrigation water are thought to have little importance, although they are likely to be beneficial in increasing the fertility of the soil to which they are applied. Only in excess quantities will nitrate tend to reduce soil permeability (McKee and Wolf 1973: 225, 241).

c) Recreation and Aesthetics

In the report Characteristics and Pollution Problems of Irrigation Return Flows, the U.S Department of Interior (1969: 115) states that nitrates and phosphates adversly affect practically all recreational uses. They act as nutrients for the stimulation of excessive aquatic plant growth resulting in bad tastes and odours.

d) The Aquatic Environment

The environmental impacts of nutrient (N and P) loading are most severe on the aquatic environment. Nitrogen (N) and phosphorus (P), from fertilizers, decaying plant materials, and other organic wastes, will accrue to the Souris and Red Rivers as a result of the Garrison Diversion Unit. The influence of these nutrients in the aquatic environment is significant in the context of the entire aquatic ecosystem although these nutrients may not be directly toxic to any particular organism.

Nutrients cause increased plant production which, if excessive, tends to clog streams with plant material and debris. When this increased plant material dies it is decomposed by bacterial fermentation, which is at first aerobic, and the oxygen concentration of the water may be reduced. When oxygen concentration is reduced, decomposition of the increased plant material will proceed anaerobically. This may result in the release of noxious gases such as hydrogen sulfide, which is toxic to a variety of aquatic organisms (U.S. Department of Interior 1969: 105). Increased production of plant material may also lead to the secretion of toxins by certain species of blue-green algae; these toxins may be lethal to both invertebrates and vertebrates (U.S. Department of Interior 1969: 105). Reduced oxygen in water during critical winter-ice conditions may result in massive fish kill.

Decreases in the dissolved oxygen content of water may be directly harmful to many invertebrates. Invertebrates with high oxygen requirements may be eliminated and replaced by invertebrates which have lower oxygen requirements, resulting in drastic changes in the aquatic ecosystem (U.S. Department of Interior 1969: 105).

Enrichment of water bodies with nutrients induces changes in production of plant material such as algea. A principal consequence may be dominance in planktonic algeas and encouragement of growth of rooted, vascular aquatic plants.

Inland Waters Branch (1972: 121) states:

> "Among the more active nutrients, dominant roles have been assigned to phosphorus and nitrogen. There is still some controversy as to whether other nutrients may have equal or even greater effects, or, on the contrary, be of secondary importance in comparison to phosphorus and nitrogen: at the present state of knowledge, it may be safely assumed that these phosphorus and nitrogen are, in most cases, the principal contributors ..."

Holt et al. (1970: 781) state that the phosphorus content of water is frequently the limiting factor for growth of algae and aquatic weeds. They state that any small increase in soluble phosphorus can create conditions suitable for abundant algea production. Schindler and Fee (1974) describe experiments in which various amounts of phosphorus, nitrogen, and carbon were added to four lakes in northwestern Ontario. These experiments indicated that phosphorus was the major contributor to eutrophication. On lakes where only carbon and nitrogen were added, no eutrohpication problems occured. Zubriski et al. (1971: 66) state that phosphorus in water is considered a pollutant when the concentration exceeds 0.01 to 0.05 mg/l (as P), assuming other factors such as toxic substances, temperature, acidity, CO_2 content, 0_2 supply, and lack of light are not limiting. Viets (1970: 791) cites 0.01 mg/l of P as sufficient to produce an obnoxious algal bloom; whereas 0.3 mg/l of N is sufficient for an obnoxious algal bloom. Analyses of waters in the United States which support a good fish life have shown that 5% have nitrate concentrations less than 0.2 mg/l; 50% less than 0.9 mg/l; and 95% less than 4.2 mg/l (McKee and Wolf 1973: 225).

As the historical concentration of nitrate in the Souris River is 7 mg/l (as NO_3), which is well above levels cites previously that may cause noxious algal blooms, nitrogen and in all probability phosphorus, are not limiting factors for plant production. Therefore, an increase in nitrogen and phosphorus levels in the Souris is unlikely to cause further increases in plant production. However, this conclusion may not be valid for the Assiniboine River into which the Souris River drains, nor for the Red River into which the Sheyenne and Wild Rice Rivers drain. Unfortunately, historic and projected data are lacking on nitrogen levels in the Red River and on phosphorus levels in the Souris, Assiniboine, and Red Rivers. Without this data, impacts on aquatic ecosystems in these rivers, as a result of nutrient loading resulting from the Garrison Diverion Unit, cannot be accurately predicted.

Of concern to Canadians is the total nutrient load which will be discharged into the Red and Souris Rivers which will primarily accrue to Lake Winnipeg. Inland Waters Branch (1972: 122) cites the estimation of nutrient (N and P) loads as one approach for estimating the degree of eutrohpication in an aquatic ecosystem. the Branch states that: "The same loading rate per unit can cause quite different effect on lakes of different depths in the sense that deeper lakes can withstand higher loading rates than shallower ones without displaying apparent effects". As Lake Winnipeg is a shallow lake, having a maximum depth of 32 m (105 ft) and a mean depth of 10.6 m (34.8 ft) (Brunskill 1974: 1), high nutrient loads have the potential to cause rapid eutrohpication. This eutrohpication potential is somewhat reduced by the extreme turbulence and by mixing of waters in the

North and South Basins of the Lake, caused by the effects of high winds on a lake with a large surface areas and a very shallow depth. However, Brunskill (1974: 4) states: "Studies of Freshwater Institute staff revealed that the South Basin was eutrophic by morphometric, chemical, zoobenthic, attached algal and phytoplanktonic standards. Frequent blooms of the blue green algae Microcystis flosaquae and M. aeruginosa were observed".

Currently rivers flowing into Lake Winnipeg contribute 61,920 metric tons of total nitrogen (TN) and 5,215 tons of total phosphorus (TP) annually (Brunskill 1974). This is equivalent to 68,255 short tons of TN and 5,749 shorts tons of TP. The projected increase in nitrate-nitrogen loading in the Souris and Red Rivers, as a result of the Garrison Diversion Units, was cited earlier as 1,306 short tons. This is equivalent to $\frac{1,306}{4.5} \times 100 = 290$ short tons of nitrogen (N) or $\frac{290}{68,255} \times 100 = 0.42\%$ of the TN that is discharged into Lake Winnipeg annually. This is a minimum figure which does not account for nitrates carried by surface runoff, nitrates incorporated into plant tissues, nitrogen in animal wastes, or nitrogen in agricultural processing wastes. No similar calculation can be made for phosphorus due to a lack of base data. However, it is valid to assume that increases phosphorus loads will enter Lake Winnipeg as a result of the Garrison Diversion Unit. Brunskill argues that algal growth in the South Basin of Lake Winnipeg did not appear to be limited by N or P, "but was more likely limited by light penetration into the very turbid and turbulent water" (Brunskill 1974: 4). Thus, additional N and P would not be significant in terms of increased eutrohpication in the South Basin of the Lake. According to Brunskill (1974: 4) the North Basin of the Lake was clearer water than the South Basin, with concentrations of NO_3, NH_3, and molybdate-reactive PO_4 dropping to "very low or undetectable loads in mid-summer after blue-green algal blooms". It is possible that increased N and P loading in Lake Winnipeg could, to a minor extent, accelerate mercial and sport fisheries operating in the North Basin as well as other beneficial uses such as recreational activities. In its comments on the Final Environmental Statement, EPA (1974b: 5) states:

> "The effects of Garrison return flows on Lake Winnipeg may be more serious than described in the Final EIS (Bureau of Reclamation 1974a). Although it is true that flow contributions to Lake Winnipeg from the Souris and Red Rivers are small in comparison to other sources, TDS and nutrient

> loads from any source become significant when the currently degraded status of Lake Winnipeg is considered.... As the Bureau of Reclamation's draft report 'Irrigation Return Flows to the Souris River and Canada, Garrison Diversion Unit' indicates, nutrient (NO_3 - N) loads to the Souris River will be increased by almost 50% over historic average loads. We do not feel that these increased pollutant loads to Lake Winnipeg will be consistent with pollution control efforts in Canada."

Also to be considered are the impacts on Lake Manitoba which will receive some N and P from Garrison return flows during the spring when the Portage diversion allows excess water in the Assiniboine River to flow into Lake Manitoba. Data are not available at this time to predict any impact on Lake Manitoba, although due to the short period of time during which Garrison return flows could enter Lake Manitoba each year, the impact would likely be quite small. Any impact, however, could be crucial for Delta Marsh, a major waterfowl staging, feeding, and breeding area on the south end of the lake.

II.E PESTICIDES

II.E.1 Introduction

Pesticides[1] will be used both on land irrigated by the Garrison Diversion Unit and in, and along the banks of, canals, distribution laterals, and drains. These pesticides may be classified into four groups:

1) Group A Pesticides are aquatic herbicides to be used in canals, laterals, and drains to control algae and other aquatic vegetation. These pesticides may be carried into Canadian water bodies in operational losses, whereby water from canals and laterals will be discharged directly into the drainage system, and in seepage losses, whereby water seeping from canals and distribution laterals will percolate through the soil into the drainage system.

2) Group B Pesticides are herbicides to be used along banks of canals, laterals, and drains to control grasses and weeds. The mechanisms whereby these pesticides may enter Canadian water bodies are the same as those for Group A pesticides.

3) Group C Pesticides are herbicides and Group D Pesticides are insecticides. Both groups will be used on proposed irrigation areas of the Garrison Diversion Unit. These pesticides may be transported in surface runoff or they may be leached into the ground water drainage system.

Group A and Group B pesticides, (and any toxic breakdown products) which may be present in operational wastes, are the most likely groups to enter Canadian water bodies. These pesticides are not subject to percolation through soil, a process which can be expected to remove a significant portion of pesticide residues in water due to adsorption to soil particles.

Group C and Group D pesticides (and any toxic breakdown products) which may be present in surface runoff could also enter Canadian water bodies. Surface runoff may carry pesticide residues in solution and/or adsorbed to suspended soil particles. Sprinkler irrigation will not normally cause surface runoff; however, snowmelt and rainstorms will. It is anticipated that surface runoff will be increased in the proposed irrigation areas due to the increased moisture content of the soil resulting from irrigation (see section II.C). In addition, Group C and D pesticides may enter Canadian water bodies as a result

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1 Pesticides are taken to include herbicides and insecticides.

of the misuse or overuse of irrigation equipment by farmers in irrigated areas, which could cause both surface runoff and increased leaching of pesticides through soil.

The pesticides discussed will not likely enter waters flowing into Canada if they must pass through the soil enroute. For example, Group A and B pesticides are not likely to be transported to a measurable extent in canal seepage and Groups C and D pesticides are not likely to be transported to watercourses via leaching through the soil. Soil has a very high capacity for the adsorption of organic pesticides largely due to the presence of soil organic matter. Pesticides subject to movement by seepage or leaching alone therefore will move only very short distances (in the order of inches or feet) through the soil. With increased water supply to croplands due to irrigation, leaching of pesticides through soil would be increased but pesticide levels in ground water destined for Canadian rivers are still projected to be very low. However, this process depends upon the type of soil, climactic conditions, the type of pesticides used, and the distance which ground water must pass through soil before reaching the surface drainage system.

Another potential mechanism whereby pesticides used as a result of the Garrison project may enter Canadian water bodies is the accidental spillage and dumping of pesticides by careless operators, and the careless disposal of spray machine washings, excess pesticides and used pesticide containers, both along canal banks and on irrigated croplands.

II.E.2 Pesticides Used as a Result of the Garrison Diversion Unit

In the Final Environmental Statement, the Bureau of Reclamation (1974a: III-69) indicates that the following pesticides will be used as a result of the Garrison Diversion Unit:

1) Copper sulfate, xylene, and acrolein to control algae and submerged and floating pondweeds in canals, laterals, and drains (Group A);

2) herbicides, including 2, 4-D, dalapon, and TCA, to control grasses and annual weeds on canals, laterals, and drains (Group B). The primary herbicide to be used would be 2, 4-D;

3) herbicides, used on irrigated crops in North Dakota to control broadleaf weeds and grasses (Group C). Commonly used herbicides include soil-applied

herbicides such as propachlor, atrazine, and trifluralin and the phenoxy herbicides including 2,4-D and MCPA; and

4) insecticides, which are not used on a regular basis, but which are required when substantial insect infestations occur on crops (Group D). The most common insecticides used are organo-phosphates and carbamates.

The Bureau states that the use of herbicides on individual crops, such as corn, will increase with irrigation and that a net increase in the use of pesticides is expected for the total areas as a result of irrigation development (Bureau of Reclamation 1974a: III-69).

To assess the environmental impact that increased pesticide use, resulting from the Garrison Diversion Unit, will have on Canada, the following baseline data are required:

1) The change in crop patterns due to irrigation;

2) changes in types of pesticides used and changes in their rates of application;

3) specific information on solubility in water, adsorption by soil particles, persistence in soil, breakdown and its products, and toxicological properties for the various pesticides to be used; and

4) data on the projected levels of pesticides which may accrue to Canadian water bodies and assessment of the environmental impacts associated with those levels.

The only baseline data provided by the Bureau in its Final Environmental Statement are the proposed percentage crop distribution on irrigation areas in the Souris Loop and a partial list of pesticides to be used in, and along the banks of, canals, laterals, and drains and on croplands. The Bureau does not provide information on properties of the pesticides, their rates of application, or the projected levels of pesticides which may accrue to Canadian water bodies.

The most comprehensive information provided for present and future land use in the Souris Loop area is given in Table 13 which was derived from the Supplement to the Final Environmental Statement (Bureau of Reclamation 1974d). The percentage land use in a 202,600 acre block area in the Souris Loop, of which 116,000 acres will be irrigated, indicates a change in land use to planted cropland and hayland from summer fallow, idle cropland, tame pasture, native range, and water and marsh. Crops grown before irrigation are primarily small grains. With irrigation, small grains will be replaced by le 13. Land use - Souris block area.[1]

d Use	Area Before Irrigation (Acres)	(%)	Area With Irrigation (Acres)	(%)	Percent change due to Irrigation
nted cropland	77,490	38.2	107,040	52.8	+14.6
mer fallow	37,370	18.4	16,320	8.1	-10.3
land	16,660	8.2	45,810	22.6	+14.4
e cropland	13,410	6.6	5,850	2.9	- 3.7
e pasture	3,770	1.9	1,600	0.8	- 1.1
ive range	32,000	15.8	13,700	6.8	- 9.0
ds	9,530	4.7	9,530	4.7	0
er and marsh	10,960	5.4	1,340	0.7	- 4.7
er lands	1,410	0.7	1,410	0.7	0
ALS	202,600	100	202,600	100	0

ta are from Bureau of Reclamation (1974d).

corn, potatoes, sugar beets, and barley (see Table 13). This change implies increased intensification of agriculture and hence, increased use of pesticides.

In their latest report, Irrigation Return Flows to the Souris River and Canada, the Bureau (1974b: 39) states:

> "...with the present tight controls on the use of persistant compounds established by the Environmental Protection Agency (for both herbicides and insecticides), it appears that any approved material used to combat weeds and insects will be degradable and of such short life that there will be no appreciable increase in pesticide levels of the Souris River."

The Bureau cites tests by Evans and Duseja on sprinkler-irrigated croplands which showed that:

> "...all herbicide concentrations dropped below the limit of detection within a few hundred meters below the sprayed area.[1] Presumably soil filtration, adsorption, and dilution are primarily responsible for the loss of herbicides from water" (EPA 1973, cited in Bureau of Reclamation 1974b: 39).

The Bureau cites another pesticide study on the Columbia Basin Project and claims that "...this study is the only investigation that has been or is being conducted to monitor and study pesticide residues in the return flows from a large operating irrigation project" (Bureau of Reclamation 1974b: 40). The Bureau found no significant amounts of pesticide residues in return flows from the Columbia Basin Project and because of similarities between soil and other conditions, concludes that "..there will be no problems with pesticide residues on the Garrison Diversion Unit."

In its review of the latest Bureau report (Bureau of Reclamation 1974b), EPA (1974a: 7) concludes:

> "We do not feel that conclusions concerning pesticide concentrations in surface waters are appropriate until the North Dakota State University study results are available for evaluation. In our view, reference and comparison to preliminary study results in the Columbia River Basin, without the benefit of actual data collection and analysis in the Souris Loop Area, is premature, and could be misleading."

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1 "Below the sprayed area" is equivalent to downstream of the sprayed area.

The Bureau does not indicate whether pesticides in water, pesticides adsorbed to suspended sediments, or both were measured in return flows from the Columbia River Basin. This distinction is very crucial. Lichtenstein (1972: 190) notes "It appears unlikely that commonly used insecticides are moved within water through soils. They could, however, be transported with washed off soil particles." The Bureau does not indicate the types of crops grown in the Columbia River Basin, nor do they describe the environmental similarities or differences between the basin and the proposed irrigation areas of the Garrison Diversion Unit. The type of crop grown and the environmental conditions define the type and rate of application of the pesticide. In addition, environmental conditions affect the solubility, persistence in soils, and other physical properties of pesticides. Thus, we cannot rely on the Bureau's comparison with their Columbia Basin study as an indicator that pesticide levels in return flows from Garrison irrigation areas will not be significant.

Moreover, the Bureau ignores what could be the most significant source of residual contamination - that of Group A and B pesticides which may be present in canal, drain, and lateral water which would enter Canadian rivers in operational wastes from the project.

II.E.3 Changes in Pesticide Levels in Canadian Water Bodies

The Bureau provides incomplete information on the types and quantities of pesticides to be used on crops in proposed irrigation areas. For this reason, Manitoba Department of Agriculture (1974b) and Western Committee on Crop Pesticides (1973) specifications for pesticide application rates were used for potatoes, corn and sugar beets. Due to the proximity and similarity in climactic conditions of the Souris Loop area to Manitoba, extrapolating Manitoba pesticide application recommendations to the Souris Loop area in North Dakota should be reasonably valid.

Group A and B pesticides, which are used in and along canals, laterals, and drains, and Group C and D pesticides, which are recommended for use on corn, potatoes, and sugar beets are pesticides whose use will increase in North Dakota as a result of the Garrison Diversion Unit. Pesticide types, rates of application, solubilities in water, and adsorption by and persistence in soil are given in Table 14. These characteristics are important in determining the potential for pesticides to be carried with surface runoff or leached from soil into ground water. Two pesticides in Table 14, namely chlordane and endosulfan are chlorinated hydrocarbons, and may not be used in the United States, due to their high toxicity (to fish, birds, and aquatic invertebrates) and long persistence in the environment. However, EPA has recently approved the use of toxaphene (a chlorinated hydrocarbon) to control beetles in sunflowers in North Dakota and the use of DDT in special cases (tussock moth, pea weevil) although a general ban is in effect. This recent approval may increase pressures for relaxation of restrictions on persistent pesticides.

a) Group A and B Pesticides

Operational losses, which are expected to equal 7,000 acre-feet per year in the Souris Loop area (Bureau of Reclamation 1974b: 26) could carry Group A and B pesticides into the Souris River either in soluble form or adsorbed to suspended sediments. Information on adsorption to soils is very limited for Group A and B pesticides. Group B pesticides are generally highly soluble in water and leach readily from soils, whereas Group A pesticides range from insoluble to moderately soluble (see Table 14).

b) Group C and D Pesticides

Group C and D pesticides may enter the Souris River in irrigation return flows or in surface runoff from rainstorms and spring melt. As sprinkler irrigation will be used on lands to be irrigated by the Garrison Diversion Unit, irrigation return flows will primarily consist of water which has percolated through the soil into the ground-water drainage system. No surface-water return flows are anticipated by the Bureau (J. Keyes, personal communication), except in the event of overuse of irrigation equipment by individual landowners. Approximately 63,000 acre-feet per year of return flows will drain into the Souris River (Bureau of Reclamation 1974b: 28).

Surface runoff may carry pesticides by removing unadsorbed pesticides, by desorbing the pesticides and transporting them either in solution or in suspension, or by carrying away some of the soil and the adsorbed pesticides with it. Usually a higher concentration of pesticides is associated with sediments carried by surface runoff than in runoff water itself (Webster 1974: 13). Ground water carries pesticides which have been leached from the soil. Webster (1974: 17) argues that:

Table 14 (cont.)

[1]Data are from Manitoba Department of Agriculture (1974a).

[2]Data are from Manitoba Department of Agriculture (1974b).

[3]Data are from Mantioba Department of Agriculture (1974c).

[4]Data are from Bureau of Reclamation (1974a).

[5]Data are from Western Committee on Crop Pesticides (1973).

[6]Data are from U.S. Dept. of Interior (1969).

[7]Data are from Weed Society of America (1970).

[8]Data are from Agriculture Canada (1973).

[9]Data are from McKee and Wolf (1973).

[10]Data are from U.S. Office of Science and Technology (1971).

[11]Group 1 weeds include flixweed, kochia, lamb's-quarters, mustard, ragweed, shepherd's purse, stinkweed.

Group 2 weeds include Canada thistle, dog mustard, pigweed, russian thistle, sow-thistle, cocklebur.

[12]Chlordane and Endosulfan are chlorinated hydrocarbons which may not be permitted for use in the U.S. due to EPA regulations; however, they are registered for use in Canada.

Blanks on Tables indicate that no data are available.

