INTERNATIONAL GARRISON DIVERSION STUDY BOARD

APPENDIX C
Biology Report

REPORT TO THE INTERNATIONAL JOINT COMMISSION - 1976

The report of the International Garrison Diversion Study Board is bound in six volumes as follows:

REPORT

APPENDIX A - WATER QUALITY
APPENDIX B - WATER QUANTITY
APPENDIX C - BIOLOGY
APPENDIX D - USES
APPENDIX E - ENGINEERING

CANADA-UNITED STATES

INTERNATIONAL JOINT COMMISSION

INTERNATIONAL GARRISON DIVERSION STUDY BOARD

APPENDIX C:

BIOLOGY COMMITTEE FINAL REPORT-

ENVIRONMENTAL IMPACT ASSESSMENT, ALTERNATIVES AND RECOMMENDATIONS, ATTACHMENTS

Prepared under the direction of: J. Loch - Canadian Co-Chairman

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Date: November 1976

November 1976

R. P. Baldwin and R. E. Dorothy
Co-Secretaries
International Garrison Diversion
Study Board

Dear Messrs. Baldwin and Dorothy:

We are pleased to enclose thirty copies of Appendix C of the International Garrison Diversion Study Board - Final Report of the Biology Committee. These copies are for Study Board members and International Joint Commissioners and staff. We have sent, under separate cover, one copy to each of the other Committee Chairmen.

The final report consists of the Environmental Impact Assessment, Recommendations, Abstract and Summary, and Attachments. One copy of our Information File will be forwarded to you under separate cover.

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ABSTRACT AND SUMMARY OF IMPACT PREDICTIONS

Our assignment was to describe the potential impacts, with and without the Garrison Diversion Unit on living resources in Canada through changes in water quality and quantity and introduction of exotic species.

In this report Canada's "living resources" are grouped as wildlife, fish, aquatic invertebrates, humans and other animals, plants and eutrophication of lakes and streams. Impact assessments are determined from project specifications, correspondence, scientific literature, other International Garrison Diversion Study Board committee reports and consultation with project personnel and other experts. Impact assessments are followed by suggestions for reduction of predicted damages and recommendations to satisfy deficiencies of this report.

Major predicted adverse impacts on Canada's living resources as a result of completion and operation of GDU are:

1) Loss of 124,400 to 257,700 ducks annually in North Dakota (Manitoba's share of this loss will be 24,900 to 51,600 birds annually) due to wetland loss and/or alteration in North Dakota.

2) Potential for increased incidence of waterfowl diseases resulting in additional losses of North Dakota and proportionately, Manitoba ducks and geese; these losses may approach those mentioned above.

3) Damage ranging from 15 to 75 percent of Manitoba's commercial fisheries in Lakes Winnipeg, Winnipegosis and Manitoba due to introduction of exotic fish species. These impacts will commence shortly (less than 10 years) after the project is completed with full effects within 25-50 years.

4) Increased algal growth in Lakes Manitoba and Winnipeg due to an increase of up to 7 and 24 percent, respectively, in the rate of annual phosphorus input.

5) A potential for large scale algal growth in the Souris and Assiniboine rivers resulting in seasonal oxygen depletions. Increased algal clogging of water intakes with associated taste and odor problems for water treatment plants along the Souris, Assiniboine and Red rivers.

6) A potential for significant quality deterioration of public and animal drinking water resulting from increases in nitrate, TDS and sulphate levels in the Souris River.

7) A potential for increased incidence and spread of human and animal diseases due to scouring of sediments from the Sheyenne and Wild Rice rivers and resulting transport of pathogens into the Red River. A similar potential exists for the Souris and Assiniboine rivers.

Lesser predicted adverse impacts are:

1) Damage to lake sturgeon populations in Lake Winnipeg due to introduction of two exotic sturgeon species and also introduction of an ovarian parasite.

The Committee identified the following impacts but were unable to fully quantify them:

1) Additional loss of waterfowl in North Dakota and Manitoba due to loss of nesting cover by conversion of grasslands to irrigated croplands in North Dakota.

2) Loss of shorebirds and other marsh birds in North Dakota and Manitoba due to wetland drainage and alteration of habitat in North Dakota.

3) In North Dakota, loss of wetlands and creation of large reservoirs and lakes resulting in altered fall staging, changed migration routes and shortstopping of waterfowl, shorebirds and other marshbirds; a proportion of these would have nested in Manitoba the following spring.

4) Loss of small, temporary wetlands resulting in possible reduced food sources for waterfowl migrating through North Dakota in spring to Manitoba.

5) Loss of waterfowl, shorebirds and other migratory marshbirds to other Canadian provinces or territories due to habitat damage or alterations in North Dakota.

6) Potential for introduction and/or increased incidence of certain fish diseases and parasites resulting in additional potential losses to fish populations of Manitoba.

7) Changes in aquatic plant and aquatic invertebrate species composition in the Souris River due to water quality changes (dissolved oxygen, TDS, nitrates, etc.) and damage to the sport fishery on the Souris and Assiniboine due to potential increases in algal growth in these rivers.

8) A potential for introduction of reptiles and amphibians exotic to Manitoba.

9) Increase in blackfly populations along portions of the Souris River.

10) Increased incidence of allergenic (including asthmatic) health problems due to irruptions of exotic caddisfly and mayfly populations in portions of the Souris and Red rivers.

11) Biological effects, other than increased algal growth, (oxygen depletion and changes in species diversity) of increased rate of nutrification to the North Basin of Lake Winnipeg and to Lake Manitoba.

12) Effects of water quality changes on indigenous fish populations in Lakes Winnipeg and Manitoba.

We predicted no adverse impacts for:

1) Rare and endangered plant and animal species along GDU Manitoba waterways.

2) Waterfowl production areas in Manitoba.

3) Indigenous Manitoba plants as a result of introduction of exotic plant diseases and terrestrial weeds.

4) Manitoba indigenous reptiles and amphibians.

5) Upland and wetland habitat along all GDU impacted Manitoba waterways.

Alternatives and recommendations for amelioration of some of the above predicted adverse impacts and further study to satisfy assessment deficiencies are presented in detail in the last section of this report. In summary we recommend:

1) The concept to reclaim drained wetlands and flood dry basins be adopted and implemented; this and other measures reported in the text could entirely mitigate predicted losses to waterfowl due to habitat alteration and/or loss.

2) A monitoring program be established to detect waterfowl disease outbreaks in GDU project areas in North Dakota.

3) Elimination of the Kindchi Lake turnout, Sheyenne River outlet (in the Lonetree Dam), New Rockford-Upper James River turnout; elimination of operational wasteways in all North Dakota project areas and installation of the McClusky Canal fish screen with design modifications and operating considerations suggested in this text. These could entirely mitigate adverse effects of introduction of exotic fish, fish diseases and parasites.

4) Due to a lack of comprehensive data on nitrogen in the Souris area, undertake an intensive study for the Souris River of eutrophication factors such as denitrification, assimilation of nitrogen, phosphorus and nitrogen transport, effects of primary productivity, relationship between oxygen depletion and increased algal production. This kind of information is essential to fully predict the impact of nutrient concentrations and loadings on the Souris River which we cannot do at this time. At present we cannot recommend any measure that will reduce the impact of nutrient loading on the Souris or other Manitoba waters.

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ABBREVIATIONS

CDHNW	Canada Department of Health and National Welfare
CLI	Canada Land Inventory
CWS	Canadian Wildlife Service
CDC	Center for Disease Control
DU	Ducks Unlimited
EPA	Environmental Protection Agency
GMA	Game Management Area
GDU	Garrison Diversion Unit
IGDSB	International Garrison Diversion Study Board
IJC	International Joint Commission
MDMREM	Manitoba Department of Mines, Resources and Environmental Management
MDRRTS	Manitoba Department of Renewable Resources and Transportation Services
MWTC	Manitoba Waterfowl Technical Committee
MDNR	Minnesota Department of National Resources
MPCA	Minnesota Pollution Control Agency
NWR	National Wildlife Refuge
NDGFD	North Dakota Game and Fish Department
NDHD	North Dakota Health Department
NDSU	North Dakota State University
OMNR	Ontario Ministry of Natural Resources
O&M	Operation and Maintenance
pers comm	Personal Communication
USSR	Union of Soviet Socialist Republic
US	United States
USACE	United States Army Corps of Engineers
BuRec	United States Bureau of Reclamation
FWS	United States Fish and Wildlife Service
HEW	United States Health, Education and Welfare
USPHS	United States Public Health Service
U of M	University of Manitoba
WPA	Waterfowl Production Area
WMA	Wildlife Management Area
/	per

TABLES AND FIGURES

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PUBLIC CONCERNS AND INTRODUCTION

To assess the magnitude of the problem and the degree of public concern about GDU, the IJC held a series of public hearings in Minot, Bismarck, Fargo and Winnipeg in November 1975. Briefs were presented by public officials, various groups and citizens at large.

A number of briefs expressed biological concern associated with GDU (Information file). Introduction of exotic biota (fish, fish diseases, bacteria, aquatic invertebrates, algae and plant materials) was a major concern expressed, along with increased nutrient loading to Lake Winnipeg and loss of waterfowl and wildlife habitat. In its study plan the Biology Committee addressed all of these concerns and others that surfaced during deliberations.

The Biology Committee is one of five study committees assigned to provide information and recommendations to IGDSB to answer questions raised by the governments of Canada and the US relative to the transboundary effects of completion and operation of GDU in North Dakota. The basic question is whether or not irrigation return flows, resulting from irrigation development in the watersheds of the Souris and Red rivers in North Dakota, will cause injury to health and property in Canada in contravention of Article IV of the Boundary Waters Treaty of 1909. The study assignment given to the Biology Committee, outlined in the Study Board's plan of study, is excerpted as follows:

1) Describe impacts of water quality and quantity, with and without GDU, on aquatic biota of pertinent Manitoba waters (Red, Souris and Assiniboine rivers and Lakes Winnipeg and Manitoba).

2) Describe impacts of possible introductions of exotic fish species, fish diseases and fish parasites on indigenous fish fauna, with and without GDU, in the Red, Souris and Assiniboine rivers, Lakes Winnipeg and Manitoba and appropriate Canadian tributaries.

3) Describe impacts of the possible introduction of other exotic biota (including plant diseases, aquatic plants, aquatic invertebrates and human and animal diseases), with and without GDU, on indigenous plants and animals in the Red, Souris and Assiniboine rivers, Lakes Winnipeg and Manitoba and appropriate Canadian tributaries.

4) Describe the effects on living resources of possible modifications, alterations or adjustments to the GDU plan.

STUDY PLAN

I. DEFINITIONS

The Biology Committee's assignment was to describe the impacts, with and without GDU, of potential changes in water quality and quantity and introduction of exotic biota on indigenous living resources in Manitoba.

We considered "biota" to include species of wildlife, fish, aquatic invertebrates, plants and diseases of wildlife, domestic animals, fish, plants and humans. "Indigenous living resources" refers to populations of wildlife, fish, aquatic invertebrates and plants and domestic animals that presently occur (either native or introduced) in Manitoba; humans were also included in indigenous living resources. "GDU Manitoba project areas" refer primarily to the following Manitoba waters: Red, Souris and Assiniboine rivers (downstream from its confluence with the Souris River), Lakes Winnipeg and Manitoba (including Delta and other major marshes) and areas of human habitation near these areas (Fig. C.1). "Exotic biota" therefore are biota not indigenous to Manitoba.

II. APPROACH

We considered two major categories: impact as a result of changes in water quality and quantity and impact as a result of introduction of foreign biota. Each of the biological groups within living resources may be impacted in different ways depending upon the biology of the particular group.

We based our major study activities on the kind of impact - water quality, quantity and introductions - and subdivided each activity as to impact on a particular biological group within living resources. We also defined a third activity, case history, which involved reviewing existing literature to document case histories (in other locales, with other biota) of either of the two impacts referred to above (Attachment C.A.).

We then identified target dates and external information input requirements. The latter was required from the Water Quality Committee (period of record and predicted water quality data, with and without GDU), the Water Quantity Committee (period of record and predicted water quantity data, with and without GDU) and the Engineering Committee (period of record and predicted suspended solids data, comments on alternate fish screen design and information on Portage Diversion).

Initial internal requirements were species lists from pertinent watersheds for wildlife, fish, aquatic invertebrates, plants, plant diseases, fish diseases, fish parasites and human diseases and parasites.

Species were then selected from the species lists on the basis of either indigenous biota that could be impacted upon or foreign biota

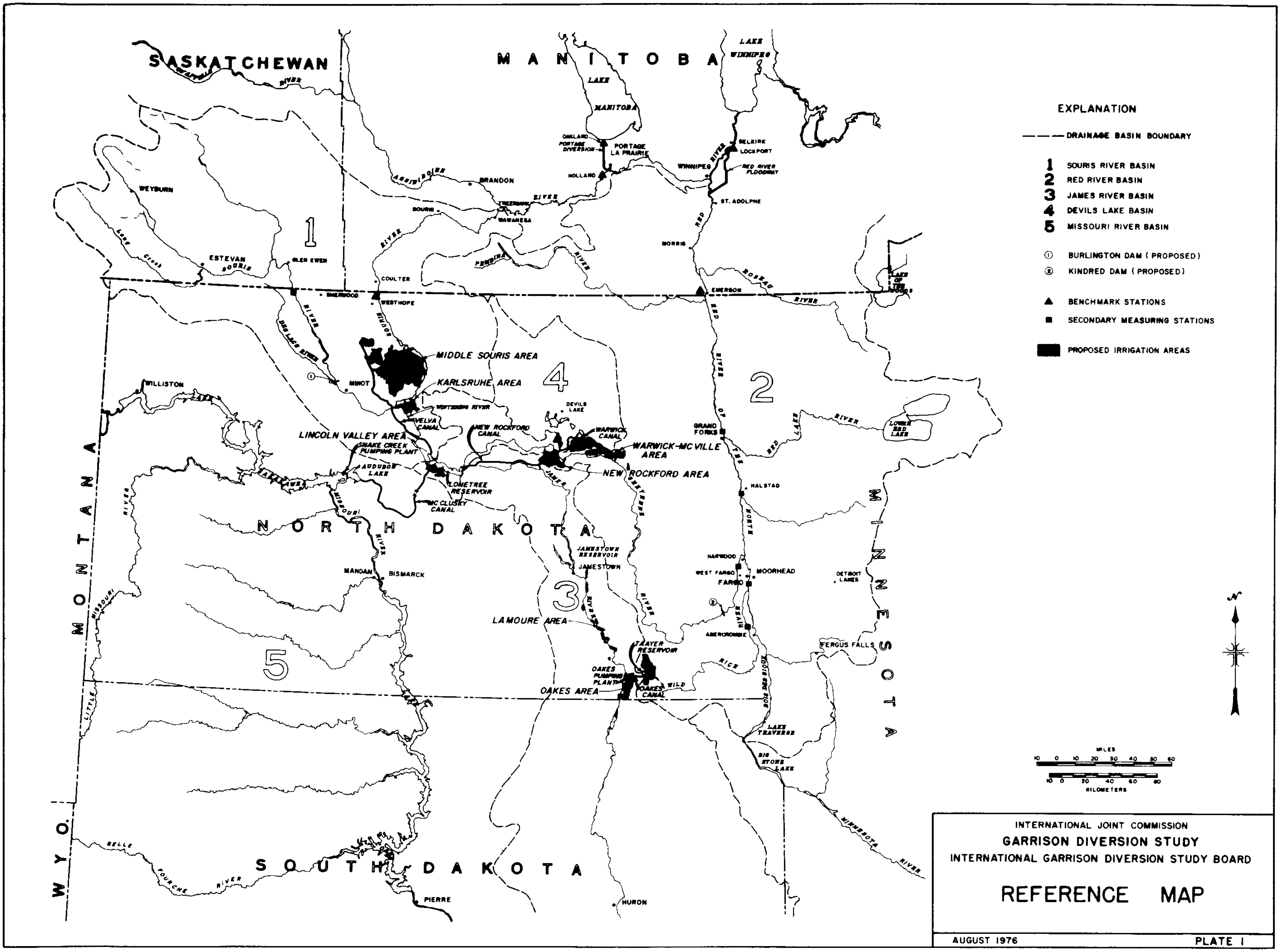
EXPLANATION
DRAINAGE BASIN BOUNDARY
1 SOURIS RIVER BASIN
2 RED RIVER BASIN
3 JAMES RIVER BASIN
4 DEVILS LAKE BASIN
5 MISSOURI RIVER BASIN
① BURLINGTON DAM (PROPOSED)
② KINDRED DAM (PROPOSED)
BENCHMARK STATIONS
SECONDARY MEASURING STATIONS
PROPOSED IRRIGATION AREAS
SASKATCHEWAN
MANITOBA
NORTH DAKOTA
SOUTH DAKOTA
MONTANA
MINNESOTA
WYO.
LAKE MANITOBA
LAKE WINNIPEG
PORTAGE LA PRAIRIE
WINNIPEG
SELKIRK
LOCKPORT
RED RIVER FLOODWAY
ST. ADOLPHE
MORRIS
EMERSON
BRANDON
WEYBURN
ESTEVAN
GLEN EWEN
SHERWOOD
WESTHOPE
COULTER
MINOT
WILLISTON
MIDDLE SOURIS AREA
KARLSRUHE AREA
VELVA CANAL
NEW ROCKFORD CANAL
LINCOLN VALLEY AREA
SNAKE CREEK PUMPING PLANT
AUDUBON LAKE
LONETREE RESERVOIR
MC CLUSKY CANAL
DEVILS LAKE
WARWICK CANAL
WARWICK-MCVILLE AREA
NEW ROCKFORD AREA
GRAND FORKS
HALSTAD
HARWOOD
WEST FARGO
FARGO
MOORHEAD
DETROIT LAKES
ABERCROMBIE
FERGUS FALLS
MANDAN
BISMARCK
JAMESTOWN RESERVOIR
JAMESTOWN
LAMOURE AREA
TAAYER RESERVOIR
OAKES PUMPING PLANT
OAKES AREA
OAKES CANAL
LAKE TRAVERSE
BIG STONE LAKE
PIERRE
HURON
LAKE OF THE WOODS
LOWER RED LAKE
MILES
KILOMETERS
INTERNATIONAL JOINT COMMISSION
GARRISON DIVERSION STUDY
INTERNATIONAL GARRISON DIVERSION STUDY BOARD
REFERENCE MAP
AUGUST 1976
PLATE I

Fig. C.1

that could be introduced. Detailed life histories were then developed for these key species.

Two aspects of potential GDU impact did not fit readily into the scheme as outlined. We decided to consider water as a resource which, while not "living" *per se*, has a number of biological aspects, one being eutrophication. Also, viewing and sport hunting of waterfowl and other wildlife species were considered within the study terms of reference.

Upon completion of an interim report, submitted to the Study Board on 22 April 1976 we integrated final figures from the Water Quality, Water Quantity and Engineering committees plus alternative schemes suggested by the Engineering committee and performed final assessments on all alternatives. We undertook field trips to view the project area during flood conditions, the McClusky Canal fish screen under construction and intermittent watershed connections at Milk River and Big Stone Lake. Initially we intended to complete our report by 30 June 1976, but various pieces of information were not available for some time thereafter and 30 August 1976 was set as final draft report deadline. This final draft was reviewed by the Board and comments were received. We then rewrote the final report for release to the Study Board on 10 November 1976.

III. REPORT ORGANIZATION

This report consists of the following major sections: Public Concerns and Introduction, Study Plan, Results and Discussion and Alternatives and Recommendations. The Results section is subdivided by resource groups: wildlife, fish, aquatic invertebrates, plants, water and humans. Each of these sections has its own introduction, methods, results, discussion, summary, literature cited and personal communications cited. A resumé of each of these sections is included in the Abstract and Summary of Major Adverse Impact section, following the letter of transmittal. In addition to the actual impact assessment, various alternatives, mitigation measures and recommendations for further study are included in this report. Attachments to various sections are also included. Readers will note the prefix "C" in titles of tables, figures and appendices. This prefix is intended to identify the Committee report source when a table, figure or appendix is lifted from this report for use in other IJC publications.

Readers will also note divergencies in this report from recognized methods of citing literature and personal communications. We felt these were necessary to make available to readers, sources of documents and reports emanating from the study which will not be available through normal library channels. The first divergence is considering letters, unpublished data, etc. as published literature and defining personal communications as oral communications only. Thus sections entitled "Literature Cited" include everything except oral (personal) communications.

A second divergence is inclusion of sections entitled "Personal Communications Cited". In these sections readers will find names, positions and addresses of persons annotated in the text ahead of personal communications. A third divergence is referring the reader, after certain literature citations, to an information file, shelved at the Freshwater Institute library, 501 University Crescent, Winnipeg and Division of Natural Sciences library, University of North Dakota, Grand Forks. The information file is on a reference-only basis at these libraries as the file is composed of unpublished documents and reports.

A resumé of the study plan including actual expenditures, list of committee personnel and record of committee meetings is included in this information file.

RESULTS AND DISCUSSION

I. WILDLIFE

A. Introduction

Wild animals are difficult to categorize for environmental impact assessment work. Traditional systems, such as breakdown by taxa, are efficient because of the manner in which scientific and wildlife management knowledge is categorized. On the other hand, society has placed different degrees of emphasis on various animal groups and thus a system of separating rare and endangered species, waterfowl and game animals from reptiles, amphibians and invertebrates, is desirable.

This report is a combination of these two systems. Information is presented by major vertebrate taxa but separate sections emphasize the importance of the international waterfowl resource and rare and endangered species. This categorization and approach bears witness to the state of the wildlife management art: we know much more about game animals than about non-game animals. No information on upland invertebrates is proferred. We recognize the large importance of these animals in ecosystems but their inclusion was not possible due to a paucity of information and time constraints of the study.

Considerable effort was made to relate effects of GDU to wildlife via wildlife habitat, since the quantity and quality of habitat is directly proportional to sizes and health of wildlife populations. In assessing effects of changes in water quantity and quality on wildlife, averages and means are used with discretion; of more value are maximums and minimums. Obviously, if a wild animal population is extirpated by a maximum concentration or innundation, how well it might have withstood average conditions would be irrelevant. For this reason, the Committee used extreme expected values, wherever feasible, for water quality and quantity assessments.

Impact assessment decisions rely on project specifications provided by BuRec, IGDSB committees, scientific literature and personal communications with experts. New GDU project features and processes which could alter impacts are reported in the discussion section. Scientific names of animals discussed in this section of the report are listed in Attachment C.I-1. Alternatives and recommendations for amelioration or mitigation of adverse impacts are not included in this section, but are set out separately.

In summary then, wildlife sections in this report are: Introduction, Overview, Mammals and Birds except Waterfowl, Waterfowl, Major Waterfowl Diseases, Amphibians and Reptiles, Rare and Endangered Species, Summary of Impacts, Literature Cited and Personal Communications Cited.

B. Overview

The Souris River Basin of Manitoba embraces a diversity and abundance of wildlife. Riverine habitat changes from grasslands and shrub communities in upstream reaches (near the US border) through mixed cropland/grassland/shrub complexes to stands of timber. Interspersed throughout these habitat types are marshes, mostly river oxbows. The river basin is an important wintering area for white-tailed deer.

The Assiniboine River, from its confluence with the Souris River to its confluence with the Red River at Winnipeg, is continuous with Souris River habitat in upper reaches and blends into Red River Valley habitat at its downstream end. The river passes through a unique topological feature, the Carberry Sand Hills. Here floral composition, reflecting the sandy soils and drifting dunes, provides habitat for some species of wildlife not found in abundance elsewhere in the province.

Near the City of Portage la Prairie an 18-mile diversion canal shunts flood waters from the Assiniboine River to Lake Manitoba through Delta Marsh. This marsh supports large populations of waterfowl and muskrats; the wooded beach ridge between the marsh and the lake is a wintering area for white-tailed deer.

The Red River in Manitoba, from a wildlife standpoint, is hardly distinguishable from upper reaches in the US. Heavily farmed and with many riverbank feedlots, the river provides limited habitat for wildlife.

Lake Manitoba and the southern half of Lake Winnipeg reflect aspen woodland and aspen parkland habitat preferred by white-tailed deer, coyotes, snowshoe hares and ruffed and sharp-tailed grouse. Several marshes on both lakes produce and stage large numbers of waterfowl. The north end of Lake Winnipeg exhibits the boreal forest or "spruce-moose" biome. Here species composition changes from ruffed and sharp-tailed grouse to spruce grouse, from white-tailed deer to moose, from great-horned owls to great gray owls. Caribou inhabit shorelines of the north basin of the lake. Lynx and snowshoe hares occur in cyclic abundance.

C. Mammals and Birds except Waterfowl

1. Planned Methodology: GDU project areas in Manitoba follow those defined by the Uses Committee (1976): one-half mile on either side of rivers and one-half mile inland along shores of lakes. In Manitoba these project areas are the Souris, Assiniboine and Red rivers, Lakes Manitoba and Winnipeg and Delta Marsh.

Five habitat types were selected in these project areas for impact assessment on wildlife. They are timber, shrub communities, grasslands, wetlands (marshes and rivers) and croplands. These five types encompass all habitats used by wildlife under consideration by the Uses Committee.

Assessment procedure was to measure these habitat types with and without GDU to determine percent gain or loss attributable to the project. This was to be accomplished by aerial photo interpretation and habitat measurement to establish the "without" (baseline) condition and superimposing GDU water quantity and quality expectations for the "with" condition.

Against these baseline habitat acreages, average known densities of indicator species were compared to estimate both present populations and population changes as a result of GDU (Table C.I.1). Indicator species are white-tailed deer and moose (ungulates), white-tailed jack rabbits and snowshoe hares (prey species), sharp-tailed, ruffed and spruce grouse (upland game birds), red fox, coyotes and lynx (long-haired furbearers), beaver, muskrats and mink (aquatic furbearers) and meadow and red-backed voles (small prey species).

Average known densities applied against habitat types were winter densities, since summer habitat is not a limiting factor for most of these indicator species. In the case of cyclic species such as snowshoe hares, ruffed grouse and lynx, peak densities were used, since habitat size is not believed limiting at lower densities.

The methodology outlined above tends to underestimate populations by categorizing habitats for indicator species. For example, "favored" habitat for coyotes is listed as timber/shrub communities (Table C.I-1). Yet, they are found in lower densities in other habitat types. Thus population estimates for indicator species in this report are minimal for those species not listed for all habitat types.

For water quantity assessment, GDU expectations were related to contour maps of the project areas to determine habitat changes. Expected water quality changes resulting from GDU were examined against wildlife tolerances to chemical and physical components. This information is reported in terms of percent habitat lost or gained and in population changes of indicator wildlife species.

Table C.I-1. Indicator species, habitats and areas of potential GDU impact in Manitoba.

Indicator species	Habitat type	Areas of potential GDU impact
White-tailed deer	Shrub/timber	All areas except north half and east side Lake Winnipeg.
Moose	Shrub/timber	North half of Lake Winnipeg.
White-tailed jack rabbit	Grassland/ cropland	All areas except north halves of Lakes Winnipeg and Manitoba and east side of Lake Winnipeg.
Snowshoe hare	Shrub/timber	All areas except south half of Souris River and Delta Marsh.
Sharp-tailed grouse	Grassland/ shrub	All areas except north half and east side of Lake Winnipeg.
Ruffed grouse	Shrub/timber	All areas except south half of Souris River, Delta Marsh and north half and east side of Lake Winnipeg.
Spruce grouse	Timber	North half and east side of Lake Winnipeg.
Red fox	All habitats	All areas except north half and east side of Lake Winnipeg.
Coyote	Shrub/timber	All areas except north half and east side of Lake Winnipeg.
Lynx	Timber	North half and east side of Lake Winnipeg.
Muskrat	Riverbank/ marsh	All areas.
Beaver	Rivers	All areas.
Mink	Riverbank/ marsh	All areas.
Meadow vole	All habitats	All areas except north half and east side of Lake Winnipeg.
Red-backed vole	Timber	North half and east side of Lake Winnipeg.

Two other indicator groups, raptors (birds of prey) and passerines (perching birds), were considered for inclusion in this report. However, so little density information is available for these groups and their diversity is so broad across geographic and habitat types that no meaningful assessment methodology could be reached for them.

2. Actual Methodology: As with mice and impact assessors, whose plans "gang aft agley", so it is with the methodology outlined above. Before habitat and indicator populations on parts of the Souris River and all of the Red and Assiniboine rivers and Lakes Manitoba and Winnipeg could be measured, preliminary reports from both the Water Quantity and Water Quality Committees indicated such baseline information would not be necessary.

The Water Quantity Committee (1976a) stated, "On the Assiniboine and Red rivers the impact of GDU return flows on flooding would be insignificant . . . levels on Lake Manitoba and Winnipeg would not be measurably affected by GDU return flows.

Concern over additional flooding in the Delta Marsh as a result of high spring levels on the Assiniboine River at Portage la Prairie in 1976 prompted this response from the Engineering Committee (1976): ". . . The incremental chance the occurrence of a peak daily discharge of 23,000 cfs or more (flow necessary upstream of Portage la Prairie to spill into Delta Marsh via the Portage Diversion) in any one year as a result of GDU is 0.003 or 0.3%".

A comparison of expected GDU levels of several water quality components, forwarded by the Water Quality Committee (1976) against tolerance levels of various animal species showed no anticipated impact on wild animals. The Water Quality Committee (1976) also predicted no changes in levels of heavy metals or other pesticide residues under "expected good management practices". Accordingly, we considered only water quantity changes in the upper reaches of the Souris River in Manitoba.

3. Baseline Results - Without GDU: The first 107 miles of the Souris River, from the US border downstream to Heaslip Station, encompasses 68,480 acres of all habitat types one-half mile on either side (Table C.I-2). Date of the photo series from which interpretation was done is July, 1968 and represents a low-flow condition. Applying average known densities of indicator species to these habitat sizes produces total estimated populations of 418 white-tailed deer, 3,150 snowshoe hares and 820 sharp-tailed grouse, etc. (Table C.I-3).

4. Effects of GDU: Anticipated return flows from GDU will cause some additional flooding on the Souris River, according to our interpretation of Water Quantity information (1976a,b). However, this additional flooding and/or duration of flooding will be too small to

Table C.I-2. Habitat sizes one-half mile on either side of 107 miles of Souris River, Manitoba.

Habitat type	Habitat size[2] mi^2	acres	Percent
Timber	10.6	6,784	10
Shrubs	10.3	6,592	10
Grassland	22.5	14,400	21
Cropland	51.7	33,088	48
Marsh	5.4	3,456	5
River	2.7	1,728	2
Urban[1]	0.6	384	1
Other (roads, etc.)[1]	3.2	2,048	3
TOTAL	107.0	68,480	100

[1] Not included as indicator species.
[2] Source: MDRRTS (1976a).

Table C.I-3. Population estimates of indicator species one-half mile on either side of 107 miles of Souris River, Manitoba.[1]

Indicator species	Habitat type(s)	Habitat size (mi^2)	Densities (mi^2)	Estimated population
White-tailed deer	Shrub/ timber	20.9	20	418
White-tailed jack rabbit	Cropland/ grassland	74.2	16	1,187
Snowshoe hare	Shrub/ timber	10.5	300	3,150
Sharp-tailed grouse	Grassland/ shrub	32.8	25	820
Ruffed grouse	Shrub/ timber	10.5	75	788
Red fox	All except river	90.5	1	90
Coyote	Shrub/ timber	26.3	0.75	20
Muskrat	River/ marsh	-	10; 1,920[2]	11,438
Beaver	River	-	1[3]	107
Mink	River/ marsh	-	4[3]	428
Meadow vole	All except marsh and rivers	95.1	9,600	912,960

[1]Source: MDRRTS (1976a), D. Rusch (pers comm) and Manitoba Museum of Man and Nature (1976).
[2]Density/river mile; density/wetland mi^2.
[3]Density/river mile.

significantly alter upland habitat along the Souris River.

5. Discussion: The preceding impact assessment is based on existing information available to Study Board committees and congressionally-authorized GDU features (BuRec 1974a,b). New information, processes and project features either not fully documented or as yet unauthorized could change the predicted effects of GDU on Manitoba birds and mammals.

Water quantity predictions, as reported by the Water Quantity Committee, could change in two ways. First, the congressionally-authorized fish and wildlife mitigation plan contained in BuRec's earlier proposals allocated 165,000 acre feet of GDU water annually for waterfowl production and recreation purposes (FWS 1962). This plan has been revised by FWS.

The new FWS idea calls for replacement of GDU-drained wetlands with acquisition and development of former wetland basins which had been drained for agricultural purposes. This new idea, which calls for about the same acreages and the same funding, has received approval in principle from both BuRec and the Garrison Conservancy District.

The new wildlife idea will use only about 5,000 acre-feet of GDU water annually, leaving a balance of 160,000 acre-feet available for other purposes. If this residual water is used for other purposes it could affect water quantity (and quality) impacts on Manitoba birds and mammals.

Second, water quantity (and quality) change is seen in private drainage of wetlands into GDU waterways in North Dakota. The practice of private landowners draining wetlands into new ditches is an old and common practice in the prairie pothole regions of the Dakotas and Minnesota: its documented presence in the GDU project areas of North Dakota comes as no surprise. This drainage is reported in detail in the Waterfowl Section.

In addition, no projections have been made on future water quality of Lake Sakakawea, source of GDU. Industrial and agricultural field appropriations, options and requests for water upstream of Lake Sakakawea may be in the neighborhood of 3 million acre-feet annually (Northern Plains Resource Council 1974). How many of these requests will be granted and what effect this water use will have on the quality of Lake Sakakawea is not known. Should Sakakawea water quality deteriorate significantly, expected water quality of GDU return flows into Manitoba, as reported by the Water Quality Committee, could worsen, with concomitant impacts on birds and mammals not foreseen in this report.

Furthermore, final impact assessment statements from Water Quality and Quantity committees are based on best management practices by GDU water users. The Committee feels it is unlikely that this level of efficiency will be attained. Less than best water management by the many GDU irrigators and other water users will change quantity and quality predictions and may result in further effects on Manitoba wildlife.

D. Waterfowl

1. Introduction: The term waterfowl usually refers to ducks, geese, cranes, swans, gulls, terns, shorebirds and other marsh birds which frequent wetlands and migrate. Quantified sections of this report refer only to ducks, except where otherwise noted, because much more data are available for ducks than for the other groups. A list of shorebirds and other marsh birds, studied in one North Dakota GDU project area (Kraft Slough) is presented in Attachment C.I.2.

Waterfowl are a valuable international resource which support considerable recreation in Canada and the US. To conserve this natural resource and ensure optimum fall flights to meet recreational demands, publicly and privately owned wetland habitats in the US and Canada must be preserved and wisely managed.

To meet this objective, Canada established a National Wildlife Policy and Program, which called for the preservation of suitable wetland habitat by acquisition, lease or agreement in amounts sufficient to support desired waterfowl populations without crop depredation.

In response to this policy the International Migratory Birds Committee of Canadian, American and Mexican members was formed in 1962. To achieve Committee goals, government agencies and waterfowl hunters have contributed more than $100 million for acquisition of waterfowl habitat in the US and Canada. In addition, several privately sponsored organizations, such as DU, have developed waterfowl breeding habitat. Several million acres have been set aside in Canada and the US in this manner. North Dakota is the heart of these programs. NWRs, WMAs, GMAs, WPAs, state and provincial refuges and DU project areas managed specifically for ducks and geese in Manitoba and North Dakota attest to the zeal of North Americans to maintain harvestable waterfowl populations.

Banding returns and other population data indicate that waterfowl present in North Dakota one year may occupy habitat in Manitoba another year, forming an international breeding reservoir; even within the same year, "shuffles" find large numbers of birds moving northward across the international border (Anderson and Henny 1972). For these reasons it was necessary for us to assess potential GDU impact on Manitoba waterfowl in both North Dakota and Manitoba.

Three major potentials for GDU effects on Manitoba waterfowl are presented in this report:

a) Effects on the Manitoba/North Dakota breeding reservoir. This assessment includes effects on Manitoba waterfowl populations by GDU-caused wetland drainage or alteration in North Dakota: project drainage, private drainage adjacent to project waterways, reduced production in NWRs and stream channelization.

b) Effects on Manitoba's fall waterfowl populations through reduction of fall shuffle bird numbers, ducks which are present in North Dakota in summer and "shuffle" to Manitoba in a post-breeding dispersal before their migration to southern wintering areas.

c) Direct effects on Manitoba's waterfowl production areas.

CWS has an obligation under the Migratory Bird Treaty to protect and manage migratory birds. If necessary CWS may take unilateral action to protect Canada's interest in migratory bird populations and habitat and will do so whenever extensive, critical or unique production areas are threatened.

2. The GDU Wildlife Plan: GDU calls for the irrigation of 250,000 acres in North Dakota. In this area are marshes, potholes and waterways used by wildlife, especially waterfowl. Some of these areas will be drained, channelized or flooded by the project, reducing their value to waterfowl.

In 1962 FWS developed a GDU mitigation plan for BuRec to offset wetland loss. A number of documents were prepared by FWS, reviewing potential adverse wetland impact and providing advice to ameliorate this impact. These plans are incorporated in BuRec's GDU authorization and are referred to collectively in this report as the original fish and wildlife plan.

The plan specifies that 146,530 acres will be obtained and used for wildlife purposes. Approximately 92,000 acres are to mitigate wetland and upland losses while the remainder is to serve as enhancement. The number of acres of wildlife habitat to be lost to GDU was estimated as follows: the total GDU concept is to irrigate 1,007,000 acres. In 45 percent of the 250,000-acre initial stage project area (including Oakes, LaMoure, Warwick-McVille and Lincoln Valley areas) wetland losses were documented from topography maps and aerial photos with a small amount of ground truthing. For the other portion of the 250,000-acre project area (55 percent), wetland losses were estimated from 10 samples from the 1,007,000-acre total project area. According to BuRec (1974b), FWS extrapolated wetland losses from these 10 sample areas to the remaining portion of the 250,000-acre project area, assuming that the density, distribution and proportional composition of wetland types in the sample areas were similar to those in the entire project area. Others have shown that wetlands are not uniformly distributed (Smith et al. 1964).

This resulted in a mitigation proposal to acquire a number of existing wetlands (BuRec [1974a] showed 28,700 acres but inadvertently omitted 5,400 acres of Class I ponds) and 92,000 acres of uplands.

Some of these wetlands will be altered by adding project water to enlarge and deepen them. This operation will expand the original wetland acreage from 34,100 to approximately 56,000, although no new areas will be created. It must be emphasized that for the most part, only existing wetlands are to be acquired and "improved" via the original plan.

Prairie wetlands have been categorized by size, shape and permanency. In North Dakota they vary from Class I (shallow, ephemeral ponds which dry up during the growing season) to Class V (permanent ponds or lakes). Although all are used by waterfowl during some portion of the year, Classes III and IV (6 inches to 3 feet of water throughout the growing season) support almost 90 percent of waterfowl production (Stewart and Kantrud 1971, 1973, Table C.I-4). Class I ponds, while ephemeral, are important as feeding and resting areas for waterfowl during spring migration, since they thaw early and are thus available to the birds before larger, deeper wetlands. Large, deep wetlands (Class V) are used by waterfowl for fall staging and are thus important in the fall migration phenomenon.

Many wetlands to be altered under the original plan are desirable Classes III and IV bodies of water. Additional water will not benefit these wetlands and may enlarge and deepen them to the point that their value as production areas is greatly decreased. Other wetlands in the project area will be furnished with "dependable" water supplies, according to the original plan, but such water manipulations do not necessarily improve such wetlands for waterfowl production (Smith 1971, Johnsgard 1956). On the basis of reviews (Krapu and Duebbert 1974, Pearson et al. 1975) of wetlands to be altered, the Committee believes that no increase in waterfowl production will accrue as a result of changes authorized under the GDU plan (Table C.I-5).

In addition to the enhancement procedures outlined in the original plan and explained above, the number of acres of wetlands to be altered, as reported by FWS, is underestimated.

FWS recently surveyed the Oakes, Lincoln Valley and McClusky Canal areas to test the validity of the anticipated GDU wetland drainage. FWS (1976a) advised that recent evaluations in Oakes show an anticipated loss of 10,500 acres and an adverse impact on an additional 2,000 wet acres. This contrasts with an original GDU appraisal of 4,200 acres adversely affected (BuRec 1974a).

In the McClusky Canal area 4,738 acres will be adversely affected instead of the 2,790 shown by BuRec (1974a). The loss to Lonetree Reservoir construction will be 5,522 acres (C. Elliott pers comm) instead of 3,850 as originally indicated (BuRec 1974a).

These field determinations indicate the original wetland loss will likely be doubled and form the basis for FWS's anticipated loss of

Table C.I-4. Ecological distribution of breeding duck populations in the prairie pothole region of North Dakota[1].

Habitat type	Percent of 872 pairs in 1967	Percent of 1,529 pairs in 1968	Percent of 4,790 pairs in 1969	Percent average 1967-69
Natural wetlands				
Basin wetlands				
Prairie ponds and lakes (with untilled bottom soils)				
Ephemeral ponds (Class I)	T[2]	T	0	T
Temporary ponds (Class II)	2	1	2	1
Seasonal ponds (Class III)	50	32	45	42
Semipermanent ponds and lakes (Class IV)	16	41	23	27
Permanent ponds and lakes (Class V)	0	8	1	3
Alkali ponds and lakes (Class VI)	1	T	T	T
Fen ponds (Class VII)	0	T	T	T
Cropland ponds (with tilled bottom soils)				
Temporary ponds (Class II)	0	1	2	1
Seasonal ponds (Class III)	3	3	9	5
Undifferential tillage ponds (Class II and III)	8	2	6	5
Streams and oxbows	7	5	4	6
Man-made wetlands				
Stock ponds	T	2	1	1
Dugouts	0	2	2	1
Reservoirs and large impoundments	11	0	3	4
Road ditches and drainage channels	2	1	1	2
Other (sewage lagoons etc.)	0	T	0	T
Upland habitats	T	T	1	T
Total	100	100	100	100

[1]Source: Stewart and Kantrud (1973).
[2]T indicates 0.5 percent or less.

Table C.I-5. Predicted waterfowl production changes as a result of wetland improvement on 34,100 acres of existing wetlands[1] in GDU North Dakota project area[2].

Area	Present wetland acreages	New wetland acreages	Comments	Estimated changes in waterfowl production
Principal supply works	5,974	11,760	8 lakes and creeks to be enlarged	Decrease
Lamoure	551	1,250	1 marsh to be enlarged	Increase
Oakes	4,150	8,271	9 marshes and lakes to be enlarged	Decrease
Souris	6,972	9,560	1 lake and 2 rivers to be enlarged	None
Devils Lake	5,744	16,737	West Bay of Devils Lake to be enlarged	Decrease
Central North Dakota	3,436	4,771	8 marshes to be enlarged	Increase
Miscellaneous	1,805	3,826	wetlands not identified	Unknown
Totals and summary	28,632[1]	56,175	Most increases to low produc-ion lakes. Most decreases due to deepening of shallow-marshy areas	No forseeable increase in waterfowl production

[1]Approximately 5,400 acres of Class I wetlands not included.
[2]Summarized from BuRec (1974a).

50,000 acres (1976a). The Committee agrees with this new analysis of wetland loss and the remainder of this report is based on an anticipated loss of 50,000 acres to project drainage, not 26,950 as originally predicted by FWS and reported by BuRec (1974a).

In summary, the Committee believes the project will adversely impact an estimated 50,000 wetland acres. It will protect 34,100 wetland acres and 90,000 upland acres presently in existence. It will add 22,000 acres to these existing wetlands by flooding and deepening, processes which will not result in a net increase in waterfowl production.

3. Methods: GDU project areas used in this report are Souris River Basin (US and Canada), Red River Basin (US and Canada, including Sheyenne and Wild Rice rivers), Missouri River Basin including the James River, Devils Lake Basin, Assiniboine River, Delta Marsh and the shores and marshes of Lakes Winnipeg and Manitoba. Project areas include wildlife refuges, waterfowl production areas and other managed and unmanaged wetlands in these drainage basins.

Habitat is the key to waterfowl production. Habitat and waterfowl population information was quantified, where research data were available, for US and Manitoba GDU project areas. Wetland classification and waterfowl production capabilities were garnered from Stewart and Kantrud (1971) and Canada Land Inventory (CLI) maps, respectively.

Production ratios for breeding waterfowl were established at 1.08 fledged young/adult. This figure is an eight-year average of fledged young/adult production ratios (FWS 1964-75) for the Mississippi Flyway. The breeding waterfowl population of 3.03 million birds and estimated production of 3.27 million birds in North Dakota east of the Missouri River represents a 10-year average (FWS 1964-75). A production ratio for wetlands of 1.1 fledged young/wetland acre is used throughout the report. This figure was derived from an estimate of 3 million wetland acres (Stewart and Kantrud 1974) and a waterfowl production estimate of 3.27 million birds. Average annual mortality was estimated at 51 percent. This figure is an eight-year average of spring-to-spring breeding populations (1966-74) in North Dakota. (Henny [1973] used 50 percent mortality in his waterfowl overflight study). Summer mortality of adults was established at 22.4 percent (Johnson and Sargent in press). This percentage has been deducted from displaced (non-breeding) adult losses in this report.

Except for managed areas such as Upper Souris and J. Clark Salyer NWRs, riverine habitat in the entire project area is undeveloped for waterfowl production. Riverine population figures for Canada and the US are based on eight breeding pairs/river mile (extrapolated from Stewart and Kantrud 1973) with an estimated production success of 1.08 fledged young/adult in unmanaged portions of the river. Along the Souris River managed areas are J. Clark Salyer, Upper Souris and des Lacs NWRs; along the Wild Rice, Tewaukon NWR and on the Sheyenne River, Arrowwood NWR. These refuges and the Coulter area of the Souris River in Manitoba provide staging areas where fall flights are formed for southward migration. On the Canadian portion of the Souris River there are no large wildlife management areas specifically managed for waterfowl production.

Throughout this report mallards are used as an indicator species for ducks, since more information is available for them than any other species. Mallards are the most sought-after duck species in Manitoba and have been the target of considerable population research and modeling in recent years by MWTC, FWS and CWS. The international interchange of mallards between North Dakota and Manitoba is well documented; such information on other duck species is sparse but the interchange is known to occur for several of them. We therefore assumed that these species of ducks in North Dakota behaved the same as mallards in their contribution to Manitoba's waterfowl populations.

Because of time constraints we were not able to quantify migratory shorebird, other marsh bird and goose population changes in Manitoba as a result of wetland drainage and alteration in North Dakota. The complexity of marsh and shorebird species composition is shown by documentation of species associated with one GDU North Dakota area, Kraft Slough (Attachment C.I.2). Biologists working at Kraft Slough, (to be inundated and re-named GDU's Taayer Reservoir), tallied 135 species of birds in 1974, comprising 40 percent of all bird species known to breed in North Dakota (Krapu and Duebbert 1974). Included were an estimated 3,323 breeding pairs. These and other non-duck species comprise 65 percent of birds breeding on North Dakota wetlands (Stewart and Kantrud 1976).

Hundreds of thousands of geese stage in North Dakota spring and fall; FWS (1960-74) estimated that more than 220,000 geese use the J. Clark Salyer-Coulter area annually. What effect GDU may have on these resources could not be determined in time for this report. Recent information shows that even in northern climes, creation of reservoirs and other large water bodies tends to change goose migration patterns and may short-stop geese for varying periods of time in their southern migrations (Dzubin et al. 1975). We recognize the importance of these birds and their protected status in North Dakota and Manitoba and under the Migratory Bird Treaty.

We were also unable to pursue GDU-caused waterfowl losses in North Dakota into Saskatchewan and Alberta, although we recognize the participation of these two provinces in the international breeding reservoir and fall shuffle.

We searched a wide range of published and unpublished waterfowl literature and consulted with many waterfowl experts to produce this assessment. Reports used were chosen because they best represented average conditions. Waterfowl personnel at CWS (Saskatoon and Winnipeg), MWTC, DU, MDRRTS (Winnipeg) and FWS (Bismarck and Jamestown) provided information for this report. Final manuscript review was provided by personnel at FWS, CWS and MWTC. Waterfowl numbers in this report are rounded to the nearest hundred.

4. Baseline Results: Production estimates: spring population estimates conducted by FWS (1964-75) indicate that breeding populations in southern Manitoba average 1,880,000 ducks. In GDU Manitoba project areas approximately 76,300 breeding pairs produced 182,100 fledged birds (Tables C.I-6,7 and 8). This amounts to a total fall population of approximately 300,000 waterfowl (after average summer adult mortality of 22.4 percent). North Dakota estimates for the years 1964-74 indicated an average breeding population of 3.03 million ducks which produce 3.27 million young for a total fall population (after summer adult mortality) of approximately 5.62 million birds.

Fall shuffle estimates: direct band returns indicate that 4.5 percent of North Dakota's fall mallard population flies northward to stage in Manitoba each year (Anderson and Henny 1972). Other species which participate in the fall shuffle to a lesser or greater extent are blue-winged teal, wigeon, lesser scaup, pintails, canvasbacks, redheads and northern shovelers (D. Trauger pers comm). Since the shuffle phenomenon for these species is not well quantified, we assumed they participated at the same rate as mallards. These species, including mallards, comprise 80 percent of North Dakota's fall waterfowl populations (Stewart and Kantrud 1972). Thus the fall shuffle from North Dakota to Manitoba involves an estimated 202,320 birds annually. Direct band recoveries also show that approximately 20 percent of the mallards produced in Manitoba are harvested by Manitoba hunters (MWTC 1975). Extrapolating this harvest ratio to the other species of fall shuffle birds, we estimate that in 1975, Manitoba hunters harvested approximately 40,400 waterfowl from North Dakota or about 12 percent of Manitoba's waterfowl harvest.

Breeding reservoir estimates: due to behavioral characteristics of waterfowl and under average water conditions ("May ponds"), approximately 20 percent of surviving mallards, originally fledged in North Dakota, will nest in Manitoba in subsequent years (A. Dzubin pers comm). During years of drought in North Dakota this percentage increases. The breeding reservoir rate of 20 percent was established by averaging estimated pioneering rates for those species (mallards, northern shovelers, pintails, wigeon, redheads, ruddy ducks and blue-winged teal) which readily pioneer new habitat. These species comprise about 82 percent of North Dakota's waterfowl populations. Assuming an average North Dakota spring population of 3.03 million waterfowl and applying the pioneering rate and the reservoir rate, about 497,000 North Dakota reared ducks will nest in Manitoba in a subsequent year (Table C.I-9). At a rate of 1.08 fledged young/adult, these waterfowl then add approximately 536,000 birds to Manitoba's population.

Table C.I-6. Estimated waterfowl production for GDU Manitoba areas, all species.

GDU areas	Estimated annual production	Estimated fall flight
Souris River[1]	2,600	4,500
Assiniboine River[2]	3,800	6,400
Red River[3]	2,600	4,500
Lake Manitoba[4]	115,100	189,600
Lake Winnipeg	58,000	95,300
Total	182,100	300,300

[1]151.5 river miles.
[2]217.0 river miles.
[3]151.6 river miles.
[4]Includes Delta Marsh.

Table C.I-7. Breeding pair use by all species of ducks of Lake Winnipeg and major marshes on Lake Winnipeg, 1969[1].

Major marshes	Acres	Breeding pairs	Estimated fall flight[2]
Netley-Libau	55,000	12,304	48,526
Willow Point	2,200	492	1,940
Riverton	5,400	1,208	4,764
Hecla Island	6,100	1,365	5,384
Washow Bay	4,500	1,006	3,968
Sturgeon Bay	15,000	3,356	13,236
Grand Marais	900	201	792
Victoria Beach	550	123	485
Beaconia	1,100	246	970
Fisher Bay) Long Point) Limestone Bay)	9,250[3]	2,070	8,164
Total, major marshes	100,000	22,371[4]	88,231
Lake Winnipeg	6,000,000	1,800[3]	7,099
TOTAL		24,171	95,330

[1]Source: Townsend (1969).
[2]1.2 fledged young/adult less 22.4 percent adult summer mortality.
[3]Two pairs/mile of shoreline.
[4]23.2 observed pairs/mile for Netley-Libau, one pair/4.47 acres for other marshes.

Table C.I-8. Breeding pair use by all species of waterfowl of Lake Manitoba and major marshes on Lake Manitoba, 1976.

Major marshes	Acres	Breeding pairs[1]	Estimated fall population[2]
Mouth of E Waterhen River	14,500	2,517	9,947
Base of Toutes Aide Bay	2,200	382	1,510
Bays N of Garden Island	23,000	3,993	15,780
Crane Bay	4,700	816	3,224
Base of Peonan Peninsula	3,700	642	2,537
Bay S of Pine Island	4,000	694	2,743
Elm Bay	2,500	434	1,716
Moosehorn Bay	7,800	1,354	5,351
Vankaughnet Bay, Nina Lake	9,500	1,649	6,517
The Narrows	38,000	6,597	26,072
Dog Creek	7,000	1,215	4,802
Lily Bay	7,600	1,319	5,213
Marshy Point	12,000	2,083	8,232
Sandy Bay	20,000	3,472	13,722
S rim of Lake	66,000	11,458	45,282
Bay SW of Point Asham	1,000	174	688
Bay W of Reykjavik	5,000	868	3,430
Delta	43,000	7,465	29,502
Total, major marshes	271,500	47,132	186,268
Lake Manitoba	1,088,000	832[3]	3,288
TOTAL		47,964	189,556

[1]Density of 1 pair/5.76 acres (pair density for Delta Marsh, MDRRTS, 1976b).
[2]1.2 fledged young/adult.
[3]Two pairs/mile of lake shoreline (excluding major marshes).

Table C.I-9. Summary of duck production in North Dakota and effects on Manitoba's fall populations, without GDU.

North Dakota	
Spring breeding population:	3.03 million
Production:	3.27 million[1]
Fall flight:	5.62 million[2]
Manitoba	
Fall shuffle:	202,300
Production:	536,800
Fall flight adults:	385,700
Total annual increment to Manitoba's fall flight from North Dakota origin	1,124,800[2]

[1]1.08 fledged young/adult.
[2]Manitoba's breeding reservoir and fall shuffle "share" of North Dakota's waterfowl population equates to 20 percent.

Direct band recoveries indicate that 27 percent of out-of-state mallards harvested in Minnesota originate in Manitoba and 10 percent from North Dakota (Langowski and Jessen 1975). Therefore loss in breeding waterfowl due to GDU in North Dakota will also be a loss to Minnesota. We were unable to determine the size of similar losses to Saskatchewan and Alberta within the time available.

5. Indirect effects in Manitoba due to GDU in North Dakota: As already noted, construction of GDU will destroy waterfowl production on an estimated 50,000 wetland acres in North Dakota through project drainage. This loss will not be offset by the plan to acquire and "improve" 34,100 acres. In addition, waterfowl losses will result from private drainage and reduced production at NWRs and on streams. A discussion of each of these impacts follows:

Project wetland drainage: drainage of 50,000 acres of wetlands in North Dakota will result in the loss of approximately 55,000 fledged ducks annually (1.1 fledged young/wetland acre). In addition, 50,900 adult ducks (1.08 fledged young/adult) will be displaced. These birds will go elsewhere in an attempt to breed, but experience indicates they will not contribute significantly to the fall population. When ducks overfly North Dakota due to poor water conditions, Manitoba populations often increase correspondingly but this increase does not produce a proportionately larger number of fledged ducks (FWS 1976d). The displaced ducks would, of course, contribute to Manitoba's recreational sport hunting, albeit at ever-decreasing levels as they continue to experience annual mortality. Once these birds are removed from the population the annual loss will be 94,500 waterfowl.

Private and/or wetland drainage: an additional impact is anticipated through wetland drainage in portions of GDU North Dakota project areas. These wetlands provide waterfowl to Manitoba both as breeding pairs and as fall shuffle birds. BuRec (1974b) stated, "Discharge of drain water from natural wetlands or potholes located within non-irrigated land areas into project drains will not be allowed unless permission is granted by the project-operating agency based on no adverse environmental impact in accordance with recommendations from the Bureau of Sport Fisheries and Wildlife" (now FWS).

FWS (1976a) advised that new private drainage is presently occurring into the McClusky Canal. At least 20 potholes have already been drained by 13 ditches, some of which are known to be newly constructed. To quantify this potential drainage we assumed loss of private wetlands into GDU waterways would occur at a rate equal to similar losses estimated for highway drains in Minnesota. There, an estimated 29 percent of existing Class III, IV andV wetlands within one mile of highways have been drained into highway ditches (FWS 1975). We recognize that drainage into highway ditches may or may not approximate drainage into irrigation canals and wasteways but we were unable to find a more pertinent reference. We therefore assumed these drainage rates to be comparable.

The relative proportion of Class III, IV and V wetlands within GDU North Dakota are respectively 13.43, 9.31 and 9.61 wetland acres/mi^2 (computed from FWS 1974 including appropriate drainage rates). BuRec (1974a) estimated that a total of 287 miles of canals and 358 miles of drains will be constructed. Therefore we estimate that 17,325 acres of Class III, 10,720 acres of Class IV and 12,397 acres of Class V wetlands are located within one mile on either side of project canals and could be drained.

Applying the 29 percent rate to these 40,400 wetland acres shows a potential private drainage of Class III, IV and V wetlands into project canals of 11,700 acres. As witnessed in court cases and on the face of the land, promises not to drain into new, public canals and ditches are difficult to keep and legislation against unauthorized drainage is difficult to enforce. The fate of private wetlands adjacent to GDU waterways rests with BuRec's willingness to comply with their stated objective of no drainage. If BuRec stops present drainage into project waterways, restores those wetlands already drained and undertakes a continuous, efficient program of monitoring and enforcing the no-drain objective, no waterfowl loss because of private drainage need occur.

If, however, the present situation is not rectified and preventative measures are not instituted, all the potential private drainage will be realized, with concomitant loss to waterfowl. We estimate this waterfowl population loss to private drainage along GDU waterways will range from zero to 76,300 (1.1 fledged young/wetland acre plus 1.08 fledged young/adult) depending upon the extent of drainage.

North Dakota recently passed new regulations which require a permit to drain basins of 40 acres or larger. This permit system will be administered by the state water commission. This regulation may aid in prohibiting unrestricted drainage on private land.

Impact to NWRs and Devils Lake Basin: FWS (1976b) published a report dealing with the expected impact of GDU to NWRs in North Dakota. BuRec (1976a) and CDM Limnetics (1976) stated these impacts will not be as great as predicted by FWS. It is not our role to arbitrate this disagreement. All reports on this issue have been studied and the Committee believes that waterfowl populations at Arrowwood, J. Clark Salyer, Upper Souris, des Lacs and Tewaukon NWRs will be adversely effected by GDU. Other NWRs and designated wildlife areas described in the report may or may not be affected by GDU; we were unable, in the time allotted, to adequately review these other units.

An evaluation of anticipated effects of GDU on the five North Dakota NWRs named above and the Devils Lake Basin follows:

Arrowwood - This refuge, located on the James River above Jamestown Reservoir, contains four river lakes totaling 5,379 surface acres. GDU will increase water flows at Arrowwood from June to October (FWS 1976b) reducing water management capabilities of the refuge during the period vital to rearing young ducks. The installation of three 450 cfs radial gates on Arrowwood NWR at the lower end of Arrowwood Lake, Jim Lake and DePuy Marsh by BuRec will provide for passage of GDU irrigation flows. Although these structures will provide conveyance for natural and project flows through the refuge at a lower elevation than present structures are capable of achieving, they will not offset the impact of additional flows on the refuge's water management program. The present water management plan for Arrowwood NWR calls for rotational drawdown of refuge pools during July and August once every 4-5 years and has resulted in increased waterfowl use in succeeding years. Project volumes, turnover rates and resultant flushing effects will hamper proper water-waterfowl management at the refuge. It is possible that in extreme low-flow years, some waterfowl benefits will accrue to the refuge from GDU but for the most part, increased flows will persist too long into the summer season to enhance waterfowl production. We estimate the most likely GDU impact to this refuge to be equivalent to a 40 percent reduction in waterfowl production with a range from 20 to 60.

J. Clark Salyer - This refuge is on the Souris River just south of the Canadian border. There are approximately 20,000 wetland acres associated with the refuge. GDU impacts from increased flows will cause somewhat more difficult water management throughout the waterfowl production season. High water conditions in recent years have partially simulated conditions expected with GDU on line. Evaluation of production for the refuge during this period indicates no correlation can be drawn between high water naturally occuring conditions which occur in the spring and those which occur throughout the production season as a result of GDU. GDU will also introduce carp to the refuge. Carp impact waterfowl production areas by uprooting aquatic plants used by ducks for food and/or increasing turbidity, thus further reducing plant growth through decreased photosynthetic processes. This roiling of the water also reduces invertebrate populations, used extensively by young ducks for food. Carp are so detrimental that most managed waterfowl areas attempt winter drawdown techniques to winterkill carp populations. We estimate a most likely adverse impact on this refuge to waterfowl production of 40 percent with a range from 25 percent to 65 percent.

Upper Souris and des Lacs NWRs - These two refuges, located on the upstream portion of the Souris Loop, will be affected by introduction of carp. We estimate that waterfowl production of these two areas will most likely be reduced by 15 percent with a range from zero to 25 percent.

Tewaukon NWR - This refuge, located on the Wild Rice River, consists of 4 dike pools and 16 other pools under water management. A total of 1,677 acres of wetlands are subject to direct impact via GDU flows in the Wild Rice River. Water management at Tewaukon NWR will be adversely affected during waterfowl production periods. Carp will become more prevalent, as winterkill will not be as effective in limiting their populations. We believe that waterfowl production at this NWR will be reduced by 50 percent (most likely impact) with least impact of 30 percent and greatest impact of 75 percent.

A further impact may be felt as a result of carp introduction into the Devils Lake Basin and upper Sheyenne River. Carp do not presently exist in these areas. These areas encompass an estimated 550,000 acres of waterfowl habitat but most of this consists of potholes where carp are not likely to be introduced or survive. However, several areas, such as the West Bay of Devils Lake do produce ducks at the estimated statewide averages. We estimate that 75,000 acres of suitable habitat will be adversely impacted by carp introduction via the Devils Lake feeder canal. Two sources of carp introduction will exist with GDU in place: the McClusky Canal and the James River. The most likely impact from carp introduction in these areas is estimated at a 25 percent reduction in waterfowl production with a range from 10 percent to 35 percent.

The most likely total waterfowl loss of these five NWRs and the Devils Lake Basin is estimated at 54,900 birds annually (Table C.I-10). These estimates were arrived at from FWS refuge reports (1960-74), riverine habitat maps and personal communication with managers at all five refuges.

Channelization: Engineering Committee (pers comm) estimated that 103 miles of the Souris River and tributaries will be channelized. BuRec estimated 5 miles of channelization for the Wild Rice (BuRec 1974a), for a total of 108 miles of channelization. Also, project modifications to the James River may result in reduced duck use. New waterways created by these operations may also provide waterfowl benefits. We are unable to assess these possibilities.

Channelization of streams reduces waterfowl production by shortening the stream, increasing flow rates and decreasing shallow water areas. As a result an estimated 8,000 ducks will be lost annually (Table C.I-11).

New drains and canals: GDU will create 358 miles of open deep drains and 287 miles of canals (BuRec 1974a). Vegetation in most of these waterways will be controled by herbicides. The physical nature of these drains and canals (straight, steep-sided), irregular water regimes and vegetation control reduces their waterfowl production capability to an estimated level of one pair of breeding birds/mile, or approximately 3,000 ducks. At this level the waterfowl production accruing to Manitoba's breeding reservoir and fall shuffle from new GDU waterways will be about 600 birds annually.

Table C.I-10. Effects of GDU on waterfowl populations at five NWRs and Devils Lake Basin in North Dakota.

NWR	Adults[1] (Fall)	Production	Total	Estimated annual waterfowl population loss		
				Least	Most likely	Greatest
Arrowwood[2]	3,600	5,000	8,600	1,720 (20%)	3,400 (40%)	5,160 (60%)
J. Clark Salyer[2]	10,800	15,000	25,800	6,450 (25%)	10,300 (40%)	16,800 (65%)
Upper Souris and des Lacs[2]	9,300	13,000	22,300	- (0%)	3,300 (15%)	5,600 (25%)
Tewaukon[2]	1,900	3,000	4,900	1,500 (30%)	2,450 (50%)	3,675 (75%)
Devils Lake Basin[3]	59,300	82,500	141,800	14,180 (10%)	35,450 (25%)	49,630 (35%)
Totals	84,900	118,500	203,400	23,850	54,900	80,865

[1]Includes summer mortality.
[2]FWS (1960-74).
[3]E. Steucke (pers comm).

Table C.I-6. Estimated waterfowl production for GDU Manitoba areas, all species.

GDU areas	Estimated annual production	Estimated fall flight
Souris River[1]	2,600	4,500
Assiniboine River[2]	3,800	6,400
Red River[3]	2,600	4,500
Lake Manitoba[4]	115,100	189,600
Lake Winnipeg	58,000	95,300
Total	182,100	300,300

[1]151.5 river miles.
[2]217.0 river miles.
[3]151.6 river miles.
[4]Includes Delta Marsh.

6. Direct Effects of GDU on Manitoba Waterfowl Production Areas: Direct waterfowl losses in Manitoba waterways from GDU could occur as a result of changes in water quantity and quality. Additional GDU flows in the Red and Assiniboine rivers, Lakes Manitoba and Winnipeg and Delta Marsh will be too small to affect waterfowl in those areas (Water Quantity Committee 1976a,b). Additional flooding on the Westhope reach of the Souris River is too small to affect riverine waterfowl populations (Water Quantity Committee 1976c).

A comparison of expected GDU levels of these water quality components forwarded by the Water Quality Committee (1976a,b), against tolerance levels for ducks and geese showed no anticipated impact on waterfowl.

We therefore predict no effects from GDU on Manitoba waterfowl production areas due to changed water quality or quantity.

7. Other Aspects: Several factors associated with GDU but either not authorized or impossible to quantify, could affect Manitoba's waterfowl populations. A discussion of these factors follows:

New wetlands from canal seepage: In projects of this type, new wetlands are often created by canal seepage into low areas. The extent of this wetland creation in GDU North Dakota and its offsetting effect on waterfowl population losses cannot be quantified from available project information.

The new FWS wetland restoration concept: Since development of the original wildlife plan a great deal of waterfowl research has occurred. Based on this research FWS developed a new waterfowl mitigation concept (FWS 1974; 1976e) within the framework of the original plan. A major feature of the new concept is acquisition of presently drained wetlands of low agricultural capability together with upland nesting cover. This premise is vital to the concept as it calls for establishment of "new" wetlands to replace drained ones, instead of modifying existing wetlands. The theory is that if enough of these acres can be obtained to replace the acres to be drained by GDU, most waterfowl production loss due to project construction and drainage can be offset. FWS has begun surveys to delineate such wetland basins in the 25-county GDU Conservancy District in North Dakota (E. Steucke pers comm). The new concept has been endorsed by BuRec and has received congressional and administrative sanction (BuRec 1976b). FWS has begun structuring a plan based on this new concept.

Conversion of North Dakota grasslands: Additional adverse impact on Manitoba's waterfowl populations can be expected from conversion of North Dakota grasslands to irrigated croplands. We have predicted the loss, through drainage, of 50,000 wetland acres in North Dakota and have estimated Manitoba's waterfowl loss due to this drainage. Another unquantifiable waterfowl loss will accrue to Manitoba through reduced production on remaining wetlands as grasslands adjacent to these wetlands, now furnishing nesting habitat for dabbling ducks, are converted to irrigated croplands. We were unable to ascertain from project information (BuRec 1974a) the amount or type of such conversions.

Additional migration stress: Removal of 50,000 acres of wetlands in North Dakota due to project drainage is likely to have some effect on reproduction capabilities of ducks, geese and swans which rely on these wetlands to build fat reserves as they migrate north in the spring. Especially crucial to these birds are the small, shallow wetlands which thaw early and furnish large amounts of high protein foods. Such foods are not found in abundance in deep wetlands, lakes and reservoirs and are not available to migrants in any case, since these waters are usually still ice-covered when the birds arrive.

Another unquantifiable potential effect of large magnitude, that of the impact of GDU on staging geese and shorebird and other marsh bird populations, has already been mentioned.

8. Summary of effects of GDU: Biological impacts to waterfowl from GDU are summarized in Table C.I-12. This summary provides three scenarios for some impacts: least impact, most likely impact and greatest impact. The most likely prediction indicates losses attributable to GDU which we feel will occur. We predict:

a) An annual waterfowl loss of between 124,400 and 257,700 ducks as a result of GDU. We believe the most likely loss will be 177,500 ducks. Manitoba's annual loss will vary between 24,900 and 51,600 ducks with 35,500 the most likely impact. About 7,500 of these will be mallards.

b) Losses will accrue from project wetland drainage, altered habitat at NWRs, stream channelization, carp introduction into the Devils Lake area and private/public drainage of wetlands adjacent to GDU waterways.

c) No direct GDU impacts are predicted on waterfowl production areas in Manitoba as a result of changed water quality or quantity.

d) The 34,100 acres of existing wetland and additional water for 22,000 acres planned as mitigation for wetland losses in North Dakota will provide no net waterfowl benefits.

e) The reported 26,950 acres to be drained by the project are based on a wetland/upland ratio which underestimates acres to be drained in the 250,000-acre initial stage plan under consideration. We estimate 50,000 acres will be drained or altered.

f) Several unquantifiable or unauthorized project factors could drastically influence waterfowl populations

Table C.I-12. Summary of anticipated annual impacts of GDU on North Dakota and effects on Manitoba duck populations.

Impact	North Dakota loss Least	North Dakota loss Most likely	North Dakota loss Greatest	Manitoba loss[1] Least	Manitoba loss[1] Most likely	Manitoba loss[1] Greatest
Project wetland drainage	94,500	94,500	94,500	18,900	18,900	18,900
Stream channelization	9,000	9,000	9,000	1,800	1,800	1,800
Private/public wetland drainage	0	22,100	76,300	0	4,400	15,300
Alteration of NWRs and Devils Lake	23,900	54,900	80,900	4,800	11,000	16,200
Waterfowl produced as a result of GDU	-3,000	-3,000	-3,000	-600	-600	-600
Total	124,400	177,500	257,700	24,900	35,500	51,600

[1]Manitoba's breeding reservoir and fall shuffle "share" of North Dakota's waterfowl population equates to 20 percent (see Table C.I-9).

in North Dakota and Manitoba. These are fate of the new FWS idea, effects of GDU on shorebird and other marsh bird production, staging of geese in North Dakota, conversion of grassland nesting areas near remaining wetlands to irrigated croplands and loss of high-protein food sources for spring migrants through loss of Class I ponds.

g) Project conveyances and reservoirs will provide additional waterfowl habitat but not in proportion to that adversely impacted.