TABLE 14. Pesticides — Use and physical properties

PESTICIDE	ALTERNATE NAMES	APPLIED TO	PESTS	APPLICATION RATE	SOLUBILITY IN WATER	SOIL ADSORPTION	PERSISTENCE IN SOIL
GROUP A — Used in Canal, Lateral, Drain Water — HERBICIDES							
ACROLEIN	2-Properal, Aqualin, Acrylaldehyde	Water	Algae, Submerged and Floating Pondweeds	0.1-15.0 mg/l[5]	Moderate at 20°C[8]		2-3 days[7]
COPPER SULPHATE	Bluestone, Blue Vitriol, Cupric Sulphate, Blue Copperas	Water	Algae, Submerged and Floating Pondweeds	0.5-3.0 mg/l[5]	316g/100g at 0°C[8]		
XYLENE		Water	Algae, Submerged and Floating Pondweeds		Insoluble[9]		
GROUP B — Used along Canal, Lateral, Drain Banks — HERBICIDES							
2, 4-D	Chloroxane, Salvo, Weedone, Weedar 64	Banks	Grasses and Annual Weeds	1-4 lb/A[6]	Acid-.06-.07g/100g (at 20°C) Amine Salt - 300g/100g at 20°C Ester - Insoluble	Salts - Readily Leached[7]	1-4 weeks[7]
DALAPON	Basfapon, Doupon, Gramevin, Radapon, Unipon	Banks	Grasses and Annual Weeds	30-50lb/A[6]	Very Soluble[7]	Readily Leached[7]	2-4 weeks[7]
T.C.A.	Trichloroacetic Acid	Banks	Grasses and Annual Weeds	50-200 lb/A[7]	Highly Soluble [7] 1306g/100g	Readily Leached[7]	3-10 weeks[7]
GROUP C — Used on Irrigated Crops — HERBICIDES							
ATRAZINE	Aatrex, Fenamine, Fenatol, Gesaprim, Primatol A.	Corn	Wild Oats, Green Foxtail, Barnyard Grass, Groups 1 and 2[11]	1lb/a with 3-4 lb/a Butylate[7]	0.0033g/100g at 25°C[8]	Adsorbed More Readily on Muck or Clay Soils[7]	17 months[10]
BARBAN	Carbamate, Carbyne	Corn	Wild Oats	8-12 oz/a[2]	0.0011g/100g - Insoluble[7]	Adsorbed and Held on Most Soils[7]	3 weeks[7]
BUTYLATE	Sutan	Corn	Wild Oats, Green Foxtail, Barnyard Grass, Groups 1 and 2[11]	3-4 lb/a with 1 lb/a Atrazine[7]	0.0036g/100g at 20°C[8]	Leached ⅓ of Distance that 8" of Water Moved Through Soil[7]	T½=1.5 - 3 weeks[7]
CYCLOATE	Ro-Neet	Sugar Beets	Barnyard Grass, Broadleaf Weeds	4-5 lb/a[2]	0.0075g/100g at 20°C[8]	Resists Leaching in Clay and High Organic Matter Soils Leached 3-6" Downwards with 8" of Water in Loamy Soils[7]	T½= 4 - 8 weeks[7]
CYANAZINE	Bladex	Corn	Broadleaf Weeds, Wild Oats, Green Foxtail, Barnyard and Crab Grass	2 lb/a[2]	0.0171g/100g at 25°C[7]	Reversibly Adsorbed[7]	T½= 2 - 7 weeks[7]
CYPRAZINE	Outfox	Corn	Broadleaf Weeds, Wild Oats, Green Foxtail, Barnyard and Crab Grass	¾-1 lb/a[2]	0.00069g/100g at 25°C Low Solubility[8]	Adsorption Inversely Related to Clay and Organic Matter Content of Soils[7]	Less Than 12 Months[7]
2, 4-D	Chloroxane, Salvo, Weedone Weedar 64	Corn	Buckwheat, Smartweeds, Cowcackle, Groups 1 and 2[11]	6-8 oz/a in combination with Dicamba, Mecoprop[2]	Acid - .06 - .07g/100g at 20°C Amine Salt 300g/100g at 20°C Ester - Insoluble[7]	Salts - Readily Leached[7]	1-4 weeks[7]
EPTC	Eptam	a) Potatoes b) Sugar Beets	a) Annual Grasses, Broadleaf Weeds b) Wild Oats, Green Foxtail	3-4 lb/a[2]	0.0375g/100g at 20°C[8]	Adsorbed into Dry Soil But Can be Removed by Leaching[7]	3 to 8 weeks with Little or No Leaching[10]
MECOPROP	Banvel 3, Compitox, Mecopn, Mecopex, Mopp, Kil-Mor	Corn	Buckwheat, Smartweeds, Cowcackle, Groups 1 and 2[11]	6-8 oz/a in combination with Dicamba and 2, 4-D[2]	0.069g/100g at 20°C Slightly Soluble[7,8]	Similar to Other Phenoxy-Type Herbicides[7]	3-4 weeks[7]
MONOLINURON	Aresin, Afesin	Potatoes	Annual Weeds	2 lb/a[2]	0.058g/100g[8]		
PARAQUAT	Gramoxane, Pextrone X, Ortho Paraquat, Weedol	a) Sugar Beets b) Potatoes	a) Seedling Weeds b) Emerged Annual Weeds	0.5-1 lb/a[2]	Completely Soluble[7]	Completely Adsorbed by Soil - Cannot Be Removed By Washing[7]	Very Long Persistence[7]
PHENMEDIPHAM	Betanol	Sugar Beets	Broadleaf Weeds, Green Foxtail	0.75-1.25 lb/a[2]	Essentially Insoluble Less Than 0.001g/100g[7]	Remains in Top Layers of Soil After Application[7]	T½= 25 days[7]
T.C.A.	Trichloroacetic Acid	Sugar Beets	Green Foxtail	4-7 lb/a[2]	Highly Soluble - 1306g/100g[7]	Readily Leached[7]	3-10 weeks[7]
TRIALLATE	Avadex BW, Far-Go	Sugar Beets	Wild Oats	2 lb/a[2]	0.0004g/100g at 25°C [7,8]	Adsorbed by Colloidal Particles[7]	Up to 6 Weeks[7]
GROUP D — Used on Irrigated Crops — INSECTICIDES							
AZINPHOSMETHYL (ORGANO-PHOSPHATE)	Guthion, Carfene, DBD, Gusathian, Methylguthion, Cotnion Methyl	Potatoes	Colorado Potato Beetle	4-6 oz/a[5]	0.0033g/100g at 20°C[8]		
CARBARYL (CARBAMATE)	Sevin	a) Corn b) Potatoes	a) European Corn Borer b) Colorado Potato Beetle	a) 2 lb/a[5] b) 8 oz/a[5]	Slightly Soluble[8] 0.004g/100g at 30°C		
CARBOFURAN (CARBAMATE)	Furadan	a) Potatoes b) Sugar Beets	a) Colorado Potato Beetle b) Sugar Beet Root Maggot	a) 3 oz/a[5] b) 12 oz/a[5]	0.07g/100g at 25°C[8]		
CARBOPHENATHION (ORGANO-PHOSPHATE)	Trithion, Dagadrie, Garrathion	Sugar Beets	Sugar Beet Root Maggot	1 lb/a[5]	Less than 0.0002g/100g at 20°C[8]		Greater Than 6 Months[10]
CHLORDANE[12] (ORGANO-CHLORIDE)	Chlordan, Chlor Kil, Corodane, Kypchlor, Octachlor, Orthoklor, Synklor, Topiclor 20, Velsicol 1068	Potatoes	Wireworms	10 lb/a,[5] Once Every 4 Years	Insoluble[8]	Stable in Soil [9]	8 Years [10]
DIAZINON (ORGANO-PHOSPHATE)	Basudin, Dazzel, Diazajet, Diaziole, Gardentox, Spectracide	Potatoes	Colorado Potato Beetle, Flea Beetle	8-10 oz/a[5]	0.004g/100g at 20°C[8]		9 days - 12 weeks[10]
DIMETHOATE (ORGANO-PHOSPHATE)	Cygon, Daphene, Fostion, MM, Ferkethion, Perfekthion, Rogor, Roxion, Trimethion	Potatoes	Aphids	4-9.6 oz/a[5]	2.0 - 3.0g/100g[8]		Less than 2 months[10]
DYFONATE (ORGANO-PHOSPHATE)	Fonofos	Potatoes	Wireworms	5 lb/a[5]	0.0013g/100g at 22°C[8]	Shows Little Leaching or Movement in Soil[8]	
ENDOSULFAN[12] (ORGANO-CHLORIDE)	Tniodan, Chlorthiepin, Cyclodan, Insectophene, Malic, Malix, Thifox, Thimol	a) Potatoes b) Corn	a) Colorado Potato Beetle, Flea Beetle b) Aphids	12-20 oz/a[5]	Insoluble[8]		
MALATHION (ORGANO-PHOSPHATE)	Carbafos, Cythion, Emmatos, Chemathion, Mercapthion, Kypfos, Malamar, Malaspray	a) Corn b) Potatoes	Grasshoppers, Aphids	a) 12-20 oz/a[5] b) 10-15 oz/a[5]	0.0145g/100g[8]		2 days[10]
PHOSVEL (ORGANO-PHOSPHATE)	Leptophos, Abar	Sugar Beets	Redbacked Cutworm	8 oz/a[5]	Practically Insoluble[8]		
TRICHLORPHON (ORGANO-PHOSPHATE)	Dylox, Neguvon, Chlorophos, Dipterex, Tugon, Metrifonate	Sugar Beets	Beet Leaf Miner, Beet Webworm	8 oz/a[5]	15.4g/100g at 25°C[8]		

"Leaching appears to be an extremely small factor in the moving of pesticide derived material to water, but the input from runoff is considerable and tends to maintain a reservoir of residual pesticides in sediments in rivers and lakes, from which they are very probably slowly released to maintain an equilibrium concentration in the water."

Typically, the more water soluble a pesticide is, the greater is the probability of it being leached through the soil or carried in solution by surface runoff. The greater the adsorption to soil particles which a pesticide exhibits, the greater is the probability that it will be carried along with sediments in surface runoff. Paraquat is an exception to the first part of the rule. Although highly soluble in water, it is adsorbed to the soil by an ion exchange phenomenon, and will be tightly held against leaching (Webster 1974: 13).

Group C herbicides, such as atrazine, barban, butylate, cyprazine, cycloate, 2,4-D ester, phenmedipham and triallate, and Group D insecticides, such as azinphosmethyl, carbaryl, carbophenothion, chlordane, diazinon, dimethoate, dyfonate, endosulfan, and phosvel, have low solubilities in water and moderate to high levels of adsorption to soil particles. These pesticides could potentially be adsorbed onto sediments carried with surface runoff. Group C herbicides, such as cyanazine, 2,4-D amine salts, dalapon, endothall,EPTC, mecoprop, monolinuron, and TCA, and Group D insecticides, such as carbofuran, malathion, and trichlorphon, have moderate to high water solubility and low or reversible adsorption to soil particles. These pesticides may be carried in solution by surface runoff or leached into the soil.

Pesticides in the soil may break down by microbial and chemical action. The products of breakdown may or may not be more toxic than the original pesticides; however, they eventually break down themselves, usually into less toxic compounds. It is the rate and extent of decomposition of these compounds which largely determines their impact on non-target organisms and on the environment.

c) Pesticides accruing to the Red River

The preceeding analysis cites only mechanisms whereby pesticides may enter the Souris River. By the same mechanisms pesticides may enter the Red River. Discussion in this section has been limited to the Souris River as the Bureau does not provide information or crop distributions for proposed irrigation areas whose return flows drain into the Red River.

II.E.4 Environmental Impacts of Pesticides in Canadian Water Bodies

a) General

McKee and Wolf (1973: 355), in their report entitled Water Quality Criteria, conclude:

> "If the number of fish killed per year in the streams of the United States were the criteria of water quality problems, first place among the list of pollutants would be occupied by pesticides."

The possibilities of increased levels of pesticides in Canadian rivers, particularly the Souris River, and the impact of any increased levels on the aquatic ecosystem, and on the quality of water for domestic and industrial consumption, livestock watering, irrigation and recreational uses must be thoroughly examined.

Examination of the impacts of potential increases in pesticide levels in water flowing into Canada by the Bureau is very incomplete. In the Final Environmental Statement the Bureau (1974a: III-74) states "Weed control activities will cause a temporary reduction in wildlife cover and run the risk of possible contamination of project water through accidental spills of herbicides, overapplication of chemicals, and other accidental acts." The Bureau claims that potential misuse of pesticides will be minimized by weed schools and seminars which will be instituted on the project "to teach operators the environmental hazards of weed control work and to train them in the approved methods of operation" (Bureau of Reclamation 1974a: IV-22).

The Bureau, by discussing its educational program, obviously recognizes the risk that could be caused by the potential misuse of pesticidies. However, the Bureau prefers to assume that such misuse will not happen if it institutes weed schools and seminars rather than thoroughly assessing the impacts associated with the use and misuse of pesticides.

b) Impact on the Aquatic Environment

The United States Department of Interior, in its report Characteristics and Pollution Problems of Irrigation Return Flow, states that toxicity of pesticides in water to aquatic species is a function of the temperature, pH, amount of silt, calcium, and magnesium in the water, the species involved, the age of the organism, and other pesticides present (U.S. Department of Interior 1969: 105). However, the Department of Interior (1969: 106) argues:

> "Even in extremely low concentration, pesticides affect all levels of the ecosystem and sublethal doses produce deleterous effects. Fish and wildlife have been killed by pesticides reaching streams from sprayed areas... At sublethal levels, pesticides may produce toxic effects on fish and affect the population's vitality, and it is possible that pesticides may also affect enzyme activity and cell permeabilities within the cells of organisms. Thus, the transfer of nutrients into and within the orgnism may be greatly influenced by pesticide caused damage."

Pesticides, which have not broken down, or their toxic metabolites, when carried into streams, may become concentrated in particulate matter of detritus and utilized as food by the invertebrates. The first step of concentration of pesticide residues in food chains is concentration by the invertebrates upon which some fish feed (U.S. Department of Interior 1969: 106). Group C herbicides 2,4-D and endothall showed significant levels of biological concentration as did Group D insecticides chlordane and diazinon (see Table 16). Bottom organisms concentrated endothall to 200 times the ambient levels.

Tables 15 to 16 provide information on toxicological properties of the pesticides which may be used as a result of the Garrison Diversion Unit, while Table 17 provides a quick summary.

Toxicities of Group A herbicides range from high to low to mammals, high to moderate to fish, and low to moderate to arthropods and amphibians (see table 17). Toxicities of Group B herbicides range from very low to birds, very low to high to fish, moderate to low to arthropods and amphibians, and moderate to benthic organisms (see table 17). The pesticide 2,4-D exhibits biological concentrations ranging from 150 times to 700 times in mussels (see table 16). Combined with its moderate toxicity to fish food organisms, 2,4-D applied to canal banks could pose a serious threat to aquatic ecosystems, if it enters the water.

Toxicities of Group C herbicides range from very low to high to mammals, very low to low to birds, very low to very high to fish, moderate to arthropods and amphibians, and moderate to benthic organisms (see Table 17). Toxicities of Group D insecticides range from moderate to very high to mammals, very low to high to birds, and moderate to very high to arthropods and amphibians (see Table 17).

c) Impact on Domestic and Industrial Water Supply

Information on the environmental impact of various pesticides on aquatic ecosystems and in many cases, information on behaviour and toxicological properties of the pesticides is inadequate. Toxicities to various non-target species, and the role of biological concentration are known for some pesticides. Less is known about the effects of pesticide levels in domestic and industrial water supplies, and in water used for recreational purposes. What is known is that pesticide residues cannot readily be removed. Studies conducted by the Federal Water Quality Administration at the Taft Sanitary Engineering Centre in the United States assessed the effects of various treatments on the removal of dieldrin, endrin, lindane, DDT, 2,4,5-T, and parathion from water. The study showed that: "while each part of the treatment plant may have potential for reducing certain pesticides, no effective practical treatment is known for large volumes of water containing pesticides." (U.S. Department of Interior 1969: 97).

Table 15 (cont.)

[1]Data are from Inland Waters Branch (1972).

[2]Data are from McKee and Wolf (1973).

[3]Data are from Weed Society of America (1970).

[4]Data are from U.S. Office of Science and Technology (1971).

[5]Data are from EPA (1973).

[6]Data are from Agriculture Canada (1973).

ND = Not Detectable.

TABLE 15. Pesticides — permissible levels in water and toxicities

PESTICIDE	DRINKING WATER			INDUSTRIAL WATER			IRRIGATION	LIVESTOCK & WILDLIFE			BIRDS				FISH AND AQUATIC LIFE								AMPHIBIANS, ARTHROPODS		
	CRITERIA		HUMAN TOXICITY	PERMISSIBLE CRITERIA			TOXICITY TO CROPS	TOXICITY TO:			TOXICITY TO:				TOXICITY TO:								TOXICITY TO:		
	PERMISSIBLE CONCENTRATION (mg/l)	DESIRABLE CONCENTRATION (mg/l)	(for a 60-90 kg man)	DAIRY INDUSTRY (mg/l)	BEVERAGES (mg/l)	FOOD PROCESSING (mg/l)		RATS LD50 (mg/kg)	RABBITS LD50 (mg/kg)	CATTLE	MALLARDS (mg/l)	PHEASANT (mg/l)	BOBWHITES (mg/l)	COTURNIX (mg/l)	RAINBOW TROUT LC50 (mg/l)	HARLEQUIN FISH LC50 (mg/l)	BLUEGILLS LC50 (mg/l)	BASS LC50 (mg/l)	CARP LC50 (mg/l)	CATFISH LC50 (mg/l)	PERCH LC50 (mg/l)	FATHEAD MINNOW LC50 (mg/l)	TOAD TADPOLES LC50 (mg/l)	FROG TADPOLES LC50 (mg/l)	WATER FLEAS LC50 (mg/l)
GROUP A																									
ACROLEIN	0.1[1]	ND[1]					60mg/l to[2] beans, corn, sugar beets	4.60[2,3,4]	7.1[2,3]	>600mg/kg[2] (in food)					>5.0[2]		>5.0[2]		1-2[2]					>3.0[2]	
COPPER SULPHATE	1.0[1,2]	<0.01[1]	44mg/l[2] (in water)	0.0[1]	1.0[1]	2.0[1]	.17-20mg/l to sugarbeets & barley 20mg/l to tomatoes[2]	1.0(in food) Toxic Dose[5]		1.0g/LB/day (in food)[5]	SLIGHT TOXICITY TO BIRDS[4]				>.14[2]		.15 (24 hr.)[4]	1.5 (24 hr.)[4]	>0.33[2]	>0.40[2]	>0.67[2]		LOW TOXICITY[4]		0.01-20[2]
XYLENE		<0.3[2]					1200mg/l to beans, 3000 mg/l to corn[2]	4300.0[2]																	
GROUP B																									
2,4-D	0.1[1,2]	ND[1,2]	LD50=[2] 0.7g/kg				3.5mg/l to Sugar Beets[2]	375-666[2,4,6]	800[4]	LD50=[2] 100-800 mg/kg	>5000[4]	>5000[4]	>5000[4]	>5000[4]	SALT-250 (24 hr.) ESTER-0.96 -1.1 (48 hr.)[4]	Salt-1160[4] (24 hr.) ESTER-1.0 (24 hr.)	SALT-350[2] (24 hr.) ESTER-1.3 -2.1 (48 hr.)[4]	SALT-350 (24 hr.)[2]	SALT>260[2]	SALT>500[2]				100[4] (24 hr.)	ESTER-3200 (48 hr.)[4]
DALAPON	0.1[1]	ND[1]						6950-9330[2,3,4]	3860[3,4]	>lg/kg/day in food		>5000[4]	>5000[4]	>5000[4]	>500[4] (24 hr.)	>500[4] (24 hr.)	115-480[4] (24 hr.)	>1000[2] (24 hr.)				440[4] (24 hr.)			6.0[4] (48 hr.)
T.C.A.	0.1[1]	ND[1]	LD50=[2] 3.3g/kg					LD50= 3300-5000mg/kg[2,3,4]	4000[3,4]	NO DANGER[2]					LOW ORDER OF TOXICITY[3]										
GROUP C																									
ATRAZINE	0.1[1]	ND[1]						3080[3]			>5000[4]	>5000[4]	700-800[4]		12.6[4] (48 hr.)	.55[4] (24 hr.)	LOW[3] TOXICITY								3.6[4] (48 hr.)
BARBAN	0.1[1]	ND[1]						1350[3,4,6]																	
BUTYLATE	0.1[1]	ND[1]						4659[3]	4640[3]				>5000[3]		4.2[4] (96 hr.)		6.9[4] (96 hr.)								
CYCLOATE	0.1[1]	ND[1]						2000-3190[3]			LOW TOXICITY[4]				4.5[4] (96 hr.)										
CYANIZINE	0.1[1]	ND[1]						334-340[3,6]			LOW TOXICITY[3]				LOW TOXICITY[3]										
CYPRAZINE	0.1[1]	ND[1]						1000-1400[3]							6.2±1.75[3] (96 hr.)										
2,4-D	0.1[1,2]	ND[1,2]	LD50=[2] 0.7g/kg					375-666[2,4,6]	800[4]	LD50=[2] 100-800 mg/kg	>5000[4]	>5000[4]	>5000[4]	>5000[4]	SALT-250 (24 hr.)[4] ESTER-0.96 -1.1 (48 hr.)	SALT-1160 (24 hr.) ESTER-1.0 (24 hr.)[4]	SALT-350[2] (24 hr.) ESTER-1.3 -2.1 (48 hr.)[4]	SALT-350 (24 hr.)[2]	SALT>260[2]	SALT>500[2]				100 (24 hr.)[4]	ESTER-3200 (48 hr.)[4]
DALAPON	0.1[1]	ND[1]					<0.35 to Corn[2]	6950-9330[2,3,4]	3860[3,4]	>lg/kg/day (in food)[2]		>5000[4]	>5000[4]	>5000[4]	>500[4] (24 hr.)	>500 (24 hr.)[4]	115-480 (24 hr.)[4]	>1000 (24 hr.)[2]				440[4] (24 hr.)			6.0[4] (48 hr.)
DICAMBA	0.1[1]	ND[1]						2900± 300			LOW TOXICITY[3]				28[6] (96 hr.)		130[4] (48 hr.)								
ENDOTHALL	0.1[1]	ND[1]					25mg/l to Corn[2]	35-51[2,3,4,6]							>10[2]		125[4] (96 hr.)	120[4] (96 hr.)	175[4] (96 hr.)			>560[4] (24 hr.)			
EPTC	0.1[1]	ND[1]						1630[4,6]			LOW TOXICITY[4]				19[4] (96 hr.)		27[4] (96 hr.)								
MECOPROP	0.1[1]	ND[1]						650[3,6]			TOXICITY SAME AS OTHER PHENOXY-TYPE HERBICIDES[3]														
MONOLINURON	0.1[1]	ND[1]						2250[6]																	
PARAQUAT	0.1[1]	ND[1]						150[3,6]			GENERALLY SAFE[3]					840[4] (24 hr.)	400[4] (24 hr.)						54[4] (24 hr.)	43[4] (24 hr.)	3.7[4] (48 hr.)
PHENMEDIPHAM	0.1[1]	ND[1]						>8000[3]							LETHAL[3] AT .02	HIGHLY TOXIC TO FISH[6]									
T.C.A.	0.1[1]	ND[1]	LD50=[2] 3.3g/kg					LD50=[2,3,4] 3300-5000mg/kg	4000[3,4]	NO DANGER[2]					LOW ORDER TO TOXICITY[3]										
TRIALLATE	0.1[1]	ND[1]						1350-2165[3,6]																	
GROUP D																									
AZINPHOSMETHYL	0.1[1]	ND[1]	LD50=[2] .003g/kg					16.4-18[4,6]		0.5mg/kg[2] TOXIC	1900-2000[4]	1800-2000[4]	400-500[4]	600-700[4]	.014[4] (96 hr.)	.13[4] (24 hr.)	0.22[4] (96 hr.)		.695[4] (96 hr.)	3.29[4] (96 hr.)	.013[4] (96 hr.)	.235[4] (96 hr.)	.68[4] (24 hr.)		.0002[4] (96 hr.)
CARBARYL	0.1[1]	ND[1]						540-560[4,6]	125-250[2]		>5000[4]	>5000[4]	>5000[4]	>5000[4]	4.38[4] (96 hr.)	3.4[4] (24 hr.)	6.76[4] (96 hr.)		5.28[4] (96 hr.)	15.8[4] (96 hr.)	.745[4] (96 hr.)	13.0-14.6[4] (96 hr.)			.006-.008[4] (48 hr.)
CARBOFURAN	0.1[1]	ND[1]						10-11[4,6]			FAIRLY TOXIC[4]														
CARBOPHENOTHION	0.1[1]	ND[1]						30-32.2[4,6]								3.4[4] (24 hr.)	.225[4] (48 hr.)							.10[4] (24 hr.)	.009[4] (48 hr.)
CHLORDANE	.003[1]	ND[1]	LD50=[2] 0.086-0.86g/kg					200-590[2,4,6]	100-300[4]	91mg/kg[2] TOXIC	800-850[4]	400-500[4]		300-350[4]	.010[4] (48 hr.)		.022[4] (96 hr.)	>0.2[2]		.5[2] (96 hr.)		.052-.069[2] (96 hr.)			.020[4] (48 hr.)
DIAZINON	0.1[1]	ND[1]	FATAL[2] DOSE-0.36g/kg					76-600[2,4,6]		10mg/kg LETHAL	HIGHLY TOXIC TO BIRDS[4]					1.45[4] (24 Hr.)	0.30[4] (48 hr.)								.0009[4] (48 hr.)
DIMETHOATE	0.1[1]	ND[1]						185-245[4,6]			900-1100[4]	300-400[4]		300-400[4]	19.0[4] (24 hr.)		9.6[4] (48 hr.)								2.5[4] (48 hr.)
DYFONATE	0.1[1]	ND[1]						212[6]																	
ENDOSULFAN								90-110[2,4,6]			900-1100[4]	1200-1350[4]	800-900[4]	2100-2250[4]	.0012[4] (48 hr.)	.00002[4] (48 hr.)	HIGHLY TOXIC TO FISH[6]								.240[4] (48 hr.)
MALATHION	0.1[1]	ND[1]	LD50=[2] 0.86g/kg					480-1500[4]		20mg/kg TOXIC[2]	>5000[4]	2500-4500[4]	3300-3700[4]	2000-2300[4]	.170[4] (48 hr.)	10.0[4] (24 hr.)	.103[4] (96 hr.)	.285[4] (96 hr.)	6.59[4] (96 hr.)	8.97[4] (96 hr.)	.263[4] (96 hr.)	8.65-12.5[4] (96 hr.)	1.9[4] (24 hr.)	.56[4] (24 hr.)	.002[4] (48 hr.)
PHOSVEL	0.1[1]	ND[1]						42-53[6]																	
TRICHLORPHON	0.1[1]	ND[1]						450-560[4,6]					700-800[4]	1800-2000[4]	3.2[4] (48 hr.)			10.4[4] (24 hr.)				180.0[4] (96 hr.)			.00018-[4] .0081 (48 hr.)