In this report we have predicted GDU-caused impacts on Manitoba waterfowl populations. To accomplish this task it was also necessary to assess impacts of GDU on North Dakota waterfowl populations. This predicted loss amounts to 176,500 ducks annually.

What this loss means to international waterfowl populations or how it might be viewed under the International Migratory Bird Treaty are questions beyond the scope of this study, but in the opinion of Committee members, questions which clearly merit answers.

E. Major Waterfowl Diseases

Waterfowl diseases, which can destroy hundreds of thousands of birds in short time periods, have received heavy research emphasis in recent years because of their catastrophic effects on populations. Three waterfowl diseases are discussed in this report; botulism, fowl cholera and duck viral enteritis.

1. Avian botulism: For many years avian botulism was associated with alkaline soils but the epidemiology of the disease is far more complex. Now the criteria related with large epizootics of botulism are concentrations of large numbers of birds, staging in shallow, intermittently flooded areas during late summer and fall.

Spores from the bacterium *Clostridium botulinum* are ubiquitous in nature and may germinate and elaborate toxin whenever and wherever proper conditions of oxygen deficiency, warm temperatures and bacterial growth media exist.

One of the present limiting factors for the growth of *C. botulinum* and subsequent production of toxin resulting in botulism epizootics is the absence of dead or decaying organic matter. Environmental factors, such as fluctuating water levels in waterfowl staging areas, available nutrients and toxic substances such as heavy metals, herbicides and insecticides have significant influence on invertebrate survival. Once the limiting factor is removed or the growth medium and anaerobic environment provided for *C. botulinum*, waterfowl botulism outbreaks are possible. Waterfowl are poisoned by ingested toxic material.

2. Duck viral enteritus (DVE): DVE or duck plague is an acute, frequently fatal, disease of ducks, geese and swans, characterized by listlessness, watery diarrhea, nasal and ocular discharges and sudden death. Mortality can range from 5 to 100 percent. The causative agent of duck plague is a filterable virus belonging to the Herpes group.

Scientists believe DVE is usually spread by infected waterfowl that shed the virus in droppings. Outbreaks of the disease in domestic ducks are frequently associated with aquatic environments that are cohabited by wild waterfowl (Leibovitz and Hwang 1968).

The virus survives in water. It may be spread through polluted, stagnant and slow moving pools, ponds and waterways. Waterfowl may contract the disease by drinking or swimming in polluted water or eating contaminated feed. The virus may enter susceptible birds through the mouth, nose, cloaca or breaks in the skin. While DVE may occur at any season, many outbreaks have been associated with weather extremes. A combination of stresses such as overcrowding of ducks, other diseases and bad weather may increase the severity of the outbreaks. The creation of open water areas north of former wintering areas results in short-stopping and concentration of ducks and geese during fall migrations. This may increase the incidence of DVE.

In mid January 1973 DVE struck wintering mallards on Lake Andes NWR in South Dakota. Mortality was estimated at 40,000 to 43,000 ducks and 350 Canada geese. Since 1973, there have been annual outbreaks of DVE in waterfowl populations on wintering areas in the US. It is feared that DVE, along with botulism and fowl cholera, is becoming established as another major killer of waterfowl. In Canada outbreaks of DVE have been confined to display flocks and aviculturist flocks. DVE has not been diagnosed in free flying waterfowl (Leibovitz and Hwang 1968).

3. Fowl cholera: Fowl cholera has been reported in sparrows, robins, starlings and wild and domestic fowl. It is caused by endotoxin from the bacterium, *Pasteurella multocida*, (previously known as *P. septica*). Fowl cholera in domestic ducks was a serious problem on Long Island where it was diagnosed on 32 of 68 commercial duck farms and where it affected ducks over 4 weeks of age with a 50 percent mortality rate (Dougherty 1953). Jensen and Williams (1964) reported the death of 60,000 waterfowl due to fowl cholera during the winter of 1956-7 at the Muleshoe NWR in Texas.

Birds are chronic carriers of fowl cholera and may be reservoirs until they die. Swine and cattle may also be carriers and if in contact with birds, may serve as sources of infection (Iliev et al. 1963; M. Schipper pers comm). Man may also serve as a source of infection (Henderson 1963) and arthropods such as ticks and flies have been implicated (Iovev 1967).

Dissemination of *P. multocida* within a flock is primarily by excretions from the mouth, nose and conjunctiva of diseased birds that contaminate their environment, particularly the feed and water. Dorsey and Harshfeld (1959) reported a higher incidence of fowl cholera during late summer and fall months in South Dakota. Carrier birds among the older flock, held over for a second year, provided a reservoir of infection for young susceptible pullets housed with them.

The disease in wild waterfowl seems to be associated in the US with over-concentration at staging areas, particularly near infected flocks of carrier birds (domestic or wild) or near swine-rearing areas (Iliev et al. 1963). Fowl cholera increased in the north central states from 109 outbreaks in 1962 to 137 in 1966. Vaught et al. (1967) reported that over 1,000 wild geese died of fowl cholera in one night at the Squaw Creek NWR in Missouri. G. Pearson (pers comm) reported that fowl cholera is moving northward from Missouri in wild fowl. An outbreak of fowl cholera was reported from Renzeinhausen Slough during November, 1975. This is only 25 miles from Oakes, North Dakota, a GDU project area. Waterfowl in Canada do not experience the high mortality from cholera that has been reported from the US.

4. Effects of GDU on waterfowl diseases: Open water extending into the winter months will create conditions for short-stopping and concentrating waterfowl populations. This situation occurred in January and February 1973 at Lake Andes NWR in South Dakota where 40 percent of an estimated 100,000 wintering waterfowl (primarily mallards) died from an outbreak of DVE. Vaught et al. (1967) reported a similar situation on a wildlife refuge in Missouri where pumps maintained open water and concentrated a large number of waterfowl which subsequently suffered a fowl cholera outbreak.

The operating scheme of changing water levels proposed by BuRec for Lonetree Reservoir, Taayer Reservoir and other project areas will create shallow water situations conducive to waterfowl botulism. While it is beyond the scope of this study to quantify impacts on waterfowl caused by GDU via waterfowl diseases, it is our opinion that GDU will create situations which will increase the potential for avian botulism, DVE and fowl cholera.

In summary, we believe that waterfowl diseases, described above, have potential for immediate, large scale waterfowl mortality. These diseases are difficult to diagnose and treat before thousands of birds are infected. Duck and geese losses from these diseases may approach losses from all other causes, including project and private drainage of wetlands and damage Canada's portion of the international waterfowl resource.

F. Wildlife - Amphibians and Reptiles

1. Introduction: Manitoba amphibians and reptiles number 24 species in 10 families (Table C.I-13). Three of these, prairie skink, western hog-nosed snake and plains spadefoot toad are recognized as rare or endangered species in Manitoba (Van Zyll de Jong and Nero 1971). Other species, red-sided garter snake, tiger salamander and leopard frog, are harvested in Manitoba marshes, meadows and uplands. Harvest seasons, quotas and licensing systems are controlled under the Manitoba Wildlife Act.

GDU Manitoba project areas where impact on harvestable amphibians and reptiles could occur are Delta Marsh and marshes on southern shores of Lakes Manitoba and Winnipeg. Most snakes are harvested in or near hibernacula in the uplands of Manitoba's Interlake region. No hibernacula are known to be located in GDU Manitoba project areas.

2. Methods: K. Stewart (pers comm), was consulted concerning indigenous amphibians and reptiles and potential introductions as a result of GDU. Potential impacts on Manitoba reptiles and amphibians were assessed on the basis of reports from the Water Quantity (1976b) and Quality (1976a) committees. The final report was reviewed by personnel from MDRRTS.

3. Effects of GDU: As previously mentioned in this report, additional flooding as a result of GDU will be felt only along the Westhope-Lauder section of the Souris River. No impact as a result of this additional flooding is expected for Manitoba amphibians and reptiles.

For water quality assessment, constituent levels were compared against tolerance levels of various amphibians and reptiles. No impacts are predicted on Manitoba reptiles and amphibians as a result of changed water quality.

Four reptiles and one amphibian are possible candidates to be introduced into Manitoba as a result of GDU. They are the prairie rattler (*Crotalus viridis viridis*), bull snake (*Pituophis melanoleucus sayi*), yellow-bellied racer (*Coluber constrictor flaviventris*), western spiny softshell turtle (*Trionyx spiniferus hartwegie*) and the Great Plains toad (*Bufo cognatus*).

Prairie rattlers and bull snakes occupy the same range in river valley habitat. Bull snakes can occupy cooler and moister habitats than prairie rattlers. GDU, with its system of canals, may provide a medium for range extensions of both these species into Manitoba.

The diversion of the Colorado River into the South Platte River through the continental divide is a case history for colonization

Table C.I.13. Check list of Manitoba amphibians and reptiles[1].

Family	Species	Common name
Amphibians		
Ambystomidae	*A. tigrinum diaboli*	Grey tiger salamander
	A. laterale	Blue spotted salamander
Proteidae	*Necturus maculosus*	Mud puppy
Pelobatidae	*Scaphiopus bombifrons*	Plains spadefoot toad
Bufonidae	*Bufo americanus*	American toad
	B. hemiophrys	Dakota toad
Hylidae	*Pseudacris triseriata maculata*	Northern chorus frog
	Hyla crucifer	Spring peeper
	H. versicolor	Gray tree frog
	H. chrysoscelis	Southern graytree frog
Ranidae	*Rana pipiens pipiens*	Northern leopard frog
	R. sylvatica	Wood frog
	R. septentrionalis	Mink frog
	R. clamitans melanota	Green frog
Reptiles		
Chelydridae	*Chelydra serpentina serpentina*	Common snapping turtle
Testadiniidae	*Pseudemys scripta elegans*	Western painted turtle
Scincidae	*Eumeces septentrionalis septentrionalis*	Northern prairie skink
Colubridae	*Thamnophis sirtalis parietalis*	Red-sided garter snake
	T. radix haydeni	Western plains garter snake
	Storeria occipitomaculata	Red-bellied snake
	Opheodrys vernalis blanchardi	Western smooth green snake
	Heterodon nasicus nasicus	Western hognose snake

[1]Source: K. Stewart, pers comm.

of irrigated farmland by prairie rattlers and bull snakes. This irrigated farmland was within the range of both species but was unoccupied by both prior to irrigation. Both species are now found in the irrigated portion. Probability of introduction into Manitoba of both these species, as a result of GDU, is unknown.

The same rationale is used for yellow-bellied racers except they are known to exist near Estevan and Val Marie, Saskatchewan. Probability on introduction into Manitoba as a result of GDU is low.

Great Plains toads are already found in Saskatchewan and the southern Red River Valley near Grand Forks, North Dakota. There are few physical barriers to prevent their inhabiting Manitoba at the present time. Project waterways could provide a medium for establishment in southwestern Manitoba. Probability of introduction of this species because of GDU is low.

The western spiny softshell is a river-dwelling turtle, one of the strongest swimmers of the turtle family and well adapted for an aquatic existence. It has pronounced spring and early summer dispersal movements and occupies the same isotherms as gizzard shad. Probability of introduction of this species because of GDU is high. What impact this species could have on Manitoba fisheries is not known.

G. Wildlife - Rare and Endangered Species

1. Introduction: Concern for animal species which may be headed for extinction or are already greatly reduced in abundance has lead to creation of several "save the species" organizations, lists of rare and endangered species and related terminology. At the international level, most notable among the groups is the International Union for Conservation of Nature and Natural Resources which publishes data books on status of birds, mammals, amphibians and reptiles in several categories.

At national levels FWS and Canadian Wildlife Federation publish rare and endangered species lists of North American animals. The National Audubon Society also maintains rare and endangered species lists. Canada recently joined with 80 other nations to form a treaty on commercial trade in rare or endangered animal species, ratified in 1975. While not a formal rare and endangered species list, the treaty does contain trade restrictions on many species and thus focuses federal concern on those animals which may be in population trouble.

At the provincial level a list of extinct, rare and endangered wildlife was published by the Manitoba provincial government (Van Zyll de Jong and Nero 1971). This list treats wildlife in five categories: endangered, rare, peripheral, status undetermined and extinct. An "endangered" species is one whose prospects for survival are in immediate jeopardy; the species must have help or extinction is likely. A "rare" species is one which is not presently threatened with extinction, but is found in such small numbers throughout its range that it may become endangered if its environment worsens.

2. Methods: The Committee compared national and international lists with the Manitoba list to ferret out those species which could be affected by GDU. Specific habitat information was gleaned from provincial experts, especially for raptors. The manuscript was reviewed by personnel from MDRRTS.

3. Results: Eleven species found in GDU Manitoba project areas are listed on at least one international or national rare and endangered species list. They are: prairie falcon, peregrine falcon, sparrow hawk, osprey, great gray owl, snowy owl, golden eagle, bald eagle, timber wolf, cougar and northern prairie skink.

The Manitoba list names 16 species which inhabit the GDU Manitoba region as rare (8) or endangered (8). A single species listed as "peripheral", the cougar, also merits discussion, since its home ranges are closely tied to white-tailed deer populations and these are tied to wooded river valleys in southern Manitoba. A brief discussion of the 17 species from the Manitoba list follows (R. Nero pers comm):

Cougar (*Felis concolor*) - peripheral; as many as five may inhabit Souris and Assiniboine river valleys; home ranges are huge (an individual may travel up to 50 miles in a single night), thus exact locations are difficult to map; a specimen was inadvertently killed in the province recently; continued existence is dependent on white-tailed deer populations and large, uninterrupted blocks or strips of timber; protected provincially.

Mule deer (*Odocoileus hemionus*) - endangered; may occur in small numbers in Spruce Woods Provincial Park and along wooded Souris and Assiniboine river valleys; once common in Manitoba; apparently cannot compete successfully with white-tailed deer; probably less than 100 animals in Manitoba, most in the southwest or south central; difficult to protect because of similarity to regularly hunted white-tailed deer.

White pelican (*Pelecanus erythrorhynchos*) - endangered; colonial nester of Lakes Manitoba and Winnipeg; populations threatened by inundation of breeding islands and pesticide poisoning; colonies in Manitoba rated as most important in North America; estimated population 10,000; protected internationally.

Double crested cormorant (*Phalacrocorax auritus*) - endangered; colonial nester on islands of Lake Manitoba, estimated population, 10,000; Manitoba colonies are some of the most important in the prairie provinces; decline due mostly to human disturbance on nesting islands; protected internationally.

Golden eagle (*Aquila chrysaetos*) - rare; Manitoba population levels have always been low because of lack of suitable habitat; cliff nesting common over much of its range; resident Manitoba population not more than 25; no known breeding records from southern Manitoba; protected internationally.

Ferruginous hawk (*Buteo regalis*) - rare; found on plains of southwestern Manitoba including grasslands along Souris River and the Carberry Sand Hills; populations once large but now no more than a dozen residents in the province; pesticide residues may be decimating factor; protected internationally.

Bald eagle (*Haliaeetus leucocephalus*) - endangered; presently distributed in coniferous northern areas of the province; present populations estimated at several hundred; common migrant along southern rivers; pesticide residues blamed for general decline; protected internationally.

Osprey (*Pandion haliaetus*) - endangered; alarming declines in US populations due to pesticide poisoning; Manitoba population estimated at a few hundred; uncommon migrant along southern rivers; most breeding grounds in northern regions; protected internationally.

Prairie falcon (*Falco mexicanus*) - rare, possibly still nests in extreme southwestern Manitoba; preferred nest sites include rough breaks or cliffs; pesticide residues believed responsible for overall declines; nest sites may be limiting factor in southwestern Manitoba, thus management, by carving nest shelves along river cliffs, is possible; protected internationally.

Merlin (pigeon hawk) (*Falco columbarius richardsonii*) - endangered; Manitoba breeding records, from the southwest, few; declining across its range from pesticide residues and mercury poisoning; protected internationally.

Long-billed curlew (*Numenius americanus*) - rare; now very scarce in Manitoba; former range included southern plains of the province east to Red River; may still breed in small numbers in native grasslands of the southwest although there are no recent nesting records; possible Manitoba breeding population, 50; decline due to loss in intact grassland nesting habitat; protected internationally.

Great gray owl (*Strix nebulosa*) - rare; resident of Manitoba's boreal forest; population unknown, but regarded as the rarest owl in North America; several recent nest records in Manitoba, two in Minnesota; population probably in the neighborhood of several hundred; this species is very tame and tends to be killed by unthinking hunters and collisions with vehicles; protected internationally.

Burrowing owl (*Speotyto curricularia*) - endangered; found in treeless areas of southwestern Manitoba; much reduced over former range due to loss of grassland habitat and reduction in ground-dwelling mammals; estimated Manitoba population, 50; protected internationally.

Plains spadefoot toad (*Scaphiopus bombifrons*) - rare; found in extreme western portion of Shilo Military Base on the Assiniboine River; prefers arid grasslands; limited by lack of suitable habitat; present Manitoba population considered relict; unprotected.

Northern prairie skink (*Eumeces septentrionalis*) - rare; densest Manitoba population north of the Assiniboine River between Provincial Trunk Highways 240 and 258; found in Spruce Wood Provincial Park; population size unknown; limiting factors unknown; unprotected.

Western hog-nosed snake (*Heterodon nasicus*) - rare; found in low numbers in south-central and southwestern regions of the province; distribution probably limited by loose, sandy substrate suitable for digging, Manitoba population size unknown; unprotected.

In addition to concern over the above species, GDU Manitoba project areas host a wide array of other birds, such as pileated woodpeckers and wood ducks, which are not common locally. Rivers associated with GDU Manitoba furnish migration routes for many species of songbirds; warbler watches along these waterways spring and fall are gaining in popularity as more and more Manitobans take to bird watching and nature study. In addition, GDU reservoirs may alter whooping crane migration routes and/or staging behavior.

4. Effects of GDU: As mentioned elsewhere in this report, GDU-caused flooding in Manitoba will be restricted to a small area in the Souris River. Adverse impacts are not expected for rare and endangered species listed above because of additional flooding.

Effects of changed water quality on rare and endangered species is more difficult to assess. Some species listed in this report (raptors, pelicans and cormorants) occupy niches at the tops of food chains and thus receive the brunt of chemical loadings in the environment. The disastrous effects of pesticide residues on raptors are well documented. According to the Water Quality Committee (1976), levels of concentrations and loadings of heavy metals and other pesticide residues will not be increased in Manitoba waters as a result of GDU. Therefore adverse impacts are not expected for rare and endangered species as a result of changed water quality.

However, the final impact assessment statements from Water Quality and Quantity Committees are based on best management practice by GDU water users. The Committee feels it is unlikely that this level of efficiency will be attained. Less than best water management by the many GDU irrigators and other water users will change water quantity and quality predictions and may result in further adverse effects on Manitoba wildlife.

H. Summary of Impact Predictions

1. Waterfowl:

a) GDU project drainage, stream channelization, alteration of NWRs and private wetland drainage adjacent to GDU waterways in North Dakota will result in the most likely annual loss of 177,500 ducks with a range between 124,400 and 257,700 in North Dakota. Manitoba's share of this loss is estimated to be 35,500 (24,900 - 51,600) of which 5,700 (4,000 - 8,300) will be mallards.

b) Conversion of grasslands, currently furnishing nesting habitat for dabbling ducks, to irrigated croplands will increase Manitoba's waterfowl loss. This loss cannot be quantified due to lack of project information.

c) Removal of Class I wetlands as a result of GDU cropland development may place stress on migrating waterfowl in spring through a reduction in readily available food supplies. Effects of this potential stress cannot be quantified.

d) Reduction of relatively small wetlands and an increase in large waterbodies (reservoirs) in GDU North Dakota will change fall staging behavior and migration patterns of waterfowl (particularly geese). Effects of these changes cannot be quantified.

e) Manitoba will share North Dakota's shorebird and other marsh bird losses as a result of GDU wetland drainage and habitat alteration. Manitoba's share of these losses cannot be quantified.

f) Changes in water quality and quantity from GDU are not expected to adversely impact waterfowl production areas in Manitoba.

g) GDU impacts on waterfowl in other parts in Canada were not evaluated due to lack of time.

2. Waterfowl Diseases:

a) Extended open water conditions in fall and winter in project areas, return flows entering project areas during winter months and fluctuating water levels from June through September in various GDU impoundments and waterways will increase the potential for significant outbreaks of waterfowl diseases. These waterfowl losses may approach losses from all other causes.

3. Amphibians and Reptiles:

a) Direct adverse impacts are not expected on Manitoba's indigenous amphibians and reptiles as a result of GDU-caused changes in water quality and quantity.

b) GDU may provide range extension routes for exotics: prairie rattlers, bull snakes, yellow-bellied racers, western spiny soft-shell turtles and Great Plains toads. Probability of introduction for these species and ultimate effects on Manitoba cannot be quantified.

4. Rare and Endangered Species:

a) Adverse impacts are not expected on Manitoba's rare and endangered wildlife species as a result of GDU based on the assumption that best water management practices by GDU water users will prevail. Less than best water management by the many GDU irrigators and other water users will result in further adverse effects on Manitoba wildlife.

5. Mammals and Birds Except Waterfowl:

No significant impacts are expected.

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II. FISH

A. Introduction

There are two major sources of concern associated with the potential impact of GDU on the fish resources of Manitoba. One is the possibility of interbasin transfer of exotics; that is, the transfer of fish species, fish diseases and fish parasites indigenous to the Missouri River Basin into the Hudson Bay Basin. GDU will provide direct connections between these basins. BuRec is presently building a fish screen on the McClusky Canal to prevent interbasin transport of fish eggs, larvae and adults. In assessing the potential for successful introduction and establishment of exotics we evaluated: 1) the possibility for passage of exotic species into the Hudson Bay Basin via means other than those related to GDU (existing natural inter-basin connections), 2) the possibility for passage through the fish screen, 3) the possibility of passage into the Hudson Bay Basin via other GDU project works, 4) known biological requirements of the potential exotics and 5) existing conditions in the Hudson Bay Basin pertinent to survival of exotics.

A second area of concern is the impact of changes in water quality and quantity caused by GDU on fishes indigenous to Manitoba. This impact was assessed by relating existing toxicological and other biological information on indigenous species to projected GDU water quality and quantity levels.

B. Description of The Study Area and Fish Resources

Areas under study in the Missouri River Basin are the Missouri and James rivers and in the Hudson Bay Basin the Red River Basin and Lakes Winnipeg, Winnipegosis and Manitoba. The Red River Basin includes the Souris, Assiniboine and Red rivers. Although water quality in Lake Winnipegosis will not be influenced by GDU, the lake is considered here since any exotic fishes introduced to Lake Manitoba may ultimately find their way to Lake Winnipegosis via Waterhen River and Waterhen Lake.

The Missouri River is the water source for GDU. It originates in Montana, flows easterly into North Dakota and then southerly into South Dakota. The river has been impounded by a series of large dams located in Montana, North and South Dakota. North Dakota now has approximately 400,000 acres of mainstem reservoir waters on the Missouri River with only 80 miles of free-flowing river remaining. The sport fishery in these waters consists of walleye, northern pike and introduced salmonids. The commercial fishery in the Missouri River reservoirs is the largest in North Dakota. Primary species harvested are buffalofish, carp and goldeye. The Missouri River contains a number of fishes which are considered problem species should they be introduced via GDU into the Hudson Bay Basin. There are also some fish diseases and parasites in the Missouri River which have not been reported in the fishes of Hudson Bay Basin.

The James River originates in central North Dakota and flows southward into South Dakota to its confluence with the Missouri River near the Nebraska border. With the exception of Jamestown Reservoir in North Dakota, the sport fishery on the James River is of low quality. Sport fishing is for northern pike, walleye and yellow perch. The river is dominated by non-sport species. There are a number of fish species in the James River that could be introduced into the Red River as a result of GDU. Fish diseases and fish parasites in the James River drainage are not well known.

The Souris River originates in Saskatchewan, meanders southward into North Dakota and then northward into Manitoba where it empties into the Assiniboine River. One reservoir (Lake Darling) on the Souris River in North Dakota supports a good sport fishery for walleye, northern pike and yellow perch. The river, just before it enters Manitoba, has been developed as a large waterfowl marsh (J. Clark Salyer NWR) by FWS. Fishes in this area are subject to winterkill because of low flows and anoxic conditions (see carp section). Six small dams exist on the Souris River between the US border and the confluence with the Assiniboine River. These low dams will not prevent fish movements in the Souris River during periods of high flows. The Manitoba portion of the river does provide some sport fishing. There are no known fish diseases, fish parasites or undesirable fishes in the US portion of the Souris which are not found in Canada. However, carp are found in the Manitoba reach but not in North Dakota or Saskatchewan reaches of the Souris River.

Headwaters of the Assiniboine River originate in Saskatchewan. The river meanders eastward through southern Manitoba to its confluence with the Red River in Winnipeg. Periodically, high spring flows in the Assiniboine River cause flooding in the lower reaches. This has necessitated construction of a flood control dam at Shellmouth, Manitoba. Another flood control structure is the Assiniboine Diversion at Portage la Prairie built in 1969 to divert flood waters into Lake Manitoba. This has provided an avenue for the introduction of black bullheads into the Delta Marsh area of Lake Manitoba (J. Gee pers comm). The Assiniboine River does not support any major sport fishing, but some walleye, sauger and northern pike as well as other species are caught.

The Red River is the geographic boundary between North Dakota and Minnesota. It originates near the North Dakota-South Dakota border, flows north across the US-Canadian border and empties into Lake Winnipeg. The Red River has many tributaries from North Dakota, Minnesota and Canada. There is an historic link at high water levels between the upper Mississippi River Basin (Minnesota River) and the Red River Basin at Lake Traverse-Big Stone Lake on the Minnesota-South Dakota border. The sport fishery on the Red River is variable, depending on flow regimes. In North Dakota the sport fishery consists primarily of sauger and channel catfish while in Manitoba it consists of sauger and freshwater drum. The intensity of sport fishing on the Red River in Manitoba has increased in recent years, particularly below Lockport. No commercial fishery exists on the Red River either in the US or Manitoba.

Lake Manitoba, third largest lake in the Province, drains into northern Lake Winnipeg via the Fairford (Dauphin) River. Lake Manitoba supports a large winter commercial fishery. Principal commercial species are sauger, walleye and northern pike. Large quantities of suckers and carp are also landed but are of lesser commercial importance. Other species harvested by the commercial fishery are yellow perch, lake whitefish, lake herring and burbot. Most of the sauger catches are made in the South Basin. Although sauger catches have fluctuated considerably in the past, annual catches during the last 10 years have been relatively stable and averaged 180 metric tons. Walleye catches, which are made primarily in the North Basin, have exhibited a steady decline since the early 1950's. In 1974 the walleye catch was nearly half the average annual walleye catch over the period 1931-74. Reasons for this decline are not known precisely but over-exploitation may be one factor. Extremely high infestations by parasitic copepods (*Ergasilus* spp.) have been observed in walleye and sauger from the North Basin of Lake Manitoba (H. Welch pers comm). This infestation may be stressing these populations. Lake Manitoba also supports a significant sport fishery. Angling for walleye and northern pike is concentrated in the North Basin and around The Narrows which separates the North and South basins.

Lake Winnipegosis is the second largest lake in Manitoba. It drains via the Waterhen River and Waterhen Lake into northern Lake Manitoba. Lake Winnipegosis has a large commercial fishery which operates during spring, summer and winter seasons. Until about 1964 major species in the commercial catch were walleye and northern pike. During the period 1960-63 the average annual catch of walleye and northern pike combined was 1,440 metric tons with the majority (807 metric tons) being walleye. This combined walleye and northern pike catch constituted 47 percent of the average annual catch of all species over the 1960-63 period. For the 1970-73 period the average annual catch of walleye and northern pike combined was only 451 metric tons. Walleye contributed only 72 metric tons. The northern pike-walleye catch made up only 29 percent of the average annual catch of all species during the period 1970-73. The commercial fishery on Lake Winnipegosis is now largely dependent on low valued species such as suckers. In 1973 suckers accounted for more than 50 percent of the total catch from the lake. Reasons for the declines of walleye and pike catches from Lake Winnipegosis are not fully understood although it was recognized that over-exploitation was a significant contributing factor (A. Derksen pers comm). At one time, in the 1950's and early 1960's, sport fishing for walleyes in tributary streams flowing into the west side of Lake Winnipegosis was significant. Although sport fishing still occurs in some of these areas, angling success has declined (W. Howard pers comm). Management officials are presently attempting to rebuild the walleye stocks in Lake Winnipegosis (Anonymous 1976). These efforts are being directed primarily at revitalization of the commercial fishery, although the sport fishery will also benefit from any increase in walleye abundance.

Lake Winnipeg is the largest lake in Manitoba. It is similar in size to Lake Erie and is the third largest of all lakes entirely in Canadian territory. Lake Winnipeg drains into Hudson Bay via the Nelson River. Major drainages are the Saskatchewan and Winnipeg river systems. Lake Winnipeg supports the largest commercial fishery in Manitoba; this fishery operates during summer, fall and winter. Major commercial fish species harvested from Lake Winnipeg are walleye, sauger and lake whitefish. The harvest of these species is regulated by catch quotas. Northern pike are also taken in large quantities but possess a lower commercial value. Other species caught, but of lesser importance in the overall fishery, are suckers, carp, burbot and fresh-water drum.

Walleye and sauger are caught throughout Lake Winnipeg but the catch of these species is concentrated primarily in the southern half of the lake. There has been a considerable decline in walleye catches from Lake Winnipeg. Commercial catches dropped from a record high of 2,722 metric tons in 1951 to 389 metric tons in 1969, just before the commercial fishery was closed because of mercury contamination found in some Lake Winnipeg fishes. Walleye catches from Lake Winnipeg improved following the re-opening of the commercial fishery in 1972. From 1972 to 1974 annual walleye catches averaged 835 metric tons. Steady declines in walleye catches have been observed in the Grand Rapids and Sturgeon Bay areas of Lake Winnipeg despite improved catches in other parts of the lake. The reduction in walleye catches in the Grand Rapids area appears to be largely related to destruction of a major walleye spawning area by a hydroelectric dam near the mouth of the Saskatchewan

River. Over-exploitation on the other hand, is believed responsible for decreases in walleye landings from Sturgeon Bay. Although extremely high sauger catches were made in the earlier years of the Lake Winnipeg fishery (4,641 metric tons in 1941), sauger catches have been relatively stable over the last 20 years with annual landings averaging about 1,400 metric tons.

The lake whitefish fishery is centered in the North Basin of Lake Winnipeg. Large whitefish catches were made between 1931 and 1950 and wide fluctuations in catches occurred (2,418 metric tons in 1933 and 303 metric tons in 1936). Since 1950, whitefish catches from Lake Winnipeg exhibited a steady decline to a low of 342 metric tons in 1969. Over-exploitation was the major cause of this decline in whitefish catches (Davidoff et al. 1973). With increased management of the whitefish fishery instituted in 1971 whitefish catches from Lake Winnipeg have improved. Annual whitefish catches over the 1971-74 period averaged 695 metric tons.

Lake Winnipeg also furnishes an important sport fishery based on walleye and northern pike. Sport fishing occurs predominantly in the South Basin and along the west shore of the lake where there is access. Indian and Métis communities adjacent to Lake Winnipeg also utilize the fish resources for subsistence (approximately 100 metric tons/year, Uses Committee 1976).

C. Potential for Introduction of Exotic Fish Via Means Other Than Those Related To GDU

1. Introduction: A number of recent and historic connections exist between the Hudson Bay watershed and other major North American watersheds. These include connections between the Hudson Bay and St. Lawrence River watersheds, the Hudson Bay and Mississippi River watersheds and the Hudson Bay and Missouri River watersheds. Furthermore, one of the potential problem species associated with GDU, the rainbow smelt, already occurs in the Hudson Bay watershed. Another source for introductions are accidental or intentional but unauthorized introductions of exotics.

2. Methods: A literature survey was conducted and a number of experts were contacted to locate information on known presence and transfer of aquatic biota with respect to these connections and drainage basins (Table C.II-1). For both the Hudson Bay-Mississippi River and Hudson Bay-Missouri River connections, Committee members visited the sites for direct observation and compiled fish species lists. Most of the experts listed in Table C.II-1 were also asked to review early drafts of this subsection. The Committee also performed a qualitative assessment of the potential for accidental or intentional but unauthorized introductions.

3. Results and Discussion:

Hudson Bay-St. Lawrence River Connection: Ryder et al. (1964) discussed the potential for introduction of fish as a result of interbasin connections between the Hudson Bay and St. Lawrence River watersheds in northern Ontario. Two diversions of the Albany River watershed (Hudson Bay) have diverted waters formerly entering James Bay into Lake Superior (St. Lawrence River). These are the Longlac and Ogoki River diversions and were established to obtain a larger flow of water for pulpwood drives and hydropower on the Aguasabon and Nipigon rivers. A third diversion of the Albany River watershed diverts water from Lake St. Joseph, at the Albany headwaters into Lac Seul which drains into the Nelson River watershed and eventually Hudson Bay. This diversion was constructed primarily for generation of hydropower.

Impassable dams prevent upstream passage at all three diversion locations; as a result, passage of fish can only occur from Longlac into Lake Superior, from the upper Albany (upstream from Mojikit Lake) into Lake Nipigon and into Lake Superior and from the upper Albany River into Lac Seul and into the Nelson River and Hudson Bay. Therefore, there is no opportunity for direct fish passage from the St. Lawrence River watershed into the Hudson Bay watershed. Furthermore, none of the GDU problem fish species listed (Table C.II-7) occur in the Albany River system and therefore none of the fish species we are concerned with in this report can be introduced into the Red River system via the Hudson Bay-St. Lawrence River interbasin connections.

Table C.II-1. Experts contacted concerning introduction of exotic biota via existing interbasin transfers between the Hudson Bay and other drainages.

Interbasin Connection	Name	Affiliation
Hudson Bay-St. Lawrence	R. Ryder[1]	Ontario Ministry of Natural Resources
	E. Crossman[1]	Royal Ontario Museum
	K. Loftus	Ontario Ministry of Natural Resources
Hudson Bay-Mississippi	J. Calton[1]	US Army, Corps of Engineers
	J. Seaman[1]	US Army, Corps of Engineers
	R. Hanten[1]	South Dakota Fish and Game
	C. Lindsey[1]	University of Manitoba
Hudson Bay-Missouri	B. Green	US Bureau of Reclamation
	N. Thorson	Montana Department of Fish and Game
	A. Whitney[1]	Montana Department of Fish and Game
	M. Paetz[1]	Alberta Recreation, Parks and Wildlife
	M. Atton[1]	Saskatchewan Department of Natural Resources
	R. Baldwin[1]	Inland Waters, Department of Environment
	R. Hofer[1]	Inland Waters, Department of Environment

[1]These people were also asked to review Subsection C.

Table C.II-2. List of fishes occurring in watersheds pertinent to existing Hudson Bay-Missouri River interbasin connection.

Common name[1]	Mainstem Missouri R. (Montana to L. Sakakawea)[2]	Yellowstone R.[3] (Montana)	Milk R.[4]		St. Mary R.[4]		South Saskatchewan Alberta[7]
			(upper)[5]	(lower)[6]	Montana	Alberta	
Lake sturgeon							x
Pallid sturgeon	x	x					
Shovelnose sturgeon	x	x					
Paddlefish	x	x		x			
Shortnose gar	x						
Goldeye	x	x		x			x
Mooneye							x
Lake whitefish	x		x	x	x	x	x
Mountain whitefish	x	x	x	x		x	x
Coho salmon	x						
Kokanee	x	x		x	x		
Arctic grayling	x	x			x		x
Cutthroat trout	x	x	x		x	x	x
Rainbow trout	x	x	x			x	x
Brown trout	x	x	x			x	x
Dolly Varden					x	x	x
Brook trout	x	x	x	x	x	x	x
Lake trout	x	x			x	x	x
Golden trout	x	x					x
Rainbow smelt	x						
Northern pike	x	x	x	x	x	x	x
Sturgeon chub		x					
Lake chub	x	x	x	x	x	x	x
Goldfish	x	x	x				x
Carp	x	x		x			
Brassy minnow	x	x	x	x			
Silvery minnow	x	x	x	x			x
Flathead chub	x	x	x	x			x
Golden shiner	x	x					

(cont'd...)

Table C.II-2. (cont'd)

Common name[1]	Mainstem Missouri R. (Montana to L. Sakakawea)[2]	Yellowstone R.[3] (Montana)	Milk R.[4] (upper)[5]	Milk R.[4] (lower)[6]	South Saskatchewan St. Mary R.[4] Montana	South Saskatchewan St. Mary R.[4] Alberta	South Saskatchewan Alberta[7]
Emerald shiner	x	x	x	x		x	x
River shiner						x	x
Blacknose shiner							x
Spottail shiner						x	x
Sand shiner		x					
Fathead minnow	x	x	x	x		x	x
Longnose dace	x	x	x	x	x	x	x
Creek chub		x					
Pearl dace	x	x	x		x	x	
Finescale dace	x		x	x			
Northern redbelly dace	x		x	x		x	x
Utah chub	x						
Redside shiner	x						
River carpsucker	x	x		x			
Quillback							x
Longnose sucker	x	x	x	x	x	x	x
White sucker	x	x	x	x	x	x	x
Mountain sucker	x	x	x	x		x	x
Blue sucker	x	x					
Smallmouth buffalo	x	x		x			
Bigmouth buffalo	x			x			
Shorthead redhorse	x	x	x	x		x	x
Silver redhorse							x
Black bullhead	x	x		x			
Yellow bullhead		x					
Channel catfish	x	x		x			
Stonecat	x	x	x	x			
Plains killifish		x					

(cont'd...)

Table C.II-2 (cont'd)

Common name[1]	Mainstem Missouri R. (Montana to L. Sakakawea)[2]	Yellowstone R.[3] (Montana)	Milk R.[4] (upper)[5]	Milk R.[4] (lower)[6]	South Saskatchewan St. Mary R.[4] Montana	South Saskatchewan St. Mary R.[4] Alberta	South Saskatchewan Alberta[7]
Variable platyfish	x						
Shortfin molly	x						
Green swordtail	x						
Burbot	x	x	x	x	x	x	x
Brook stickleback	x	x	x			x	x
Plains minnow	x	x					
Trout-perch					x	x	x
Rock bass		x					
Green sunfish	x	x					
Pumpkinseed	x	x		x			
Bluegill	x	x		x			
Largemouth bass	x	x		x			
White crappie	x	x	x	x			
Black crappie	x	x		x			
Yellow perch	x	x	x	x		x	
Iowa darter	x	x	x	x			
Sauger	x	x	x	x		x	
Walleye	x	x	x	x			x
Freshwater drum	x	x		x			
Mottled sculpin	x	x	x	x	x	x	
Slimy sculpin			x				
Spoonhead sculpin			x		x	x	

[1] See Attachment C.II-6 for key to scientific names.
[2] Source: Brown (1971) and from Attachment C.II-4.
[3] Source: Brown (1971).
[4] Source: Brown (1971), Paetz and Nelson (1970) and Scott and Crossman (1973).
[5] Above or in Fresno Reservoir.
[6] Below Fresno Reservoir.
[7] Source: Paetz and Nelson (1970), Paetz (pers comm) and Scott and Crossman (1973).

Hudson Bay-Missouri River Connection: An area of existing interbasin connection between the Missouri River and Hudson Bay drainages occurs in northern Montana, southern Alberta and southwestern Saskatchewan. A year-round connection via an irrigation canal (600 cfs, B. Green pers comm) has connected the St. Mary River in Montana with the north fork of the Milk River in Montana since 1917. There also appears to be an ephemeral connection (once in 1952, R. Hofer pers comm) between Frenchman River (tributary to the Milk River) and Swift Current Creek (tributary to South Saskatchewan) near East End Coulee. There also once was a year-round connection near Cypress Hills Park, Saskatchewan between Belanger Creek (tributary to Frenchman River) and Maple Creek which flows into a closed drainage system (R. Hofer pers comm).

A list of fishes occurring in watersheds of the existing St. Mary-Milk River connection (Table C.II-2) was compared with GDU problem species (Table C.II-7, subsection F) to determine if any of these fish occurred in the upper Milk River (above Fresno Reservoir) and could therefore be introduced into the South Saskatchewan River via upstream movement either via St. Mary or Frenchman rivers. With the exception of carp, none of 10 problem fish species associated with GDU occur in the Saskatchewan, St. Mary or Frenchman rivers. Paddlefish, river carpsucker and smallmouth buffalo occur in various lower reaches (all below Fresno Reservoir) of the Milk River in Montana; none occur in upper reaches in Alberta or Montana.

An apparently isolated population of carp occurs in Frenchman River and has since 1921 (Atton 1959). Atton pointed out, "The species has not spread in this area because there are very few permanent waters in the semi-arid country to the north and east". Presumably Atton is referring to spreading north and east into the Saskatchewan River drainage. Carp do not occur in any portion of the entire Saskatchewan River drainage (Scott and Crossman 1973); carp do occur in the Assiniboine River system in Saskatchewan.

Brown (1971) reported lake whitefish from Fresno and Nelson reservoirs in the Milk River system. In discussions with Montana fisheries biologists (A. Whitney and N. Thorson pers comms) it is evident that lake whitefish and perhaps dolly varden trout have been transferred from the St. Mary system to the Milk River system. We questioned the Montana biologists as to the source of these fish in the Milk River - either via stocking or direct passage through the irrigation canal; Whitney and Thorson were convinced that lake whitefish had entered the reservoirs via movement through the irrigation canal.

We considered Fresno Dam on the Milk River to be an impassable upstream barrier for any fish, thereby preventing introduction of paddlefish, river carpsucker and smallmouth buffalo into the upper reaches of the Milk River and potentially via the irrigation canal into St. Mary River. Furthermore, we considered the drop structures in the canal itself to be impassable barriers to upstream movement. The Committee agreed with Atton's thoughts about restricted carp movement in southwestern Saskatchewan. Therefore we felt that none of the 11 problem fish species associated with GDU would be introduced into the Hudson Bay drainage via St. Mary River-Milk River-Frenchman River-South Saskatchewan River interbasin connections.

Hudson Bay-Mississippi Connection: A concern has been expressed by the IJC and others that aquatic biota may already have a path of entry from the Missouri River Basin to the Red River Basin. This route of entry would be as follows: Missouri River, Mississippi River, Minnesota River, Big Stone Lake, Little Minnesota River, Lake Traverse, Bois de Sioux River and finally the Red River (Fig. C.II-1).

Big Stone Lake is considered headwaters of the Minnesota River and Lake Traverse forms headwaters of Bois de Sioux River which flows into the Red River. These lakes are only a few miles apart. In the past, when extensive spring flooding occurred in the Little Minnesota River, a tributary of Big Stone Lake, a continuous body of water was formed connecting the two lakes (USACE 1963).

Historically one of the major routes to the Red River Valley from St. Paul, Minnesota, was up the Minnesota River to Big Stone Lake and thence to Lake Traverse and down Bois de Sioux River to the Red River. When flooding and favorable conditions existed that entire trip could be made by boat. There are reports of light-draft steamboats making the entire trip from St. Paul, Minnesota to Winnipeg (USACE 1963), in some cases being hauled across the low water connection.

With settlement and development of the Lake Traverse-Big Stone Lake area the need for flood control arose. The Lake Traverse-Bois de Sioux Flood Control and Water Conservation project was constructed, consisting primarily of White Rock Dam across Bois de Sioux River and Reservation Highway Dam between Lake Traverse and Mud Lake (Fig. C.II-1). Also constructed was a dike near Browns Valley, Minnesota on the south end of Lake Traverse. This closed off the lake and enabled flood water storage in that reservoir to a maximum design elevation of 981. This dike formed a barrier between Lake Traverse and Big Stone Lake. The project was completed, for all practical purposes, on 31 December 1941 (USACE 1963). However, in 1946 a 30 by 6-foot culvert was placed through South Dakota State Highway 10 to allow overflows from the Little Minnesota River to enter Lake Traverse.

Information received from USACE (R. Fast and J. Seaman pers comms) indicated that there is an opportunity for overflows from the Little Minnesota River into Lake Traverse. Since construction of the Browns Valley dike, no flow from Lake Traverse into Big Stone Lake has occurred and a flow in that direction could only happen if a major flood occurred filling Lake Traverse to near maximum design level. There are a number of dams on the Minnesota River below Big Stone Lake (Fig. C.II-1). One of these (Granite Falls) had been considered by Schneider (1966) to be impassable to upstream passage by fish. Our recent investigation leads us to the conclusion that these are not impassable barriers to upstream movement (M. Hora pers comm).

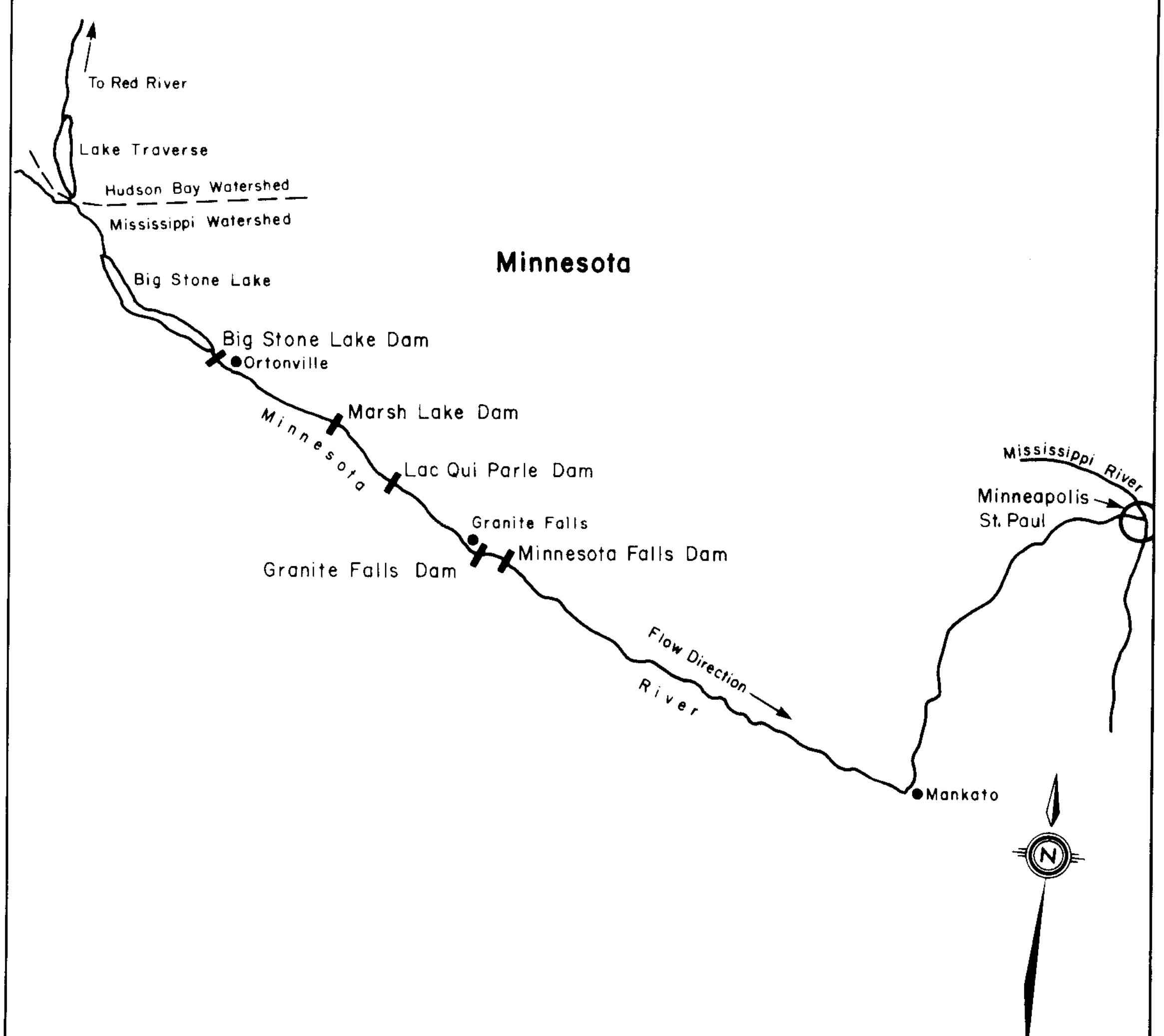

Fig. .11-1. Map showing dams on the Minnesota River and also the location of the existing interbasin connection between Big Stone Lake and Lake Traverse.

From Table C.II-3 it can be seen that carp, shortnose gar and gizzard shad have a theoretical opportunity to move from the Minnesota River to Big Stone Lake to Lake Traverse and on downstream into the Red River. Carp, of course, already occur in Lake Traverse and the Red River (see subsection F). However gizzard shad and shortnose gar are not present in the Red River and Hudson Bay drainage. It appears doubtful whether these species can or will pass the existing barriers to move into the Red River but we cannot entirely discount this.

It should be noted that before 1871 (and therefore for at least 6,000 years) there were no physical barriers preventing movement of fish into Big Stone Lake and on into Lake Traverse. Gizzard shad have been recorded from the lower Minnesota River since 1892 (Cox 1897). R. Miller (pers comm) and others believe these fish have been in Minnesota for many years. The only fish species suspected to have moved into the Red River system through this linkage is the stonecat and they more likely entered roughly 10,000 years ago while glacial Lake Agassiz was discharging southward through the Warren River outlet (Stewart and Lindsey 1970). Therefore water connection does not seem to have supported significant movement into the Hudson Bay drainage. This perhaps can be partially explained by the limnology of Lake Traverse. Lake Traverse is a shallow eutrophic lake prone to frequent winter kill (D. Henegar pers comm). It is not optimum fish habitat and does not serve as a good refuge from which invasions into the Red River can occur. This is supported by comparing the species lists for Lake Traverse and Big Stone (Table C.II-4) where Lake Traverse has 20 species and Big Stone Lake 44 species.

We considered the potential for interbasin transfer in considerable detail and were influenced both by the fact that gizzard shad, shortnose gar or any other potential GDU problem species have not moved into the Red River in 6,000 years and by the fact there have been 5 dams constructed on the Minnesota River in the last century. Gizzard shad were reported in the lower Minnesota River in 1892 (Cox 1897). MDNR commercial fisheries reports show no documentation of gizzard shad above Granite Falls Dam (Tews 1976). Schneider (1966) reported no gizzard shad above Granite Falls Dam. The Committee believes that since these fish have not moved into the upper Minnesota River in 84 years it is unlikely that they will move up the river unless significant changes occur in either the river itself or physical barriers on the river. Therefore we doubt that any of the GDU problem fish species would be introduced by natural passage through the Big Stone-Lake Traverse connection; however, we cannot entirely dismiss the possibility.

In addition to the well known interbasin connection at Traverse-Big Stone, Underhill (1957) reported another connection at Cutfoot Sioux Lake (Mississippi River drainage) and Bowstring Lake (Hudson Bay drainage-Lake of the Woods) where apparently a biologist tagged walleye in the former lake and they were recaptured in the latter lake. This occurred in the 1930's. Recent information from a local biologist (W. Johnson pers comm) suggests that such a connection is a

Table C.II-3. Occurrence of GDU problem fish species in area of Lake Traverse-Big Stone Lake connection.

Problem GDU species[1]	Red River	Lake Traverse	Big Stone Lake and inflow tributaries[2]	Minnesota River: Below Minnesota Falls Dam	Minnesota River: Below Granite Falls Dam	Minnesota River: Below Lac Qui Parle Dam	Minnesota River: Below Marsh Lake Dam	Minnesota River: Below Big Stone Lake Dam
Pallid sturgeon								
Shovelnose sturgeon								
Paddlefish								
Shortnose gar			x	x	x			
Gizzard shad				x	x			
Rainbow smelt								
Carp	x	x	x	x	x	x		
River carpsucker								
Smallmouth buffalo								

[1]See Attachment C.II-6 for scientific names.
[2]Little Minnesota River, Whetstone Creek.

Table C.II-4. Fish species in Minnesota River and its tributaries, Big Stone Lake and Traverse[1].

Common name[2]	Minnesota River and tributaries	Minnesota River below Granite Falls Dam	Minnesota River above Granite Falls Dam	Big Stone Lake and tributaries	Lake Traverse
Northern longnose gar	x				
Shortnose gar	x	x		x	
Gizzard shad	x	x			
River carpsucker	x				
Smallmouth buffalo	x				
Golden redhorse	x	x	x	x	
Northern redhorse	x	x	x	x	
White sucker	x	x		x	x
Northern hog sucker	x	x			
Carp	x	x	x	x	x
Golden shiner	x				
Creek chub	x			x	
Pearl dace	x				
Blacknose dace	x			x	
Northern redbelly dace	x				
Southern redbelly dace	x				
Hornyhead chub	x			x	
Speckled chub	x				
Silver chub	x				
Brassy minnow	x			x	x
Common shiner	x			x	
Emerald shiner	x			x	
Bigmouth shiner	x			x	
Sand shiner	x			x	
Spotfin shiner	x				
Mimic shiner	x				
River shiner	x				
Central weed shiner	x			x	
Rosyface shiner	x			x	

(cont'd.)

Table C.II-4. (cont'd)

Common name [2]	Minnesota River and tributaries	Minnesota River below Granite Falls Dam	Minnesota River above Granite Falls Dam	Big Stone Lake and tributaries	Lake Traverse
Fathead minnow	x			x	x
Bluntnose minnow	x			x	
Stoneroller	x			x	
Lake chub				x	
Spottail shiner				x	
Tadpole madtom				x	
Rock bass				x	
Pumpkinseed				x	
Brown bullhead				x	
Black bullhead	x			x	x
Channel catfish	x	x			x
Stonecat	x			x	
Yellow perch	x			x	x
Slenderhead darter	x			x	
Blackside darter	x			x	
Johnny darter	x			x	
Eastern banded darter	x				
Fantail darter	x				
Rainbow darter	x				
Iowa darter	x			x	x
Sheepshead (freshwater drum)	x	x	x	x	x
White bass	x	x		x	x
Largemouth bass	x			x	x
Smallmouth bass	x	x			
Green sunfish	x				x
Orangespot sunfish	x			x	x
White crappie	x			x	x
Brook stickleback	x			x	

(cont'd.)

Table C.II-4. (cont'd)

Common name[2]	Minnesota River and tributaries	Minnesota River below Granite Falls Dam	Minnesota River above Granite Falls Dam	Big Stone Lake and tributaries	Lake Traverse
Quillback	x	x	x	x	
Walleye	x	x	x	x	x
Sauger	x	x			
Northern pike	x	x	x	x	x
Silver redhorse	x	x	x		
Goldeye	x	x			
Mooneye	x	x			
Bigmouth buffalo	x	x	x	x	x
Black crappie				x	x
Bluegill				x	x
Yellow bullhead				x	x

[1]Source: Schneider (1966), MDNR (1963-1965, 1971), Bailey and Allum (1962).
[2]See Attachment C.II-6 for scientific names.

rare event. Furthermore there are a number of barriers on the Mississippi River downstream from Cutfoot Sioux, including a 39-foot high structure at the outlet from Lake Winnibigoshish (immediately downstream from Cutfoot Sioux). None of the problem species were taken from either Cutfoot Sioux or Bowstring lakes in a recent netting survey. As the Committee learned of this connection only during the final stages of writing it could not perform a full investigation (we do not know how frequently there has been a water connection between the two lakes). At this time we can only say that fish have passed through this connection at least once in the past; however, this connection has otherwise not been reported from the literature. Again the same arguments apply as for the Traverse-Big Stone connection: there is no evidence of exotic fish being introduced into the Hudson Bay drainage via Cutfoot Sioux Lake, but there appears to be a theoretical risk.

Existing Presence of Exotics in Hudson Bay Drainage: In the Hudson Bay drainage smelt are found in headwater lakes of the Rainy River system in Ontario (Eva Lake) and Minnesota (Burntside Lake, Fig. C.II-2). We defined how far smelt had spread from Eva Lake and Burntside Lake after they were introduced there. This information permitted some comparisons of the rate of dispersal in the Eva Lake and Burntside Lake areas with that of the Great Lakes and with known rates of dispersal for other species.

Smelt were first observed in the stomach of a lake trout (one specimen) from Eva Lake in the winter of 1971-2 (B. Caldwell pers comm). Caldwell observed in excess of 200 smelt spawning in a tributary into Eva Lake in the spring of 1972. Since 1972 several hundred smelt have been seined from Eva Lake by a high school biology class; OMNR has not conducted any netting in Eva Lake. Apparently the population is now well established. It is believed that these smelt were introduced by dumping fertilized eggs into Eva Lake: people from Eva Lake do go "smelting" in Lake Superior near Thunder Bay during the spawning run. It is known that fertilized smelt eggs can remain viable out of water for several hours provided no dessication occurs (R. Ryder pers comm). OMNR netted for smelt in French Lake (180 m downstream from Eva Lake) in the spring of 1974: one smelt was taken (OMNR only sampled enough to establish smelt presence; that is, they stopped netting after capturing one specimen, B. Gibson pers comm). Four smelt were taken from lake trout stomachs from French Lake in the spring of 1976 (B. Gibson pers comm). It is evident that smelt are now established in French Lake. No netting has been conducted in French Lake since 1974. OMNR netted Pickerel Lake (the next lake downstream from French Lake) in 1974 and did not catch any smelt; however they were not fishing for smelt and mesh size was too large for smelt (B. Gibson pers comm). It has been suggested by various Ontario biologists (B. Gibson and A. Elsey pers comm) that in contrast with French and Eva lakes, which are "deep cold trout lakes", there are shallow warm lakes which may serve as thermal barriers for downstream movement of smelt into Lake Winnipeg.

Smelt were first observed in Burntside Lake, Minnesota in the summer of 1972; these were three-plus years of age and were captured by

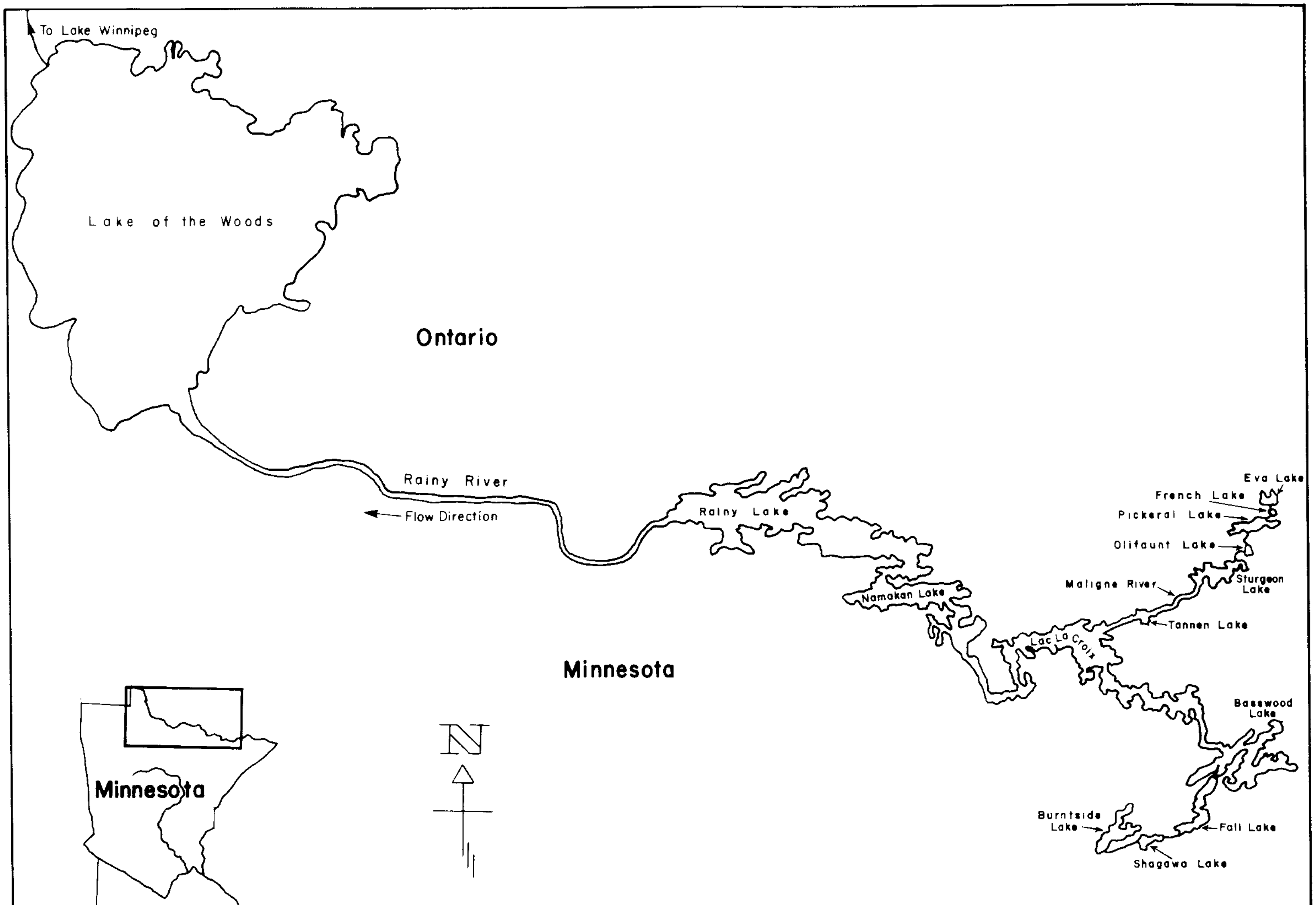

Fig. C.II-2. Sketch map showing possible pathway for smelt introductions into Manitoba from Ontario and Minnesota lakes.

netting (Johnson 1976). Since that time smelt have increased substantially in numbers. They are reported to be competing with a dwarf cisco population; in addition they have been preying on newly-hatched lake trout, lake herring, whitefish and walleye fry (Johnson 1976). Smelt have moved downstream to Shagawa Lake where two specimens were taken in a University of Wisconsin study (Johnson 1976). Johnson felt that Shagawa Lake and a series of small lakes downstream would serve as thermal barriers because of their shallow, warm-water nature. Beyond the series of small lakes, Basswood Lake is the next large lake on the chain before the Rainy River; this is upstream from where the Eva Lake chain of lakes empties into the Rainy River drainage. For reasons discussed in subsection F we do not agree with suggestions that warm shallow lakes in the Eva and Burntside drainages will stop the downward movement of smelt to Rainy River. However there may be other reasons (unknown to us) to explain why smelt have not moved rapidly downstream; in other instances that we are aware of, smelt have moved rapidly downstream from the point of introduction (smelt have moved at least 250 miles down the Missouri River within 4 years of being introduced into Lake Sakakawea [F. June pers comm]).

There is presently no physical obstruction to prevent the eventual (and perhaps inevitable) invasion of Manitoba waters by smelt from the Rainy River system in Ontario or Minnesota. For smelt from the Rainy River headwaters to reach Lake Winnipeg they must pass through two large lakes (Rainy Lake and Lake of the Woods), numerous smaller lakes and six hydroelectric impoundments on the Winnipeg River. However, there is a bypass that would permit movement of smelt, once in Lake of the Woods to move directly into the Red River: the Greater Winnipeg Water District aquaduct which conducts water from Lake of the Woods. There is a 4-mesh screen and chlorine infection system (2 ppm and greater) at the inlet but along the aquaduct there are a number of overflows (to handle excess flows to prevent bursting of pipes), one of which (Deacon) can spill up to 10 million gallons/day. The Deacon overflow drains into the Red River Floodway. Pike and whitefish have been reported in water reservoirs within Winnipeg; their occurrences are best explained by movement down the aquaduct from Lake of the Woods.

Most lakes on the Rainy and Winnipeg rivers have large populations of predatory fishes such as northern pike and walleyes. Predatory pressures by these fishes could retard colonization of new waters by smelt although this did not happen at Lake Sakakawea where populations of smelt have become established in four years since their introduction (E. Berard pers comm). Furthermore, it is evident from observations on the Great Lakes that smelt do not have to colonize a new water body before they move on to another lake. Smelt were first introduced in the Great Lakes system in Crystal Lake, Michigan in 1912. They were first observed from Lake Superior in 1930 (Van Oosten 1937a) and Lake Erie in 1936 (Van Oosten 1937b). Colonization and proliferation of smelt appeared to occur during the 1930's in Lakes Michigan and Huron and during the late 1940's in Lake Erie and Ontario. The buildup of smelt stocks in Lake Superior occurred between 1952 and 1964 (Christie 1974).

If the above events are extrapolated to the Hudson Bay drainage, it may require anywhere from 25 to 50 years for smelt from the Rainy River headwaters to reach and colonize Lake Winnipeg. Applying the rate of carp invasion in Manitoba and Saskatchewan (Atton 1959), it would require a minimum of 15 years for smelt from Eva Lake to reach Lake Winnipeg. In contrast with the above, smelt have been in Lake Winnipeg headwaters for at least seven years and have not been reported in Rainy River or further downstream. Therefore we cannot predict when or if smelt will reach Lake Winnipeg from this source.

Accidental or Intentional but Unauthorized Introduction of Exotic Fish Species into Canada: In spite of legislation, regulations and best management practices, there is always a possibility that accidental or intentional but unauthorized introductions of foreign fish species or diseased fish stock into Canadian waters could occur. These introductions can be accomplished by various means such as transport of eggs or larvae by waterfowl, bait bucket transfer by fishermen, non-official stocking or ventures where locals feel fishing can be improved by introduction of an exotic. With or without GDU, the possibility of such transfers has existed and will continue to exist. The potential or probability of such introductions occurring cannot be estimated; however, the potential for introductions of this type has existed since the region was settled and with one exception it has apparently not resulted in the successful introduction of any of the Missouri fish species considered to be problem species. One problem species, rainbow smelt, has been accidentally/intentionally transferred from the St. Lawrence watershed to the headwaters of the Rainy River in the Hudson Bay watershed. Even though problem species (Table C.II-7) exist in close proximity to the Hudson Bay Basin (Lake Sakakawea and the James and Minnesota rivers), unauthorized introductions have not occurred. GDU will provide a permanent but seasonal high flow connection between the Missouri and Hudson Bay watersheds and even if downstream barriers completely filter out foreign species of fish, it will unite the two watersheds and thus increase the possibility of accidental or intentional but unauthorized interbasin transfers.

4. Conclusions:

a) Existing interbasin connections between the Hudson Bay Basin and both the St. Lawrence and Missouri River basins will not permit introduction of any GDU problem fish species.

b) There is a remote possibility of transfer between the Mississippi River and Hudson Bay basins: gizzard shad and shortnose gar could move up the Minnesota River into Big Stone Lake and into the Little Minnesota River, through the culvert on Highway 10, and thence into Lake Traverse.

There is an additional point of transfer between these basins in northern Minnesota. However, a number of manmade barriers occur in the upper Mississippi River preventing further upstream movement of fish through this route.

c) One of the potential GDU problem species, rainbow smelt, occurs in tributaries to the Rainy River (Hudson Bay Basin). We cannot predict when or if smelt will reach Lake Winnipeg from this source.

d) The possibility for accidental or intentional but unauthorized introduction of problem species into the Hudson Bay Basin has and always will exist.

D. Evaluation of The McClusky Canal Fish Screen

1. Introduction: A major concern associated with GDU is the possible interbasin transfer of fishes from the Missouri River Basin to the Hudson Bay Basin. Some of these fish may cause damage to Manitoba fisheries. GDU will provide a permanent seasonal high volume water exchange between the two basins. The McClusky Canal fish screen is being constructed in an attempt to prevent this transfer of fish, fish larvae and fish eggs between the two basins. This fish screen is located in what is now an extension of the Hudson Bay drainage. Therefore, the importance of the screen cannot be overemphasized; for as long as water continues to pass through the screen it must prevent the passage of undesirable fish.

2. Methods: In January 1976 we received a presentation from BuRec engineers dealing with research activities leading to design of the GDU fish screen; members were briefed on construction and operation of the fish screen and had an opportunity to observe water flowing over an experimental hydraulic unit of an inclined screen. The GDU screen design has been partially derived from an inclined weedseed screen developed by BuRec and first used on the Whitestone Coulee unit, Chief Joseph Dam project, Washington. The inclined screen was used by Wolf (1951) to trap fish and other organisms moving downstream. After observing the hydraulic unit of an inclined screen in operation we developed a list of questions concerning the screen. These were forwarded to BuRec for consideration and reply. Further sets of questions and responses followed, involving the Biology and Engineering committees as well as BuRec.

BuRec provided an internal file report on methods for restricting movements of fish. The Committee, wishing to supplement this bibliography, performed its own literature search. We learned from BuRec that an inclined fish screen was built and operating in Sweden (Biology Committee 1976). Subsequently two experts in Sweden were contacted to obtain an assessment of the effectiveness of this screen.

In June 1976 members of the Biology Committee viewed the weedseed screen in operation at the Whitestone Coulee unit. In addition a number of fish screens in use in the states of Washington and Oregon were observed. In July 1976 committee members viewed the partially-constructed McClusky Canal fish screen.

Because of continual design modifications by BuRec, we were unable to ascertain final specifications of the screen. We therefore decided to consider all material provided by BuRec concerning the fish screen prior to 18 June 1976, but not after that date.

3. Results: Fish screen structure design and operation (Fig. C.II-3): The following is a resume of discussions with BuRec engineers (BuRec pers comm, Attachments C.II-1 and 2) and BuRec fish

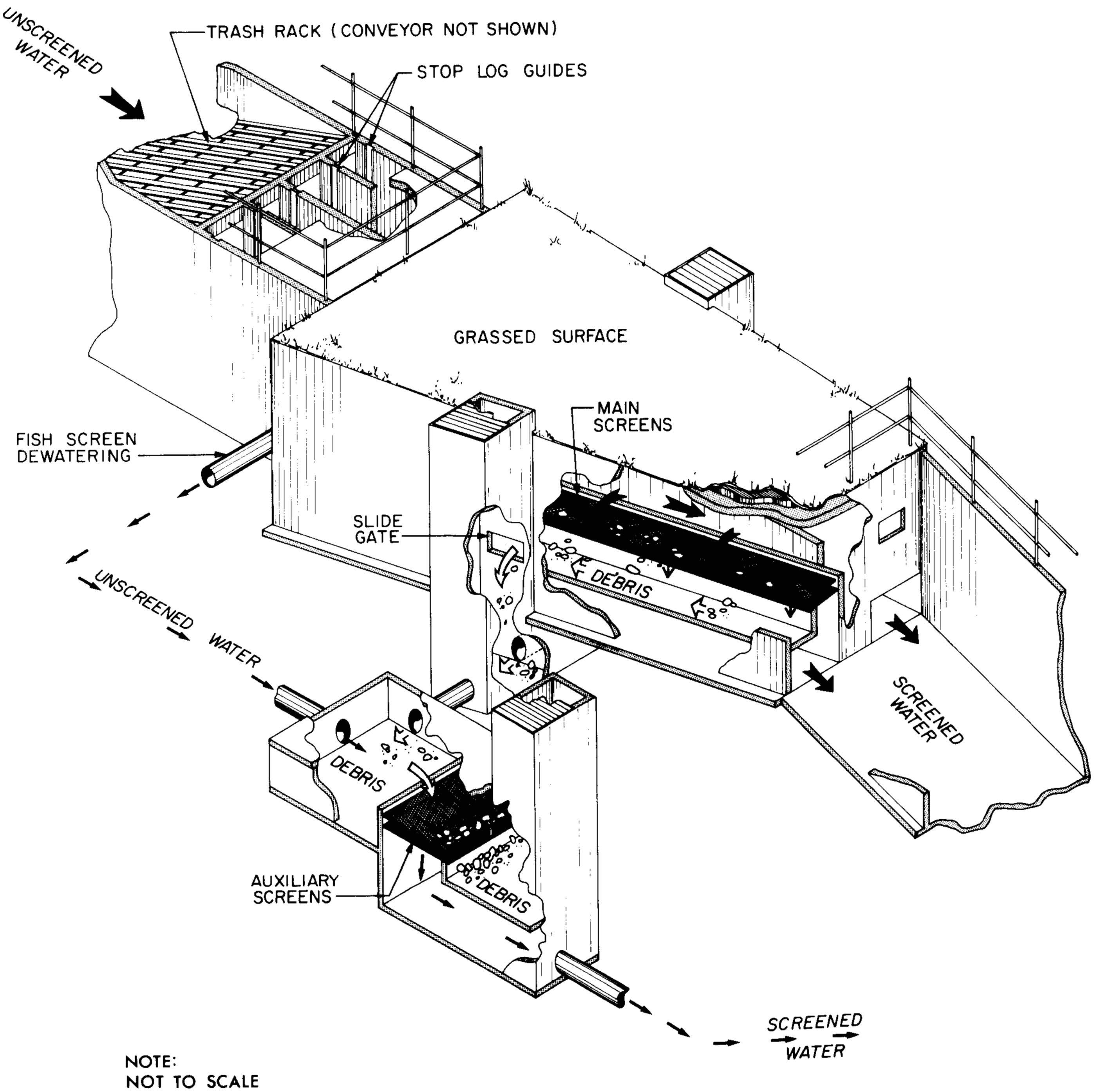

Fig. C.II-3. Fish screen as currently designed by BuRec.

screen blueprints (1976a). McClusky Canal water will flow (maximum 1,950 cfs) through the inlet trashrack upstream from the fish screens, where large floating or submerged objects will be retained and removed. Canal water then will enter a concrete inflow channel which narrows distally to maintain an even head over the weir. It then will flow to the left and right over a weir crest (total length 325 feet) onto and through the inclined screens and into a concrete sluiceway at the bottom of the structure.

There will be two sets of main screens, an upper service screen and a backup screen 1 foot below and parallel to the service screen. Both screens will be inclined at a 5-degree angle to permit self cleaning (Attachment C.II-1). Both screens will consist of a friction woven wire of 40-mesh (openings in the screen are 0.43 x 0.43 mm) phosphor bronze filter screen backed up by a 2-mesh screen supported in place by a steel frame. Phosphor bronze was selected: a) because of its high percentage of copper content which BuRec feels could inhibit algae growth on the screen and b) because of its high tensile strength. There will be approximately 60 upper screen panels and 60 lower screen panels on both sides of the concrete channel (Attachment C.II-2).

All screened material and water that does not pass through either of the 40-mesh screens will move across the screens and fall into trash gutters adjacent to the screens. This material will then flow through a single port into cleanout chambers and then into a deep (approximately 20-foot) manhole (4 feet x 4 feet). A pair of 40-mesh auxiliary screens similar to the main screens will be located at the bottom of the manhole to screen the water from the well before it is allowed to flow into the canal. Well screens will be cleaned at periodic intervals. In each gutter screened material will be conducted through a gated port into cleanout chambers; excess screened material and water would pass on to the well.

Detailed O&M criteria have not yet been developed to meet full scale project operating discharges. Mechanical plans and criteria are not available. Alarm systems, procedures for cleaning screens and emergency procedures to be followed in event of severe clogging of all screens are presented in Attachment C.II-2.

<u>Other screens</u>: We contacted two experts in Sweden to obtain an evaluation of inclined screens. Both experts advised that while the inclined screens were quite effective in collecting detritus in streams, they were not effective in preventing fish passage (Rosemarin 1976, Svardson 1976).

Four members of the Committee had an opportunity to view and assess a number of screen types used to control downstream and upstream passage of fish and downstream passage of weedseeds. These were located on various tributaries of the Columbia River in Washington and Oregon (Attachment C.II-3). The Whitestone Coulee unit weedseed screen had significant clogging problems because: a) the trashrack did not remove enough debris, b) the screens were too flat to allow debris to move down and spill into the gutter and c) the mesh may have been too small for the material being screened. We also observed that established operating criteria for functioning of screens were not always properly discharged by operators. Clogging of the weedseed screen occurred because debris was not removed manually and worn screens were not replaced. We observed that worn seals in the revolving fish screen in the Oroville-Tonasket Canal were not replaced and punctures in the Crown Zellerbach inclined screen were allowed to remain without screen replacement. However, the screen-filtered water at the Crown Zellerbach plant does go through a sand filter before it is used in paper-making. The Committee believes these were examples of normal operating practices for the observed screens.

Literature review on fish screens: Two literature reviews were conducted on methods for controling fish movement (Swain 1976a; BuRec 1973a). In summary, the three most commonly used methods of preventing passage of fish are traveling or drum screens, louver deflectors and electric barriers. None of these devices are 100 percent effective against adult or juvenile fish; none are at all effective against fish eggs. As a result, BuRec considered "only sand filters or fine self-cleaning screens . . . to be 100 percent effective in stopping the passage of fish as well as fish eggs and larvae" (BuRec 1973a). BuRec opted for the "fine self-cleaning screen".

In its investigations and interviews, the Committee did not encounter a fish screen design that had been intended to totally prevent passage of fish, fish eggs and larvae. Therefore the McClusky Canal fish screen is unique in this design objective.

4. Discussion: BuRec (1974) wrote that the fish screen, "if properly operated and maintained . . . is expected to be 100 percent effective in removing all fish and eggs from the Canal". The importance of the screen cannot be over emphasized; it must function without fail for the life of the project. The specific job of the screen is to ensure that no fish, fish eggs or fish larvae pass via the McClusky Canal from the Missouri River drainage (Lake Audubon) to the Hudson Bay drainage (Lonetree Reservoir). Therefore, we have critically reviewed the design and operation of the fish screen.

Screen resistance to perforation and wear: The phosphor-bronze screens in use at Crown Zellerbach were perforated. Other screens of similar mesh size viewed by the Committee supported sizeable loads of detritus. Unless complete clogging occurs, it is unlikely the McClusky Canal screens will break although they may be subject to small punctures. The screens may be subject to corrosion and ionization as a result of water quality in the canal. We are not aware of the extent to which this will occur. No method of determining the extent of possible screen puncture or wear exists at this time. BuRec (pers comm, Attachment C.II-2) advised that these criteria will be developed based on actual operating conditions.

Screen mesh size: The mesh size of the screen (apertures 0.43 x 0.43 mm) is designed to prevent passage of fish, fish eggs and larvae. Actual dimensions of the opening will be 0.43 mm on the sides and 0.6 mm across the diagonal. As discussed in subsection F, we believe rainbow smelt, gizzard shad and Utah chub could pass through the 40-mesh screen. Furthermore, while the cross-sectional area of eggs and larvae of other fish species may be greater than the minimum required, they may have sufficient compressibility to pass through the screen. In addition, there are other fish species, not considered as problem species, which likely are small enough in the larval and egg stage to pass through.

A final consideration here is that there must be a 100 percent assurance of fish passage prevention over infinite time. Under these conditions the frequency distribution of sizes becomes important. Extremely rare sizes at the lower end of the spectrum become increasingly common over time.

Screen clogging: The proposed fish screen, by design, is inclined five degrees downward to aid in self-cleaning. An on-site inspection of the Whitestone Coulee unit weedseed screen by the Biology Committee showed that the inclined screen concept does remove sizeable amounts of debris but is subject to plugging. However, this screen was not hydraulically modeled prior to construction while the upper main screens of the McClusky fish screen were. Local O&M personnel at Whitestone advised the Committee that screen plugging was caused by algae and other material such as tumbleweed. Water flow over and/or through the screen at time of viewing was about one-third of design capacity (15 or 45 cfs). Water turbidity was virtually non-existent.

The McClusky Canal fish screen has not been field tested. BuRec did subject the experimental screen unit, in their Denver laboratory, to a number of potential "pluggers" (P. Johnson pers comm). The tests were not conducted under controled experimental conditions, were not conducted in the McClusky Canal under field conditions and did not represent the wide range of size and type of materials that McClusky Canal water will transport. The fish screen will need to filter both air-borne and water-borne material of a diminutive size. A partial list includes: weedseeds, plant debris, organic material in all stages of fragmentation/decomposition, skeletal components of plants and animals, soil particles, living invertebrates both micro and macroscopic in size and algae (filamentous as well as planktonic). Some of these materials will collect on the screen; some of them will impregnate there. The Committee observed that the Whitestone Coulee weedseed screen (40-mesh) was plugged with weedseeds and other organic matter. It should be further pointed out that algae, etc. does not need to remain alive to cause clogging problems; furthermore, decaying organic matter on the screen will serve as an excellent medium for iron bacteria, sewage fungi (eg. *Sphaerotilus* spp.) and fungal (eg. *Saprolegnia* spp.) growth. Therefore it is likely the screen will clog.

We do not anticipate an instantaneous 100 percent clogging of all screens. (BuRec stated that up to 50 percent of the total screen area can be clogged without danger to the operation of the screen). However, we expect rapid clogging of greater than 50 percent of the screens at certain times of the summer due to water-borne materials in the canal waters.

As the screens begin to clog, an increasing amount of water and debris will pass over them into the collection gutters and through the clean-out port into the well screen system. This flow will continue until the water level in the gutters rises to approximately two inches; it is intended that the flow will activate the alarm system and stop water flow into the fish screen structure.

BuRec (pers comm, Attachment C.II-2) described the following sequence of events proposed in the event of complete clogging of the screen.

> "In the event of severe clogging the following would occur: alarms would sound; slide gates that control drainage from the trash troughs would automatically close; radial gates at upstream checks would automatically close; pumps at Snake Creek pumping plant would automatically turn off; stop logs would be placed at the upstream end of the screen structure; the structure would be pumped out (returning the water to the canal upstream of the structure); screens would be cleaned and replaced as previously described."

We do not have official verification that these events will occur; no operational criteria are available for review. Furthermore, at this time, the Committee doubts this is the sequence of events that will actually occur; in particular we are unsure of the automatic nature of the closing of the upstream radial gates and shutting off of the Snake Creek pumping plant.

With or without clogging, water will pass over the screens via two routes. First, some water will continuously flow into the trash gutters by splash, spray and flow over unscreened portions of the unit, such as the screen joining structures. Second, a proportion of the screens will fill with debris. At some time water will flow across this screened material and into the gutters. BuRec (pers comm, Attachment C.II-2) reported that, "as the screens start to clog, small quantities of flow will enter the trough. By having the alarm sound when flows in the trough are small, the O&M forces are given adequate time to clean out the screen." We are not sure that O&M forces will have adequate time to clean the screen. This is partially because we lack operating criteria and partially because we have a number of concerns about O&M; three examples are: we do not know 1) if water will build up within the structure rapidly, preventing access, 2) where the O&M forces will be housed and 3) whether there is an automatic power backup system.

Even without major clogging of the main screens the 2-inch clearance from the floor of the collecting gutter to the sensor will allow a significant, continuous flow through the gutter port. As a result the following sequence of events will take place. Spray, wet screened material and water passing across the screen joints will constantly cause unscreened water to flow into the trash collection system. It appears some of the screened material ½-inch or smaller washed from 120 screen units will find its way to the well screen unit. This material will contain eggs, larvae and small fish. The continuous flow plus the well screen weir pool will provide a good environment for survival of these organisms. Water plus screened material must eventually arrive at the well screen. This water will then pass through the well screen with the screened material being retained. No operational details are available concerning the plugging or cleaning of this screen, although an alarm system will detect when water rises one foot above the well screen. When this occurs, the bottom screen will be under more than two feet of water before any cleaning can take place. We believe the cleaning of the submerged well screens in place will be extremely difficult, if not impossible. Any removal of screens for cleaning with consequent opening of the joint seals will allow passage of organisms.

Removal, cleaning and replacement of screens: The Committee was informed by BuRec design and O&M personnel that the proposed standard procedure for cleaning screens would occur as follows (BuRec pers comm, Attachment C.II-2):

Screens cleaned in place - "A hinged 3-sided bulkhead secured to the ceiling will be lowered and surround the clogged screen and two adjoining screens. The bulkhead will be butted against the weir wall and will have neoprene flaps; this will cause water to pass around the bulkhead. Debris will be removed from the screens in place by using water spray and/or brushing. Screens will then be put back into operation at this point if adequately cleaned."

Screens removed for cleaning - "Seals will be cleaned to make sure no loose debris falls through when screens are removed. When the clogged screen panel is removed it will be lifted via an overhead hoist. The eye bolt on the screen panel is located off-center such that when it is lifted it will hang obliquely rather than horizontally, which could permit detritus to fall from it onto a second screen. The screens will be replaced with previously cleaned screens. The bulkhead can then be raised and the screens put back into operation".

The Committee found these procedures and plans to be incomplete in that blueprints provided (BuRec 1976a) did not support the verbal description given for the bulkhead. Furthermore, the blueprints were preliminary and many specifications were not given. No detailed operating procedures were provided. Two areas of unscreened water passage appear likely. A neoprene flap apparently provides water blockage between the bulkhead and the weir crest to prevent unscreened water from passing under the bulkhead and into the spaces where the screens are removed. The neoprene flap must not leak - yet the only apparent provision for positive sealing is water pressure from flow on the screen. Also, water may flow around edges of the bulkhead and into vacant screen spaces. From information provided it appeared that if a number of screens were clogged, when the bulkhead was lowered to enable screen cleaning adjacent clogged screens would pass considerable water either into the gap left by the removed screen panels or into the trough.

The Committee believes that cleaning arrangements for backup lower screens are inadequate as outlined by BuRec. No method of determining the extent of plugging of the backup screen is available without removing the top screen. We are unsure of the ability of the second screen to be self-cleaning. The hydraulic characteristics of the flow-over backup screen will be different from those established for the top screen. Therefore the bottom screen may not self clean. Because operating and design details were not available, an in-depth review of the cleaning procedures could not be made.

Spacing between screen panels: Design criteria indicate neoprene seals will be used to cover small spaces between screens (BuRec pers comm, Attachment C. II-2). These same criteria also allow as much as ½-inch separations between screens and various support structures. These tolerances are, we believe, to allow screen removal. Because of the wet environment and their secretive nature, fish larvae will collect in small spaces around the screen edges. BuRec indicated that seal regions will be cleaned before removal. Such cleaning cannot be 100 percent effective all the time. Therefore when the screen section is lifted for maintenance, these organisms will find their way to the backup screen and by the same process, by-pass the screen. In addition, water falling onto the upper screens will pass under the neoprene flaps that lap onto adjacent screens. This passage of water could lift the flaps, permitting passage of fish, larvae and/or eggs back into the McClusky Canal. We are also concerned with vibrations of the screen panels due to water pressure, causing the neoprene flaps to jiggle, waffle or warp sufficiently to allow organism passage. From plans that were provided to the Committee there is no provision to alleviate this problem.

Operating considerations: We are concerned that operating and maintenance criteria have not been developed by BuRec. We obviously cannot review operating criteria to be developed in the future. However, little or no latitude exists, in operation of the screen, for correcting deficiencies discovered during operation. Operational research with the actual diversion water and transported material should be done prior to putting the screen into operation. We do not believe normal engineering O&M development procedures are valid for the McClusky fish screen. A fail-safe system (which it must be) cannot be tested on site under actual operating conditions. It appears to be a very vulnerable way to develop a mandate of great responsibility.

The Committee is concerned as to the responsibility for supervision and operation of the McClusky fish screen. We have been told that BuRec may delegate this operation to the Conservancy District. If this were to occur the "mandate of responsibility" would only further expand. Fish screens associated with irrigation projects in Washington and Oregon were maintained by local Conservancy Districts; as discussed previously, O&M was not properly conducted at these facilities.

4. Summary: The Biology Committee, for the following reasons, believes the McClusky Canal fish screen as proposed will not prevent interbasin transfer of problem fish species, their larvae or eggs:

a) The screen mesh size is large enough that some larvae could pass through the screens.

b) Fish and fish eggs will pass by and through the auxiliary (well) screen due to design and operational considerations.

c) Fish larvae and fish eggs will pass by the screens, utilizing spaces between screens. In addition, fish, larvae and eggs will collect in various nooks and crannies along screen edges and they will pass around and through screens during cleaning.

d) We are particularly concerned about the lack of specific O&M procedures and details of the actual alarm system.

In addition, to date no screens of this type have been constructed or operated for fully preventing fish passage. Certain alternatives are available which may decrease the probability of fish passage. These will be discussed under Recommendations.

E. Evaluation of the Potential for Fish Passage Via GDU Project Works

1. Introduction: The Committee has determined that fish will pass the McClusky Canal fish screen, allowing transport of fish into Lonetree Reservoir, which is in the Hudson Bay Basin. Once this event has occurred there are three major routes of invasion into the Red River system: the Sheyenne, the James-Wild Rice and the Souris river drainages.

2. Methods: We reviewed various routes within the project works by which fish might move from the Missouri River Basin to the Hudson Bay Basin. Prior to this review, the Committee met with the Engineering Committee and BuRec project managers who described methods used to move water in and out of the areas to be irrigated.

3. Results and Discussion: For all of the irrigation areas, water will be shunted to wasteways whenever supply canal levels exceed the weir level of the wasteway. Canal levels will increase: a) when between 5 and 10 percent of the entire water supply will be wasted to ensure that water use logistics do not result in the operation of a dry pump; this water must be spilled to a wasteway, b) when severe rainstorms create runoff into the canals or c) when improper or undesignated agricultural use occurs. Furthermore, heavy snowfall may create spring flooding and project works may serve as drains; electrical outages or mechanical failures will result in water spillage from canals to wasteways.

We discussed with BuRec personnel and members of the Engineering Committee the operation of feeder canals, laterals and wasteways. While this is a complex system and it is impossible at this time to pinpoint all areas of possible fish transfer. it can be said than when Lonetree Reservoir becomes contaminated with undesirable fish species there are no effective barriers to their downstream movement into the Souris, Sheyenne and Red rivers.

Fish will move downstream from Lonetree via the Velva Canal. During periods of high flows and wasting of operational water, fish will move from various features in the supply system to the wasteways. There are no effective barriers to downstream movement in wasteways into the Souris River; there will be obstacles to indiscriminate upstream migration (high drop structures).

Fish from Lonetree Reservoir will pass directly through the outlet works into the headwaters of the Sheyenne River. They can then proceed downstream into the Red River.

Release from Lonetree into the New Rockford Canal to the James River feeder canal will provide direct routes down the James River into the Oakes area. The fish will then go into the Oakes Canal and into Taayer Reservoir. Pumping stations commonly transfer fishes from one area to another (lake whitefish were transferred from Lake Sakakawea, by the Snake Creek pumping plant, to Lake Audubon, D. Henegar pers comm);

they are not barriers to fish movement. There are no fish screens proposed for the Oakes area (BuRec 1974, 1976b). From Taayer Reservoir fish will move to the Wild Rice River and into the Red River via project works in a manner similar to that described above for the Velva Canal. This same sequence of events will occur for any species of fish moving upstream from the South Dakota portion of the James River.

Within the time constraints imposed on the Biology Committee it was impossible to evaluate all possibilities for fish transfer within the area encompassed by GDU. There are a number of laterals and small and large wasteways that have not as yet been finalized in relation to design and/or location. There is also a possibility of fish moving upstream via laterals which by-pass drop structures, normally barriers to upstream movement. These need to be fully evaluated if a complete assessment is to be made.

Two potential natural basin connections were reviewed by the Committee. A natural waterway between the Pembina River drainage and the Devils Lake Basin at Rock Lake, North Dakota was examined. The Engineering Committee provided topographic maps and an evaluation line drawing which indicated no interbasin transfer is possible because of a 4-foot differential in elevation. A natural interchange at Bear Creek on the James-Wild Rice divide was examined in the same manner. A similar barrier was indicated at this point.

A further connection is the Kindchi Lake turnout. This is a water bypass located in the McClusky Canal approximately four miles upstream from the McClusky Canal fish screen. Water will be diverted into Kindchi Lake to enhance this area as a wetland. Kindchi Lake is part of the Sheyenne River drainage; it will drain into Lonetree Reservoir. Therefore, there is a direct by-pass of the McClusky Canal fish screen. A fish screen has been proposed and designs available for this turnout (Engineering Committee 1976). We did not review the design plans thoroughly as it was very similar in design to the McClusky Canal fish screen and fish will pass this screen in the same ways as described previously.

Another turnout available for fish passage is from the New Rockford Canal into the upper James River (upstream from the James River feeder canal). At present this turnout has a 3-foot drop from the canal into the James River. This drop is not sufficient to prevent movement of fish (presently in the James River above Jamestown Dam) from the James River into the New Rockford Canal and then both into the Devils Lake area and Lonetree Reservoir.

4. Summary: We believe fish in Lonetree Reservoir will pass via project works into the Red River systems of North Dakota, Minnesota and Manitoba. A further mode of direct introduction will be via the Oakes pumping plant, Taayer Reservoir and the Wild Rice River.

F. Potential for and Impact of Introduction of Exotic Fish Species Due to GDU

1. Introduction: On a worldwide basis, the introduction of exotic animals has led to significant destabilization of ecosystems. There are a number of examples - hares in Australia, sea lamprey in the Great Lakes, carp in North America. Consequently much concern has been expressed about the effects of introduction of exotic fishes via GDU on the fishery resource of Manitoba.

Fish species presently found in the Hudson Bay drainage by-and-large originated from the Missouri-Mississippi River drainages approximately 12,000 years ago following the retreat of the last continental ice sheet and the formation of glacial Lake Agassiz (Crossman 1976). Except for several intermittent connections between the headwaters (subsection C), the Missouri-Mississippi River and Hudson Bay systems have been distinctly separate drainages for about the last 10,000 years. During this time different fish faunas have developed in the two drainage basins. A number of fish species now occur in the Missouri River Basin which are not found in the Hudson Bay Basin. Most of these species are native to the Missouri River but a few have been introduced by man in recent years. The observation that the species composition of fishes found in the Missouri River Basin differs from that found in the Hudson Bay Basin suggests that existing intermittent connections have been of minor importance in the interbasin transfer of fishes. GDU will provide a high volume connection between the waters of the two basins from at least May to October.

The Committee has determined that fish will be able to pass through or by the GDU fish screen and through GDU irrigation works to reach the Souris, Assiniboine and Red rivers. Following is a detailed analysis of the biology of the "GDU problem species" and an evaluation of the potential for and impact of introduction of these exotics.

2. Determination of Problem Species: We reviewed literature describing past and present fish distribution in North Dakota, Minnesota and Manitoba drainage systems affected by GDU (Owen and Russell 1975a, b and c; Scott and Crossman 1973; Eddy et al. 1972; Benson 1968). Fish distribution records in adjacent states (Montana, South Dakota) and provinces (Ontario, Saskatchewan, Alberta) were examined (Brown 1971; Simon 1946; Bailey and Allum 1962; Scott and Crossman 1973). From these records, lists were compiled of fish species occurring in the following drainage basins: a) Missouri River drainage in North Dakota and the James River in North and South Dakota, b) Red River drainage in Minnesota, North and South Dakota, c) Assiniboine River drainage, including the Souris River, in North Dakota and Manitoba and d) Red River drainage in Manitoba, Lake Manitoba and Lake Winnipeg. These lists (Attachment C.II-4) summarize the fish distribution in waters that could be directly or indirectly affected by GDU. A number of experts (C. Lindsey, W. Scott, E. Crossman pers comms) reviewed and verified these lists and provided additional information on certain species.

We recognized that in dealing with possible range extensions of fish up the James River there is no impassable fish barrier on the Missouri River between the mouth of the James River and the Mississippi River. Therefore, fish species in the Mississippi River are also available for introduction. It was impossible to make an assessment of all possible fish introductions from this mammoth area. We evaluated only those species considered to be close enough to the GDU project area to be readily and easily influenced by changes in upper James River and which may have a potential negative impact if introduced into Canada. This does not infer that introductions of fish from the lower Missouri or Mississippi rivers may not occur nor does it infer that such fish introductions may not be as serious as range extensions of fish from the lower James River.

A composite list including all the above lists was compiled to determine which fishes do not occur in the Hudson Bay Basin but occur in the Missouri River Basin (Table C.II-5). Twenty species were identified and considered as "potential problem species" that might be involved in interbasin transfer resulting from GDU (Table C.II-6). Carp were added to Table C.II-6 even though they occur in both North Dakota and Manitoba. They are not known to occur in the North Dakota or Saskatchewan portions of the Souris River. GDU may enhance habitat conditions for carp in the Souris River in North Dakota. This would allow the establishment of carp populations in some North Dakota wildlife refuges and in Saskatchewan portions of the Souris River.

We also compared fish species lists for the various drainages to determine those fishes found in Manitoba but not in the upper Missouri River Basin in North Dakota. A total of 17 species were identified (Attachment C.II-5) and we concluded that these fish did not pose a serious problem. This conclusion was premised on the capability of manmade barriers such as Baldhill Dam and GDU drop structures inhibiting the emigration of fishes from the Hudson Bay Basin to the Missouri River Basin. Furthermore the IJC directive to the Biology Committee was to examine effects of fish introductions through GDU into Canada, not from Canada.

Brief life histories of the 21 potential GDU problem species (Table C.II-6) were prepared and evaluated using the following criteria: a) frequency of occurrence within study area, b) reproductive potential in preferred habitat, c) history of population irruptions, d) undesirable characteristics e) migratory habits and f) assessment of positive, negative or neutral impact of these species on Manitoba fishes based on knowledge and familiarity with the species.

Topeka shiner, sturgeon chub, plains minnow, blue sucker, red shiner, flathead catfish, plains topminnow, yellow bullhead, coho salmon, blue catfish and silverband minnow were not considered to be GDU problem species because of a combination of the following: a) rare in the study area, b) of low reproductive potential, c) have no history of population irruptions, d) have restricted migratory tendencies, e) non-competitive or f) would have neutral or minimal impact if introduced into Canada.

Table C.II-5. List of fishes occurring in watersheds affected by GDU.

Common name[1]	Watershed											
	Missouri River		James River		Souris R		Assiniboine	Red River		Lake Winnipeg		L
	Sakakawea	Oahe	Upper	Lower	ND	Man.	River	ND and Minn.	Man.	S Basin	N Basin	Man.
Chestnut lamprey					x		x		x	x	x	x
Silver lamprey									x	x	x	
Lake sturgeon							x	x	x	x	x	x
Pallid sturgeon	x	x										
Shovelnose sturgeon	x	x		x								
Paddlefish	x	x										
Longnose gar[2]								x				
Shortnose gar	x	x		x								
Bowfin								x				
Gizzard shad		x[3]		x								
Goldeye	x	x		x		x	x	x	x	x	x	x
Mooneye							x	x	x	x	x	x
Lake herring							x	x	x	x	x	x
Blackfin cisco										x	x	x
Shortjaw cisco										x	x	
Lake whitefish	x						x	x	x	x	x	x
Coho salmon	x											
Rainbow trout	x					x	x	x	x	x	x	x
Brown trout	x							x				
Brook trout					x			x	x			
Lake trout	x								x	x	x	x
Rainbow smelt	x											
Central mudminnow					x			x	x	x	x	
Northern pike	x	x	x	x	x	x	x	x	x	x	x	x
Muskellunge								x				
Sturgeon chub		x										
Lake chub	x					x	x		x	x	x	x
Stoneroller				x				x	x[4]			

Table C.II-5. (continued)

Common name[1]	Watershed: Missouri River, Sakakawea	Missouri River, Oahe	James River, Upper	James River, Lower	Souris R, ND	Souris R, Man.	Assiniboine River	Red River, ND and Minn.	Red River, Man.	Lake Winnipeg, S Basin	Lake Winnipeg, N Basin	L Man.
Goldfish								x	x[4]			
Carp	x	x	x	x		x	x	x	x	x	x	x
Brassy minnow	x			x	x	x	x	x	x			
Silvery minnow	x			x				x	x			
Flathead chub	x	x				x	x		x	x	x	x
Hornyhead chub				x	x			x				
Silver chub							x	x	x			
Silverband minnow		x										
Golden shiner	x	x	x	x	x	x	x	x	x	x	x	x
Emerald shiner	x	x	x		x	x	x	x	x	x	x	x
Rosyface shiner								x	x			
River shiner		x	x			x	x	x	x	x	x	x
Common shiner			x	x	x	x	x	x	x			x
Bigmouth shiner				x	x			x	x			
Blacknose shiner				x		x	x	x	x	x	x	x
Pugnose shiner						x		x	x[4]			
Spottail shiner				x	x	x	x	x	x	x	x	x
Weed shiner								x				
Blackchin shiner						x		x	x[4]			
Red shiner	x			x								
Sand shiner	x		x	x		x	x	x	x	x		
Mimic shiner							x	x	x	x	x	x
Spotfin shiner								x	x[4]			
Topeka shiner				x								
Bluntnose minnow				x	x		x	x	x			
Fathead minnow	x	x	x	x	x	x	x	x	x	x	x	x
Blacknose dace		x	x	x	x	x	x	x	x	x	x	x
Longnose dace						x	x	x	x	x	x	x
Creek chub	x	x	x	x	x	x	x	x	x	x	x	x

Table C.II-5. (continued)

Common name[1]	Watershed: Missouri River Sakakawea	Missouri River Oahe	James River Upper	James River Lower	Souris R ND	Souris R Man.	Assiniboine River	Red River ND and Minn.	Red River Man.	Lake Winnipeg S Basin	Lake Winnipeg N Basin	L Man.
Pearl dace	x				x	x	x	x	x	x	x	x
Finescale dace								x				
Northern redbelly dace					x			x				
River carpsucker	x	x		x	x							
Quillback	x						x	x	x	x	x	x
Lake chubsucker								x				
Longnose sucker	x				x	x	x		x	x	x	x
White sucker	x	x	x	x	x	x	x	x	x	x	x	x
Blue sucker	x	x										
Smallmouth buffalo	x	x	x	x								
Bigmouth buffalo	x	x	x	x			x	x	x			
Shorthead redhorse	x	x	x	x		x	x	x	x	x	x	x
Silver redhorse						x	x	x	x	x	x	x
Golden redhorse								x				
Greater redhorse								x	x[4]			
Black bullhead	x	x	x	x	x	x	x	x	x			x
Brown bullhead				x	x	x	x	x	x	x	x	
Yellow bullhead				x								
Channel catfish	x	x		x			x	x	x	x	x	x
Blue catfish		x										
Stonecat	x	x						x	x			
Tadpole madtom	x			x	x	x	x	x	x	x		x
Flathead catfish	x	x										
Banded killifish								x	x			
Burbot	x	x				x	x	x	x	x	x	x
Plains topminnow				x								
Brook stickleback	x		x	x	x	x	x	x	x	x	x	x
Plains minnow	x			x								

Table C.II-5. (continued)

Common name[1]	Watershed: Missouri River Sakakawea	Missouri River Oahe	James River Upper	James River Lower	Souris R ND	Souris R Man.	Assiniboine River	Red River ND and Minn.	Red River Man.	Lake Winnipeg S Basin	Lake Winnipeg N Basin	L Man.
Ninespine stickleback						x	x		x	x	x	x
Trout-perch					x			x	x	x	x	x
White bass	x	x	x					x		x		
Rock bass							x	x	x	x	x	
Green sunfish		x		x				x	x[4]			
Pumpkinseed	x			x				x				
Orangespotted sunfish	x	x	x	x				x	x[4]			
Bluegill	x	x	x					x				
Smallmouth bass	x				x	x		x	x	x		
Largemouth bass		x		x				x	x			
White crappie	x	x		x	x			x	x[4]			
Black crappie	x	x	x	x	x		x	x	x	x		
Crappie sp.	x				x			x				
Yellow perch	x	x	x	x	x	x	x	x	x	x	x	x
Blackside darter			x	x	x	x	x	x	x	x		
Iowa darter	x		x	x	x	x	x	x	x	x	x	x
Johnny darter	x		x	x	x	x	x	x	x	x	x	x
River darter							x	x	x	x	x	x
Least darter								x	x[4]			
Logperch							x	x	x	x	x	x
Sauger	x	x				x	x	x	x	x	x	x
Walleye	x	x	x	x	x	x	x	x	x	x	x	x
Freshwater drum	x	x		x			x	x	x	x	x	x

Table C.II-5. (continued)

Common name[1]	Watershed											
	Missouri River		James River		Souris R		Assiniboine River	Red River		Lake Winnipeg		L
	Sakakawea	Oahe	Upper	Lower	ND	Man.		ND and Minn.	Man.	S Basin	N Basin	Man.
Mottled sculpin							x	x[5]	x	x	x	x
Slimy sculpin						x	x		x	x	x	x
Spoonhead sculpin							x		x	x	x	x

[1]See Attachment C.II-6 for corresponding scientific names.
[2]Reported from the Otter Tail River in the 19th century but Eddy et al. (1972) suggested its removal from the faunal list of the Red River drainage until supporting specimens are found.
[3]Carufel and Witt (1963) reported a single gizzard shad in the Missouri River 2.5 miles below Garrison Dam.
[4]Fedoruk (1971) noted that these species occur in the Red River drainage in North Dakota or Minnesota and thus may spread into Manitoba via the Red River or may already be present in the province in the Red River system. (A large goldfish was taken from a small tributary stream of the Red River near Selkirk in 1976).
[5]No reported incidence in the Red River drainage in North Dakota or Minnesota but Eddy et al. (1972) suspect its presence there.

Table C.II-6. Potential problem fish species associated with GDU.

Common Name [1]	Common Name [1]
Pallid sturgeon	Plains minnow
Shovelnose sturgeon	River carpsucker
Paddlefish	Blue sucker
Shortnose gar	Smallmouth buffalo
Gizzard shad	Flathead catfish
Rainbow smelt	Yellow bullhead
Carp [2]	Plains topminnow
Topeka shiner	Utah chub [3]
Sturgeon chub	Silverbank minnow
Red shiner	Coho salmon
Blue catfish	

[1]See Attachment C.II-6 for corresponding scientific names.
[2]See text for rationale for inclusion in this list.
[3]Not included in Table C.II-5, this species occurs in upper Missouri River in Montana.

Therefore, the initial list of 21 potential problem species was reduced to 10 problem species (Table C.II-7). It should be emphasized that the above analysis was a preliminary screening to sort out those species we could scrutinize in considerable detail. The rationale developed for the problem species is not an impact assessment. On the other hand, by omission from further consideration we are not dismissing the possibility of introduction of the 11 eliminated potential problem species. We are saying the impact of introduction of these species would likely be minimal.

We examined, discussed and evaluated the detailed biology and life history literature reviews that were prepared (Swain 1976b-g, McRae 1976, Attachment C.II-7) on the 10 problem species to determine those species most critical in terms of ecological impacts on fisheries in Canada if introduced by GDU.

3. Life Histories and Potential Impact of GDU Problem Species

Impact of introduction of rainbow smelt (*Osmerus mordax*): In the Missouri River drainage smelt exist in Lake Sakakawea upstream from Garrison Dam. Smelt were introduced to Lake Sakakawea by NDGFD in 1972 to provide forage for predatory game fishes.

As discussed previously in subsection C, rainbow smelt already occur in the Hudson Bay Basin but only in the headwaters of the Rainy River system in Quetico Park, Ontario and in the Boundary Waters area of Minnesota. These smelt populations represent a potential source for the invasion of smelt into Lake Winnipeg. GDU would provide a second source (Lake Sakakawea) from which smelt may invade Lake Winnipeg. It has already been stated that smelt from Lake Sakakawea will bypass the fish screen in the McClusky Canal and enter Lonetree Reservoir (subsection D). It is our opinion that the Lonetree-Lake Winnipeg route provided by GDU will allow rapid invasion. This opinion is based on the fact that smelt generally move down major watercourses rapidly as evidenced in the Great Lakes and also in the Missouri River where smelt have moved at least 250 miles downstream from Lake Sakakawea in four years. As stated in subsection C, we cannot predict when or if smelt will move through the natural lake-river system (Rainy Lake, Rainy River, Lake of the Woods, Winnipeg River) to Lake Winnipeg. This was primarily based on the fact that smelt have been in the Rainy River headwaters for at least seven years but have not yet been reported in the Rainy River (less than a 50-mile downstream trip). This is in contrast to other instances where smelt have been introduced into headwaters as discussed above. Furthermore, the current problem presented by the existence of smelt in the Rainy River system is complicated by GDU. GDU will complicate management with respect to smelt in three ways: a) it doubles the sources from which invasion can occur, b) it places management in an international setting which is more difficult to resolve and c) due to the possible rapid invasion via GDU, it shortens lead time for any remedial actions. On the basis of these and other factors, rainbow smelt were considered to be a problem species.

Table C.II-7. Problem fish species associated with GDU.

Common name[1]	Common name[1]
Pallid sturgeon	Rainbow smelt
Shovelnose sturgeon	Carp
Paddlefish	River carpsucker
Shortnose gar	Smallmouth buffalo
Gizzard shad	Utah chub

[1]see Attachment C.II-6 for corresponding scientific names.

Smelt have successfully reproduced and established themselves in Lake Sakakawea (E. Berard pers comm). It is unknown whether they have been transferred from Lake Sakakawea to Lake Audubon but they have moved at least 250 miles down the Missouri from Lake Sakakawea to Lake Sharpe (F. June pers comm). Smelt will move into Lake Audubon when Snake Creek pumping plant operates. We expect that smelt will successfully reproduce and establish there. Furthermore, adult smelt could move into the McClusky Canal and spawn. MacCallum and Regier (1970) reported smelt spawning in a ditch near Lake Erie; Rupp (1959) reported that smelt eggs have been found deposited on sand, boulders, mud, aquatic vegetation, brush, flooded grasslands, concrete or wood sluicebeds and on all types of debris. Rupp reported a large variation in timing of spawning runs, with runs beginning as early as 55 days before ice-out and as late as 19 days after ice-out and ending as early as 40 days before and as late as 31 days after ice-out. In the case of Lakes Sakakawea and Audubon, ice-out varies from mid-March to mid-April. Therefore, spawning may occur anytime from 1 March or earlier to 1 May or later. Consequently, ripe adults can move through the McClusky Canal in April and May. Smelt eggs require 10 days at 60°F to 30 days at 43°F to hatch (Swain 1976b). Therefore larvae could be present in McClusky Canal by 1 April or earlier to 1 June or later. BuRec will likely begin operating the Snake Creek pumping plant shortly after ice-out to fill up Lonetree Reservoir. Therefore there will be water moving in the canal to transport eggs, larvae and both ripe and spawned-out adults to the McClusky fish screen. Owen and Russell (1975c) believed that adult fishes would survive in the canals but suggested that young-of-the-year fish would not survive because of lack of suitable food. We believe that plankton in waters diverted from Lake Audubon will provide a suitable food supply in the canals immediately; furthermore, some populations of aquatic macroinvertebrates will be established in the canals within a year after filling. It should be further noted that several species of fish already occur in portions of the McClusky Canal (D. Henegar pers comm). In addition, lakes in the canal system will provide suitable habitat for overwintering fish.

As previously described, the proposed opening for the GDU fish screen is 0.43 x 0.43 mm. The diameter of smelt egg ranges from 0.79 to 0.99 mm with an average of 0.86 mm (Bailey 1964). Therefore it is unlikely that smelt eggs could pass through the fish screen.

To determine whether smelt larvae could pass through 0.43 x 0.43 mm, information on the cross-sectional body dimensions of smelt larvae was obtained from D. Faber (pers comm). Faber measured five smelt larvae which had an average total body length of 5.5 mm. The following average measurements were received:

Head depth	= 0.8 mm
Head width at eye	= 1.2 mm
Body depth at yolk sac	= 0.8 mm

Head width is greater than the head depth since the eyes protrude slightly from the head. Faber indicated that the yolk sac of these larvae contributed one-third of the body depth dimension. These measurements indicate that smelt larvae will not pass through a 0.43 x 0.43 mm opening. However, it should be noted, as previously stated, that the size of smelt eggs varies. Furthermore we do not consider five fish to be an adequate sample to conclude anything about the diameter of smelt larvae. Smaller eggs produce smaller larvae. The Committee was unable to find any data on the frequency and distribution of body sizes of smelt larvae. Judging from the minimum egg diameter reported by Bailey (1964) the cross-sectional body sizes of some smelt larvae hatched from small eggs could approach or equal the diagonal dimension (0.6 mm) of a 0.43 x 0.43 mm pore opening. Although most smelt larvae may be too large to pass through the 0.43 x 0.43 mm openings, in some cases smelt larvae will likely pass.

As discussed in subsection D, a final consideration is that there must be a 100 percent assurance of fish passage prevention over infinite time. Under these conditions the frequency distribution of sizes becomes important. Extremely rare sizes at the lower end of the spectrum become increasingly common over time. With time, the probability that extremely small (or rare) smelt larvae will pass through the 0.43 x 0.43 mm mesh screen increases. This probability could not be determined because of the lack of data on the frequency distribution of smelt larvae body sizes. We believe, however, that eventually smelt larvae will pass through the GDU fish screen even though it functions continually without mechanical failures. Establishment of a smelt population there will provide a source for further downstream invasions.

The most direct and likely routes by which smelt from Lonetree Reservoir will invade Manitoba are via the Sheyenne and Red rivers or the Velva Canal and Souris River. The Sheyenne, Red River route will be the first avenue opened for the invasion of smelt into Manitoba. Lonetree Reservoir is scheduled for filling in 1978 and waters will be spilled almost immediately into the Sheyenne River. BuRec has not indicated that a fish screening device will be placed on the Lonetree Reservoir outlet to the Sheyenne River. Once smelt reach the Sheyenne River, their transfer to Lake Winnipeg could occur rapidly.

Another route by which smelt may invade Manitoba from Lonetree Reservoir is the Sheyenne River, James River feeder canal, James River, Oakes Canal, Wild Rice River and finally Red River route. Invasions via this route will occur after the Oakes Canal is completed, about 1981.

The Velva Canal, Souris River route will not be available until approximately 1985 when the Velva Canal is scheduled for completion and irrigation return flows will be spilled into the Souris River.

One critical habitat requirement that must be considered regarding smelt emigration is temperature. Water temperatures in GDU waterways and the Souris and Assiniboine rivers, during most of the year, will not exceed the upper thermal tolerance for smelt. Smelt appear to be relatively eurythermic; that is, they can tolerate a wide range in temperature. Smelt populations are known to exist in lakes which do not thermally stratify and when summer temperatures sometimes exceed 70°F (Swain 1976b). Young-of-the-year, yearling and adult smelt have been captured by trawling during May and October in Lake St. Clair, which is a relatively shallow, warm water lake. Young-of-the-year smelt have also been caught during mid-summer in shallow inshore waters of Lake St. Clair (A. Derksen pers comm).

There are no known environmental conditions or barriers which would preclude the existence and reproduction of smelt in Lake Winnipeg. Although the South Basin of Lake Winnipeg, because of its very shallow depth and high turbidity, will not provide suitable habitat for the establishment of large smelt populations, we believe the North Basin will provide near-optimum habitat conditions. We believe northern Lake Winnipeg will support high smelt densities.

Christie (1974) noted that colonization of smelt in Lakes Michigan and Huron was largely restricted to Green Bay and Saginaw Bay, respectively. These bays have shallow to moderate depths. The chief smelt concentration in Lake Superior occurs in the shallow western end (Baldwin and Saalfeld 1962, Anderson and Smith 1971). Smelt first appeared in large numbers at the west end of the Central Basin of Lake Erie (Kennedy 1961), which has been compared to Saginaw Bay and Green Bay (Christie 1974). The Central Basin of Lake Erie is relatively uniform in configuration with depths ranging from 18 to 24 m. Smelt populations have also become very abundant in the Eastern Basin of Lake Erie. Annual commercial catches from a 518 km^2 area in Long Point Bay, eastern Lake Erie, averaged 75 kg/ha during the years 1961-1965 (MacCallum and Regier 1970). The Eastern Basin has a maximum depth of 64 m (Appelgate and Van Meter 1970). Smelt in Lake Ontario are found in all parts of the Lake and at depths to 46 m (Christie 1974). The North Basin of Lake Winnipeg is comparable in terms of depth to the Central Basin of Lake Erie. Northern Lake Winnipeg has an average depth of 15 m and a maximum depth of 30 m (Rybicki 1966).

Summer temperature conditions in northern Lake Winnipeg are also suitable for the survival of smelt. Smelt prefer cold water but they can exist in temperatures ranging from 60° to 70°F (Swain 1976b). MacCallum and Regier (1970) observed that for yearling smelt in Lake Erie, "spatial distribution is affected by a complex interaction of factors rather than a simple temperature preference". Surface water temperatures in Lake Winnipeg reach 70°F during July and early August. Bottom temperatures in the North Basin during midsummer may average 59 to 66.2°F, depending on depth (Rybicki 1966). However, since these temperatures prevail in Lake Winnipeg for only a relatively short period of time (two months or less), we believe smelt will adapt to the thermal regime in the northern portion of the lake.

Smelt are spring spawners and will spawn in streams of almost any type or on shoals and beaches in lakes (Rupp 1959). Lake Winnipeg and environs contain numerous areas which would provide suitable spawning habitat for smelt. Smelt would spawn in the tributary streams presently used by such species as walleye for spawning. There are also extensive areas of wave-swept gravel beaches in northern Lake Winnipeg which would provide optimum spawning habitat for smelt. Smelt may also spawn on the rocky shoals and reefs which are strewn along the entire east shore of the North Basin.

Smelt spawn over a relatively wide range of water temperatures (35.6°-59°F, Swain 1976b). The onset of smelt spawning runs closely follows ice breakup (Rupp 1959). Peak concentrations of smelt on or near spawning grounds may be expected for periods up to several weeks (MacCallum and Regier 1970). Breakup on northern Lake Winnipeg occurs usually during the latter half of May and walleyes and northern pike begin spawning from about mid-May to early June. Smelt spawning in northern Lake Winnipeg would therefore coincide closely with walleye and northern pike spawning.

Food would not be a limiting factor to smelt survival in Lake Winnipeg since hatching of smelt eggs would coincide closely with the spring plankton pulse. Food organims similar to those utilized by smelt in other areas are also common to Lake Winnipeg.

Although it can be concluded from the above considerations that smelt will establish in Lake Winnipeg, precise impacts of an invasion of smelt on indigenous fish fauna cannot be easily identified or quantified. There is no doubt smelt will have a disruptive influence on existing fish communities in Lake Winnipeg. The extent to which smelt may affect native fish stocks depends on levels of abundance that smelt populations achieve. Since food and habitat availability will not be limiting to the proliferation of smelt, the key factor is predation upon smelt by piscivorous fishes.

Because of competition for habitat and food that may occur between smelt and other predatory fishes it may require some time for smelt to colonize Lake Winnipeg and attain levels of abundance which have been witnessed in the Great Lakes. Lake Winnipeg, throughout, contains populations of piscivorous fishes such as northern pike, walleye and sauger. Predation by these populations may retard the spread and proliferation of smelt. However, in Lake Sakakawea smelt have established large populations within four years despite the presence of major predator populations (E. Berard pers comm). Furthermore, any severe reduction in Lake Winnipeg predator populations resulting from natural fluctuations and/or exploitations will sufficiently relieve predation pressures and allow smelt populations to increase in size and number. Excessive exploitation, coupled with adverse environmental conditions, could reduce predator populations, at least in some areas of Lake Winnipeg, to a level at which smelt could increase.

It is not possible to state the degree of predator stock reduction before smelt populations would proliferate. It should be noted, however, that smelt densities in Lake Erie were increasing when blue-pike (*Stizostedion vitreum glaucum*) and walleyes were being heavily over-exploited during the 1950's. The record yield of smelt from Lake Erie was in 1962 when 8.2 million kg were caught (Christie 1974). This was only four years after the almost total collapse of walleye populations in the lake (Baldwin and Saalfield 1962).

Reasons for the proliferation of invading species may not be as simple as described above. Experiences on the Great Lakes have demonstrated that invading fishes will proliferate despite the presence of reasonably large populations of predators. For example, Christie (1974) pointed out that the alewife (*Alosa pseudoharengus*) colonized Lake Ontario at a time when lake trout stocks were declining but still relatively abundant. He further noted that a similar situation existed when smelt colonized Lake Michigan. Christie suggested that declines in predator stocks would allow significant increases in the indigenous forage fish populations and consequently relieve predation on invading fish.

Lake Winnipeg contains large populations of native forage fishes such as cyprinids, trout-perch and the young of other species (lake herring, yellow perch) which are sufficient to maintain existing predator populations by an increase in their own abundance. A slight reduction in predator populations in Lake Winnipeg as a result of either exploitation, adverse spawning conditions or both could initiate a major increase in native forage stocks. Under these circumstances, smelt in Lake Winnipeg would not be as vulnerable to predation, since predatory fishes would feed on their natural prey. Smelt, relieved of predation, could then increase in abundance.

Other factors may affect the relationship or interactions between invading fish and predators. Regier et al. (1969), for example, suggested that depletion of dissolved oxygen in the hypolimnial waters of central Lake Erie provided the pelagic young of smelt a sanctuary from predation by walleyes. Walleyes, which use the bottom as the base from which they forage, were excluded from the area because of dissolved oxygen depletion. Although dissolved oxygen depletion does not occur in Lake Winnipeg, similar environmental conditions may occur which in a subtle way will provide some advantage to smelt.

Given the advantage in Lake Winnipeg, smelt could attain a rapid rate of increase. It is generally postulated that invading species may temporarily lose some of their specialized habitat requirements and increase at a greater rate than native species which are still subject to ecological constraints (Christie 1974). Furthermore, since smelt mature in two or three years and have a high reproductive capacity, their proliferation could well attain proportions of a population irruption. In other words, the rate of increase would be so rapid that smelt densities would soon reach or exceed the intrinsic carrying capacity of the lake. Predator populations in Lake Winnipeg, because of their slower rate of maturation and other environmental constraints, would not be able to increase quickly enough to effectively contain the smelt population irruption. Provided they were not adversely affected by smelt, predator populations would require several generations (10 to 20 years) before they would be able to bring smelt populations into some state of equilibrium or stability.

Irrupting smelt populations might also be counteracted by factors other than predation. Van Oosten (1947) reported a drastic mortality of smelt in Lakes Michigan and Huron during the winter of 1942-43. Nepszy and Dechtiar (1972) reported an unusually high post-spawning mortality of smelt in Lake Erie in 1971 and suggested it may have been partly due to a heavy infestation of *Glugea hertwigi*, a microsporidian parasite specific to smelt. The infestation of Lake Erie smelt with *G. hertwigi* did not attain significant proportions until the middle and late 1960's. It should be noted, however, that these events did not occur until well after the population irruption occurred. By that time, damage by smelt upon native fish stocks could markedly affect at least some native fish stocks.

Some beneficial affects could accrue. Smelt could provide some additional forage for predatory fishes and result in increased growth rates and abundance of such species as northern pike, walleyes and saugers. Such benefits, however, may be only transitory. There is a greater danger that smelt could compete with more desirable fish species for food and space. Smelt could also prey on other species. Young smelt are pelagic and feed on invertebrate organisms (Gordon 1961) and therefore could compete with the pelagic young of native species for food. Larger smelt could be competitors for food but they also constitute a predatory threat because of their fish-eating habits (Baldwin 1948). In Burntside Lake, Minnesota, smelt have been observed preying on newly hatched lake trout, lake herring and on lake whitefish larvae (Johnson 1976). Large concentrations of smelt can also cause other fishes to be crowded out of an area. Crowding can be particularly detrimental if it displaces the spawning runs of other fishes.

Some insight into the possible ramifications resulting from the invasion and proliferation of smelt in Lake Winnipeg was obtained from a review of literature on the Great Lakes fisheries. Although evidence presented in the Great Lakes literature for this case is largely circumstantial, the association between increases in smelt as well as other non-native fish populations and subsequent occurrences in indigenous fish populations are too apparent to be simply dismissed as coincidental.

Concern over possible adverse effects of smelt in the Great Lakes was expressed as early as the 1930's. Van Oosten (1937a) stated,

> "The phenomenal spread of the introduced smelt . . . throughout the Great Lakes region during the past decade will be referred to repeatedly in the years to come as another classic example illustrating the many complications that follow the successful

establishment of an exotic species of fish. Whether the smelt will prove to be a curse or a blessing to the Great Lakes states I cannot say."

Although it was not known at that time what effects flourishing smelt populations were exerting on other fish populations in the Great Lakes, Schneberger (1937) reported smelt in Green Bay, Lake Michigan were fouling gill nets to such a degree that commercial fishing had to cease for part of the season.

Van Oosten (1947) found some evidence that smelt had limited year class success on lake herring, lake whitefish and "perhaps walleyes" in Green Bay. As stated previously, the smelt population in Green Bay suffered a heavy mortality in the winter of 1942-43. In the late 1940's a high abundance of lake herring, lake whitefish and walleye occurred because of the phenomenal strength of the 1947 year class in each population (Hile et al. 1953, Pycha 1961). Anderson and Smith (1971) suggested that this occurred because of reduced pressure by smelt. The same events were experienced by lake herring and smelt stocks in Lake Huron at the same time (Christie 1974). An intensive study by Anderson and Smith (1971) into factors involved in the decline of lake herring in western Lake Superior strongly suggested that an increase in smelt populations, and to a lesser extent, bloater (*Coregonus hoyi*) populations was the major cause. Food competition between larval stages of lake herring and between smelt and bloaters was implicated. Results of this study also suggested a loss of recruitment in lake herring populations due to their displacement from spawning grounds by smelt.

A recent and comprehensive review of fish species changes in the Great Lakes was made by Christie (1974). He noted that an apparently consistent reaction to smelt invasions of Lakes Superior and Michigan was a swift collaspe of lake herring stocks. Christie postulated that these collapses occurred because of close similarities between lake herring and smelt in their distribution and habits. Smelt, like lake herring, will spawn along lake shorelines. Both species occupy the thermocline in summer and feed on plankton. Christie disagreed, however, with Van Oosten regarding the effect of smelt on lake whitefish. Christie suggested the two species do not interact significantly since whitefish in Lake Superior have increased along with a thriving smelt population and since Lake Ontario whitefish have persisted long after the invasion of smelt. Christie also stated that whitefish catches have improved significantly in Lake Michigan. He interpreted the increases in whitefish catches in Lakes Michigan and Superior as a response to sea lamprey (*Petromyzon marinus*) control. With respect to Lake Michigan, it should be noted that concomitant with the program to control the sea lamprey there has been an intensive program to plant salmonids (Pacific salmon, lake trout, etc.). These plantings of predaceous fishes may have resulted in some control of smelt and other pest fishes, which, in turn, has allowed whitefish stocks to recvoer.

Regier et al. (1969) tended to support Van Oosten's claim that smelt may interact with walleyes. They postulated that, along with intensive exploitation and environmental degradation, growing smelt populations in Lake Erie had an added deleterious effect on walleyes, especially in the Central Basin. However, Leach and Nepszy (1975) disputed this statement and indicated that the present smelt abundance in Lake Erie does not appear to have affected success of recent year classes of walleyes.

On the basis of experiences with smelt in the Great Lakes it is expected that an invasion of smelt into Lake Winnipeg will result in collapse of lake herring stocks. Lake herring are commercially exploited in Lake Winnipeg. The record commercial catch of lake herring was made in 1947 when approximately 2 million kg were produced. Since 1961 catches have been less than 0.5 million kg. Commercial production statistics do not, however, reflect the abundance of lake herring in Lake Winnipeg. Lake herring are generally too small to be captured in legal mesh sizes of gill nets allowed in commercial fisheries on the lake. Furthermore, lake herring are not specifically sought since they are infested with *Triaenophorus* sp. which encysts in their flesh and reduces their commercial value. Experimental gill netting in Lake Winnipeg indicated that lake herring are at least as abundant as lake whitefish (G. Prouse pers comm). The loss of lake herring stocks as a result of smelt invasion could affect other populations of more desirable fishes. Young lake herring may provide a significant source of forage for predator populations in Lake Winnipeg (K. Doan pers comm). Lake herring may compete with lake whitefish, particularly at the young stages, for food. A reduction in lake herring could therefore also result in an increase in whitefish populations.

There is concern that smelt in Lake Winnipeg will compete with whitefish stocks. That such interactions have not apparently occurred in the Great Lakes may be related to the greater diversity of habitats. Those Great Lakes where whitefish populations still exist have deep areas which undergo thermal stratification. The hypolimnial areas of these lakes have sufficient dissolved oxygen tensions to maintain whitefish, which are primarily benthic feeders. Smelt, on the other hand, are pelagic feeders and usually found in or above the thermocline. It is therefore evident that habitats of smelt and whitefish in the Great Lakes may not overlap significantly.

This would not be the case in Lake Winnipeg and particularly the North Basin. The North Basin is relatively shallow compared to the Great Lakes and does not undergo any permanent thermal stratification during the summer. It is argued therefore, that the distribution of smelt and whitefish habitats will overlap significantly. Since whitefish form a major component of the fish community in northern Lake Winnipeg, major competition will occur between them and smelt, should smelt populations attain high levels of abundance. These interactions will most probably be in the form of competition between young smelt and whitefish for food. Some predation of smelt upon larval whitefish will also occur but its potential for negative effects upon whitefish is largely speculative. The presence of large smelt concentrations on whitefish spawning grounds will have some effect on reproduction of whitefish. Whitefish populations in Lake Winnipeg have been subject to over-exploitation previously (Davidoff et al. 1973). If it occurred again, smelt could easily gain a competitive advantage over whitefish. The potential therefore exists for smelt to cause a collapse in Lake Winnipeg whitefish stocks.

There is also a potential for localized impacts of smelt on walleye populations in Lake Winnipeg. Significant declines have been observed in commercial walleye catches in the Grand Rapids and Sturgeon Bay areas. The decline in the Grand Rapids area appears related to the destruction of a major walleye spawning ground in the area. Stresses created by a large population of smelt could result in an even further decline of walleye stocks in the area. Smelt may have a positive effect on walleye stocks in Sturgeon Bay since the problem there appears to be more related to exploitation rather than availability of spawning habitat.

Smelt will invade Lake Manitoba either by the Assiniboine River Diversion or possibly from Lake Winnipeg via the Dauphin-Fairford River during very high water periods (when the Fairford Dam is overtopped). Smelt in Lake Manitoba could freely enter Lake Winnipegosis through the Waterhen River system.

Although smelt will enter Lake Manitoba it is not expected that populations could attain the abundance considered possible in Lake Winnipeg. Environmental conditions, particularly water temperatures in the shallow South Basin of Lake Manitoba, are not conducive to establishment of permanent smelt populations. Smelt may use the South Basin during spring for spawning and perhaps during winter. Some portions of northern Lake Manitoba, where lake herring and lake whitefish populations occur, may be favorable to smelt. However, since water depths similar to those found in northern Lake Winnipeg do not occur in the North Basin of Lake Manitoba, habitat for smelt is limited.

The possible impacts of smelt on indigenous fish populations in Lake Manitoba are polemic. Generally, Lake Manitoba contains sizable populations of predaceous fishes such as sauger, walleye and northern pike. Deficiency of preferred habitat for smelt in concert with pressures from existing predatory populations would act to control smelt in Lake Manitoba. Smelt populations could provide additional forage and consequently favour the growth and production of predatory fishes. On the other hand, smelt may exert pressures similar to those described in reference to Lake Winnipeg and cause the collapse of lake herring and lake whitefish populations in northern Lake Manitoba. Since lake herring and whitefish catches are small in comparison to catches of other species, loss of lake herring and whitefish populations would not have a major impact upon the total commercial fishery on Lake Manitoba. Establishment of smelt populations in northern Lake Manitoba may also present another source of stress to walleye populations. As discussed in subsection B, walleye populations in northern Lake Manitoba have declined and may be presently stressed by heavy infestations of *Ergasilus* sp. The combined effect of exploitation, parasitic infestation and pressures from smelt could culminate in collapse of walleye populations in northern Lake Manitoba. To state the very least impact, the presence of smelt in Lake Manitoba will complicate fisheries management efforts.

The invasion and establishment of smelt populations in Lake Winnipegosis may have impacts similar to those discussed above for Lake Manitoba. Despite the minor contribution of whitefish to the commercial fishery on Lake Winnipegosis, loss of whitefish stocks will be significant. Absence of whitefish, a valuable commercial species, would decrease the number of management options for revitalizing the commercial fishery on Lake Winnipegosis. Replacement of lake herring populations in Lake Winnipegosis with smelt may be beneficial. Lake herring in Lake Winnipegosis are small or stunted fish which have little or no commercial value. Smelt may be of more commercial value than lake herring. As stated earlier, walleye stocks have seriously declined in the last decade. The presence of smelt in Lake Winnipegosis will greatly complicate management efforts to restore dwindling and depauperate walleye stocks.

In summary, we believe that rainbow smelt will be successfully introduced and established in Manitoba waters. Smelt introduced to Lonetree Reservoir via GDU will move into Lake Winnipeg. Smelt could also invade Lake Winnipeg from the Rainy River system which is within the Hudson Bay drainage. The Committee anticipates rapid invasion into Lake Winnipeg via GDU; we do not know when and if invasion will occur through the natural lake, river system (Rainy Lake and River, Lake of the Woods and Winnipeg River). GDU compounds the problem by creating an additional source of invasion, places fisheries management in an international setting which is more difficult to administer and lastly, due to potential rapid invasion of smelt via GDU waterways, shortens lead time for any possible remedial measures. The Committee further believes that smelt, when introduced to Manitoba, will cause the collapse of lake herring populations in Lakes Winnipeg, Manitoba and Winnipegosis and will have a major negative impact on the lake whitefish fishery in the North Basins of Lakes Winnipeg and Manitoba. Smelt will also have negative impacts on walleye fisheries in certain locales of Lakes Winnipeg, Manitoba and Winnipegosis. Declines in the abundance of higher-valued species will result in decreases in fishermen's incomes such as occurred in Lake Erie during the late 1950's (Frick 1965). These losses will not generally be replaced by utilization of smelt, which have a lower market value.

Impact of introduction of gizzard shad (*Dorosoma cepedianum*): Gizzard shad do not occur in Manitoba waters. A single specimen has been taken from the Missouri River several miles below the Garrison Dam (Carufel and Witt 1963). This is the only record of the species in North Dakota. Populations of gizzard shad do exist in Missouri River reservoirs in South Dakota. The current distribution of gizzard shad in the Missouri River appears closely related to construction of mainstem reservoirs on the river.

The gizzard shad is basically an anadromous marine species of the eastern Atlantic seaboard. It has adapted to a totally freshwater existance. Gizzard shad exhibit a high propensity for moving into man-made canals and waterways and by this means extended their inland range in eastern North America (Miller 1957). Gizzard shad have long been present in and are considered native to the Mississippi River. From this source they invaded the Missouri River.

Gizzard shad were first recorded from the lower Missouri River near Sioux City, Iowa around the turn of the century and since then have gradually moved upstream (F. June pers comm). They presently occur in the Missouri River as far north as the tail-waters of Oahe Dam near Pierre, South Dakota. Gizzard shad must have reached this area sometime prior to 1952. In July 1952, Fort Randall Dam, which is on the Missouri River downstream from Pierre, was closed. It is not known whether the movement of gizzard shad into South Dakota resulted from the creation of Fort Peck Reservoir on the Upper Missouri in Montana. This large mainstem reservoir came into being in 1938. Since large reservoirs tend to store heat, downstream discharges, during late autumn, winter and early spring will tend to be warmer than under natural riverine conditions. Fort Peck Reservoir may have increased average downstream water temperatures enough to allow the northward incursion and survival of gizzard shad. The continued northward movement of gizzard shad appears to have been further stimulated by completion of Garrison Dam (Lake Sakakawea) in 1953. It has been observed that gizzard shad presently occurring in the Missouri River will move upstream in autumn in response to warmer discharges from the reservoirs (F. June pers comm). Discharges from Lake Sakakawea may have ameliorated temperature conditions in the Missouri River enough to permit gizzard shad to invade North Dakota. This would explain the one specimen that was collected from Garrison Dam tail-waters in October, 1955 (Carufel and Witt 1963). Although gizzard shad had evidently begun to invade the North Dakota portion of the Missouri River, they did not establish populations. Intensive sampling of Lake Oahe, downstream of Garrison Dam, has not produced any gizzard shad (Beckman and Elrod 1971). It is conceivable that activities associated with the construction of Oahe Dam, which was completed in 1958, may have prevented movement of sufficient numbers of gizzard shad into North Dakota to establish a reproducing population.

Gizzard shad occur in two areas of the James River system in South Dakota and in the Missouri River in South Dakota (Bailey and Allum 1962). Lake Mitchell, which drains a distance of about 2 km via Firesteel Creek into the James River in South Dakota, contains a self-sustaining population of gizzard shad. Gizzard shad in Lake Mitchell and the Missouri River form a nucleus for invasion up the James River. There are presently no insurmountable physical barriers to prevent their movement from Lake Mitchell, down Firesteel Creek, up the James River and into North Dakota as far as Jamestown Dam (Harza 1976, Owen and Russell 1975a, BuRec 1976b). In fact, fish kills involving gizzard shad have been reported in the James River upstream of Huron, South Dakota (Fig. C.I, Study Plan Section, R. Hanton pers comm).

Gizzard shad are restricted in their movement to and survival in the James River in South Dakota by low flows and low dissolved oxygen during summer and winter. Winter fish kills are common in the James River in South Dakota. GDU, however, will substantially increase flows in the river during both summer and winter. Water Quality (1976) has determined that a) improved flows will increase dissolved oxygen levels in the James River in South Dakota and b) dissolved oxygen conditions in the James between the North Dakota-South Dakota border and Oakes-Lamoure will continue to be satisfactory. Harza (1976) and BuRec (1976b) have determined there will be increased flows (3,600 to 13,000 AF/yr near the State Line) in the James River in North and South Dakota as a result of GDU. In addition, substantial increases in flow will occur in the James River in South Dakota as a result of the Oahe project (BuRec 1973b). There will be an annual increase of 259,000 AF/yr at a point above James River Diversion Dam located near Huron, South Dakota with the majority of this increase resulting from irrigation return flows. These improved conditions should permit the gizzard shad to extend their range into North Dakota.

Distribution of gizzard shad, once in North Dakota, will be further influenced by GDU. Swain (1976c) indicated that gizzard shad spawning generally occurs between temperatures of 60°-75°F which in the James River in North Dakota at Oakes would be from the end of May to mid-July. At these temperatures, eggs would hatch in less than one week (Swain 1976c). Therefore during the summer when the Oakes pumping station and Canal would be in operation, there could be eggs (the adhesive eggs sink or drift with the current, attaching to any object contacted, usually aquatic vegetation [Miller 1960]), larvae and adult shad in the canals (gizzard shad have used canals for range extension (Miller 1960), making interbasin transfer quite possible. Gizzard shad adults or eggs will be pumped into Oakes Canal by the Oakes pumping plant. Project waters in Oakes Canal will be pumped by the Taayer pumping plant into Taayer Reservoir for storage and subsequent release when required. The Oakes pumping plant will have a traveling water screen which BuRec (1976b) believes should prevent fish from moving from the James River into the Oakes Canal and Taayer Reservoir. This is the only mitigation measure proposed to inhibit movement of fish from the James River into the Wild Rice River. The Committee does not find this measure satisfactory and feels gizzard shad and other fish species will move from the James River to the Red River via Oakes Canal, Taayer Reservoir and Wild Rice River.

If a fish screen similar to the McClusky Canal fish screen is incorporated in the Oakes pumping plant or constructed at some point along Oakes Canal, this screen will have to be smaller than the 0.43 x 0.43 mm-mesh proposed for the McClusky Canal fish screen. Newly hatched gizzard shad larvae are 3.25 mm in total length and have an estimated average body depth of only 0.2 mm (Swain 1976c). Since the eggs of gizzard shad are adhesive shortly after they are spawned, they may cling to a fish screen. Water flowing through the screen will provide almost optimum conditions for incubation and hatching. Upon hatching, the larvae will pass through any screen with a mesh size of 0.43 x 0.43 mm. Furthermore the other concerns regarding the inclined screen concept apply here as discussed previously. Therefore, we do not feel any fish screen similar to the proposed McClusky Canal fish screen would prevent passage of gizzard shad into the Wild Rice and Red rivers.