Table 16. Supplemental information on toxicity of pesticides.

Pesticide	Toxicity to Benthic Organisms	Biological Concentration
GROUP B		
2,4-D	LC50 to fish organisms is .2-7.5 ppm[2]	Eastern Oysters = 180 times ambient levels Sunfish = 150 times ambient levels Mussels = 380-700 times ambient levels
GROUP C		
Atrazine	Various benthic organisms = .5-2.0 ppm[2]	
2,4-D	Same as above	Same as above
Endothal	Concentrations above 1.0 ppm killed all bottom organisms in pond	Bottom organisms = 200 times ambient levels
GROUP D		
Chlordane		Eastern Oysters = 7300 times ambient levels[2]
Diazinon		Fish = 10 times ambient levels

[1] Data are from McKee and Wolf (1973).

[2] Data are from U.S. Office of Science and Technology (1971).

Table 17. Summary of toxicity of pesticides.

PESTICIDE	TOXICITY TO: MAMMALS	BIRDS	FISH	ARTHROPODS AMPHIBIANS	BENTHIC ORGANISMS	BIOLOGICAL CONCENTRATION
GROUP A						
ACROLEIN	HIGH		MODERATE	MODERATE		
COPPER SULPHATE		LOW	HIGH	LOW		
XYLENE	LOW		MODERATE			
GROUP B						
2, 4-D	MODERATE	VERY LOW	ESTERS—HIGH SALTS—LOW	LOW	MODERATE	180-700 TIMES
DALAPON	VERY LOW	VERY LOW	VERY LOW	MODERATE		
T.C.A.	LOW		VERY LOW			
GROUP C						
ATRAZINE	LOW	VERY LOW	MODERATE	MODERATE	MODERATE	
BARBAN	MODERATE		MODERATE			
BUTYLATE	LOW	VERY LOW	MODERATE			
CYCLOATE	LOW	LOW	MODERATE			
CYANIZINE	MODERATE	LOW	LOW			
CYPRAZINE	MODERATE		MODERATE			
2, 4-D	MODERATE	VERY LOW	ESTERS—HIGH SALTS—LOW	LOW	MODERATE	180-700 TIMES
DALAPON	VERY LOW	VERY LOW	VERY LOW	MODERATE		
DICAMBA	LOW	LOW	LOW			
ENDOTHALL	HIGH		LOW		HIGH	200 TIMES
EPTC	LOW	LOW	MODERATE			
MECOPROP	MODERATE					
MONOLINURON	LOW					
PARAQUAT	MODERATE	LOW	VERY LOW	MODERATE		
PHENMEDIPHAM	VERY LOW		VERY HIGH			
T.C.A.	LOW		VERY LOW			
TRIALLATE	LOW					
GROUP D						
AZINPHOSMETHYL	VERY HIGH	MODERATE	HIGH	VERY HIGH		
CARBARYL	MODERATE	VERY LOW	MODERATE	HIGH		
CARBOFURAN	VERY HIGH	MODERATE				
CARBOPHENOTHION	HIGH		MODERATE	HIGH		
CHLORDANE	MODERATE	HIGH	VERY HIGH	HIGH		7300 TIMES
DIAZINON	MODERATE	HIGH	HIGH	VERY HIGH		10 TIMES
DIMETHOATE	MODERATE	HIGH	MODERATE	MODERATE		
DYFONATE	MODERATE					
ENDOSULFAN	MODERATE	MODERATE	VERY HIGH	HIGH		
MALATHION	MODERATE	LOW	MODERATE	HIGH		
PHOSVEL	HIGH					
TRICHLORPHON	MODERATE	MODERATE	MODERATE	VERY HIGH		

Table 17 (cont.)

[1]Toxicity ratings based on lethal concentrations, lethal doses, and general toxicities in Tables 15 and 16:

- Very High indicates very low LC, LD, or toxic levels in comparison with all pesticides listed.
- High indicates comparatively low LC, LD, or toxic levels.
- Moderate indicates average LC, LD, or toxic levels.
- Low indicates comparatively high LC, LD, or toxic levels.
- Very Low indicates very high LC, LD, or toxic levels.

II.F TRACE ELEMENTS

II.F.1 Introduction

Trace elements, such as arsenic, boron, copper, iron, lead, and zinc may be carried by irrigation waters or may be leached from soils into irrigation return flows. Seepage and operational losses may carry trace elements which are present in irrigation waters into Canadian water bodies while irrigation return flows may carry trace elements which are leached from soils into Canadian water bodies.

II.F.2 Changes in Trace Element Levels in Canadian Water Bodies

To establish the potential for changes in trace element concentrations in Canadian water bodies, the following must be known:

1) Trace element concentrations and pH of applied irrigation waters;
2) trace element levels in soils in proposed irrigation areas;
3) adsorption characteristics of trace elements in soil particles; and
4) projected trace element concentrations in irrigation return flows and operational losses and in seepage.

As none of this information is provided by the Bureau with the exception of boron and iron concentration in applied irrigation water to the Souris Loop area (see table 18), no evalution of changes in trace element levels in Canadian water bodies is possible.

In its latest report, Irrigation Return Flows to the Souris River and Canada, the Bureau (1974b: 50) states:

> "Irrigation in the Souris Loop area is not expected to increase concentrations of trace metals in Souris River streamflow. In reviewing the limited data available on heavy metals in soils and streamflow in the basin, it was found that there is little difference between concentrations of these materials in streamflows during wet and dry years. The increased precipitation on lands of the area (similar to irrigation) appeared to have no relationship with levels of trace metals in flows of the Souris River."

However, this conclusion is made with very limited supporting data. The limited data which the Bureau refers to for heavy metals concentrations in Souris River streamflow is based on samples taken from the Souris River

Table 18. Trace elements - concentrations and criteria.

Element	Conc. in Irrigation Water (mg/l)	Historic Conc. in Souris River (mg/l)	Objective Level (mg/l)	Acceptable Level (mg/l)	Max. Permis- sible Level (mg/l)	North Dakota Water Quality Standard[4] (mg/l)	Criteria- Irrigation Waters[5] (mg/l)
Arsenic		0.006	ND	0.01	0.05	0.050	1.0
Barium		0	ND	1.0	1.0	1.000	
Berylium		0					0.5
Boron	0.05	0.174		5.0	5.0	0.500	0.75
Cadmium		0	ND	0.01	0.01	0.010	0.005
Chromium		0				0.050	5.0
Cobalt		0					0.2
Copper		0.011		0.01	1.0	0.050	0.2
Iron	0.03	NT		0.05	0.3		
Lead		0.001	ND	0.05	0.05	0.050	5.0
Lithium		0.044					5.0
Mercury		0			0.0001[6]		
Molybdenum		0.002					0.005
Nickel		0.003					0.5
Selenium		0.008	ND	0.01	0.01	0.010	0.05
Silver		0			0.05		
Strontium		0.266				10.0[7]	
Vanadium		0.001				0.500	10.0
Zinc		0.015		1.0	5.0		5.0

Table 18. (cont.)

[1]Data are from Bureau of Reclamation (1974b: 30)

[2]Data are from Bureau of Reclamation (1974b: 49)

[3]Data are from Inland Waters Branch (1972: 29,31)

[4]Data are from Bureau of Reclamation (1974c: 93)

[5]For water used continuously on all soils - Data are from U.S.D.A. (1962, cited in U.S. Dept. Interior 1969: 47)

[6]Level recently set by Provinces of Alberta and Saskatchewan.

[7]NTAC - FWPCA standard cited in U.S. Dept. Interior (1969: 93)

ND = not detectable

NT = element not included in U.S.G.S. sampling

Blanks on Tables indicate data are not available.

at Westhope, North Dakota by the U.S. Geological Survey. Sixteen samples were taken during the period October 1968 to October 1973 (see Table 18 for average concentrations). This is not a sufficient length of time to conclude that there was little difference in trace element concentrations between wet and dry years.

The Bureau does not provide any information on projected trace element concentrations in return flows or seepage and operational losses which drain into the Sheyenne and Wild Rice and thus into the Red River.

II.F.3 Environmental Impacts of Trace Elements

a) Municipal Water

Historic concentrations of trace elements in the Souris River, for the period October 1968 to October 1973 along with both Canadian and North Dakota drinking water standards are given in Table 18.

No concentrations in the Souris River presently exceed the standards although selenium is close to the Canadian maximum permissible level and the North Dakota standard. It is impossible with the present data to predict whether any of these elements will exceed the criteria for drinking water as a result of the Garrison Diversion Unit.

b) Irrigation Water

Criteria for trace element concentrations in irrigation waters are given in Table 18. Historic levels in the Souris are well below these criteria. However, it is known that boron, which may appear in irrigation return flows in significant quantities, may be toxic to plants in concentrations as low as 1.0 to 4.0 mg/l (U.S. Department of Interior 1969: 53).

c) Aquatic Environment

The U.S. Department of Interior (1969: 104) claims:

> "Of the components listed as significant in irrigation return waters, only the compounds of boron, fluorine, sulfur, and iron occur in concentrations sufficiently great to be toxic to fish or to other components of the aquatic ecosystem. Of the elements, the heavy metals which for the most part appear as trace elements are universally toxic to both plants

and animals when sufficiently concentrated. Zinc, for example, is toxic to fish in concentrations as low as 0.3 mg/l; lead in concentrations as low as 0.1 mg/l; silver as low as 0.005 mg/l."

The U.S. Department of Interior (1969: 104) claims that boron may occur in return flows in amounts toxic to vascular plants in the aquatic ecosystem.

II.G TEMPERATURE

II.G.1 Introduction

Irrigation return flows and seepage and operational losses which accrue to the Souris and Red Rivers from proposed irrigation areas of the Garrison Diversion Unit may have a substantially different temperature than river water. Mixing of accruals with river water may result in dramatic changes in the temperature regime of the Souris and Red Rivers.

II.G.2 Temperature Changes in Canadian Rivers

a) Souris River

The Bureau of Reclamation in its latest report Irrigation Return Flows to the Souris River and Canada, indicates that the contribution of return flows, which will be at the ambient ground-water temperature of the area, to the Souris River "...should result in lower temperatures of the water in the summer and higher temperatures in the winter." (Bureau of Reclamation 1974b: 47).

The Bureau cites results of sampling 40 or more ground-water wells in the Souris Loop area from 1969-1971. Figure 3, which is reproduced from the Bureau's report (Bureau of Reclamation 1974b), shows the results of those studies. From early October to late April, ground-water temperatures were higher than river-water temperatures, and from early June to early October they were lower. During May, the spring runoff period, the two temperatures were nearly the same.

Table 19 calculates the resultant temperature when accruals are mixed with Souris River water, based on average monthly flows and on average monthly temperatures estimated from Figure 3. Column 6 from Table 19 - the resultant temperature - has been traced on Figure 3. It is important to note that this resultant temperature curve merely joins the monthly average resultant temperatures. It is not a continuous curve as are the other two. Thus, for the resultant temperature curve the peaks and valleys are underemphasized. Souris River temperatures will be increased by a maximum of 7.3° C in December and decreased by a maximum of 4.7° C in August. These increases or decreases are only valid at the point of mixing in North Dakota. Whether

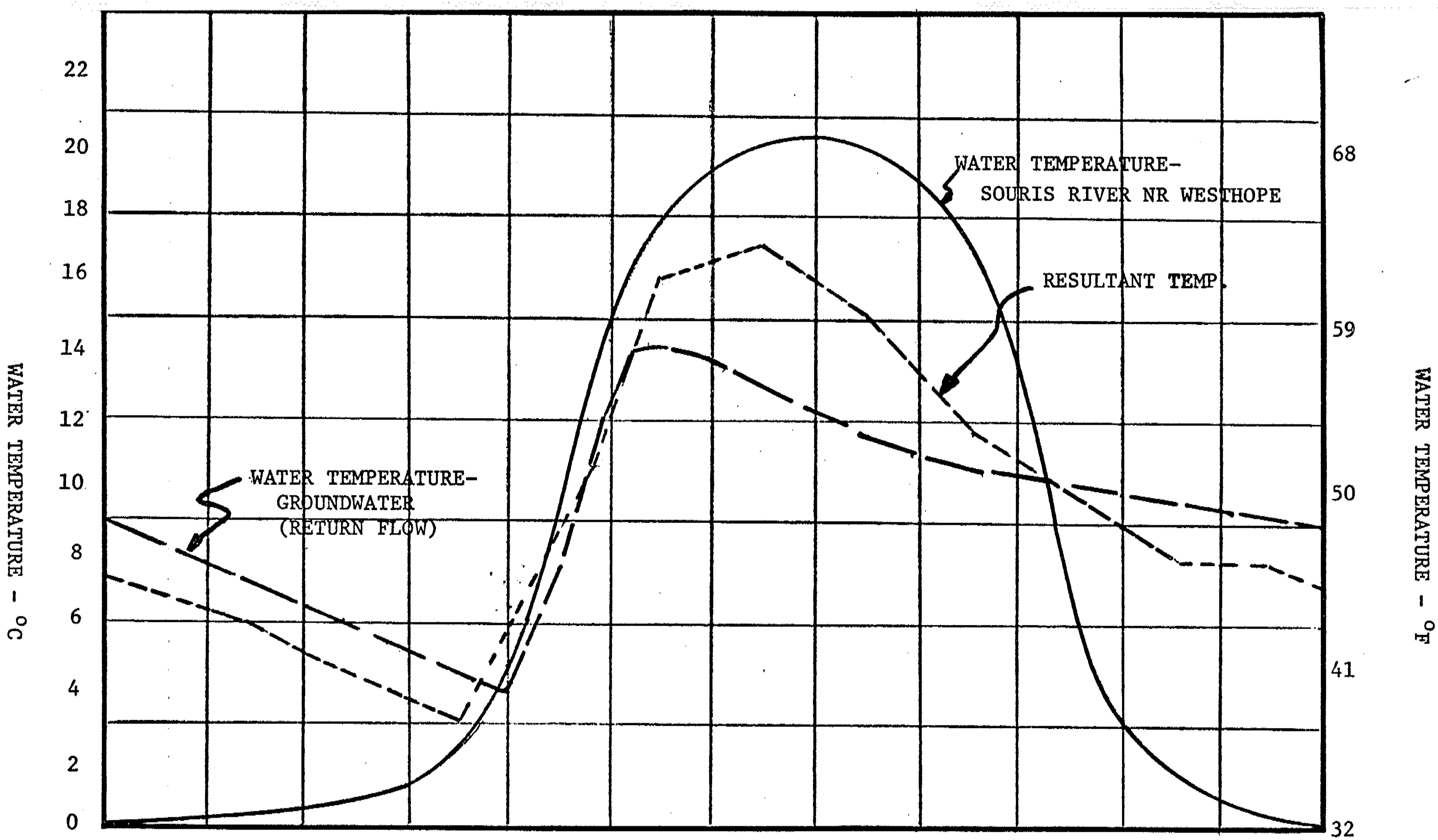

FIG. 3 Typical water temperature patterns - Souris Loop Area. (Based on observations at 1969, 1970, 1971) (from Bureau of Reclamation 1974b).

able 19. Souris River - resultant water temperature.

	Flows			Temperatures		
	Historic Avg.[1] (cfs)	Accruals[2] (cfs)	Resultant[3] (cfs)	Historic Avg.[4] (°C)	Accruals[4] (°C)	Resultant[5] (°C)
an	26.4	115.9	142.3	0.1	8.5	6.9
eb	21.5	86.1	107.6	0.4	7.3	5.9
ar	36.4	87.8	124.2	0.8	5.8	4.3
pr	553.1	81.1	634.2	2.9	4.7	3.1
ay	821.4	124.2	945.6	9.4	9.0	9.3
un	546.5	150.7	697.2	16.7	13.2	15.9
ul	322.9	216.9	539.8	19.8	13.2	17.1
ug	172.2	233.6	395.8	19.8	11.5	15.1
ep	66.2	210.3	276.5	16.5	10.5	11.9
ct	79.5	185.5	265.5	8.5	10.2	9.7
ov	48.0	159.0	207.0	2.1	9.8	8.0
ec	28.2	140.0	169.0	0.5	9.3	7.8

verage for period 1952-1970 (from Table 21).

quilibrium average accruals (from Table 21).

otal of Col. 1 and Col. 2.

stimated from Fig. 3.

esult of [(Col. 1 x Col. 4) + (Col. 2 x Col. 5)] ÷ (Col. 3).

they will hold true further downstream depends upon channel conditions downstream of the mixing point. For example, if increased flows resulted in increased flooding downstream of the mixing point (see section III), then a greater surface area of water would be exposed. Thus, the ambient air temperature may have greater influence on river temperature than under historic conditions. Water temperature may be cooler in winter and warmer in summer, the reverse of what the Bureau indicates. Further studies are required before the relationship between accruals to the Souris and water temperatures at various points along the Souris can be determined.

b) Red River

As no data are provided for monthly accruals or for temperatures of these accruals to the Red River, no changes in water temperature can be predicted. However, since the volume of accruals will be less significant for the Red than for the Souris, water temperature changes will not occur to such a degree.