Temperature is apparently important in controlling the distribution of gizzard shad. Lindsey (1975) reported that although gizzard shad in North America are distributed primarily south of the 70°F July isotherm, they have extended their range northward between the 70°F and 65°F July isotherms (Fig. C.II-4). The southern end of Lake Winnipeg lies between the 65° and 70°F July isotherms (Fig. C.II-4). As gizzard shad occur throughout the Great Lakes the Committee attempted to obtain seasonal water temperature data for the Great Lakes and Lake Winnipeg. The critical data, winter water temperatures, were lacking but K. Patalas (pers comm) made the following generalization: there may be up to a 4°F difference between Lake Erie and Lake Winnipeg and less for other Great Lakes during winter months with the temperature in Lake Winnipeg going as low as 34°-36°F, depending upon freeze-up conditions. Certainly Lake Erie is warmer during summer, but the summer water temperature of Lake Winnipeg does exceed 60°F for at least three months in summer. Once gizzard shad reach Lake Winnipeg they may experience some winter mortality. Water temperatures of 34°F have been reported in the South Basin of Lake Winnipeg during March (Crowe 1973). Swain (1976c) reported a number of lower lethal temperatures; however all of them range from 36°-38°F. Some mortality of gizzard shad in Conchas Lake, New Mexico, occurred at water temperatures of 36°F (Jester and Jensen 1972). However, gizzard shad were found in Presque Isle Bay, western Lake Erie, in water temperatures of 34°to 35°F. They appeared to be acclimated to these temperatures since mortalities occurred in an area of thermal outfall in the bay where the temperatures of adjacent waters were elevated to 55° or 60°F (Miller 1960). In Lake Erie shad are most plentiful in shallow waters around the periphery of the western end and in the Bass Islands area, especially in protected bays and mouths of tributaries with mud bottoms (Bodola 1966, Nash 1950). Similar habitat conditions prevail in Netley and Libau marshes at the south end of Lake Winnipeg.

Gizzard shad spawn over a variety of substrates from boulders and gravel to silt beds and rocky shorelines (Swain 1976c). These habitat types occur in the South Basin of Lake Winnipeg. Young gizzard shad feed on zooplankton while adults are phytoplankton feeders. Organisms utilized as food by gizzard shad occur in Lake Winnipeg. Therefore, habitat requirements for gizzard shad are met in Lake Winnipeg and particularly in the South Basin and central area of the lake.

Gizzard shad have a high reproductive capacity and exhibit rapid growth during their first and second summer. In favorable habitats, shad will produce large populations. Extremely large populations are likely to occur in shallow warm water lakes with mud bottoms, high turbidity and high fertility. Because gizzard shad feed almost exclusively on phytoplankton they are immediately benefited by any increase in aquatic productivity. For example, in George Lake, Florida, gizzard shad populations increased 300 to 400 percent over a 20-year period. This

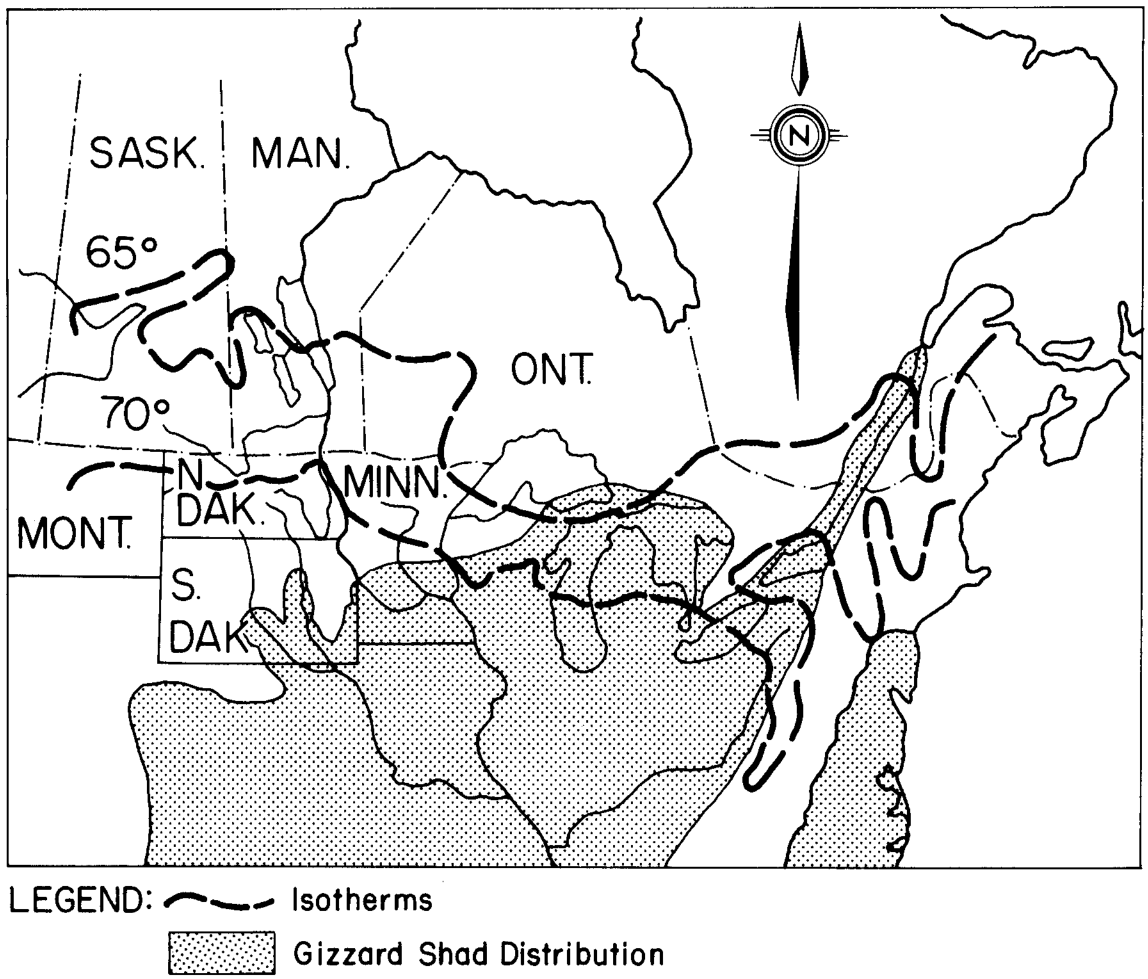

Fig. C.II-4. Distribution of gizzard shad in relation to the 65 and 70° July isotherms (after Lindsey 1975).

increase was attributed to the increasing nutrient enrichment of the lake (Williams 1976).

Because gizzard shad can grow rapidly to a large size, their population growth is not effectively controled by predation. Only the very largest predators, such as northern pike, may utilize large shad. Kutkuhn (1958) stated that studies of gizzard shad in the mid-western US indicated the species, by the middle of its second year of life, is beyond the size range which is effectively utilized as forage. Therefore, gizzard shad essentially represent a "dead end" in the aquatic food chain and, since they are not used as human food, in the total food chain (Coutant 1976).

Extensive proliferation of gizzard shad in lakes has, almost invariably, resulted in adverse effects on the indigenous fish populations. Shad are efficient competitors with other fishes. Valesquez (1939) stated that gizzard shad may selectively feed on phytoplankton which would tend to eliminate the more desirable phytoplankton species and favor the undesirable species. This could directly affect other fish species which feed on phytoplankton or indirectly affect fish by altering the species composition of zooplankton which feed on phytoplankton. Gizzard shad could affect other fishes simply by numbers. Large numbers of young-of-the-year walleyes were not caught in areas along the south shore of Lake St. Clair, Ontario where heavy catches of young-of-the-year gizzard shad were made (A. Derksen pers comm). Thompson et al. (1940) suggested that large numbers of gizzard shad may roil the water, interfering with other species that depend on vision for feeding.

Gizzard shad have received "bad press" in many areas where they have become established either through invasion or by introduction to provide forage for game fish species. Reservoirs in the mid-southern US have been overpopulated with shad resulting in declines in game fish populations (Miller 1960, Coutant 1976). Bennett (1943) observed that large shad populations were always associated with small numbers of bass in artificial warmwater lakes in Illinois. An irruption of shad in Black Hawk Lake, Iowa, resulted in decreased game fish catches (Madden 1951). The selective removal of gizzard shad from waters in Kentucky and from other southern US reservoirs resulted in improved fishing success for game fishes (Smith 1959, Zellar and Wyatt 1967). Gizzard shad have only been valued as a forage fish in impoundments with deep waters, fluctuating water levels, no littoral zones, abrupt shorelines, adequate plankton crops and large predatory fish populations (Miller 1960). It should be noted that these conditions are artificial and rarely, if ever, occur in natural lakes. In general, gizzard shad are presently considered a pest species. This is illustrated by the fact that importation or possession of gizzard shad is prohibited by law in the states of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming (Lindsey 1975).

Introduction and proliferation of gizzard shad in Lake Winnipeg will result in native fish populations having to contend with increased competition for food and space. Severe competition from shad will alter the existing balance between predator fishes and their major prey species. Gizzard shad will most likely compete with minnows (Cyprinidae) and the young of other, larger species. This will affect such species as walleye and sauger which utilize minnows and young fishes as forage. Gizzard shad may also compete directly with young walleye and sauger in the South Basin and central areas of Lake Winnipeg. As gizzard shad rapidly achieve a size where they are not vulnerable to predation, shad populations could soon replace the out-competed forage species. This would reduce the amount of forage fish available and reduce predator fish populations in Lake Winnipeg even further. The impact of gizzard shad invasion into Lake Winnipeg will be greatest in the South Basin and central area of the lake where the greatest concentrations of walleye and sauger occur and where shad will find favorable habitat conditions.

Habitat requirements of adult gizzard shad are essentially different from those of adult whitefish and lake herring. Shad primarily occupy shallow or littoral areas of lakes whereas whitefish and lake herring prefer open water during most of the year. It is therefore doubtful that shad will interact significantly with whitefish or lake herring. There may be some interaction between them during their juvenile stages. However, since major whitefish and lake herring populations in Lake Winnipeg occur in areas not as suitable to gizzard shad, the interactions will be limited.

In view of experience elsewhere, availability of suitable habitat, and potential for interactions with desirable fish species, the Committee believes gizzard shad will have an adverse impact on Lake Winnipeg fisheries. The extent of this impact cannot be precisely quantified but it will range from moderate to high. Final outcome of the introduction and proliferation of gizzard shad in Lake Winnipeg will also depend to some extent on other factors such as changes in exploitation of existing fish populations and in eutrophication processes which may act to increase or retard impact. The worst possible impact would be total collapse of walleye and sauger populations within the South Basin and central areas of Lake Winnipeg.

Gizzard shad can enter Lake Manitoba from Lake Winnipeg via the Dauphin (Fairford) River during periods of high flows in which the Fairford Dam is overtopped. Environmental conditions in Lake Manitoba are even more favorable for establishment of shad populations. The impact of gizzard shad on the fisheries of Lake Manitoba would be similar to those outlined for Lake Winnipeg. The loss of walleye and sauger populations in Lake Manitoba as a result of introduction and proliferation of gizzard shad would cause a significant reduction in commercial fish harvest from the lake.

Lake Winnipegosis lies south of the 65°F July isotherm and has habitat conditions similar to those found in Lake Manitoba. Gizzard shad could, therefore, become established in Lake Winnipegosis from Lake

Manitoba. They would present further problems to the management of commercial fisheries in Lake Winnipegosis. Management is presently striving to overcome economic difficulties resulting from recent drastic declines in walleye stocks. The commercial fishery on the lake is currently dependent on low and medium value species such as suckers and northern pike.

In summary, the Committee believes gizzard shad will be introduced and can be established in Lakes Winnipeg, Manitoba and Winnipegosis. There are suitable environmental and habitat conditions, food supplies and spawning areas for establishment of gizzard shad populations in these waters. The extent or magnitude of impact of gizzard shad on these lakes will depend on acclimation of gizzard shad to colder temperature, predation from existing fish populations and changes in habitat due to eutrophication. Magnitude of impact may range from minimal impact to the worst possible impact of total collapse of walleye and sauger populations in these lakes.

Impact of introduction of paddlefish (*Polyodon spathula*): Paddlefish occur in North Dakota in Lakes Sakakawea, Audubon and Oahe. They have also been found in the lower James River approximately 29 km upstream from its confluence with the Missouri River (E. Steucke pers comm). It is not known whether paddlefish in the James River represent a reproducing population or are simply transient from the Missouri River. Paddlefish do not occur in Manitoba.

The interbasin transfer of paddlefish from Lakes Sakakawea and Audubon is likely to occur in spite of the McClusky Canal fish screen, for reasons discussed previously, except the fish screen mesh will stop eggs and larvae of paddlefish. Paddlefish eggs vary from 2.7 to 4.0 mm in diameter and larvae range from 8.0 to 9.5 mm in total length (Purkett 1961). Paddlefish are highly migratory and improved fish habitat in the James River as a result of GDU may permit paddlefish to move into the North Dakota portion of the river. Paddlefish could move from the James to the Wild Rice and Red rivers via Oakes Canal and Taayer Reservoir.

Paddlefish can survive and become established in Lakes Winnipeg, Winnipegosis and Manitoba because environmental and habitat conditions are favorable for their reproduction and growth. Since winter temperatures in Lake Sakakawea do not differ greatly from those in Lakes Winnipeg, Winnipegosis and Manitoba there is no reason to suspect that paddlefish could not exist in these lakes and in tributaries of these lakes. Paddlefish are largely planktivorous (cladocerans, copepods, rotifers and phytoplankton) although aquatic insects and small fish are also cometimes consumed. Lakes Winnipeg, Winnipegosis and Manitoba contain an abundance of these food organisms.

Paddlefish have reached an appreciable level of abundance in Lake Sakakawea. Populations of this species may also become abundant in Lakes Winnipeg, Winnipegosis and Manitoba. The result of large numbers of paddlefish in these lakes could be a reduction in the zooplankton biomass. Since paddlefish may attain a large size (in excess of 50 kg) the impact of a large population on the zooplankton crop could be severe.

Reductions in the plankton crop in localized areas of these lakes, particularly after spring breakup, would adversely affect indigenous fish populations. It is during the spring that newly hatched fishes in Lakes Winnipeg, Winnipegosis and Manitoba are heavily dependent on zooplankton and phytoplankton. The impact of paddlefish would be felt by most fish species rather than by only one or a few species. Since paddlefish grow rapidly during their first year, they quickly attain a size where they cannot be eaten by other fishes. Predators, therefore, would not be a factor in controling the abundance of paddlefish.

Paddlefish may also indirectly affect lake sturgeon populations in the Hudson Bay Basin. Eggs of paddlefish in the Missouri River Basin contain a coelentrate parasite (*Polypodium* sp., Suppes and Meyer 1975). Lubinsky (1976a) reported that *P. hydriforme* is found in sturgeon in the USSR and that it destroys a considerable number of oocytes (eggs cells) in these fish. This inhibits both reproduction of these fish and quality of the caviar. Lubinsky further stated, "The percentage of oocytes varies greatly, from a fraction of one percent to several percent, though an infection rate of over 10 percent seldom occurs." *Polypodium* had not been recorded in any lake sturgeon in Manitoba (Lubinsky 1976a). This parasite could have a negative impact on sturgeon populations, which have already been subjected to overexploitation.

Although nothing is known about the free-living stage of *Polypodium* sp. it is likely that the spread of the parasite would not be contained by the McClusky Canal fish screen. The parasite could also be transferred to the Hudson Bay Basin by adult paddlefish moving into the Red River via Oakes Canal and the Wild Rice River.

In summary, we believe paddlefish will be successfully introduced and established in Manitoba waters. Because of their plankton feeding habits they will cause reduction in food availability for other fish species. We are unsure that the Manitoba lakes will provide a large amount of suitable habitat and suspect paddlefish will have limited distribution in these lakes. Paddlefish will have a negative impact on Manitoba fisheries but not as extensive as gizzard shad or smelt.

Impact of introduction of shovelnose sturgeon (*Scaphirhynchus platorhynchus*) and pallid sturgeon (*Scaphirhynchus albus*): Two species of acipenserid fish, shovelnose and pallid sturgeon occur in the Missouri River in North Dakota. Both species are found in Lakes Sakakawea and Oahe. The only acipenserid in Manitoba waters is the lake sturgeon.

Shovelnose and pallid sturgeon could be introduced to Manitoba by GDU from Lakes Sakakawea and Audubon via the McClusky and Velva canals, from the James River via Oakes Canal to the Wild Rice River and from Lonetree Reservoir to the Sheyenne River. Although these species may be transferred by GDU, the probability of this occurring appears remote. Both species are non-migratory, for example, tagged shovelnose sturgeon are usually recaptured within a few miles of the tagging site (Helms 1973). Pallid sturgeon are also rare in Lake Sakakawea. Eggs and larvae of both species, should they reach the McClusky Canal, are too large to pass through the fish screen mesh.

In the event that shovelnose and pallid sturgeons bypassed the McClusky Canal fish screen by methods described previously or were introduced from the James River via Oakes Canal, environmental conditions in the Souris, Assiniboine and Red rivers would be suitable for natural propagation of both species. These rivers possess fast water areas with rocky or gravelly substrate which are ideal for sturgeon spawning. Silty areas of these rivers would also provide a food source for the species. With time, shovelnose and pallid sturgeon might invade Lakes Winnipeg, Winnipegosis and Manitoba and their tributary streams.

The establishment of populations of shovelnose and pallid sturgeon in Manitoba waters is most likely to have an impact on indigenous lake sturgeon polulations. Shovelnose sturgeon mature at an earlier age and smaller size than lake sturgeon and therefore can quickly attain high population levels. Shovelnose sturgeon attain sexual maturity after about four years. Lake sturgeon, on the other hand, are not mature until about age 20. Since both species have approximately the same habitat requirements, an abundant shovelnose population would compete directly with lake sturgeon for food and space. Little biological information is available on pallid sturgeon.

The impact of shovelnose and pallid sturgeon on the lake sturgeon cannot be precisely quantified. In many areas of Manitoba lake sturgeon populations have been seriously depleted by overexploitation and deleterious environmental conditions such as dams which interfer with spawning. Because of these conditions most sturgeon fisheries in Manitoba have been closed. Competition from shovelnose and pallid sturgeon could extirpate existing lake sturgeon populations in some areas.

Introduction of shovelnose and pallid sturgeon into Manitoba waters could adversely impact native lake sturgeon populations in another way. Shovelnose and pallid sturgeons in the Missouri River, like paddlefish, may also be carriers of *Polypodium* sp. The worst effect of this coelenterate parasite upon reproductive capacity of lake sturgeon would be a potential 10 percent reduction in egg survival (Lubinsky 1976a).

In summary, the Committee believes pallid and shovelnose sturgeon could become established in Manitoba waters if introduced by GDU. However, due to the non-migratory habits of both species and the rarity of pallid sturgon, the probability of this occurring is remote. Shovelnose and pallid sturgeon may negatively impact Manitoba waters by directly competing with native lake sturgeon populations or by transferring the coelenterate parasite *Polypodium* sp. Precise magnitude of this impact cannot be assessed but the worst impact would be eventual destruction of existing lake sturgeon populations.

Impact of introduction of shortnose gar (*Lepisosteus platostomus*): Shortnose gar are found in Lake Sakakawea, Lake Oahe and in the lower James River. The species does not occur in Manitoba nor do any members of the family of garfishes. With GDU the potential exists for introduction of shortnose gar to Manitoba waters.

Little is known of the biology of shortnose gar. To obtain some assessment of the possibility of introduction and impact of shortnose gar, additional information on a close relative, the longnose gar, was evaluated.

Eggs of longnose gar range from 2.1 (Netsche and Witt 1962) to 5.0 mm (Mansueti and Hardy 1967) in diameter; eggs of shortnose gar are smaller (Echelle and Riggs 1972). Larvae of shortnose gar are about 8 mm long (Echelle and Riggs 1972). Body depth of shortnose gar larvae is likely greater than 1 mm. Eggs and larvae of shortnose gar should not pass through the McClusky Canal fish screen mesh.

Shortnose gar could gain access to the Hudson Bay Basin by bypassing the McClusky Canal fish screen or from the James River via Oakes Canal. Shortnose gar prefer calm, clear and shallow waters such as pools, oxbows and backwaters of slow moving streams. It is not known whether shortnose gar now occur in the James River in North Dakota. The species could exist in this area during open water periods despite low flows and low dissolved oxygen levels. (They are capable of supplementing branchial respiration by gulping air.) Any shortnose gar that may sporadically occur in the North Dakota portion of the James River are winterkilled annually. Increased flows occurring to the James River and resultant increased dissolved oxygen levels may permit shortnose gar to establish a permanent population in the area.

If shortnose gar reach Lonetree Reservoir or Oakes Canal, they can reach Lakes Manitoba, Winnipegosis and Winnipeg. Shortnose gar are primarily adapted to warm waters. The lower lethal temperature for shortnose gar is not known. However, the fact that they exist in Lake Sakakawea implies that they have some capability to adapt to colder habitat conditions.

Shortnose gar could establish populations in Lakes Winnipeg, Winnipegosis or Manitoba because environmental conditions of these lakes do not differ markedly from those of Lake Sakakawea. Winter water temperatures of Lake Sakakawea are similar to those experienced in these lakes but the annual heat budget for Lake Sakakawea may be somewhat greater. Shortnose gar may find more favorable habitat in areas adjacent to Lakes Winnipeg, Winnipegosis and Manitoba than exists in Lake Sakakawea. The quiet backwaters of Netley and Delta marshes closely approximate preferred habitat for garfishes. Other marshes occur around these lakes where shortnose gar may establish populations. The level of abundance that shortnose gar could reach in these areas cannot be estimated in the southern portion of their range, however, garfishes attain high population densities. Gar in Florida reached densities of 270 fish/100 yards of canal (Hunt 1952) but will not approach these levels in Manitoba.

Adult shortnose gar are highly predaceous and feed almost exclusively on other fishes. Young gar feed on insects and other aquatic invertebrates. There is an abundance of food in Lakes Winnipeg, Winnipegosis and Manitoba available to shortnose gar. Shortnose gar would therefore act as both predators and competitors of indigenous fish populations. The degree of impact of shortnose gar on fisheries resources in Lakes Winnipeg, Winnipegosis and Manitoba would depend on levels of population abundance attained and extent of interactions with other fish species.

In summary, shortnose gar are sufficiently cold-tolerant to exist in Manitoba waters and would find an available food supply and suitable habitat in Manitoba waters. Therefore the Committee believes shortnose gar can establish in and have a negative impact on Manitoba waters. The impact of shortnose gar will not be as extensive as that forecast for smelt or gizzard shad because environmental and habitat conditions are not optimum for them.

Impact of introduction of Utah chub (*Gila atraria*): Utah chub are native to the Bonneville Basin of Utah and the upper Snake River drainage of Wyoming and Idaho. They are found in the Missouri River in Montana at Canyon Ferry Reservoir and may eventually invade and become established in Lake Sakakawea.

Sigler and Miller (1961) reported that Utah chub are found in a wide variety of waters and thrive over a wide range of temperatures. They are at home in cool (60°-68°F) or warm (81°-88°F) springs, irrigation ditches, ponds, sloughs, creeks, lakes, rivers and reservoirs. They are omniverous feeders, readily feeding on plants, aquatic and terrestrial insects, crustaceans and occasionally small fish and fish eggs. They spawn in less than two feet of water and spread their eggs at random over a wide diversity of substrate. The eggs are heavier than water and sink to the bottom. We do not anticipate any ecological barriers preventing downstream movement in the Missouri River to Lake Sakakawea and on through the GDU study area to the Red River Basin.

Peak spawning usually occurs between June 5-15 but this activity can start in mid-May and last until mid-August. Temperatures associated with spawning range from 52°-68°F. The eggs hatch within two weeks. We were able to obtain limited information on egg diameters of the Utah chub from Wydoski (1976). Graham (1961) found Utah chub larvae lengths in August 1953 to average 0.8 inches and range from 0.4 inches to 1.3 inches and in July 1954 to average 0.3 inches and range from 0.25 inches to 0.5 inches. Approximately 30-50 eggs from 10 Utah chub were measured with egg diameters ranging between 1.04 and 1.17 mm for fish between 1.69 and 2.67 mm total length.

Therefore we suspect but cannot confirm that Utah chub larvae may pass through the 40-mesh screen; in addition, they may bypass the screens by methods described previously.

Considering the ecological requirements of Utah chub, we believe they could exist and thrive in waters such as Lakes Winnipeg and Manitoba or Manitoba streams or rivers to which they gain access. Utah chub have a high reproductive potential and population irruptions may occur after they enter waters where they have been previously excluded by natural barriers. Their generalized feeding habits may enable them to become serious competitors with most fish species for food.

Brown (1971) referred to the Utah chub as follows: "It has proven to be a nuisance to fishermen who find difficulty avoiding it while fishing for trout . . . there is no economically feasible way of eradicating such pest fish once they are established and widely distributed." Furthermore Sigler and Miller (1961) reported:

> "Because of its great abundance, wide distribution, large size and generalized feeding habits, this species may become a serious competitor of game fishes. It is known to compete with them for food. Widely used as bait fish, it has established itself in reservoirs to which it was originally barred by natural barriers. Under these conditions its high reproductive potential may lead to rapid multiplication to the point where it overpopulates such bodies of water; expensive means of control may then be required, as for example in Fish Lake, Panguitch Lake and Scofield Reservoir (Olson 1959). The Utah chub became so abundant in Strawberry Reservoir that a special trash fishery was set up to handle the menace (Anonymous 1949). Its spread outside of the Bonneville Basin should be discouraged. It is significant that those waters in which the species has become a nuisance are either not within its native range or, if so, have been much modified by man."

In summary, Utah chub have a high reproduction potential, a potential for population irruptions and likely can establish in Manitoba waters. We believe Utah chub could be successfully introduced and established in Manitoba waters if they get to Lake Sakakawea. Furthermore, if in Manitoba waters, Utah chub will have a negative impact on indigenous fishes and may become a nuisance to anglers and commercial fishermen (through sheer volume of catch in the nets). We expect Utah chub will compete with whitefish and walleye for food and likely displace, to a major extent, existing forage species, particularly minnows. On the other hand, Utah chub were introduced in the 1930's in Montana and have not spread significantly through the mainstem Missouri River (or at least have not been detected). We believe that it is a matter of time before they exploit the Missouri River as there are no ecological barriers preventing their downstream movement. Therefore we consider this fish to represent the same potential for major impact as rainbow smelt or gizzard shad.

Impact of introduction of smallmouth buffalo (*Ictobus bubalus*): Smallmouth buffalo are present in Lake Sakakawea and the James River. This species is not known to occur in Canada.

Habitat requirements of smallmouth buffalo are variable. This species usually inhabits deeper, swifter and clearer waters of large rivers. Food of smallmouth buffalo consists largely of aquatic insects, crustaceans, molluscs and some vegetation, mainly duckweed. There is little published information on spawning characteristics of these fish. No information is available on egg or larvae sizes. Eggs are deposited at random over river bottoms and aquatic vegetation. Egg size of a similar species, the bigmouth buffalo, is in the range of 1.2 to 1.8 mm in diameter.

Considering the close similarity between bigmouth and smallmouth buffalo and that bigmouth exist in the Red River in Manitoba, we believe smallmouth buffalo could also survive in Manitoba. The potential for harm from the introduction of smallmouth buffalo cannot be assessed due to lack of available data. If smallmouth buffalo cause no more harm than the already present bigmouth buffalo, the adverse impact of introduction will not be significant.

Impact of introduction of river carpsucker (*Carpiodes carpio*): River carpsuckers occur in Lakes Sakakawea and Oahe and in the James River. They are not known to occur in the Red River Basin.

No information is available on river carpsucker egg or larvae sizes. This species could be introduced into the Hudson Bay Basin by bypassing the McClusky Canal fish screen by methods discussed previously or by entering Oakes Canal from the James River. Preferred habitat of river carpsuckers is backwater and quiet places in rivers, larger streams and canals. Carpsuckers are especially found near piles of brush or exposed roots.

Food of river carpsuckers consists of immature insects, other aquatic invertebrates and organic matter contained in bottom sediments. Their food is similar to other members of the sucker family except that a greater amount of silt and detritus is included.

River carpsuckers spawn in the spring in lowland areas after flooding and in backwater areas among submerged portions of trees and shrubs. They are similar to quillback suckers which already occur in Lake Winnipeg and the Red River in Manitoba. Considering environmental, habitat and food requirements of river carpsuckers, we believe they could survive in Manitoba waters.

The impact of introduction of river carpsuckers to Manitoba waters cannot be assessed due to a lack of available information. It is known that quillback suckers, a similar species which already exists in Manitoba waters, are very rare and have little or no impact on existing fish populations.

Impact of introduction of carp (*Cyprinus carpio*): The introduction of carp to the Souris River Basin in North Dakota as a result of GDU has been identified as a concern of the Biology Committee. Carp, found in many North Dakota waters, presently do not occur in the Souris River loop (Owen and Russell 1975c). Although carp are not common in the upper Souris River in Manitoba, individual specimens have been captured there occasionally (Swain 1975d). Carp populations do exist, however, in the Assiniboine River. Movement of carp up the Souris River is prevented during low water periods by six small dams between the Souris-Assiniboine confluence and the US border. During high spring flows carp could move up the Souris River as far as North Dakota. High water may have, on occasion, allowed carp to enter Souris River impoundments within J. Clark Salyer NWR. Absence of reproducing carp populations in this refuge has been attributed to low winter flows and dissolved oxygen conditions. Winterkills have occurred within J. Clark Salyer NWR system in 7 out of 13 years, covering the period 1960 to 1973 (FWS 1960-1974). Low winter oxygen levels occur frequently in the Souris River from Lake Darling to J. Clark Salyer NWR (NDHD 1968-72). No other habitat conditions are believed limiting to establishment of carp in this area.

The Souris River in North Dakota from below Lake Darling to the Canadian border reflects a fish species composition similar to that found in Lake Darling. The downstream movement of fishes from Lake Darling occurs annually during spring runoff. The only sport fish of any major consequence that exists in J. Clark Salyer NWR on an intermittent basis is northern pike. Northern pike are the most resistent of all game fishes to low oxygen levels. This tolerance to low oxygen levels exceeds that of carp. This explains why northern pike can furnish a limited sport fishery in J. Clark Salyer NWR, while carp may be absent from the system.

The Water Quantity Committee (1976) predicted that return flows from GDU will increase mean flows in the Souris River at Westhope during January through March from about 24 to 85 cfs. These increased flows will prevent winter dissolved oxygen levels in J. Clark Salyer NWR impoundments from falling below 5.0 mg/l (Water Quality Committee 1976). Winterkill of carp in the Souris River therefore will not occur and populations will become established. Establishment of a sizable population in J. Clark Salyer NWR will greatly enhance possibilities for invasion of carp further upstream, to Lake Darling and the Souris River into Saskatchewan. Carp will have some impacts on indigenous fishes of the Souris River in North Dakota. Scott and Crossman (1973) noted that carp ". . . increase the turbidity of the water and uproot and destroy submerged aquatic vegetation that is essential for the survival of native species, since such growth provides cover, food and sometimes spawning sites." Scott and Crossman further noted that carp ". . . also adversely affect duck populations by the destruction of rooted aquatic plants in marshes." Proliferation of carp in North Dakota wildlife refuges along the Souris River will result in damage to waterfowl-producing marshes and exacerbate other waterfowl losses resulting from GDU.

General Discussion: The foregoing discussions on the 10 fish species identified as problem species (except carp) have primarily stressed possible impacts on three major lakes in Manitoba (Lakes Winnipeg, Manitoba and Winnipegosis). Emphasis has been placed here since these lakes support a large part of the commercial fishing industry, as well as some sport fishing in Manitoba. The Committee, however, recognizes that impacts resulting from invasion of exotic fishes will not be limited to the above lakes. It is very likely that the invasion of problem species into Manitoba will have some impact upon fish stocks in the Souris, Assiniboine and Red rivers. Some problem species, such as the pallid and shovelnose sturgeons, shortnose gar, smallmouth buffalo and river carpsucker, which are adapted to lotic environments, may become established in these rivers. Availability of suitable habitats, however, may restrict their proliferation in these rivers.

Establishment of invading species in the Souris, Assiniboine and Red rivers would undoubtedly have some biological impacts on indigenous fishes. The precise nature of extent of these impacts cannot be assessed since very little is known concerning the distribution, behavior or population sizes of fishes in these rivers. The Souris, Assiniboine and Red rivers are utilized for angling. One area which is subjected to heavy angling pressure is on the Red River below Lockport. Although desirable species such as sauger, walleye and northern pike are caught, other less desirable species such as freshwater drum, burbot, suckers and bullheads are also angled. Since angling on the Souris, Assiniboine and Red rivers is largely nonselective, it is doubtful that the invasion of new species would deter anglers and consequently cause a serious negative impact on the angling fishery. Indeed paddlefish and shortnose gar would likely provide interesting new species for anglers.

Although it is beyond our ability to go into the same detail as above, some brief comments should be made concerning invasion of exotic fishes into Manitoba waters other than those referred to above. Exotic fishes will not be able to invade the Saskatchewan or Winnipeg rivers because of large, impassable dams near the mouths of these rivers. Most smaller tributaries to the west side of Lake Winnipeg and those to Lake Manitoba which have low gradients may be subject to invasion. Exotic fishes could also invade lower reaches of some tributaries to Lake Winnipegosis. There are no barriers to halt downstream invasion of the Nelson River. It might be assumed that not all invading exotic fishes will extend their range northward into the Nelson River. This assumption could be argued on the premise that since invaders come from southerly climes, they would not be able to cope with the more rigorous environmental conditions in the Nelson River. This argument, however, is weakened by observation of carp in the Nelson River. Although it is believed that carp populations in the Nelson River lakes have not attained a significant level of abundance, carp have nonetheless extended their distribution in the river as far downstream as Hudson Bay.

4. Effects of Introduction of Exotic Fishes on the Canadian Fishery Resource: We identified 20 fish species which presently occur in the Missouri River Basin but not in the Hudson Bay Basin in Manitoba. Because GDU will provide a direct link between the 2 basins, the 20 species were considered as potential problem species. We then briefly reviewed information on the 20 species and consequently recognized 9 fish species which, if introduced to Manitoba, will create adverse impacts on indigenous fish resources. These species are the pallid and shovelnose sturgeon, paddlefish, shortnose gar, gizzard shad, rainbow smelt, Utah chub, smallmouth buffalo and river carpsucker. Carp was added to the list since GDU will enhance conditions for the introduction of this species into the Souris River in North Dakota and Saskatchewan where they presently do not occur.

These assessments, by species, of the potential for introduction and survival as well as the extent and nature of impact of these exotics on fishes in Manitoba are summarized in Table C.II-8.

After assessing in a qualitative manner the impact of each of the problem species we then quantitatively predicted the overall impact of these introductions on commercially important species in Lakes Winnipeg and Manitoba. This impact assessment is our prediction based on data presented in this report. Our predictions were based to some extent on Great Lakes experiences and in these cases effects of introduction of exotics were complicated by other factors such as eutrophication, overexploitation, management efforts and introduction of exotic fish diseases or parasites.

The four commercially important species considered were lake whitefish, lake herring, walleye and sauger. The predicted impact was measured as percent reduction in population size. Water bodies considered were Lake Winnipeg (South and North basins) and Lake Manitoba. (Lake Winnipegosis was not considered, as the commercial fishery is in such a poor state that the impact of introduction of exotics could not be predicted). We estimated percent reduction in population size by giving a range of percentages representing low, most likely and maximum impact (Table C.II-9).

Lake Winnipeg: As discussed previously, smelt will have a major impact on lake whitefish, particularly in the North Basin. We do not think smelt will do well in the South Basin and therefore their impact will be less. We do anticipate major interactions between lake whitefish and Utah chub as well, due to competition for food. This analysis resulted in a prediction of 25-50-75 percent reduction in the

Table C.II-8. Summary of interbasin fish introductions based on life history information.

Species	Potential for introduction	Potential for survival in Hudson Bay Basin	Potential for biological impact	Potential for adverse impact on Manitoba	Availability of information for evaluation
Pallid sturgeon	low	high	medium	low	low
Shovelnose sturgeon	low	high	medium	low	low
Paddlefish	medium	high	medium	low	medium
Shortnose gar	medium	high	medium	medium	low
Gizzard shad	high	medium	high	medium	high
Rainbow smelt	high	high	high	high	high
River carpsucker	medium	high	medium	low	low
Smallmouth buffalo	medium	high	medium	low	low
Utah chub	medium	high	high	high	medium

Table C.II-9. Biology Committee's prediction of percent reduction in population size of four commercially important fish species in Lakes Winnipeg and Manitoba as a result of introduction of exotic fish species.

	Percent reduction in population size (lowest-most likely-maximum)		
	Lake whitefish	Lake herring	Walleye and sauger
Lake Winnipeg			
North Basin	25-50-75	50-75-99	25-50-75
South Basin	0- 5 -10	0- 5 -10	25-50-75
Lake Manitoba	10-30-50	50-75-99	50-75-99

lake whitefish population size in the North Basin and 10-25-40 percent reduction in the South Basin.

We believe that smelt could cause the collapse of the lake herring fishery in the North Basin but, as with whitefish, smelt will not have a major influence in the South Basin. Other exotics are anticipated to negatively interact with lake herring. Therefore we predict a 50-75-99 percent reduction in the lake herring population size in the North Basin and a 0-5-10 percent reduction in the South Basin.

With respect to walleye and sauger we believe rainbow smelt, gizzard shad and Utah chub will cause major negative impact in Lake Winnipeg: 25-50-75 percent in both basins.

Lake Manitoba: The Committee believes that introduction of smelt, gizzard and Utah chub primarily, will result in a reduction in population size of 10-30-50 percent for whitefish, 50-75-99 percent for lake herring and 50-75-99 percent for walleye and sauger. Table C.II.9 summarizes these impact predictions.

In addition to the four species described above, lake sturgeon will also likely be negatively impacted in Lake Winnipeg. We predict a possible 50-75-99 percent reduction in populations due to introduction of the pallid and shovelnose sturgeon, paddlefish and the parasite *Polypodium* sp.

The Committee, while anticipating a negative impact on bait fish, could not provide a quantitative assessment of this impact. This was due both to a lack of information and also a feeling that potential losses to indigenous bait fish could be offset by use of Utah chub and to a lesser extent smelt or gizzard shad, as bait fish.

We point out that percent reduction in population size is not necessarily equivalent to percent reduction in the fisheries harvest. It may be that the effort required to catch a reduced population is not economical such that a 50 percent reduction in the population size may mean a 100 percent reduction in harvest. Furthermore some of the introduced exotics may irrupt to such large numbers that nets become plugged with trash fish, again influencing fishermen's efforts to catch commercially valuable species; such could likely be the case with Utah chub.

In addition to the question of impact of introductions, it was necessary to address the question of impact timing. This was accomplished by reviewing literature on dispersal rates of selected fish (those for which enough pertinent data were available: carp, white perch [*Roccus americanus*], rainbow smelt and alewife [*Alosa pseudoharengus*], which are noted for invasion into new watersheds, Table C.II-10). All four species could move 360 miles on the average in less than 55 years. Extreme ranges are from 6 years to 180 years. Of particular interest are the data for rainbow smelt: 6-16-45 years. Furthermore, tagging studies

Table C.II-10. Rates of dispersal and resulting estimated traverse times (from GDU to Lake Winnipeg) for four known exotic fishes.

	Rate of dispersal (miles/year)			Calculated time (years) to move 360 miles[1]		
	Minimum	Mean	Maximum	Maximum	Mean	Minimum
Carp[2]	20	26	40	18	14	9
White Perch[3]	7	15	29	51	24	12
Smelt[4]	8	23	63	45	16	6
Alewife[5]	2	7	9	180	55	40

[1] Using 360 river miles as the distance from GDU to Lake Winnipeg.
[2] Source: Atton (1959).
[3] Source: Scott and Christie (1963).
[4] Source: Dymond (1944) and Biology Committee data on Missouri River.
[5] Source: Miller (1957).

by the Freshwater Institute in Winnipeg (D. Hodgins pers comm) have shown that sauger have moved from the City of Winnipeg up the Red River as far as Drayton (140 km) in 4 weeks, and walleye have moved as far as Grand Forks in 12 weeks. Therefore, we anticipate rapid movement down the Red River by introduced species.

Therefore, based on the Great Lakes and other experiences, the Committee believes these introductions and impacts will commence shortly (less than 10 years) after GDU is completed but full effects will be felt within 25-50 years. Remedial (after-the-fact) measures to GDU will be futile after initial introduction of species.

In summation, the Committee is firm in its belief that introduction of exotic fishes via GDU poses a serious threat to the fisheries resources of Manitoba. We wish to underline our general concern regarding the introduction of exotics in general. Literature reviews on the history of unmanaged exotic introductions emphasize this concern: (hares in Australia, sea lamprey in the Great Lakes, carp in North America, ad nauseum). The introduction of exotics has led to significant destabilization of ecosystems. Concern over the introduction of exotic fishes is exemplified by recent action in the US requesting a protocol governing interstate transfer of exotic fishes (Sport Fishing Institute 1976).

G. Fish Diseases and Parasites

1. Introduction: The linking of the Hudson Bay and Missouri River watersheds will permit interbasin transfer of parasites and agents which cause fish diseases. An inclined fish screen such as that proposed for the McClusky Canal will not prohibit the passage of these organisms.

There is little information on fish diseases in wild populations. Unless mortalities occur in areas of particular interest (hatcheries, recreational areas) an epizootic usually goes unnoticed. Consequently, bacterial and viral diseases are well known from hatchery environments. Parasitic diseases, however, generate an academic interest and have been extensively studied.

There are several ways by which fish parasites may degrade a recipient environment. They may cause death of large numbers of fish (epizootic), impair growth and reproduction or make the fish unsightly.

2. Methods: Lists of fish parasites for both the Hudson Bay and Missouri River basins were prepared from a list of problem fish developed by the Committee, by reviewing Hoffman (1967), Larson (1972) and Lubinsky (1976a). Twenty fish species (Table C.II-6) were identified as potential hosts and their known parasites identified and in addition Lubinsky (1976b, c and d) provided assistance in compilation of potential problem species lists, life histories and case histories from Russian literature. Bacterial and viral fish diseases in the US were listed and their significance in the transbasin diversion of water evaluated with the assistance of fish disease specialists in Canada and the US. D. Gillespie (pers comm) provided the Committee with comments on bacterial and viral diseases of fish in Manitoba. He also aided in defining a problem species list for fish diseases. Other experts were contacted as well.

The Committee reviewed these lists of fish diseases and parasites and established the potential for introduction and impact via GDU.

3. Results and Discussion: Infectious hematopoietic necrosis virus (IHN) infects chinook and sockeye salmon and rainbow trout. Diseased fish display changed activity, pop-eye, abdominal swelling and internal organ pathology culminating in death due to kidney failure. Outbreaks of the diseases have occurred in the GDU study area in South Dakota, Minnesota and Montana (Anderson 1976, Smith 1976, Whitney 1976). Kelly (pers comm) reported IHN has only been reported in British Columbia; he further asserted that if IHN had been present in any diagnostic work conducted on Hudson Bay drainage fish it would have been detected. It has not been observed. Wolf (1976) considered IHN a pathogen which might cause problems in central Canada. An IHN epizootic in rainbow trout was reported in Minnesota by Wolf (1972) and naturally the possibility exists, albeit small, that the virus may enter the Hudson

Bay drainage via the Big Stone Lake and Lake Traverse connection. The Committee suspects that salmonids and, according to D. Gillespie and G. Kelly (pers comms), perhaps whitefish in Canada may suffer mortality as a result of this disease being transmitted via GDU.

Infectious pancreatic necrosis (IPN) is a viral disease of salmonids known throughout the trout producing area of the US. It causes a physiological degeneration beginning with the pancreas. It is transmitted from fish to fish by feces and genital products in water and from parent to offspring via eggs. Beginning with the onset of an epizootic and extending throughout the life of survivors, of which there always seems to be some, the disease is communicable. Healthy appearing survivors harbor the virus. Infected fish stocked in natural environments apparently do not continue to suffer mortalities.

Smith (1976) reported IPN from federal and commercial hatcheries in Montana which drain into the Missouri River Basin; E. Steucke (pers comm) noted it to have occurred (last report 1969) at the Garrison National Fish Hatchery below Lake Sakakawea. This stock was used in North Dakota fish management programs (D. Henegar pers comm) involving several reservoirs draining into the Red River. This stocking has been going on for more than 15 years.

IPN has been diagnosed from Shell Lake in Duck Mountain Provincial Park, Manitoba (Gillespie 1976). Shell Lake is a closed basin and the infection likely originated in hatchery stocked fish. IPN was also recently diagnosed from two salmonid hatcheries in Manitoba (Kelly 1976). In an effort to eliminate the continued occurrence of the disease in hatcheries the salmonids were eradicated and the hatcheries disinfected (A. Derksen pers comm).

Two associated observations seem to further complicate the epidemiology of IPN relating to GDU. We suspect that large numbers of fish from a commercial hatchery in the US with a history of IPN were stocked during the past eight years in Manitoba farm ponds. In addition, Wolf (1972) reported research results from the University of Guelph, Ontario, which appear to indicate the long-term survival and dispersion of IPN in non-salmonid fish and piscivorous birds.

For these reasons the Committee recognizes long standing opportunities, in addition to non-salmonid fish and piscivorous birds, for introduction of IPN into the Hudson Bay drainage.

At any rate, we feel that GDU, while providing another route of transport of the virus, may not significantly increase the incidence or intensity of the infection in Manitoba.

Channel catfish virus disease (CCVD) is a disease of channel and blue catfish (Plumb 1972). The disease is not known north of West Virginia. Epizootics of CCVD generally occur above 77°F and the disease will not likely pose a threat to catfish in Manitoba and North Dakota (Wolf 1976).

Lymphocystis is a disease which affects several species of fish. The virus stimulates cells to enlarge resulting in a white "cauliflower" lesion, especially about the fins. It seldom causes mortalities but reduces marketability of fish, especially walleye. It is known from the Missouri River and Red River in the US (Hanten 1976; Economon 1976) and from fish in Lake of the Woods, Ontario and from certain areas of Saskatchewan (R. Kelly pers comm). However Kelly (1976) examined 5,000 spawning walleye at Duck Bay in Lake Winnipegosis and found no incidence of the disease. Therefore, the interbasin transfer of water into the Souris and Red rivers will not introduce the disease to Manitoba but will provide an additional source for infection.

Most of the bacterial diseases of fish are shown in Table C. II-11. The Committee reviewed the potential for transfer of these into Manitoba and established that only one, enteric redmouth of salmonids (ERM) is a likely candidate for impact. ERM is characterized by an oral inflamation which may spread to the fins. The disease, involving a low level mortality, can result in large losses. Infections are spread by fish to fish contact and bacteria shed by carriers. The disease is known from rainbow trout, steelheads, cutthroat trout and coho and chinook salmon. ERM has been diagnosed at Livingston (1972 to 1976) and Emigrant (1976), Montana (Anderson 1976) in the Missouri River drainage. Although it is not known from Manitoba it has been reported from Saskatchewan (Wobeser 1973). The interbasin transfer of water by GDU will develop an avenue for the spread of the causative agent of ERM into Manitoba. The magnitude of the impact cannot be ascertained.

Almost all other bacterial diseases of fish are known in the GDU areas of both Manitoba and the US. Human infection due to these organisms is unlikely as the bacteria are generally killed by cooking.

Parasites from all potential problem fish species were listed (Holloway 1976). However, Hoffman (1971) reported ten known fish parasites of epizootic interest (Table C.II-12) which were used to evaluate the significance of parasites of potential problem species. Of these, *Saprolegnia parasitica* (fungus), *Ichthyophthirus multifilis* (protozoan), *Argulus appendiculosis* and *Ergasilus arthrosis* (copepods), *Gyrodactylus* sp. (trematode) and *Ligula intestinalis* (cestode) are cosmopolitan. It is unlikely that the interbasin transfer of water will introduce or increase populations of these parasites.

Other parasites on Hoffman's list may be eliminated from further consideration because they have not been identified from the GDU study area. *Ceratomyxa shasta* and *Myxosoma cerebralis* are myxosporidian parasites which may cause severe mortalities in trout and salmon. Neither has been diagnosed from the study area and they are not considered further.

Two parasites on Hoffman's list may be of some concern inasmmuch as they do not appear in Lubinsky's (1976b) Manitoba list of fish parasites.

Table C.II-11. Bacterial-caused fish diseases in the US.[1]

Disease name	Etiological agent	Host	Stressor	Geographical distribution	Associated with epidemics in wild?
Furunculosis	*Aeromonas, Salmonicida*	Trout, freshwater salmonids and most freshwater fish	Low dissolved oxygen and high water temperatures	Hatcheries in US and Canada, also in wild fish	Yes
Hemorrhagic septicemia	*Aeromonas liquefaciens, Pseudomonas, Vibrio angulilarum*	Goldfish, rainbow trout	Low dissolved oxygen	Ubiquitous cultured and wild fish	?
Red mouth or ERM	Enteric red mouth bacterium or R-M bacterium	Salmonids	Variety	Ubiquitous	Yes
Ulcer disease	*Hemophilus piscium*	Salmonids	?	Eastern North America	Outbreaks
Columnaris disease	*Chondrococcus columnaries, Cytophaga columnaris*	Trout, salmon and catfish	High water temperatures	Ubiquitous cultured and wild fish	Yes
Coldwater disease	*Cytophaga psychrophila*	Juvenile coho	Low water temperatures	Hatcheries, Pacific NW	Yes
Peduncle disease	*Cytophaga psychrophila*	Salmon and fingerling trout	Low water temperatures	Probably ubiquitous	Yes

Table C.II-11. (Cont'd)

Disease name	Etiological agent	Host	Stressor	Geographical distribution	Associated with epidemics in wild?
Gill disease	*Myxobacterium* spp.	Salmonids, bass and crappie	Stress	Widespread US	No
Tail rot	*Myxobacterium* spp.	Salmonids	?	Probably ubiquitous	?
Kidney disease	*Coryne-bacterium* spp.	Salmonids	Severity increased in hard water	California, Massachusetts and Scotland	?
Myxobacteriosis	*Myxobacterium salmoniphilum*	Salmonids	Raw adult salmon in diet	Washington, Idaho, Oregon, California, Alaska and ubiquitous	No
Vibrio disease	*Vibrio anguillarum*	Salmonids, smelt	High water temperatures	Ubiquitous	?
Kidney streptococcosis	*Streptococcus faecalis* (?)	Rainbow trout and golden shiner	?	Japan and US (Arkansas)	?
Pasteurella piscicida	*Pasteurella* spp.	White perch	?	Chesapeake Bay	Yes
Nocardiosis	*Nocardia*	Rainbow trout	?	?	No

[1]Source: Bullock and McLaughlin (1970) and Wolf (1972).

Table C.II-12. Known epizootic parasites of North American freshwater fish[1].

Fungi	None
Protozoa	*Ceratomyxa shasta* *Ichthyophthirius multifilis*[2] *Myxosoma cerebralis*
Trematoda	
Monogenea	*Gyrodactylus* sp.[2]
Digenea	
Metacercariae	*Ascocotyle* sp. *Bucephalus* sp.[2]
Cestoda	*Ligula intestinalis*[2]
Nematoda	None
Acanthocyphala	None
Leeches	None
Copepods	*Argulus appendiculosis*[2] (syn. *A. biramosus*)[3] *Ergasilus arthrosis*[2] (syn. portim *E. versicolor*) *Lernaea cyprinacea*

[1]Source: Hoffman (1971).
[2]Known in Manitoba. See Appendix II-10.
[3]Source: Hoffman (1967).

Lernaea cyprinaceae is a copepod which is thought to be cosmopolitan. G. Lubinsky (pers comm) suspected its absence from Manitoba was due to a lack of sampling. The Committee agreed with Lubinsky's analysis and did not further consider the organism.

The other parasite on Hoffman's list is the digenetic trematode *Ascocotyle* sp. The metacercaria of trematodes utilize fish as a secondary host. While some debilitation of the host may occur, mortalities are seldom encountered as a result of metacercarial infestation. The Committee does not feel *Ascocotyle* sp. will impact fish populations in Canada to any great extent.

Lubinsky, in his review of Manitoba parasites, also developed information on two parasites of paddlefish. Both have been identified from the Missouri River drainage. One, the nematode *Thynnascaris dolfusi*, was reported from Lake Sakakawea in North Dakota (Schmidt et al. 1974). Its epizootic significance is not known at this time. The second, the coelentrate *Polypodium* sp. has recently been recorded from paddlefish in the Osage River in Missouri (Suppes and Meyer 1975).

A member of this genus, *Polypodium hydriforme*, affects sturgeon in Russia, infiltrating the ovary and reducing reproductive capability by as much as 10 percent. It is possible that *Polypodium* sp. may be transmitted via GDU waterways into Lake Winnipeg where susceptible hosts (sturgeon) are available. The economic impact of this parasite on sturgeon in Lake Winnipeg will likely be small because of the low level of the present fishery. However, the impact of a 10 percent reduction in reproductive effort by a depressed species may severely impact the ability of the fish to remain a viable member of the lake community.

The Committee attempted to deal with another relationship of fish diseases and parasites; namely the changes which may occur in indigenous populations of disease organisms as a result of GDU. The many complex conditions involved in creating these conditions (changes in flow, temperature, chemical parameters, etc.) are such that no determinations were possible. Stresses on host fish usually provide avenues for the expansion of viruses, bacteria and parasites.

4. Summary: Viral diseases IHN and IPN may be transmitted from the US to Canada. IHN is not known from central Canada (Hudson Bay watershed) and IPN has only been recently diagnosed from that area. Affected fish species would likely be salmonids although whitefish might also come under attack. The Committee was unable to assign any probability of infection or loss to these diseases although interbasin transfer is likely.

Lymphocystis is known from the Missouri River, the US portion of the Red River, Saskatchewan and Ontario (Lake of the Woods). Why it has not been found in Manitoba and is not known but it certainly is already in the Hudson Bay drainage. GDU will provide another avenue for transfer.

The only bacterial fish disease of concern is ERM. The disease may be introduced via GDU. Its impact on Manitoba salmonids and whitefish could be substantial.

The parasite *Polypodium* sp. will likely be transported via GDU from the Missouri River to Lake Winnipeg. While the economic impact of *Polpodium* sp. on the sturgeon fishery may not be great, the impact on reproductive efforts of these fish in Lake Winnipeg may reduce sturgeon populations.

H. Effects of Water Quality and Quantity on Indigenous Fish Fauna

We reviewed the predicted changes in water quality and quantity due to GDU (Water Quality 1976, Water Quantity 1976) with respect to major ions. The predicted changes in major ions will lead to changes in the structure of aquatic ecosystems of the Souris, Assiniboine and Red rivers and the greater the change in water quality, the greater will be the change in ecosystems. We were unable to make quantitative assessments; however, we do not believe there will be direct lethal effects as a result of changes in concentrations of major ions.

In addition, a report was received on the interrelationship of toxicity and suspended solids in water (Turner 1976). This report strongly implies that this Committee would have great difficulty in interpreting laboratory-derived toxicity data for valid application to pertinent GDU Manitoba waters and fauna. This is due to lab-derived toxicity data being based on filtered, dechlorinated city tap water at a single oxygen concentration and a single temperature, hardness and pH level.

Increases in water flows in the Souris River are expected to improve the dissolved oxygen. No adverse impacts are expected from changes in water quantity in Manitoba waters. The Biology Committee has predicted there will be increased algal growth as a result of increased nutrient production in the three rivers and Lakes Manitoba and Winnipeg. This could result in localized fish kills in the Souris and Assiniboine and perhaps the Red due to oxygen depletion and/or algal blooms.

I. Summary

1. None of the existing interbasin connections (Hudson Bay-Missouri, Hudson Bay-Mississippi, Hudson Bay-Great Lakes) are expected to permit introduction of any of the GDU problem fish species. The potential for accidental or intentional but unauthorized introductions (bait buckets, etc.) has existed for some time and will continue to exist. GDU will enhance this potential. Rainbow smelt, one of the GDU problem species, already occurs in the headwaters of the Rainy River drainage (Hudson Bay Basin). These fish have existed there for at least seven years and apparently have not moved very far downstream in contrast with other instances of introduction of this species into previously unoccupied watersheds. We do not know when or if smelt will move into Manitoba waters from this source.

2. Because of the dimensions and compressibility of certain fish eggs and larvae (rainbow smelt, Utah chub), some of these will pass through the 0.43 x 0.43 mm openings in the McClusky Canal fish screen as will fish disease organisms and parasites. Because of spaces between screen panels, fish eggs, larvae and perhaps even adults will pass around the main and well screens. In addition the screens may be subject to small punctures and corrosion.

3. The fish screens will clog at some point in time and considerable screened material (including fish) and water will arrive at the well screen. The well screen will clog causing backup of water and it will be difficult if not impossible to clean the well screen without permitting passage of fish.

4. Fish can bypass the McClusky fish screen at the Kindchi Lake turnout and the screening device proposed for that site will be no more effective than the one proposed for the McClusky Canal.

5. Fish from the Missouri River drainage, once past the McClusky Canal fish screen, will be in the Hudson Bay Basin. There are no impassable barriers within other GDU project works to prevent fish passage into the Red River Basin. Fish will also pass into the Hudson Bay Basin via James River, Oakes Canal, the Oakes pumping plant, Taayer Reservoir and the Wild Rice River.

6. Paddlefish, shortnose gar, gizzard shad, Utah chub and rainbow smelt have medium to high potential for introduction and successful establishment in the Hudson Bay Basin, specifically Lake Winnipeg. All of these species have at least a medium potential for impact on Canadian fisheries; the smelt, shad and chub have potential for a major impact. Carp, already present in the Hudson Bay drainage but absent from the upper Souris River in Saskatchewan, have a high potential for introduction, establishment and negative impact in those waters. Other fish species (pallid sturgeon, shovelnose sturgeon, red shiner, river

carpsucker and smallmouth buffalo) have either a low or medium potential for introduction and successful establishment and all have a low potential for impact on Canadian fisheries.

7. It is predicted that the introduction of various problem fish species will reduce the population size of commercial fish. The range in percent reduction will be 25-75 for whitefish, 50-99 for lake herring and 25-75 for walleye and sauger in the North Basin of Lake Winnipeg; 10-40 for whitefish, 0-10 for lake herring and 25-75 for walleye and sauger in the South Basin of Lake Winnipeg; and 10-50 for whitefish and 50-99 for lake herring, walleye and sauger in Lake Manitoba.

8. The fish diseases IHN and ERM have a potential for introduction into Manitoba waters. GDU will increase the potential for transfer of lymphocystis and IPN in Manitoba waters. Extensive and expensive measures have been undertaken by Manitoba to eradicate IPN. The effects of introductions of these fish diseases is expected to be minimal. However, while perhaps remote, there is a possibility of outbreaks of these diseases in trout and whitefish. Such outbreaks could cause large scale mortalities. A paddlefish parasite, *Polypodium* sp. has a medium probability of introduction and it may infect the lake sturgeon in the Hudson Bay Basin. The potential for introduction and/or impact in a number of other diseases and parasites is low.

9. Changes in water quality and quantity as a result of GDU may have significant but presently unquantifiable effects on indigenous fish species through ecosystem perturbations.

10. These impacts will commence within 10 years after the project is completed; full effects will be felt within 25-50 years after initial introduction of exotic species. Remedial measures to GDU will be futile.

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III. AQUATIC INVERTEBRATES

A. Introduction

Aquatic invertebrates, as a resource, have not received the same degree of attention as fish and wildlife. Indeed, far from being in a position to manage aquatic invertebrates, most surveys are still turning up new species. Nevertheless, this group is of considerable importance to fish and wildlife since it constitutes a primary food source. Interbasin introduction of foreign species via GDU is a possibility; furthermore, changes in water quality or quantity may have an impact on indigenous species.

Some aquatic invertebrates, such as biting flies (mosquitoes and blackflies) and swarming insects (mayflies and caddisflies) have major interactions with humans, cattle and poultry. Therefore, introduction of new species or adverse water quality or quantity effects on endemic species can have significant ramifications for fisheries, wildlife and humans.

B. Methods

The potential for introduction of new species was delineated by compiling species lists of aquatic invertebrates for GDU Manitoba waters, combining these with North Dakota information on the Red and Souris rivers and comparing these with lists from the North Dakota-Missouri River system. Species occurring in the Missouri River but absent from the other system were to be listed as potential problem species. All species lists were reviewed by taxonomists; in addition, these experts and others (Attachment C.III-1) were asked to indicate any particular problem species they thought might be introduced as a result of GDU. Life histories were compiled by the Biology Committee for those problem species.

The effects of changes in water quality on indigenous fauna were assessed by Clarke (1976). A literature review was performed to investigate the relationship between toxicity of chemicals and suspended solids in water.

C. Results and Discussion

1. Introduction of Exotic Species: A tentative list of species of most major aquatic invertebrate groups was compiled for the Canadian portions of the Red, Souris and Assiniboine rivers and Lakes Winnipeg and Manitoba (Attachment C.III-2). We were unable to obtain comparable data for US portions of the Red, Souris or Missouri rivers (Smithsonian Institute 1976). However, through correspondence with various specialists a tentative potential problem species list was derived (Table C.III-1). Life histories were documented for these species (McRae 1976). These were supplemented by advice from experts.

These experts indicated that a blackfly species (*Titanopteryx maculata*), a caddisfly genus (*Rhyacophila*) and a mayfly species (*Hexagenia bilineata*) could be introduced into the Red River system as a result of GDU.

Titanopteryx: The potential problem species *T. maculata* has been reported from the Missouri-Mississippi drainage; it does not occur in the Red River system (O. Saether pers comm). This species is pollution tolerant and lives in slow moving, large rivers in Europe and Asia. In the USSR this species has proved to be a nuisance to humans and a vector of a protozoan blood disease in waterfowl. We attempted to corroborate this information and learned that major waterfowl die-offs in North America have been associated with transmission of disease (Sherwood 1970); B. Tarshis (pers comm) was unfamiliar with *Titanopteryx*; and R. Petersen (pers comm) felt this species was synonomous with *Byssodon* (*Simulium*) *meridionale* Maloch and already occurs in Manitoba. The Committee arranged to send specimens identified by Saether as *Titanopteryx* to Petersen for verification. He determined that these are synonomous and therefore we believe there is no concern for introduction of a new species.

Caddisflies and Mayflies: J. Flannagan (pers comm) suggested that some species of the caddisfly genus *Rhyacophila* may be introduced into the Red River system as a result of GDU. Most species of this genus prefer fast water. The genus is reported from the Missouri River drainage, Ontario, Quebec, Appalachian states, Oklahoma, North Carolina and Tennessee. Caddisflies are weak flyers and the chance of airborne introduction is slight; Flannagan felt the possibility of transfer of this genus via GDU was high as was the chance of successful establishment in the Red and Souris river systems.

Caddisflies can undergo major population irruptions, particularly when introduced to a new environment (McRae 1976). Massive emergence from the pupal stage can produce large swarms of mating adults which in areas of dense human populations can cause asthmatic and allergenic responses via emanations (setae and body particles) of the adult (McRae 1976). Such problems have occurred in the Winnipeg River (Manitoba) at a hydroelectric dam (Gabriel 1974), in Lake Erie at the town of Fort Erie (Peterson 1952) and at the 1967 Expo site in Montreal.

Table C.III-1. A list of potential problem species of aquatic invertebrates that may be introduced as a result of GDU.

Problem species	Potential/known Biological impact	Source[1]
Titanopteryx maculata = *Simulium meridionale*	Blackfly of slow turbid rivers (found in Missouri and Mississippi rivers); annoying blood sucker, can transmit a protozoan infecting blood of ducks; larvae are pollution tolerant.	O. Saether
Rhyacophila spp.	Many caddisflies undergo population irruptions which in areas of dense human habitation can cause asthmatic and allergenic responses.	J. Flannagan
Hexagenia bilineata	Mayfly of slow turbid waters; can undergo population irruptions causing "fish fly" swarms (public nuisances) and perhaps allergenic problems.	J. Flannagan

[1]Pers comm.

Flannagan also suggested that the probability of a mayfly (*Hexagenia bilineata*) being introduced into Manitoba via GDU is high. This species co-exists with *H. limbata* and *H. rigida* in the Mississippi-Missouri system. The latter two species occur in the Red River system and therefore Flannagan felt *H. bilineata* would successfully establish itself once introduced. Mayflies can also undergo major population irruptions particularly when introduced to a new environment and a massive emergence from the nymph stage can produce large swarms of mating adults. These swarms not only cause public nuisances on beaches and roads but also create health problems for certain individuals prone to asthma. The actual causative agent is the skin shed from the subimago stage.

The caddisfly and mayfly introductions are similar problems. The Committee believes that mayflies and caddisflies will be successfully introduced and established in Manitoba with completion and operation of GDU. We believe that *H. bilineata* will occur in the same areas of the Red River system as *H. rigida* and *H. limbata*. *Rhyacophila* will occur in the Souris and some of the Red River tributaries.

Population irruptions of introduced species are of high probability; these will not be of infinite duration but will continue until the population of the introduced species reaches equilibrium with that of native species. We recognize the allergenic and asthmatic potential of these population irruptions but believe the potential will be reduced as the introduced populations reach equilibrium; we have no comment on the time before equilibrium.

It is probable that other species of aquatic invertebrates will be introduced via GDU. These various introductions are bound to create perturbations in Manitoba ecosystems as evidenced by the history of introductions (Elton 1958). We are unable to assess these effects because of the complexity of the problem and time constraints of the study.

2. Effects of Water Quality and Quantity: An increase in the rate of flow and area flooded by the Souris River caused by GDU will have an effect on the suitability and size of breeding sites of aquatic insects. Of particular interest are blackflies.

Blackflies are a recurring problem along the Souris River, particularly in years of excessive flooding during spring runoff. The predominant species are *Simulium venustum* (which constitutes 75 to 100 percent of the blackfly problem in most areas of Canada), *S. luggeri*, *S. meridionale*, *S. vittatum* and *S. verecundum*. Following are some brief notes on these species, provided by F. Fredeen (pers comm).

S. venustum, the common "white-stockinged" blackfly pest, attacks humans, animals and there are confirmed reports (R. Brust pers comm) of poultry deaths during severe outbreaks. Eggs, in which stage it overwinters, are laid in masses along wet margins of rocks and plants and in early spring these hatch to produce larvae that colonize flooded bush and grasslands in swiftly flowing portions of the river. River flows of at least 1,000 to 2,000 cfs are required for optimum development of larvae. Under cool conditions in the spring the larval stage lasts from four to five weeks after which they pupate for a few days. Adults emerge from mid-May to mid-June at which time outbreaks are most severe. *S. venustum* is reported to have two generations a year but it is now believed that the blackfly observed that occurs during the summer is a closely related but less important species, *S. verecundum*.

S. vittatum attacks animals mainly around the ears. It overwinters as larvae or pupae and brief but massive outbreaks of emerging adults occur immediately after ice breakup in the spring. These first generation adults swarm massively for a few days around animals and humans but seldom bite. Later generations from July to freeze-up attack some animals but not humans.

S. luggeri is another species of blackfly that attacks animals but it is of lesser importance than *S. venustum*.

S. meridionale attacks poultry and is a vector of a blood parasite. The species occurs in the Souris River Valley but the blood parasite has not been found in Manitoba.

The Committee considered the possibility that increased flow rates caused by added GDU flows (Water Quantity Committee 1976) could intensify the blackfly problem along the Souris River. However, we were unsure as to where the blackflies bred and what their specific habitat requirements were regarding dissolved oxygen, riffles, grass, etc. We were unable to come to a conclusion on impact. This was primarily due to unavailability of information on location of specific breeding sites along the Souris River and specific breeding and rearing habitat requirements (dissolved oxygen, substrate preference) of the various species. Therefore it remains a concern that GDU increased flows as a result of GDU could intensify the blackfly problem along the Souris River.

We also reviewed expected changes in water quality parameters (Water Quality Committee 1976) and concluded that some impact would occur to indigenous invertebrate communities. We were unable to assess these changes.

D. Summary of Impact Predictions

1. Several species of caddisfly (genus *Rhyacophila*) and one species of mayfly (*Hexagenia bilineata*) will be introduced as a result of GDU and will successfully establish in the Red River system. Population irruptions of these species will increase the potential for allergenic and asthmatic problems in areas invaded, including the city of Winnipeg. This potential will reduce as the introduced populations reach equilibrium. Indigenous communities of aquatic invertebrates could be adversely affected by introductions of new species. However, there is a paucity in distributional data for aquatic invertebrates; therefore some of these problem species may indeed already occur in Manitoba waters. Conversely, other problem species not known to us may be introduced.

2. Due to increases in flows, flood stage and duration of flooding in the Souris River the Biology Committee is concerned that the blackfly problem already affecting humans and livestock could worsen. We could not assess this concern due to lack of pertinent information.

3. The species composition of indigenous communities of aquatic invertebrates in the Souris will be changed due to changes in water quality. We were unable to assess the direction or magnitude of these changes.

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IV. PLANTS

A. Introduction

The Committee was concerned with the possibility that the GDU will have an impact on plants in Manitoba in two ways: foreign plants or plant diseases may be introduced into Manitoba via the Souris and Red rivers and altered water quality and quantity may adversely affect indigenous flora. Both aquatic plants and terrestrial noxious weeds were considered but members of other plant groups such as algae, fungi (other than plant pathogens), bryophytes, ferns or trees were not.

B. Methods

Lists of the species of aquatic plants, noxious weeds and plant diseases that occur in the Red, Souris and Missouri river watersheds in North Dakota, Montana and Manitoba were compiled from literature searches and consultation with experts. These lists were compared to determine differences in distribution. A species occurring in the Missouri River watershed but absent from the other systems was considered a potential problem. The possibility that other species of weeds or plant pathogens, now now present in these watersheds, might be introduced at a later date was also considered.

Aquatic species lists for Manitoba were compiled by Jennifer Shay and Gloria Keleher (1976, Attachment C.IV-1) and for North Dakota by Vera Facey (1976, Attachment C.IV-2). Sheila Anderson and Gloria Keleher (1976) provided life histories of aquatic plant species that might be introduced into Manitoba and an assessment of the potential of each to cause a detrimental effect on the aquatic environment.

Data provided by the Water Quality (1976) and Water Quantity (1976a) committees were utilized to appraise the effects of changes in these two factors on the introduction of foreign flora and the growth of indigenous plants in areas affected in Manitoba. A list of rare and endangered plants for GDU Manitoba was provided by Jennifer Shay (1976, Attachment C.IV-3). McKernan (1976) provided a literature review on the tolerance of aquatic macrophytes to salinity.

C. Results and Discussion

1. Introduction of Foreign Flora: Sixteen species of aquatic plants that have not been reported or are rarely found in Manitoba were identified by comparing species lists from North Dakota (Attachment C.IV -2) and Manitoba (Attachment C.IV-1). Vera Facey commented on their potential detrimental effects on the aquatic environment (Table C.IV-1). None of the species were considered to have any detrimental traits and most of them are valuable food sources for wildlife, especially waterfowl. Sheila Anderson and Gloria Keleher (1976) were in agreement with this assessment. Furthermore most aquatics and many small seeded marsh plants are widely distributed by migrating water birds which not only carry seeds from place to place internally, but also on their feathers and feet. It would appear that aquatics would spread naturally from the Missouri River to the Souris River, particularly in view of their proximity, without the help of waterways such as the GDU canal system connecting the two river systems.

All terrestrial weed species classed as noxious in North Dakota and Montana are present now in Manitoba (McDonald 1976a, Attachment C.IV -4). Natural methods of weed seed dispersal such as wind, transport on farm machinery, vehicles, birds and animals, as contaminants in commercial seed, fodder, packing material and nursery stock and by natural flood water have ensured distribution of weeds over a wide area of the central plains in US and Canada. If a new species of noxious weed was introduced into North Dakota or Montana, seeds of it would eventually be distributed into Manitoba by one or more of these methods of dispersal. Completion of GDU will provide an additional method of transport of seeds from the Missouri River watershed through the canal system to Manitoba.

All of the fungal and bacterial diseases of major crops that occur in North Dakota also occur in Manitoba (McDonald 1976b, Attachment C.IV-5). Natural spread of these diseases by wind-borne soil and plant debris, transport by farm machinery and periodic flooding of rivers has ensured wide distribution throughout the Red River valley and adjacent areas. Plant diseases now present in or introduced in the future into the watershed of the Missouri River in Montana will have an additional means of spread into Manitoba if GDU is completed. Pathogens could be transported by water via the McClusky and Velva canal systems into proposed irrigation districts in North Dakota and eventually to Manitoba. Most of these diseases, such as nematode diseases of sugar beets and alfalfa, would be important in irrigated crops only and their impact on agriculture in Manitoba would depend on the acreage of crops irrigated by water from the Souris and Red rivers in Manitoba.

2. Effect of Changes in Water Quantity: An increase in the area of land flooded in Manitoba as a result of GDU return flows will affect the aquatic flora of marshland, sites of rare and endangered plant species, local dispersal of noxious weeds and plant pathogens and the severity of plant diseases in agricultural crops planted late. However,

Table C.IV-1. Potential problem species of aquatic plants.

Species	Common Name	Present in Manitoba?	Comments[1]
Marsilea mucronata	Water fern	No	Uncommon, no known detrimental traits.
Sparganium chlorocarpum	Bur-reed	No	Uncommon, no known detrimental traits.
Ruppia maritima	Pidgeon grass	Rare	May proliferate with increased salinity; highly rated as food for waterfowl.
Alisma subcordatum	Water plantain	No	Food for waterfowl.
Dulichium arundinaceum	Three-way sedge	No	Rare in North Dakota.
Scirpus nevadensis	Nevada bulrush	No	Food for waterfowl; no known undesirable traits.
Lemna perpusilla	Duckweed	No	Food for waterfowl.
Heteranthera dubia	Water stargrass	No	No known detrimental characteristics.
Pontederia cordata	Pickerelweed	No	No known detrimental characteristics.
Allocarya scopulorum		Rare	Annual of wet, saline areas.
Myriophyllum heterophyllum	Water milfoil	No	Rare in North Dakota.
Rumex verticillatus	Water dock	No	Common in North Dakota.
Elatine americana	Mud purslane	Rare	No evidence as a problem species[2].
Limosella subulata	Mudwort	No	No detrimental qualities[2].
Macuillamia rotundifolia	Water hyssop	No	No detrimental characteristics[2].
Nasturtium officinale	Watercress	No	Trout food[2].

[1]Assessed by Vera Facey (1976).

[2]Identified and assessed by Sheila Anderson and Gloria Keleher (1976).

data provided by the Water Quantity Committee (1976a) indicate that there will be no impact from GDU flows on flooding along the Assiniboine and Red rivers, the Assiniboine diversion, Delta Marsh and Lakes Manitoba and Winnipeg. There will also be no increase in flooding from the Souris River beyond the town of Souris. The main effect of increased flooding will be in the six miles north of the US border and reaches of the river near Melita and Hartney. But the effect will be significant only at sub-maximum flows and the total area subject to flooding under natural conditions once in 20 years will not be increased significantly. Floodwaters will recede more slowly in the Souris River watershed from the US border to the town of Souris under the influence of added return flows from GDU in July and August but this would have no effect on the wider dispersal of weed seeds or plant pathogens.

It is estimated that an additional 94 acres of land will be flooded for up to 30 additional days mainly in the Westhope and Lauder reaches every second year (Water Quantity Committee, 1976b). Most of this area is a narrow strip covered by brush, marsh and grasses. Very little is used for cultivated crops and therefore the effects of GDU would have an insignificant impact on seeding dates or increased severity of plant diseases.

None of the 33 plant species identified (Attachment C.IV-3) as endangered in Manitoba presently have been found along the Souris River south of the town of Souris (Scoggan 1957). As there will be no increase in the area of land flooded because of GDU return flows in river watersheds of the Souris River beyond the town of Souris or in other GDU affected waterways there will be no impact of GDU on endangered species of plants in Manitoba due to flooding.

3. Effects of Changes in Water Quality: The major impact of changes in water quality would be on aquatic plants in streams and marshlands affected by GDU return flows. There will be no effect on the growth of terrestrial weeds or plant diseases.

Differences in species composition of wetland vegetation in North Dakota were correlated with salinity levels of surface waters by Stewart and Kantrud (1972). Their data were compared with those supplied by the Water Quality Committee (1976) to determine changes in species composition that could occur in marshlands and along streambanks in Manitoba as a result of increased salinity in GDU return flows.

The range of salinity levels, expressed as total dissolved solids (TDS), that will occur at various points along GDU waterways is summarized in Table C.IV-2. These figures represent the worst possible situation at low flow rates in the rivers and include data for each month of the year. Vegetation in the Red River will not be affected by higher salinity levels; it would be classified as a slightly brackish

Table C.IV-2. Range of TDS levels (mg/l) during the year under minimum flow rates at stations along GDU waterways[1].

	Pre-project	Peak loading	Equilibrium
Red River at Emerson	426 - 901	451 - 1030	444 - 944
Red River at Selkirk	377 - 684	393 - 857	389 - 783
Assiniboine River at Portage	446 - 835	503 - 1178	493 - 1044
Souris River at Westhope	667 - 1652	1366 - 1740	1203 - 1401

[1]Source: Water Quality Committee (1976).

waterway by Stewart and Kantrud (Table C.IV-3) and will remain so with GDU. Water in the Assiniboine and Souris rivers will be affected more seriously and the impact of GDU on these rivers will be examined more critically. In this assessment only data for the months of April to October were considered as this is the growing season for plants and the season in which Stewart and Kantrud's data were obtained.

Stewart and Kantrud recognized that individual anions and cations as well as TDS have an influence on growth of vegetation. They analyzed the principal ionic constituents of surface waters of ponds and lakes, differentiated into salinity ranges by type of vegetation and related these to specific conductance (Table C.IV-4). Their data were compared to that provided by the Water Quality Committee (1976) for the Assiniboine and Souris rivers and the condition of these rivers before and after GDU was assessed (Table C.IV-5).

There will be an increase in levels of TDS and some ionic constituents in the Assiniboine River, particularly during the peak leach period, but these increases will not be sufficient to change the character of the water from its present slightly brackish range of salinity at minimum rates of flow (Table C.IV-5).

One of our main concerns was the effect of changes in water quality on the Delta Marsh ecosystem, a major wetland resource in Manitoba. This area obtains water from maximum flows of the Assiniboine River during spring runoffs via the Assiniboine River Diversion. Flows only occur in this channel during the months of April to August. Data on TDS and ionic constituents of the water in the Assiniboine River in these months, pre and post-project, show that there will be no significant increase in their concentration (Table C.IV-6). Thus there will be no effect on the vegetation of Delta Marsh as a result of the quality of GDU return flows.

The major impact of GDU on water quality will occur along the Souris River. During the peak leaching period increased concentrations of TDS, bicarbonate, calcium and sulphates will change the character of the water from slightly brackish to moderately brackish. Concentrations will be lower under probable flow conditions, but levels of TDS, calcium, and sulphates will still reflect a moderately brackish condition.

Plant species composition in wet meadows, shallow marshes and along streambanks will be modified in some extent because of changes in water quality. Stewart and Kantrud (1972) compared the abundance of plant species in water with different ranges of salinity; those that increase in prevalence under moderately brackish conditions are listed in Table C.IV-7. Saltgrass, which is not eaten readily by livestock, will become fairly common and occasionally abundant; common arrowgrass, which is poisonous to livestock, could occasionally become fairly common among the large complex of grasses and other plants present in wet meadows. The vegetation of shallow marshes will not be affected significantly. Drastic reductions in species that are important sources of duck food

Table C. IV-3. Relationship between plant communities and salinity as measured by specific conductance (micromhos/cm at 25°C) and TDS (mg/l).

Salinity range[1]	Specific conductance normal range[1]	TDS[2]
Fresh	<40 - 500	26 - 320
Slightly brackish	500 - 2,500	320 - 1,280
Moderately brackish	2,000 - 5,000	1,280 - 3,200
Brackish	5,000 - 15,000	3,200 - 9,600
Subsaline	15,000 - 45,000	9,600 - 28,800
Saline	45,000 - 100,000+	28,000 - 64,000

[1]Source: Stewart and Kantrud (1972).

[2]Source: McGauhey (1968). Conversion based on 1 μmho/cm ≃ 640 mg/l.

Table C.IV-4. Principal ionic constituents and specific conductance of surface water from prairie ponds and lakes[1,2].

Salinity range as indicated by plants	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	Specific conductance
Fresh	25	15	9	44	170	0	32	14	295
Slightly brackish	86	62	42	38	340	55	200	19	1,010
Moderately brackish	99	150	235	31	445	40	775	33	2,100
Brackish	50	310	1,020	140	450	260	2,340	235	6,320
Subsaline	205	540	1,380	175	610	480	9,310	1,050	12,200
Saline	210	2,240	39,100	870	880	715	27,300	6,320	37,500

[1]Source: Stewart and Kantrud (1972).

[2]Figures represent mean values from four typical ponds or lakes in the indicated range of salinity. Chemical values are in ppm; specific conductance, in micromhom/cm at 25°C.

Table C.IV-5. Salinity characteristics of the Assiniboine and Souris rivers at minimum flows, April to October[1].

	Assiniboine River[2]			Souris River[2]		
	Pre-project	peak leach	Equilibrium	Pre-project	peak leach	Equilibrium
TDS	SB	SB	SB	SB	MB	SB-MB
Bicarbonate	SB	SB-MB	SB	SB-MB	MB-Su	MB
Calcium	SB-MB	MB	MB	F-SB	B	B
Sodium	SB	SB	SB	SB-MB	SB-MB	MB
Magnesium	F-SB	SB	SB	SB	SB	SB
Chloride	MB	MB	MB	MB	MB	MB
Sulphate	SB	SB-MB	SB	SB	MB	MB
Potassium	F	F	F	F	F	F
Nitrogen	.06 - 1.55	.90 - 1.84		.63 - .92	2.03 - 7.89	
Phosphorus	.00 - .46	.06 - 1.00		.33 - 1.00	1.30 - 1.86	

[1]Source: Water Quality Committee (1976).

[2]F (Fresh), SB (slightly brackish), MB (moderately brackish), B (brackish), Su (subsaline).

Table C. IV-6. Range of concentrations (mg/l) of principal ionic components at maximum flow in the Assiniboine River at Portage la Prairie April to August[1].

	Pre-project	Peak leach	Equilibrium
TDS	190 - 412	193 - 428	193 - 429
Bicarbonate	129 - 243	130 - 246	130 - 245
Calcium	39 - 63	39 - 63	39 - 63
Sodium	15 - 40	15 - 41	16 - 43
Magnesium	11 - 27	11 - 28	11 - 28
Chloride	7 - 17	7 - 17	7 - 18
Sulphate	62 - 155	64 - 161	64 - 160
Potassium	6 - 8	6 - 8	6 - 8
Nitrogen	0.02 - 0.38	0.02 - 0.38	0.04 - 0.38
Phosphorous	0.0 - 0.14	0.0 - 0.14	0.0 - 0.14

[1]Source: Water Quality Committee (1976).

Table C.IV-7. Plant species of prairie potholes that increase in abundance in moderately brackish water[1].

Wet-meadow vegetation	
Distichlis stricta (saltgrass)	B[2]
Glaux maritima (sea milkwort)	B
Plantago eripoda (alkali plantain)	B
Potentilla anserina (silverweed)	B
Atriplex patula (orach)	B
Polygonum prolificum (longbranch knotweed)	C
Lactuca scariola (prickly lettuce)	C
Triglochin maritima (common arrowgrass)	C
Muhlenbergia asperifolia (scratchgrass)	C
Spartina gracilis (alkali cordgrass)	C
Shallow-marsh emergent vegetation	
Alisma gramineum (narrowleaf waterplantain)	A
Scirpus americanus (common threesquare)	B
Puccinella nuttalliana (alkali grass)	C
Deep-marsh emergent vegetation	
Scirpus paludosus (alkali bulrush)	B
Submerged and floating vegetation	
Zannichellia palustris (horned pondweed)	A
Chora spp. (muskgrass)	A
Potamogeton pectinatus (sago pondweed)	A
Potamogeton vaginatus (bigsheath pondweed)	A

[1]Adapted from Stewart and Kantrud (1972).

[2]A (frequently common or abundant; B (frequently fairly common, occasionally common or abundant); C (occasionally fairly common).

such as slender bulrush (*Scirpus heterochaetus*), river bulrush, (*S. fluviatilis*) and hybrid cattail (Typha "glauca") will occur in water that becomes moderately brackish. However, hardstem bulrush, which is also a good source of food for waterfowl, is adapted to this range of salinity and will become the dominant species. Of the many species of submerged and floating vegetation that occur in deep marshes, sago and bigsheath pondweeds will increase in abundance. These also are favored by ducks as food.

D. Summary of Impact Predictions

1. There will be minimal impact of GDU on the introduction of plant diseases, terrestrial noxious weeds or aquatic plants into Manitoba as alternate, equally effective methods of introduction exist.

2. Changes in water quantity will not affect plant diseases, terrestrial weeds or aquatic plants.

3. Increased salinity will alter the species composition of wetland vegetation along the Souris River. Species more tolerant of moderately brackish water such as saltgrass, which is not readily eaten by livestock, and common arrowgrass, which is poisonous to livestock, will increase in abundance in wet meadows. There will be no significant effect on vegetation in other GDU Manitoba waterways as a result of changes in water quality.

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V. WATER: EUTROPHICATION

A. Introduction

The Biology Committee has considered biological responses to changes in water quality and the influence of GDU on eutrophication processes in Manitoba waters. GDU will result in addition of nutrients (nitrogen and phosphorus) and suspended solids to the Red, Souris and Assiniboine rivers and Lakes Manitoba and Winnipeg. This increase in nutrients and suspended solids will influence eutrophication in various Manitoba waters.

Eutrophication can be defined as the result of an accelerated rate of nutrient supply to a water body; however, Vallentyne (1974) expanded this definition:

> "The immediate ecosystem response (. . . to increased rate of nutrient supply) is an increase in photosynthesis and abundance of plants. This gives rise to: increased productivity at all levels of the food chain, up to and including fish; successional changes in the kinds of organisms inhabiting aquatic ecosystems; and reduced levels of dissolved oxygen in bottom waters."

Most eutrophication experts have studied lakes rather than rivers. Staff of the Freshwater Institute, Canada Department of the Environment has studied the chemistry and biology of Lake Winnipeg from fall 1968 to spring 1971 (Brunskill 1973). In addition, work has been done by MDMREM on Lake Manitoba (Crowe 1972).

B. Methods

To assess eutrophication in Manitoba waters we requested the following data from the Water Quality Committee: loading and concentration data for total nitrogen, phosphorus and sediments for monthly period of record from stations at Westhope, Emerson, Selkirk, Assiniboine River above Portage Diversion, Portage Diversion near Oaklands, Sheyenne River at Red River confluence, Wild Rice River at Red River confluence, Souris River north of Lake Darling and James River near the North Dakota-South Dakota border.

We then requested G. Brunskill of the Freshwater Institute to review data and provide his opinion of: 1) the present status of eutrophication in Manitoba waters and 2) future status of eutrophication with GDU based on existing nutrient loadings on his predicted (to year 2000 without GDU) loadings. Work by Brunskill et al. (1976) was then reviewed by other limnologists and biologists. In addition, their paper on future nutrient loadings was reviewed by Water Quality and Uses committees.

C. Results and Discussion

Data were reviewed to permit assessment of nutrient loadings into Lakes Winnipeg and Manitoba (Water Quality Committee 1976).

1. Present Status of Eutrophication - Lake Winnipeg: There is a high rate of nutrient supply into Lake Winnipeg at the present time (Brunskill 1973). However, there is difference of opinion among limnologists as to whether the South Basin of Lake Winnipeg is eutrophic. These differences of opinion seem to arise from each scientist's concept of eutrophication. Using the strict definition of eutrophication (rate of nutrient supply to a water body) and the theoretical nutrient loading model of Vollenweider (1976) the South Basin is eutrophic (Brunskill et al. 1976, Attachment C.V-1).

However, using the broader biological definition of Vallentyne's (1974), it is more difficult to call the South Basin eutrophic since there is no evidence of oxygen depletion and insufficient evidence of successional changes in species of aquatic biota (Brunskill et al. 1976). Brunskill believed the reason these biological effects have not been observed despite the high rate of nutrient loading is that high suspended sediment concentrations limit the penetration of light energy which in turn limits algal photosynthesis and primary productivity. There is, however, direct evidence of significant algal blooms during summer and winter periods, as evidenced by fouling of beaches and commercial nets.

Turbidity does decrease in the Narrows or Central Basin and indeed this is the area of the lake where there are higher rates of primary production (P. Campbell pers comm). Nevertheless, there is no evidence of oxygen depletion nor most of the other biological effects mentioned above. The North Basin has greater transparency and the concentrations of nutrients are rarely low (Water Quality Committee 1976). Brunskill's light-limiting concept for the South Basin is not universally endorsed; however no one has offered an alternative explanation.

Factors limiting the rate of eutrophication in other lakes have been described: Schindler (1974) reported that when phosphate additions to an experimentally eutrophied lake were stopped, recovery was almost immediate. He did, however, state that when waterways are overwhelmed with phosphorus and nitrogen, algae may increase until light becomes limiting. Studies on Lake Washington in Seattle (Edmondson 1970) suggested that phosphorus return from sediments would not seriously delay recovery of a lake from cultural eutrophication once major phosphorus sources were eradicated. Rapid recoveries were noted in Lake Washington once phosphorus input from sewage and industry was eliminated.

Because of the conflicting views presented above and the lack of long-term data the Biology Committee cannot assess the present state of eutrophication in Lake Winnipeg.

2. Future Status of Eutrophication - Lake Winnipeg: We assessed the future status of eutrophication in Lake Winnipeg in two ways: a) predicted nutrient loadings after GDU compared with existing nutrient loadings and b) predicted nutrient loadings with GDU compared with those loadings forecast by Brunskill et al. (1976) likely to occur by the year 2000 without GDU. For purposes of our evaluation we assumed the South Basin to be either phosphorus or light-limited.

Water Quality Committee (1976) projected a most likely increase in loading of phosphorus to the South Basin of 5 percent and a maximum loading of 24 percent. If we accept Brunskill's light-limiting hypothesis for the South Basin, there will be no effects from any nutrient increase. If we do not accept the light-limiting idea then any increased nutrient loading will increase algal blooms with a consequent increase in the rate of eutrophication. Nevertheless, it is quite possible that increased nutrient supplies from GDU may cause a northward migration of high nutrient and chlorophyll concentration isopleths from the South Basin. Since the northern part of the South Basin (Hecla Island) exhibits greater transparency (is less turbid), increased nutrient concentrations will cause increased algal blooms of longer duration there.

Brunskill et al. (1976) forecast a 200-600 percent increase in phosphorus loading to Lake Winnipeg by the year 2000; the GDU-caused loadings would therefore represent a small portion of the overall loading. The Biology Committee was not able to assess the linear extrapolations used in forecasting this 200-600 percent increase but believes the non-GDU increase will be substantially less.

In summary, the rate of nutrient supply will increase as a result of GDU; for comparison with existing phosphorus levels there may be up to a 24 percent increase. The total biological effects of this in Lake Winnipeg cannot be predicted. We do believe there will be increased algal growth.

3. Lake Manitoba: Water Quality Committee (1976) predicted up to a seven percent increase in phosphorus loadings. Therefore the Biology Committee believes there will be an increase in algal growth in this lake as well.

4. River Systems: Water Quality Committee (1976) data indicate that total nutrient concentrations in the Souris Loop project area, whether at "best estimate" or "high estimate" post-project conditions, will increase above pre-project levels during May to November. Most inorganic phosphorus originating from crop production reaches the streams adsorbed to clay sediments resulting from water erosion of the land (Wagner and Dodds 1971). Organic phosphorus reaches the streams from natural and cropland vegetation or from animal and human wastes. Water Quality Committee (1976) predicted increases of more than 0.3 mg/l nitrate concentration in the Souris River for all months. Once in the water these nutrient increases are sufficient to produce greatly increased

algal growth as well as increased growth of other aquatic plants in the Souris River, particularly in back waters. Clogged screens or filter beds in a city's water intake, unpleasant tastes and odours in drinking water from algal metabolites and toxins from certain blue-green algae may all occur from these increased algal blooms. Oxygen depletion of the river may occur due to increased algal and aquatic plant growth since, when these organisms die, the released organic material exerts an oxygen demand for its decomposition by the decomposer organisms.

Nutrient concentrations in the other rivers (Assiniboine, Sheyenne, Wild Rice and Red) will also be increased above existing levels. Effects similar to those discussed above for the Souris project area are possible.

The Biology Committee believes that there is a risk of a significant increase in aquatic plant growth in the GDU rivers (particularly the Souris) if nutrient levels increase as predicted.

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VI. HUMAN AND ANIMAL DISEASE

A. Introduction

Irrigation return flows and/or river transport of sediments from either bank or channel erosion to GDU in the affected riverine systems of North Dakota and Manitoba could increase the incidence and spread of various human and animal parasitic, bacterial and viral diseases in Manitoba.

Another public and animal health concern relating to increased flows is the possible chemical contamination of urban or rural water supplies. These chemical problems include: elevated nitrate and sulfate concentrations, increased pesticide and herbicide concentrations, increased organochlorine concentrations due to chlorination of wastes and sewage and increased heavy metal concentrations (mercury, arsenic, cadmium, copper, etc.).

B. Methods

A review of literature on waterborn human and animal disease agents as well as chemical agents was undertaken. Lists of protozoan and helmenthic diseases were formulated and reviewed by Larson (1976). Other consultants included G. Lubinsky, E. Snell and I. Schipper (pers comm). Lists of bacterial and viral diseases were formulated and reviewed by I. Schipper and K. McMahon (pers comms). Major waterfowl and fish diseases and parasites are considered elsewhere in this report; some fish-borne human parasites are considered in this section.

STORET retrieval data (MPCA and NDHD), North Dakota Water Resources Institute data and data from the Bacteriology Department, NDSU furnished the bacteriologic and chemical information for the past 10 years on rivers in North Dakota. The Engineering (1976) and Water Quality committees (1976c) of IGDSB furnished return flow and sediment loading predictions of GDU impact.

C. Results and Discussion

1. Parasites: The following protozoan and helminthic waterborne human diseases were reviewed for North Dakota and Manitoba waters (Larson 1976): *Entamoeba histolytica* (amoebic dysentery), *Dientamoeba fragilis* (diarrhea), *Giardia lamblia* (giardiasis), *Balantidium coli* (balantidiasis), *Isospora belli* (coccidiosis) *Enterobius vermiculosis* (pinworm infection), *Ascaris lumbricoides* (ascariasis), *Humenolepis nana* (dwarf tapeworm infection) *Metorchis conjunctis* (liver infection), *Diphyllobothrium latum* (broad fish tapeworm) and *Dioctophyma renale* (giant kidney worm).

These diseases, except for pinworm infection, are far more common in warmer climates. There are probably no other endemic and cycling human intestinal parasites in Manitoba or North Dakota. It is anticipated, however, that advances in laboratory techniques and standardization of reporting of waterborne disease outbreaks may reveal increased incidence and intensity of some of the preceding parasitic disease agents. For example, CDC (1974b) reported that, of the four largest outbreaks of waterborne disease, the largest involved an estimated 4,800 persons with symptomatic giardiasis. This was the first time giardiasis was demonstrated in water and shown to be infective for laboratory animals. Presumably, such outbreaks were previously of unknown etiology and grouped with other bacterial and viral diarrhial diseases as "sewage poisoning". Of the gastrointestinal diseases of known etiology, giardiasis was responsible for most of the outbreaks and cases.

Although we have no specific information on the effects of sediment disturbance on the distribution of protozoan cysts and helminth ova, we have assumed that their dispersal would be significantly influenced when sediments are disturbed and transported.

2. Bacterial and Viral Diseases: Literature relating to the waterborne bacterial and viral human and/or animal diseases (or zoonoses) was searched and reviewed (Table C.VI-1). All of these diseases have been diagnosed in Manitoba (with the possible exception of hemorrhagic disease of deer); we are, however, addressing the problem of increased incidence due to GDU.

Information regarding the occurrence and density of bacterial pathogens in any river system is extremely difficult to obtain since none is routinely sought or reported in state, provincial or federal water analyses. Any conclusion regarding their incidence and intensity in water must be inferred from coliform or fecal coliform data in Public Health or USGS monitoring reports, detected using research techniques or gleaned from scientific literature. For example, Shuval (1970) reported that coliform numbers in sewage effluents were reduced 5-fold by final chlorination while enteroviruses were reduced only 2-fold and thus remained

Table C.VI-1. Possible waterborne bacterial and viral diseases in North Dakota and Manitoba.

Disease agent	Animals affected
Viral:	
Infectious bovine rhinotracheitis	Cattle
Parainfluenza-like	Zoonoses[1]
Reo	Zoonoses
Reo #3	Zoonoses
Reo-like	Zoonoses
Hemorrhagic disease	Deer
Duck viral enteritis	Ducks
Duck viral hepatitis	Ducks
Poliomyelitis	Human
ECHO	Zoonoses
Coxsackie	Zoonoses
Infectious hepatitis	Human
Encephalitides (Western equine, St. Louis, etc.)	Zoonoses with insect vectors
Bacterial:	
Salmonellosis (typhoidal, non-typhoidal)	Zoonoses
Shigellosis (bacterial dysentery)	Human
Colibacillosis (one agent of scours)	Animals
Botulism (bacterial toxin)	Zoonoses
Leptospirosis	Zoonoses
Brucellosis (undulant fever, abortion)	Human, cattle
Listeriosis (listeric abortion)	Birds to man (esp. geese, ducks and chickens)
Enteropathogenic *E. coli* (neonatal diarrhea)	Young animals and humans
Fowl cholera	Waterfowl
Tularemia	Zoonoses
Gas gangrene (and perfringens food intoxication)	Humans
Limberneck	Turkeys, chickens
Black leg	Cattle, sheep
Scarlet fever and strept throat	Zoonoses

[1]Zoonoses is a disease affecting all animals.

in effluent waters at significant levels. But in routine water analyses, viruses are never quantified or even identified and it was impossible for us to obtain any STORET or other official data on the incidence of bacterial or viral disease agents in either Manitoba or North Dakota waters.

Of the four largest waterborne outbreaks of human disease in 1974 (CDC 1974b), the second and fourth largest outbreaks, involving 1,200 and 500 persons were both caused by *Shigella sonnei*. This microorganism is not routinely sought by water monitoring agencies since it is so difficult and time-consuming to isolate from water. But, since shigellosis constitutes a severe gastroenteritis solely in humans, the shigellae are even better indicators of water contamination by municipal sewage than are fecal coliforms or *Salmonella* spp. (another waterborne intestinal pathogen) which are more ubiquitously distributed in all animal intestinal tracts.

Shigellae were found in 35 percent of the samples collected from the lower Sheyenne River in June, July and August from 1973 to 1975, with *Salmonella* spp. present in 43 percent of the samples (Table C.VI-2, Kunkel 1975, Grosz 1976). We believe that no outbreaks of waterborne illness due to these etiological agents occurred (or were reported) because: 1) the Sheyenne River is not used for swimming; 2) drinking water for municipalities along the lower Sheyenne comes from wells - not the river; 3) mild gastroenteritis is not reported to State Health authorities or CDC.

In a documented instance of waterborne shigellosis, epidemiologic data from Iowa (CDC 1974a) strongly implicated swimming in the Mississippi River as the vehicle for transmission of shigellae for 21 of 29 initial cases. The small number of swallowed shigellae necessary to cause disease (from 10 to 100 *Shigella* spp. organisms, compared to 100, 000 *Salmonella* spp.) strongly suggests that these organisms pose significant risks to swimmers in polluted waters (Dupont and Horneck 1973) or consumers of unchlorinated waters.

Human (or other animal) consumers of unchlorinated drinking water are also at grave risk when heavily sediment-laden and polluted river water gains access to water supplies during a flood, such as was the case in the Red River Valley in June, July and August of 1975 for rural residents of Cass County in North Dakota and Clay County in Minnesota. Of 700 water samples collected from rural wells during the summer of 1975, 60 percent yielded fecal coliform counts above the state limit of 200 organisms/100 ml (NDSU 1975). When the flood of 1975 sent the Sheyenne, Wild Rice and Red rivers over their banks so that river sediments were resuspended in the flood waters, which then spread to cover many rural wells, it was apparent that a public health problem was imminent.

Although we were not able to obtain specific public health data for the summer of 1975 from Manitoba, Gustafson (1976) provided the

Table C.VI-2. Bacterial counts from Sheyenne River in North Dakota (organisms/100 ml).[1]

Month/ Year	Valley City		Lisbon		Harwood	
	C[2]	FC[3]	TC	FC	TC	FC
6/68	810					
7/68	230					
8/68	440					
6/69	11,000					
7/69	4,000					
8/69	1,360					
6/70	4,500					
7/70	6,000					
8/70	7,500					
6/71	3,600					
7/71	2,300					
8/71	240					
6/72	210,000	5,900	3,500	500		
7/72	250	70				
8/72	600	120				
6/73	7,100	650			840	540[4]
7/73	2,700	450			1,200	520
8/73	4,300	110			2,090	1,010
6/74	13,000	6,000			1,720	490
7/74	13,000	1,000			900	260
8/74	2,800	200			6,600	640
6/75	32,683	13,608	1,733	207	15,000	5,000[5]
7/75	13,825	6,320	11,375	4,773	6,300	1,280
8/75	22,863	7,598	3,223	618	4,000	330

[1]Sources: for 1968-72, NDHD (1968-72); for 1973-75, NDSU (1975).

[2]Coliforms.
[3]Fecal coliform.
[4]43 percent of samples collected in 1973-74 yielded *Salmonella* spp.
[5]40 percent of samples collected in 1974-75 yielded *Salmonella* spp. and 36 percent yielded *Shigella* spp.

following information regarding agents of infectious gastroenteritis identified in the Grand Forks laboratory for the months of May through September, 1975. In the communities along the Sheyenne and Red rivers in North Dakota there were seven reported cases of shigellosis and nine reported cases of salmonellosis during the months of runoff and flooding. While such data cannot be directly correlated with polluted water in the Red or Sheyenne rivers, there remains some public health concern about the disruption and resuspension of bank or stream bed sediments through increased GDU flows if these sediments contain viable pathogenic bacteria.

Sediments are defined as solid materials, both mineral (inorganic) and organic, that are being transported or have been moved from their original site by water, ice, air or gravity (Wagner and Dodds 1971). Sediments resulting from water erosion of soil in the Red River basin are usually composed of clay particles or colloidal materials high in organic matter (Timmons et al. 1968). This organic material enters the Red River tributary streams from: 1) natural sources such as leaf falls and dead plant or animal material or 2) agricultural activities, feedlots, sewage disposal lagoons, septic tanks, etc.

Hendricks and Morrison (1967) demonstrated that extracts of organic matter eluted from bottom sediments of a clear cold mountain stream not only could maintain populations of enteric bacteria (both pathogenic and non-pathogenic) but also supplied sufficient nutrients (0.70 μg/l glucose, 0.30 μg/l hexose, 0.65 μg/ℓ ammonia and 10 μg/ℓ protein) to initiate multiplication and *de novo* protein synthesis by the bacteria. Hendricks (1971a) analyzed the bottom sediments of the Oconee River in Georgia for bacterial nutrients (i.e. growth substrate) and found concentrations of sugars, protein and ammonia from four to six times that found in the free flowing water.

When Hendricks investigated bacterial respiration rates for the substrates eluted from the sediments, both pathogenic species (*Shigella flexneri*, *Salmonella senftenberg* and *Arizona arizonae*) as well as non-pathogenic species (*Escherichia coli* and *Enterobacter aerogenes*) could utilize as energy and carbon sources the low concentrations of organic matter adsorbed on bottom sediments. These organic substrates were present as tightly bound films surrounding the sediment particles with buffer elutable concentrations of 12 mg/l hexose, 45 mg/l protein and 9 mg/l ammonia nitrogen. More loosely bound organic substrate material could be washed off the sediment particles at concentrations of 1 mg/l hexose, 1.5 mg/l protein and 0.6 mg/l ammonia nitrogen. McGrew and Mallette (1962) showed that intestinal bacteria (both pathogenic and non-pathogenic) can grow in a medium containing less than 5 μg/ml of glucose; thus the concentrations reported by Hendricks more than satisfy such growth requirements.

These data strongly suggest that sufficient organic substrate is present in polluted river sediments to support the growth of heterotrophic microorganisms including the enteric pathogens, *Salmonella* spp. and *Shigella* spp. A concentration of 5 μg/ml of glucose is probably far lower than that present in the Sheyenne and Wild Rice rivers since these streams receive runoff or drainage from many feedlots. In terms of solids, biochemical oxygen demand (BOD) or nitrogen, livestock waste represents 10 times that attributable to human waste (Rhodes and Hrubant 1972). If only 0.5 to 1 percent of animal waste products are involved in runoff or bank erosion to streams the BOD loads are similar to total municipal loads from human communities (EPA 1976).

Hendricks (1971b) further stated that sediment bacterial populations may control basal nutrient concentrations in the river water itself. That is, once the adsorptive capacity of the sediments has been reached, a portion of the sediment-nutrient complex is removed by aqueous extraction or transformation (mineralization) by benthic microorganisms and these nutrients (sulfates, nitrates, phosphates) are then resuspended or dissolved in the water. These suspended or dissolved organic or inorganic nutrients then act to support the continued viability of bacteria released from the sediments under conditions of increased flows, as well as the growth of algae and other aquatic plants.

Leopold et al. (1964) demonstrated that moderate flows occurring with greater frequency than flood flows not only contain larger concentrations of dissolved salts but also accomplish greater transport of sediments than do larger but rarer catastrophic floods. Leopold also suggested that evidence from measurements of dissolved and suspended loads carried by rivers indicated that a large proportion of work done in erosion and transport is performed by relatively frequent events of moderate magnitude.

When increased flows from GDU, released on a continuous basis, reach the major project rivers an increased load of bacterial, viral and chemical pollutants derived from land use along these rivers will be carried with the flows. BuRec (1976) stated, "In the river channels, where there are rocky ledges, increased flows could have a moderate scouring effect and deposits of fine silty bottom material may be reduced in size." It is this scouring effect on banks and river beds with resultant transport of the fine silty bottom materials which will result in resuspension of the aforementioned pollutants. Sediments have been reported to exhibit anywhere from a 10 to 1,000-fold higher bacterial count over that in overlying water (Smallbeck 1975, Hendricks 1971a, Grimes 1975, Sayler et al. 1975, Van Donsel and Geldreich 1971 and Spino 1966).

Grimes (1975) reported that during disturbance and relocation of bottom sediments by dredging of a polluted stretch of the Mississippi River below La Crosse, Wisconsin, large numbers of sediment-bound fecal coliform bacteria (up to 2,700/100 ml) were released in direct proportion to the type of sediment and the direction and intensity of channel currents downstream from the dredging operation. The bottom sediment type in this stream was sand which was shown by Meadows and Anderson (1966) to serve as a natural attachment site for benthic bacteria but to adsorb these bacteria very loosely. Most bacteria in the Wisconsin study were released into the water during initial disturbance of sediments and, under increased channel flow due to increased volumes of water needed to pump spoil, were carried far downstream where later deposition occurred.

Tsernoglou and Anthony (1971) submitted sediments from 10 lakes (for which bacterial counts were available) to particle-size analysis both before and after removal of organic material. They found that while sediments were not so highly aggregated as soils, they did contain water-stable aggregates the size of which was inversely related to the amount of organic material removed. That is, if organic material was removed chemically, sediment particles did not aggregate. This phenomenon demonstrated that stability of the sediment aggregates was conferred by the organic component of the sediment and production of more binding fractions of the material stemmed from metabolic products of associated microflora.

It was further shown by Tsernoglou and Anthony that there were, depending on the soil type of the sediment (sand, gravel or silt), 3,000 to 15,000 bacteria/mm^2 of sediment particle surface. So even if initial aggregation of very small particles of a silty sediment occurs independently of the microbial flora, metabolic activities of the flora subsequently confer upon these unions greater stability than would be observed in a sterile environment.

In a recent (July 1976) study of sediments by the Bacteriology Department at NDSU (Table C.VI-3) these literature references of increased bacterial count in sediments over the bacterial count in the overlying water were confirmed for the Sheyenne and Red rivers. The greatest differences (1,000-fold increase) were observed when the sediment material was of a silt-clay nature. When the sediments were gravel or sand the bacterial counts were from 10 to 100 times higher than in the water. Highest fecal coliform counts were also found in silt-clay sediments, reflecting the rich organic content of these sediments. It may also be seen that fecal streptococcal counts were very high, clearly demonstrating the contribution of many feedlots along the lower reaches of the Sheyenne River. (Fecal streptococci outnumber fecal coliforms in cattle manure by about 100 to 1). Prost and Riemann (1967) found that in clinically healthy cattle about 13 percent were infected with and shedding salmonellae into the environment.

Grosz (1976), in a two-year water quality study of the lower Sheyenne River, compared fecal coliform densities to frequency of pathogen isolation. From data presented in Table C.VI-4 several conclusions may be drawn:

a) Of 70 water samples containing fecal coliform populations below 200/100 ml (the upper fecal coliform limit allowable in recreational waters according to North Dakota state standards) 21 samples or 50 percent were found to also contain *Salmonella* spp. or *Shigella* spp. or both. Three salmonellae and one shigellae isolations were made when no fecal coliforms were found in the water samples, indicating

Table C.VI-3. Comparison of bacterial water quality indicators in water and sediments.

River site	Sediment type	Total aerobic bacteria /100 ml Water	Total aerobic bacteria /100 ml Sediment	Total coliform MPN/100 ml Water	Total coliform MPN/100 ml Sediment	Fecal coliform MPN/100 ml Water	Fecal coliform MPN/100 ml Sediment	Fecal Streptococci /100 ml Water	Fecal Streptococci /100 ml Sediment
Sheyenne:									
Below Baldhill.	Gravel	3×10^6	4.4×10^8	430	280	90	90	2,300	3×10^6
10 miles upstream of Valley City (near fish hatchery).	Gravel	5×10^5	2.5×10^8	75	2,100	43	430	400	1.5×10^5
10 miles downstream of Valley City.	Silt-clay	1.4×10^6	8.7×10^8	430	24,000	230	24,000	2,400	6.6×10^5
20 miles downstream of Valley City.	Silt-clay	3.7×10^6	1.1×10^9	11,000	15,000	2,400	4,300	1,900	5×10^5
Little Yellowstone Creek:									
Tributary of Sheyenne upstream.	Sand	2.6×10^6	1.9×10^8	930	2,300	930	400	2,700	3×10^5
Downstream.	Gravel	2.2×10^6	2.4×10^7	430	230	430	90	1,750	3×10^5
Red River: Fargo.	Silt-clay	4×10^6	1.2×10^9	8,270	16,000	5,385	11,590	3,802	4,000
Below Fargo.	Silt-clay	5×10^6	7×10^9	14,919	26,490	703	8,000	550	2,000
Cass County Drain #3, Fargo.	Clay mud	No Water	14.4×10^9	No Water	7.9×10^5	No Water	7.8×10^5	--	--

the danger in too much reliance on indicator bacterial counts in assessment of water quality.

b) From the 13 liters of water examined, 110,720 fecal coliform colony forming units (cfu) and 43 pathogen cfu were isolated for a 0.03 percent pathogen incidence. Fifty percent of the pathogens isolated during 1975 were isolated in a 2-week period when the river was running bank full after a flood and reflected the contribution of disturbed bank and bottom sediments.

c) While more pathogens (20) were isolated from water during the flood period there was an 0.2 percent pathogen incidence isolated from mud during the months when ice covered the river, indicating that nutrient levels in the Sheyenne permit pathogen survival during adverse climatic conditions.

d) The predominant *Shigella* spp. was *sonnei*, reported by CDC to be the etiologic agent in two of the four largest waterborne epidemics in 1974. In the case of this Sheyenne study, 58 percent of the enteric pathogens isolated were *Shigella* spp. Since this heterotrophic organism is strictly a human pathogen, its predominance indicates the potential public health problems associated with untreated sewage lagoon effluents entering this river which, with the animal wastes, also contribute organic nutrients upon which microorganisms can grow.

3. Human and Animal Illnesses due to Chemical Consitutents of water: Water may transport chemicals, in either the soluble or particulate state, as well as parasites, viruses and bacteria. Sediments act as "sinks" and/or sorbants for many inorganic and organic compounds which may be resuspended under increased flows or solubilized under changes in pH of the overlying water.

The effects of these chemical substances can range from life threatening to merely debilitating disease in humans, domestic and wild animals (including fish). Many communities have found their drinking water supplies do not meet USPHS recommended limits in one or more constituents (Table C.VI-5).

An EPA study (1972) relating to these concerns involved a search of the literature to determine what organic chemicals are found in water, what known industrial and agricultural chemicals are probably in water but have not yet been isolated and what data are available on the possible health effects of both. The health effects were grouped as follows: toxic (poisonous to living things), carcinogenic (cancer-causing), teratogenic (causing abnormal offspring in the next generation) and mutagenic (harmful to future generations). It was determined that 66 organic chemicals reported in the literature have been found in fresh

Table C.IV-4. Fecal coliform densities/100 ml in relation to isolation of salmonellae and shigellae.

Month/ Day/ Year		Sites 1	2	3	4	5	6	7	8	9	10	11	12	13	Pathogen/ fecal coliform ratio	Pathogen (%)
04/03/75	Fecal coliform	0	0	0	790	0	-	-	110	170	0	70	-	230	2/1370	0.1
	Salmonella spp.				+									+		
	Shigella spp.															
06/03/75	Fecal coliform	0	0	50	130	20	-	130	20	330	270	330	-	170	4/1450	0.2
	Salmonella spp.		+					+								
	Shigella spp.				A	A										
06/09/75	Fecal coliform	50	0	70	230	70	-	80	110	170	220	140	-	1090	3/2230	0.1
	Salmonella spp.		+													
	Shigella spp.				D				D							
06/23/75	Fecal coliform	-	0	110	1090	1300	790	220	490	2300	-	4900	4900	7900	8/24000	0.03
	Salmonella spp.		+	+	+	+		+		+				+		
	Shigella spp.					D										
07/07/75	Fecal coliform	0	20	80	4900	790	330	120	2400	-	1100	1410	3300	-	5/14450	0.03
	Salmonella spp.			+												
	Shigella spp.		B					B	B				D			
07/14/75	Fecal coliform	0	20	13000	700	490	130	230	10900	-	330	330	40	490	7/26660	0.02
	Salmonella spp.				+		+							+		
	Shigella spp.				D	D	D	D								
08/04/75	Fecal coliform	20	20	7900	790	1720	80	80	490	170	170	80	460	490	2/12470	0.01
	Salmonella sp															
	Shigella sp									B	B	D				

Table C.VI-4. (Continued)

Month/Day/Year		Sites 1	2	3	4	5	6	7	8	9	10	11	12	13	Pathogen/fecal coliform ratio	Pathog %
08/11/75	Fecal coliform	0	0	22100	330	80	80	490	130	50	70	270	270	50	7/23920	0.02
	Salmonella spp.				+											
	Shigella spp.		A						D	D		D	D	D		
09/09/75	Fecal coliform	0	50	170	130	2210	40	80	490	170	130	130	230	310	1/4140	0.02
	Salmonella spp.															
	Shigella spp.				B											
12/09/75	Fecal coliform	0	0	170	80	170	80	20	230	0	170	40	20	50	2/1030	0.2
	Salmonella spp.							+								
	Shigella spp.													B		
02/28/76	Fecal coliform [1]														1/--1	--
	Salmonella spp.															
	Shigella spp.							A								
															42/111,720	0.03

+ = *Salmonella* spp. identified biochemically and serologically.
A = *Shigella* Group A identified biochemically and serologically.
B = *Shigella* Group B identified biochemically and serologically.
D = *Shigella* Group D identified biochemically and serologically.
[1] = Fecal coliform densities were not determined for these samples.

Note: 21 pathogen isolations when fecal coliform counts were under 200 organisms/100 ml.

Total pathogens: 18 *Salmonella* spp., 24 *Shigella* spp. including 4 *S. dysenteriae*, 6 *S. flexneri* and 14 *S. sonnei*.

water and that 15 of 33 of these, tested for carcinogenicity, caused cancer. Another 87 organic chemicals suspected of being water contaminants were tested for carcinogenicity and 17 of these were found to cause cancer. Many of the same compounds were also mutagenic or teratogenic. In addition, 343 chemical compounds suspected of being water contaminants have not yet been investigated either to determine whether they actually occur in drinking water supplies or to learn what their potential effects on health may be.

Harris (1974) and Page et al. (1976) demonstrated the presence of chemical carcinogens in Mississippi River water (at the parts/billion level) and in treated municipal drinking water in Louisiana. These researchers were investigating the lower Mississippi, which has received petrochemical wastes for many years in amounts far greater than would be the case for the Red or Souris rivers. However, Harris and Page indicated that any river receiving high concentrations of industrial and agricultural emissions will be heavily laden with organic chemicals and, when this water is treated with chlorine for municipal consumption, carcinogenic compounds (i.e. organohalides) are formed (Dowty et al. 1975).

Chloramine (which occurs widely as a by-product of sanitary chlorination of water supplies) was shown by Shih and Lederberg (1976) to enhance mutation frequencies in a bacterial test system and was judged by these authors to be a weak mutagen.

Nitrate Toxicity: Direct threats to health by a number of chemicals (both organic and inorganic) can be expected to increase if present industrial and agricultural trends continue. Table C.VI-5, depicting results of a USPHS survey (Leland et al. 1970) of 969 community water systems shows that 19 of these systems contained excessive amounts of nitrate. These communities were not identified but other studies (Smith and Baier 1969, The Resource Agency 1971) indicate that the problem has arisen primarily in agricultural communities relying on wells or river water that has traversed heavily fertilized areas. Kohl et al. (1971) showed in their study of a watershed in central Illinois that at least 55 to 60 percent of the nitrate found in surface waters came from fertilizer nitrogen rather than natural sources. Since World War II the production of nitrogen fertilizers has increased 14-fold and there has been a 70 percent increase in sewage nitrogen (CBNS 1970).

Nitrate presents no particular health problems but may be converted by certain bacteria within the body to nitrites. Nitrites react with hemoglobin in red blood cells causing the cells to lose their ability to carry oxygen and resulting in asphyxiation. Infant humans or young animals are particularly susceptible to this condition - called methemoglobinemia (blue babies) - because the free gastric acidity is low (pH 4 or lower), permitting growth of nitrate-reducing bacterial flora in a portion of the gastrointestinal tract from which nitrite absorption can occur (Shearer et al. 1972). Shearer also stated that fetal hemoglobin forms methemoglobin more readily than the adult form. Mothers who are themselves unaffected by nitrate may pass it on to their

Table C.VI-5. USPHS survey of 969 community water systems.

Contaminant	Recommended limit (mg/l unless otherwise specified)	Number of communities exceeding recommended limit	Mandatory limit (mg/l)	Number of communities exceeding mandatory limit
Biological coliform	N/A	N/	1/100 ml[1]	120
Organic Chemical (CCE [carbon-chloroform extract])[2]	0.2	12	N/A	N/A
Inorganic chemical:				
Arsenic	0.01	2	0.05	2
Barium	N/A	N/A	1.0	1
Boron	1.0	9	5.0	0
Cadmium	N/A	N/A	0.01	3
Chloride	250.0	9	N/A	N/A
Chromium	N/A	N/A	0.05	4
Copper	1.0	11	N/A	N/A
Fluoride	0.8-1.7[3]	52	1.4-2.4	24
Iron	0.3	96	N/A	N/A
Lead	N/A	N/A	0.05	14
Manganese	0.05	90	N/A	N/A
Nitrate	45.0	19	N/A	N/A
Selenium	N/A	N/A	0.01	5
Sulfate	250.0	25	N/A	N/A
Zinc	5.0	1	N/A	N/A
Particulate:				
Total dissolved solids	500	95	N/A	N/A
Turbidity in:				
untreated water,	5 units	26	N/A	N/A
treated water.	1 unit	26	N/A	N/A

Table C.VI-5. (Continued)

Contaminant	Recommended limit (mg/l unless otherwise specified)	Number of communities exceeding recommended limit	Mandatory limit (mg/l)	Number of communities exceeding mandatory limit
Radioactive:				
Radium 226[4]	3 pC/l[5]	6	N/A	N/A
Color	15 units	7	N/A	N/A

[1]Arithmetic average coliform density no greater than 1/100 ml or 2 or more samples (5 percent if more than 20 examined) greater than 5/100 ml when using membrane filter technique.
[2]Water is first filtered through activated charcoal and organics are extracted in chloroform. Only 110 of the 969 water systems in the study were tested for organic chemicals.
[3]Not included in 1962 PHS standards, but proposed.
[4]Standard varies with temperature.
[5]Radium 226 is a naturally occurring radioisotope found in water in areas where the rock is high in radium. Radioactivity is measured in curies or fractions thereof. (A picocurie (pC) is a millionth of a millionth of a curie).

infants in breast milk. Children (and calves) may also receive nitrate from cow's milk if cows drink water high in nitrate, from vegetables (especially spinach) that have taken in nitrate from the soil or from processed foods to which nitrate or nitrite has been added.

From 1947 to 1950, 139 cases of methemoglobinemia, including 14 deaths due to nitrate in farm well-water supplies, were reported in Minnesota alone (Bosch et al. 1950). More than 1,000 cases of infant methemoglobinemia have been reported throughout the world, with 83 deaths. The more than 278 cases reported in the US in the late 1940's were associated with high levels of nitrate in water used in the infants' formulae; 39 of these babies died (Lee 1972). Adult humans and animals can be poisoned by nitrate if the concentration is sufficiently great.

USPHS have set 10 mg/l nitrate nitrogen or 45 mg/l as nitrate as maximum permissible limits for drinking water (HEW 1962). Canadian guidelines for drinking water (CDHNW 1968) for nitrate plus nitrite (as N) have set 10 mg/l as the maximum permissible level with less than 10 mg/l both the objective and acceptable levels (a nitrate concentration of 10 mg/l as N is equivalent to 45 mg/l as nitrate). EPA (1973) established a maximum permissible nitrate level as 100 mg/l as nitrate (or 22 as nitrate N) in water for livestock watering. McKee and Wolf (1973) noted that special attention should be paid to the concentrations of nitrates in stock waters especially when the total salt concentrations exceed 570 to 1,000 mg/l. The major impact of nitrates in livestock water (except for calves and lambs) would be the stimulation of algal growths which may be toxic to livestock rather than direct nitrate toxicity.

Predicted nitrate concentrations for GDU peak leaching years (Water Quality Committee 1976a) indicate that permissible levels for both drinking water and livestock water will not be exceeded. These concentrations were based on Water Quality Committee assumptions of nitrate assimilation or denitrification by aquatic flora and fauna. If we accept these assumptions the Biology Committee cannot forsee problems of nitrate toxicity from GDU influenced river systems. We are concerned, however, with the effect of increased nitrogen assimilation producing blooms of toxic algal populations (e.g. *Aphanosomenon* spp. and *Microcystis* spp.) that may affect the health of man and animals. If we do not accept these assumptions then the nitrate levels formerly predicted (Water Quality Committee 1976b) for the Souris River indicate that permissible levels for drinking water will be exceeded and nitrate toxicity may become a human and animal health problem.

Sulfate concentrations capable of causing a laxative effect in non-adapted individuals (above 250 ppm) will be present in the Souris River for 12 months and in the Assiniboine for 11 months of the year if GDU peak leaching "high estimates" prevail and for 11 months in the Souris River and 6 months in the Assiniboine River if "best estimate" levels prevail (Water Quality Committee 1976a).

Total dissolved solids (TDS) in the Souris Loop project area will exceed the USPHS drinking water standards of 500 mg/l for all months except April if probable post-project conditions prevail and will far exceed 100 mg/l for all months if maximum post-project conditions prevail (Fig. C.VI-1). TDS levels in the Assiniboine River and Red River at Selkirk will exceed 500 mg/l for 10 months and 11 months respectively if probable post-project concentrations prevail.

Pesticides and heavy metals: For the purpose of this discussion the term pesticides includes organic and inorganic insecticides, herbicides and fungicides. Heavy metals of importance in human and animal health include arsenic, lead, cadmium, copper, mercury, zinc, chromium and selenium.

The following artificial classification of extensively used pesticides has been adapted from Rudd (1964):

a) Organic phosphate compounds, examples of which are parathion and malathion. These chemicals inhibit the production of cholinesterase at the synapse between adjoining nerve cells, resulting in diminution of nerve impulse transmission. Extreme muscular weakness, tremors and dizziness are common symptoms in poisoned mammals. Fish and other aquatic organisms are apparently little affected. These insecticides are short-lived in soil although high concentrations may be associated with sediments at runoff periods.

b) Chlorinated hydrocarbons, examples of which are DDT, dieldrin, chlordane, endosulfan and toxaphene. These insecticides affect primarily the central nervous system and symptoms in poisoned animals include increased excitability muscular tremors and convulsions. Stored in body fats, they are released during stress situations such as migrations or food deprivations. These insecticides are very resistant to biodegradation by bacteria in either water or soil. Most of the chlorinated hydrocarbons may not now be used in the US due to their high toxicity to fish, birds and aquatic invertebrates as well as their long persistance in the environment. However, EPA recently approved the use of toxaphene to control sunflower beetles in North Dakota and the use of DDT in special cases (tussock moth and pea weevil) although a general ban is in effect. This recent approval may increase pressures for relaxation of restrictions on persistant pesticides.

A large number of pesticides developed for use in agriculture are toxic to fish or other aquatic species. Fish have often been cited (Henderson et al. 1971, Holden 1972) as bioaccumulators of pesticides in water. This can impair their value as food, damage their biological functions or result in mortality.

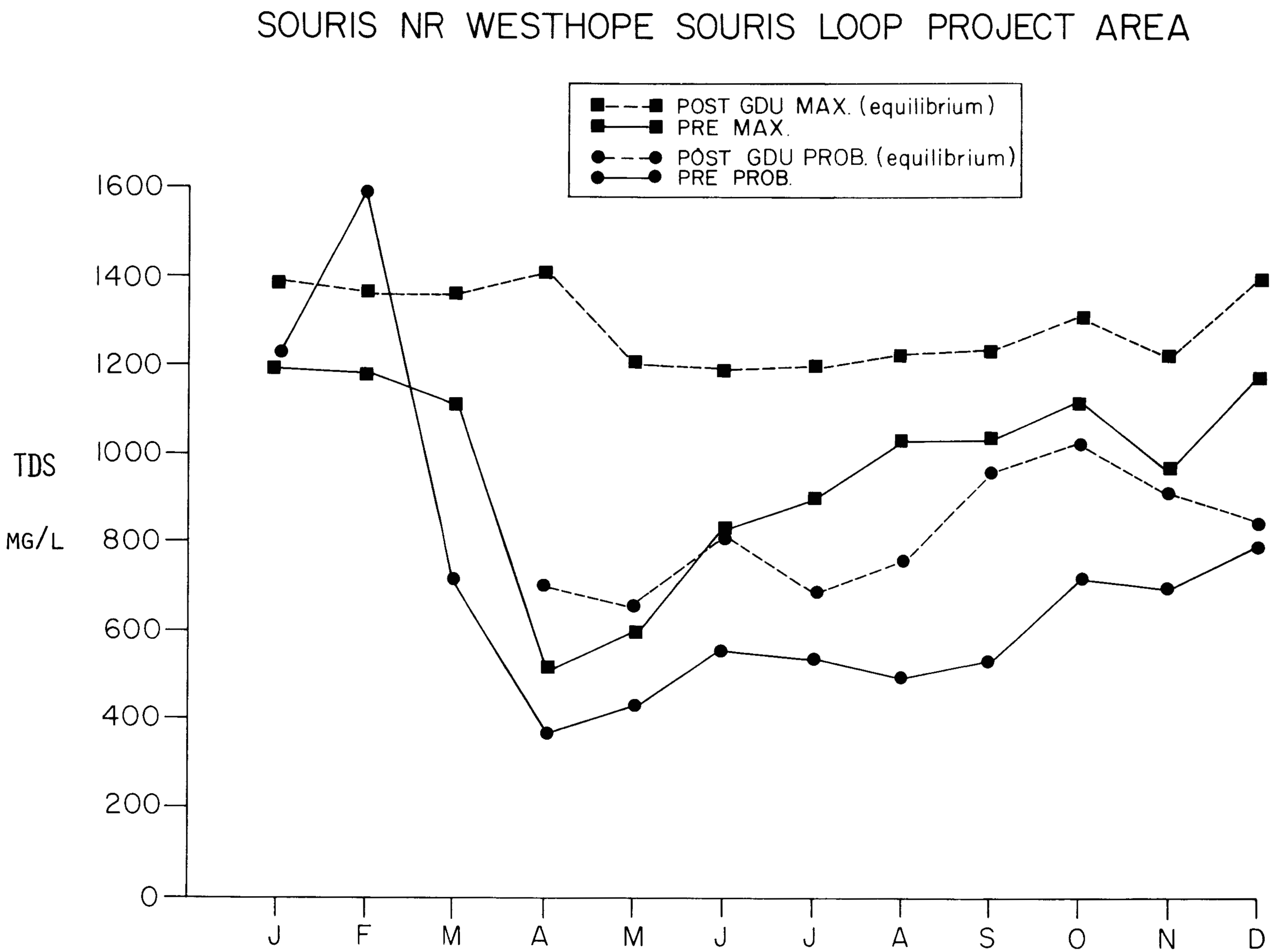

Fig. C.VI-1. Equilibrium TDS levels in the Souris River at Westhope, North Dakota after Water Quality Committee (1976).

Although pesticide residues in forage are not hazardous to livestock under conditions of ordinary usage, they do accumulate in tissues of livestock and are excreted in their milk (as is the case with high nitrate levels), thereby constituting a potential hazard to people consuming their products (Neal 1971).

Herbicides: The most extensively employed of the herbicides is 2,4-D which causes plant death by accelerating growth rate. 2,4-D can be quite selective because it is much more effective on broad-leaved plants (such as plantain) than on narrow-leaved grasses (wheat and barley). Dalapon and TCA (trichloroacetic acid) are other herbicides in this group. These herbicides are biodegradable within 2 weeks but their salts are readily leached. The more powerful defoliant of this group of herbicides, 2,4,5-T has now been banned for most agricultural uses except for "rangeland pest control" (Owen 1975: 455).

Fungicides: These compounds are employed to destroy molds on seed grains, fruits and vegetables. Until recently many fungicides, especially those applied to seed grain, contained the element mercury. The use of mercury-containing fungicides has been greatly curtailed in recent years but since mercury is most likely to be associated with the fine-sized fraction of lake and river sediments where it is likely to be transported in the suspended load, it is still a problem wherever it has been used in the past. Benthic bacteria metabolize this element by methylating it and it enters the food chain where it is concentrated in the most lethal form (D'Itri 1972). Accidental ingestion of mercury (via the food chain) may cause brain damage, kidney and liver malfunction and death.

Heavy Metals: Copper, zinc, cadmium, lead, chromium, selenium and arsenic are trace elements which, in miniscule concentrations are essential (except lead) to life processes. However, in higher concentrations many of these heavy metals, like mercury, are toxic.

It is known that in aquatic ecosystems microbial methylation of metals such as mercury (previously mentioned), arsenic, lead and selenium can yield compounds that are extremely toxic to higher organisms (Huey et al. 1974). In the case of selenium (an inorganic carcinogen) Chau et al. (1976) found three bacterial genera in the sediments of 21 lakes of Ontario that convert inorganic and organic selenium compounds to dimethyl selenide, dimethyl diselenide and an unknown volatile selenium compound. Such transformations could be important in transportation from sediments and subsequent bioconcentration in the food chain.

Copper as copper sulfate is widely used as an algicide but in large quantities is extremely toxic because of the affinity of the metal (like mercury) for the reactive groups of catalytic enzymes, resulting in inhibition of respiratory processes. The toxicity of copper increases under anoxic conditions (McCaull and Crossland 1974: 190) and exacerbates fish kills when oxygen levels drop. Increased urinary copper levels with a higher mortality rate in humans have been found in collagen disease

(Oski 1970) and cardiovascular disease (Harman 1965).

These parameters have not nor will be modeled for GDU by BuRec; however, the Water Quality Committee (1976a) "looked at present concentrations in ground water, applied water, mobility in the soil, expected best management practices with pesticides and herbicides and other factors". In the Water Quality Committee's judgment, none of these parameters will be increased significantly above their present concentrations in the Souris, Assiniboine and Red rivers.

The final impact assessment statements from Water Quality Committee (1976a) and BuRec (1974) are based on best management practice by GDU water users. The Committee feels it is unlikely that this level of efficiency will be attained. Less than best management practices by the many GDU irrigators regarding pesticide, herbicide and fungicide usage may increase concentrations above their present level and could constitute a risk to human and other animal health.

D. Summary of Impact Predictions

1. Increased flows from GDU will cause river bank or bed scour which may increase the concentrations of bacteria, viruses, organic and inorganic nutrients and toxic chemicals in the Red River and Souris River tributary streams. These substances or organisms may then be transported in suspension across the US-Canadian border. The Biology Committee believes a risk exists for increased incidence and spread of human and animal disease because of GDU mediated transport of sediments in the Canadian sections of the Red and Souris River.

2. Based on the Water Quality Committee's concept of "best" management practices, the Biology Committee cannot forsee any health problems from pesticides, herbicides and heavy metals in the Canadian sections of the Red and Souris rivers.

3. Increased sulfate levels could cause laxative effects in non-adapted individuals in the Canadian sections of the Red and Souris rivers.

4. TDS concentrations will exceed USPHS maximum permissible levels for drinking water in the Canadian sections of the Red and Souris rivers.

5. If the August Water Quality Committee (1976b) nitrate concentration predictions prevail, permissible nitrate levels for drinking water will be exceeded in the Souris River and nitrate toxicity problems could occur. If the nitrate concentrations predicted in October (1976a) by Water Quality Committee prevail, no health problems will occur.

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F. Personal Communications Cited

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RECOMMENDATIONS

I. INTRODUCTION

One of our tasks was to forward to the Study Board recommendations for ameliorating adverse GDU impacts. To complete this task we recommended project changes and pointed out deficiencies in our impact assessment. The Committee did not extend its recommendation mandate to consider project curtailment.

This section consists of recommendations developed by the Biology Committee. Following the recommendations there is a list of research needs in areas for which there is insufficient information.

II. WILDLIFE

A. Reduction of Waterfowl Loss to Manitoba through Wetland Drainage and Habitat Alteration in North Dakota

1. Develop and Manage Oxbows Cut Off by Stream Channelization.

2. Lateral Diking Along Return Flow Streams Instead of Channelization.

3. Implement the New Wetland Restoration Concept: The FWS concept of wetland restoration to offset habitat losses through project construction is biologically valid. A comprehensive plan to fulfill that concept should be developed immediately and implemented concurrent with project construction. It should be responsive to the following:

   a) Reclaimed wetland basins should make up the major portion of the lands acquired.

   b) The complexes to be restored should be capable of producing, on the average, 1.1 fledged young/acre.

   c) Areas should be selected in a manner which will least impact agricultural land use while still providing the biological capability necessary for adequate waterfowl production. Furthermore, the plan should not remove from consideration the acquisition of existing wetlands of extremely high waterfowl value, creation of wetlands in areas where they do not now exist or some use, however small, of the original GDU wildlife plan.

4. Eliminate the Turnout from the New Rockford Canal into the Upper James River to Prevent the Movement of Carp into Lonetree Reservoir and then through Project Works into the Souris, Upper Sheyenne and Devils Lake Areas.

5. Divert Flows around NWRs where Possible, or Expand NWRs to Accommodate Return Flows.

6. Develop a Program to Monitor Private Wetland Drainage and Enforce BuRec's Policy of No Wetland Drainage into Project Works.

7. Develop a Monitoring Program to Detect the Increase in Incidence of Waterfowl Disease Outbreaks in GDU North Dakota Waters.

8. Detailed Plans to Implement These Recommendations Must Be Developed and/or Approved by State, Federal and Provincial Wildlife Agencies.

We strongly recommend that the wetland restoration concept and elimination of private wetland drainage be expedited. It is also essential that biological expertise be provided in all phases of project development. If the recommendations above are implemented, especially Nos. 3 and 6, we believe most if not all of the duck loss to Manitoba can be offset.

III. FISH, AQUATIC INVERTEBRATES, PLANTS, WATER, HUMANS AND OTHER ANIMALS

1. To Insure that All Water Pumped from Surface Water in the Missouri River Basin is Passed through a Sand or Soil Filter: This recommendation includes elimination of operational wasteways in all project areas in North Dakota, elimination of Sheyenne River outlet in Lonetree Reservoir, sand filtration of all municipal and industrial water into the Sheyenne and Souris River drainages, elimination of the Kindchi Lake turnout and elimination of the New Rockford turnout.

2. Modify Existing Design Features to Prevent Fish Passage: This includes accepting Engineering Committee recommendations concerning modifications to McClusky Canal fish screen design and design and installation of some form of fish screen at Oakes pumping plant.

3. Develop Operating Criteria for Fish Screen Structures: A model of the McClusky Canal fish screen must be evaluated. This evaluation should take place in Lake Brekkon-Holmes turnout for at least five years. The fish screen must be identical in design to the proposed McClusky screen. All water passing through the test facility must return to its source; test water cannot be permitted to pass down the McClusky Canal to Lonetree Reservoir during the testing period.

Development of O and M criteria should be developed in conjunction with the modeling and evaluation of the fish screen and biologists and engineers from the US and Canada should comprise the model evaluation team.

We believe that adoption of our first recommendation (above) would remove the potential for interbasin transfer of exotics except through the accidental introduction via Lonetree Reservoir or some calamity in the middle Souris or East Oakes which would permit connections of irrigation distribution canals with wasteways (e.g. collapse of canal banks, unusual rain storms). To mitigate these latter potentials we believe that recommendations Nos. 2 and 3 (above) should be adopted in conjunction with recommendation No. 1. This would therefore serve as "first line of defence", albeit not entirely effective on its own.

No single recommendation will alleviate all possible fish transfer problems. Therefore all three recommendations must be adopted concomitantly to alleviate all fish transfer problems.

4. Prevention of the Introduction of Exotic Fish Diseases and Parasites: There are no known methods of filtering all viral particles. However, it is our judgment that recommendation No. 1 (above) will significantly reduce the possibility of viral transfer.

5. Prevention of Introduction of Exotic Invertebrates: Adoption of recommendation No. 1 (above) will eliminate aquatic but not aerial transport of these organisms.

6. Elimination of Impacts on Aquatic Plant Species Composition: Disturbances in species composition in the Souris River as a result of water quality changes could not be ameliorated without installation of a deionization unit on the Souris River. We cannot recommend this in view of the degree of potential impact.

7. Reduction of Impacts as a Result of Nutrient Loading: Adoption of the combinations of no unfiltered return flows to Canada, FWS concept of wetland restoration, elimination of 1893 acres of Class A soils in the Souris Loop and lining of the glacial till portion or all of the Velva Canal will not reduce nutrient levels. The lack of comprehensive data makes it impossible to evaluate the total nitrogen picture. This in no way lessens potential impact of all other factors contributing to the eutrophication process in Manitoba. Questions such as transport of nitrogen and phosphorus, effect of turbidity on primary productivity and relationship between oxygen depletion and increased algal production all require answers. This kind of information is essential to predict impact on nutrient loading.

The Committee recommends that an intensive study of these relationships be undertaken immediately to provide the necessary information upon which to base further recommendations and that no project construction take place in the Souris Loop until these questions are answered.

8. Reduce Impacts of Chemicals, Sediments and Diseases on Human and Animal Health: The Committee is unable to recommend any method to eliminate these potential impacts. Adoption of the closed system (No. 1 above) will reduce these potential risks. We are unable to quantify this reduction.

IV. LIST OF FURTHER RESEARCH NEEDS

A. Quantify Loss of Shorebirds and Other Marsh Birds Due to Wetland Drainage and Habitat Alteration in North Dakota.

B. More Fully Determine the Impact of the Use of Pesticides in GDU North Dakota on Manitoba's Rare and Endangered Species.

C. Construct a Population Simulation Model to Analyze Banding Data to Verify Canada's Share of the GDU-caused North Dakota Waterfowl and Shorebird Loss.

D. Determine Changes in Migration Patterns of Migratory Birds as a Result of GDU.

E. Conduct a Comprehensive Limnological Research Program for Lakes Winnipeg and Manitoba.

F. Expand Water Quality Monitoring Programs in Manitoba to Include Pesticides, Fecal Coliforms, Fecal Streptococci and Total Aerobic Bacterial Counts.