II.G.3 Impacts of Temperature Changes

The Bureau states that the resultant changes in water temperatures "should prove beneficial to the Souris River." The Bureau cites a lower potential for spring ice jams and hence flooding, and the provision of some open water during winter as benfits of high average water temperatures in the winter and early spring; a decreased potential for algal blooms and thus higher dissolved oxygen levels are cited as benefits of lower average water temperatures in summer and early fall (Bureau of Reclamation 1974b: 48). While this may be true at the mixing point, increased exposure of the water surface further downstream to ambient air temperatures may nullify these benefits and could change them into negative impacts. Reduced temperatures in winter could cause icing and thus a greater potential for ice jams. Increased temperature in the summer could result in a greater potential for algal blooms and thus in a reduced dissolved oxygen content.

If the Bureau is correct and the Souris River does stay open longer, this could result in problems downstream of the open water section. Frazzle ice is found where water contacts the cold winter air. These ice particles then go with the flow under the ice until the flow is slow enough that they become attached to the bottom of the river ice cover. As this process continues, the flow is restricted causing the water to back up in the open water section - eventually flowing out over the ice and freezing. This added weight depresses the ice cover, restricting the flow further. This example, in which the river freezes to the bottom is the worst possible case. However, if this worst case were to occur, impact on aquatic life in the Souris River and on surrounding lands which would be flooded and "iced" would be significant.

Perhaps the greatest impact of temperature changes in the Souris River may be on the aquatic ecosystem. Aqautic organisms have evolved within the historic temperature regime of the Souris River. A dramatic temperature change, which will occur at the mixing point, may make conditions unsuitable for existing organisms and thus disrupt the aquatic ecosystem at that point. Inland Waters Branch (1972: 100) states:

> "It should be recognized that only very small differences in temperature may be accommodated before the ecosystem is in danger of becoming unbalanced. Temperature is an extremely important 'master' or controlling factor and as such it operates uniquely and singly. However, it also acts in conjunction with other environmental factors in significant ways. A stress imposed by temperature will undoubtedly increase the stress imposed by any other factor to which the organism must attempt to accommodate."

CHAPTER III

HYDROLOGY

- INTRODUCTION
- FLOODING POTENTIAL
- STABILIZATION OF FLOWS

III.A INTRODUCTION

As a result of the accrual of irrigation return flows and seepage and operational losses to the Souris and Red Rivers, flows in those rivers will increase. Return flows and seepage and operational losses will accrue to the Souris River from irrigated croplands, canals, laterals, and drains in the Karlsruhe and Middle Souris irrigation areas, and to the Red River (via the Sheyenne and Wild Rice Rivers) from irrigated croplands, canals, laterals, and drains in the New Rockford, Warwick-McVille, and Oakes East irrigation areas (see Table 2).

These accruals will cause a change in flow characteristics in these rivers which may result in increased flooding potential, changes in the timing of flood peaks, and increased stablization of flow.

III.B FLOODING POTENTIAL

a) Souris River

Table 20 provides monthly breakdowns of return flow and seepage and operational losses which will accrue to the Souris River under equilibrium conditions. The total monthly accrual in units of acre-feet is converted to average, monthly cfs (cubic feet per second) units so that comparison can be made with channel capacities. Table 21 provides average, monthly values for historic flows and augmented flows (historic flows plus accruals) for average-, high-, and low-water year conditions. Historic values were obtained from the Bureau of Reclamation's 1953-1970 study period. The full range of the Bureau's discharge data for the Souris River (1931-1970) was not used because the "dry decade" from 1931-1941 is not typical of average historic conditions in the Souris River. Data in Table 21 indicate that the average annual flow will increase from 226.9 cfs to 375.4 cfs (65.4%) under average conditions, from 1069.9 cfs to 1218.4 cfs (13.9%) under high-water conditions, and from 4.0 cfs to 152.5 cfs (3712.5%) under low-water conditions. Figure 4 displays the potential for flooding at four sites along the Souris River. These sites were selected by Environment Canada (1974) for a study entitled Some Effects of the Garrison Diversion Unit on the Souris River in Canada[1], which will be discussed later. Site I, which has a channel capacity of 150 cfs, is immediately north of the Canada - U.S. Boundary. Flows over 150 cfs will innundate pasture lands. Site II, with a channel capacity of 500 cfs, is adjacent to Coulter, Manitoba. Flows over 500 cfs will innundate agricultural lands. Site III, with a channel capacity of 1,400 cfs, is at Melita. Flows over 1,400 cfs flood municipal wells, buildings, access roads, and agricultural lands. Site IV, with a channel capacity of 1,100 cfs is near Lauder. Flows over 1,100 cfs flood agricultural lands and roads. Results shown in Figure 4 indicate that for an average year, accruals to the Souris River increase the flooding from 5 to 9 months for Site I and from 3 to 4 months for Site II. For a low-water year, accruals increase the flooding period from 0 to 7 months at Site I. For a high-water year, accruals increase the flooding period from 6 to 12 months (resulting in all-year flooding) at Site I, from 3 to 4 months at Site III, and from 4 to 5 months at Site IV. These sites represent the

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1 The Environment Canada study referred to was written by individuals in Environment Canada and in the Manitoba Department of Mines, Resources and Environmental Management.

ble 20. Average monthly accruals to the Souris River.

	Return Flows[1] (1000 acre-ft)	Seepage and Operational Losses[1] (1000 acre-ft)	Total Accruals (1000 acre-ft)	Total Accruals[2] (cfs)
	5.0	2.0	7.0	115.9
	4.2	1.0	5.2	86.1
	4.3	1.0	5.3	87.8
	3.9	1.0	4.9	81.1
	4.5	3.0	7.5	124.2
	5.1	4.0	9.1	150.7
	6.1	7.0	13.1	216.9
	6.5	7.0	13.5	223.6
	6.7	6.0	12.7	210.3
	6.2	5.0	11.2	185.5
	5.6	4.0	9.6	159.0
	5.5	3.0	8.5	140.8
AL	63.7	44.0	107.7	1781.9
	5.3	3.7	9.0	148.5

ta are from Bureau of Reclamation (1974c).

nversion: 1000 acre-feet/month = 16.56 cfs ble 21. Historic and augmented flow - Souris River.

	Historic Flows[1] (cfs)			Accruals[5]	Augmented Flows (cfs)		
	Average[2]	High[3]	Low[4]	(cfs)	Average	High	Low
n	26.4	142.4	0	115.9	142.3	258.3	115.9
b	21.5	124.2	0	86.1	107.6	210.3	86.1
r	36.4	155.7	0	87.8	124.2	243.5	87.8
r	553.1	3192.8	0	81.1	634.2	3273.9	81.1
y	821.4	4608.6	0	124.2	945.6	4732.8	124.2
n	546.5	1768.6	5.0	150.7	697.2	1919.3	155.7
l	322.9	1233.7	6.6	216.9	539.8	1450.6	223.5
g	172.2	1031.7	9.9	223.6	395.8	1255.3	233.5
p	66.2	142.4	9.9	210.3	276.5	352.7	220.2
t	79.5	157.3	16.1	185.5	265.5	342.8	202.1
v	48.0	173.0	0	159.0	207.0	332.9	159.0
c	28.2	107.6	0	140.8	169.0	248.4	140.8
AL	2722.3	12,838.9	48.0	1781.9	4504.7	14,620.8	1829.9
G	226.9	1069.9	4.0	148.5	375.4	1218.4	152.5

ata are from Bureau of Reclamation (1974c) -
onverted to cfs.

or period: January 1952-December 1970.

or period: July 1953-March 1954; April 1969-June 1969.

or period : June 1962-May 1963.

ata are from Table 20.

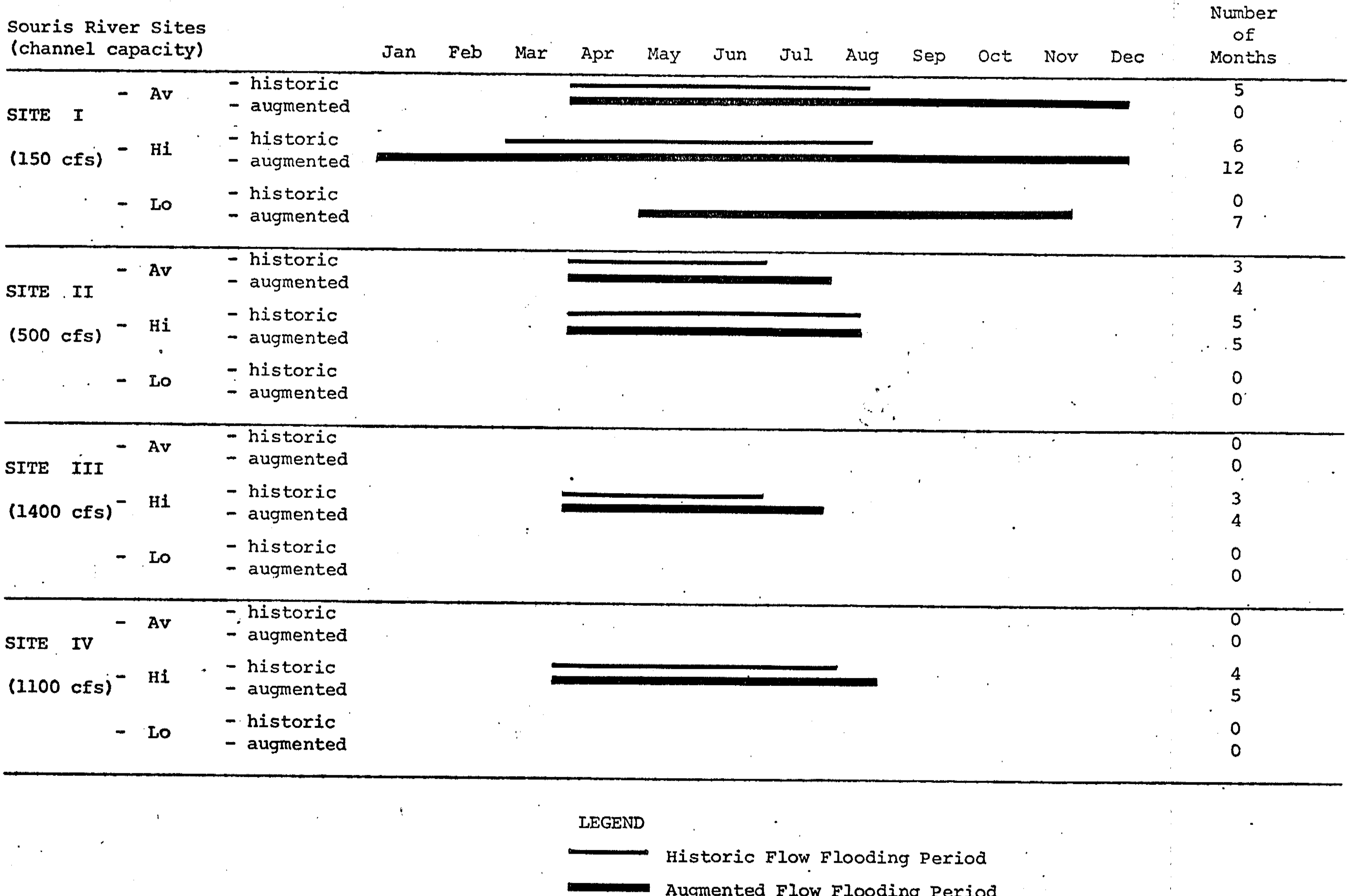

Fig. 4 Flooding periods for historic and augmented flows for four sites along the Souris River (data are from Table 21).

critical section of the Souris River from the Boundary to a point near Lauder (see Figure 2). Farther downstream of Lauder, the channel capacity increases rapidly. At Hartney, it is approximately 3,000 cfs and at Wawanesa (near the junction with the Assiniboine River) it is approximately 10,000 cfs. Only during very high-water years would accruals from the Garrison project increase the period or severity of flooding in the section of the Souris River from a point near Lauder (Site IV) to its confluence with the Assiniboine. Two observations concerning Figure 4 must be made. The first is that Figure 4 only depicts the increase in the period of flooding at the four sites. With increased flows in the Souris, the severity or extent of flooding will also increase for the entire flooding period. The second observation is that increased periods of flooding (as depicted in Figure 4) and increased severity of flooding (see increased flows in Table 21) are only minimum predictions for Sites II, III, and IV. They are only accurate for Site I. Between Sites I and II, natural runoff enters the Souris; between Sites II and III, the Gainsborough Creek and Antler River, and natural runoff enter the Souris; and between Sites III and IV, Graham Creek and Jackson Creek, and natural runoff enter the Souris River. While flows in streams which enter the Souris River are small in comparison with flows in the river, they will increase the period and severity of flooding beyond predicted values.

The Environment Canada (1974) study cited previously, included flows of the Antler River and Gainsborough Creek for Sites III and IV; however, it also notes that additional tributary and local inflow cannot be included and cautions and "...flood flow information quoted herein should be viewed as minimum estimates of historical and potential flood flow conditions." The Environment Canada study tabulates the number of flood days for historic and augment conditions over a 43-year time-span (from 1930 to 1972). Table 22 provides a summary of the results of this study. Both my analysis and the Environment Canada study indicate a substantial increase of flooding at Site I and moderate increases at Sites II to IV. The impact of this will be to innundate pasture-land and cropland along the upper reach of the Souris River in Manitoba to a greater extent and for longer periods, and during high-water years to cause greater damage to municipal wells, buildings, and access roads around Melita. Increased flows will also cause greater severity of flooding along the lower reach of the Souris River and along the Assiniboine River during

Table 22. Number of flood days in 43 years - Souris River.[1]

Location	Recorded Conditions (days)	Augmented Conditions (days)	Difference (days)	Average Annual Increase in Flood Days (days/year)	Percent Increase in Flood Days per year
Site I	3,197	10,613	7,416	172	232%
Site II	1,605	2,037	432	10	27%
Site III	742	1,037	295	7	40%
Site IV	932	1,505	573	13	61%

[1]Mainly from Environment Canada (1974)

periods when flooding normally occurs. In addition, Smith (1974) indicates that flooding may result in a loss of archaeological sites along the Souris River. She states that Professor Leigh Syms of the Department of Anthropology at Brandon University has protested against the Garrison Diversion Unit because of the likely loss of study areas.

Flooding may be one of the most significant environmental impacts for residents along the lower reach of the Souris River resulting from the Garrison Diversion Unit. However, the Bureau only devotes one small paragraph to flooding potential along the Souris in its latest report, Irrigation Return Flows to the Souris River and Canada. According to the Bureau (1974b: 60):

> "Although the majority of Garrison Diversion Unit return flows will accrue with an annual cycle different from that of natural runoff from the basin, the presence of the additional water in the stream channel will cause a slight increase in the flood potential of lower reaches of the Souris River. Peak irrigation return flows will accrue to the river during the late summer and early fall and will not coincide with high runoff periods of the river. However, the conveyance of heavy runoff from intense thunderstorms could be limited by the amount of return flow in the stream channel at the time of the flood. The occurrence of this situation will probably be rare, but the potential for flooding of lower sections of the river could be increased slightly."

In view of the data presented in this section, the Bureau's assessment is very vague and inadequate.

b) Red River

No monthly breakdown is provided by the Bureau for return flows or seepage and operational losses which would accrue to the Red River as a result of the Garrison Diversion Unit. Thus, no prediction of increases in the flooding period or the number of flood days can be made. Data from Table 9 indicates that flows in the Red River may increase by 3.8% (at the Canada - U.S. Boundary) as a result of the Garrison Diversion Unit. While this magnitude of increase will probably not result in a significant increase in the flooding period, it will slightly increase the severity of normal floods along the Red. As some flooding occurs in most years along the section of the Red River from the Boundary to Winnipeg, increased flows in the Red may cause greater damage to agricultural lands, roads, and buildings in flooded areas.

III.C STABILIZATION OF FLOWS

The Bureau, rather than discussing flooding potential along the Souris River, constantly notes the low-flow condition of the Souris River during the 1930's, and cites benefits to Canada from stabilization of flows in the Souris River.

In the Final Environmental Statement, the Bureau (1974a: II-85) emphasizes the low-flow conditions in the Souris River, citing no flow for 11 months of 1937 and for 49 months in the 10-year period from 1931-1940. The Bureau states: "A completely dry river channel was experienced more than 40 percent of the time for an entire decade." This data is cited again by the Bureau in its latest report, Irrigation Return Flows to the Souris River and Canada (Bureau of Reclamation 1974b: 12). EPA (1974a: 3), in its comments on this report, states:

> "Although the drought period of the 1930's is worth noting from an historical stanpoint, repeated references to it in this report are confusing since the period of record 1952-70 was used in reporting water quality data. Reference to 'extended' periods of no flow, 'usually occurring during each year', should be explained. Figure 5 (in Bureau of Reclamation 1974b) indicates that for the period of record 1942-70, no-flow conditions lasting more than one month occurred on only three occasions."

My analysis of data provided by the Bureau for the historic flow of the Souris River for the 19-year period of 1952 to 1970 (Bureau of Reclamation 1974c: 8) shows that there are 8 periods of no-flow conditions lasting for more than one month on the Souris. There were a total of 37 months over the 19-year period for which there was no flow, for an average of 2 months per year. However, there were a total of 54 months over this period where flooding occurred at Site I on the Souris River, for an average of approximately 3 months per year. While the addition of return flows and seepage and operational losses would eliminate these 37 no-flow months over the 19-year period, it would increase the number of months during which flooding occurs at Site I to 156, for an average of 8 months of flooding per year. Thus, while the elimination of no-flow periods is a positive impact, the increased flooding in lower sections of the Souris River is an offsetting negative impact.

The Bureau cites the dilution of high-salt concentrations as a positive impact of the accrual of return flows and seepage and operational losses to the Souris River (Bureau of Reclamation 1974a: III-21, 1974b: 27). However, this positive impact must be analyzed in the context of the negative impact resulting from increases in the average TDS level in the Souris River (see Table 6).

The Bureau (1974b: 55) also cites benefits to Canada resulting from increased water for hydroelectric power generation:

> "...return flow to the Souris River would also result in additional water for hydropower generation in the power plants along the Nelson River and in the Churchill area complex in northern Manitoba. Although 107,000 acre-feet of water is very small when compared with average annual flows of the Nelson River, this water could potentially produce about 18 million kilowatt-hours of electrical energy annually."

The average annual discharge of return flows and seepage and operational losses which would accure to the Souris River is 148.5 cfs (Table 20). This is less than 0.15% of the 100,000 cfs plus flow, projected for the Nelson River on completion of the Churchill-Nelson-Lake Winnipeg hydroelectric project. Three observations can be made. The first is that for most years the volume of water in Lake Winnipeg will be greater than the maximum regulated level. Therefore, any additional water will be discharged from the lake and spilled over the spillways of the hydroelectric dams on the Nelson River. The second is that for dry years, when there is a lack of water in Lake Winnipeg, there may also be a lack of water in the Missouri River system. Under these circumstances, it seems doubtful that priority for Missouri River water will be given to irrigation in the Souris Loop. The third observation is that water diverted from Lake Sakakawea to the Souris Loop will result in a reduction in the hydroelectric capacity of the Garrison Dam. However, this water would not be used to produce power in Nelson River power plants if there is excess water in Lake Winnipeg. Thus, there would be a net loss of hydroelectric power when one considers the interconnected Manitoba-Minnesota-North Dakota electrical networks.

In summary, it appears that the Bureau of Reclamation has tried to exaggerate the benefits of increased flows in the Souris River. While positive impacts from elimination of no-flow periods and reduction of high-salt concentrations in the Souris occur, these must be seen in the context of negative impacts caused by increased flooding and increases in average salt concentrations.

CHAPTER IV

FISH AND WILDLIFE

- INTRODUCTION
- IMPACTS ON WATERFOWL POPULATIONS
- CHANNELIZATION
- INTRODUCTION OF EXOTIC SPECIES

IV.A INTRODUCTION

Impacts on fish and other animals which depend on the aquatic environment, which may occur as a result of changes in water quality in the Souris, Assiniboine, and Red Rivers, and in Lakes Winnipeg and Manitoba, have been discussed in section II. However, other aspects of the Garrison Diversion Unit may affect fish and wildlife populations in Canada.

The loss of wetlands and increased incidence of botulism in waterfowl in North Dakota may affect waterfowl populations in Canada. If channelization becomes necessary to accomodate increased flows in lower reaches of the Souris River in Canada, wildlife habitat along the riverbanks may be destroyed. Finally, the introduction of exotic species into the Red River drainage basin from the Missouri River drainage basin may affect the aquatic environment of lakes and streams in the Red River drainage basin (see Figure 2).