G. Develop a Research Program to Determine Use of Marsh Areas for Nutrient Removal.

H. Develop a Research Program to Evaluate Methods to Prevent Carp Introduction into the Souris River.

I. Quantify Duck Loss Due to Conversion of Grassland to Irrigated Croplands in North Dakota.

ATTACHMENTS

Attachment C.A

Biology Committee Study Plan

INTERNATIONAL GARRISON DIVERSION STUDY BOARD - BIOLOGY COMMITTEE

PROPOSED STUDY PLAN

Activity 1	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Describe impacts of water quality & quantity, with & without GDU, on aquatic life.	Identify biota* in key watersheds: Red R. Souris Assiniboine L. Winnipeg) L. Manitoba) include indicators of eutrophication.	Identify from Step 1, key biota which may be impacted by changes in water quality or quantity.	Develop specific biological requirements of key species include case history. Evaluate habitat available.	Establish likelihood of occurrence of impacts. Write interim report. Impacts from non-GDU sources requires reports from q & q Committee.	Input of GDU impact	Reevaluation of impacts after alteration of the existing project plan. Establish a cost of any changes due as a result of Step 5 data. Delineate any habitat changes which will occur as a result of Step 5.	Reexamine all data. Resolve differences. Develop alternatives. Write final report.
Time Frame	S: December 8, 1975 F: January 7, 1976 Verbal report on December 22, 1975.	By January 8, 1976	S: January 8, 1976 F: February 25, 1976	S: February 27, 1976 F: March 30, 1976	S: April 1, 1976 F: April 30, 1976	S: May 1, 1976 F: May 31, 1976	By July 1, 1976
Input of other committees				Required from q & q committee data on water quality & quantity.	Required from engineering.		
Travel (for Activity 1 & 2)	Meeting in Minneapolis, Jan. 7 -8, 1976.	Meeting in Minneapolis, Jan. 7 -8, to review checklists and perform Step 2.	Meeting in Denver (Jan. 28) to view fish screen model & review progress of Step 3. Meeting in Winnipeg (Feb. 19, 20) to review Step 3 progress & plan interim report.	Meeting in Bismark (Mar. 3, 4) to review progress. Meeting in Winnipeg (Mar. 17, 18) to review progress and edit report.	Meeting in Grand Forks (Mar. 31, Apr. 1) to review progress. Meeting in ? (Apr. 28) to prepare final review.	Undefined.	Undefined.

*biota to include human parasites and bacteria, fish parasites and bacteria, aquatic invertebrates, fish, wildlife, vascular plants and animal diseases.

Activity 2	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Describe impacts of possible introduction of foreign biota on endemic biota in Canada. Include probability analysis with and without GDU.	Identify all biota in watersheds: Red R. Souris R. Assiniboine L. Winnipeg L. Manitoba Missouri R.	Identify from Step 1 all biota which are subject to transmission or introduction. Evaluate life histories available.	Develop specific biological data on species identified in Step 2.	Develop likelihood of occurrence, write interim report. Delineate impact of physical aspects of GDU, i.e. fish screen, etc.	Input of GDU impact.	Re-evaluate Step 5 with new data & develop probability analysis of occurrence or transmittance.	Write final report.
Time Frame	S: December 8, 1975 F: January 7, 1976 Verbal report on December 22, 1975	By January 8, 1976	S: January 9, 1976 F: February 25, 1976	S: February 27, 1976 F: March 30, 1976	S: April 1, 1976 F: April 30, 1976	S: May 1, 1976 F: May 31, 1976	By July 1, 1976
Input of other committees				Water q & q	Water q & q, engineering		

Activity 3	Step 1	Step 2	Step 3				
Evaluate prior diversion projects in view of their impacts.	Define projects to be examined.	On-site examination.	Evaluation of project impact & final report.				
Time Frame	S: December 8, 1975 F: January 28, 1976	S: January 28, 1976 F: February 27, 1976	S: February 27, 1976 F: March 30, 1976				
Travel		To be defined in Step 1					

Attachment C.I-1

Scientific Names for Wildlife

Attachment C.I-1. List of common and scientific names for birds[1] and mammals[2] in Wildlife Section.

Class Aves - Birds

Anatidae - geese, duck, swans

Canada goose	*Branta canadensis* (Linnaeus)
Mallard	*Anas platyrhynchos* Linnaeus
Pintail	*Anas acuta* Linnaeus
American wigeon	*Mareca americana* (Gmelin)
Northern shoveler	*Spatula clypeata* (Linnaeus)
Blue-winged teal	*Anas discors* Linnaeus
Wood duck	*Aix sponsa* (Linnaeus)
Redhead	*Aythya americana* (Eyton)
Canvasback	*Aythya valisneria* (Wilson)
Lesser scaup	*Aythya affinis* (Eyton)
Ruddy duck	*Oxyura jamaicensis* (Gmelin)

Tetraonidae - grouse

Spruce grouse	*Canachites canadensis* (Linnaeus)
Ruffed grouse	*Bonasa umbellus* (Linnaeus)
Sharp-tailed grouse	*Pediecetes phasionellus* (Linnaeus)

Strigiformes - owls

Great horned owl	*Bubo virginianus* (Gmelin)
Great gray owl	*Strix nebulosa* Forster

Picidae - woodpeckers

Pileated woodpecker	*Dryocopus pileatus* (Linnaeus)

Turdidae - thrushes

Robin	*Turdus migratorius* Linnaeus

Sturnidae - starlings

Starling	*Sturnus vulgaris* Linnaeus

Ploceidae - weaver finches

House sparrow	*Passer domesticus* (Linnaeus)

Attachment C.I-1. (Cont'd)

Class Mammalia - Mammals

Family Leporidae - rabbits, hares

Snowshoe hare	*Lepus americanus* Erxleben
White-tailed jack rabbit	*Lepus townsendii* Bachman

Castoridae - beaver

American beaver	*Castor canadensis* Kuhl

Muridae - rats, mice

Gapper's red-backed vole	*Clethrionomys gapperi* (Vigors)
Muskrat	*Ondatra zibethicus* (Linnaeus)
Meadow vole	*Microtus pennsylvanicus* (Ord)

Canidae - dogs

Coyote	*Canis latrans* Say
Red fox	*Vulpes vulpes* (Linnaeus)

Mustelidae - weasels

American mink	*Mustela vison* Schreber

Felidae - cats

Lynx	*Lynx lynx* (Linnaeus)

Cervidae - deer

Caribou	*Rangifer tarandus* (Linnaeus)
White-tailed deer	*Odocoileus virginianus* (Zimmermann)
Moose	*Alces alces* (Linnaeus)

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[1]Godfrey, W. 1966. The birds of Canada. Bulletin No. 203, Biological Series No. 73. National Museum of Canada, Ottawa, Ontario. 428 pp.

[2]Banfield, A. 1974. The mammals of Canada. National Museum of Canada, U. of Toronto Press, Toronto. 438 pp.

Attachment C.I-2

Shorebirds and Other Marsh Birds Inventoried at Kraft Slough, North Dakota, 1974

Attachment C.I-2. Shorebirds and other marsh birds inventoried at Kraft Slough, North Dakota, 1974[1].

SPECIES	SPECIES
Eared grebe	House wren
American bittern	Gray catbird
Virginia rail	Yellow warbler
Killdeer	House sparrow
American avocet	Yellow-headed blackbird
Black tern	Baltimore oriole
Great-horned owl	Brown-headed cowbird
Eastern kingbird	Savannah sparrow
Horned lark	LeConte's sparrow
Black-capped chickadee	Swamp sparrow
Short-billed marsh wren	Black-crowned night heron
Robin	Ring-necked pheasant
Yellow-breasted chat	American coot
Western meadowlark	Marbled godwit
Orchard oriole	Franklin's gull
Common grackle	Black-billed cuckoo
American goldfinch	Hairy woodpecker
Grasshopper sparrow	Willow flycatcher
Chipping sparrow	Barn swallow
Chestnut-collared longspur	Long-billed marsh wren
Pied-billed grebe	Brown thrasher
Marsh hawk	Common yellowthroat
Sora rail	Bobolink
Willet	Red-winged blackbird
Wilson's phalarope	Brewer's blackbird
Mourning dove	Dickcissel
Common flicker	Clay-colored sparrow
Western kingbird	Sharp-tailed sparrow
Tree swallow	Song sparrow

[1]After Krapu and Duebbert 1974.

Attachment C.II-1

A Description of the BuRec
Study to Develop and Refine the
Design of a
Self-Cleaning Fish Screen

The screen is designed to be self-cleaning. A sloping fixed screen was selected by the BuRec and a study was initiated to develop and refine the design (Johnson, 1975). To aid in developing the design, a sectional hydraulic model of the screen was constructed. The model was a full-scale representation of a 20 inch wide section of the proposed prototype structure. The three main objectives of the model study were to:

1. Evaluate the ability of the screen to self-clean.

2. Confirm that the screen will satisfactorily meet the filtration requirements.

3. Minimize the screen and structure size required to filter the total canal flow.

Six basic factors considered to achieve these objectives were:

1. Unit discharge;

2. Drop from weir crest to screen;

3. Slope of screen;

4. Length of screen;

5. Screen mesh and wire size; and

6. Effects of various types of debris.

The purpose of the BuRec hydraulic model study was to refine the design of a fish control structure for the McClusky Canal, GDU. The structure was a new concept and, therefore, no design guidelines existed.

Johnson (1975) reported the following results from his hydraulic model study.

1. The structure as developed functioned satisfactorily in the model. The screen should remove all fish, fish eggs, and fish larvae from the flow. Likewise, the model data indicates that the screen surface should be self-cleaning.

2. The flatter the downward slope of the screen, the shorter the flow length of the screen required to pass a given discharge. Thus, a horizontal screen would result in a smaller structure than would be required for a downward sloping screen.

3. The steeper the downward slope of the screen, the more efficient the screen self-cleans. The tendency for debris to cling to the screen depends on the angle at which the flow impinges on the screen. If the flow direction is nearly tangent to the screen's surface, then the debris is swept

clear of the surface and no clogging occurs. But if the flow impinges sharply, then the debris will accumulate in the impingement area. This accumulation resulted from the impact head of the flow, forcing and holding the debris against the screen surface. The debris did not actually tangle with the screen fiber; therefore, it could easily be dislodged and washed clear.

4. Screen mesh and wire size affect the length of screen required to pass a given discharge. Finer mesh screens tend to require more screen length as do screens made from larger diameter wire.

5. If the region under the screen is inadequately vented, reduced pressures will develop. Reduced pressures under the screen tend to suck water through the screen, which reduces the required screen length and increases clogging. The reduced pressures also place additional loading on the screen structure.

6. The quantity of debris that will be encountered in the prototype is unknown. Therefore, it is conceivable that the screens might be overwhelmed by debris, and clogging could become a problem. The screen arrangement allows the installation of several possible devices which would improve self-cleaning. For the present, none of these devices is to be incorporated in the prototype structure. If a clogging problem is found to exist when the prototype structure goes into operation, then the devices could be installed without major modifications.

7. The optimum screen configuration developed from this study has a screen length in the direction of flow of 6.5 feet (2.0 m) and a slope of 5° downward from horizontal. This structure was developed to pass a maximum unit discharge of 6 ft^3/s (0.2 m^3/s).

The Committee reviewed the paper by Johnson (1975) which were responsible for the design guidelines used for the fish screen structure. They further evaluated the paper by Starbuck, Sartoris, and Johnson (1975) dealing with the fish screen structure design. The salient features of the design are:

1. A 40 mesh screen made from 0.007 inch (0.18 mm) diameter will be used.

2. A 3 inch (7.6 cm) drop from the weir crest to the surface will be included.

3. The discharge per linear foot of weir will be 6 ft^3/s (0.17 m^3/s).

4. The screen will be placed at a downward slope of 5°.

Attachment C.II-2

Committee Concerns With

McClusky Canal Fish Screen

Attachment C.II-2.1

A list of initial questions (with BuRec responses) posed by the Biology Committee concerning the Fish Screen Structure.

Question 1: Spiny-rayed fish may be impaled on screen which may lead to:

- the fish being caught and the force of water tearing the screen as fish is pushed down the slope;
- a small perforation, not especially visible to the eye.

Answer 1: Because of the small openings (0.43 mm square) it is unlikely that fish would become impaled on the screen. If a fish should become impaled, it is again unlikely that enough force could be developed to break even one strand of the 40-mesh screen. But if a strand were broken, the opening would become larger and the fish would be freed. A tear of the screen could not occur. The 2-mesh support screen and the steel support frame take most of the water load and thus the force of the water would not enlarge a perforation. Finally, it should be again noted that even if the service 40-mesh screen would be damaged, the 2-mesh screen and steel frame would remain in place, protecting the backup screen which would continue filtering the flow.

Question 2: Any perforation that is not visible or noticeable may allow passage of eggs and also may slowly increase in size due to the force of the water passing through it.

Answer 2: The screen is designed so that the force of water would not enlarge a perforation. The backup screen would filter the fish eggs which pass through perforations in the upper service screen. Screen sections will be inspected and, based on actual operating experience, will be replaced when wear occurs.

Question 3: How are large fish prevented from falling onto screen?

Answer 3: Larger-sized fish may fall onto the screen. However, there is an inlet trashrack with a clear spacing of 1½ inches wholly or partially submerged, objects with measurement greater than 1½ inches will not enter the structure nor find their way onto the fish screen. The present design calls for an automatic self-cleaning mechanical trash removal structure. This structure will automatically remove floating and submerged trash larger than 1½ inches. The fish screen structure is also designed to accommodate an endless belt type mechanical trashrack for removal of smaller floating debris if operating conditions indicate the need.

Question 4: How effective will trashrack be in removing large objects, especially wholly/partially submerged (e.g., fence posts)?

Answer 4: The clear space on the inlet trashrack structure is 1½ inches wholly or partially submerged, objects with measurement greater than 1½ inches will not enter the structure nor find their way onto the fish screen. The present design calls for an automatic self-cleaning mechanical trash removal structure. This structure will automatically remove floating and submerged trash larger than 1½ inches. The fish screen structure is also designed to accommodate an endless belt type mechanical trashrack for removal or smaller floating debris if operating conditions indicate the need.

Question 5: How often will the screen be checked for wear/perforations?

Answer 5: Preliminary operating criteria have not been developed for the screen. Stage development over a period of several years will allow time to operate and test the fish screen through a full range of flows. Initial operation criteria will be developed for the fish screen based on actual conditions. These operating criteria will define procedures for checking screen wear and perforations.

The operation and maintenance headquarters for the canal will be at McClusky, North Dakota, approximately 10 miles south of the fish screen. Personnel will be stationed at the fish screen as required during operations.

Question 6: How does the manual switch-over from one screen to the other?

Answer 6: Panels can be lowered from the ceiling which will seal off portions of the screen from flow. The screen in these areas could then be replaced, the panels raised, and normal operations resumed. Standard size replacement panels will be available for any part of the screen.

Question 7: If a screen clogs:

- how strong is the screen?
- Where does the impounded water go?

Answer 7: The structure contains two screens, a service screen which would filter the flow under normal conditions and a backup screen (1 foot directly below the service screen) which would filter the service screen. Both screens are identical. They consist of a 40-mesh phospher bronze wire cloth, which in turn is supported by a steel frame. Phospher bronze was selected because of its high percentage copper content (which prevents algae growth on the screen) and because of its high tensile strength. The 40-mesh wire cloth is made from a 0.008 inch diameter wire. The tensile strength of each wire strand is approximately 6.3 pounds. Thus, the tensile strength of a 1 inch wide strip of screen is 250 pounds. The 2-mesh support screen is made from 0.063 inch diameter wire which has a tensile strength of 390 pounds. The screen structure is designed to support a total load of over 3 psi.

Plugging of the fish screen will not cause the canal to overflow its banks. Total screen plugging is highly improbable. However, if it did occur, water would pond in the canal above the structure but would not overflow the banks. Sequential automatic closings of upstream structures would contain the canal water well within the existing freeboard. If plugging would occur, there are provisions for installing stop-locks at the head of the fish screen and unwatering the structure for access to the screens for cleaning. Operating criterial will call for prevention and removal of trash (algae, pond weeds, windblown debris, etc.) upstream from the fish screen structure. Additional mechanical equipment for trash removal, such as endless belt mechanical trashracks and canal side floating weed traps, will be installed as necessary.

Question 8: What is to prevent soggy leaves and grass from matting on the screen?

Answer 8: In laboratory testing, the screen was found to self-clean soggy leaves and grass effectively. The screen's self-cleaning effectiveness would be evaluated during the first two years when it would be operating at reduced discharges.

Attachment C.II-2.2

Supplementary concerns of the Biology Committee with respect to the proposed G.D.U. fish screen structure.

Question and Answer 1: How much force could a spiny-rayed fish exert on the screen and could this force either break or separate the wires of the 40-mesh and subsequently tear the screen? In addition to spiny-rayed fishes such as bluegills, yellow perch, walleyes, etc. we are also concerned about fishes that have single spines such as bullheads and catfish and the force they can exert on the 40-mesh screen.

Question and Answer 2: How is the 40-mesh screen designed to prevent the force of water and debris from enlarging or tearing a perforation. Describe how the screen wires are braised, welded, plated, soldered, etc. to each other or do the wires stay in place by friction?

Question and Answer 3: No additional questions or comments.

Question and Answer 4: When will the automatic self-cleaning mechanical trash removal structure be put in operation?

Question and Answer 5: Explain in more detail proposed operating criteria. For example:

a) Describe procedures being considered for detecting wear on the screen.

b) Describe procedures being considered for evaluating self-cleaning capabilities during different seasons of the year.

c) Describe procedures being considered for *operating and maintaining screen* by project personnel.

Question and Answer 6: Explain in more detail using diagrams, the steps required for replacing a screen replacement panel.

Question and Answer 7: What is the relationship between force of area (psi) and tensile strength (pounds). Is the screen structure design for total load of 6 psi, strong enough to prevent a free-falling fish with single spines or spiny-rays from breaking wire stands. If cleaning is necessary and the screen structure must be unwatered, where does the water go? What is a canal side weed trap? How is an endless belt mechanical trashrack designed and how does it operate?

Question and Answer 8: How long (in hours) would unscreened water remain above the structure before it becomes an unmanageable problem? When are standby power units going to be build for all in-line canal structures? How many and where are the in-line canal structures located?

Additional question. Describe the size of the replaceable screen panels and indicate the type of rubber sealant material used between the individual screens and the structure itself.

Attachment C.II-2.3

REPORT BY THE BIOLOGY COMMITTEE ON

BIOLOGY COMMITTEE - ENGINEERING COMMITTEE - BuREC E&R MEETING

JUNE 17, 1976 DENVER, COLORADO

A meeting was held on June 17 at the BuRec E&R Center, Denver Colorado. A list of attendees is attached. The purpose of the meeting was to discuss the design and operation of the proposed McClusky Fish Screen. Design engineers from BuRec were invited to attend. A list of questions had been previously developed by the Biology Committee and discussed with the Engineering Committee in Bismarck on May 28, 1976. At the May 28 meeting it was agreed to rewrite and forward the questions to BuRec Center for a complete response at the June 17 meeting.

These questions were discussed in considerable detail by all attendees. A list of these questions and answers given is attached.

There were a number of additional points of interest that arose during the meeting that warrant mentioning:

1) The fish screen design had been altered between May 28 and June 17: gates on the ports of the troughs, alarm sensors in the troughs and well, neoprene flaps on the proximal ends of the fish screens; all were added to the proposed design since the May 28 meeting. The Committee was provided with a new set of blueprints dated June 16, 1976.

2) No mechanical blueprints have yet been drawn up.

3) Members of the Engineering Committee commented that the continuous changing of design plans and absence of mechanical plans was an unorthodox procedure.

4) When the Biology Committee indicated they were having considerable difficulty deciding which design plan for the fish screen they were to assess they were told that the design was viable and subject to change. The contract specifications is scheduled for December 1976.

5) Considerable confusion existed about the nature of the bulkhead. When questioned about its operation Mr. Starbuck indicated it would permit cleaning of one screen panel. Mr. Rakowski thought that three panels had to be serviced by the bulkhead at one time due to the overlapping nature of the neoprene flaps on every second screen panel; Mr. DeLapp, BuRec concurred with Mr. Rakowski. A discussion ensued resulting in 1) agreement that three panels had to be serviced at one time; 2) the designs for the bulkhead were incomplete - the bulkhead as designed would be too small to block off passage of water over three panels at one time.

6) No modelling has been performed using water quality and quantity similar to the actual McClusky canal situation.

7) The Biology Committee doubted that the barn cleaner, referred to in Answer 2, could be used because of grade.

8) Considerable discussion existed about the size of the screen panels; Mr. Starbuck believed they were all the same size; Mr. Rakowski pointed out that the blueprints showed the backup screens to be shorter than the main screen; Mr. De Lapp concurred that the backup screen was shorter.

9) In response to a question from Messrs. Steucke and Henegar with respect to Question 7 relating to the procedure for shutting off canal flow, Mr. Starbuck stated there were no turnouts (locations for passage of water through the sides of the canal) between the fish screen and the check gate 9 miles upstream. Therefore, there would be no inadvertent opportunity for canal water to bypass the fish screen into the Sheyenne drainage.

10) Mr. Loch indicated that the Biology Committee believed certain fish juveniles, including American smelt, would pass through the 40 mesh screen. He enquired as to what design changes in the fish screen would be necessary if BuRec decided to employ a smaller mesh screen (eg. 50 or 60 mesh). Mr. Johnson replied that the screen panels would have to be lengthened.

11) Mr. Loch stated that the Biology Committee would use all blueprints and information on the fish screen provided to date in its evaluation. He went on to state that June 17 was the final date for input on the fish screen design and operation; the Committee would not use information provided at a later date in its Impact Assessment report; the Committee would consider additional information for use in its Alternatives and Recommendations report.

Summary

The questions and responses developed at this session suggested several situations to the Biology Committee; namely BuRec had just redesigned some portions of the screen as noted in the revised plans issued. These plans had been revised the day before the meeting. The responses to the questions were, for the most part, pertinent and clear. BuRec personnel were generally helpful and responsive.

The alarm system (question 1) was explained to our satisfaction. We were concerned that no puncture detecting/alarm device is available.

The gutter cleaning operation was not clearly described. A number of alternatives were presented. The major scheme seems to call for someone to scrub the trash from the lower ends of the self-cleaning screens to the gutter and then clean it out of the gutter into some type of conveyance for destruction. The gutter is sloped to a central aperature leading to a pit with a hydraulic basket lift. It appears this was the original method devised for screening (this is the method used at the Weed Seed Screen). However, all trash must be dewatered across a single screen if this cleaning procedure is used.

Rather than subject this screen unit to that type of stress, the pit is now fitted with a sensor which will be activated with a 1' head, shutting down a gutter gate (not in the design) to prevent screen overload. It appeared to the Biology Committee the operation (cleaning the gutters) has been changed to fit the uncomfortableness of the design.

The cleaning and removing of screens is also questionable. The bulkhead to stop weir crest flow is designed too small - the Biology Committee was assured this would change.

The removal of an individual screen suggests it is designed to be removed one end at a time, assuring debris along, or under the gasket, will fall to the lower screen. The physical scraping of the screen appeared to be a questionable procedure: sticks, stones and other detritus may be physically pushed through the screen in this manner.

Other than actual penetration through the screen, the screen gasketing system seems to provide the most probable source of entry into the system. The 4 inch overlap afforded each screen constitutes more than 10 percent of the screen surface without perforation. Water passes down these neoprene surfaces directly to the gutter without being screened. Only alternate screens are gasketed and fit over the contiguous screens. None of the screens are fastened down, and the gaskets must rely on weight and water pressure to hold them firmly in place. No gasket is planned for the trailing edge of the top screen, yet it is the area that <u>all</u> screened material must pass over. It does not appear that the gaskets will remain tight against the screen. It does appear that fish larvae will pass under the gasket and through the screen joints (¼" tolerance by design).

The Biology Committee believes eggs and larvae, as well as fish, will pass over the screen into the gutter. Mr. Johnson and Mr. Starbuck agreed that water will flow continually through the gutter (from wet trash, spray, and water running down the neoprene strips). Mr. Starbuck pointed out that the sensor at the gutter would be placed some 2" above the bottom of the gutter so as not to be activated by this "normal" flow. Water, eggs, larvae, trash, etc. will pass to the collection pit where only a simple screening device keeps the material from entering the canal. The collector pit screen is identical to the large screen, which presumably means it has no gasket at the trailing edge on the top screen. Anything that can crawl or swim in 2 inches of water will likely arrive at this unit.

QUESTIONS AND ANSWERS ON McCLUSKY FISH SCREEN STRUCTURE FROM JUNE 17 MEETING IN DENVER: BIOLOGY COMMITTEE, ENGINEERING COMMITTEE, BuREC (ENGINEERING AND RESEARCH)

QUESTION 1: What monitoring systems, to detect failures in the fish screen complex, are proposed? Details on the type and location of sensors are requested.

ANSWER 1: Three alarms which warn of excessive clogging are included in the design. The first measures differential head accross the trash collector. If the trash collector starts to clog, the water surface will rise on the upstream side of the collector. When the difference in water surface elevation from the upstream to the downstream side of the collector reaches a set point, the alarm would sound. The second alarm will be located in the trash trough near the exit port. The alarm will be activated when the water surface in the trough comes in contact with an electrical probe. This alarm will be located in the auxiliary screen structure. The auxiliary screen filters all flows that pass over the main screens and into the troughs. The probes would be located at the weir above the auxiliary screens and would be positioned so that the alarm would be activated if the flow over the weir is greater than 1 foot deep (this corresponds to a discharge of 27 ft^3/s or 50% of capacity). With the sounding of this alarm, automatic shutdown of the canal would begin. Puncture damage of the screens would be detected solely by visual observation.

QUESTION 2: What is the mechanism to control flows from the trash trough into the cleanout chambers? What are the design and operational considerations for the collection conduit and the auxiliary screen structure? Is it possible for the head to build up on the auxiliary screen due to debris plugging the screen to overstress the screen?

ANSWER 2: As now planned, trash would be manually moved from the trash trough to the clean out chambers. If debris quantities were found to be excessive, an endless belt-type barn cleaner could be used to move the debris.

The collection conduit and auxiliary screen are designed to pass a maximum discharge of 54 ft^3/s. Structurally the auxiliary screens are identical to the main screens. Each screen panel was designed for a static load of 1.75 ft of water with a factor of safety of approximately 3. The slide gates which control drainage of flow from the trash trough to the auxiliary screen automatically close when flow to the auxiliary screen reaches 50% of the auxiliary screen's capacity. The slide gates will be designed to close in less than 3 minutes. Thus the screens would have to plug almost instantaneously if head build up and screen stress were to become problems.

QUESTION 3: What is the daily load of canal detritus material expected to be collected on the fish screen? How will this material be removed from the screen and where and how will this material be disposed of?

ANSWER 3: The daily load is unknown. All detritus will be removed from the collection baskets, well, main screens and trough and disposed of. As of now it is expected that the debris removed will be placed in a closed basin where it will be spread and dried. When dry it would be either burned or buried. Operating procedures have not yet been defined but disposal will be likely in a pit nearby but in the Missouri River drainage upstream from the fish screen. Disposal will likely be via truck into a pit. There were some discussions about using the detritus as fish food but these were speculative and preliminary.

QUESTION 4: What procedures are proposed for cleaning a clogged screen? Explain in detail what monitoring devices will be used to alert O&M forces that a screen is plugged. How will screen section be unwatered? How will screen be removed and replaced?

ANSWER 4: A hinged 3 sided bulkhead secured to the ceiling will be lowered and surround the clogged screen and two adjoining screens. The bulkhead will be butted against the weir wall and will have neoprene flaps; this will cause water to pass around the bulkhead. Debris will be removed from the screens in place by using water spray and/or brushing. Screens will then be put back into operation at this point if adequately cleaned. Seal regions will be cleaned to make sure no loose debris falls through when screens are removed. If it is necessary to remove a clogged screen panel it will be lifted via an overhead hoist. The eye bolt on the screen panel is located off-centre such that when it is lifted it will hang obliquely rather than horizontally which could permit detritus to fall from it onto second screen. The screens would be replaced with previously cleaned screens. The bulkhead can then be raised and the screens put back into operation. The clogged screens can then be either cleaned inside the structure or on the surface. The monitoring device that alerts O&M forces is discussed in the answer to question 1. The most important alarm in this respect is the one in the trash trough. As the screens start to clog, small quantities of flow will enter the trough. By having the alarm sound when flows in the trough are small, the O&M forces are given adequate time to clean the screens.

QUESTION 5: Explain the jointing details of the neoprene seals between adjacent screen sections.

ANSWER 5: Screens are sealed with 4" neoprene covers at each joint. Alternate screens lie over its adjacent screen - therefore every other screen has no gasket on its sides, hence the necessity of removing three screens to get at a single unit. A similar gasket is located along the screen edge at the weir crest, but none is located at the trailing edge (gutter) on the top screen.

QUESTION 6: What rate of flow is required to ensure that collected material is flushed from the screens into the troughs?

ANSWER 6: It is intended that no flushing occur but rather that detritus be pushed down the incline into the trough.

QUESTION 7: What is the sequence of events proposed in the event of complete clogging of the screens? This should include canal shutdown sequence, structure dewatering procedure, and cleaning and replacement of screen sections.

ANSWER 7: In the event of severe clogging the following would occur: the alarms would sound; the slide gates that control drainage from the trash troughs would automatically close; the radial gates at upstream checks would automatically close; the pumps at Snake Creek Pumping Plant would automatically turn off; stop logs would be placed at the upstream end of the screen structure; the structure would be pumped out (returning the water to the canal upstream of the structure); screens would be cleaned and replaced as previously described.

QUESTION 8: What provisions are incorporated into maintenance procedure to ensure no accidental transfer of waterborne material across the Fish Screen Structure?

ANSWER 8: NONE - no O&M procedures manual yet.

QUESTION 9: It is understood that a traveling water screen is proposed between the trashracks and the screens. When is it expected that this facility will be installed? What are the general design details of such a screen?

ANSWER 9: Because of economic reasons it is hoped this will not be necessary. General design details are not available. However, the structure has been designed to accept traveling water screens if needed. Such screens would be placed just downstream of the trash collector. Because of limited head loss that could be tolerated, a 4-mesh screen is the finest that could be used. This traveling screen would be similar in design to those manufactured by Link-Belt, Colmar, Pennsylvania 18915; and Envirex, Milwaukee, Wisconsin 53201.

June 17, 1976: Meeting of IJC Committees and Bureau Personnel; Room 1050, E&R Center, Denver, Colorado, Re McClusky Fish Screen.

Forrest Ritchey	USBR - Denver - E&R Center	Canals and Bridges
Don Mountjoy	USBR - Denver - E&R Center	Mech. Gate & Valves
J. Art DeLapp	USBR - Denver - E&R Center	Mech. Gate & Valves
Phil Nelson	USBR - Denver - E&R Center	Mech. Br.
Warren Thomas	USBR - Denver - E&R Center	Mech. Br.
John Starbuck	USBR - Denver - E&R Center	Canals & Diversion Structures
Perry Johnson	USBR - Denver - E&R Center	Hydraulics Branch
John Kuall	USBR - Bismarck - E&R Center	Water and Land
James A. Rawlings	USBR - Billings	Water and Land Division
Ben A. Prichard	USBR - Denver - E&R Center	Water O&M Division
Howard M. Olson	NDSU - Carrington	IJC Garrison Study Board
Sam Shimamoto	USBR - Billings	Water Operations
Tom Weber	Prov. of Manitoba - Winnipeg	IJC Garrison Study Board
Louis Kowalski	Corpos of Engineers - St. Paul, Minn.	
Pat Rakowski	CWS - Winnipeg	Biology Committee - IJC
John Loch	F&MS - Winnipeg	Biology Committee - IJC
Steve Lanich	U.S. EPA - Denver	Engineering Committee - IJC
George Balacko	Prov. of Manitoba - Winnipeg	Engineering Committee - IJC
John Bathurst	DOE - Hull	Engineering Committee - IJC
Peter L. Balkan	Soil Cons. Service - Bismarck	Engineering Committee - IJC
John C. Peters	USBR - Denver - E&R Center	Biology Committee - IJC
Fred Hunt	USBR - Billings	Engineering Committee - IJC
Andy Hamilton	F&MS - Winnipeg	IJC Garrison Study Board
Tom Dafoe	EPS - Winnipeg	Engineering Committee - IJC
Wally Steucke	F&WS - Bismarck	Biology Committee - IJC
Dale Henegar	NDGF - Bismarck	Biology Committee - IJC

Attachment C.II-3

Trip Report –
Inclined Screen Tour
Columbia River Basin

TRIP REPORT

INCLINED SCREEN TOUR

COLUMBIA RIVER BASIN

WASHINGTON AND OREGON

The following personnel participated in the inclined screen tour in the Columbia Basin on June 1-3, 1976: Sam Shimamota, O&M, BuRec, Billings, Montana; Dale Henegar, Biology Committee; Wally Steucke, Biology Committee; John Loch, Biology Committee; John Peters, Biology Committee; and George Balacko, Engineering Committee.

June 1, 1976

Toured Whitestone Coulee inclined weedseed screen, Chief Joseph Dam Project and drum screen at the inlet works main Oroville - Tonasket Canal, Washington with Don Fillis and Wm. Melander, Bureau of Reclamation. Overflew BuRec's Columbia Basin Project to view Crab Creek, Esquitzel Coulee Waterways and other project features in operation (Pilots Dale Major and Wm. Ryder). Flew on to Portland, Oregon.

The inclined weedseed screen was at the terminal of the Spectacle Lake canal. The canal was designed to carry 40 cfs maximum. Canal water passed through a trashrack with vertical clearances of approximately 2½ inches. Water then entered a collecting basin; level in basin being controlled by stop logs. The water then passed over a weir crest off to the side over a drop of 6" and then through a set of screens (3 - 40 mesh, 7 - 18 mesh). Screens were approximately 3' x 7'; the 40 mesh screens were stainless steel and the 18 mesh screens were nylon (window screen). The water that passed through the screen was collected in a basin and then on into the canal.

The detritus that collected on the screens moved down the screen into a gutter. Some water passed over the screen (mostly over the 40 mesh screen) into the gutter to transport the detritus. The origin of this water was primarily via passage of water directly over and along the mouldings of the 40 mesh screens; in addition some water passed over one of the 18 mesh screens and along these mouldings as well. However this volume of water was insufficient to carry the detritus into and down the gutter. Therefore a plank was used at the front of the screens to permit additional water to pass directly into the gutter.

The Committee was informed that initially the 40 mesh screens were seated below the lip of the gutter such that the detritus would not be passively carried by water into the gutter. However, in operating the screens it became apparent that passive transport of detritus down the screen and into the gutter was desirable. This necessitated raising the seat for the screens such that they were flush with the gutter lip. The Committee observed that all of the 18 mesh screens were being installed flush with the gutter.

The Committee became aware a number of problems had arisen. Last year the trashrack had clogged after a storm and the canal water had flooded and bypassed the entire structure causing severe erosion. In addition while the Committee was on site the 40 mesh screens were being replaced with 18 mesh screens due to clogging of the screens.* Committee members observed a small amount of algal growth (probably diatoms and green algae) on the screen and enquired about problems associated with algal clogging. The Committee was informed that during the summer months

* Since our visit the 18 mesh screens were replaced again with 40 mesh screen.

drift of filamentous algae from Spectacle Lake collects on the screens. This proved to be a significant problem requiring more than twice daily hand scrubbing. Twice daily inspection (and cleaning if necessary) was the standard operating procedure.

The revolving drum fish screen at the inlet works for the main Oroville - Tonasket Canal inlet works was viewed by the Committee. The screen seemed to be functioning properly. However the seals on the revolving drum screens were worn away thereby permitting some fish passage. The Committee was impressed with the amount of sediment that had been dredged from the canal in front of the screen.

The Committee also had an opportunity in its flight from Omak down the Columbia River to see a large irrigation project in full operation.

June 2, 1976

Met with Charles Wagner and Richard Weaver, National Marine Fisheries Service, Portland, Oregon, to discuss inclined screens designed and built by NMFS in the Willamette River Basin. Received a bibliography on inclined screens. Discussed fish passage problems associated with GDU and design of McClusky fish screen with NMFS personnel. Travelled with Charles Wagner, NMFS to West Linn, Oregon, in vicinity of Williamette Falls to see inclined screen built by Crown Zellerbach Corporation.

The screen is used to filter debris from river water. The filtered water used goes through a sand filter and is used to produce paper. Pressure nozzles at 75#/sq in tip pressure at each sprinkler head was used to effectively clean algae and debris from the screen. The screens were checked at least once a year normally during the Christmas holidays. Mr. Robert Geyser of Crown Zellerbach was the host for the screening and fish passage facilities in vicinity of the West Linn plant. Discussions with plant personnel revealed that holes were formed in the inclined screen due to rusting out. The Committee felt that more regular checks for screen wear would alleviate this problem.

June 3, 1976

The group travelled with Chuck Wagner, NMFS, to Corp of Engineer, Green Peter Dam, South Santiam River, Oregon, to view "humpback" inclined screens designed to filter out reservoir debris in conjunction with downstream migrant fish passage facilities. Approximately 190 to 200 cfs of water is used in fish passage is filtered by the "humpback" inclined screen. A perforated plate with ¼" openings is used to screen the 200 cfs required to operate the downstream migrant fish passage facilities.

The group also, visited the Fall Creek Dam, Fall Creek, Oregon, to view another "humpback" inclined screen. A perforated plate with ¼" opening is used to screen 300 cfs required to operate the downstream migrant fish passage facilities. About 90 percent of the flow (i.e. 270 cfs) is filtered by the screen.

Both the "humpback" inclined screens were judged effective by the NMFS for downstream passage. They are designed to filter about 90 percent of the flow used to pass downstream migrants.

Attachment C.II-4

List of Fish Species[1] Occurrences in Various Areas within the Biology Committee Study Area

Attachment | Page

[1]List of fishes is by common name alone; scientific names are in Attachment C.II-6.

Attachment C.II-4.1 List of fishes in North and South Dakota in the Missouri River drainage, including the James River.

Common name	Missouri River		James River		References[3]
	Sakakawea	Oahe	Upper[1]	Lower[2]	
Pallid sturgeon	x	x			2,3
Shovelnose sturgeon	x	x		x	2,3,4
Paddlefish	x	x			2,3
Shortnose gar	x	x		x	1,2,3
Gizzard shad		x[2]		x	1,3
Goldeye	x	x		x	1,2,3
Lake whitefish	x				3
Coho salmon	x				3
Rainbow trout	x				2,3
Brown trout	x				2,3
Lake trout	x				3
Rainbow smelt	x				3
Northern pike	x	x	x	x	1,2,3
Sturgeon chub		x			2
Lake chub	x				2,3
Stoneroller				x	1,3
Carp	x	x	x	x	1,2,3
Brassy minnow	x			x	1,3
Silvery minnow	x			x	3
Flathead chub	x	x			2,3
Hornyhead chub				x	3
Silverband minnow		x			2
Golden shiner	x	x	x	x	1,2,3
Emerald shiner	x	x	x		2,3
River shiner		x	x		2,3
Common shiner			x	x	1,3
Bigmouth shiner				x	1
Blacknose shiner				x	1,3
Spottail shiner				x	1,3
Red shiner	x			x	1,3
Sand shiner	x		x	x	1,3
Topeka shiner				x	1
Bluntnose minnow				x	3
Fathead minnow	x	x	x	x	1,2,3
Blacknose dace		x		x	1,2,3
Creek chub	x	x	x	x	1,2,3
Pearl dace	x				2,3
River carpsucker	x	x		x	1,2,3
Quillback	x				2,3
Longnose sucker	x				2,3
White sucker	x	x	x	x	1,2,3
Blue sucker	x	x			2,3
Smallmouth buffalo	x	x	x	x	1,2,3
Bigmouth buffalo	x	x	x	x	1,2,3

Attachment C.II-4.1 (cont'd)

Common name	Missouri River Sakakawea	Missouri River Oahe	James River Upper[1]	James River Lower[2]	References[3]
Shorthead redhorse	x	x	x	x	1,2,3
Black bullhead	x	x	x	x	1,2,3
Brown bullhead				x	3
Yellow bullhead				x	3
Channel catfish	x	x		x	1,2,3
Blue catfish		x			2
Stonecat	x	x			2,3
Tadpole madtom	x			x	1,3
Flathead catfish	x	x			2,3
Burbot	x	x			2,3
Plains topminnow				x	1
Brook stickleback	x		x	x	3
White bass	x	x	x		2,3
Green sunfish		x		x	1,2
Pumpkinseed	x			x	1,2,3
Orangespotted sunfish	x	x	x	x	1,2,3
Bluegill	x	x	x		2,3
Smallmouth bass	x				3
Largemouth bass		x		x	1,2
White crappie	x	x		x	1,2,3
Black crappie	x	x	x	x	1,2,3
Crappie spp.	x				3
Iowa darter	x		x	x	1,3
Johnny darter	x		x	x	1,3
Yellow perch	x	x	x	x	1,2,3
Blackside darter				x	3
Sauger	x	x			2,3
Walleye	x	x	x	x	1,2,3
Freshwater drum	x	x		x	1,2,3

[1]The upper and lower James River refer to the stretches of river above and below Jamestown Dam, respectively.

[2]Carufel and Witt (1963) reported one gizzard shad in the Missouri River 2.5 miles below Garrison Dam.

[3]References:
1. Bailey and Allum (1962).
2. Benson (1968).
3. Owen and Russell (1975a).
4. Zweiacker (1967).

Attachment C.II-4.2 List of fishes in the Red River drainage in Minnesota and North Dakota.

Common name	Reference[1]
Chestnut lamprey	2,3
Lake sturgeon	3
Longnose gar[2]	3
Bowfin	3
Mooneye	3
Goldeye	3
Lake herring	3
Lake whitefish	3
Brown trout	3
Rainbow trout	2,3
Brook trout	3
Quillback	2,3
White sucker	1,2,3
Silver redhorse	3
Shorthead redhorse	2,3
Greater redhorse	2,3
Golden redhorse	3
Goldfish	2
Carp	1,2,3
Lake chubsucker	2
Bigmouth buffalo	1,2
Golden shiner	2,3
Northern creek chub	2,3
Northern pearl dace	3
Finescale dace	3
Northern redbelly dace	3
Hornyhead chub	3
Silver chub	3
Blacknose dace	2,3
Longnose dace	2,3
Emerald shiner	2,3
Rosyface shiner	2,3
River shiner	3
Spottail shiner	2,3
Weed shiner	3
Blackchin shiner	3
Bigmouth shiner	2,3
Sand shiner	2,3
Mimic shiner	3
Spotfin shiner	2,3
Blacknose shiner	2,3
Pugnose shiner	2,3
Common shiner	2,3
Brassy minnow	2,3
Silvery minnow	2
Fathead minnow	1,2,3

Attachment C.II-4.2 (cont'd)

Common name	Reference[1]
Bluntnose minnow	2,3
Stoneroller	3
Black bullhead	1,2,3
Brown bullhead	2,3
Channel catfish	2,3
Stonecat	2
Tadpole madton	1,2,3
Central mudminnow	3
Northern pike	1,2,3
Muskellunge	2
Western banded killifish	2,3
Trout-perch	1,2,3
Burbot	3
Brook stickleback	1,2,3
Yellow perch	1,2,3
Walleye	1,2,3
Sauger	2
Northern logperch	3
River darter	3
Blackside darter	2,3
Johnny darter	2,3
Iowa darter	2,3
Least darter	3
Smallmouth bass	1,2,3
Largemouth bass	2,3
White bass	2
Rock bass	2,3
Green sunfish	2,3
Bluegill	1,2,3
Pumpkinseed	1,2,3
Orangespotted sunfish	2,3
White crappie	2,3
Black crappie	1,2,3
Crappie sp.	2
Freshwater drum	1,2,3
Mottled sculpin[3]	

[1]References: 1. Owens and Russell (1975a).
2. Owens and Russell (1975b).
3. Eddy et al. (1972).

[2]Reported for Otter Tail River in 19th century, but Eddy et al. (1972) suggested its removal from faunal list of the Red River drainage until supporting specimens are found.

[3]No reported incidence in the Red River drainage, but Eddy et al. (1972) suspect its presence there.

Attachment C.II-4.3 List of fishes occurring or believed to occur in the Assiniboine River drainage in North Dakota and Manitoba.

Common name	Souris River North Dakota	Souris River Manitoba	Assiniboine River and other tributaries in Manitoba	References[1]
Chestnut lamprey			x	4,5
Lake sturgeon			x	5
Rainbow trout		x	x	2,5
Brook trout		x		5
Lake herring			x	5
Lake whitefish			x	5
Goldeye		x	x	5
Mooneye			x	5
Central mudminnow	x			3
Northern pike	x	x	x	1,2,3,4,5
Lake chub		x	x	5
Carp		x	x	1,4,5
Brassy minnow	x	x	x	3,4,5
Silver chub			x	4,5
Flathead chub		x	x	2,5
Hornyhead chub	x			3
Golden shiner	x	x	x	3,5
Pugnose shiner		x		2
Emerald shiner	x	x	x	3,5
River shiner		x	x	2,5
Common shiner	x	x	x	2,3,4,5
Bigmouth shiner	x			3
Blackchin shiner		x		2
Blacknose shiner		x	x	5
Spottail shiner	x	x	x	2,3,5
Sand shiner		x	x	4,5
Mimic shiner			x	5
Northern redbelly dace	x			3
Bluntnose minnow	x		x	3,5
Fathead minnow	x	x	x	2,3,4,5
Blacknose dace	x	x	x	3,5
Longnose dace		x	x	2,4,5
Creek chub	x	x	x	2,3,4,5
Pearl dace	x	x	x	3,4,5
River carpsucker	x			3
Quillback			x	5
Longnose sucker	x	x	x	3,5
White sucker	x	x	x	1,2,3,4,5
Bigmouth buffalo			x	5
Silver redhorse		x	x	5
Shorthead redhorse		x	x	1,2,5
Black bullhead	x	x	x	2,3,4,5

Attachment C.II-4.3 (cont'd)

Common name	Souris River North Dakota	Souris River Manitoba	Assiniboine River and other tributaries in Manitoba	References[1]
Brown bullhead	x	x	x	3,4,5
Channel catfish			x	5
Tadpole madtom	x	x	x	3,5
Trout-perch	x	x	x	2,3,4,5
Burbot		x	x	5
Brook stickleback	x	x	x	2,3,4,5
Ninespine stickleback		x	x	4,5
Rock bass			x	1,4,5
Smallmouth bass	x	x		3,5
White crappie	x			3
Black crappie	x		x	3,5
Crappie sp.	x			3
Iowa darter	x	x	x	2,3,4,5
Johnny darter	x	x	x	2,3,4,5
Yellow perch	x	x	x	1,2,3,4,5
Blackside darter	x	x	x	2,3,4,5
River darter			x	5
Sauger		x	x	1,5
Walleye	x	x	x	1,2,3,5
Log perch			x	5
Freshwater drum			x	5
Mottled sculpin			x	5
Slimy sculpin		x	x	4,5
Spoonhead sculpin			x	5

[1]References:
1. W. Howard, personal communication.
2. Manitoba Museum of Man and Nature collections - Souris River.
3. Owens and Russell (1975c) - Souris River in North Dakota.
4. Royal Ontario Museum collections - Assiniboine and Souris rivers, Manitoba.
5. Scott and Crossman (1973).

Attachment C.II-4.4 List of fishes in Lake Manitoba and its tributaries, Lake Winnipeg and the Red River in Manitoba.

Common name	Red River	Lake Winnipeg S Basin	Lake Winnipeg N Basin	L Man.	References[1]
Chestnut lamprey	x	x		x	5,6
Silver lamprey	x	x	x		6
Lake sturgeon	x	x	x	x	6
Rainbow trout	x	x	x	x	3,6
Brook trout	x				5,6
Lake trout	x	x	x	x	6
Lake herring	x	x	x	x	3,6,7
Blackfin cisco		x	x	x	5,6
Shortjaw cisco		x	x		5,6
Lake whitefish	x	x	x	x	3,6,7
Goldeye	x	x	x	x	3,5,6,7
Mooneye	x	x	x	x	5,6
Central mudminnow	x	x	x		6
Northern pike	x	x	x	x	2,3,4,5,6,7
Lake chub	x	x	x	x	3,6
Carp	x	x	x	x	1,2,3,5,6,7
Brassy minnow	x				5,6
Silvery minnow	x				6
Silvery chub	x				5,6
Golden shiner	x	x	x	x	5,6
Emerald shiner	x	x	x	x	1,2,3,5,6,7
River shiner	x	x	x	x	5,6
Common shiner	x			x	4,5,6,7
Bigmouth shiner	x				5,6
Blacknose shiner	x	x	x	x	3,5,6
Spottail shiner	x	x	x	x	1,2,3,5,6,7
Rosyface shiner	x				6
Sand shiner	x	x			5,6
Mimic shiner	x	x	x	x	5,6
Bluntnose minnow	x				5,6
Fathead minnow	x	x	x	x	2,3,4,5,6,7
Flathead chub	x	x	x	x	5,6
Blacknose dace	x	x	x	x	5,6
Longnose dace	x	x	x	x	3,5,6,7
Creek chub	x	x	x	x	2,5,6
Pearl dace	x	x	x	x	3,5,6
Quillback	x	x	x	x	1,2,3,6,7
Longnose sucker	x	x	x	x	3,5,6
White sucker	x	x	x	x	1,2,3,4,5,6,7
Bigmouth buffalo	x				6
Silver redhorse	x	x	x	x	5,6,7
Shorthead redhorse	x	x	x	x	1,3,5,6,7
Black bullhead	x			x	2,4,5,6,7
Brown bullhead	x	x	x	x	2,3,5,6,7

Attachment C.II-4.4 (cont'd)

Common name	Red River	Lake Winnipeg S Basin	Lake Winnipeg N Basin	L Man.	References[1]
Channel catfish	x	x	x	x	2,3,5,6
Stonecat	x				5,6
Tadpole madtom	x	x		x	2,5,6
Banded killifish	x				5,6
Burbot	x	x	x	x	3,5,6,7
Brook stickleback	x	x	x	x	2,4,5,6,7
Ninespine stickleback	x	x	x	x	2,3,5,6,7
Trout-perch	x	x	x	x	1,2,3,5,6,7
White bass		x			6
Rock bass	x	x	x		3,5,6
Smallmouth bass	x	x			4,6
Largemouth bass	x				6
Black crappie	x	x			5,6
Yellow perch	x	x	x	x	1,2,3,4,5,6,7
Sauger	x	x	x	x	1,2,3,6,7
Walleye	x	x	x	x	1,2,3,5,6,7
Iowa darter	x	x	x	x	3,4,5,6
Johnny darter	x	x	x	x	2,3,4,5,6,7
Logperch	x	x	x	x	3,5,6,7
Blackside darter	x	x			4,5,6
River darter	x	x	x	x	5,6
Freshwater drum	x	x	x	x	1,2,3,5,6,7
Mottled sculpin	x	x	x	x	1,5,6
Slimy sculpin	x	x	x	x	3,5,6
Spoonhead sculpin	x	x	x	x	5,6

References:
1. Doan and Andrews (1964).
2. J. Gee, personal communication.
3. D. Gillies, personal communication.
4. Manitoba Museum of Man and Nature Collections.
5. Royal Ontario Museum.
6. Scott and Crossman (1973).
7. A. Storimans, personal communication.

Attachment C.II-5

List of Fish Species[1] Occurring in
Hudson Bay Drainage but not in the
Upper Missouri River Drainage

[1]List of fishes is by common name alone; scientific names are in Attachment C.II-6.

Attachment C.II-5 List of fish species occurring in Hudson Bay Drainage but not it the Upper Missouri River Drainage.

Common name	Common name
Silver lamprey	Silver redhorse
Lake sturgeon	Trout-perch
Lake herring	Ninespine stickleback
Blackfin cisco	Logperch
Shortjaw cisco	River darter
Mooneye	Mottled sculpin
Mimic shiner	Slimy sculpin
Rosyface shiner	Spoonhead sculpin
Longnose dace	

Attachment C.II-6

Accepted common and scientific names of fishes occurring in watersheds under study by the Biology Committee

Attachment C.II-6 Accepted[1] common and scientific names of fishes occurring in watersheds under study by the Biology Committee.

Common name	Family	Scientific name
	Petromyzontidae	
Chestnut lamprey		*Ichthyomyzon castaneus* Girard
Silver lamprey		*Ichthyomyzon unicuspis* Hubbs and Trautman
	Acipenseridae	
Lake sturgeon		*Acipenser fulvescens* Rafinesque
Pallid sturgeon		*Scaphirhynchus albus* (Forbes and Richardson)
Shovelnose sturgeon		*Scaphirhynchus platorynchus* (Rafinesque)
	Polyondontidae	
Paddlefish		*Polyodon spathula* (Walbaum)
	Lepisosteidae	
Longnose gar		*Lepisosteus osseus* (Linnaeus)
Shortnose gar		*Lepisosteus platostomus* Rafinesque
	Amiidae	
Bowfin		*Amia calva* Linnaeus
	Clupeidae	
Gizzard shad		*Dorosoma cepedianum* (Lesueur)
	Hiodontidae	
Goldeye		*Hiodon alosoides* (Rafinesque)
Mooneye		*Hiodon tergisus* Lesueur
	Salmonidae	
Cisco (lake herring)		*Coregonus artedii* Lesueur
Lake whitefish		*Coregonus clupeaformis* (Mitchill)
Blackfin cisco		*Coregonus nigripinnis* (Gill)

(cont'd...)

Attachment C.II-6 (cont'd)

Common name	Family	Scientific name
	Salmonidae (cont'd.)	
Shortjaw cisco		*Coregonus zenithicus* (Jordon and Evermann)
Coho salmon		*Oncorhynchus kisutch* (Walbaum)
Sockeye salmon (Kokanee)		*Oncorhynchus nerka* (Walbaum)
Mountain whitefish		*Prosopium williamsoni* (Girard)
Goldon trout		*Salmo aquabonita* Jorden
Cutthroat trout		*Salmo clarki* Richardson
Rainbow trout		*Salmo gairdneri* Richardson
Brown trout		*Salmo trutta* Linnaeus
Brook trout		*Salvelinus fontinalis* (Mitchill)
Dolly Varden		*Salvelinus malma* (Walbaum)
Lake trout		*Salvelinus namaycush* (Walbaum)
Arctic grayling		*Thymallus arcticus* (Pallas)
	Osmeridae	
Rainbow smelt		*Osmerus mordax* (Mitchill)
	Umbridae	
Central mudminnow		*Umbra limi* (Kirtland)
	Esocidae	
Northern pike		*Esox lucius* Linnaeus
Muskellunge		*Esox masquinongy* Mitchill
	Cyprinidae	
Stoneroller		*Campostoma anomalum* (Rafinesque)
Goldfish		*Carassius auratus* (Linnaeus)
Lake chub		*Couesius plumbeus* (Agassiz)
Carp		*Cyprinus carpio* Linnaeus
Brassy minnow		*Hybognathus hankinsoni* Hubbs
Silvery minnow		*Hybognathus nuchalis* Agassiz
Plains minnow		*Hybognathus placitus* Girard

(cont'd...)

Attachment C.II-6 (cont'd)

Common name	Family	Scientific name
	Cyprinidae (cont'd.)	
Sturgeon chub		*Hybopsis gelida* (Girard)
Flathead chub		*Hybopsis gracilis* (Richardson)
Silver chub		*Hybopsis storeriana* (Kirtland)
Hornyhead chub		*Nocomis biguttatus* (Kirtland)
Golden shiner		*Notemigonus crysoleucas* (Mitchill)
Pugnose shiner		*Notropis anogenus* Forbes
Emerald shiner		*Notropis atherinoides* Rafinesque
River shiner		*Notropis blennius* (Girard)
Common shiner		*Notropis cornutus* (Mitchill)
Bigmouth shiner		*Notropis dorsalis* (Agassiz)
Blacknose shiner		*Notropis heterolepis* Eigenmann and Eigenmann
Spottail shiner		*Notropis hudsonius* (Clinton)
Red shiner		*Notropis lutrensis* (Baird and Girard)
Rosyface shiner		*Notropis rubellus* (Agassiz)
Silverband shiner [2]		*Notropis shumardi* (Girard)
Spotfin shiner		*Notropis spilopterus* (Cope)
Sand shiner		*Notropis stramineus* (Cope)
Weed shiner		*Notropis texanus* (Girard)
Topeka shiner		*Notropis topeka* Gilbert
Mimic shiner		*Notropis volucellus* (Cope)
Northern redbelly dace		*Phoxinus eos* (Cope)
Finescale dace		*Phoxinus neogaeus* Cope
Bluntnose minnow		*Pimephales notatus* Rafinesque
Fathead minnow		*Pimephales promelas* (Rafinesque)
Blacknose dace		*Rhinichthys atratulus* (Hermann)
Longnose dace		*Rhinichthys cataractae* (Valenciennes)
Redside Shiner		*Richardsonius balteatus* (Richardson)
Creek chub		*Semotilus atromaculatus* (Mitchill)
Pearl dace		*Semotilus margarita* (Cope)
Utah chub		*Gila atraria* (Girard)
Blackchin shiner		*Notropis heterodon* (Cope)

(cont'd...)

Attachment C.II-6 (cont'd)

Common name	Family	Scientific name
	Catostomidae	
River carpsucker		*Carpiodes carpio* (Rafinesque)
Quillback		*Carpiodes cyprinus* (Lesueur)
Longnose sucker		*Catostomus catostomus* (Forster)
White sucker		*Catostomus commersoni* (Lacépède)
Mountain sucker		*Catostomus platyrhynchus* (Cope)
Blue sucker		*Cycleptus elongatus* (Lesueur)
Lake chubsucker		*Erimyzon sucetta* (Lacépède)
Smallmouth buffalo		*Ictiobus bubalus* (Rafinesque)
Bigmouth buffalo		*Ictiobus cyprinellus* (Valenciennes)
Silver Redhorse		*Moxostoma anisurum* (Rafinesque)
Golden redhorse		*Moxostoma erythrurum* (Rafinesque)
Shorthead redhorse		*Moxostoma macrolepidotum* (Lesueur)
Greater redhorse		*Moxostoma valenciennesi* Jorden
	Ictaluridae	
Blue catfish		*Ictalurus furcatus* (Lesueur)
Black bullhead		*Ictalurus melas* (Rafinesque)
Yellow bullhead		*Ictalurus natalis* (Lesueur)
Brown bullhead		*Ictalurus nebulosus* (Lesueur)
Channel catfish		*Ictalurus punctatus* (Rafinesque)
Stonecat		*Noturus flavus* Rafinesque
Tadpole madtom		*Noturus gyrinus* (Mitchill)
Flathead catfish		*Pylodictis olivaris* (Rafinesque)
	Percepsidae	
Trout-perch		*Percopsis omiscomaycus* (Walbaum)
	Gadidae	
Burbot		*Lota lota* (Linnaeus)

(cont'd...)

Attachment C.II-6 (cont'd)

Common name	Family	Scientific name
	Cyprinodontidae	
Banded killifish		*Fundulus diaphanus* (Lesueur)
Plains killifish		*Fundulus kansae* Garman
Plains topminnow		*Fundulus sciadicus* Cope
	Poeciliidae	
Shortfin molly		*Poecilia mexicanna* Steindachmer
Green swordtail		Xiphopnorus (Gunther)
Variable platyfish		*Xiphophorus variatus* (Meek)
	Gasterodteidae	
Brook stickleback		*Gulaea inconstans* (Kirtland)
Ninespine stickleback		*Pungitius pungitius* (Linnaeus)
	Perichtyidae	
White bass		*Morone chrysops* (Rafinesque)
	Centrarchidae	
Rock bass		*Ambloplites rupestris* (Rafinesque)
Green sunfish		*Lepomis cyanellus* Rafinesque
Pumpkinseed		*Lepomis gibbosus* (Linnaeus)
Orangespotted sunfish		*Lepomis humilis* (Girard)
Bluegill		*Lepomis macrochirus* Rafinesque
Smallmouth bass		*Micropterus dolomieui* Lacépède
Largemouth bass		*Micropterus salmoides* (Lacépède)
White crappie		*Pomoxis annularis* Rafinesque
Black crappie		*Pomoxis nigromaculatus* (Lesueur)
	Percidae	
Iowa darter		*Etheostoma exile* (Girard)
Least darter		*Etheostoma microperca* Jordan and Gilbert

(cont'd...)

Attachment C.II-6 (cont'd)

Common name	Family	Scientific name
	Percidae (cont'd.)	
Johnny darter		*Etheostoma nigrum* Rafinesque
Yellow perch		*Perca flavescens* (Mitchill)
Logperch		*Percina caprodes* (Rafinesque)
Blackside darter		*Percina maculata* (Girard)
River darter		*Percina shumardi* (Girard)
Sauger		*Stizostedion canadense* (Smith)
Walleye		*Stizostedion vitreum vitreum* (Mitchill)
	Sciaenidae	
Freshwater drum		*Aplodinotus grunniens* Rafinesque
	Cottidae	
Mottled sculpin		*Cottus bairdi* Girard
Slimy sculpin		*Cottus cognatus* Richardson
Spoonhead sculpin		*Cottus ricei* (Nelson)

[1]American Fisheries Society. 1970. A list of common and scientific names of fishes from the United States and Canada, 3rd ed. R.M. Builey Editor. Special Publication No. 6, September 1970. 150 pp.

[2]Also called the silver band minnow; formerly *N. illecebrosus*.