IV.B IMPACTS ON WATERFOWL POPULATIONS

IV.B.1 Loss of Wetlands in North Dakota

In the Final Environmental Statement, the Bureau of Reclamation (1974a:Table 10) indicates that 26,950 acres of wetlands will be lost as a result of the Garrison Diversion Unit. This includes 3,800 acres of Type 1 wetlands, 11,320 acres of Type III wetlands, 7,230 acres of Type IV wetlands, and 4,600 acres of Type V wetlands. In general, Type I wetlands refer to small, temporary wetlands while Types IV and V refer to larger, more permanent wetlands. The area of wetlands lost includes the Sheyenne Lake National Wildlife refuge, a 797-acre refuge which will be innundated by the Lonetree Reservoir; the Taayer Game Management area which will be innundated by the Taayer reservoir; the Crete and Mezaros Sloughs, which will be drained by project drains; and the 380-acre John's Lake marsh which has already been completely drained by construction of the McClusky Canal (Bureau of Reclamation 1974a: III-52 to III-57).

The Bureau cites the importance of wetland habitat in the project area, noting that it lies within the prairie "pothole" region of south-central Canada and north-central United States. The Bureau (1974a: II-50) states:

> "The U.S. portion produces the major share of ducks hatched in the contiguous[1] United States. Hundreds of thousands of ducks and geese use the wetlands during migration. Many species of shore birds and other non-game birds pass through the area during migration and large numbers remain to nest."

Aerial surveys by the Bureau of Sport Fisheries and Wildlife (BSFW) over the project area from 1966-1971 showed an average of 7 wetlands per square mile, ranging from a low of 4.95 in 1966 to a high of 10.62 in 1969 (Bureau of Reclamation 1974a: II-51). The estimated waterfowl population in the area ranged from 97,000 ducklings in 1968 to nearly 317,000 in 1970 (Henry et al. 1972, cited in Bureau of Reclamation 1974a: II-51). Henry et al. found that blue-winged teal comprised greater than one-quarter of all nesting ducks in the Dakotas in the period 1960-1971 while pintail,

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1 Contiguous refers to the lower 48 states.

mallards, and gadwalls comprised 76.7% of the breeding ducks. Several hundred thousand blue and snow geese use the James River sub-flyway during spring and fall migrations while many thousands of Canada geese migrate through the entire area. Some lakes are favoured nesting sites for whistling swans which migrate through North Dakota (Bureau of Reclamation 1974a: II-51).

To compensate for the 26,950 acres of wetlands to be drained, the Bureau (1974a: III-56) states that 56,175 acres will be developed for mitigation and enhancement, comprising 27,513 acres of new water and marsh and 28,662 acres of existing wetlands of all types. According to the Bureau (1974a: III-56): "With development and management, these wetlands will be provided with a permanent and controlled water supply and managed specifically for wildlife with primary emphasis on waterfowl, thereby enhancing their value as wildlife areas." The Bureau (1974a: V-6) notes that while the alteration of about 27,000 acres of existing habitat would result in a loss of up to 40,000 ducks, the production on developed and managed wetland and upland areas could exceed 350,000 ducks.

The Bureau cites other aspects of the Garrison Diversion Unit which may affect existing wetlands but does not adequately quantify the associated impacts. The Bureau cites the introduction of carp into waterfowl habitats in North Dakota as a potential impact. According to the Bureau (1974a: III-51) certain wetland areas within the project area such as wildlife areas in the Devils Lake chain and the J. Clark Salyer National Wildlife Refuge on the Souris River, will probably provide suitable habitat for carp.

By their feeding habits, carp can uproot aquatic plants, increase the turbidity of the water, and in general make areas appear undesirable to waterfowl. Another potential impact is that large areas of natural wetlands in the project area will receive irrigation return flows with a high dissolved-salt content. The Bureau (1974a: III-52) cites an increase in water levels in the 14,775-acre Audubon National Wildlife Refuge, and a potential increase in water levels and salt concentrations in the 58,700-acre J. Clarke Salyer National Wildlife Refuge (NWR) which extends along the Souris River, the 15,934-acre Arrowwood NWR on the James River, the 2,799-acre Dakota Lake NWR on the James River, the 7,869-acre Tewaukon

NWR on the Wild Rice River, the 21,450-acre Sand Lake NWR in South Dakota, and the 605-acre Hyatt Slough Game Management Area. The Bureau (1974a: V-6) states that the lower half of the J. Clark Salyer National Wildlife Refuge could be affected by higher average levels of dissolved solids and increased flows resulting from irrigation of the Souris area. According to the Bureau, the replacement of less salt-tolerant vegetative species be more salt-tolerant species could reduce the carrying capacity for fish and wildlife.

Many groups have questioned the Bureau's conclusions that wetland habitat will be increased due to the replacement of 26,950 acres of wetland loss by 56,175 acres to be developed for mitigation and enhancement and that the loss of 40,000 ducks will be replaced by increased production of 350,000 ducks.

The North Dakota Chapter of Wildlife (1973) notes that most of the areas of new water and marsh, which the Bureau claims for mitigation and enhancement, "...consists of newly flooded peripheral lands surrounding extant marshes and lakes..." The Chapter (1973) states that most of this new water and marsh claimed appears to result from flooding of wet-meadow zones or intermittent alkali zones of existing wetlands. This would result in sizeable acreages of less-productive, deep-marsh zone and in the central deep-marsh zone of many wetlands being innundated and converted to open water, making it less productive for waterfowl. The Chapter questions whether benefits for new marsh development can be claimed for merely altering the hydrological regime of existing lakes and marshes.

BSFW (1974) claims that the 27,000 acres of new marsh, which the Bureau of Reclamation claims will be created, are not adequately related to existing habitat types within these areas, and that the effects of enlarging and deepening the 29,000 acres of existing water and marsh on the quality and quantity of over-water nesting cover for waterfowl are not adequately discussed. BSFW claims that: "This is significant in light of the precarious status of such highly desirable species as the canvasback (Aythya Valisineria), which requires over-water nesting cover."

Thus, it is questionable whether the 27,513 acres of new water and marsh can be claimed as enhancement or mitigation. The inclusion of at least part of this area in total wetlands lost could be justified. The

28,662 acres of existing wetlands of all types, which the Bureau of Reclamation claims will be developed and managed for mitigation and enhancement benefits, already exist, in part, as Federal or State wetlands. Since the major management "benefit"for these wetlands will be increased regulation and augmentation of water supply, and since some of these wetlands will be subject to increased water depth, introduction of carp and other rough fish, and increased salt loads carried by irrigation return flows, it is questionable whether most of this area should be claimed for mitigation and enhancement and thus for increased waterfowl production. To do so, ignores the present quality of these wetlands and present production on these wetlands. Therefore, it is doubtful whether much of the 56,175 acres which the Bureau claims as mitigation and enhancement can actually be claimed as such. Much of the increased wetland area cited by the Bureau results from increasing water levels. This conflicts with a study cited by the Bureau which concludes:

> "Successful waterfowl production in this region is dependent upon seasonal buildup and recession of water levels on flood plains of rivers and impoundments and in potholes. Waterfowl food production and organic decomposition are both dependent on the cyclic fluctuations. If pothole water levels remain constant, the unique blend of floating, submergent, and emergent vegetation required for cover and food would be replaced by less desirable plant communities. If much of the pothole bottoms which are covered by water at high-level times were not later exposed to air, oxidation necessary to nutrient cycling would cease or be drastically reduced. Organic debris would accumulate and aquatic succession would accelerate. Wtih minerals and other nutrients locked up in such debris, the pothole ecosystem would be less productive (Cooper and Jolly 1969; cited in Bureau of Reclamation 1974a: II-52)."

Concerns have been raised which indicate that the 26,950 acres claimed as wetland loss by the Bureau is too low. The Bureau of Reclamation (1974d: 10) accounted for wetlands which would be drained by project and on-farms drains or canals, or innundated by reservoirs; wetlands lost due to land leveling; and wetlands drained indirectly by lowering of water tables.

However BSFW (1974) notes that due to both the magnitude of project drainage features and the location of the project in the prairie pothole region "... the use of project features for non-project wetlands needs additional clarification." BSFW (1974) claims:

"The lowering of the water tables by as much as 15 feet in areas of project work will require extensive short- and long-term evaluation of impacts. We note that de-watering of wells has already occurred up to one mile away in the Painted Woods aquifer and that 15,000 acre-feet of water will be permanently drained from the aquifer."

EPA (1974b), in its comments on the Final Environmental Statement notes that: "Impacts of constructing the McClusky Canal have already been severe. Wetlands have been drained, farm operations severely disrupted, and ground-water tables lowered." Another mechanism for increased wetland loss would be drainage of wetlands by individual landowners. Although the Bureau (1974d) assumes that "... no project features would be used as outlets for drainage of non-irrigable land", the proximity of project canals, distribution laterals, and drains may encourage adjacent landowners to do so.

Finally, BSFW (1974) notes that the Bureau does not adequately describe the impacts of decreased water quality in river systems affecting 6 National Wildlife Refuges (Arrowood, Audubon, Dakota Lake, J. Clark Salyer, Sand Lake and Tewaukon).

Thus, it appears that there will be a net loss of wetlands in North Dakota, as well as a good possibility for degradation of many existing wetlands. This will likely lead to a decreased waterfowl population in North Dakota and thus a decreased waterfowl population in Canada.

EPA (1974b) states:

"We deplore the extensive losses of natural wetlands associated with the development and operation of the Garrison Diversion Unit... We consider the issue of wetland destruction to be a project impact of the greatest importance."

Loss of natural wetlands in North Dakota will affect northward migration of post-juvenile waterfowl into Canada, described as the "Autumn Shuffle". It will also affect spring migrants which use temporary ponds (Types I and II wetlands) for feeding, courtship and staging. These early migrant breeding pairs generally prefer shallow, temporary marshes over permanent water bodies such as lakes, which are often frozen on their arrival. The following spring migrants could be adversely affected by the loss of Types I and II wetlands: whistling swans, Canada geese, mallards, pintails, green-winged teal, blue-winged teal, American widgeon, shovelers, wood ducks, redhead, ring-necked ducks, canvassbacks, common goldeneyes and buffleheads. (R. Oetting[1], personal communication).

A reduction in waterfowl populations would have a significant impact in Manitoba. Ducks are important for Manitoba's hunting and tourism industry, and for recreational and aesthetic amenities. Netley marsh on Lake Winnipeg and Delta Marsh on Lake Manitoba are two of the most important waterfowl marshes in Canada. Delta marsh is cited as the best quality marsh in Canada and possibly in North America (R. Oetting, personal communication). Two research stations (the Delta Waterfowl Research Station and the University of Manitoba Field Station), approximately 12 traditional hunting lodges (now primarily leisure retreats), and some private cabins are presently located at Delta marsh. They would all be adversely impacted by any reduction in waterfowl populations.

Waterfowl in North America cannot be considered the property of any nation, province, or state. They are truly an international resource. As a result, one nation should not be allowed to reduce wetland habitat which results in a reduction in the waterfowl population in another nation. Reductions in natural wetlands in North Dakota as a result of the Garrison Diversion Unit, which would cause a reduction in waterfowl populations, may not be acceptable to Canadians or Mexicans.

IV.B.2. Botulism

Type C botulism,or Clostridium botulinum, is the most common type in waterfowl in the Western U.S. and Canada. Pearson (1973) states:

> "The spores of C. botulinum are ubiquitous in nature and may germinate and elaborate toxin whenever and wherever the proper conditions of oxygen deficiency, warm temperatures, and suitable media (especially those containing animal protein) become available in the environment. When these conditions are met with sufficient frequencey in foods consumed directly or indirectly by waterfowl, botulism outbreaks result."

Pearson (1973) claims that the "sludge bed hypothesis", which suggests that toxin is produced in a "soup of decaying organic matter in marsh mud and water", is inadequate to explain the variety of conditions under which botulism outbreaks occur. Instead, Pearson (1973) states that the "micro-

1 Dr. Oetting is a wildlife biologist with the Manitoba Department of Mines Resources and Environmental Management.

environment concept", which proposes that C. botulinum produces toxin in small, discrete, particulate food items, such as invertebrate carcases, which provide the requirements for growth of bacteria independent of the surrounding wetland environment and protect the toxin from dilution or inactivation, is now generally accepted by waterfowl botulism investigators. Thus, the crucial factor is the presence of dead or decaying organic matter. Pearson (1973) states that environmental factors such as water levels, salinity, dissolved oxygen available, nutrients, toxic substances, and other factors rather than having a direct association with botulism outbreaks, "...may have significant influences on media available for the growth of C. botulinum, especially when these factors become unfavourable for invertebrate survival." Pearson claims that rising water levels, declining water levels, influence of nutrients, and introductions of insecticides and herbicides could result in sudden changes in the aquatic environment which may result in mortality of invertebrate populations, thus providing media for the growth of C. botulinum.

The Bureau of Reclamation (1974a: III-58) states that botulism outbreaks are not a problem on existing wetlands in the project area and that incidences of botulism should not occur in Garrison Diversion Unit wetland development areas. The Bureau claims that wetland managers will have several options open to eliminate or treat botulism outbreaks if they do occur. These measures primarily involve the regulation of water levels, either by drainage or the addition of "fresh" water. The Bureau (1974a: III-59) states that efforts will be made to:

1) Stabilize water levels within natural wetland basins during the summer;
2) provide for rapid and complete drainage if wetlands are to be periodically dried;
3) avoid water quality alterations which will result in unstable invertebtrate and vertebrate populations; and,
4) discourage the concentration of waterfowl and shorebirds on wetlands that may develop a botulism history during periods of greatest potential for botulism outbreaks in order to minimize mortality in the event such outbreaks occur.

The North Dakota Chapter of Wildlife (1973) states:

> "Benefits claimed concerning the ability to partially control botulism outbreaks are questionable. According to the water delivery schedule for fish and wildlife areas ... it appears that water will not be available during the period of peak botulism outbreaks in North Dakota. The water delivery schedule suggests that declining water levels in managed wetlands during this period will be common."

The Chapter cites studies by Kalenbach and Gunderson (1934), Quortrup and Sudheimer (1942), and Hunter (1969) which indicate that botulism outbreaks have "come about through diversion of water for irrigation purposes." The Bureau (1974a: III-59) states that while early planners felt that most water for wildlife units would be used during fall and spring off irrigation-peak periods, project water deliveries are not restricted to fall and spring periods. The Bureau (1974a: III-60) claims that 200-cfs flow of water will be made available to fish and wildlife areas "during periods of critical water supply and extreme drought." However, there is concern that this minimum promised delivery may not be adequate if severe botulism outbreaks occur. Pearson (1973) claims that "a number of factors would appear to suggest that a serious potential does exist for increasing waterfowl and shorebird botulism losses on wetlands affected by the Garrison Diversion Unit." These include:

1) "Increasing water levels in wetland basins above normal levels." Pearson claims that serious botulism outbreaks have occurred in recent years in California and Utah which have been associated with high water levels. He argues that the most direct correlation seems to be with flooding or reflooding of areas which have previously been dry, an aspect which will be much more pronounced and regular occurrence under the management system provided by the Garrison project.

2) "Making water deliveries in spring and fall." Pearson claims that this will assure declining water levels during the peak botulism period of July and August, the precise time at which water may be most urgently needed to provide control if management practices should result in an increased occurrence of botulism outbreaks.

3) "Utilizing water from project drains or natural drainageways receiving irrigation return flows" to supply "other potential fish and wildlife areas."

Pearson claims that influxes of agricultural nutrients, salts, pesticides, and other residues may radically de-stabilize wetland ecosystems, resulting in abrupt fluctuations in invertebrate and vertebrate populations.

4) "Providing water to wetland basins in dry years." Pearson claims that when spring deliveries are terminated, water levels in wetlands will drop rapidly, resulting in highly unstable conditions and increased probabilities of botulism outbreaks.

5) "Altering ground-water levels in the project area." Pearson claims that this could increase the occurrence of botulism outbreaks on areas where no possibilities exist for instituting control measures.

6) "Creating widely and rapidly fluctuating water levels in reservoirs." Pearson claims that the history of botulism outbreaks on other reservoirs suggests the possibility does exist for outbreaks on these areas.

7) "Introducing fish into wetlands." Pearson claims this could increase the total animal protein medium available for toxin production if water conditions and/or quality became adverse to their survival.

Another mechanism whereby waterfowl losses may occur, due to the outbreak of botulism, is the loss of wetlands resulting from the Garrison Diversion Unit. Waterfowl may be dispersed from botulism-free wetlands to wetlands which have a history of botulism outbreaks.

If waterfowl losses occur from botulism outbreaks which could occur as a result of the Garrison Diversion Unit, then losses may occur in waterfowl populations in Canada. Impacts cited in the previous section for waterfowl losses would be intensified.

IV.C CHANNELIZATION

As section III indicated, significant increases in flooding will occur along the lower reach of the Souris River in Canada as a result of increased flows from proposed irrigation areas of the Garrison Diversion Unit. Although the Bureau of Reclamation does not discuss this possibility, channelization may be necessary to enable the Souris River to carry this increased flow and to reduce the flooding previously cited.

The Bureau of Sport Fisheries and Wildlife (BSFW) (1974) states:

> "We view channelization as a major disruption of the natural ecosystem which requires detailed description and intensive evaluation. This environmental disruption can be particularly severe in areas of extensive surface and ground water resources. When a channel is straightened and reshaped, oxbows and other bends are cut off, riverine vegetation is removed, banks are sloped, channel bottoms are widened and lowered, and a uniform bottom grade may be imposed.
>
> Wetlands adjoining the channel may be drained, felled, or cut off from overflow by spoil, and ground water levels may be lowered and stream recharge reduced. Channeling may facilitate drainage throughout the watershed by permitting construction of drains otherwise not physically feasible, or by encouraging drainage which would not otherwise have occurred because of the flooding it would cause downstream. Also siltation and turbidity are usually markedly increased during construction, and erosion and scouring may continue after project works are completed. The resulting turbidity and siltation (with attendant nutrient and pesticide loads) are not restricted to the channeled area, but can also affect aquatic resources downstream."

Channelization in the lower reach of the Souris River would have negative impacts on aquatic life, recreational benefits, and aesthetic amenities of the river. Channelization would also degrade these portions of the Souris River for sports fishing and hunting. Archaeological sites may be destroyed along the Souris River and wetlands adjacent to the river may be drained.
Dr. R. Oetting (personal communication) states that forested areas along the Souris River are important habitat for Manitoba's white-tail deer population. These forested areas, which are concentrated along the banks, may be destroyed in areas where channelization becomes necessary.

IV.D INTRODUCTION OF EXOTIC SPECIES

Garrison Diversion Unit project works will link two river systems - the Red River watershed and the Missouri River watershed. These two watersheds have been separated for some 10,000 years since the last Ice Age laid down the Continental Divide as a barrier between them. As a result, different species of fish, plants, invertebrates, bacteria, and viruses have evolved in these two watersheds; many of the same species occur in both watersheds but others do not. As a result of interconnection by the Garrison Diversion Unit, species from the Missouri watershed which are currently not present in the Red watershed (exotic species) may be introduced into the Red River watershed. Figure 2 shows two locations where the watersheds are connected. At location A, Lake Sakakawea, on the Missouri River, is connected with the Souris River, part of the Red River watershed, via the McClusky and Velva Canals and the Lonetree Reservoir. At location B, the James River, part of the Missouri River watershed, is connected to the Red River via the Oakes Canal and Wild Rice River.

In the Final Environmental Statement, the Bureau of Reclamation (1974a: III-50) states that: "The construction of project facilities will provide a route from the Missouri River for carp, goldeye, burbot, green sunfish, shortnose gar, quilback, buffalo fish, sauger, and fresh water drum to enter sections of the Souris and Sheyenne (above Baldhill Dam) drainages that do not presently support these fish."

Lindsey (1974) lists the following species which now occur in or near Lake Sakakawea above Garrison Dam and which could stand a good chance of finding their way into the Red River: pallid sturgeon, shovelnose sturgeon, paddlefish, shortnose gar, sturgeon chub, plains minnow, blue sucker, and river carpsucker. Lindsey also lists the following species which occur in the James River and which might also find their way into the Red River: gizzard shad, red shiner, smallmouth buffalo, and plains topminnow.

Lindsey (1974) claims that the gizzard shad is the species which might cause most concern. According to Lindsey:

"This is a 12-inch herring-like fish which reaches fantastic levels of abundance followed by spectacular die-offs which sometimes lead to public health problems. Overpopulation of Gizzard shad is typically associated with manmade modification of the environment... The fish is of little value for human food or for sport. As a herbivore, it sometimes competes severely with more desirable species for food; it may also serve as a forage fish for such carnivorus fish as pike and walleye. The chances of it crossing to the Red River system if given the assistance of an irrigation diversion are high...

If Gizzard shad entered southern Manitoba they might become explosively abundant as they have done in other places; whether the lower temperatures would check their spread is conjectural. Their possible impact on local fisheries is also conjectural, but it might well be strong... In Oklahoma, lakes lacking Gizzard shad had sport fish with higher standing crops and better condition factors than had lakes containing Gizzard shad."

Lindsey (1974) sees no alarm concerning introduction of any other species listed above. He states: "Some might contribute occassionally to sport or even commerical fishing; most would probably pass unnoticed." However, he does caution that there is a risk that parasites or diseases, exotic to fish in the Red River basin, might be introduced with these species.

The Bureau provides no information on potential impacts of the introduction of exotic species into the Red River Watershed. Dr. D. Punter[1] (Personal communication) notes that no attention has been given in the Final Environmental Statement to the introduction of undesirable plants, algae, or fungi.

The Bureau is planning to use a fish screen at the inlet to the McClusky Canal. The Bureau (1974a: IV-11) claims: "If properly operated and maintained the screen is expected to be 100 percent effective in removing all fish and eggs from the canal flows entering Lonetree Reservoir." The screen size would be 40 mesh and a backup screen would be provided in case the top screen ruptures.

Derksen (1974) states that no specific reference is made as to what

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1 Dr. D. Punter is a botanist at the University of Manitoba

countries used the Bureau's method of screening. He also notes that the Bureau hedges considerably on the probable success of the proposed screening method (see Bureau of Reclamation 1974a: IV-11), leading him to the conclusion that "...the U.S. Bureau of Reclamation is not absolutely certain that rough fish from the Missouri River can be prevented from entering Canadian water." A review of literature led Derksen (1974) to conclude:

> "...my impressions are that fish screens are not totally effective in preventing the introduction of fish into new waters. Fish screens have been used on culverts around the Delta Marsh to prevent carp from entering the marsh. I gather that although these screens prevented many carp from entering the marsh, some still did get through... Even though it may be possible to control much of the spread of rough fish within the Garrison Diversion, some may still escape into Canadian waters."

According to Pearson (Personal communication, cited in Smith 1974) any screen with a mesh fine enough to keep out all fish eggs would be too fine to allow the free passage of water. Pearson also noted that a screen would not prevent parasites, diseases, and other microorganisms from passing into the Red River drainage basin from the Missouri River watershed.

The only screen the Bureau plans to install is at the entrance to the McClusky Canal (location A on Figure 2). No mention is made of screens at the Oakes Canal, which supplies James River water to the Oakes irrigation area (see Location B on Figure 2), whose return flows drain into the Wild Rice and thus into the Red River, or at the James River Feeder Canal, which connects the New Rockford Canal with the James River. Retrograde movement of rough fish could occur into the New Rockford Canal and then east to Devils Lake and west to the Lonetree Reservoir.

The gross catch on Lake Winnipeg in 1973, primarily whitefish, sauger, and pickerel, was approximately seven million lbs. A total of 1,185 commercial and domestic fishing licences were issued in the summer of 1973 and 384 in the winter. Any negative impact on the Lake Winnipeg fishery which could be caused by the introduction of exotic species of fish, parasites, bacteria, viruses, etc. from the Missouri River watershed could result in extreme economic hardship for people in the Lake Winnipeg area who earn their livelihood either directly from fishing or indirectly from the tourism industry made possible by sport fishing on the lake.

CHAPTER V

SUMMARY AND CONCLUSIONS

- PROJECT DESCRIPTION
- SUMMARY OF IMPACTS
- ADDITIONAL INFORMATION AND RESEARCH REQUIREMENTS

V.A PROJECT DESCRIPTION

In 1943, the U.S. Congress awarded the U.S. Bureau of Reclamation the Garrison Diversion Unit. It was not until 1957 that the Bureau proposed a general plan to irrigate 1,007,000 acres of land in North Dakota. Congress finally approved a 1965 Bureau proposal to irrigate only 250,000 acres and to include municipal and industrial water supply, fish and wildlife conservation and enhancement, recreation, flood control, and other benefits. Projected costs have escalated from $212 million in 1965 to $405 to $460 million in 1974. The planned, 26-year construction period began in July 1969.

The Garrison Diversion Unit, a project located in the south-eastern and north-central area of the state of North Dakota, involves the transfer of Missouri River water from Lake Sakakawea to these areas to irrigate 250,000 acres of land and provide muncipal and industrial water, fish and wildlife conservation and enhancement, recreation, and flood control.

Impacts of the project on Canada will be many and varied. Changes in water quality in Canadian streams, caused by accruals from the Garrison Diversion Unit, may have impacts on municipal, industrial, agricultural, and recreational uses of water as well as on aquatic ecosystems and aesthetic amenities. Increased flows in Canadain streams may cause flooding in Canada or may necessitate channelization of Canadian streams. Losses of waterfowl habitat and increased botulism in waterfowl in North Dakota could mean a reduction in waterfowl populations in Canada. Finally, exotic species, which may enter the Red River drainage basin when it is linked with the Missouri River drainage basin, may have detrimental effects on the aquatic environment of Canadian rivers and lakes.

V.B SUMMARY OF IMPACTS

V.B.1 Water Quality

Irrigation return flows, and seepage and operational losses will accrue to the Souris and Red Rivers from Garrison Diversion Unit irrigation areas. These flows will change the dissolved salts, suspended sediment, nutrient, pesticides, and trace element levels and the temperature of the Souris and Red Rivers. As well as the Souris and Red Rivers, the Assiniboine River, and Lakes Winnipeg and Manitoba - all part of the Red River drainage basin - may also be affected.

a) Dissolved Salts

Changes in dissolved salts concentrations will occur in the Souris Assiniboine, and Red Rivers. As the Bureau's methodology for projecting changes in concentrations in the Souris River is inadequate, an independent computer study was undertaken. This study, which made projections of dissolved salts concentrations for both the Souris and Assiniboine Rivers, showed that while TDS increases slightly in both rivers, substantial increases occur in calcium and sulphate concentrations in the Souris River and in sulphate concentrations in the Assiniboine River. Substantial decreases occur in sodium, bicarbonate, and chloride concentrations in the Souris River. The Bureau of Reclamation does not provide an analysis of changes in dissolved salts concentrations in the Red River; it only states that TDS in the Red River will increase from 350 to 400 mg/l.

Increases in total hardness in the Souris and Assiniboine Rivers will cause increases in water treatment costs for the towns of Souris and Portage la Prairie. Sulphate concentrations in the Souris and Assiniboine Rivers may be raised to the point where noticeable objectionable tastes occur which would affect municipal drinking water, and industrial water for Superior Cheese Canada Limited in Souris and Campbell Soup Company Limited in Portage la Prairie. In some months, during the initial leaching period, sulphate levels in the Souris River may be raised above the level at which adverse human physiological effects occur.

Change in quantity or composition of dissolved salts such as will occur in the Souris, Assiniboine, and Red Rivers as a result of the Garrison project, may cause changes in the structure and function of aquatic ecosystems.

An additional concern is the accrual of most of the increased salt load in Canadian rivers to Lake Winnipeg. The Bureau without the benefit of supporting data, claims that the Lake will not be affected.

b) Suspended Sediments

Increased suspended sediment loads in Canadian rivers may result from increases in flows in those rivers, increased surface runoff from irrigated croplands in North Dakota, and erosion, stream channelization, and cleaning of the canals, laterals, and drains of the Garrison Diversion Unit. The Bureau only considers the latter possibility, ignoring what may be the most important mechanism, namely increases in flow.

Increases of turbidity may cause increased water treatment costs for the town of Souris, decreases in recreational and aesthetic amenities, and abrasive injuries to fish and shellfish in the Souris, Assiniboine, and Red Rivers.

c) Nutrients

Nutrients (nitrogen and phosphorus) may accrue to the Souris and Red Rivers as a result of surface runoff or leaching of nitrogen and phosphorus from fertilizers, nutrient-laden runoff from feedlots, drainage of natural wetlands, and processing wastes from agriculture-based industries.

The Bureau's analysis of potential accruals of nutrients to Canadian waters is inadequate, concentrating basically on accruals due to leaching through the soil and ignoring other, perhaps more important, mechanisms.

The most serious environmental impact from increased nutrient loading in Canadian waters would be the excessive production of aquatic plant growth, lower dissolved oxygen content, and hence, accelerated eutrophication. This will probably not affect the Souris River or the South Basin of Lake Winnipeg, where plant growth is likely limited by other factors, butcould affect the Assiniboine and Red Rivers and the North Basin of Lake Winnipeg.

d) Pesticides

Pesticides used in, or along the banks of, canals, laterals, and drains may be transported directly to Canadian Rivers in operational losses. Pesticides applied to irrigated crops, may be leached through the soil or transported in surface runoff to water flowing into Canada.

The Bureau does not adequately discuss the types and quantities of pesticides to be used on irrigated crops; nor does it discuss the mechanism which will most likely cause pesticide accruals to Canadian streams, namely pesticides used in and along the banks of canals, laterals and drains.

The most serious environmental impact which pesticide accruals could cause is on the aquatic ecosystem. Pesticide residues may be toxic to invertebrates, fish, and birds - especially residues that can be biologically concentrated.

e) Trace Elements

The Bureau provides very limited information on the potential for trace elements, such as arsenic, boron, copper, iron, lead, and zinc, to be transported with accruals into Canadian streams.

The main environmental concern in regards to trace element accruals is their toxicity to fish or other aquatic organisms.

f) Temperature

The Bureau claims that temperatures will be stablized in the Souris River as a result of accruals. It cites open water in winter, a lessening of the flood potential, and a decrese in excessive aquatic plant production as benefits from these accruals. However, the Bureau has not examined the capacity of the river channel in making these projections. Increased flows may mean increased water-surface-area exposure to atmospheric conditions, negating or even reversing the proposed benefits.

V.B.2 Hydrology

Flows will increase by an average of 65.4% in the Souris River as a result of accruals from the Garrison Diversion Unit. Both the period and extent of flooding will be increased along the lower reach of the Souris River, inundating pasture lands and croplands and municipal wells, buildings, and access roads around Melita.

The Bureau does not attempt to assess the flooding potential in Canada, confining its comments mainly to the elimination of no-flow periods on the Souris River.

V.B.3 Fish and Wildlife

a) Loss of Wetlands and Increase in Botulism

The Garrison Diversion Unit will result in a net loss of productive wetlands and may increase the incidence of botulism in waterfowl in North Dakota. Both may result in decreased waterfowl populations in Canada which would affect Manitoba's hunting and tourism industry and recreational and aesthetic amenities.

The Bureau cites an increase in wetlands habitat; however, this conclusion is disputed by waterfowl biologists from other groups and agencies.

b) Stream Channelization

Should stream channelization become necessary in the lower reach of the Souris River to accommodate increased flows, a very severe environmental impact will result, destroying areas of important white-tailed deer habitat. The Bureau does not address the possibility of channelization of the lower Souris River in Manitoba.

c) Introduction of Exotic Species

Exotic species of fish, invertebrates, bacteria, and viruses may be introduced into the Red River watershed due to its connection with the Missouri River watershed. One fish, the Gizzard shad, may have extremely adverse impacts on native fish populations if it becomes established in the Red River watershed. The Bureau proposes a fish screen to prevent this introduction; however, many aquatic ecologists doubt the effectiveness of screening.

V.C. ADDITIONAL INFORMATION AND RESEARCH REQUIREMENTS

In the Final Environmental Statement, the Bureau of Reclamation (1974a) devoted very little space to discussing the impacts of the Garrison Diversion Unit on Canada. The only impact on Canada discussed in the Final Environmental Statement was increased salt loads in the Souris and Red Rivers. A more comprehensive treatment of impacts on Canada was provided in the Bureau's latest report Irrigation Return Flows to the Souris River and Canada. This report discussed the accrual of dissolved salts, suspended sediments, nutrients, trace elements, pesticides, and water with a different temperature to the Souris River as well as impacts caused by increased flows in the Souris River. However, considering this report, there are significant gaps in information. No mention is made of impacts on the Assiniboine River into which the Souris River empties and very little mention is made on impacts on Lake Winnipeg where most of the water in the Souris, Assiniboine, and Red River drains. Generally, when citing impacts on Canada, the Bureau limits its discussion to environmental changes which could occur in Canada. It does not analyze what impacts these changes will have on aquatic ecosystems in Canada's rivers and lakes, on municipal, industrial, and agricultural uses of water, or on recreation and aesthetics. For example, while the Bureau provides data on changes in dissolved salts concentrations in the Souris River, it does not provide a comprehensive analysis of the impacts of these changes on the above categories. Moreover, no similar information exists on impacts on the Red River as it does for the Souris River. This is a very significant gap in information required to adequately assess the impacts of the project on Canada.

The following is a partial listing of specific areas where more information and/or research is required:

a) Dissolved Salts:

1) Further soil testing in proposed irrigation areas.

2) Information describing the methodology of the Bureau's computer simulation model.

3) More information (or research) on the leaching period and associated salt contents for seepage losses.

4) Information on projected salt concentrations in the Assiniboine and Red Rivers.

5) Information on the total salt load which will accrue to Lakes Winnipeg and Manitoba and to Netley and Delta Marsh.

b) Suspended Sediments

1) Information on projected suspended sediment loads in the Souris, Assiniboine, and Red Rivers.

2) Research on the amount of erosion of banks which may be caused by increased flows in these rivers.

3) Research on changes in the quantity of surface runoff from irrigated croplands.

c) Nutrients

1) Information on why nitrate levels are projected to be so low in return flows during the first few years of the leaching period.

2) Information on changes in phosphorus concentrations for the Souris River and on changes in nitrogen and phosphorus concentrations for the Assiniboine and Red Rivers.

3) Information on the total nitrogen and phosphorus loads which will accrue to Lakes Winnipeg and Manitoba.

d) Pesticides

1) Information on changes in crop patterns or proposed irrigation areas, changes in types and quantities of pesticies to be used, toxic properties of the pesticides, and their projected concentrations in return flows.

2) Information on quantities of pesticides to be used in canals and along their banks and on projected concentrations of pesticides in seepage and operational losses.

3) Information on projected pesticide residue concentrations in Canadian water bodies.

e) Trace Elements

1) Projected trace element concentrations in losses and return flows and in Canadian water bodies.

f) Temperature

1) Information on effects of the temperature change at the mixing point in the Souris River at various locations downstream.

2) Information on projected temperature changes in the Red River.

3) Research on the effects of increased flows creating a larger water-surface area in rivers.

g) Increased Flows

1) Contour information to assess the amount of land flooded by increased flows in the Souris River.

2) Channel capacities at various locations along the lower reach of the Souris River.

3) Information on the locations along the Souris River and time intervals for which elimination of no-flow periods will occur.

h) Waterfowl

1) More research on types of wetlands lost or gained and the effects of these changes on waterfowl migration patterns and waterfowl populations.

2) More research on the possibilities of increases in botulism.

i) Channelization

1) Information on any plans for channelization of the Souris River to accommodate the increased flows.

j) Exotic Species

1) More research on which aquatic species in the Missouri River basin are exotic to the Red River basin and which have a chance of surviving in the Red River basin.

2) Information (or research) on the effectiveness of screening in removing fish fry and eggs, microscopic plants, bacteria, and viruses.

Only when all of the above information is provided, a thorough and comprehensive study documenting the potential impacts of the Garrison Diversion Unit on Canada can be undertaken.