Attachment C.II-7

Ichthyoparasites of Manitoba

by

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ICHTHYOPARASITES OF MANITOBA

PART 1

PROTOZOA

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
CNIDOSPORIDIA				
Chloromyxum catostomi	Catostomus commersoni	gall bladder	Lake of the Woods	Dechtiar 1972
C. gibbosum	Lepomis gibbosus	"	"	"
Henneguya acuta	Esox masquinongy	gills	"	"
H. sp.	Coregonus artedii	"	"	"
Myxobolus asburni	Micropterus dolomieui	mesenteries	"	"
M. conspicuus	Chrosomus neogaeus	skin	"	"
M. intestinalis	Pomoxis nigromaculatus	intestine wall	"	"
M. percae	Perca flavescens	eye	"	"
M. sp.	Ambloplites rupestris	intestine wall	"	"
M. sp.	Cottus bairdi	gills	"	"
M. sp.	Etheostoma exile	intestine wall	"	"
M. sp.	E. nigrum	muscle	"	"
M. sp.	Ictalurus nebulosus	gills	"	"
M. sp.	Lepomis gibbosus	connective tissue	"	"
M. sp.	Lota lota	gills	"	"
M. sp.	Moxostoma anisurum	"	"	"
M. sp.	M. erythrurum	"	"	"
M. sp.	Noturus gyrinus	"	"	"
M. sp.	Percina caprodes	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 1

PROTOZOA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
CNIDOSPORIDIA (cont'd.)				
Myxobolus sp.	Pungitius pungitius	gills	Lake of the Woods	Dechtiar 1972
M. sp.	Rhinichthys cataractae	"	"	"
M. sp.	Semotilus margarita	"	"	"
M. catostomi	Catostomus commersoni	muscle	"	"
Myxosoma bibullatum	C. commersoni	"	"	"
M. grandis	Notropis hudsonius	liver	"	"
M. procerum	Percopsis omiscomaycus	gills	"	"
M. rotundum	Carpiodes cyprinus	"	"	"
Nosema pimephales	Pimephales notatus	internal organs, muscle	"	"
N. pimephales	P. promelas	muscle	"	"
CILIATA				
Epistylis sp.	Etheostoma exile	gills	"	"
Ichthyophthirius multifiliis	Catostomus commersoni	skin	"	"
I. multifiliis	Perca flavescens	"	"	"
Trichodina sp.	Cottus bairdi	gills	"	"
T. sp.	Lota lota	urine, bladder	"	"
T. sp.	Perca flavescens	ureters	"	"
T. sp.	Percina caprodes	gills	"	"

ICHTHYOPARISITES OF MANITOBA

PART 1

PROTOZOA (continued)

PARASITES	HOST	LOCATION	LOCALITY	REFERENCE
CILIATA (cont'd.)				
Trichodina sp.	*Percopsis omiscomaycus*	gills	Lake of the Woods	Dechtiar 1972
T. sp.	*Pomoxis nigromaculatus*	"	"	"
T. sp.	*Ictalurus nebulosus*	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 2

MONOGENEA

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Actinocleidus fusiformis	Micropterus dolomieui	gills	Lake of the Woods	Dechtiar 1972
Anonchohaptor anomalum	Carpiodes cyprinus	gills, fins	Lake of the Woods	Dechtiar 1972
Anonchohaptor anomalum	Moxostoma anisurum	gills, fins	Lake of the Woods	Dechtiar 1972
Anonchohaptor anomalum	" erythrurum	gills, fins	Lake of the Woods	Dechtiar 1972
Anonchohaptor anomalum	Catostomus commersoni	gills, fins	Lake of the Woods	Dechtiar 1972
Cleidodiscus aculeatus	Stizostedion canadense	gills	Lake of the Woods	Dechtiar 1972
Cleidodiscus aculeatus	" v.vitreum	gills	Lake of the Woods	Dechtiar 1972
Cleidodiscus banghami	Micropterus dolomieui	gills	Lake of the Woods	Dechtiar 1972
Cleidodiscus brachus	Chrosomus neogaeus	gills	Lake of the Woods	Dechtiar 1972
Cleidodiscus malleus	Percina caprodes	gills	Lake of the Woods	Dechtiar 1972
Cleidodiscus pricei	Ictalurus nebulosus	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus banghami	Rhinichthys cataractae	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus bifurcatus	Pimephales notatus	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus eucalius	Culaea inconstans	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus mylocheilus	Couesius plumbeus	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus urus	Moxostoma erythrurum	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus parvicirrus	Notemigonus chrysoleucas	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus sp.	Cottus bairdi	gills	Lake of the Woods	Dechtiar 1972
Dactylogyrus sp.	Notropis hudsonius	gills	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 2

MONOGENEA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Dactylogyrus sp.	Pimephales promelas	gills	Lake of the Woods	Dechtiar 1972
Diclybothrium armatum	Acipenser fulvescens	gills	Lake of the Woods	Dechtiar 1972 J FR Bd C
Discocotyle sagittata	Caregonus artedii	gills	Lake of the Woods	Dechtiar 1972
Discocotyle sagittata	" clupeaformis	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus bairdi	Cottus bairdi	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus eucaliae	Culaea inconstans	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus macrochiri	Lepomis gibbosus	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus spathulatus	Catostomus commersoni	gills, fins	Lake of the Woods	Dechtiar 1972
Gyrodactylus spathulatus	Moxostoma anisurum	fins, gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus sp.	Ambloplites rupestris	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus sp.	Etheostoma exile	fins	Lake of the Woods	Dechtiar 1972
Gyrodactylus sp.	" nigrum	fins	Lake of the Woods	Dechtiar 1972
Gyrodactylus sp.	Notropis anogenus	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus sp.	Noturus gyrinus	gills	Lake of the Woods	Dechtiar 1972
Gyrodactylus sp.	Percopsis omiscomaycus	gills	Lake of the Woods	Dechtiar 1972
Octomacrum lanceatum	Catostomus commersoni	gills	Lake of the Woods	Dechtiar 1972
Octomacrum microconfibula	Notemigonus chrysoleucas	gills	Lake of the Woods	Dechtiar 1972
Octomacrum semotili	Chrosomus neogaeus	gills	Lake of the Woods	Dechtiar 1972
Octomacrum semotili	Semotilus margarita	gills	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 2

MONOGENEA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Octomacrum sp.	*Couesius plumbeus*	gills	Lake of the Woods	Dechtiar 1972
Pellucidhaptor nasalis	*Catostomus commersoni*	nasal cavities	Lake of the Woods	Dechtiar 1972
Pseudomurraytrema copulatum	*Moxostoma anisurum*	gills	Lake of the Woods	Dechtiar 1972
Pseudomurraytrema copulatum	*Catostomus commersoni*	gills	Lake of the Woods	Dechtiar 1972
Pseudomurraytrema sp.	*Moxostoma anisurum*	gills	Lake of the Woods	Dechtiar 1972
Pseudomurraytrema sp.	" *erythrurum*	gills	Lake of the Woods	Dechtiar 1972
Tetraonchus monenteron	*Esox lucius*	gills	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA
PART 3
TREMATODA

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Acolpenteron catostomi	Catostomus commersoni	ureters	Lake of the Woods	Dechtiar 1972
Allocreadium ictaluri	Ictalurus nebulosus	intestine	"	"
A. lobatum	Catostomus commersoni	intestine	"	"
A. lobatum	Pimephales promelas	"	"	"
A. lobatum	Rhinichthys cataractae	"	"	"
Alloglossidium corti	Noturus gyrinus	"	"	"
A. geminus	Ictalurus nebulosus	"	"	"
Amphimerus pseudofelineus	Catostomus commersoni	musclature	Lake Manitoba near Oak Point	Evans 1963
Apophallus itascensis	Etheostoma nigrum	muscle	Lake of the Woods	Dechtiar 1972
A. itascensis	E. exile	"	"	"
A. itascensis	Perca flavescens	"	"	"
Azygia angusticauda	Ambloplites rupestris	intestine	"	"
A. angusticauda	Esox lucius	intestine, stomach	"	"
A. angusticauda	E. masquinongy	intestine	"	"
A. angusticauda	Etheostoma exile	"	"	"
A. angusticauda	E. nigrum	"	"	"
A. angusticauda	Ictalurus nebulosus	"	"	"
A. angusticauda	Lepomis gibbosus	"	"	"
A. angusticauda	Lota lota	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Azygia angusticauda	Micropterus dolomieui	intestine	Lake of the Woods	Dechtiar 1972
A. angusticauda	Stizostedion v. vitreum	"	"	"
A. longa	Esox lucius	intestine, stomach	"	"
Bucephalus pusillus	Stizostedion canadense	intestine	"	"
Bunodera sacculata	Perca flavescens	"	"	"
B. sacculata	Stizostedion v. vitreum	"	"	"
B. eucaliae	Culaea inconstans	"	"	"
B. eucaliae	Pungitius pungitius	"	"	"
Caecincola parvula	Micropterus dolomieui	"	"	"
Centrovarium lobotes	Perca flavescens	"	"	"
C. lobotes	Stizostedion vitreum	"	Lake Dauphin	Stewart Hay 1951
C. lobotes	S. vitreum	"	Winnipeg River	Dickson 1964
C. lobotes	S. canadense	"	Lake of the Woods	Dechtiar 1972
Cleidodiscus adspectus	Perca flavescens	gills	"	"
Cleidodiscus capax	Pomoxis nigromaculatus	"	"	"
Clinostomum marginatum	Stizostedion vitreum	muscle	Lake Wallace	Evans/1963, Dickson/1964
C. marginatum	Perca flavescens	"	Lakes Caribou, Shoal, and Wallace	Evans/1963, Dickson/1964
C. marginatum	Ambloplites rupestris	muscle	Lake of the Woods	Dichtiar 1972
C. marginatum	Esox lucius	muscle, mesenteries	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Clinostomum marginatum	Etheostoma nigrum	muscle	Lake of the Woods	Dechtiar 1972
C. marginatum	Ictalurus nebulosus	"	"	"
C. marginatum	Lepomis gibbosus	"	"	"
C. marginatum	Micropterus dolomieui	"	"	"
C. marginatum	Notropis hudsonius	"	"	"
C. marginatum	Perca flavescens	"	"	"
C. marginatum	Pimephales notatus	"	"	"
C. marginatum	Stizostedion canadense	"	"	"
C. marginatum	S. v. vitreum	"	"	"
Clinostomum sp.	Ambloplites rupestris, Micropterus dolomieu, Perca flavescens, Salmo irideus and Stizostedion vitreum	"	Lakes of the Whiteshell Reserve	?
Crassiphiala bulboglossa	Perca flavescens	skin	Lake of the Woods	Dechtiar 1972
Crepidostomum cooperi	Catostomus commersoni	intestine	"	"
C. cooperi	Lepomis gibbosus	"	"	"
C. cooperi	Micropterus dolomieui	"	"	"
C. cooperi	Perca flavescens	"	Lake Wellman	Stewart Hay 1951
C. cooperi	Perca flavescens	"	Winnipeg River	Dickson 1964
C. cornutum	Ambloplites rupestris	"	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Crepidostomum cornutum	Noturus gyrinus	intestine	Lake of the Woods	Dechtiar 1972
C. ictaluri	Ictalurus nebulosus	"	"	"
C. isostomum	Percina caprodes	"	"	"
C. isostomum	Percopsis omiscomaycus	"	"	"
C. lintoni	Acipenser flavescens	"	"	"
Cryptogonimus chilli	Ambloplites rupestris	"	"	"
Diplostomulum bairi eucaliae	Culaea inconstans	brain	"	"
D. flexicaudum	Catostomus commersoni	eye	"	"
D. flexicaudum	Moxostoma anisurum	eye	"	"
D. scheuringi	Lepomis gibbosus	eye	"	"
D. scheuringi	Percina caprodes	eye	"	"
D. scheuringi	Perca flavescens	eye	"	"
D. scheuringi	Pomoxis nigromaculatus	eye	"	"
D. scheuringi	Rhinichthys cataractae	eye	"	"
D. scheuringi	Stizostedion v. vitreum	eye	"	"
Diplostomulum sp.	Acipenser fulvescens	eye	"	"
D. sp.	Ambloplites rupestris	eye	"	"
D. sp.	Couesius plumbeus	eye	"	"
D. sp.	Coregonus artedii	eye	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Diplostomulum sp.	Coregonus clupeaformis	eye	Lake of the Woods	Dechtiar 1972
D. sp.	Cottus bairdi	eye	"	"
D. sp.	Esox lucius	eye	"	"
D. sp.	Etheostoma exile	eye	"	"
D. sp.	E. nigrum	eye	"	"
D. sp.	Ictalurus nebulosus	eye	"	"
D. sp.	Lepomis gibbosus	eye	"	"
D. sp.	Lota lota	eye	"	"
D. sp.	Micropterus dolomieui	eye	"	"
D. sp.	Notemigonus crysoleucas	eye	"	"
D. sp.	Notropis anogenus	eye	"	"
D. sp.	N. atherinoides	eye	"	"
D. sp.	N. heterolepis	eye	"	"
D. sp.	N. hudsonius	eye	"	"
D. sp.	Perca flavescens	brain	"	"
D. sp.	Percina caprodes	eye	"	"
D. sp.	Percopsis omiscomaycus	eye	"	"
D. sp.	Pimephales notatus	eye	"	"
D. sp.	P. promelas	eye	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Diplostomulum sp.	Pomoxis nigromaculatus	eye	Lake of the Woods	Dechtiar 1972
D. sp.	Rhinichthys cataractae	eye	"	"
D. sp.	Salvelinus namayacush	eye	"	"
D. sp.	Stizostedion canadense	eye	"	"
D. sp.	Stizostedion v. vitreum	eye	"	"
D. sp.	Umbra limi	eye	"	"
Metorchis conjunctus	Canis familiaris	liver	The Pas District	Allen and Wardle 1934
M. conjunctus	C. familiaris	"	Berens and Norway House	Cameron, Parnell and Lyster 1940
M. conjunctus	C. familiaris	"	Kenora, near Manitoba's border	Cameron, Parnell and Lyster 1940
M. conjunctus	C. familiaris	"	South Indian Lake and Nelson House	Mongeau 1961
M. conjunctus	C. commersoni	muscle	Black River	Evans 1963
M. conjunctus	Perca flavescens	muscle	Black River	Evans 1963
Microphallus opacus	Micropterus dolomieui	intestine	Lake of the Woods	Dechtiar 1972
Neascus sp.	Catostomus commersoni	connective tissue	"	"
N. sp.	Chrosomus neogaeus	"	"	"
N. sp.	Couesius plumbeus	skin	"	"
N. sp.	Culaea inconstans	skin	"	"
N. sp.	Etheostoma exile	skin	"	"
N. sp.	Lepomis gibbosus	skin	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Neascus sp.	Moxostoma anisurum	skin	Lake of the Woods	Dechtiar 1972
N. sp.	Notropis anogenus	"	"	"
N. sp.	N. hudsonius	"	"	"
N. sp.	Percina caprodes	"	"	"
N. sp.	Pimephales promelas	"	"	"
N. sp.	Pomoxis nigromaculatus	"	"	"
N. sp.	Rhinichthys cataractae	"	"	"
N. sp.	Stizostedion canadense	"	"	"
Neochasmus umbelus	Micropterus dolomieui	intestine	"	"
Phyllodistomum coregoni	Coregonus clupeaformis	ureters	"	"
P. lysteri	Catostomus commersoni	"	"	"
P. staffordi	Ictalurus nebulosus	"	"	"
P. superbum	Perca flavescens	"	"	"
P. superbum	Stizostedion canadense	"	"	"
P. superbum	S. v. vitreum	"	"	"
P. undulans	Cottus bairdi	"	"	"
Phyllodistomum sp.	Catostomus catostomus	"	"	"
P. sp.	Coregonus artedii	"	"	"
Plagioporus sinitsini	Catostomus commersoni	intestine	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Posthodiplostomum minimum	Chrosomus neogaeus	liver, mesenteries	Lake of the Woods	Dechtiar 1972
P. minimum	Esox lucius	"	"	"
P. minimum	Lepomis gibbosus	liver	"	"
P. minimum	Notemigonus crysoleucas	liver, mesenteries	"	"
P. minimum	Notropis heterolepis	liver	"	"
P. minimum	N. hudsonius	liver, mesenteries	"	"
P. minimum	Percina caprodes	liver	"	"
P. minimum	Pimephales notatus	"	"	"
P. minimum	P. promelas	"	"	"
P. minimum	Pomoxis nigromaculatus	"	"	"
P. minimum	Rhinichthys atralulus	"	"	"
P. minimum	R. cataractae	"	"	"
Sanguinicola sp.	Moxostoma anisurum	blood	"	"
S. sp.	Pimephales notatus	"	"	"
S. sp.	P. promelas	"	"	"
Tetracotyle communis	Catostomus catostomus	mesenteries	"	"
T. communis	C. commersoni	"	"	"
T. communis	Chrosomus neogaeus	"	"	"
T. communis	Percopsis omiscomaycus	liver, mesenteries	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Tetracotyle communis	*Stizostedion canadense*	mesenteries	Lake of the Woods	Dechtiar 1972
T. communis	*S. v. vitreum*	"	"	"
T. intermedia	*Coregonus artedii*	heart, mesenteries	"	"
T. intermedia	*C. clupeaformis*	"	"	"
Tetracotyle sp.	*Ambloplites rupestris*	mesenteries	"	"
T. sp.	*Cottus bairdi*	"	"	"
T. sp.	*Culaea inconstans*	"	"	"
T. sp.	*Esox lucius*	"	"	"
T. sp.	*Etheostoma exile*	"	"	"
T. sp.	*E. nigrum*	"	"	"
T. sp.	*Ictalurus nebulosus*	mesenteries, kidney	"	"
T. sp.	*Lepomis gibbosus*	mesenteries	"	"
T. sp.	*Lota lota*	"	"	"
T. sp.	*Micropterus dolomieui*	"	"	"
T. sp.	*Notropis hudsonius*	"	"	"
T. sp.	*Perca flavescens*	"	"	"
T. sp.	*Pimephales notatus*	"	"	"
T. sp.	*Pomoxis nigromaculatus*	"	"	"
T. sp.	*Pungitius pungitius*	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 3

TREMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Tetracotyle sp.	*Rhinichthys cataractae*	mesenteries	Lake of the Woods	Dechtiar 1972
Triganodistomum attenuatum	*Carpiodes cyprinus*	intestine	"	"
T. attenuatum	*Moxostoma anisurum*	"	"	"
Uvulifer ambloplitis	*Esox lucius*	skin	"	"
U. ambloplitis	*Micropterus dolomieui*	skin, fins	"	"

ICHTHYOPARASITES OF MANITOBA
PART 4
CESTODA

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Biacetabulum infrequens	*Moxostoma anisurum*	Intestine	Lake of the Woods	Dechtiar 1972
Biacetabulum sp.	*Pimephales promelas*	Intestine	Lake of the Woods	Dechtiar 1972
Bothriocephalus claviceps	*Lepomis gibbosus*	"	"	"
B. claviceps	*Ambloplites rupestris*	"	"	"
Bothriocephalus cuspidatus	*Ictalurus nebulosus*	"	"	"
B. cuspidatus	*Notropis atherinoides*	"	"	"
B. cuspidatus	*Perca flavenscens*	"	"Hudson Bay drainage"	Wardle 1932
B. cuspidatus	*P. flavenscens*	"	Lake of the Woods	Dechtiar 1972
B. cuspidatus	*Stizostedion canadense*	"	"	"
B. cuspidatus	*S. vitreum*	"	Lake Athapapaskow	Stewart Hay 1953 b
B. cuspidatus	*S. vitreum*	"	Lake Dauphin	Stewart Hay 1951 a
B. cuspidatus	*S. vitreum*	"	Pickerel Lake	Stewart Hay 1952 a
B. cuspidatus	*S. vitreum*	"	Lake Wellman	Stewart Hay 1951 b
B. cuspidatus	*S. vitreum*	"	Winnipeg River	Dickson 1964
B. cuspidatus	*S. vitreum*	"	Lake of the Woods	Dechtiar 1972
B. cuspidatus	*Cristivomer namaycush* *Esox lucius* *Salvelinus malma* *Stizostedion vitreum*	Intestine and caecae	Lakes Athapapaskow, Child, Dauphin, Glad, Pickerel, Snow, Wellman, Whitefish and Moosey River	Little 1954
Bothriocephalus formosus	*Percina caprodes*	Intestine	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Bothriocephalus formosus	Etheostoma exile	intestine	Lake of the Woods	Dechtiar 1972
B. formosus	Percopsis omiscomaycus	"	"	"
Bothriocephalus sp.	Perca flavescens	"	Burton Lake	Stewart Hay 1952 b
Bothriocephalus sp.	Pomoxis nigromaculatus	"	Lake of the Woods	Dechtiar 1972
Corallobothrium fimbriatum	Ameiurus nebulosus	"	Lake Winnipeg	Wardle 1932
C. fimbriatum	Ictalurus nebulosus	"	Lake of the Woods	Dechtiar 1972
C. fimbriatum	Noturus gyrinus	"	"	"
Cyathocephalus truncatus	Coregonus artedii	"	"	"
C. truncatus	Coregonus clupeaformis	"	Lake Winnipeg	Wardle 1932
C. truncatus	Coregonus clupeaformis	"	Lake of the Woods	Dechtiar 1972
C. truncatus	Leucichthys zeniticus	"	Lake Winnipeg	Wardle 1932
C. truncatus	Perca flavescens	pyloric caecae	Lake of the Woods	Dechtiar 1972
Diphyllobothrium latum	Esox lucius	pleurocercoids	Lake Bell	Stewart Hay 1952
D. latum	Esox lucius	"	Lake Heming	Lawler and Watson 1958
D. latum	Esox lucius	"	Lake Winnipeg	Nickolson 1932
D. latum	Esox lucius	"	Lake Winnipeg	Vergeer 1928
D. latum	Esox lucius	"	Lake Winnipeg	Nickolson 1928
D. latum	Esox lucius	"	Lake South Steeprock	Stewart Hay 1952
D. latum	Esox lucius	"	Lake North Steeprock	Stewart Hay 1952

ICHTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Diphyllobothrium latum	*Esox lucius*	pleurocercoids	Lake Burton	Stewart Hay 1952
D. latum	*Esox lucius*	"	Lake Athapapaskow	Stewart Hay 1953
D. latum	*Esox lucius*, *Perca flavescens*	"	Lake Wellman	Harvey 1955
D. latum	*Perca flavescens*	"	Lake Burton	Stewart Hay 1952
D. latum	*Salvelinus namaycush*	"	Lake Athapapaskow	Stewart Hay 1953
D. latum	*Stizostedion vitreum*	"	Lake Heming	Lawler and Watson 1958
D. latum	*S. vitreum*	"	Lake Manitoba	Vergeer 1928
D. latum	*S. vitreum*	"	Lake Winnipeg	Magath 1927
D. latum	*S. vitreum*	"	Lake Winnipegosis	Vergeer 1928
D. latum	*S. vitreum*	"	Lake Wellman	Harvey 1955
D. latum	*Esox lucius*, *Perca flavescens*, *Stizostedion canadense*, *Stizostedion vitreum*	"	Lake Winnipeg	Wardle 1932
D. latum	*Esox lucius*, *Lota lota*, *Perca flavescens*, *Stizostedion vitreum*	"	Lake Winnipeg	Bajkov 1933
D. latum	*Esox lucius*, *Lota lota*, *Perca flavescens*, *Stizostedion canadense*, *Stizostedion vitreum*	"	Lake Winnipegosis	Wardle 1932
Diphyllobothrium sp.	*Coregonus artedii*	cysts on stomach, pyloric caecum	Lake of the Woods	Dechtiar 1972
D. sp.	*Coregonus clupeaformis*	cysts on stomach, pyloric caecum	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Diphyllobothrium sp.	Esox lucius	pleurocercoids	Lake Armit	Stewart Hay 1952
D. sp.	Esox lucius	"	Lake Pickerel	Stewart Hay 1952
D. sp.	Salvelinus namaycush	"	Lake Child	Stewart Hay 1951
D. sp.	Salvelinus namaycush	"	Lake Second Cranberry	Stewart Hay 1953
D. sp.	Stizostedion vitreum	"	Lake Athapapaskow	Stewart Hay 1953
D. sp.	S. vitreum	"	Lake Pickerel	Stewart Hay 1952
D. sp.	S. vitreum	"	Lake Wellman	Stewart Hay 1951
Eubothrium rugosum	Lota lota	intestine	Lake of the Woods	Dechtiar 1972
Eubothrium salvelini	Salvelinus namaycush	intestine	Lake of the Woods	Dechtiar 1972
Glaridacris catostomi	Catostomus commersoni	intestine	Lake Athapapaskow	Stewart Hay 1953
G. catostomi	C. commersoni	intestine	Lake of the Woods	Dechtiar 1972
Glaridacris confusus	Carpiodes cyprinus	intestine	Lake of the Woods	Dechtiar 1972
Glaridacris intermedius	Catostomus commersoni	intestine	Lake of the Woods	Dechtiar 1972
Glaridacris sp.	C. commersoni	intestine	Lake Armit	Stewart Hay 1952 a
Hunterella nodulosa	C. commersoni	intestine	Lake of the Woods	Dechtiar 1972
Ligula intestinalis	C. commersoni	pleurocercoid body cavity	Lake Heming	Lawler 1964
L. intestinalis	Notropis hudsonius	"	Lake Heming	Lawler 1964
L. intestinalis	N. hudsonius	"	Lake of the Woods	Dechtiar 1972
L. intestinalis	Perca flavescens	"	Lake Heming	Lawler 1964

ICHTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Ligula intestinalis	*Pimephales notatus*	body cavity	Lake of the Woods	Dechtiar 1972
L. intestinalis	*Catostomus commersoni*	body cavity	Lake of the Woods	Dechtiar 1972
Proteocephalus ambloplitis	*Ambloplites rupestris*	liver, mesenteries	Lake of the Woods	Dechtiar 1972
P. ambloplitis	*Cottus bairdi*	liver	Lake of the Woods	Dechtiar 1972
P. ambloplitis	*Culaea inconstans*	liver	Lake of the Woods	Dechtiar 1972
P. ambloplitis	*Ictalurus nebulosus*	mesenteries	Lake of the Woods	Dechtiar 1972
P. ambloplitis	*Lepomis gibbosus*	liver, mesenteries	"	"
P. ambloplitis	*Micropterus dolomieui*	intestine	"	"
P. ambloplitis	*Perca flavescens*	liver, mesenteries	"	"
P. ambloplitis	*Pomoxis nigromaculatus*	liver	"	"
P. ambloplitis	*Stizostedion canadense*	mesenteries	"	"
P. ambloplitis	*Stizostedion v. vitreum*	mesenteries, liver	"	"
Proteocephalus exiguus	*Coregonus artedii*	intestine	"	"
P. exiguus	*C. clupeaformis*	"	"	"
P. fluviatilis	*Micropterus dolomieui*	"	"	"
P. laruei	*Coregonus artedii*	"	"	"
P. laruei	*C. clupeaformis*	"	"	"
P. luciopercae	*Stizostedion canadense*	"	Lake Winnipeg	Wardle 1932
P. luciopercae	*S. vitreum*	"	Lake Athapapaskow	Stewart Hay 1953 b
P. luciopercae	*Stizostedion canadense* and *S. vitreum*	intestine and caecae	Lakes Dauphin, Hemming, Waskesiu and Winnipeg	Little 1954

ICHTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Proteocephalus luciopercae	Stizostedion vitreum	intestine	Lake Dauphin	Stewart Hay 1951 a
P. luciopercae	S. vitreum	"	Lake Heming	Lawler and Watson 1958
P. luciopercae	S. vitreum	"	Lake Pickerel	Stewart Hay 1952 a
P. luciopercae	S. vitreum	"	Lake Second Cranberry	Stewart Hay 1953 a
P. luciopercae	S. vitreum	"	Lake Wellman	Stewart Hay 1951 b
P. luciopercae	S. vitreum	"	Winnipeg River	Dickson 1964
P. luciopercae	S. vitreum	"	Lake Winnipeg	Wardle 1932
Proteocephalus pearsei	Notropis atherinoides	"	Lake of the Woods	Dechtiar 1972
P. pearsei	Perca flavescens	"	"	"
P. pearsei	Pomoxis nigromaculatus	"	"	"
Proteocephalus parallacticus	Salvelinus namayacush	"	"	"
Proteocephalus pinguis	Esox lucius	"	Lakes Atapapaskow, Bell, Burton, Dauphin, Heming, Snow and Steeprock	Little 1954
P. pinguis	E. lucius	"	Lake of the Woods	Dechtiar 1972
Proteocephalus pusillus	Leucichthys tullibee	Oesophagus, intestine and intestinal caecae	Lake Atapapaskow	Little 1954
Proteocephalus stizostethi	Stizostedion canadense	intestine	Lake of the Woods	Dechtiar 1972
P. stizostethi	Stizostedion v. vitreum	"	"	"
Proteocephalus sp.	Carpiodes cyprinus	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Proteocephalus sp.	Chrosomus neogaeus	intestine	Lake of the Woods	Dechtiar 1972
P. sp.	Pungitius pungitius	"	"	"
Schistocephalus solidus	Cottus bairdi	body cavity	"	"
S. solidus	Cottus cognatus gracilis	body cavity	Lake Heming	Lawler and Watson 1958
S. solidus	Eucalia inconstans	body cavity	Lake Heming	"
Schistocephalus sp.	Pungitius pungitius	body cavity	Lake Armit	Stewart Hay 1952 a
S. sp.	P. pungitius	"	Lake Whitefish	Stewart Hay 1952 b
Spartoides wardi	Carpiodes cyprinus	intestine	Lake Dauphin	Stewart Hay 1951 a
S. wardi	Notropis hudsonius	"	"	Stewart Hay 1951 a
Triaenophorus crassus	Coregonus artedii	muscle	Lake of the Woods	Dechtiar 1972
T. crassus	Coregonus clupeaformis	"	"	"
T. crassus	Esox lucius	intestine	"	"
T. crassus	Esox masquinongy	"	"	"
T. crassus	Salvelinus namayacush	muscle	"	"
Triaenophorus nodulosus	Catostomus commersoni	liver	"	"
T. nodulosus	Esox lucius	intestine	"	"
T. nodulosus	E. masquinongy	"	"	"
T. nodulosus	Lepomis gibbosus	liver	"	"
T. nodulosus	Lota lota	"	"	"
T. nodulosus	Moxostoma anisurum	"	"	"

ICTHYOPARASITES OF MANITOBA

PART 4

CESTODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Triaenophorus nodulosus	Perca flavescens	liver	Lake of the Woods	Dechtiar 1972
T. nodulosus	Stizostedion canadense	mesenteries	"	"
Triaenophorus stizostedionis	Cottus cognatus gracilis	muscle	Lake Heming	Lawler 1953
T. stizostedionis	Percopsis omiscomaycus	"	Lake Heming	Lawler 1951
T. stizostedionis	P. omiscomaycus	liver	Lake of the Woods	Dechtiar 1972
T. stizostedionis	Stizostedion vitreum	intestine	Lake Dauphin	Stewart Hay 1951 a
T. stizostedionis	S. vitreum	"	Lake Heming	Lawler 1951
T. stizostedionis	S. vitreum	"	Lake Second Cranberry	Stewart Hay 1953 a
T. stizostedionis	S. vitreum	"	Winnipeg River	Dickson 1964
T. stizostedionis	Stizostedion v. vitreum	"	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 5

NEMATODA

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Agamonema sp.	*Culaea inconstans*	mesenteries	Lake of the Woods	Dechtiar 1972
Agamonema sp.	*Micropterus dolomieui*	liver, mesenteries	"	"
Camallanus oxycephalus	*Catostomus commersoni*	intestine	"	"
C. oxycephalus	*Cottus bairdi*	"	"	"
C. oxycephalus	*Culaea inconstans*	"	"	"
C. oxycephalus	*Etheostoma exile*	"	"	"
C. oxycephalus	*Lota lota*	"	"	"
C. oxycephalus	*Micropterus dolomieui*	"	"	"
C. oxycephalus	*Perca flavescens*	"	"	"
C. oxycephalus	*Percina caprodes*	"	"	"
C. oxycephalus	*Stizostedion canadense*	"	"	"
Capillaria bakeri	*Lota lota*	"	"	"
Capillaria catenata	*Ambloplites rupestris*	"	"	"
Contracaecum brachyurum	*A. rupestris*	liver	"	"
C. brachyurum	*Esox lucius*	intestine	"	"
C. brachyurum	*E. masquinongy*	"	"	"
C. brachyurum	*Lota lota*	"	"	"
C. brachyurum	*Moxostoma anisurum*	liver, mesenteries	"	"
C. brachyurum	*Notropis atherinoides*	intestine	"	"

ICHTHYOPARASITES OF MANITOBA

PART 5

NEMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Contracaecum brachyurum	Percopsis omiscomaycus	intestine	Lake of the Woods	Dechtiar 1972
C. brachyurum	Stizostedion canadense	"	"	"
C. brachyurum	S. vitreum	"	"	"
C. sp.	Catostomus commersoni	liver, mesenteries	"	"
C. sp.	Cottus bairdi	liver	"	"
C. sp	Etheostoma exile	mesenteries	"	"
C. sp.	E. nigrum	liver, mesenteries	"	"
C. sp.	Ictalurus nebulosus	liver, mesenteries	"	"
C. sp.	Lepomis gibbosus	liver	"	"
C. sp.	Micropterus dolomieui	intestine	"	"
C. sp.	Notropis hudsonius	liver	"	"
C. sp.	Perca flavescens	liver, mesenteries	"	"
C. sp.	Percina caprodes	liver	"	"
Cystidicola cristivomeri	Coregonus artedii	swim bladder	Lake Winnipeg	Eckbaum 1936
C. cristivomeri	C. clupeaformis	swim bladder	Lake Jackfish	Smedley 1933
C. cristivomeri	C. clupeaformis	"	Lake Murray	"
C. cristivomeri	C. clupeaformis	"	Lake Winnipeg	"
C. cristivomeri	Salvelinus namaycush	"	Lake of the Woods	Dechtiar 1972
C. stigmatura	Coregonus artedii	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 5

NEMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Cystidicola stigmatura	*Coregonus clupeaformis*	swim bladder	Lakes Winnipeg, lakes of The Pas district	Smedley 1933
C. stigmatura	*C. clupeaformis*	"	Lake of the Woods	Dechtiar 1972
C. stigmatura	*Salvelinus namaycush*	"	Lake Athapapaskow and Second Cranberry	Stewart Hay 1953
C. stigmatura	*S. namaycush*	"	Lake Forbes	Dickson 1967
Dichelyne cotylophora	*Lota lota*	intestine	Lake of the Woods	Dechtiar 1972
D. cotylophora	*Perca flavescens*	"	"	"
Eustrongylides sp.	*Perca flavescens*	cysts on viscera	"	"
E. sp.	*Stizostedion canadense*	cysts in body cavity	"	"
E. sp.	*S. vitreum*	cyst in muscles	"	"
Philometra cylindracea	*Perca flavescens*	body cavity	"	"
P. sp.	*Micropterus dolomieui*	"	"	"
P. sp.	*Perca flavescens*	"	"	"
Rhabdochona cascadilla	*Ambloplites rupestris*	intestine	"	"
R. cascadilla	*Etheostoma exile*	"	"	"
R. cascadilla	*E. nigrum*	"	"	"
R. cascadilla	*Lota lota*	"	"	"
R. cascadilla	*Notropis anogenus*	"	"	"
R. cascadilla	*N. hudsonius*	"	"	"
R. cascadilla	*Rhinichthys atratulus*	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 5

NEMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Rhabdochona cotti	Cottus bairdi	intestine	Lake of the Woods	Dechtiar 1972
Raphidascaris canadensis	Esox lucius	"	Lakes Armit, Bell, North Steeprock, South Steeprock	Stewart Hay 1952
R. canadensis	E. lucius	"	Lake Athapapaskow	Stewart Hay 1953
R. canadensis	E. lucius	"	Lake Burton	Stewart Hay 1952
R. canadensis	E. lucius	"	Lake Caddy	McLeod 1943
R. canadensis	E. lucius	"	Lake Dauphin	Stewart Hay 1951
R. canadensis	E. lucius	"	Lakes Winnipeg, Winnipegosis and The Pas district lakes	Smedley 1933
R. canadensis	Stizostedion vitreum	"	Lake Pickerel	Stewart Hay 1952
R. sp.	Esox lucius	"	Lake Caddy	McLeod 1943
R. sp.	E. lucius	"	Lake Pickerel	Stewart Hay 1952
R. sp.	Perca flavescens	intestine; larvae	Lake Burton	"
R. sp.	Stizostedion vitreum	intestine	Lake Dauphin	Stewart Hay 1951
Spinitectus carolini	Ambloplites rupestris	"	Lake of the Woods	Dechtiar 1972
S. carolini	Ictalurus nebulosus	"	"	"
S. gracilis	Coregonis artedii	"	"	"
S. gracilis	Lota lota	"	"	"
S. gracilis	Moxostoma anisurum	"	"	"
S. gracilis	Perca flavescens	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 5

NEMATODA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Spinitectus gracilis	*Percopsis omiscomaycus*	intestine	Lake of the Woods	Dechtiar 1972
S. gracilis	*Pomoxis nigromaculatus*	"	"	"
Spiroxys sp.	*Catostomus commersoni*	mesenteries	"	"

ICHTHYOPARASITES OF MANITOBA

PART 6

ACANTHOCEPHALA.

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Echinorhynchus coregoni	Catostomus commersoni, Coregonus clupeaformis, Salvelinus namaycush	intestine	Lake Athapapaskow	Stewart Hay 1953
E. coregoni	Coregonus clupeaformis	"	Lake Second Cranberry	"
Leptorhynchoides thecatum	Ambloplites rupestris	"	Lake of the Woods	Dechtiar 1972
L. thecatum	Catostomus commersoni	"	"	"
L. thecatum	Culaea inconstans	"	"	"
L. thecatum	Esox lucius	"	"	"
L. thecatum	E. masquinongy	"	"	"
L. thecatum	Etheostoma exile	cysts attached to mesenteries	"	"
L. thecatum	E. nigrum	intestine	"	"
L. thecatum	Ictalurus nebulosus	"	"	"
L. thecatum	Lepomis gibbosus	"	"	"
L. thecatum	Lota lota	"	"	"
L. thecatum	Micropterus dolomieui	"	"	"
L. thecatum	Moxostoma anisurum	"	"	"
L. thecatum	Notropis anogenus	"	"	"
L. thecatum	Noturus gyrinus	"	"	"
L. thecatum	Perca flavescens	"	"	"
L. thecatum	Percina caprodes	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 6

ACANTHOCEPHALA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Leptorhynchoides thecatum	Pomoxis nigromaculatus	intestine	Lake of the Woods	Dechtiar 1972
L. thecatum	Pungitius pungitius	"	"	"
L. thecatum	Rhinichthys atratulus	"	"	"
L. thecatum	Umbra limi	"	"	"
Metechinorhynchus lateralis	Coregonus clupeaformis	"	"	"
M. salmonis	Coregonus artedii	"	"	"
M. salmonis	C. clupeaformis	"	"	"
M. salmonis	Cottus bairdi	"	"	"
M. salmonis	Esox lucius	"	"	"
M. salmonis	E. masquinongy	"	"	"
M. salmonis	Ictalurus nebulosus	"	"	"
M. salmonis	Lota lota	"	"	"
M. salmonis	Salvelinus namaycush	"	"	"
M. salmonis	Stizostedion canadense	"	"	"
M. salmonis	S. v. vitreum	"	"	"
Neoechinorhynchus crassus	Catostomus commersoni	"	Lake Dauphin	Stewart Hay 1951
N. crassus	C. commersoni	"	Lake of the Woods	Dechtiar 1972
N. crassus	Stizostedion vitreum	"	Lake Dauphin	Stewart Hay 1951
N. cristatus	Catostomus commersoni	"	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 6

ACANTHOCEPHALA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Neoechinorhynchus cylindratus	Perca flavescens, Stizostedion vitreum	intestine	Winnipeg River	Dickson 1964
N. cylindratus	Ambloplites rupestris	"	Lake of the Woods	Dechtiar 1972
N. cylindratus	Micropterus dolomieui	"	"	"
N. rutili	Cottus bairdi	"	"	"
N. rutili	Culaea inconstans	"	"	"
N. strigosus	Catostomus commersoni	"	"	"
N. tenellus	Esox lucius	"	"	"
N. tenellus	E. masquinongy	"	"	"
N. tenellus	Stizostedion canadense	"	"	"
N. tenellus	S. v. vitreum	"	"	"
N. tumidum	Coregonus artedii	"	"	"
N. tumidum	C. clupeaformis	"	"	"
N. sp.	Catostomus commersoni	"	Lake Burton	Stewart Hay 1952
N. sp.	Notropis atherinoides	"	Lake of the Woods	Dechtiar 1972
N. sp.	N. hudsonius	"	"	"
N. sp.	Pimephales notatus	"	"	"
N. sp.	Stizostedion vitreum	"	Lake Pickerel	Stewart Hay 1952
Octospinifer macilentus	Catostomus commersoni	"	Lake of the Woods	Dechtiar 1972
Pomphorhynchus bulbocolli	C. commersoni	"	Lake Dauphin	Stewart Hay 1951

ICHTHYOPARASITES OF MANITOBA

PART 6

ACANTHOCEPHALA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
Pomphorhynchus bulbocolli	*Catostomus commersoni*	intestine	Lakes North Steeprock and South Steeprock	Stewart Hay 1952
P. bulbocolli	*C. commersoni*	"	Lake Wellman	Stewart Hay 1951
P. bulbocolli	*C. commersoni*	"	Lake of the Woods	Dechtiar 1972
P. bulbocolli	*Carpiodes cyprinus*	"	"	"
P. bulbocolli	*Ictalurus nebulosus*	"	"	"
P. bulbocolli	*Noturus gyrinus*	"	"	"
P. bulbocolli	*Lota lota*	"	"	"
P. bulbocolli	*Percina caprodes*	"	"	"
P. sp.	*Catostomus commersoni*	"	Lake Armit	Stewart Hay 1952
P. sp.	*Stizostedion vitreum*	"	Lake Dauphin	Stewart Hay 1951
Tanaorhamphus sp.	*Catostomus commersoni*	"	Lake North Steeprock	Stewart Hay 1952

ICHTHYOPARASITES OF MANITOBA

PART 7

CRUSTACEA

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
BRANCHIURA				
Argulus appendiculosus	Stizostedion canadense	fins	Lake of the Woods	Dechtiar 1972
A. canadensis	Coregonus artedii	surface of the body	"	"
A. canadensis	Perca flavescens	fins	"	"
A. canadensis	Stizostedion v. vitreum	fins	"	"
A. canadensis	Notropis hudsonius	fins, body	"	"
A. catostomi	Catostomus commersoni	fins	"	"
A. catostomi	Etheostoma exile	fins	"	"
A. catostomi	E. nigrum	fins	"	"
A. stizostethi	Catostomus commersoni Stizostedion vitreum	on skin	Lake Dauphin	Stewart Hay 1951
A. versicolor	Percopsis omiscomaycus	fins	Lake of the Woods	Dechtiar 1972
A. versicolor	Stizostedion v. vitreum	fins	"	"
COPEPODA				
Achtheres corpulentus	Coregonus clupeaformis	gill arches	Lake of the Woods	Dechtiar 1972
A. micropteri	Ambloplites rupestris	"	"	"
Ergasilus caeruleus	Ambloplites rupestris	gills	"	"
E. caeruleus	Catostomus catostomus	"	"	"
E. caeruleus	C. commersoni	"	"	"
E. caeruleus	Micropterus dolomieui	"	"	"

ICHTHYOPARASITES OF MANITOBA

PART 7

CRUSTACEA (continued)

PARASITE	HOST	LOCATION	LOCALITY	REFERENCE
COPEPODA (cont'd.)				
Ergasilus caeruleus	*Moxostoma anisurum*	gills	Lake of the Woods	Dechtiar 1972
E. caeruleus	*M. erythrurum*	"	"	"
E. caeruleus	*Perca flavescens*	"	"	"
E. caeruleus	*Percina caprodes*	"	"	"
E. caeruleus	*Pomoxis nigromaculatus*	"	"	"
E. caeruleus	*Stizostedion canadense*	"	"	"
E. caeruleus	*S. v. vitreum*	"	"	"
E. centrarchidarum	*Micropterus dolomieui*	"	"	"
E. centrarchidarum	*Stizostedion v. vitreum*	"	"	"
E. centrarchidarum	*Ambloplites rupestris*	"	"	"
E. osburni	*Lota lota*	"	"	"
E. versicolor	*Ictalurus nebulosus*	"	"	"
E. sp.	*Coregonus artedii*	"	"	"
E. sp.	*Moxostoma erythrurum*	"	"	"
E. sp.	*Notropis* sp. *Perca flavescens*	"	Lake Armit	Stewart Hay 1952
E. sp.	*Notropis hudsonius* *Pungitius pungitius*	"	Lake Whitefish	"
E. sp.	*Notropis hudsonius*	"	Lake of the Woods	Dechtiar 1972

ICHTHYOPARASITES OF MANITOBA

PART 7

CRUSTACEA (continued)

PARASITES	HOST	LOCATION	LOCALITY	REFERENCE
Ergasilus sp.	*Perca flavescens*	gills	Lake Pickerel	Stewart Hay 1952
E. sp.	*Perca flavescens* *Stizostedion vitreum*	"	Lake Caddy	McLeod 1943
Salmincola siscowet	*Salvelinus namaycush*	fins	Lake of the Woods	Dechtiar 1972
S. sp.	*S. namaycush*	fins	Lake Second Cranberry	Stewart Hay 1953

Attachment C.III-1

List of Aquatic Invertebrate Experts
Contacted by the Biology Committee

Attachment C.III-1 List of aquatic invertebrate experts contacted by the Biology Committee.

Name	Affiliation	Area of Expertise
J. Flannagan	Freshwater Institute, Winnipeg	Ephemeroptera, Plecoptera and Trichoptera
O. Saether	Freshwater Institute, Winnipeg	Diptera
D. Cook	JFRB, Ottawa	Oligochaeta
E. Bousfield	National Museum, Ottawa	Amphipoda
R. Mulvey	Biosystematics Research Institute, Ottawa	Nemotoda
A. Clarke	National Museum, Ottawa	Mollusca
R. Davies	U of Calgary, Calgary	Hirudinea
N. Hynes	U of Waterloo, Waterloo	Introduction of exotics
D. Barr	Royal Ontario Museum, Toronto	Hydracarinidae
F. Schmid	Biosystematics Research Institute, Ottawa	Trichoptera
G. Wiggins	Royal Ontario Museum, Toronto	Trichoptera
J. Martin	Biosystematics Research Institute, Ottawa	Ephemeroptera, Plecoptera
W. Ricker	Pacific Biological Station, Nanaimo	Ephemeroptera, Plecoptera
Smithsonian Institute	Washington, DC	All
M. Blumenthal	Minneapolis	Allergies
R. Patterson	Chicago	Allergies
S. Tse	Health Sciences Centre, Winnipeg	Allergies

Attachment C.III-1 (cont'd)

Name	Affiliation	Area of Expertise
B. Tarshis	Deptartment of Interior, Patuxent, Maryland	Simuliidae (Blackflies)
J. Semanchuk	Canada Agriculture, Lethbridge	Simuliidae
S. McClintock	Canada Agriculture, Saskatoon	Simuliidae
G. Bennett	Memorial University, St. John's, Newfoundland	Simuliidae
G. Davies	McMasters University, Hamilton	Simuliidae
G. Sewell	Canada Agriculture, Ottawa	Simuliidae
H. Fredeen	Canada Agriculture, Saskatoon	Simuliidae
J. Anderson	University of California, Berkely	Simuliidae
R. Clarke	Freshwater Institute, Winnipeg	Water Quality

Attachment C.III-2

A List of Aquatic Invertebrates Present in Southern Manitoba Waters

AMPHIPODA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Gammaridae:							
Crangonyx pseudogracilis Bousfield	X						
Gammarus sp.	X	X		X		X	X
Gammarus lacustris (Sars)	X	X		X		X	
Haustoriidae:							
Pontoporeia sp.				X		X	X
Pontoporeia affinis (Lindstrom)	X			X		X	X
Talitridae:							
Hyalella sp.		X		X		X	
Hyalella azteca (Saussure)	X	X		X	X	X	X

DECAPODA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of the Woods)
Astacidae							
Cambarus sp.						X	
Orconectes sp.		X			X		
Orconectes immunis (Hagen)	X						
Orconectes rusticus (Girard)							X
Orconectes virilis (Hagen)	X	X	X	X		X	X

EPHEMEROPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Ametropidae:							
Pseudiron centralis McDunnough							X
Siphoplecton basale (Walker)	X			X			
Siphoplecton interlineatum Walsh			X				
Baetidae:							
Baetis sp.	X			X			X
Baetis intercalaris McDunnough	X						
Baetis herodes (Burks)	X						
Baetis Mcdunnaughi Ide						X	
Callibaetis ferrugineus (Walsh)	X			X			
Centroptilum sp.	X						
Centroptilum in frequens McDunnough				X			
Centroptilum quaesitum McDunnough				X			
Cloeon sp.						X	
Pseudocloeon sp.							X
Pseudocloeon (dubium Walsh ?)					X		
Pseudocloeon myrsum Burks	X						
Baetiseidae:							
Baetisca sp.	X						X
Baetisca bajkovi Neave			X	X			
Baetisca lucustris McDunnough						X	
Baetisca obesa (Say)						X	
Caenidae:							
Brachycercus sp.	X						
Caenis sp.	X	X			X	X	X
Caenis forcipata McDunnough				X		X	
Caenis simulans McDunnough				X		X	
Tricorythodes sp.	X						X
Tricorythodes Ca. *stygiatus* McDunnough	X						
Ephemerellidae:							
Ephemerella attenuata McDunnough	X						
Ephemerella bicolor Clemens				X			
Ephemerella needhami McDunnough	X						
Ephemerella prudentalis McDunnough						X	
Ephemerella temporalis McDunnough				X		X	
Ephemerella walkeri Eaton						X	

EPHEMEROPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Ephemeridae:							
Ephemera sp.					X	X	X
Ephemera simulans Walker	X		X	X		X	
Ephemera varia Eaton ?					X		
Hexagenia sp.						X	X
Hexagenia limbata (Serville)	X	X	X	X	X	X	
Hexagenia rigida McDunnough	X		X	X		X	
Pentagenia vittigera (Walsh)	X		X				
Heptageniidae:							
Cinygma sp. ?	X						
Heptagenia sp.	X	X				X	
Heptagenia diabasi Burks			X				
Heptagenia elegantula (Eaton)			X	X			
Heptagenia hebe McDunnough				X			
Heptagenia maculipennis Walsh	X						
Heptagenia pulla (Clemens)				X			
Heptagenia walshi McDunnough			X				
Stenonema sp.	X					X	X
Stenonema bipunctatum (McDunnough)			X				
Stenonema candidum Traver	X						
Stenonema (carlsoni?) Lewis	X						
Stenonema integrum (McDunnough)	X						
Stenonema interpunctatum (Say)				X			
Stenonema interpunctatum canadense Spieth	X		X	X			
Stenonema mediopunctatum (McDunnough)							X
Stenonema minnetonka Daggy	X						
Stenonema nepotellum (McDunnough)	X					X	
Stenonema pulchellum (Walsh)	X						
Stenonema terminatum (Walsh)			X	X			
Stenonema tripunctatum (Banks)	X			X			
Stenonema tripunctatum tripunctatum Spieth				X			
Stenonema vicarium (Walker)						X	X
Leptophlebiidae:							
Blasturus cupidus Say	X			X			
Blasturus nebulosus Walker				X			
Choroterpes sp.						X	
Habrophleboides sp.	X						
Leptophlebia sp.	X						
Leptophlebia cupida (Say)				X	X		
Leptophlebia nebulosa (Walker	X					X	

EPHEMEROPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Leptophlebiidae (cont'd):							
Paraleptophlebia debilis (Walker)						X	
Paraleptophlebia mollis (Eaton)	X						
Paraleptophlebia praepidita (Eaton)	X						
Thraulodes sp.						X	
Polymitarcidae:							
Ephoron sp.						X	
Ephoron album (Say)	X	X		X		X	
Ephoron leukon Williamson							X
Potamanthidae:							
Potamanthus sp.	X						
Siphlonuridae:							
Ameletus lineatus Traver						X	
Arthroplea sp.		X					
Callibaetis ferrugineus Walsh						X	
Callibaetis nigritus Banks						X	
Isonychia sp.	X	X	X	X			
Siphlonurus alternatus (Say)	X			X			
Siphlonurus phyllis McDunnough						X	

GASTROPODA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of the Woods)
Ancylidae							
Ferrissia parallela (Haldeman)						X	X
Ferrissia rivularis (Say)	X	X		X	X	X	
Hydrobiidae							
Amnicola limosa (Say)	X	X		X	X	X	X
Amnicola walkeri Pilsbry	X			X		X	X
Cincinnatia cincinnatiensis (Anthony)	X			X		X	
Marstonia decepta (Baker)	X					X	
Probythinella lacustris (Baker)	X	X		X	X	X	
Lymnaeidae							
Lymnaea bulimoides (Lea)	X						
Lymnaea caperata (Say)	X	X	X		X		
Lymnaea catascopium catascopium Say	X			X	X	X	
Lymnaea catascopium nasoni Baker						X	X
Lymnaea catascopium preblei (Dall)				X			
Lymnaea columella (Say)				X		X	
Lymnaea dali Baker	X						
Lymnaea decampi (Streng)	X			X	X	X	
Lymnaea elodes (Say)	X	X	X	X	X	X	X
Lymnaea exigua (Lea)	X			X		X	
Lymnaea megasoma (Say)				X		X	X
Lymnaea modicella (Say)	X		X		X	X	
Lymnaea parva Lea	X	X		X	X	X	
Lymnaea reflexa (Say)						X	
Lymnaea stagnalis (Linnaeus)	X	X	X	X	X	X	X
Physidae							
Aplexa hypnorum (Linnaeus)	X	X	X	X	X	X	X
Physa gyrina Say	X	X	X	X	X	X	X
Physa jennessi skinneri Taylor	X	X	X	X	X	X	X

GASTROPODA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Planorbidae:							
Armiger crista (Linnaeus)	X			X	X		
Gyraulus circumstriatus (Tryon)	X	X				X	
Gyraulus deflectus (Say)	X	X	X	X	X	X	X
Gyraulus parvus (Say)	X	X	X	X	X	X	X
Helisoma (*Helisoma*) *anceps anceps* (Menke)	X		X	X	X	X	X
Helisoma (*Helisoma*) *anceps royalense* (Walker)						X	
Helisoma (*Pierosoma*) *corpulentum corpulentum* (Say)						X	X
Helisoma (*Pierosoma*) *corpulentum vermilionense* Baker	X					X	
Helisoma (*Pierosoma*) *corpulentum whiteavesi* Baker						X	
Helisoma (*Pierosoma*) *pilsbryi infracarinatum* (Baker)	X			X	X	X	
Helisoma (*Pierosoma*) *trivolis subcrenatum* (Carpenter)	X			X	X	X	
Helisoma (*Pierosoma*) *trivolis trivolis* (Say)	X			X	X	X	
Helisoma (*Planorbella*) *campanulatum campanulatum* (Say)				X		X	X
Helisoma (*Planorbella*) *campanulatum collinsi* Baker						X	
Planorbula armigera (Say)	X		X	X	X	X	
Planorbula campestris (Dawson)	X		X	X	X	X	
Promenetus exacuous exacuous (Say)	X	X		X	X	X	
Promenetus exacuous megas (Dall)	X		X		X		
Valvatidae:							
Valvata sincera helicoidea Dall	X			X	X		X
Valvata sincera sincera Say	X			X		X	X
Valvata tricarinata (Say)	X	X		X	X	X	X
Viviparidae:							
Campeloma decisum (Say)	X			X		X	X

HIRUDINOIDEA	Red River System	Vicinity of Wpg., Man.	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Erpobdellidae	X							X
Erpobdella punctata (Leidy)	X		X		X	X	X	
Mooreobdella SP.	X							
Mooreobdella microstoma (Moore							X	
Nephelopsis obscura (Verrill)	X					X	X	
Glossiphoniidae								
Actinobdella triannulata (Moore)								X
Batracobdella sp.							X	X
Glossiphonia sp.	X				X		X	
Glossiphonia complanata (Linnaeus)						X	X	
Glossiphonia heteroclita (Linnaeus)						X		
Helobdella sp.	X		X		X		X	
Helobdella elongata (Castle)							X	
Helobdella stagnalis (Linnaeus)	X				X	X	X	X
Helobdella triserialis (Blanchard)						X		
Marvinmeyeria lucida (Moore)						X		
Placobdella sp.	X		X		X			X
Placobdella montifera (Moore) ?	X							
Placobdella papillifera (Verrill)							X	
Placobdella ornata (Verrill)					X	X		
Theromyzon rude (Baird)					X			
Hirudinidae:								
Bdellarogatis plumbeus (Moore) ?	X							
Macrobdella decora (Say) ?					X			
Mollibdella grandis (Verrill)	X				X		X	
Percymoorensis marmorata (Say)		X						
Pisciolidae:								
Myzobdella moorei (Meyer)						X		X
Piscicola sp.								X
Piscicola punctata (Verrill)								X

HYDRACARINA	Red River System	Manitoba (General)	Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Arrenuridae:								
Arrenurus auricularis Lavers				X				
Arrenurus auris Lavers				X				
Arrenurus megalurus Marshall							X	
Arrenurus planus Marshall	X							
Arrenurus serratus Marshall						X		
Eylaidae								
Eylais spp.				X				
Eylais as No. 62 Marshall 1929	?				X			
Eylais Ghost River Form A.Marshall/1929?				X				
Eylais abitibiensis Marshall ?				X	X		X	
Eylais extendens (Müller) ?	X		X	X	X		X	
Eylais rimosa Piersig ?	X		X	X				
Hydrachnidae:								
Hydrachna sp.				X				
Hydrachna canadensis Marshall ?	X							
Hydrachna conjecta Koenike ?	X				X			
Hydrachna crenulata Marshall ?				X	X			
Hydrachna cruenta (Müller) ?				X				
Hydrachna geographica (Müller) ?	X							
Hydrachna marshallae Lundblad ?		X						
Hydrachna miliaria (Berleese) ?			X					
Hydrachna rotunda Marshall ?							X	
Hydrodromidae:								
Hydrodroma despiciens (Müller)	X			X				
Hydryphantidae:								
Hydryphantes sp.	X							
Hydryphantes ruber (Geer)					X			
Hygrobatidae:								
Hygrobates neooctoparus (Marshall)	X							
Lebertiidae:								
Lebertia n. sp.				X				
Lebertia regia Habeeb ?				X				

HYDRACARINA	Red River System	Manitoba (General)	Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Limnesiidae:								
Limnesia sp.	X				X			
Limnesia columbica Marshall ?					X			
Limnesia cornuta Wolcott ?							X	
Limnesia paucispina (Wolcott) ?							X	
Mideopsidae:								
Mideopsis americanus (Marshall)					X			
Mideopsis orbicularis (Müller)						X		
Pionidae								
Forelia cooki Habeeb						X		
Hydrochoreutes ungulatus (Koch)					X			
Piona sp.						X	X	
Piona carnea (Koch)	X			X				
Piona constricta (Wolcott)	X			X				
Piona exilis (Wolcott)					X		X	
Piona inconstans (Wolcott)					X			
Piona interrupta Marshall					X			
Piona nodata (Müller)	X						X	
Piona rotunda (Kramer)					X		X	
Piona spinulosa (Wolcott)							X	
Tiphys simulans (Marshall)	X							
Sperchonidae:								
Sperchon glandulosa Koenike ?	X							
Thyasidae:								
Thyas stolli Koenike ?		X						
Unionicolidae:								
Koenika sp.	X					X		
Neumania sp.	X							
Neumania n. sp.				X				
Neumania onondaga Habeeb				X				
Unionicola sp.	X							
Unionicola aculeata (Koenike) ?							X	
Unionicola crassipes (Müller) ?							X	
Unionicola gracilipulpis (Viets)?							X	
Hamappendix sp.	X							
Cryptostigmata:								
Hydrozetes lacustris			X			X		

OLIGOCHAETA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Enchytraidae:							
Enchytraeus sp. Henle					X		
Lumbriculidae:	X	X				X	
Naididae:							
Arcteonais lomondi (Martin)				X			
Nais sp.							X
Nais pardalis Piquet					X		
Specaria josinae (Vejdovsky)					X		
Stylaria sp.				X	X		
Stylaria lacustris (Linnaeus)					X		
Uncinais uncinata (Orsted)				X			
Vejdovskyella comata (Vejdovsky)				X			
Tubificidae:							
Aulodrilus americanus Brinkhurst and Cook				X			
Aulodrilus piqueti Kowalewski				X	X		
Ilyodrilus templetoni (Southern)				X	X		
Limnodrilus sp.	X	X		X	X	X	
Limnodrilus augustipenis Brinkhurst	X						
Limnodrilus claparedianus Ratzel	X						
Limnodrilus hoffmeistri Claparède	X			X	X		
Limnodrilus profundicola (Verrill)	X				X		
Limnodrilus udekemianus Claparède	X			X			
Peloscolex sp.					X	X	
Peloscolex ferox (Eisen)					X		
Peloscolex multi setosus (Smith)				X			
Rhyacodrilus sodalis (Eisen)					X		
Tubifex sp.	X	X		X	X	X	
Tubifex kessleri Hrabě				X			
Tubifex tubifex (Müller)	X			X	X		

PELECYPODA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Sphaeriidae:							
Pisidium (Cyclocalyx) adamsi Prime						X	
Pisidium (Cyclocalyx) casertanum (Poli)	X	X	X	X	X	X	X
Pisidium (Cyclocalyx) compressum Prime	X	X	X	X	X	X	X
Pisidium (Cyclocalyx) fallax Sterki	X						
Pisidium (Cyclocalyx) ferrugineum Prime					X	X	X
Pisidium (Cyclocalyx) lilljeborgi Clessin	X			X	X	X	X
Pisidium (Cyclocalyx) milium Held						X	
Pisidium (Cyclocalyx) nitidum Jenyns	X			X	X	X	X
Pisidium (Cyclocalyx) subtruncatum Malm	X			X	X		
Pisidium (Cyclocalyx) variabile Prime				X	X		X
Pisidium (Cyclocalyx) ventricosum Prime				X	X	X	X
Pisidium (Neopisidium) conventus Clessin				X			
Pisidium (Neopisidium) punctatum Sterki				X			
Pisidium (Pisidium) idahoense Roper				X			
Pisidium (Cyclocalyx) walkeri Sterki	X				X		
Sphaerium (Herringtonium) occidentale (Prime)						X	
Sphaerium (Musculium) lacustre (Müller)	X		X	X	X	X	X
Sphaerium (Musculium) partumeium (Say)				X			
Sphaerium (Musculium) securis (Prime)						X	
Sphaerium (Musculium) transversum (Say)	X	X	X	X			
Sphaerium (Sphaerium) nitidum Clessin				X			
Sphaerium (Sphaerium) rhomboideum (Say)				X			
Sphaerium (Sphaerium) simile (Say)	X	X	X	X	X	X	X
Sphaerium (Sphaerium) striatinum (Lamarck)	X	X	X	X	X	X	X
Unionidae:							
Amblema plicata (Say)	X		X	X		X	
Anodonta grandis grandis Say	X	X	X	X	X	X	X
Anodonta grandis simpsoniana Lea				X	X	X	
Anodontoides ferussacianus (Lea)	X	X	X	X	X	X	X
Fusconaia flava (Rafinesque)	X	X	X	X			
Lampsilis ovata (Barnes)	X		X	X		X	
Lampsilis radiata siliquoidea (Say)	X			X	X	X	X
Lasmigona complanata (Barnes)	X	X	X	X	X	X	X
Lasmigona compressa (Lea)	X				X	X	
Lasmigona costata (Rafinesque)	X					X	
Ligumia recta (Lamark)	X		X	X		X	X
Proptera alata (Say)	X					X	X
Quadrula quadrula (Rafinesque)	X		X	X			
Strophitus undulatus (Say)	X		X	X	X	X	X

PLECOPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	Lake of The Woods
Capniidae:							
Capnia gracilaria Claasen			X				
Capnia manitoba Claasen			X				
Chloroperlidae:							
Hastaperla sp.	X						
Hastaperla brevis (Banks)			X	X			
Nemouridae:							
Nemoura sp.				X			
Zapada cinctipes (Banks)			X				
Perlidae:							
Acroneuria sp.	X					X	
Acroneuria abnormis (Newman)	X		X	X		X	
Acroneuria lycorias Newman	X		X	X		X	
Attaneuria ruralis (Hagen)			X				
Claassenia sabulosa (Banks)				X			
Neoperla sp.	X						
Paragnetina media (Walker)	X			X			
Perla sp.						X	
Perlesta sp.	X						
Perlesta placida (Hagen)	X					X	
Phasganophora capitata Pictet	X					X	
Perlodidae:							
Isogenoides sp.						X	
Isogenoides elongatus (Hagen)			X				
Isoperla sp.	X						
Isoperla bilineata (Say)	X		X	X		X	
Isoperla longiseta Banks	X		X				
Isoperla marlynia Needham and Claassen			X				
Isoperla transmarina (Newman)			X	X		X	
Pteronarcidae:							
Pteronarcys sp.	X					X	
Pteronarcys dorsata	X		X	X		X	
Taeniopterygidae:							
Taeniopteryx parvula Banks			X				

TRICHOPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Brachycentridae:							
Brachycentrus Ca. *numerosus* (Say)	X						
Glossosomatidae:							
Glossosoma sp.	X						
Helicopsychidae:							
Helicopsyche sp.	X					X	
Helicopsyche borealis (Hagen)	X			X			
Hydropsychidae:							
Cheumatopsyche sp.	X					X	X
Cheumatopsyche analis (Banks)				X			
Cheumatopsyche campyla Ross				X			
Cheumatopsyche miniscula (Banks)				X			
Cheumatopsyche speciosa (Banks)				X			
Diplectrona sp. Westwood	X						
Hydropsyche sp.	X	X		X		X	X
Hydropsyche Ca. *aerata* Ross	X						
Hydropsyche alternans (Walker)	X						
Hydropsyche Ca. *bifida* Banks	X			X			
Hydropsyche guttata Pictet				X			
Hydropsyche morosa Hagen	X						
Hydropsyche orris Ross	X						
Hydropsyche recurvata Banks	X			X			
Hydropsyche scalaris Hagen	X			X			
Hydropsyche Ca. *simulans* Ross	X						
Macronemum sp. Burmeister	X						
Hydroptilidae:							
Agraylea sp.	X						
Agraylea multipunctata Curtis				X			
Hydroptila sp.	X						
Hydroptila sp. II	X						
Hydroptila albicornis Hagen				X			
Hydroptila armata Ross				X			
Hydroptila consimilis Morton				X			
Hydroptila hamata Morton				X			
Hydroptila nr. *rono* Ross				X			
Hydroptila salmo Ross				X			
Hydroptila nr. *scolops* Ross				X			

TRICHOPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Hydroptilidae (cont'd):							
Hydroptila spatulata Morton				X			
Hydroptila vala Ross				X			
Hydroptila waubesiana Betten				X			
Hydroptila wyomia Denning				X			
Ithytrichia clavata Morton				X			
Mayatrichia ayama Mosely	X						
Neotrichia sp.	X			X			
Orthotrichia cristata Morton				X			
Oxyethira serrata Ross				X			
Lepidostomatidae:							
Lepidostoma togatum (Hagen)				X			
Leptoceridae:							
Ceraclea sp.	X			X	X		
Ceraclea alagmus Ross				X			
Ceraclea ancyclus (Vorhies)				X			
Ceradea angustus (Banks)				X			
Ceraclea annulicornis (Stephens)				X			
Ceraclea arielles Denning				X			
Ceraclea cancellatus (Betten)				X			
Ceraclea dilutus (Hagen)				X			
Ceraclea erraticus Milne				X			
Ceraclea Ca. flava (Banks)	X						
Ceraclea resurgens (Walker)	X			X			
Ceraclea tarsipunctatus (Vorhies)	X			X			
Ceraclea transversus (Hagen)				X			
Mystacides sp.				X	X		
Mystacides interjecta (Banks)				X			
Mystacides sepulchralis (Walker)				X		X	
Nectopsyche sp.	X			X		X	
Nectopsyche albida (Walker)	X			X			
Nectopsyche candida (Hagen)	X						
Nectopsyche species A	X						
Oecetis sp.	X			X	X	X	X
Oecetis avara (Banks)				X			
Oecetis immobilis (Hagen)				X			
Oecetis inconspicua (Walker)				X	X		
Oecetis ochraea (Curtis)				X	X		X
Setodes incerta (Walker)				X			

TRICHOPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Leptoceridae (cont'd):							
Triaenodes sp.	X			X		X	
Triaenodes a ba Milne				X			
Triaenodes baris Ross				X			
Triaenodes frontalis Bants				X			
Triaenodes marginata Sibley				X			
Triaenodes tarda Milne				X			
Limnephilidae:							
Anabolia bimaculata Walker	X			X		X	
Anabolia consocia (Walker)				X			
Asynarchus montanus (Banks)				X			
Glyphopsyche sp.				X			
Hesperophylax (designatus Walker ?)					X		
Hydatophylax sp.	X						
Limnephilus sp.			X	X	X	X	
Limnephilus canadensis Banks				X			
Limnephilus externus Hagen	X			X			
Limnephilus femoralis (Kirby)				X			
Limnephilus hyalinus Hagen	X			X			
Limnephilus infernalis (Banks)				X			
Limnephilus kennicotti Banks				X			
Limnephilus moestus Banks				X			
Limnephilus sericeus (Say)				X			
Limnephilus nr. susana Nimmo				X			
Limnephilus ornatus Banks	X			X			
Limnephilus parvulus (Banks)				X			
Nemotaulius hostilis (Hagen)				X			
Neophylax sp.	X						
Phanocelia canadensis (Banks)	X						
Platycentropus sp.						X	
Platycentropus plectrus Ross				X			
Platycentropus radiatus (Say)	X						
Pycnopsyche subfasciata (Say)				X			
Molannidae:							
Molanna sp.				X	X	X	X
Molanna flavicornis Banks				X			
Molanna musetta Betten				X			
Philopotamidae:							
Chimarrha aterrima				X			

TRICHOPTERA	Red River System	(Souris River)	(Assiniboine River)	Nelson River System Lake Winnipeg	Lake Winnipegosis System Lake Manitoba	Winnipeg River System	(Lake of The Woods)
Phryganeidae:							
Agrypnia colorata Hagen				X			
Agrypnia glacialis Hagen				X			
Agrypnia improba (Hagen)				X		X	
Agrypnia straminea Hagen				X			
Agrypnia vestita (Walker)				X			
Banksiola crotchi Banks	X			X			
Fabria inornata (Banks)				X			
Phryganea sp.	X						
Phryganea cinerea Walker				X			
Ptilostomis ocellifera (Walker)	X			X			
Ptilostomis semifasciata (Say)				X			
Polycentropidae:							
Cyrnellus sp.						X	
Neureclipsis sp.	X					X	
Neureclipsis bimaculatus (L.)				X			
Neureclipsis crepuscularis (Walker)				X			
Neureclipsis validus (Walker)				X			
Nyctiophylax affinis (Banks)				X			
Nyctiophylax moestus Banks	X						
Nyctiophylax vestitus (Hagen)				X			
Phylocentropus sp.						X	X
Phylocentropus placidus (Banks)				X			
Polycentropus sp.				X	X	X	X
Polycentropus aureolus (Banks)				X			
Polycentropus cinereus Hagen				X			
Polycentropus flavus (Banks)				X			
Polycentropus interruptus (Banks)				X			
Polycentropus Ca. *remotus* Banks	X						
Psychomyidae:							
Lype sp.	X						
Psychomyia flavida Hagen				X			

Attachment C.IV-1

A List of Manitoba Macrophytes
with Accompanying Correspondence

Environment Canada / Environnement Canada
Fisheries and Marine / Pêches et Sciences de la mer

February 4, 1976.

Your file Votre reference

Our file Notre reference
5903-82/7

Dr. J. M. Shay,
Dept. of Botany,
University of Manitoba,
Winnipeg, Manitoba.

Dear Dr. Shay:

You are aware that a major irrigation scheme has been proposed for North Dakota called the Garrison Diversion Project. Waters from the Missouri R. drainage may be permitted to enter the Souris and Red Rivers. This has resulted in concern being expressed as to the downstream environmental effects of such a diversion. As a result of a request from the Canadian and U.S. Governments, the International Joint Commission was asked to investigate the transboundary implications of the Garrison Diversion Project. The IJC established an "International Garrison Diversion Study Board" to undertake the necessary investigations and studies. This board has identified the need for 6 committees - water quality, water quantity, biology, uses, engineering and synthesis and report. The biology committee has been asked to "compile background and baseline data related to biological and ecological factors and evaluate the effects of water quality and quantity on living resources". I am Chairman of the Canadian Section of this Biology Committee.

As discussed with you on the telephone yesterday, one area of interest that the Biology Committee has pertains to the impact of Garrison on Manitoba waters as it relates to aquatic plants. Questions arise include:

1) What aquatic plants are endemic to southern Manitoba waters (Souris R., Assiniboine R., Red R., L. Winnipeg, L. Manitoba, Winnipeg R.)?

2) What aquatic plants could be introduced into Manitoba waters as a result of the Garrison Diversion?

3) What documentation is there on instances of diversions between watersheds and resulting impact (positive/negative/neutral) as it pertains to aquatic plants?

4) What documentation is there on the impact of introduction of aquatic plants into new watersheds, be it by diversion or otherwise?

.....2

Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
(204) 269-7379

Institut des eaux douces
501 University Crescent
Winnipeg (Manitoba)
R3T 2N6
(204) 269-7379

These questions are of concern and interest to the Biology Committee. However, there are time constraints within which our committee has to operate; if at all possible we need a specific answer to #1 and general feelings at least to #2 by March 1. I would like to discuss questions #3, #4 further with you but before March 15.

We do need your assistance in this task and I appreciate your interest in the problem. If you find assistance is needed from me, be it financial, typing, or whatever, please let me know.

I wish to thank you for your anticipated help in this problem and hope that you can assist us in its resolution.

Yours sincerely,

John S. Loch

J. S. Loch, Chairman
Biology Committee (Canadian Section)
International Garrison Diversion
Study Board

JSL/mb

c.c. A. Hamilton

UM

The University of Manitoba

Department of Botany

Winnipeg, Manitoba, Canada R3T 2N2

March 17, 1976.

Mr. J. S. Loch,
Freshwater Institute
501 University Crescent,
Winnipeg, Manitoba
R3T 2N6

Dear Mr. Loch,

I appreciate your need to assemble background information about the Garrison Diversion.

Unfortunately there has been insufficient time available to me to begin to adequately answer your questions. Why is it that design and engineering studies of all such projects involve large teams who work over several years and expend millions of dollars, while the impact of such projects is still approached on an ad hoc basis in an emergency. The stupidity of this approach should be emphasised.

In response to your questions.

The information I have been able to assemble deals only with submerged and emergent macrophytes. I presume that the lower plants algae, fungi, bryophytes etc. are being dealt with by other specialists.

1. Too little is known of the distribution and systematics of native and introduced aquatic plants in southern Manitoba waters to answer your question with any confidence. One of our present graduate students in searching for two pondweeds, has recently examined many waterbodies in the southern part of the province and in so doing, has greatly extended the distribution of known species and also the number of species of submerged macrophytes recorded.

   As far as I know no macrophytes are endemic to Manitoba - but this is a small part of the story. Only by knowing what we presently have can we show which species would be introduced from other watersheds. I attempted with Mrs. Keleher to check our Herbarium distribution records for the watersheds of the Souris River, Assiniboine River, Red River, Lake Winnipeg, Lake Manitoba and Winnipeg River.

   We have covered the monocotyledons, the dicotyledon data remains on the record sheets (illness within the department and other committments have precluded my completing the task.) It is not difficult but requires foreknowledge of which species to seek the distribution for.

2. Until we answer #1 we can't deal effectively with #2.

3&4. There is a wealth of information scattered through the literature. I do not have lists compiled and without searching out the papers could be listing many you already have, for presumably you are involved in an extensive literature search.

Elodea (*Anacharis*), *Eichornia* and *Alternanthera* are three well documented genera.

eg Maddox, D. M., L. A. Andres, R. D. Hennessey, R. D. Blackburn and N. R. Spencer

Insect to control Alligatorweed. An invader of Aquatic Ecosystems in the U.S. Bioscience 21 (#19), 985-991, October 1971.

More refs to come if I've time to list them.

In closing I would like to emphasize my dismay concerning the information you seek. It is deplorable that requests for detailed information with far reaching implications are made to your professional group and then come on to me. Pardon my tone! But yours was one of five letters that reached my desk in one week, each seeking detailed data on some topic. Government agencies seldom feel that the collection of basic information on plant distribution fits with their "mission" or "applied" objectives. But these same agencies continually hope for speedy responses to questions which involve precisely the same information.

I have tried to persuade the provincial government many times to employ a provincial Botanist - without success. It is ironic that we are only able to retain our part-time Herbarium assistant in the Department of Botany by cutting out other support staff. I presume someone is examining the dispersal mechanisms of plants.

Yours sincerely,

Jennifer Shay.

Dr. J. M. Shay,
Associate Professor.

JMS/mm

P.S. Monocot. listing enclosed.
Forgive letter format - inexperienced typist!

SPECIES NOT RECORDED IN S. MANITOBA COMPARED WITH KEAMMERRER et al (1975) (Can. Field Nat. 89)

Juniperus scopulorum

Salix missouriensis (eriocephala)

Ulmus pumila

Rorippa armorica

Ribes missouriense

Crataegus rotundifolia

Viola papilionacea

Verbena urticifolia

J. CLARK SALYER WILDLIFE REFUGE

Species not reported from Manitoba

Marsilea mucronata

Sparganium chlorocarpum = S. diversifolium x Herbarium Record

/ Probable within Range

* Not listed in Scoggan

J.M. Shay.
Dept. Botany
University of Manitoba.

	Souris River	Assiniboine River	Red River	Winnipeg River	Lake Manitoba	Lake Winnipeg	
Typha latifolia	X	X	X	X	X	X	
angustifolia		x	x	x			
Sparganium eurycarpum	/	x	x	x	x	x	
minimum						x	
angustifolium	x	x	/	x	/	/	
Zannichellia palustris			x		x	/	
Ruppia maritima					x		
Potamogeton alpinus				x			
* amplifolius				x			
epihydrus				x			
filiformis					x		
foliosus	/	/		x			
friesii						x	
gramineus	x	/			x	x	
natans				x		x	
* obtusifolius				x		x	
pectinatus		x	/		x	x	
praelongus	/	/				x	
pusillus	/	x	/	x	/	x	
richardsonii	x	x	/	/	x	x	
robbinsii				x			
vaginatus					x	x	
zosteriformis				x			
illinoensis							cited from Souris
Elodea canadensis	/	x	/	x	/	x	
Vallisneria americana							south east
Najas flexilis				x		/	
Butomus umbellatus				x		x	

	Souris River	Assiniboine River	Red River	Winnipeg River	Lake Manitoba	Lake Winnipeg
Acorus calamus			x		x	x
Calla palustris				x		x
Lemna minor			x		x	
Lemna trisulca		x			x	
(?Spirodela polyrhiza)						
Juncus alpinus v. ariflorus	x	x	x		x	x
balticus v. littoralis		x	x		x	x
bufonius		x	x		x	x
? compressus						
dudleyi	x	x	/	/	/	x
? filiformis						
longistylis		x				x
nodosus		x	x		x	x
tenuis			x		x	x
torreyi	x	x			x	
Iris versicolor			x			x
Triglochin maritima	/	x	x		x	x
palustris		x				x

	Souris River	Assiniboine River	Red River	Winnipeg River	Lake Manitoba	Lake Winnipeg	
Alisma gramineum		x	x				
triviale	/	x	x		x	x	
Sagittaria cuneata	x	x	x	x	x	x	
latifolia					x	x	
Glyceria borealis		x					
grandis		x	x		x	x	
pulchella						/	
striata			x			x	
Scolochloa festucacea	x	x			x	/	
	/	x	/	/	x	x	
Phragmites australis (=P. communis v. berlandiari)	/	x	/	/	x	x	
Beckmannia syzigachne	/	x	x	/	x	x	
Phalaris arundinacea	x	x	/	x	/	x	
Leersia oryzoides		x					
Zizania aquatica v. interior							east

Cyperaceae	Souris River	Assiniboine River	Red River	Winnipeg River	Lake Manitoba	Lake Winnipeg
Eleocharis acicularis			x		x	x
calva					x	x
elliptica						x
palustris			x		x	x
Eriophorum angustifolium	/	x	x	/	/	x
chamissonis				x		x
spissum				x		x
viridi-carinatum						
Scirpus acutus	/				x	
americanus		x			x	
atrovirens v. pallidus		x	/		x	
caespitosus spp. callosus					x	
cyperinus				x		x
fluviatilis		/	/		/	
hudsonianus					/	x
microcarpus v. rubrotinctus		x			x	x
paludosus	x	x			x	
rufus					x	
torreyi					x	
validus		x	x		x	x
Carex aquatilis		x	x			x
atherodes	x	x	x		x	x
lacustris				x	x	
laeviconica	x	x	x			
lanuginosa	x		x	x	x	x
lasiocarpa v. americanus						x
lenticularis			x			
pseudo-cyperus		x				x
retrorsa		x	x		x	x
rostrata		x				x
stipata						x

DICOTS SHEET 1

x Herbarium record
/ within range reported by Scoggan

Species	Souris River	Assiniboine River	Red River	Winnipeg River	L. Manitoba	L. Winnipeg
Populus balsamifera				X	X	X
deltoides	X	/	X	X	X	/
tremuloides	/	/	X	X	X	X
Salix amygdaloides	/	/	X	X	X	X
athabascensis						X
bebbiana	X	X	X	X	X	X
brachycarpa			/			
candida	X	X	/	/	/	X
discolor	/	/	X	X	X	X
humilis			/			
lucida						X
lutea			X			
maccalliana				X		
pedicellaris				X		
petiolaris	/	X	X	X	X	/
pseudomonticola		X				
pyrifolia				X		
rigida					X	not incl. by Scog
serissima				/		X
Myrica gale				X		
Alnus crispa						X
rugosa var americana				X		X
Rumex crispus	/	X	X	X	X	/
occidentalis			X			
maritimus v. fueginus	X	X	X	/	X	X
stenophyllus			/			
mexicanus		X	X		X	
Polygonum achoreum			X		X	
P. amphibium var. stipulaceum	/	X	X	/	X	X
aviculare	X	X	X		X	
coccineum	X	X	X		X	X
Polygonum lapathifolium	X	X	X	X	X	X
persicaria					/	
P. punctatum var. confertiflorum			X	/	X	/
ramosissimum			X		X	X
scandens						X
sagittatum						/
Elatine americana			/			
Ceratophyllum demersum					X	
Nymphaea adorata						/ occurs n. L. Wpg.
tetragona						/ on Minago R
Nuphar microphyllum						
variegatum						/ occurs near Norway House

DICOTS SHEET 2

Species	Souris River	Assiniboine River	Red River	Winnipeg River	Lake Manitoba	Lake Winnipeg	
Caltha palustris		X	/			X	
Ranunculus abortivus	/	X	X	X	X	X	
aquatilis		/	X	X		X	
R. circinatus var subrigidus					X	X	Norway House
cymbalaria	X	X	X	X	X	X	
flabellaris			X				
gmelini var hookeri				/	X	X	
lapponicus						X	Warren's Landin
macounii	/	X	X	X	/	X	
pensylvanicus			X	X	X		
reptans			X			X	
scleratus	/	X	/	X	X	X	
septentrionalis						X	
C lamine pensylvanica		X		/		X	
Potentilla palustris		X		X		X	
Callitriche palustris						X	
Myriophyllum exalbescens		X	X		X		
M. verticillatum v. pectinatum	/						
Hippuris vulgaris		X	/	/	X	X	
Cicuta bulbifera				X		X	
maculata			X		X	X	
Suim suave			/		X	X	
Cornus stolonifera	/	X	X	X	X	X	
Glaux maritima		X	X		X	X	
Menyanthes trifoliata		X					
Asclepias incarnata				/	X	X	
Scutellaria galericulata							
var. epilobiifolia		X	X		X		
lateriflora		X				X	
Dracocephalum formosius		X	X	/		X	
Stachys palustris var. pilosa	/	X	X	X	X	X	
Mentha arvensis var. villosa	X	X	X	X	X	X	
Lycopus americanus		X	X			X	
asper		X			X		
uniflorus		X					
Mimulus ringens			X	/			
Gratiola neglecta			X				
Limosella aquatica		X	X				
V nica peregrina var. xalapensis		X			X	X	
scutellata		X	X				
americana		X				X	
salina					X	X	
Utricularia vulgaris	X			X	X	X	

DICOTS SHEET 3

Species	Souris River	Assiniboine River	Red River	Winnipeg River	Lake Manitoba	Lake Winnipeg
Campanula aparinoides						X
uliginosa				/		
Lobelia kalmii						X
spicata var. hirtella		X	X		X	
Eupatorium maculatum var. bruneri	/	X	X	/	X	X
perfoliatum						X
Aster junciformis		X	X			X
simplex	X	X			X	
Bidens cernua		X				X
frondosa			X		X	
Petasites sagittatus		X		/	X	X
vitifolius		X		/		
Senecio congestus	X			X	X	
Viola nephrophylla		X	X			X
palustris						X
Rorippa islandica var. fernaldiana						
islandica var. hispida					X	

Attachment C.IV-2

An Appraisal of the Aquatic and Marsh Vascular Plants of North Dakota

AN APPRAISAL of the AQUATIC and MARSH VASCULAR PLANTS known to occur within the Garrison Diversion Unit Area in North Dakota

by
Vera Facey
University of North Dakota

Contents:

An effort was made to determine from the aquatic and marsh vascular flora of the North Dakota Garrison Diversion Unit Area those species not known to occur in Manitoba. The latter species were then appraised as potential hazards to the province of Manitoba.

The methods used were those most amenable to the situation:

a) A species list (appended) was prepared from the author's field notes supported by references in available literature.

b) Each species on the list was checked against Scoggan's *Flora of Manitoba* and the University of North Dakota file (Vera Facey).

c) Nomenclature, especially synonymy, was checked against the *Gray Herbarium Card Index* and/or the *Index Kewensis*. The former, a North American reference, is maintained to date at the University of North Dakota.

d) The list resulting from (b) above was reduced considerably from over fifty questionable taxa to less than twenty through (c) above.

e) The species on the final list were appraised from subjective and objective points of view. The former included observations by the writer during intervals over approximately two decades; the latter, incorporated whenever possible the published information on the species from references on each taxon's use as food for associated fauna, poisonous properties, objectionable rate of vegetative propagation if any, etc.

f) Finally an overall "impact assessment" based on a - e inclusive, was assembled.

AQUATIC AND MARSH VASCULAR PLANTS

Preliminary check list based
on field work and available references.

Compiler: Vera Facey Vera Facey
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Grand Forks, North Dakota

S = Submerged

E = Emergent

F = Floating

M = Marsh, bog, edge of 'sloughs, etc.

* = Incompletely studied

"CRYPTOGAMS"

Lower Vascular Plants

Non-flowering (non-seed bearing)

PTERIDOPHYTA

Ferns and their allies

Botrychium lunaria (L.) Sw.

"Grape Fern" (M)

*Marsilea mucronata A.Br.

"Water Fern" (E)

Equisetum arvense L.

"Field Horsetail" (M)

Equisetum pratense Ehrh. (M)

Equisetum fluviatile L. (M)

Equisetum kansanum T. H. Schaffner (M)

Equisetum laevigatum A.Br. (M)

Equisetum praealtum Raf. (M)

Equisetum variegatum Schleich (M)

Equisetum sylvaticum L (M)

"PHANEROGAMS"

(seed bearing)

Angiosperms (Anthophyta)

-- MONOCOTYLEDONS --

TYPHACEAE

Typha latifolia L.

"Broad-leaved Cattail" (E)

Typha angustifolia L.

"Narrow-leaded Cattail" (E)

Typha 'glauca' (E)

Hybrid Swarms. T. latifolia x T. angustifolia, etc. Introgressive hybridization

SPARGANIACEAE

Sparganium chlorocarpum Rydb.

var. acaule (Beeby) Fern.

"Bur-reed" (E)

Sparganium eurycarpum Engelm (E)

Sparganium multipediculatum (Morong) Rydg. (E)

NAJADACEAE (Sensu lato)

Najas flexilis (Willd) Rostk & Schmidt

"Naiad" (S)

Zannichellia palustris L.

"Horned Pondweed" (S)

Ruppia maritima L. (S)

"Wigeon Grass" (var. *occidentalis* (Wats) Graebn.)

Potamogeton natans L.

"Floating-leaved Pondweed" (S)

Potamogeton amplifolius Tuckerm. (S)

Potamogeton praelongus Wulfen (S)

Potamogeton friesii Rupr. (S)

Potamogeton gramineus L. (S)

"Variable Pondweed"

Potamogeton richardsonii (A. Benn.) Rydb (S)

Potamogeton pectinatus L. (S)

"Sago Pondweed"

Potamogeton vaginatus Turcz (S)

"Sheathed Pondweed"

Potamogeton pusillus L. (S)

"Small Pondweed"

Potamogeton zosteriformis Fern. (S)

"Eelgrass"; "Flat-stem Pondweed"

Potamogeton foliosus Raf. (S)

"Leafy Pondweed"

JUNCAGINACEAE

Triglochin maritima L. (E)

"Arrowgrass"

Triglochin palustris L. (E)

ALISMATACEAE

Alisma subcordatum Raf.

"Water-Plantain" (E)

Alisma geyeri Tarr. (E)

"Geyer's Water-Plantain"

Sagittania cuneata Sheldon (E)

"Arrowhead"

Sagittania latifolia Willd. (E)

HYDROCHARITACEAE

?*_Anacharis occidentalis_ (Pursh) Victoria (S)

"Elodea" "Waterweed"

Anacharis canadensis Michx (S)

Vallisneria americana Michx (S)

"Eelgrass" "Wild Celery"

POACEAE (GRAMINEAE)

Puccinellia nuttalliana (Schult.) Hitchc. (M)

"Alkali-grass"

Puccinellia cusickii Weatherby (M)

Glyceria grandis S. Wats. (E) & (M)

"Tall Mannagrass"

Glyceria borealis (Nash) Batch. (M)

Glyceria striata (Lam.) Hitchc. (M)

"Fowl Mannagrass"

Scholochloa festucacea (Willd.) Link (E)

"Whitetop" "Sprangletop" "Hollowstem"

Poa fendleriana (Steud) Vasey (M)

Poa pratensis L. (M)

"Canada Bluegrass"

Poa arida Vasey (M)

Poa glaucifolia Scribn. & Will. (M)

Poa palustris L. (E) & (M)

"Fowl Bluegrass"

Eragrostis hypnoides (Lam.) BST (M)

"Creeping Lovegrass"

Catabrosa aquatica (L.) Beauv. (E)

"Brookgrass"

Distichlis stricta (Torr.) Rydb. (E) & (M)

"Saltgrass"

Phragmites communis Trin. (E)

"Common Reed"

Agropyron repens (L.) Beauv. (M)

"Quackgrass"

Hordeum jubatum L. (E) & (M)

"Wild Barley" "Foxtail"

Elymus macounii Vasey (M)

"Macoun Wild-rye"

Sphenopholis obtusata (Michx) Scribn. (M)

"Prairie Wedgegrass"

Deschampsia caespitosa (L.) Beauv. (E)

"Tufted Hairgrass"

*Alopecurus ventricosus Pers. (M)

"Meadow Foxtail"

Alopecurus aequalis Sobol. (M)

"Shortawn Foxtail"

Calumagrostis canadensis (Michx.) Beauv. (M)

"Bluejoint"

Calamagrostis inexpansa A. Gray (E) & (M)

"Northern Reedgrass"

Calamagrostis neglecta (Ehrh.) Gaertn. (M)

Agrostis alba L. (E) & (M)

"Redtop"

Muhlenborgia asperifolia (Nees & Mey.) Parodi (M)

"Scratchgrass"

Muhlenborgia richardsonis (Trin.) Rydb. (M)

"Mat Muhly"

Muhlenborgia racemosa (Michx.) BSP (M)

"Marsh Muhly" "Wild Timothy"

Muhlenborgia frondosa (M)

Muhlenborgia foliosa (Roem. & Schult) Trin. (M)

Sporobolus heterolepis A. Gray (M)

"Prairie Dropseed"

Beckmannia syzigachne (Steud.) Fern. (M)

"Sloughgrass"

Leptochloa fascicularis (Lam.) Gray (E) & (M)

Spartima pectinata Link (E) & (M)

"Prairie Cordgrass"

Spartima gracilis Trin. (M)

"Alkali Cordgrass"

Hierochloe odorata (L.) Beauv. (M) & (E)

"Sweetgrass"

Phalaris arundinacca L. (E)

"Reed-canary Grass"

Leersia oryzoides (L.) Swartz (E)

"Rice Cutgrass"

Zizania aquatica L. (E)

"Wild Rice"

Setaria glauca (L.) Beauv. (M)

"Yellow Pigeongrass"

Echinochloa crusgalli (L.) Beauv. (E) & (M)

"Barnyard Grass"

Panicum virgatum L. (M)

"Switchgrass"

Sorghastrum nutans (L.) Nash. (M)

"Indian Grass"

Andropogon gerardi (M)

"Big Bluestem"

CYPERACEAE

Cyperus inflexus Muhl. (M)

Cyperus odonatus L. (M)

Eleocharis engelmanni Steud. (E)

"Spike Rush"

Eleocharis palustris (L.) R. & S. (E)

Eleocharis calva Torr. (E)

Eleocharis acicularis (L.) R. & S. (E)

Eleocharis compressa Sull. (E)

Eleocharis pauciflora (Lightf.) Link (E)

Eriophorum angustifolium Hanck.

"Cottongrass"

*Hemicarpha drummondii Nees. (M)

*Scirpus nevadensis S. Wats. (E)

"Nevada Bulrush"

Scirpus americanus Pers. (E)

"Chirmaker's Rush" (E)

Scirpus validus Vahl. (E)

"Softstem Bulrush"

Scirpus acutus Muhl. (E)

"Hardstem Bulrush"

*Scirpus heterochaetus Chase (E)

Scirpus paludosus A. Nels. (E)

"Prairie Bulrush"

Scirpus flwviatilis (Torr.) A. Gray (E)

"River Bulrush"

Scirpus atrovirens Willd. (E)

"Darkgreen Bulrush"

Scirpus rubrotmetus Fern (E)

Carex prairea Dewey (E) & (M)

Carex foena Willd.

Carex praegracilis W. Boott. (M)

Carex hookerana Dewey (M)

Carex gravida Bailey (M)

Carex vulpinoides Michx. (E) (M)

Carex diandra Schrank. (E) & (M)

Carex stipata Muhl. (E)

Carex aenea Fern

Carex molesta Mack.

Carex interior Bailey (M)

Carex bebbii Olney (M)

Carex brevior (Dewey) Mack. (M)

Carex synchrocephala Carey (E)

Carex scirpiformis Mack

Carex aurea Nutt.

Carex parrayana Dewey

?Carex torreyi Tuckerm.

Carex capillaris L.

Carex viridula Michx.

Carex aquatilis Wahl. (E) & (M)

Carex hystricina Muhl. (M) & (E)

Carex laeviconica Dewey

Carex atherodes Spreng.

Carex rostrata Stokes

Carex retrorsa Schw.

ARACEAE

Acorus calamus L. (E)

"Sweet Flag"

Calla palustris L. (E)

"Wild Calla"

LEMNACEAE

Lemna trisulca L. (F) (S)

"Duckweed"

Lemna minor L. (F)

Lemna perusilla Torr. (F)

Spriodela polyrhiza (L.) Schleiden (F)

PONTEDERACEAE

*Heteranthera dubia (Jacq.) Mack. (F) & (E)

"Water Stargrass"

Pontederia cordata L. (E)

"Pickerel Weed"

JUNCACEAE

Juncus balticus Willd (M) & (E)

"Baltic Rush"

Juncus bufonius L. (M)

"Toad Rush"

Juncus longistylis Torr. (M)

Juncus gerardi Loisel. (M)

**Juncus interior* Wiegaud (M)

Juncus nodosus L. (M)

"Knotted Rush"

**Juncus brachycephalus* (Engelm.) Buch. (M)

LILIACEAE

Lilium philadelphicum L. (M)

"Wild Lily"

AMARYLLIDACEAE

Hypoxis hirsuta (L) Coville (M)

"Yellow Stargrass"

IRIDACEAE

Sisyrinchium montanum Greene (M)

"Blue-eyed Grass"

ORCHIDACEAE

Cypripedium parviflorum Salisb. (M)

"Yellow Ladyslipper"

-- DICOTYLEDONS --

SALICACEAE

Populus deltoides Marsh (M)

"Cottonwood"

Populus acuminata Rydb. (M)

"Narrow-leaved Cottonwood"

Populus tremuloides Michx. (M)

"Aspen"

Populus balsamifera L. (M)

"Balsam Poplar"

Salix amygdaloides Anders (M)

"Peach-leaved Willow"

Salix interior Rowlee (M)

"Sandbar Willow"

Salix petiolarus J. E. Smith (M)

"Slender Willow"

**Salix cordata* Muhl. (M)

"Heart-leaved Willow"

Salix discolor Muhl. (M)

"Pussy Willow"

Salix bebbiana Sang. (M)

Salix candida Fluegge (M)

BETULACEAE

Ostrya virginiana (Mill.) Koch (M)

"Ironwood" "Hop Hornbeam"

Alnus rugosa (Du Roi) Spreng. (M)

"Speckled Alder"

Betula pumila var. *glaudulifera* Regel. (M)

"Dwarf Birch"

URTICACEAE

Pilea pumila (L.) Gray (M)

"Clearweed"

POLYGONACEAE

Rumex stenophyllus Ledeb. (M)

Rumex persicarioides L. (M)

"Golden Dock"

Rumex mexicanus Meissn. (M)

"Willow-leaved Dock"

Rumex crispus L. (M)

"Curled Dock"

Rumex occidentalis S. Wats. (M)

Rumex domesticus Hartm. (M)

Rumex orbicularis Gray (M)

"Great Water Dock"

Polygonum amphibium L. (E) & (S)

Polygonum natans forma *hartwrightii* (Gray) Stanford (M)

Polygonum coccineum Muhl. (E)

"Long-rooted Smartweed"

**Polygonum pennsylvanicum* L. (M)

Polygonum persicaria L. (E)

"Lady's Thumb"

Polygonum lapathifolium L. (E) & (M)

"Willow-leaved Smartweed"

Polygonum hydropiper L. (M)

"Water Pepper"

CHENOPODIACEAE

Chenopodium album L. (M)

"Lamb's Quarter's"

Chenopodium rubrum L. (M)

"Red Goosefoot"

Atriplex hastata L. (E) & (M)

Salicornia rubra A. Nels. (E) & (M)

Suaeda depressa (Pursh.) S. Wats. (E) & (M)

AMARANTHACEAE

Amaranthus tamariscinus Nutt. (M)

"Water-hemp"

Spergularia marina (L.) Griseb. (M)

"Sand Spurry"

Stellaria crassifolia Ehrh. (M)

Stellaria longifolia Muhl. (M)

"Long-leaved Stitchwort"

Stellaria longipes Goldie (M)

Arenaria laterifloria L. (M)

"Broad-leaved Stitchwort"

Cerastium brachypodum (Engelm.) Robins (M)

Cerastium nutans Raf. (M)

NYMPHAEACEAE

Nuphair advenum Ait. (F) & (E)

"Yellow Water Lily"

CERATOPHYLLACEAE

Ceratophyllum demersum L. (S)

"Horn Wort"

RANUNCULACEAE

Caltha palustris L. (E)

"Marsh Marigold"

Anemone canadensis L. (M)

"Canada Anemone"

Ranunculus aquatilis L. (S)

"White Water Crowfoot"

Ranunculus cymbalaria Pursh. (M)

"Seaside Buttercup"

Ranunculus flabellaris Raf. (S)

"Yellow Water Crowfoot"

Ranunculus gmelini var. *terrestris* (Ledeb.) L. Benson (M)

Ranunculus sceleratus L. (E)

"Dutch Buttercup"

Ranunculus pennsylvanicus L.F. (M)

"Bristly Buttercup"

Ranunculus macounii Britton (M)

Thalictrum venulosum Trel. (M)

"Early Meadowrue"

Thalictrum dosycarpum Fisch. & Lall. (M)

"Tall Meadowrue"

CRUCIFERAE (BRASSICACEAE)

Rorippa islandica (Oeder) Borbas. (M)

"Marsh Yellow Cress"

Rorippa obtusa (Nutt.) Britt. (M)

Cardamine pennsylvanica Muhl. (M)

"Bittercress"

**Cardamine bulbosa* (Schreb.) BSP (M)

"Bulbous Cress"

CRASSULACEAE

Penthorum sedoides L. (M)

"Ditch Stonecrop"

SAXIFRAGACEAE

Parnassia palustris L. (M)

"Northern Grass of Parnassus"

Mitella nuda L. (M)

"Bishop's Cap"

Ribes hirtellum Michx. (M)

Ribes triste Pall. (M)

"Swamp Currant"

ROSACEAE

Spiraea alba DuRoi. (M)

"Wild Spiraea"

Potentilla anserina L. (M)

"Silverweed"

Potentilla norvegica L. (M)

"Rough Cinquetoil"

Potentilla millegrana Engelm. (M)

Potentilla gracilis Dougl. (M)

Potentilla paradoxa Nutt. (M)

Geum rivale L. (M)

"Water Avens"

FABACEAE

Desmanthus illinoensis (Michx.) MacM. (M)

"Prairie Mimosa"

Trifolium hybridum L. (M)

"Alsike Clover"

Amorpha nana Nutt. (M)

POLYGALACEAE

Polygala senega L. (M)

"Senega Snakeroot"

CALLITRICHACEAE

Callitriche palustris L. (S) & (F)

"Water Starwort"

Callitriche hermaphroditica L. (S)

BALSAMINACEAE

**Impatiens pallida* Nutt. (M)

"Pale Touch-me-not"

Impatiens capensis Meerb. (M)

"Spotted Touch-me-not"

ELATINACEAE

*Elatine triandra Schkuhr. (M)

"Mud-purslane"

VIOLACEAE

Viola nephrophylla Greene (M)

"Bog Violet"

Viola papilionacea Pursh. (M)

"Common Blue Violet"

LYTHRACEAE

Ammanvia coccinea Rottb. (M)

"Ammannia"

ONAGRACEAE

Epilobium angustifolium L. (M)

"Fireweed"

Epilobium paniculatum Nutt. (M)

Epilobium leptophyllum Raf. (M)

Epilobium glandulosum var adenocaulon (Hausskn.) Fern. (E) & (M)

Circaea alpina L. (M)

"Enchanter's Nightshade"

HALORAGIDACEAE

Myriophyllum exalbesceus Fern. (S)

"Water Milfoil"

*Myriophyllum heterophyllum Michx. (S)

Myriophyllum verticillatum Michx. (S)

Hippuris vulgaris L. (E)

"Mare's Tail"

UMBELLIFERAE (Apiaceae; Ammiaceae)

Zizia aptera (A. Gray) Fern. (M)

"Meadow Parsnip"

Berula pusilla (Nutt.) Fern. (E)

"Cut-leaved Water Parsnip"

Sium suave Walt. (M)

"Water Parsnip"

Cicuta maculata L. (M)

"Water Hemlock"

Cicuta bulbifera L. (M)

"Bulbous Water Hemlock"

CORNACEAE

Cornus stolonifera Michx. (M)

"Kinnikinnick" "Dogwood"

PRIMULACEAE

Lysimachia ciliata L. (M)

"Fringed Loosestrife"

Lysimachia hybrida Michx. (M)

Lysimachia quadriflora Sims. (M)

**Lysimachia thyrsiflora* L. (M)

"Tufted Loosestrife"

**Centunculus minimus* L. (M)

"Common Pimpernel"

Glaux maritima L. (M)

"Sea Milkwort"

Dodecatheon pulchellum (Raf.) Mer. (M)

"Shooting Star"

GENTIANACEAE

Gentiana procera Holm (M)

"Small Fringed Gentian"

Gentiana acuta Michx. (M)

"Northern Gentian"

Gentiana andrewsii Griseb. (M)

APOCYNACEAE

Apocynum sibericum Jacq. (M)

"Indian Hemp"

ASCLEPIADACEAE

Acerates viridiflora (Raf.) Eaton (M)

Asclepias syriaca L. (M)

"Common Milkweed"

Asclepias speciosa Torr. (M)

"Showy Milkweed"

Asclepias ovalifolia Dec. (M)

Asclepias incarnata L. (M)

"Swamp Milkweed"

Asclepias verticillata L. (M)

"Whorled Milkweed"

POLEMONIACEAE

Navarettia propinqua Suks. (M)

BORAGINACEAE

Heliotropium curassavicum L. (M)

*Plagiobothrys scopulorum (Greene) Johnst. (M)

VERBENACEAE

Verbena hastata L. (M)

"Swamp Venvain"

LABIATAE (Lamiaceae)

Scutellaria lateriflora L. (M)

"Blue Skullcap"

Scutellaria galericulata L. (M)

"Marsh Skullcap"

*Scutellaria leonardi Epling (M)

"Small Skullcap"

Physostegia parviflora Nutt. (M)

"Obedient Plant"

Stachys palustris L. (M)

"Hedge Nettle"

**Stachys aspera* Michx. (M)

Pycnanthemum virginianum (L.) Durand & Jackson (M)

"Mountain Mint"

Lycopus uniflorus Michx. (M)

"Bugle-weed"

Lycopus americanus Muhl. (M)

"Water Hoarhound"

Lycopus asper Greene (M)

"Western Water Hoarhound"

Mentha arvensis L. (M)

"Wild Mint"

SCROPHULARIACEAE

Mimulus rigens L. (M)

"Monkeyflower"

Mimulus geyeri Torr. (M)

"Yellow Monkeyflower"

Bacopa rotundifolium (Michx.) Wettst. (F) & (M)

"Water Hyssop"

Limosella aquatica L. (M)

"Mudwort"

Gratiola neglecta Torr. (M)

"Hedge Hyssop"

*Mimulus guttatus D.C. (E)

Lindernia dubia (L.) Pennell (M)

"False Pimpernel"

Lindernia anagallidea (Michx.) Pennell (M)

Veronica americana Schwein. (E)

"Brooklime"

Veronica connata Raf. (E)

Veronica scutellata L. (M)

"Marsh Speedwell"

Gerardia aspera Dougl. (M)

"Rough Gerardia"

Gerardia tenuifolia Vahl. (M)

"Slender Gerardia"

Pedicularis canadensis L. (M)

"Lousewort"

Pedicularis lanceolata Michx. (M)

UTRICULARIACEAE (Lentibulariaceae)

Utricularia intermedia Hoyne (S)

Utricularia vulgaris L. (S)

"Bladderwort"

PLANTAGINACEAE

Plantago eriopoda Torr. (M)

"Alkali Plantain"

RUBIACEAE

Houstonia lonifolia Gaertn. (M)

"Bluets"

Galium trifidum L. (M)

"Small Bedstraw"

Galium laboradoricum Wieg. (M)

CAPRIFOLIACEAE

Viburnum trilobum Marsh. (M)

"Highbush Cranberry"

Viburnum lentago L. (M)

"Nannyberry"

Viburnum rafinesquianum Schultes (M)

CUCURBITACEAE

Echinocystis lobata (Michx.) T.& G. (M)

"Wild Cucumber"

LOBELIACEAE

Lobelia siphilitica L. (M)

"Great Blue Lobelia"

Lobelia spicata Lam. (M)

"Palespike Lobelia"

Lobelia kalmii R. & S. (M)

"Kalm's Lobelia"

ASTERACEAE (Compositae)

Vernonica fasciculata Michx. (M)

"Ironweed"

Eupatorium maculatum L. (M)

"Joe-Pye Weed"

Eupatorium perfoliatum L. (M)

"Boneset"

Liatris scariosa (L.) Willd. (M)

"Round-headed Blazing Star"

*Liatris pycnostachya Michx. (M)

"Tall Blazing Star"

Solidago gigantea Ait. (M)

"Tall Goldenrod"

Solidago graminifolia (L.) Salisb. (M)

"Narrow-leaved Goldenrod"

Boltonia latisquama A. Gray. (M)

"False Aster"

Aster novae-angliae L. (M)

"New England Aster"

Aster puniceus L. (M)

"Swamp Aster"

Aster laevis L. (M)

"Smooth Blue Aster"

Aster umbellatus Mill. (M)

"Flat-top Aster"

Aster simplex Willd. (M)

"Tall White Aster"

Aster junciformis Rydb. (M)

Aster pauciflorus Nutt. (M)

"Few Flowered Aster"

Aster brachyactis Blake (M)

"Rayless Aster"

Erigeron glabellus Nutt. (M)

"Daisy Fleabane"

Erigeron philadelphicus L. (M)

Erigeron lonchophyllus Hook. (M)

Xanthium strumarium L. (M)

"Cocklebur"

Rudbeckia serotina Nutt. (M)

"Black-eyed Susan"

Rudbeckia laciniata L. (M)

"Tall Coneflower"

Hehanthus tuberosus L. (M)

"Jerusalem Artichoke"

Coreopsis tinctoria Nutt. (M)

"Bugseed"

Bidens cernua L. (M)

"Bur Marigold"

**Bidens acuta* (Wiegand.) Britton. (M)

Bidens frondosa L. (M)

Bidens vulgata Greene (M)

Petasites sagittatus (Pursh.) Gray (M)

"Sweet Coltsfoot" (M)

Senecio congestus (R.Br.) DC (E)

Senecio aureus L. (M)

"Golden Ragwort"

Agoseris glauca (Pursh.) D. Dietr. (M)

Crepis runcinata (James) &. & G. (M)

Prenauthes racemosa Michx. (M)

"Rattlesnake Root"

Sonchus arvensis L. (M)

"Perennial Saw Thistle"

APPRAISAL

AQUATICS AND MARSH PLANTS IN NORTH DAKOTA: NOT REPORTED FOR MANITOBA

FERNS

Marsiliaceae

Marsilea mucronata A.Br. "Waterfern". Not common and has not spread to the northern part of the state. Not reported for Manitoba. Grows in shallow standing water. No known detrimental characteristics.

FLOWERING PLANTS

1) Typhaceae

Typha angustifolia and its hybrid swarms (T. 'glauca') have increased in this area in the last twenty some years. It is likely that Typha latifolia forma ambigua of Scoggan's manual is equivalent to T. angustifolia. An increase in salinity may lead to its establishment and increase. Muskrats and beaver utilize roots and shoots; birds and other organisms the habitat. Both species of Typha and their hybrids can create eradication problems in slower moving or standing water.

2) Sparganiaceae

Sparganium chlorocarpum, var. acuta (Beeby) Fernald. Rare in eastern area, North Dakota. No known undesirable attributes.

3) Zosteraceae (Potamogetonaceae, Najadaceae, etc.)

Ruppia maritima L. var. occidentalis (Wats.) Graebn. could become profuse with an increase of soluable salts in the habitat. However, all members of the Zosteraceae: Zannichellia, Ruppia, Najas and the many species of

Potomogeton are highly rated as food for waterfowl and marsh birds.

4) Alismataceae

Alisma subcordatum Raf. A question of separating it from other species in Manitoba? Tubers and fruit utilized by waterfowl.

5) Cyperaceae

Dulichium arundinaceum (L.) Britt. Should occur in Manitoba according to range cited. Rare in North Dakota.

Scirpus nevadensis S. Wats. and *S. heterochaetus* Chase occur in the eastern area of North Dakota. Food for waterfowl. No known undesirable attributes.

6) Lemnaceae

Lemna perpusilla Torr. Not common. Duck food. Does not "take over" the surface of ponds as does *L. minor* and its infrequent admixture of *Spirodela polyrhiza*.

7) Pontederiaceae

Heteranthera dubia (Jacq.) MacM. and *Pontederia cordata* L. Should occur in Manitoba. Both within Garrision Diversion Unit area. No detrimental characteristics.

8) Boraginaceae

Allocarya scopulorum Greene (=*Plagiobothyrs scopulorum* (Greene) Johnst.) Insignificant (?) annual of wet, saline areas. Could be *A. californica* (F & M) Greene of Manitoba?

9) Haloragaceae

Myriophyllum heterophyllum Michx. Rare in North Dakota.

10) Polygonaceae

Rumex verticillatus L. Common in North Dakota. Should occur in Manitoba?

ASSESSMENT

To the knowledge of the writer and from the preliminary literature search, none of the appraised species is detrimental. None will create problems more serious than can be created by a change in the habitat for species now prevalent in Manitoba, e.g. *Triglochin maritima*, a poisonous member of the Juncaginaceae occurs commonly in alkaline areas in North Dakota and Manitoba. With increasing alkalinity, both it and other halophytes including *Typha angustifolia* and its hybrids could increase. However, this is one impact that the writer is not prepared to evaluate.

Of the species known to reproduce vegetatively with some degree of rapidity none is detrimental apparently, e.g., A) The submerged *Ruppia* sp., *Zannichellia* sp., *Najas* sp., *Potomogeton* spp. are fairly ubiquitous. The habitat requirements vary with the species but all are found in standing to slower moving waters. The majority, perhaps all species, provide valuable food for wildlife, especially waterfowl. None has been reported poisonous to man. B) The floating member of the Lemnaceae is quite rare in North Dakota. Our records do not indicate a rapid vegetative reproduction like that of *Lemma minor*.

Generally stated, the emergent aquatics, except for the annuals, do not reproduce rapidly. Many arise from spreading rhizomes, hence a stand will increase in size, barring erosion and other environmental barriers to distribution. Others occur locally, arising through shallow water. All emergent (E) species have been indicated in the master check list. None cited on the appraisal list has known detrimental properties other than those already known for similar species in Manitoba, e.g., spreading and the possible expense of eradication.

Finally, in summary, none of the aquatic and marsh vascular plants within the Area under study should present future problems to Manitoba. The majority are common to both Manitoba and North Dakota. Those known from North Dakota and not from Manitoba have apparently no known detrimental qualities.

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Attachment C.IV-3

Endangered Plant Species in Manitoba

Endangered plant species in Manitoba along GDU Manitoba waterways (compiled by Jennifer Shay 1974).

Species	Souris River	Assiniboine River	Red River	Lake Winnipeg	Lake Manitoba
	GDU Location				
Anemone patens	X	X	X	X	X
Aquilegia brevistylis[1]					
Polanisia graveolens[1,2]					
Arisaema atrorubens[2]					
Arisaema triphyllum[2]			X		
Calapogon pulchellus[1,2]					
Calypso bulbosa[1,2]					
Caulophyllum thalictroides[2]			X		
Celtis occidentalis					X
Chelone glabra v. linifolia[1,2]					
Chrysosplenium tetrandum[1,2]					
Cypripedium arietinum[1]					
C. candidum[2]		X			
Desmodium canadense[2]			X		
Epigaea repens v. glabrifolia[1]					
Gentiana flavida[2]					
G. linearis[1,2]					
Hedysarum alpinum v. philoscia[2]		X			
Malaxis monophylla v. brachypoda[2]	X				
Opuntia fragilis[2]		X			
Opuntia polyacantha		X			
Phryma leptostachya[2]		X			
Potentilla concinna		X			
Psolarea esculenta[1,2]	X				
Rumex venosus	X				
Sanguinaria canadensis			X		
Scheuchzeria palustris v. americana[1,2]					
Sphaeralcea coccinea	X	X			
Symplocarpus foetidus[1,2]					
Thermopsis rhombifolia	X				
Townsendia exscapa		X			
Uvularia sessilifolia			X		
Vernonia fasciculata[2]					

[1] Species presently absent from area.

[2] Species which occupy moist habitats or riverbanks.

Distribution and habitat of "rare and endangered" plant species along GDU Manitoba waterways (compiled by Biology Committee).

Anemone patens Pasque-flower	[1]Scoggan: [2]Stevens:	Common on dry prairie and hillsides of S. Man. Common on high prairie
Aquilegia brevistylis	Scoggan: [3]Ferneld:	Woods thickets and clearings throughout Prov. Subarctic west Amer. Rock crevices, open woods, meadows
Polanisia graveolens Clammyweed	Scoggan: Gray: Stevens:	1 specimen from Aweme. Temp. east Amer. Man. E. and S. Gravelly shores and banks, Man. east and south Frequent, chiefly western ND usually in gravelly soil on lake shores and hillsides
Arisaema atrorubens Jack in the pulpit = A. triphyllum	Scoggan: Stevens:	Emerson, Carman, Wpg. Eastern American Man. E. and S. Eastern part of N.D., frequent in woods
Calapogon pulchellus Grass-pink	Scoggan: Stevens:	Bogs and wet habitats: Cedar Lake, East of Winnipeg. S.E. Man. E. and S. Not listed
Calypso bulbosa	Scoggan: Stevens:	Cool marshy woods and damp clearings in south of Prov. Point du bois. Sub arctic Not listed
Caulophyllum thalictroides Blue Cohosh	Scoggan: Stevens:	Woods along Assin. R. East Selkirk Portage la Prairie. S. Man. E. and S. Rare in woods
Celtis occidentalis Hackberry tree	Scoggan: Stevens:	Delta; S. Man. E. & S. Common along Red at Fargo, planted as shelterbelt
Chelone glabra v. linifolia	Scoggan:	low, wet ground, eastern Man. Turtle Mtn. S. Man. E. and S.
Chrysosplenium tetrandum	Scoggan: Stevens:	Wet swamp. Riding Mtn., Duck Mtn., Churchill Artic circumpolar Not listed
Cypripedium arietinum Ladyslipper	Scoggan: Stevens:	Damp woods, Richer, Arborg, Cedar Lake Temp. east Amer. SC Man. E. and S. Not listed.
C. candidum	Scoggan: Stevens:	Woodlands, Brandon, Aweme Temp. east. Amer. S. Man. S. and E. Moist prairie, common in Minn.

Desmodium canadense Tick trefoil	Scoggan:	Damp woods and stream thickets: Lake of the Woods, Winnipeg, Morden, Aweme. Temp east Amer. Man. S. and E.
	Stevens:	Occasional in grasslands
Epigaea repens v. glabrifolia Mayflower	Scoggan:	East of Wpg., Dauphin, East Amer.
	Stevens:	No record
Gentiana flavida	Scoggan:	1 spec. from south of Wpg. Temp east Amer. S. Man. E. and S.
	Stevens:	No record
G. linearis	Scoggan:	Shoal Lake Ont., Wpg., Morden, Riding Mtn. Temp east Amer. S. Man. E. and S.
	Stevens:	No record.
Hedysarum alpinum v. philoscia	Scoggan:	banks of rivers North of L. Wpg. Grand Rapids Temp. west Amer. Man. W. and S.
	Stevens:	No record.
Malaxis monophylla v. brachypoda	Scoggan:	Boggy places, Treesbank, Grandview, Lake Winnipegosis. Temp east Amer. SC Man. S. and E.
	Stevens:	No record
Opuntia fragilis Brittle prickly pear	Scoggan:	Dry granite shore,dry sandy prairie Falcon L. Spruce Woods, Temp. W. Amer. W. Ont. W. and S.
	Stevens:	Strongly saline clay flats, buttes and stony knolls
O. polyacantha Prickly pear	Scoggan:	Alkaline prairie, sandhills, Morden, Oak Lake, Miniota, Aweme, St. Lazare, Lauder. Temp. W. Amer. B.C. to Man. S.
	Stevens:	Common Miss. R. westward
Phryma leptostachya	Scoggan:	Stream thickets, moist shaded soil. Morden, Graysville, Carman, Portage. Temp. E. Amer. S. Man. E. and S.
	Stevens:	Common in S.E. N.D.
Potentilla concinna	Scoggan:	Sandy prairie and gravelly clearings in S. Man. St. Lazare, Lake Manitoba, Brandon. Temp. W. Amer.
	Stevens:	Frequent on high prairie or hills west N.D.
Psolarea esculenta Breadroot	Scoggan:	Dry prairies of S. Man. Millwood N. of Brandon, Fort Garry. Temp. W. Amer.
	Stevens:	Frequent to common on prairie

Rumex venosus Large flowered dock	Scoggan:	Sandy open habitats. Aweme, Carberry, Fisher Branch. Temp W. Amer. S. Man. W. and S.
	Stevens:	In very sandy soil. Miss. R. west
Sanquinaria canadensis Bloodroot	Scoggan:	Sandilands, Sprague, Roseisle. Temp. east Amer. SE Man. E. and S.
	Stevens:	Abundant in woods along Red and tributaries in SE N.D.
Scheuchzeria palustris v. americana	Scoggan:	1 spec. Reindeer Lake marsh subarctic temp Amer.
	Stevens:	No record
Sphaeralcea coccinea	Scoggan:	Sandy or clay prairie of S. Man. Long River, Dropmore, Temp. W. Amer.
	Stevens:	Very common in dry poor soil
Symplocarpus foetidus Skunk-cabbage	Scoggan:	Wet meadows and swampy woods. Winnipegosis Temp. east Amer. S. Man. E. and S.
	Stevens:	No record
Thermopsis rhombifolia False lupine	Scoggan:	Dry prairie SW Man. Temp. W. Amer.
	Stevens:	Frequent to common Miss. R. west.
Townsendia exscapa	Scoggan:	Cypress R., Glenboro, Aweme, sandhills Temp. W. Amer.
	Stevens:	Rather rare on prairies
Uvularia sessilifolia	Scoggan:	Thickets and open woods. 1 record from Roseisle. Temp. E. Amer. S. Man. E. and S.
	Stevens:	Woods rare
Vernonia fasciculata	Scoggan:	Spec. only from Morris by Red R. Temp. Amer. S. Man. S.
	Stevens:	Along ditches and wet grassland. S.E. N.D.

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Attachment C.IV-4

The Effects of the Garrison Diversion Unit on the Introduction and Distribution of Terrestrial Weeds in Manitoba

by

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The Effects of the Garrison Diversion Unit on the Introduction and Distribution of Terrestial Weeds in Manitoba

W. C. McDonald, Plant Pathologist and Director

Agriculture Canada Research Station, Winnipeg, Manitoba

Introduction

The growth of weeds in agricultural land is one of the main causes of crop losses in Manitoba as in other agricultural areas. The costs associated with this problem including direct loss of profits to farmers from lower yields, the costs of applying chemical or cultural control measures and the costs of maintaining a surveillance and control program for noxious weeds amount to many millions of dollars each year. Any factor that would tend to increase these costs would be of concern to the agricultural industry of Manitoba. For this reason the Biology Committee decided to consider the effects of the completion of the GDU would have on weed infestations in Manitoba.

Most weeds can be classified as common and are distributed widely over large geographic areas. Wild oats, mustards, quack grass, foxtail etc. are included in this group and, although they are probably the main cause of crop losses, their complete eradication is impossible. Other weeds, usually those that are difficult to control because of their growth habit, are classified as noxious. Some weeds have a restricted geographical distribution because they require a particular environment for growth or because they have not been distributed throughout the area in which they might grow. The introduction of the latter type of weed into a new area would be of major concern to those responsible for weed control in Manitoba.

Present Situation

The most important noxious weeds that occur in North Dakota, the Missouri River watershed of Montana and in Manitoba are listed in Table 1. The table is based on information provided by Prof. John D. Nalewaja, N.D.S.U., Fargo, N.D., Mr. M. J. Jackson, Extension agronomist - Weed Control, Co-op. Ext. Serv., Bozeman, Mont. and Mr. J. O. Forbes, Chief, Weeds Section, Soils and Crops Branch, M.D.A., Winnipeg, Man. The list is not exhaustive as the Noxious Weeds Act of Manitoba, Schedule A, lists 225 weed species that are considered noxious but many of them are common weeds that are prevalent throughout the prairies. Some weeds, such as scentless or false chamomile (Matricaria maritima L. var. agretis (Knof) Wilmott) that is of increasing concern in areas of North Dakota (Mitich, 1976), are not listed as noxious at this time. It and all of the weed species classed as noxious in the two states also occur in Manitoba.

The occurrence of the same weed species throughout the central prairie states and provinces is not surprising in view of the numerous methods there are for dispersing weed seeds. Mans activities are primarily responsible for the long distance spread of weed seeds through transporting them on farm machinery and vehicles, and as contaminants in commercial seed, fodder, packing material, nursery stock, etc. As an example it is believed that nodding thistle infestations in Manitoba resulted from the introduction of seed in forage imported from the U.S.A. during the feed shortage in 1961 (Webster, 1973). Weed seeds can also be transported long distances attached to or in the digestive tract of wild and domestic animals and birds. Wind is very important in dispersing weed seeds and many seeds are especially adapted to this mode. Many weed seeds are adapted to transport by flowing water. Some of these have special appendages such as air sacs, corky layers or hairs to help them float and others are so light and small they will float due to surface tension. Unadapted seeds can be carried along in soil sediments moved by water.

Under present conditions there is no reason to believe that seed of a new species of weed, introduced into North Dakota or Montana, would not be dispersed sooner or later into Manitoba by the normal means of weed seed dispersal. Natural flooding of the Red and Souris Rivers has provided ample opportunities for seed distribution from North Dakota into Manitoba in the past and the situation will not change in the foreseeable future.

Potential Effects of the Garrison Diversion Unit

There are two aspects to be considered in evaluating the effects that the GDU may have on weed infestations in Manitoba. One is the possibility that the GDU may increase the chances of introducing seed of a new species of noxious weed into Manitoba and the other is the probability that an increase in the area flooded in the spring will facilitate the distribution of indigenous noxious weeds to new areas.

The opportunity for the distribution into Manitoba of new weed species introduced into the watershed of the Red River in North Dakota or Minnesota already exists via the Red River. The main concern is the establishment of a new weed species on land drained by the Missouri River which will be channelled into the McClusky Canal and eventually through other canals and irrigation channels into the Red, Souris and Assiniboine Rivers. Seeds transported by this route would become established along canal and river banks and these areas would provide sources of infestation of adjacent farm land. It is possible that seeds of new species would be distributed into Manitoba sooner by this route than by other natural or artificial methods.

An increase in the area of land flooded in the spring through an increase caused by GDU in the amount of water flowing in the Red and Souris Rivers would have an adverse effect on farmland in the affected area. Seeds of noxious weeds growing on non-cultivated land would be carried by flood waters to crop land and would be concentrated particularly at the farthest point of inundation.

More effort would be required by individual farmers and weed inspectors in surveying these areas to locate pockets of infestation. If undetected, patches of weeds can enlarge rapidly and costs of control, which must be borne by the land owner, increase proportionally. In some cases land is out of production until the infestation is brought under control.

The significance of the damage caused by increased flooding depends on the extent of the additional area flooded because of the GDU. Data provided by the Water Quantity Committee indicate that there will be no measurable increases in flooded areas on either the Red or Assiniboine Rivers in Manitoba as a result of GDU added flows. On the Souris River, GDU flows will not increase the area flooded during the spring run-off period in April even with the maximum flood levels reached in the 2% of the years for which data is available. Floodwaters will recede more slowly in the Souris watershed from the U.S. border to Souris town under the influence of added return flows from GDU in July and August but this would have no effect on weed dispersal.

Conclusion

The effects of the GDU on the introduction of weed seeds into Manitoba will be minimal. The noxious weed species that are present now in North Dakota and Montana also occur in Manitoba and if new species are introduced into these states they will eventually reach Manitoba by natural methods of seed dispersal.

The distribution of weed seeds from local sources of infestation into new areas will not occur as a result of the GDU as additional flows from the GDU will not enlarge the area flooded naturally during spring run-off in April on the Red, Assiniboine and Souris Rivers.

This report was reviewed by:

Dr. E. Stobbe, Professor of Weed Science, Univ. of Man., Winnipeg.

Mr. J. C. Forbes, Chief, Weeds Section, Soils and Crops Branch, Manitoba Dept. of Agric. Winnipeg.

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Table 1. Weeds classified as noxious in areas affected by the Garrison Diversion Unit

	Montana	North Dakota	Manitoba
Canada Thistle *Cirsium arvense* (L.) Scop.	X	X	X
Field Bindweed *Convolvulus arvensis* L.	X	X	X
Leafy Spurge *Euphorbia esula* L.	X	X	X
Russian Knapweed *Centaurea repens* L.	X	X	X
Toadflax *Linaria vulgaris* Mill.	X		X
Dalmatian toadflax *Linaria dalmatica* (L.)	X		X
Spotted Knapweed *Centaurea maculosa* Lam.	X		X
Nodding Thistle *Carduus nutans* L.	X		X
Tansy *Tanacetum vulgare* L.	X		X
Perennial Sow-Thistle *Sonchus arvensis* L.	X	X	X
Wild Licorice *Glycyrrhiza lepidota* (Nutt.) Pursh	X		X
Heart-Podded Hoary Cress *Cardaria draba* (L.) Desv.	X	X	X
Dodders *Cuscuta* spp.		X	X
Absinthe *Artemisia absinthium* L.		X	X
Stinkweed *Thlaspi arvense* L.		X	X
Hedge bindweed *Convolvulus sepium* L.		X	X
Quack Grass *Agropyron repens* (L.) Beauv.		X	X
Wild Mustard *Brassica kaber* (DC.)		X	X
Wild Oats *Avena fatua* L.		X	X

X = present and classified as noxious.

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Revised Regulation N110-R1, 1973, of the Noxious Weeds Act. Province of Manitoba.

Attachment C.IV-5

The Effects of the Garrison Diversion Unit on the Incidence and Severity of Plant Diseases in Manitoba

THE EFFECTS OF THE GARRISON DIVERSION UNIT ON THE INCIDENCE AND SEVERITY OF PLANT DISEASES IN MANITOBA

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This report deals with the potential effects of developing the Garrison Diversion Unit on the incidence and severity of plant diseases in Manitoba. In it I considered the types of crops grown and the occurrence of soil-borne diseases in the areas affected, the effectiveness of water as a means of dispersing plant pathogens, the introduction of new diseases into North Dakota and the potential introduction of them into Manitoba via the Garrison Diversion Project, and the effect of flooding on planting dates and the concomitant increased severity of diseases.

GENERAL COMMENTS

Crops. Most of the major plant disease organisms or biotypes of them are host specific and their establishment in a new area depends on the availability of a susceptible host. With few exceptions North Dakota and Manitoba have similar cropping systems (Table 1). Rapeseed, mustard, peas and buckwheat are not major crops in North Dakota while soybeans, millet and edible beans are not major crops in Manitoba at this time. However, over 90% of the cultivated acreage in each region is sown to the same crops. Diseases of these crops now present or introduced at a later date in the watersheds drained by the Garrison Diversion Unit would find no lack of suitable hosts if dispersed into Manitoba.

Pathogens. Most plant diseases are caused by fungi whose spores are air-borne and distributed widely by wind. As an example, spores of the rust diseases of cereals are transported north from Texas throughout the Mississippi and Red River valleys into the northern USA and Canada. Strong winds may also disseminate fungi, bacteria, viruses and nematodes in plant debris and soil particles over considerable distances including international boundaries. Many fungal, bacterial and viral diseases are seed-borne and are dispersed in this manner. Others are dispersed by insects such as virus diseases transmitted by aphids and leafhoppers which in turn are dependent on wind for wide dispersal. None of these types of plant diseases are of any significance in a discussion of the effects of the Garrison Diversion.

The diseases with which we are concerned are those caused by pathogens which produce no aerial spores, are soil-borne, attack the root systems of host plants, and are believed to tolerate transport by water to new areas.

Representatives of the various types of pathogens that fit this criteria are listed in Table 2. Very little research has been done on the long distance spread of plant pathogens in streams or rivers; most of what has been done is on the effects of irrigation water on the spread of diseases in local areas. In many cases it is presumed that aquatic fungi, fungi that produce thick walled resting spores, bacteria, and nematodes could be transported by flowing water but quantitative data are rare particularly concerning soil-borne organisms (Hirst, 1965).

The Phycomycetes or water molds, the Plasmodiophorales or slime molds, and the Actinomycetes are generally described as being "distributed in wind or water-borne soil", "disseminated locally by drainage water", or "more severe in wet seasons and poorly drained soils". (Walker, 1950). These are represented in Table 2 by the genera Streptomyces, Pythium, Aphanomyces, Spondylocladium, Synchytrium, and Plasmodiophora. Cooke and Bartsch (1960) isolated species of Aphanomyces and Pythium from streams in Ohio and McIntosh (1966) isolated Phytophthora cactorum (Leb. & Cohn) Schroet., another aquatic pathogen, from water in British Columbia and believed that this lead to increased incidence of collar rot of apple trees in that area. These genera appear to be the most important of the fungus pathogens in relation to dispersal by water.

Species of Fusarium and Verticillium, which are not aquatic fungi, were also isolated from streams in Ohio (Cooke, 1961) and F. oxysporum and F. solani were shown to contribute to the breakdown of hydrocarbons such as motor oils in sewage water (Cooke, 1956). It is possible that thick-walled vegetative structures produced by these fungi could be deposited on agricultural land during floods and spread infection.

Bacteria. Plant pathogenic bacteria are represented by only 5 genera: Pseudomonas, Xanthomonas, Erwinia, Corynebacterium and Agrobacterium. Dispersal of those that attack growing crops is accomplished by infected seed, insects, machinery or wind-blown particles of soil or infected plant debris. Some may be transported short distances by water but they are poor saprophytes as Buddenhagen (1965) states "The susceptibility of the pathogenic bacterial cell to dessication, light and other rigors of the external environment and its short life expectancy in competition with other microorganisms emphasize the need for rapid and direct dispersal."

Viruses. There are several viruses that are known to be soil-borne but there is little evidence of their dispersal by water. Some are carried by aquatic fungi (Grogan et al, 1958) or nematodes (Raski and Hewitt, 1963) which act as vectors of the virus and these could be dispersed by water. However, none of these would be important pathogens of Manitoba crops.

Nematodes. The more important plant pathogenic nematodes that are adapted to northern environments occur in the genera *Ditylenchus* (stem and leaf nematodes) and *Heterodera* (cyst nematodes). They generally have wide host ranges and can survive for many years in soil as eggs, larva or cysts. They can be dispersed in wind-blown plant debris and soil particles and in irrigation water. In Ontario, Potter and Townshend (1973) reported that "The oat-cyst nematode, *H. avenae* and clover-cyst nematode *H. trifolii* were mainly found in the Trent, Grand, Maitland, Thames and Welland River watersheds, often within a half-mile of a creek or river." and implied that *H. avenae* had been introduced into Ontario by some method other than water and then distributed by water in these watersheds. Chitwood (1927) in New York and Thompson, Roebuck and Cooper (1949) in England concluded after extensive studies that floodwater was of minor importance in the dispersal of cysts of the golden nematode of potato.

PRESENT SITUATION

The Red and Souris rivers have flooded periodically under natural conditions for many years which has provided ample opportunity for the dispersal of plant pathogens from their watersheds in Minnesota and North Dakota into Manitoba. All of the fungal and bacterial diseases of major crops listed in Table 2 as occurring in North Dakota have been introduced already and are endemic in Manitoba.

If new disease pathogens that could be dispersed by water are introduced into areas drained by watersheds in Minnesota or North Dakota it is probable that they will eventually be introduced into Manitoba through natural drainage and periodic flooding. Dutch Elm Disease is an example that has been cited recently. It was first identified in Fargo in 1972 and was diagnosed on property adjacent to the Red River in Winnipeg and Selirk in 1975. By inference it was believed that infected elm tree debris carried by the Red River from areas in North Dakota had provided inoculum of the fungus pathogen and the beetle vector. But infected trees were also discovered in 1975 in Brandon, 140 miles west of Winnipeg. Most authorities now believe that contaminated beetle vectors were more likely introduced into Manitoba on vehicles rather than by water.

It is inevitable that new diseases that appear in the present watersheds in Minnesota or North Dakota draining into Manitoba will spread to Manitoba by one method or another. Dispersal by wind-blown plant debris and soil particles containing pathogens would be a more likely method of transfer than the less efficient transfer by flowing water.

POTENTIAL EFFECTS OF GARRISON DAM UNIT

Plant pathogens are no threat to crops so long as they remain in the drainage channels. As Hirst (1965) states "Percolating water obviously has less chance of dispersing microorganisms laterally over considerable distances than run-off water. The load of propagules will be greatest when the soil is being eroded in the catchment areas, but although propagules may be common in drainage-channel water their chances of re-establishment is small unless they are redistributed over soil or crops by flooding or irrigation."

Our main concern is with the projected increase in flooding on the Red and Souris Rivers and the effects of increased use of irrigation in the areas drained by the Souris River.

The Water Quantity Committee does not foresee any increase in flooding on the Red River as a result of the completion of the Garrison Dam Unit. Our only concern in this system would be the introduction of new diseases that could attack crops grown in Manitoba into the Lamoure Oakes area of North Dakota and their subsequent movement north via the Red River. These will be considered below.

The main impact on Manitoba agriculture will result from the completion of the Velva Canal and the establishment of a large irrigation scheme draining into the Souris River basin. This could have various effects on the plant disease situation in Manitoba.

Introduction of plant diseases.

A few diseases, controlled by quarantine measures in the USA and Canada, could present a problem in Manitoba if introduced into watersheds of North Dakota and Montana draining into Manitoba. Potato wart, a disease of potato caused by the fungus, Synchytrium endobioticum, and the golden nematode Heterodera rostochiensis are examples. The probability of introducing these diseases depends on the effectiveness of quarantine measures to exclude them and of methods used to eradicate them if they are identified in these areas.

There are other diseases not controlled by quarantine that could be introduced into Manitoba by flooding. Tip rot of sugar beets (Aphanomyces cochliodes) and root rot of peas (A. euteiches) have not been identified in Manitoba but do occur in other areas in Canada. In Ontario and Alberta they are not considered to be major pathogens of sugar beets and peas but can cause some damage in certain types of soil (Conners, 1967). Club root of crucifers (Plasmodiophora brassicae) although reported in North Dakota and unconfirmed in Manitoba should not become an important disease in this area because disease development is inhibited in alkaline soils (Walker, 1950). The stem and leaf nematode (Ditylenchus dipsaci) and the cyst nematode

(Heterodera schachtii) are important disease agents on alfalfa and sugar beets among other hosts. Neither have been reported from North Dakota or Manitoba but both occur in irrigated areas of Alberta and Western USA. H. schachtii was first identified in irrigated crop land in Alberta in 1961 and is now present in all sugar beet growing districts of the province. Rapeseed, a major crop in Manitoba, is also a susceptible host plant.

It is unlikely that water transport would be the method of dispersal for these pathogens into Manitoba. Wind is a more efficient method of carrying pathogens from field to field in plant debris and soil particles and eventually spreading diseases over large areas. It is also unlikely that the pathogens listed above could cause significant damage if introduced unless an irrigation scheme was developed along the Souris River basin in Manitoba. The fungus pathogens are favored by moist soils and the nematodes are dispersed locally by splashing water from overhead irrigation.

Effect of flooding on severity of diseases.

In Manitoba and other regions a delay in planting of a week or more results in lower yields of agricultural crops. The results of extensive experiments by Nass et al (1975) are similar to those from local tests in Manitoba (Buchannon et al, 1974). The losses in yield are caused in part by an increase in the severity of the diseases attacking these crops. The major diseases of cereal crops are caused by air-borne fungus spores and by viruses transmitted by air-borne insect vectors. The inoculum builds up on infected crops in North Dakota as the season progresses and this inoculum is blown north into Manitoba. Delayed planting produces crops that are at a vunerable stage when inoculum abundance reaches a peak and yield losses are significantly higher (Gill, 1970; Fleischmann and McKenzie, 1965).

If the Garrison Dam Unit causes an increase in the area of agricultural land flooded in the spring along the Souris River in Manitoba, farmers affected will be forced to plant later than normally and will be subject to increased losses from plant diseases.

CONCLUSIONS

In my opinion the development of the Garrison Dam Unit would have very little impact on the prevalence or severity of plant diseases in Manitoba. The major diseases of the agricultural crops grown in North Dakota and Manitoba are endemic in both regions. A few other diseases now present in North Dakota or which may be introduced some time in the future will become more important under irrigation in the Souris area. These would only have implications for Manitoba if irrigation schemes were also developed in the province utilizing the increased flow on the Souris River. The benefits from irrigation would be greater than the losses caused by introduced plant diseases.

An increase in the area of agricultural land adjacent to the Souris River that would be subject to flooding in the spring would have an indirect impact on the severity of plant diseases in Manitoba. Losses from diseases become increasingly greater when planting is delayed beyond the normal date. Other adverse affects of increased flooding on agriculture land will be found in the report of the Uses Committee.

This report was reviewed by

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Table 1. Principle crops grown in North Dakota and Manitoba, 1974.

Crop	North Dakota Acreage (000)	%	Manitoba Acreage (000)	%
Wheat	10,036	50.9	3,000	33.2
Barley	2,090	10.6	1,800	19.9
Oats	1,400	7.1	1,200	13.3
Alfalfa	1,612	8.2	included under "Hay"	
Flax	820	4.2	750	8.3
Corn	520	2.6	33	0.4
Sunflowers	366	1.9	30	0.3
Soybeans	179	0.9		
Rapeseed			500	5.5
Sugar beets	139	0.7	27	0.3
Potatoes	135	0.7	35	0.4
Millet	120	0.6		
Rye	106	0.5	92	1.0
Beans	94	0.5		
Peas			40	0.4
Buckwheat			40	0.4
Mustard			40	0.4
Hay	2,100	10.6	1,250	13.8
Vegetables			5	0.1
Mixed grains			200	2.3
Total acreage	19.717		9,043	

Sources:

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Table 2. Distribution of soil-borne plant pathogens that may be dispersed by water in North Dakota and Manitoba.

FUNGI

Streptomyces scabies (Thaxt.) Waksm. & Henrici. Common scab of potatoes and sugar beets. General USA, Man.

Plasmodiophora brassicae Wor. Clubroot of crucifers (rape). N.D., B.C., Eastern Canada, reported but unconfirmed in Man.

Spondylocladium atrovirens (Harz) Harz ex Sacc. Silver scurf of potatoes. General USA, Man.

Synchytrium endobioticum (Schilb.) Perc. Potato wart. Restricted by quarantine to Md., Pa., W.Va., Nfld., N.S.

Pythium aphanodermatum (Edson) Fitzp., P. debaryanum Hesse, P. graminicola Subram., P. ultimum Trow. Seed rot, seedling blight of all crops listed in Table 1. N.D. and Man.

Aphanomyces cochlioides Drechsl. Tap root tip rot of sugar beets. Minn., S.D., Ont., Alta.

A. euteiches Drechsl. Root rot of peas. General USA, Ont.

Fusarium oxysporum f. pisi (Lindford) Snyd. & Hansen. Pea wilt. Minn., Man.

Fusarium oxysporum f. lini (Bolley) Snyd. & Hansen. Flax wilt. N.D., Man.

Fusarium solani (Mart.) App. & Wr. Root rot and wilt of peas and potatoes. Mont., Wisc., Minn., Man.

Verticillium albo-atrum Reinke & Berth. Leaf mottle or wilt of sunflowers, potatoes and other hosts. N.D., Man.

BACTERIA

Agrobacterium tumefaciens (Sm. & Towns.) Conn. Crown gall of sugar beets and other hosts. General USA, Man.

Erwinia atroseptica (van Hall) Jennison. Black leg of potato. General U.S.A., Man.

Corynebacterium sepedonicum (Spieck, & Kotth.) Skapt. & Burkh. Ring rot of potatoes. General USA, Man.

C. insidiosum (McCull.) Jensen. Bacterial wilt of alfalfa. General in northern USA, Man.

Xanthomonas campestris (Pamm.) Dowson. Black rot of crucifers (rape), North Central States, Man.

NEMATODES

Ditylenchus dipsaci (Kuhn) Filipjev. Stem and leaf nematode of sugar beets, alfalfa and other hosts. Western USA, Alta.

Heterodera schachtii Schmidt. Root gall nematode on sugar beets and other hosts. Minn., S.D., Mont., Western USA, Ont., Alta.

H. rostochiensis Wr. Golden nematode of potato. N.Y., Nfld.

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Attachment C.V-1

Summary of Speculations

on the Future Eutrophication of Lake Winnipeg

by

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SUMMARY OF SPECULATIONS
ON THE FUTURE EUTROPHICATION OF LAKE WINNIPEG

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NOVEMBER 1976

Limnological studies on Lake Winnipeg nutrient chemistry, sediment chemistry, phytoplankton species and growth rates, zooplankton, zoobenthos, and phytobenthos were done in 1968-1970. Water and nutrient element budgets were computed for 1969-1974. Based upon rates of supply of nitrogen (N) and phosphorus (P) to the lake, we would expect that the lake should show charactetistics of an eutrophic lake (high chlorophyll concentrations, great algal biomass, oxygen depletion, species of algae and invertebrates associated with high nutrient concentrations or high food availability). However, average chlorophyll concentrations for Lake Winnipeg, and for the South Basin of Lake Winnipeg, were low in proportion to P concentration, annual supply rates of P, water flushing time, mean depth, and surface area of the lake. Zoobenthos and planktonic crustacea collected in the lake were not typical of the usual eutrophic lake fauna.

The biomass and species composition of phytoplankton of most of Lake Winnipeg had characteristics of a shallow prairie lake or pond. In smaller areas of the lake receiving dilute, nutrient poor runoff from Shield watersheds, phytoplankton species assemblages were similar to those found in oligotrophic lakes of the Shield. In the extreme southern part of the south basin of the lake, phytoplankton species assemblages were similar to those found in sewage lagoons. Oxygen depletion was not observed, due to the shallowness of the lake and frequent strong prairie winds which mixed the lake waters vertically. We propose that the flora and fauna of Lake

Winnipeg is more strongly influenced by the lake's shallowness and turbidity, than by rates of nutrient supply. Nutrient (N&P) supplies to the lake appear to be in excess of algal requirements.

Based upon historical (1900-1970) records of human and livestock populations, fertilizer and detergent consumption, and cultivated land area, we estimated the total annual mass of N & P utilized by technological and human activities in the Lake Winnipeg watershed. This mass of N & P in 1969 was found to be 30 to 200 times greater than the mass of N & P that flows into Lake Winnipeg via rivers each year. We use this data to present three speculative estimates of the rate of supply of nutrients to Lake Winnipeg in the future.

Estimate 1. We assumed that the rate and magnitude of nutrient losses from the sedimentary watershed of Lake Winnipeg are largely controlled by technological activities (city sewer systems, agriculture, industry, water control systems). We found that the 1969-1974 N & P runoff to Lake Winnipeg from its sedimentary watershed represented about 0.6% and 1.6% of the N & P excreted by humans and livestock, and utilized as fertilizer and detergents. Using linear regression equations derived from statistical and census data, we extrapolated these nutrient source terms (populations, Tonnes fertilizer/yr) to the year 2000, without economic restraints. Assuming that the above export coefficients (0.6% of N and 1.6% of P) are pertinent in the year 2000, we calculate that the runoff of N & P to Lake Winnipeg will be 320% and 628% greater than 1969 data.

Estimate 2. We suspect that nutrients are likely more efficiently transported to Lake Winnipeg from large urban populations of people near rivers or adjacent to the lake, compared to nutrient transport from areas of the watershed remote from the lake. We calculated the tonnes per human-year of N & P added directly to the Red River by the sewage treatment plants of the City of Winnipeg, and applied these per capita rates to sewered communities of the Red River watershed in Manitoba, North Dakota, and Minnesota. For the communities of Saskatchewan and Alberta within the Lake Winnipeg drainage, we used a per capita nutrient loss rate of 50% of those for the City of Winnipeg, because reservoirs along these rivers likely trap nutrients from these western sources. From these calculations, it appeared that 62% of N and 88% of P produced by human populations were directly added to rivers in the Lake Winnipeg sedimentary watershed.

The annual total mass of N & P derived from sewered communities (see above) was subtracted from our measured total annual mass of N & P that flows into Lake Winnipeg from sedimentary watersheds. This residual N & P source was attributed to livestock wastes and fertilizer runoff, and represented 0.5% of N and 1.0% of P of the estimated total annual amount of fertilizer used and/or waste from livestock in the entire sedimentary drainage.

From historical census and statistical data, we extrapolated community population, fertilizer use, and livestock numbers to the year 2000. We then applied the above per capita factors for nutrient loss from communities and the estimates loss rates of N & P from agricultural sources to these data. From this approach, we estimate that N supply to Lake Winnipeg in the year 2000 will be 290% greater than 1969 data, and that P supply will be 410% greater.

Estimate 3. Agricultural scientists do not like our extrapolation of annual fertilizer use in the Lake Winnipeg watershed, despite its apparent general agreement with fertilizer industry predictions. Agricultural scientists state that our predicted fertilizer application rates exceed their maximum recommended rates, based upon soil studies and present agricultural technology. We have estimated the total possible arable land (class 1-4) in the Lake Winnipeg sedimentary watershed, and have applied the maximum recommended fertilization rates (11.6 tonnes N $km^{-2}yr^{-1}$ and 2.54 tonnes P $km^{-2}yr^{-1}$) to this land area. Utilizing our estimated loss rate of fertilizer N & P (see Estimate 2, 0.5% N and 1.0% P of the total fertilizer applied to the land) for this computed maximum amount of fertilizer, and the previously computed human and livestock contributions of N & P to the lake (see Estimate 2), we predict an increase for N of 62% and for P of 195% compared to 1969 data.

The effect of a 200-600% increase in P supply to Lake Winnipeg is difficult to quantify. With our present data, it appears that the lake waters have concentrations of nutrient elements in excess of the needs of algae, and algal growth may be limited by light penetration in these turbid waters. The addition of even more nutrients may have little measureable affect on the lake. Higher concentrations of nutrient elements will likely occur in the south basin of the lake in the year 2000. This is not likely to affect fish, zooplankton, or zoobenthos. The duration and frequency of littoral and planktonic algal blooms may increase in the northern part of the south basin. As long as the prairie wind blows, the lake will be well-mixed, and no O_2 depletion will occur in the open-water season. Although no winter O_2 depletion presently occurs, greatly increased winter supplies of organic matter to the lake could cause concern.

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