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APPENDIX A

- COMPUTER PROGRAM
- INPUT/OUTPUT TABLES

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$JOB WATFIV     DOUG BOYD
          REAL CCN(6,12,12),NEWTCT(6,12),NEWCON(6,12,12),SEPLOS(12,12)
     X,TCTSUB(6,12)
          CCUBLE PRECISICN VARCES(12),RUNCES(5),SEPNAM
          READ,N
          REAC,L
          DC 10 I=1,N
          READ7,RUNDES(I)
          CO 1C J=1,L
          REAC7,VARDES(J)
   1C     REAC,(CCN(I,J,K),K=1,12)
          READ 7,SEPNAM
          CC 15 J=1,L
          READ7,VARDES(J)
   15     READ,(SEPLCS(J,K),K=1,12)
          DO 25 I=1,N
   25     NEWTCT(I,1)=C
          CC 30 K=1,12
          NEWCCN(1,1,K)=CCN(1,1,K)
          NEWTOT(1,1)=NEWTCT(1,1)+NEWCCN(1,1,K)
          CC 35 I=2,N
          NEWCCN(I,1,K)=CCN(1,1,K)+CON(I,1,K)+SEPLOS(1,K)
   35     NEWTOT(I,1)=NEWTCT(I,1)+NEWCCN(I,1,K)
   3C     CCNTINUE
          DC 40 I=2,N
          CC 40 J=2,L
          IF(I.NE.N) GC TO 150
          NEWTOT(1,J)=C
   15C    NEWTCT(I,J)=0
          CC 5C K=1,12
          IF(I.NE.N) GC TC 6C
          NEWCCN(1,J,K)=CCN(1,J,K)
          NEWTOT(1,J)=NEWTCT(1,J)+CCN(1,J,K)
   6C     NEWCON(I,J,K)=(CCN(1,1,K)*CCN(1,J,K)+CCN(I,1,K)*CON(I,J,K)+
     XSEPLOS(1,K)*SEPLOS(J,K))/(CCN(1,1,K)+CON(I,1,K)+SEPLOS(1,K))
   5C     NEWTCT(I,J)=NEWTCT(I,J)+NEWCCN(I,J,K)
   4C     CCNTINUE
          PRINT8
          PRINT3
          CC 120 J=1,L
          CC 14C I=1,N
          NEWTOT(I,J)=NEWTCT(I,J)/12
   14C    PRINT1,VARCES(J),RUNDES(I),(CCN(I,J,K),K=1,12)
          PRINT1,VARCES(J),SEPNAM,(SEPLCS(J,K),K=1,12)
   12C    PRINT2
          PRINT9
          PRINT3
          CC 90 J=1,L
          DC 1CC I=1,N
   1CC    PRINT1,VARDES(J),RUNDES(I),(NEWCCN(I,J,K),K=1,12),NEWTOT(I,J)
   9C     PRINT2
          PRINT 4
          PRINT3
          CC 16C I=1,N
          DC 17C K=1,12
   17C    NEWCCN(I,1,K)=NEWCCN(I,1,K)*16.56
   16C    PRINT1,VARCES(1),RUNDES(1),(NEWCCN(I,1,K),K=1,12)
          PRINT6
          LCH=L-1
          CC 180 J=2,LCH
          CC 18C I=1,N
          TCTSUB(I,J)=0
          CC 19C K=1,12
   19C    TCTSUB(I,J)=TCTSUB(I,J)+CCN(I,J,K)+SEPLCS(I,J)
          TCTSUB(I,J)=TCTSUB(I,J)*NEWTOT(I,1)*12*2.719/2
   18C    PRINT5,VARCES(J),RUNCES(I),TCTSUB(I,J)
    1     FCRMAT(' ',2A8,12F8.2,2X,F7.2)
    2     FCRMAT(/)
    3     FCRMAT(' VARIABLE  RUN        JAN       FEB       MAR       APR       MAY',
     X'    JUN       JUL       AUG       SEP       OCT       NOV       DEC        ',
     X'AVG',//)
    4     FCRMAT('1','CFS VALUES FCR FLCWS - CONVERSION',///)
    5     FCRMAT(' ',2A8,F8.2)
    6     FCRMAT('1','TCTAL QUANTITIES OF SUBSTANCES ',///)
    7     FCRMAT(A8)
    8     FCRMAT('1','NATURAL ANC IRRIGATICN RETURN FLOW DATA',///)
    9     FCRMAT('1','NATURAL ANC CCMBINEC DATA',///)
          STCP
          END
```

TABLE A.1.a Input data to Model - Concentration of TDS (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	1048	1178	1045	553	605	627	604	663	679	730	832	1011	796.25
Souris River	Historic - High Salt Year	2560	3650	2071	501	515	646	769	1140	995	1080	1350	2380	1471.42
Souris River	Historic - Low Salt Year	695	673	695	303	616	465	384	460	570	532	555	560	542.33
Assiniboine River	Historic - Average	786	816	621	472	640	599	613	603	507	709	675	731	647.67
Irrigation Return Flows	Leaching Period - High Salt Year	1411	1425	1441	1456	1452	1452	1462	1462	1472	1474	1463	1458	1452.
Irrigation Return Flows	Leaching Period - Average	1298	1295	1291	1288	1285	1276	1274	1281	1289	1286	1283	1282	1286.
Irrigation Return Flows	Equilibrium	1157	1157	1156	1155	1149	1143	1146	1152	1160	1158	1153	1151	1153.
Seepage and Operational Losses	Equilibrium	540	540	540	540	540	540	540	540	540	540	540	540	540.

TABLE A.1.b SOURIS RIVER - Output from Model - Concentration of TDS (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	1074.29	1149.70	1115.19	574.71	702.96	553.19	466.99	548.49	836.32	803.11	795.02	873.58	791.10
Leaching Period - High Salt Year	Historic Average	1116.97	1220.58	1184.16	616.21	661.41	711.64	741.97	833.76	937.61	945.72	1010.38	1103.06	923.62
Leaching Period - High Salt Year	Historic High	1134.49	1232.61	1298.60	1200.15	1018.03	982.42	937.86	977.99	1019.83	1043.93	1071.99	1137.30	1087.93
Leaching Period - Average	Historic Low	1026.33	1082.69	1045.48	556.50	690.60	542.35	457.51	536.81	787.71	757.21	754.84	817.64	754.64
Leaching Period - Average	Historic Average	1069.90	1153.27	1116.38	608.29	654.07	695.98	713.91	793.01	873.79	883.56	940.61	1015.99	876.56
Leaching Period - Average	Historic High	1075.06	1146.96	1197.00	1095.04	947.87	910.66	869.49	906.13	937.84	957.68	981.10	1033.03	1004.82
Equilibrium Period	Historic Low	945.0	989.63	963.72	528.30	675.47	531.63	449.53	526.73	747.14	721.43	718.62	772.70	714.16
Equilibrium Period	Historic Average	993.23	1066.28	1041.31	596.52	644.46	681.24	691.67	759.97	822.04	836.47	882.37	947.96	830.29
Equilibrium Period	Historic High	980.71	1038.35	1095.02	999.00	876.48	848.95	817.72	849.72	872.86	893.75	906.82	952.15	927.63

TABLE A.1.c ASSINIBOINE RIVER - Output from Model - Concentration of TDS (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	855.13	896.18	709.41	483.28	648.25	614.43	637.34	652.12	605.98	766.20	743.35	820.09	703.56
Leaching Period - Average	Historic Average	856.45	885.18	701.62	482.46	647.09	611.86	632.40	642.78	591.04	751.39	728.55	797.36	694.01
Equilibrium Period	Historic Average	834.51	863.19	686.28	481.02	645.56	609.36	628.38	634.88	577.68	739.68	714.94	778.85	682.86

TABLE A.2.a Input data to Model - Concentration of Sodium (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	179	193	163	78	96	102	107	125	127	129	138	180	134.75
Souris River	Historic - High Salt Year	466	672	364	88	100	135	181	280	217	184	211	370	272.33
Souris River	Historic - Low Salt Year	117	105	110	52	132	82	55	85	94	93	97	97	93.25
Assiniboine River	Historic - Average	67	61	54	32	44	54	53	58	58	56	65	57	54.92
Irrigation Return Flows	Leaching Period - High Salt Year	146	146	147	148	145	144	143	140	139	137	132	129	141.
Irrigation Return Flows	Leaching Period - Average	118	117	116	116	115	115	114	115	117	116	116	116	116.
Irrigation Return Flows	Equilibrium	106	107	106	106	106	105	105	106	107	107	106	106	106.
Seepage and Operational Losses	Equilibrium	60	60	60	60	60	60	60	60	60	60	60	60	60.

TABLE A.2.b SOURIS RIVER - Output from Model - Concentration of Sodium (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	118.47	124.00	124.02	73.86	127.44	85.63	61.15	87.13	98.00	99.30	100.49	102.57	100.17
Leaching Period - High Salt Year	Historic Average	130.91	141.78	139.49	83.82	97.55	102.70	103.16	109.53	107.17	111.49	111.50	117.96	113.09
Leaching Period - High Salt Year	Historic High	118.70	127.30	142.62	125.45	107.89	109.23	104.48	106.52	106.14	108.83	106.08	109.33	114.38
Leaching Period - Average	Historic Low	103.00	105.71	106.30	68.00	124.01	83.37	59.45	85.22	91.66	91.80	94.93	96.44	92.49
Leaching Period - Average	Historic Average	115.81	123.53	122.41	81.31	95.57	99.55	98.17	103.19	98.92	102.31	103.18	110.14	104.51
Leaching Period - Average	Historic High	100.94	105.82	119.35	103.37	93.25	96.17	93.04	95.89	95.80	96.31	95.08	99.22	99.52
Equilibrium Period	Historic Low	95.88	98.90	100.12	65.84	122.88	82.52	58.88	84.49	88.51	89.22	92.14	92.90	89.36
Equilibrium Period	Historic Average	108.88	116.97	116.59	80.38	94.90	98.37	96.53	100.79	94.90	98.91	98.70	104.80	100.90
Equilibrium Period	Historic High	92.86	97.96	111.61	96.12	88.52	91.44	89.35	91.90	90.76	91.78	89.37	93.02	93.72

TABLE A.2.c ASSINIBOINE RIVER - Output from Model - Concentration of Sodium (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	78.89	73.76	64.48	33.40	45.26	55.83	56.16	63.26	66.24	64.95	72.42	69.31	62.00
Leaching Period - Average	Historic Average	75.27	70.37	61.86	33.15	45.01	55.34	55.33	61.87	64.30	62.12	69.96	66.05	60.05
Equilibrium Period	Historic Average	73.44	68.84	60.75	33.04	44.91	55.16	55.05	61.32	63.26	61.32	68.92	64.67	59.23

TABLE A.3.a Input data to Model - Concentration of Calcium (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	84	96	80	42	47	48	42	44	46	53	62	79	60.25
Souris River	Historic - High Salt Year	106	85	63	46	29	27	22	28	31	38	91	140	60.50
Souris River	Historic - Low Salt Year	75	77	55	30	37	44	40	51	60	57	59	62	53.92
Assiniboine River	Historic - Average	110	106	91	58	73	72	78	69	68	75	83	104	82.25
Irrigation Return Flows	Leaching Period - High Salt Year	143	143	143	142	142	142	143	143	143	143	143	143	143.
Irrigation Return Flows	Leaching Period - Average	131	131	131	131	131	130	130	131	132	131	131	131	131.
Irrigation Return Flows	Equilibrium	123	123	123	123	122	121	121	122	123	123	123	122	122.
Seepage and Operational Losses	Equilibrium	60	60	60	60	60	60	60	60	60	60	60	60	60.

TABLE A.3.b SOURIS RIVER - Output from Model - Concentration of Calcium (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	113.75	120.37	111.38	59.54	51.84	54.00	48.77	59.72	86.11	83.48	82.60	91.30	80.24
Leaching Period - High Salt Year	Historic Average	112.72	120.83	113.45	52.65	55.17	60,53	64.76	75.61	89.95	90.06	97.65	107.92	86.78
Leaching Period - High Salt Year	Historic High	119.29	127.04	123.89	120.69	103.26	96.09	92.22	96.42	100.50	103.13	108.06	114.01	108.72
Leaching Period - Average	Historic Low	105.62	111.64	103.39	56.36	50.26	52.77	47.77	58.60	82.65	79.64	79.26	86.60	76.21
Leaching Period - Average	Historic Average	105.14	112.80	106.24	51.32	54.17	58.90	62.12	72.10	85.53	85.13	92.27	101.16	82.24
Leaching Period - Average	Historic High	110.12	117.08	114.38	112.08	96.72	89.82	86.37	90.64	94.96	96.58	101.20	106.05	101.33
Equilibrium Period	Historic Low	101.25	106.37	98.74	54.85	49.37	52.10	47.24	57.92	79.82	77.49	77.03	83.60	73.81
Equilibrium Period	Historic Average	101.09	107.91	101.99	50.72	53.59	57.98	60.65	69.90	81.92	82.31	88.69	96.60	79.45
Equilibrium Period	Historic High	105.00	110.88	108.54	106.44	92.15	85.79	82.83	86.80	90.43	92.71	96.63	100.58	96.57

TABLE A.3.c ASSINIBOINE RIVER - Output from Model - Concentration of Calcium (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	112.31	110.47	96.66	59.09	73.76	73.26	79.52	73.26	75.02	80.48	87.56	106.27	85.64
Leaching Period - Average	Historic Average	110.03	108.32	95.04	58.92	73.60	72.99	79.04	72.41	73.89	79.23	86.30	104.38	84.51
Equilibrium Period	Historic Average	108.75	107.04	94.14	58.84	73.51	72.82	78.76	71.87	72.95	78.52	85.47	103.09	83.81

TABLE A.4.a Input data to Model - Concentration of Magnesium (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	58	61	59	29	35	37	34	35	37	43	49	56	44.42
Souris River	Historic - High Salt Year	73	62	52	41	30	37	36	41	47	71	106	155	62.58
Souris River	Historic - Low Salt Year	34	36	24	12	16	21	23	27	28	27	28	29	25.42
Assiniboine River	Historic - Average	36.7	44.3	43.8	20	27	48	36	33	33	33	40	37	35.98
Irrigation Return Flows	Leaching Period - High Salt Year	112	110	108	107	101	96	93	90	88	88	88	88	98.
Irrigation Return Flows	Leaching Period - Average	85	84	84	84	84	83	83	83	83	83	83	83	83.
Irrigation Return Flows	Equilibrium	72	72	72	72	72	71	72	72	72	72	72	72	72.
Seepage and Operational Losses	Equilibrium	20	20	20	20	20	20	20	20	20	20	20	20	20.

TABLE A.4.b SOURIS RIVER - Output from Model - Concentration of Magnesium (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	69.05	76.09	67.62	29.05	24.07	26.23	26.73	30.90	42.48	41.56	51.51	46.92	43.52
Leaching Period - High Salt Year	Historic Average	71.64	78.63	75.37	34.04	37.98	40.96	40.09	43.42	49.02	51.18	55.36	60.80	53.21
Leaching Period - High Salt Year	Historic High	75.92	85.00	82.44	78.89	59.00	54.62	48.77	49.98	52.83	56.01	58.51	63.03	63.75
Leaching Period - Average	Historic Low	61.79	66.64	61.01	29.94	24.55	26.44	28.87	31.09	43.05	41.88	41.73	46.76	41.81
Leaching Period - Average	Historic Average	64.38	69.33	67.92	34.24	37.99	40.86	40.03	43.50	49.35	51.11	54.95	59.74	51.12
Leaching Period - Average	Historic High	65.88	71.45	70.62	68.92	55.95	52.73	47.97	49.64	52.95	55.59	57.76	61.61	59.26
Equilibrium Period	Historic Low	54.25	58.53	53.76	27.32	23.23	25.45	26.17	30.21	39.59	38.79	38.67	42.97	38.24
Equilibrium Period	Historic Average	57.30	61.80	61.25	33.14	37.13	39.50	38.10	40.67	44.93	47.05	50.02	54.04	47.08
Equilibrium Period	Historic High	57.14	62.00	61.64	60.21	49.63	47.13	43.52	44.84	47.41	50.09	51.47	54.83	52.49

TABLE A.4.c ASSINIBOINE RIVER - Output from Model - Concentration of Magnesium (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	44.33	50.70	48.60	20.72	27.60	48.31	36.95	35.24	36.70	36.64	42.94	42.44	39.26
Leaching Period - Average	Historic Average	43.81	49.98	48.08	20.80	27.64	48.26	36.95	35.34	36.97	36.80	43.01	42.45	39.17
Equilibrium Period	Historic Average	41.79	48.06	46.67	20.67	27.51	48.02	36.60	34.66	35.83	35.80	41.85	40.90	38.20

TABLE A.5.a Input data to Model - Concentration of Sulphate (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	296	291	268	154	191	183	168	179	187	205	236	284	220.17
Souris River	Historic - High Salt Year	530	739	376	143	110	123	132	265	307	470	549	893	386.42
Souris River	Historic - Low Salt Year	151	144	149	84	235	138	98	136	158	145	133	150	146.75
Assiniboine River	Historic - Average	223	198	175	129	168	202	174	169	157	164	195	200	179.5
Irrigation Return Flows	Leaching Period - High Salt Year	784	775	767	752	714	691	662	663	653	645	541	637	699.
Irrigation Return Flows	Leaching Period - Average	563	561	559	557	534	550	548	548	550	549	548	547	553.
Irrigation Return Flows	Equilibrium	482	481	481	481	479	477	477	479	482	482	480	480	480.
Seepage and Operational Losses	Equilibrium	188	188	188	188	188	188	188	188	188	188	188	188	188

TABLE A.5.b SOURIS RIVER - Output from Model - Concentration of Sulphate (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	484.82	526.86	482.85	207.19	274.54	197.83	137.28	178.97	305.86	289.70	283.47	321.44	307.57
Leaching Period - High Salt Year	Historic Average	489.55	526.80	487.53	195.44	220.83	231.93	249.55	296.39	356.57	353.81	387.91	432.04	352.36
Leaching Period - High Salt Year	Historic High	550.27	611.94	597.17	555.50	428.65	392.04	360.17	387.92	409.29	426.14	439.86	469.73	469.06
Leaching Period - Average	Historic Low	414.03	441.24	411.84	205.11	269.69	194.94	136.06	175.64	289.76	275.07	270.01	301.53	282.08
Leaching Period - Average	Historic Average	422.86	447.87	422.35	194.98	218.86	227.17	242.46	280.87	332.99	331.63	360.42	396.10	323.21
Leaching Period - Average	Historic High	452.71	487.86	481.56	460.29	383.45	355.52	335.38	355.23	375.73	391.35	401.08	424.36	408.71
Equilibrium Period	Historic Low	367.13	387.23	364.68	188.58	261.22	188.97	131.58	170.21	268.37	256.32	251.07	278.60	259.50
Equilibrium Period	Historic Average	379.02	397.92	379.45	188.19	213.54	219.09	230.11	263.23	305.71	307.02	329.95	361.45	297.89
Equilibrium Period	Historic High	398.00	424.65	423.05	405.15	343.89	321.60	306.58	325.00	341.47	357.76	362.22	382.94	366.03

TABLE A.5.c ASSINIBOINE RIVER - Output from Model - Concentration of Sulphate (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	286.71	263.07	226.40	134.36	173.07	209.60	188.06	197.87	204.30	206.85	235.86	257.91	215.34
Leaching Period - Average	Historic Average	278.99	258.59	222.96	134.56	172.91	208.88	187.15	195.11	200.57	203.12	231.43	250.77	212.09
Equilibrium Period	Historic Average	266.59	246.11	214.08	133.73	172.08	207.50	184.92	190.90	193.53	197.09	224.31	241.43	206.02

TABLE A.6.a Input data to Model - Concentration of Bicarbonate (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	616	710	598	277	309	339	324	354	365	403	447	546	440.67
Souris River	Historic - High Salt Year	1660	2380	1450	336	329	432	454	581	374	339	450	932	809.75
Souris River	Historic - Low Salt Year	460	448	427	169	308	233	250	322	374	340	351	354	336.33
Assiniboine River	Historic - Average	409	412	353	190	266	290	291	285	290	296	318	402	316.83
Irrigation Return Flows	Leaching Period - High Salt Year	410	415	413	411	408	408	411	414	411	406	402	395	409.
Irrigation Return Flows	Leaching Period - Average	366	366	366	366	366	365	366	370	374	372	371	372	368.
Irrigation Retrun Flows	Equilibrium	355	356	355	356	353	350	352	355	358	356	354	353	355.
Seepage and Operational Losses	Equilibrium	200	200	200	200	200	200	200	200	200	200	200	200	200.

TABLE A.6.b SOURIS RIVER - Output from Model - Concentration of Bicarbonate (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	363.75	383.57	384.76	230.70	311.45	246.48	257.22	318.62	336.62	325.95	335.16	338.23	319.38
Leaching Period - High Salt Year	Historic Average	399.49	440.92	438.87	288.63	311.08	334.15	313.65	325.21	324.17	340.72	347.80	362.81	352.29
Leaching Period - High Salt Year	Historic High	350.00	373.65	430.52	366.10	325.11	331.00	311.32	316.74	314.14	315.50	320.53	333.22	340.65
Leaching Period - Average	Historic Low	335.49	348.98	354.88	218.66	306.11	242.38	253.95	314.78	324.99	315.50	326.52	329.52	305.98
Leaching Period - Average	Historic Average	374.10	409.94	412.54	283.84	307.66	328.86	305.05	313.01	309.33	327.27	333.91	350.20	337.97
Leaching Period - Average	Historic High	317.18	333.45	394.95	331.69	300.97	309.38	291.61	296.08	295.50	297.16	302.82	317.88	315.72
Equilibrium Period	Historic Low	329.38	342.27	348.09	217.12	304.67	241.24	253.11	313.56	319.95	310.98	321.79	322.83	302.08
Equilibrium Period	Historic Average	367.51	402.80	405.61	283.03	306.74	327.13	302.61	309.17	302.91	321.35	326.30	340.17	332.94
Equilibrium Period	Historic High	310.71	326.00	385.98	324.85	294.56	302.56	286.15	289.73	287.44	289.45	293.10	306.36	308.07

TABLE A.6.c ASSINIBOINE RIVER - Output from Model - Concentration of Bicarbonate (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	394.30	403.86	356.09	192.88	267.23	290.99	291.53	287.48	294.18	299.20	317.97	384.24	315.00
Leaching Period - Average	Historic Average	386.62	395.58	350.10	192.24	266.68	290.06	289.95	284.48	290.35	295.74	314.73	380.78	311.44
Equilibrium Period	Historic Average	384.52	393.75	348.75	192.17	266.54	289.78	289.51	283.57	288.70	294.29	312.95	377.88	310.20

TABLE A.7.a Input data to Model - Concentration of Chloride (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	52	46	42	20	23	25	27	30	32	34	38	58	35.58
Souris River	Historic - High Salt Year	55	48	41	32	24	34	50	74	69	63	85	115	57.50
Souris River	Historic - Low Salt Year	40	35	44	10	16	11	10	15	20	17	17	19	21.17
Assiniboine River	Historic - Average	33	27	25	14	18	21	21	24	25	30	30	25	24.42
Irrigation Return Flows	Leaching Period - High Salt Year	61	63	65	66	67	67	67	67	68	67	64	63	65.
Irrigation Return Flows	Leaching Period - Average	34	34	34	34	34	33	33	33	33	33	33	33	33.
Irrigation Return Flows	Equilibrium	18	18	18	18	18	18	18	18	18	18	18	18	18.
Seepage and Operational Losses	Equilibrium	10	10	10	10	10	10	10	10	10	10	10	10	10.

TABLE A.7.b SOURIS RIVER - Output from Model - Concentration of Chloride (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	44.15	49.04	51.05	22.44	21.17	15.63	13.73	18.74	31.77	31.32	29.89	34.66	30.30
Leaching Period - High Salt Year	Historic Average	46.27	50.27	49.70	23.87	25.42	28.29	30.39	33.65	38.00	40.29	41.92	47.63	37.97
Leaching Period - High Salt Year	Historic High	44.81	51.48	52.56	51.91	41.11	39.91	36.83	38.44	41.28	43.98	43.83	46.46	44.38
Leaching Period - Average	Historic Low	28.62	30.07	32.66	15.81	17.68	12.88	11.58	16.06	21.27	20.04	20.06	22.26	20.75
Leaching Period - Average	Historic Average	31.71	32.69	33.14	21.13	23.16	24.52	24.45	24.92	24.50	26.07	26.80	30.38	26.96
Leaching Period - Average	Historic High	26.94	29.29	30.02	29.18	24.25	24.19	23.10	23.62	24.25	25.03	24.67	25.85	25.87
Equilibrium Period	Historic Low	18.75	18.93	22.56	11.97	15.75	11.56	10.56	14.80	16.55	15.61	15.89	16.83	15.81
Equilibrium Period	Historic Average	22.47	22.37	23.97	19.54	21.92	22.73	21.67	20.88	18.48	20.30	20.08	22.31	21.39
Equilibrium Period	Historic High	15.71	16.46	17.80	17.27	15.48	16.92	16.77	16.82	16.69	17.29	16.10	16.34	16.64

TABLE A.7.c ASSINIBOINE RIVER - Output from Model - Concentration of Chloride (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	35.72	31.71	28.98	14.57	18.48	21.70	22.04	25.68	27.88	32.38	32.48	30.15	26.81
Leaching Period - Average	Historic Average	31.52	27.48	25.67	14.24	18.13	21.07	20.07	23.59	24.44	28.71	28.82	24.95	24.13
Equilibrium Period	Historic Average	28.69	24.76	23.67	14.04	17.93	20.76	20.47	22.60	22.88	27.24	27.25	22.70	22.75

TABLE A.8.a Input data to Model - Concentration of Hardness (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	447.7	490.0	441.8	223.9	260.9	271.6	244.3	253.4	266.6	308.7	355.8	427.0	332.66
Souris River	Historic - High Salt Year	564.2	466.6	370.6	283.0	195.5	219.1	202.5	238.0	270.1	435.0	661.9	985.3	407.74
Souris River	Historic - Low Salt Year	326.8	340.0	235.9	124.2	158.1	196.1	194.3	238.2	264.8	253.2	262.3	273.9	238.96
Assiniboine River	Historic - Average	425.4	446.6	407.0	227.0	293.2	376.7	342.5	307.8	305.3	322.8	371.4	411.6	353.10

TABLE A.8.b SOURIS RIVER - Output from Model - Concentration of Hardness (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	567.36	612.76	555.60	267.91	228.23	242.48	231.46	275.93	389.38	379.04	376.61	420.53	378.94
Leaching Period - High Salt Year	Historic Average	575.42	624.34	592.51	271.14	293.57	319.20	326.20	366.98	425.76	434.91	471.02	518.98	435.00
Leaching Period - High Salt Year	Historic High	609.37	665.96	647.60	625.07	499.95	464.07	430.42	445.86	467.77	487.36	509.93	543.33	533.06
Leaching Period - Average	Historic Low	517.30	552.24	508.53	263.58	226.26	240.28	229.57	273.90	383.04	370.76	369.18	408.14	361.90
Leaching Period - Average	Historic Average	526.71	566.12	543.96	268.62	291.13	314.71	319.37	358.51	416.08	422.29	455.89	497.74	415.10
Leaching Period - Average	Historic High	545.30	585.53	575.37	562.66	471.12	440.64	412.52	430.03	454.43	469.30	489.71	517.62	496.19
Equilibrium Period	Historic Low	475.46	505.81	467.19	249.09	218.64	234.55	225.36	268.62	361.78	352.70	351.01	385.09	341.28
Equilibrium Period	Historic Average	487.58	523.05	506.00	262.63	286.15	306.86	307.78	341.43	388.96	398.61	426.74	462.97	391.56
Equilibrium Period	Historic High	496.69	531.31	523.97	512.87	433.77	407.65	385.46	400.77	420.39	437.06	452.52	476.15	456.55

TABLE A.8.c ASSINIBOINE RIVER - Output from Model - Concentration of Hardness (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	462.48	483.94	440.84	232.64	297.53	381.14	350.21	327.56	337.96	351.36	394.88	439.63	375.01
Leaching Period - Average	Historic Average	454.63	475.60	434.65	232.56	297.30	380.25	349.06	325.84	336.24	348.90	392.01	434.94	371.83
Equilibrium Period	Historic Average	443.17	464.55	426.59	231.82	296.50	378.87	346.93	321.71	329.24	343.02	385.20	425.34	366.08

TABLE A.9.a Input data to Model - Concentration of Nitrate (mg/l).

Source	Category	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Souris River	Historic - Average	6.	8.	8.	6.	4.	4.	6.	8.	8.	7.	6.	6.	6.42
Souris River	Historic - High Salt Year	14.	15.	15.	11.	7.	3.	10.	17.	24.	8.	8.	8.	11.67
Souris River	Historic - Low Salt Year	4.	4.	4.	1.	4.	3.	2.	3.	3.	3.	3.	3.	3.08
Assiniboine River	Historic - Average	2.4	3.1	3.	2.6	0.72	0.28	0.98	0.64	0.13	0.84	1.2	0.58	1.37
Irrigation Return Flows	Leaching Period - High Salt Year	15.	15.	14.	13.	13.	12.	12.	12.	12.	11.	12.	13.	13.
Irrigation Return Flows	Leaching Period - Average	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	8.	7.
Irrigation Return Flows	Equilibrium	10.	10.	10.	9.	9.	9.	8.	8.	8.	8.	8.	9.	9.
Seepage and Operational Losses	Equilibrium	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.

TABLE A.9.b SOURIS RIVER - Output from Model - Concentration of Nitrate (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Low	10.38	11.37	10.03	4.03	4.95	3.74	2.70	3.68	5.55	5.15	5.31	6.47	6.11
Leaching Period - High Salt Year	Historic Average	10.30	11.60	10.64	6.61	4.60	4.78	6.26	7.33	7.45	6.99	7.41	8.60	7.71
Leaching Period - High Salt Year	Historic High	11.29	12.50	11.91	10.77	8.48	7.03	6.94	7.32	8.03	7.04	7.84	9.10	9.02
Leaching Period - Average	Historic Low	5.33	5.75	5.58	2.52	4.20	3.28	2.34	3.25	3.98	3.94	3.92	4.61	4.06
Leaching Period - Average	Historic Average	5.62	6.42	6.62	5.99	4.13	4.17	5.32	5.97	5.44	5.43	5.17	5.88	5.51
Leaching Period - Average	Historic High	5.53	6.02	6.53	6.25	5.12	4.55	4.79	5.01	5.51	4.94	4.98	5.88	5.43
Equilibrium Period	Historic Low	7.25	7.87	7.50	3.04	4.45	3.47	2.42	3.34	4.29	4.26	4.19	5.00	4.76
Equilibrium Period	Historic Average	7.40	8.37	8.35	6.20	4.29	4.42	5.52	6.24	5.84	5.82	5.62	6.44	6.21
Equilibrium Period	Historic High	7.71	8.46	8.84	7.77	6.26	5.56	5.23	5.49	6.02	5.48	5.55	6.55	6.58

TABLE A.9.c ASSINIBOINE RIVER - Output from Model - Concentration of Nitrate (mg/l).

Category	Mixed with	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Leaching Period - High Salt Year	Historic Average	4.61	5.10	4.36	2.73	0.89	0.55	1.40	1.49	1.53	1.93	2.39	2.58	2.46
Leaching Period - Average	Historic Average	3.16	3.71	3.47	2.65	0.81	0.45	1.22	1.15	1.01	1.53	1.87	1.80	1.90
Equilibrium Period	Historic Average	3.72	4.24	3.86	2.68	0.83	0.49	1.26	1.22	1.12	1.63	1.97	1.97	2.08

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Resource Managers have become increasingly aware of the necessity of incorporating people's values into planning for resource management. It is the purpose of this practicum to develop an approach to the measurement of people's values and demonstrate its utility in resources management

DOUGLAS CHEKAY: A Theoretical Framework and Its Practical Application to Facilitate the Choice, Inventory and Description of Environmental Study Sites

This practicum will provide a theoretical framework for the establishment of environmental education study sites on a province wide basis. The theory will indicate the need for and purpose of environmental education study sites and will state parameters these sites should fulfill. It will describe a theoretical process developed to facilitate the choice, inventory and description of environmental study sites.

To substantiate the theoretical framework, the process as described above will then be tested on six sites in the Winnipeg Area.

KENNETH DAVIDSON: The Development of Remote Northern Airstrips in Manitoba

This study examines the demand factors which determine the air service requirements at a number of remote communities in Northern Manitoba. In co-operation with the Manitoba Department of Northern Affairs it will develop guidelines for the installation of various types of facilities.

IAN GILLIES: Problems and Criteria for Conventional Water and Sewer Systems in Resource Communities in Northern Manitoba

At present, remote communities in Manitoba's north have unacceptably low levels of water services. Amelioration of the situation is a stated objective of the communities and government. The research objective is to develop a system of criteria that will complement a policy for water supply in remote communities. A decision-aiding device is needed to allocate services among communities and to show the implications and impacts of the type of infrastructure development. The research will encompass political, technical, social, administrative and economic aspects of water supply development in remote communities.

ALISON HINE: The Economic Relationship between Mineral Industry Demand for Energy and Hydro-Electric Development in Manitoba's North

Energy demand by the mineral industry has been a factor in hydro-electric developments in Manitoba's North. In light of major expenditures for northern hydro-electric projects, questions have been raised concerning the economic relationship between the mining industry and Manitoba Hydro. A case study will be undertaken to examine quantitative aspects of the relationship so that objective commentory may be made.

NORMAN S. HOWE: The Economics of the White-Tailed Deer in Manitoba

This project examines the reasons for the present distribution of white-tailed deer in Manitoba. The deer have greatly increased in numbers in recent times, and are occasionally a nuisance. The study concentrates on their food habits, including damage to agricultural crops, and the costs and benefits of controlling the deer and compensating for damages.

DALE JOHNSTON: Evaluation of Usefulness of Loan and Grant Programs: Lake Winnipeg Fishery

The topic involves the socio-economic evaluation of the Special ARDA grant program to commercial fishermen and trappers. Objectives: 1) to determine if the incomes of primary producers receiving special ARDA equipment have been improved; 2) to examine some of the non-economic effects that this equipment might be having on the primary producers that receive grants.

BETTY LEITCH: Economic Costs of Applying Environmental Controls in Manitoba

This study involves an analysis of the economic problems associated with the abatement of livestock pollution. The study involves a general review of the legislation across Canada, with particular attention to Manitoba's situation. Emphasis will be focused on a single livestock operation and the economic effects pollution abatement have on it.

BRUCE RAMSAY: The Economic and Social Role of Trapping in the Contemporary Culture of Native People in Northern Manitoba

Recently, government and native groups have questioned the role that trapping plays in the lives of native people in northern Manitoba. This practicum is directed at determining whether trapping is an economic resource to the native people of Manitoba, and the role that trapping plays in their contemporary culture.

LES SHERWOOD: Problems and Criteria for Testing Non-Conventional Sewer and Water Systems in Resource Communities in Northern Manitoba

The problem involves the increasing need for suitable and satisfactory waste management systems in northern communities, where conventional mid-latitude systems often prove unacceptable. The practicum will investigate the problems and develop criteria for implementing three innovative systems in certain remote communities.

NEVILLE WARD: Development of Methods for Evaluating Technological Changes in Some Gill Net Fisheries in Manitoba

Manitoba Department of Mines, Resources and Environmental Management is attempting to increase the productivity of commerical fishermen by introducing new fishing techniques. The practicum develops methods to evaluate the changes in productivity by using actual case studies.

BRIAN WILKIE: Integrating Information for Comprehensive Planning: A Group Problem Solving Method and Case Study

This research attempts to derive solutions to complex problems using a group method called synectics. The written material deals with group interaction, problem definition and the solutions or approaches to solutions achieved. The case problem is of a social interaction, recreation nature.

Soon to be Published

Building Your Repertoire of Instructional Simulation Games by T. F. Carney and P. E. Nickel

A collection of simulations and scenarios of different types aimed at illustrating how to 'game' a variety of fairly typical problems; keyed to the booklet on Constructing Instructional Simulation Games, and meant as a companion piece, developing the points made in that booklet.

The Unmaking of Indecision by T. F. Carney

A grimly humourous survey of decision making in Arts faculties of universities and of the consequences of that decision making for the academic system (a cross between Tom Wolfe, H. L. Mencken and C. Northcote Parkinson).

Workshops: A Technique for Training in Improving Small Group Decision Making by T. F. Carney and P. E. Nickel

A survey of this new approach, setting out its component subtechniques in an easy-to-master fashion and showing how they go together to make an overall instructional approach of compelling effectiveness (in conjunction with a set of back-up studies which provide detailed training in major component subtechniques - the case study method, the 'hidden agenda' dilemma, and so on).

Analysing Other People's Perceptions of Your Business by T. F. Carney

An expert in content analysis shows how you can quickly find out what the ordinary user (rather than the planner or architect) sees in your facilities - or rapidly set out the difference between your perception of a problem and your subordinate's perception of your perception of that problem. Combined with a much-in-demand illustrative case study of the technique in action.

Hidden Agendas by T. F. Carney and R. Harbeck

A series of structured activities, keyed to the booklet on Workshops aimed at providing learning experiences in decision making and negotiation problems typically met within resource development.

Case Studies in Resource Development by T. F. Carney and P. E. Nickel

A series of different applications of the case-study approach to typical problems met in resource development; keyed to the booklet on Workshops.

The Interlake Development Game: Simulating Human and Resource Development by T. F. Carney, P. E. Nickel and N. Howe

A large-scale instructional simulation game providing experiential learning of the problems of human and resource development; also capable of use as a team-building activity. (Keyed to the N.R.I. booklets on instructional simulation games.)

MAILING LIST

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304 - 63 Albert Street
Winnipeg, Manitoba
R3B 1G4

Mr. Jack Francis, News Editor
Free Press Report on Farming
300 Carlton Street
Winnipeg, Manitoba
R3C 3C1

Mr. Keith Dryden
Agriculture Editor
The Western Producer
P.O. Box 250
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Free Press Report on Farming
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Mr. E. (Bill) Morriss
The Manitoba Co-operator
220 Portage Avenue
Winnipeg, Manitoba
R3C 0A6

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Winnipeg, Manitoba
R3C 3B2
Attention: Marie Barton

Ms. Maryon Brechin
CAC
801 - 251 Laurier Avenue W.
Ottawa, Ontario
K1P 5Z7

Mr. Clyde Sanger
Director
Public Information Office
International Development
Research Centre
Ottawa, Ontario

Mr. Alan Hunt
Box 16 Group 20 R.R.#2
Lorette, Manitoba
R0A 0Y0

Mr. Gary Charles
640 Christies
Selkirk, Manitoba

Canadian Union of Students Overseas
201 - 460 Main Street
Winnipeg, Manitoba
R3B 1B6

Canadian International Development Agency
Jackson Building
Bank Street
Ottawa, Ontario
K1A 0G4

Mr. Mike Bridges
892 Grosvenor Avenue
Winnipeg, Manitoba
R3M 0N4

Mr. Leo Quigley
The Leader-Post
1964 Park Street
Regina, Saskatchewan
S4N 2G2

Ms. Donna Keates
615 - 1833 Pembina Highway
Winnipeg, Manitoba
R3T 2G6

Mr. Don Kowal
27 Weaver Bay
Winnipeg, Manitoba
R2M 2G5

Mr. Dan Topolniski
328 - 179 Allegheny Drive
Winnipeg, Manitoba

Mr. Kelvin Whalen
Environmental Protection Service
Department of Environment
Building 310
Pleasantville
St. John's, Newfoundland

Mr. James Barlishen
Box 1107
Yellowknife, North West Territories

Mr. Romeo Princis
6241 Burns Street
Burnaby, B.C.

Mr. Andrew Miles
2 - 6 Evanson Street
Winnipeg, Manitoba

Mr. Doug Luckhurst
7 - 793 McMillan Avenue
Winnipeg, Manitoba

Mr. Ron Kabaluk
288 Wildwood Park
Winnipeg, Manitoba

Mr. John C. Burch
106 Kirby Drive
Winnipeg, Manitoba

Mr. Bernard A. Bitner
70 Calder Crescent
Regina, Saskatchewan

Mr. Carl Wall
79 Gendreau Avenue
St. Norbert, Manitoba

Ms. Lorna McKerness
1909 - 1316 Carling Avenue
Ottawa, Ontario

Mr. and Mrs. F. Cramp
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Kemptville, Ontario
K0G 1J0

Mr. Don Kotak
Box 101 R.R. #3
Saskatoon, Saskatchewan

Mr. Lorne Colpitts
278 Wellington Crescent
Winnipeg, Manitoba

Mr. Doug Boyd
15 - 375 River Avenue
Winnipeg, Manitoba

Mr. Bill Barto
903 - 1325 Taylor Avenue
Winnipeg, Manitoba

Mr. Ronald Bailey
1500 Caton Avenue
Ottawa, Ontario

Mr. Erkki Vuori
208 - 11430 40th Avenue

Mr. Erkki Vuroi
208 - 11430 40th Avenue
Edmonton, Alberta
T6J 0R5

Mr. Stephan Stephansson
1107 Downing Street
Winnipeg, Manitoba

Mr. George Daview
Cabinet Secretariat
Legislative Building
Winnipeg, Manitoba

Mr. George Ford
Cabinet Secretariat
Legislative Building
Winnipeg, Manitoba

Ms. Jo Anne Hillier, Editor
Beausejour, Manitoba Beaver
P.O. Box 1148
Beausejour, Manitoba
R0E 0C0

Mr. Don Baron, Editor,
Country Guide
1760 Ellice Avenue
Winnipeg, Manitoba
R3H 0B6

Q. H. Martinson
111 Drury Manor
1833 Pembina Highway
Winnipeg, Manitoba
R3T 2G6

Mr. Ross Dobson
CBC Agriculture & Resources
P.O. Box 160
Winnipeg, Manitoba
R3C 2H1

Mr. Lionel Moore
CBC Agriculture & Resources
P.O. Box 160
Winnipeg, Manitoba
R3C 2H1

Mr. Eric Friesen
CBC Agriculture & Resources
P.O. Box 160
Winnipeg, Manitoba
R3C 2H1

W. W. Cole
Cole's Lifestock Comments
Ninette, Manitoba
R0K 1R0

Mr. Harry Siemens
Farm Editor, CFAM-CHSM
Altona, Manitoba
R0G 0B0

Mr. Gerry Wade
CBC Radio
1840 McIntyre Street
Regina, Saskatchewan
S4P 2R1

Mr. Armand Roy
Communications Department
Saskatchewan Department
of Agriculture
Administration Building
Regina, Saskatchewan

Mr. David Suderman
Director of Information
Canadian Wheat Board
423 Main Street
Winnipeg, Manitoba
R3B 1B3

Ms. Phyllis Thomson
Information Writer
Manitoba Department of
Agriculture
711 - 401 York Avenue
Winnipeg, Manitoba
R3C 0P8

Mr. Boyd Solnes
Communications Division
Manitoba Department of
Agriculture
705 - 401 York Avenue
Winnipeg, Manitoba
R3C 0P8

Mr. Roy Atkinson, President
National Farmers'Union
205C - 2nd Avenue S.
Saskatoon, Saskatchewan
S7K 2M1

Mr. Jas. T. Cawley
Deputy Minister
Department of Mines, Resources
& Environmental Management
310 Legislative Bldg.
Winnipeg, Manitoba

The Honourable Mr. Sidney Green
Department of Mines, Resources and
Environment Management
302 Legislative Buildings
Winnipeg, Manitoba

Mr. J. L. Grey (IBM)
63 River Road
Winnipeg, Manitoba
R2M 3Z3

Mr. J. Giles
DREE Manitoba Co-ordination
Department of Agriculture
809 Norquay Building
401 York Street
Winnipeg, Manitoba
R3C 0P8

Dr. W. G. Bowen
Environmental Management Division
Assistant Deputy Minister
Department of Mines, Resources and
Environmental Management
Box 7, Bldg. 2
139 Tuxedo Blvd.
Winnipeg, Manitoba
R3N 0H6

Mr. M. C. Mckay, Manager
Special ARDA
Room 500 Montreal Trust Bldg.
213 Notre Dame Avenue
Winnipeg, Manitoba
R3B 1N3

Dr. Lionel Orlikow
Department of Education
409 Robert Fletcher Bldg.
1181 Portage Avenue
R3G 0T3

Mr. D. J. Sandell
421 St. Anthony Avenue
Winnipeg, Manitoba
R2V 0S2

Mr. J. A. Barr, Director
Resource Planning Division
Department of Mines, Resources and
Environmental Management
1007 Century Street
Winnipeg, Manitoba

Mr. E. E. Robertson
The Biomass Energy Institute Inc.
P.O. Box 129, Postal Station "C"
Winnipeg, Manitoba
R3M 3S7

Mr. D. M. Wise
271 Victoria Crescent
Winnipeg, Manitoba
R3M 1X6

The Honourable Mr. E. Whelan
Agriculture Canada
St. John Carlings Bldg.
Carlings Avenue
Ottawa, Ontario
K1A 0C5

Mrs. Beryl Plumptre
Food Prices Review Board
P.O. Box 1540, Station "B"
Ottawa, Ontario
K1P 5Z5

Mr. E. A. Poyser
Manitoba Department of Regional
Economic Expansion
P.O. Box 981
Winnipeg, Manitoba
R3C 2V2

Mr. J. D. Collinson
Director General
Manitoba Department of Regional
Economic Expansion
P.O. Box 981
Winnipeg, Manitoba
R3C 2V2

Mr. R. L. Carter
Deputy Minister
Department of Northern Affairs
349 Legislative Bldg
Winnipeg, Manitoba

Mr. Murray Cormack
General Manager
Manitoba Pool Elevators
220 Portage Avenue
Winnipeg, Manitoba
R3C 0A6

Dr. Merrill Menzies
M. W. Menzies Group Ltd.
437 Don Avenue
Winnipeg, Manitoba
R3L 0S5

The Honourable Mr. Samuel Uskiw
165 Legislative Bldg. (Minister of Agriculture)
Winnipeg, Manitoba

The Honourable Mr. Dufferin Roblin
560 Grosvenor Avenue
Westmount 217, Quebec

The Honourable Mr. Edward Schreyer
204 Legislative Bldg. (Premier of Manitoba)
Winnipeg, Manitoba

Mr. W. P. Janssen — Planning Secretariat
41A Legislative Bldg. — Director
Winnipeg, Manitoba — Dept. of Agriculture

Dr. Baldur H. Kristjanson
Department of Agriculture
Second Floor Legislative Bldg.
545 Broadway Avenue
Winnipeg, Manitoba

Dr. H. H. Austman
Assistant Deputy Minister — Rural Development
Department of Agriculture — Division
Room 157 Legislative Bldg.
Winnipeg, Manitoba

Mr. J. B. Carroll
2445 Assiniboine Crescent
Winnipeg, Manitoba
R3J 0B3

Mr. S. Lyon
705 South Drive
Winnipeg, Manitoba
R3T 0C2

Mr. H. J. Ennes
P.O. Box 54
Woodlands, Manitoba
R0C 3H0

Mr. John MacNaught
Department of Regional Economic Expansion
814 Beborough Towers
601 Spadina Crescent
Saskatoon, Saskatchewan
S7K 3G8

Mr. Karl Keeler
Department of Regional Economic Expansion
814 Beborough Towers
601 Spadina Crescent
Saskatoon, Saskatchewan
S7K 3G8

Mr. R. A. Wallace
19 Brian Crescent
Ottawa, Ontario
R2H 6X2

Mr. J. O. Wright
Wheat Pool Building
2625 Victoria Avenue
Regina, Saskatchewan
S4P 2X6

Dr. George Johnson
299 Waverley St.
Winnipeg, Manitoba
R3M 3K5

Mr. Michael C. Burns
IBM Canada Ltd.
1445 W. Georgia Street
Vancouver, B.C.
V6G 2T4

The Honourable Mr. D. L. Campbell
3 Ayr Boulevard
Winnipeg, Manitoba
R3P OK4

The Honourable Mr. Douglas J. Watt
Reston, Manitoba
ROM 1XO

The Honourable Mr. Hugh Horner
Department of Agriculture
Legislative Bldg.
Edmonton, Alberta
(Minister of Agriculture)

The Honourable Mr. John R. Messer
Minister of Agriculture
Department of Agriculture
Legislative Bldg.
Regina, Saskatchewan

Mr. Alan Scarth
409 North Drive
Winnipeg, Manitoba
R3T OA1

Mr. E. W. Somers
DREE Manitoba Co-ordination
Department of Agriculture
809 Norquay Bldg
401 York St
Winnipeg, Manitoba
R3C OP8

Mr. Stuart Anderson
Deputy Minister
Department of Finance
109 Legislative Bldg.
Winnipeg, Manitoba

Mr. David Tomasson
1157 Lorette Avenue
Winnipeg, Manitoba
R3M 1V7

The Honourable Mr. H. Bostrum
Lands, Forests and Wildlife Resources
Department of Mines, Resources and Environmental Management
144 Legislative Bldg.
Winnipeg, Manitoba

Ms. Marlyn Duncan
Departent of Mines, REsources and Environmental Management
Box 7 - 1007 Century Street
Winnipeg, Manitoba

Mr. G. L. Vogel
Canadian Wheat Board
423 Main Street
Winnipeg, Manitoba
R3B 1B3

Mr. D. W. Wilton, Secretary
Manitoba Pool Elevators
220 Portage Avenue
Winnipg, Manitoba
R3C OA6

Mr. Bruno A. Friesen, Secretary
Alberta Wheat Pools
505 - 2nd St. S.W.
Calgary, Alberta

Mr. Robert Oetting
Resource Projects
Department of Mines, Resources and Environmental Management
1301 Ellice Avenue
Winnipeg, Manitoba
R3G OG1

Mr. E. F. Bossenmeier
Senior Wildlife Planner
Department of Nines, Resources
and Environmental Management
909 Norquay Bldg.
401 York St.
Winnipeg, Manitoba
R3C 0P8

Mr. W. Danyluk, Director
Parks Branch
Department of Tourism, Recreation
and Cultural Affairs
1981 Portage Avenue
Winnipeg, Manitoba
R3J 0J9

Dr. G. H. Lawler, Director
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba