

# PEACE-ATHABASCA DELTA

## WATER MANAGEMENT WORKS EVALUATION

### APPENDIX B BIOLOGICAL ASSESSMENT

PEACE-ATHABASCA DELTA IMPLEMENTATION COMMITTEE

CANADA ALBERTA SASKATCHEWAN

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**PEACE-ATHABASCA DELTA  
WATER MANAGEMENT WORKS EVALUATION**

**APPENDIX B  
BIOLOGICAL ASSESSMENT**

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**Biology Sub-committee  
Peace-Athabasca Delta Implementation Committee  
CANADA ALBERTA SASKATCHEWAN**

April 1987



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## **Final Report**

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LETTER OF TRANSMITTAL

June 19, 1986

Chairman  
Peace-Athabasca Delta Implementation Committee  
Alberta Environment  
9th Floor, Oxbridge Place  
9820 - 106 Street  
Edmonton, Alberta  
T5K 2J6

Attention: Mr. J. Simpson

Dear Mr. Simpson:

Re: Biological Monitoring and Assessment of the  
Performance of the Rivière des Rochers and Revillon  
Coupe Weirs on the Peace-Athabasca Delta

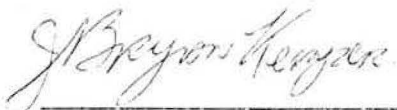
The Biology Subcommittee is pleased to submit its final report to the Peace-Athabasca Delta Implementation Committee. This report fulfills the terms of reference assigned to the committee in October 1983.

The Subcommittee concluded that the overall performance of the weirs is acceptable from a biological perspective. Recommendations for an ongoing biological monitoring program are made.

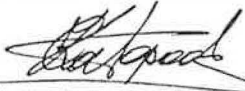
We wish to thank the Implementation Committee and the Hydrology Subcommittee for their interest and assistance.

Respectfully submitted,

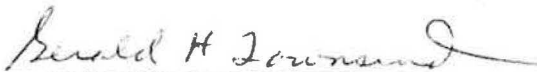
Peace-Athabasca Delta  
Biology Subcommittee



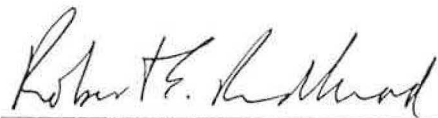
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George Hamilton  
Alberta Forestry, Lands and  
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Fish and Wildlife Division

## Executive Summary

The Biology Subcommittee was established by the Peace-Athabasca Delta Implementation Committee to assess the performance of the Rivière des Rochers and Revillon Coupé weirs from a biological perspective. The weirs were constructed in 1976 to restore low water levels that had occurred on the delta following construction of the W.A.C. Bennett Dam on the Peace River.

Based on its evaluation of biological research and analyses conducted on the Peace-Athabasca Delta, the Subcommittee drew the following conclusions and made the following recommendations:

### Biological Monitoring Program

1. The succession of immature fen to sedge meadow continued as water levels dropped between 1976 and 1978. It is likely that this trend continued during the lower water period of the 1980s.
2. Studies between 1971 and 1975 showed that spring and fall staging densities of waterfowl were highest under low water level conditions that exposed extensive areas of mudflats. Brood production was high when spring and summer flooding did not flood nests. However, persistent low water levels can cause entire perched basins to dry out, thereby reducing overall waterfowl production of the delta.
3. Muskrat populations were observed to decline as water levels dropped between 1976 and 1978. Although populations were not monitored after 1978, the low trapper success rate of the late 1970s and early 1980s indicated that muskrat populations continued to decline as water levels dropped. Local trappers observed that muskrat populations recovered in the Birch River basin as water levels rose in this basin in 1983.
4. The Rivière des Rochers weir was observed to impede the goldeye spawning migration in 1977 and 1980 when the hydraulic head exceeded 0.8 m. However, the effect that this had on goldeye spawning success has not been documented.

### Quantitative Analyses

1. A statistical analysis of waterfowl numbers and Lake Athabasca water levels showed no significant difference in waterfowl numbers before or after the dam and weirs were completed.
2. A frequency analysis of hydraulic head at the Rivière des Rochers weir showed that, on average in any given year, goldeye can successfully pass over the weir 50% of the time during the critical 42-day migration period, if it is assumed that the critical hydraulic head is 0.8 m. Based on this analysis, goldeye would have passed over the weir during part of the migration period in seven years and would have been blocked by the weir for the entire migration period during two years since completion of the weirs in 1976.

### Simulation of Wildlife Habitat

1. Productive habitats would decrease from the natural conditions by approximately 10% both with the Bennett Dam only and with the Bennett Dam plus weirs; however, the causes of the decrease would be different. With the weirs, the decrease in productive habitats would be caused by a slight increase in both the open water and forest/shrub communities; while with the dam only, the decrease in productive habitats would be caused by a significant increase in the area of shrub/forest communities and a significant decrease in open water area.
2. Waterfowl production with the weirs was predicted to be significantly better than with the dam only and would approach the natural condition. This is based upon both open water and perched basin conditions. The analysis does not consider variations in the continental waterfowl population.
3. Waterfowl staging habitat was predicted to be significantly worse for the weir regime than for both the natural condition and the Bennett Dam regimes. This is because the weirs tend to elevate fall water levels, thereby decreasing available staging habitat.

### Success of the Weirs in Restoring Biological Communities

1. The depressed water levels of the past decade have caused a decrease in the productive wetland habitat of the delta, particularly in the perched basins. Without the weirs, the extent of productive habitat would have decreased even more. Declining wildlife populations should partially recover when water levels return to average conditions.
2. The weirs have mitigated many of the long term biological impacts caused by the Bennett Dam and created a situation substantially closer to natural conditions than would have existed if they had not been built. However, the weirs will not restore the biological communities to natural conditions.
3. The reduced frequency of flooding of the perched basins at higher elevations will result in altered habitats in these wetland areas. The loss of perched basins along the Peace River will result in permanent loss of some wetland habitats.
4. The weirs may block segments of goldeye population migrating from the Peace River into the delta lakes. The effect that this may have on the goldeye population of the delta has not been documented.

### Recommendations

1. A long-term biological monitoring program should be established to measure ecological changes throughout the delta. This program should focus on vegetation responses to water.
2. A sampling program to document the age-structure of the goldeye population should be initiated to determine whether fishways are required at the Rochers and Revillon Coupé weirs.

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## 1.0 INTRODUCTION

### 1.1 Background

The Peace-Athabasca Delta is one of the largest freshwater deltas in the world. It is a complex lowland area created by the Peace and Athabasca Rivers at the west end of Lake Athabasca (Figure 1-1). The ecology of the delta evolves around the annual hydrologic cycle which floods the delta in June or July each year, filling channels and lakes and periodically recharging perched basins and sloughs. During late summer and winter, the water levels recede, reaching their minimum by March, when the annual cycle begins again.

The magnitude and duration of spring and summer flooding of the delta are determined by a complex combination of hydrological events in the Peace and Athabasca River Basins. These include:

- flooding of the Peace River, with or without ice jamming
- spring flooding of the Athabasca River
- Lake Athabasca water levels, influenced by the Athabasca and other tributary systems, and
- local runoff.

In most years, high spring flood levels have caused the Peace River to act as a hydraulic dam, preventing water from Lake Athabasca and the Athabasca River from draining away from the delta.

The W.A.C. Bennett Dam (Bennett Dam) was constructed on the Peace River in 1968. The filling and subsequent operation of the Williston Reservoir reduced the spring peak flows on the Peace River.



PEACE - ATHABASCA DELTA

FIGURE 1.1

This had serious implications on the ecology of the delta, particularly between 1968 and 1971 when the reservoir was being filled. During this time, the flood levels for Lake Athabasca were 0.8 m [metres] (2.7 ft.[feet]) lower than the long-term average. These low water levels threatened to permanently disrupt the natural processes of the delta.

In 1971, the Governments of Canada, Alberta and Saskatchewan established the Peace-Athabasca Delta Project (PADP) Group to determine an immediate solution to the problem of low water levels on the delta and to recommend long-term remedial measures. In the fall of 1971, a temporary dam was constructed on the west arm of Quatre Fourches Channel to retard the outflow of water from the Birch River Basin in order to raise the water levels of lakes Claire and Mamawi and adjacent perched basins. This proved to be a successful interim measure, raising water levels in 60% of the delta. Between 1971 and 1972, the PADP Group conducted a detailed investigation of the cause of the low water levels and the effect that these had on the ecology of the delta and the local people, in order to recommend a permanent solution to the problem. Thirty-seven coordinated studies were carried out; the results were published in the Peace-Athabasca Delta Technical Report and Appendices, (PADP Group, 1973). The PADP Group recommended a site on the Rivière des Rochers for a fixed-crest weir to restore the average summer level of Lake Athabasca. The Group also recommended that a resource monitoring program be initiated to evaluate the effectiveness of the structure.

The Peace-Athabasca Delta Implementation Committee (PADIC) was established in 1974 to prepare detailed designs and to construct the remedial works recommended by the PADP Group. The structures, which consisted of a submerged rock weir and ancillary fish bypass channel at the Little Rapids site on Rivière des Rochers and a rockfill weir on the Revillon Coupe', were completed in March 1976. The PADIC was also responsible for recommending and coordinating activities related to monitoring the effects of restoration measures on water levels, vegetation, wildlife and fish.

#### 1.2 Summary of Environmental Effects of the Bennett Dam Observed and Predicted by the PADP Group (1973)

The PADP Group (1973) observed and monitored the effects of the Bennett Dam on the ecology of the Peace-Athabasca Delta between 1971 and 1972. The Williston Reservoir was being filled between 1968 and 1971. Thus, the impacts reported in these studies reflect the filling phase of the reservoir.

-- Over 124,000 acres of mudflats became exposed as water levels declined causing submerged vegetation to die and emergent vegetation to become stranded; 70,000 acres of the exposed mudflats became vegetated with early successional communities of annuals, grasses, sedges and willows in response to the lowered water table and absence of seasonal flooding; sedge and grass communities were being replaced by reed meadows; no changes were observed in shrub and forest communities; and there was a



significant decrease in the size and number of perched basins in the north part of the delta near the Peace River which had provided important habitat for muskrats and nesting waterfowl.

- Waterfowl hatching success was good because there was no flooding during the critical nesting season; moulting habitat was reduced; and no adverse effects on staging habitat were observed.
- Low winter water levels caused a decline in muskrat population.
- The factors affecting the bison and moose population were found to be very complex and the lower water levels could not be directly related to carrying capacity or herd size.
- Despite low water levels in 1971 and 1972 both goldeye and walleye were observed to migrate and spawn successfully. (Based on later studies, the 1971 goldeye year class turned out to be extremely successful.)

The PADP Group predicted that the future operation of the Bennett Dam would result in Lake Athabasca water levels lower than the natural regime: summer water levels would be 0.33 m (1.1 ft) lower, annual maximum levels would be 0.55 m (1.8 ft) lower and the summer fluctuation would be 0.24 m (0.8 ft) instead of 0.46 m (1.5 ft). The Group concluded that the low water levels on the delta between 1968 and 1971 could be attributed to the operation of the Bennett Dam and that there would be serious long-term ecological consequences if water levels on the Peace-Athabasca Delta were not restored:

- Plant succession would proceed unchecked for longer periods of time due to less frequent summer flooding; the permanent

reduction in summer lake levels would eventually shift plant zones to lower levels around lake margins; the more stable water levels would reduce the vertical limits of early successional plant communities; and the perched basins would continue to decrease in size and number.

- Waterfowl production would decrease as habitat is lost; and staging habitat would decline, but would remain sufficient.
- Muskrat population would continue to be low.
- Bison and moose populations would not be affected.
- Low water levels would block access for walleye to Richardson Lake more frequently; and the food supply for goldeye (zooplankton) in Lakes Claire and Mamawi could decline because of reduced flushing by flood waters.

The PADP Group concluded that the international, national and regional significance of the predicted effects were important enough to warrant constructing permanent remedial works to mitigate the effects of the Bennett Dam on the ecology of the delta.

### 1.3 Description of Remedial Measures Constructed in the Peace-Athabasca Delta and Effects Predicted When They were Built

#### 1.3.1 Temporary Quatre Fourches Dam

In the fall of 1971, a temporary rockfill dam was built on Chenal des Quatre Fourches at the outlet of Mamawi Lake (Figure 1-1). The purpose of the dam was to impound water from the Birch River basin in

order to raise the water levels of lakes Claire and Mamawi and adjacent ponds and perched basins. The Quatre Fourches structure was severely damaged in the 1974 flood. It was removed in the fall of 1975, following completion of the permanent weir on the Rivière des Rochers.

The Quatre Fourches dam was a good interim solution to the problem of low water levels. In fact, the effect of this dam, combined with the exceptional flood of 1974, resulted in the highest water levels experienced on the delta since construction of the Bennett Dam. However, in its 1973 assessment, the PADP Group concluded that the Quatre Fourches dam was not suitable as a permanent structure for the following reasons:

- it was a barrier to major fish migration;
- it did not adequately duplicate the timing and amplitude of the natural delta water regime because westward flows from Lake Athabasca into Lakes Claire and Mamawi would be obstructed;
- with limited flushing from Lake Athabasca, the chemical quality of the delta waters would deteriorate; and
- the Quatre Fourches structure controlled only 60% of the delta, only within Wood Buffalo National Park.

The PADP Group concluded that controlling Lake Athabasca levels was the key to recreating more natural flow patterns within the delta.

#### 1.3.2 Weirs on the Rivière des Rochers and Revillon Coupe

Following the environmental studies of 1971-72 and public hearings held by the Alberta Environmental Conservation Authority (now

Environment Council of Alberta), the decision was made to construct a permanent weir on the Rivière des Rochers. Detailed engineering studies revealed that this weir might cause high velocities and erosion on the Revillon Coupe'. Thus, a second weir was recommended for the Revillon Coupe'.

A permanent rock weir and ancillary fish bypass channel were completed at the Little Rapids site on the Rivière des Rochers in September 1975. At this time, the temporary Quatre Fourches Dam was removed. In March of 1976, a rock weir was completed on the Revillon Coupe' (Figure 1-1).

The PADP Group (1973) predicted the following long-term effects of the Rivière des Rochers weir using the Wildlife Simulation Model (see Section 3.3).

- Open water would increase by 12%, productive wetland habitats would decrease by 2%, and shrub and forest communities would decrease by 7% when compared to the simulated natural condition. By comparison, with the Bennett Dam, only, open water would decrease by 13%, productive habitat would decrease by 9% and shrub and forest communities would increase by 16% from the simulated natural condition.
- Waterfowl production would be completely restored to the pre-dam situation. The decreased flood amplitude would allow greater reproductive success. By comparison, with the Bennett Dam, only, duck populations were simulated to

decrease 26% from the natural condition.

- Muskrat habitat and population would be restored to natural conditions by the weirs. By comparison, muskrat numbers and carrying capacity were predicted to decrease by greater than 50% with the Bennett Dam only.

The effects of the weir on fish were predicted empirically:

- Walleye movement into Richardson Lake for spring spawning would not be hindered because winter and spring water levels would be higher than either natural condition or with the Bennett Dam.
- Goldeye movement would not be hindered by the weir on the Rivière des Rochers.

At that time it was thought that the goldeye used mainly the Quatre Fourches channel for migration. Subsequent field studies showed that goldeye use the Rivière des Rochers, Revillon Coupé and Quatre Fourches channels, as is discussed in Section 2.4.2.

#### 1.4 Purpose and Objectives of the Biology Sub-Committee

The Biology Sub-Committee of PADIC was established in 1983 to review the results of all biological monitoring programs undertaken in the Peace-Athabasca Delta since construction of the weirs to determine whether the restoration measures undertaken in the Peace-Athabasca Delta were regenerating biological habitat conditions as predicted in the report "The Peace-Athabasca Delta Project, Technical Report, 1973" (PADP Group, 1973).



The Sub-Committee had the following objectives:

1. To determine whether there is enough fisheries, wildlife and vegetation data to evaluate the success of the restoration measures.
2. To determine whether there is an acceptable quantitative method to relate water levels/regimes in the delta to habitat conditions and populations.
3. To undertake a comparison of natural, post-Bennett Dam and post-weir habitat conditions and populations at selected points in the delta for the period 1960-1984.
4. To evaluate the benefits to habitat conditions and populations of a range of alternative remedial measures should the weirs prove to be (a) not performing to design specifications and/or (b) not adequately simulating the pre-Bennett Dam regime.

This report presents the results of the research and analyses conducted by the Biology Sub-Committee. A companion study to evaluate the hydrological performance of the weirs has been prepared by the PADIC Hydrology Sub-Committee (Alberta Environment and Environment Canada, 1985a, b).

## 2.0 BIOLOGICAL MONITORING PROGRAMS

In this section, the vegetation communities and wildlife and fish habitats of the Peace-Athabasca Delta are described and the results of the biological monitoring programs conducted between 1974 and 1980 under the auspices of PADIC and other agencies are presented. The biological data base is assessed in the context of its suitability for statistical, modelling or empirical analysis.

### 2.1 Vegetation

#### 2.1.1 Vegetation Succession in the Peace-Athabasca Delta

The vegetation patterns of the Peace-Athabasca Delta were described by Raup in 1935, but are still applicable today:

Although the differences in the elevation of the plain above the water table are slight, they are enough to determine the arrangement of the plant cover. Lands subject to floods have a herbaceous vegetation ranging from semi-floating aquatic plants to sedges and grasses. Large areas are covered by almost pure stands of awned sedge (Carex atherodes) or reed grass (Calamagrostis spp.). On the slightly elevated margins of stream channels, abandoned or otherwise, are long lines of willows (Salix spp.). Shrub and tree growth increases toward the margins of the plain so that the upper, older part of the delta and the banks of the larger channels support a forest of white spruce (Picea glauca) and balsam poplar (Populus balsamifera). The granite hills have a scrubby timber of white spruce, jackpine (Pinus banksiana), and white birch (Betula papyrifera var. neoalaskana).

The PADP Group (1973) developed a broad classification system for the vegetation (Table 2.1) which was used to map large portions of the delta using black and white aerial photographs taken in the

TABLE 2.1  
HABITAT TYPES OF THE PEACE-ATHABASCA DELTA

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Water	flooded area devoid of emergent vegetation
Emergents	inundated area that had erect, living vegetation rooted to the substrate
Mudflats	area above water with little or no vegetation growing on it
Immature Fen (meadow)	the community resulting from a one-year exposure of mudflats and represented by seedling stages of <u>Carex</u> sp., <u>Calamagrostis</u> sp., or shrubs.
Sedge Meadow	area dominated by sedge where woody vegetation is an occasional shrub or tree
Grass Meadow	area dominated by <u>Calamagrostis canadensis</u> where woody cover is an occasional shrub or tree.
Low Shrub	woody shrub vegetation under six feet tall
Tall Shrub	woody shrub vegetation over six feet tall
Deciduous	tree communities of primarily deciduous species, mainly balsam poplar and birch
Coniferous	tree communities of conifers
Rock Outcrop	The area of the delta where rock outcrop exists at an elevation above the upper limit of water level consideration

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SOURCE: Townsend, 1972a.

fall of 1970. This is the only year for which vegetation distribution for the Peace-Athabasca Delta has been mapped. The distribution of vegetation cover was estimated to be:

open water	27%
emergents, mudflats, immature fen	12%
meadow	19%
shrub	33%
forest	7%
rock	4%

It is important to understand the dynamic nature of the vegetation communities of the Peace-Athabasca Delta. Successional trends on the delta were examined in detail by the PADP Group (Townsend, 1972a). The following discussion of succession is abridged from the PADP Group Summary Report (1973).

The Peace-Athabasca Delta, which has formed where the Athabasca River empties into Lake Athabasca, is growing downstream as the river approaches base level and deposits its sediment load. Point bars and islands emerge within the stream bed, and the river branches into a series of channels that meander across the delta plain. Local differences in rates of erosion and deposition result in cutoff and ponded channels and in the formation of numerous shallow depressions on the delta plain.

The biological community has developed parallel with the evolution of the physical landscape. Plant species capable of becoming established in the aquatic and nutrient-rich environment of young sites are gradually replaced by species adapted to drier conditions. Thus, over time, the vegetation occupying a given

location changes from aquatic to meadow to wooded communities. Animal populations exhibit similar changes as the vegetation is altered by these processes. The phenomenon of continuing replacement of plant and animal communities over time is referred to as ecological succession.

The ecology of the Peace-Athabasca Delta has evolved in response to its unique hydrologic system. In spring and summer, the rising water of Lake Athabasca floods most of the delta and recharge lakes and the numerous perched basins with nutrient-rich waters, deposited silt and plant seeds, and flushing out or burying plant debris. During the remainder of the year, outflow and evaporation gradually lower the water levels within the delta. The spring flood has the effect of slowing the long-term trend towards climax vegetation, holding much of the area at early successional stages. It is important to realize that the vegetation patterns and animal life which now characterize the delta have developed in response to this fluctuating water level regime and are thus adapted to it. Any change in the hydrological regime, therefore, triggers ecological adjustments within the delta system.

Within the delta, three categories have been defined according to the prevailing physical deltaic processes: the active, semiactive and inactive portions of the delta. Active delta includes those locations directly affected by the hydrological interactions of the major rivers and Lake Athabasca. Semiactive delta includes perched basins and cutoff stream channels, i.e. locations which are not connected with

the major hydrologic system but have been recharged by the spring flood in most years. The inactive delta category comprises closed basins (old meander scrolls and backswamps) which are positioned on the higher, older portions of the delta, and are affected by the spring flood only during extremely high water years.

Vegetational replacement patterns vary in different parts of the delta. Within active and semiactive locations, aquatic and emergent communities are replaced by shoreline pioneers on emerging mudflats which develop into fen meadows. These meadows then change into willow shrub communities and eventually into terminal forest communities. Succession in the delta does not follow a single pathway but takes the form of a branching network in which various species or species-groups may dominate in different locations during the same seral stage, and fuse during a succeeding stage. The variety of alternate dominance-types is particularly great among shoreline and meadow communities. It is not always clear why sites which appear to be identical are occupied by different species groups. However, the supply of plant seeds at the time when conditions are favorable for germination and minute local differences in moisture and nutrient status are involved in creating this diversity.

In the inactive delta, the lack of nutrient-rich waters results in a gradual fixing of the available nutrients in undecomposed vegetative matter, in the growth of floating sedge mats over the basins, and finally the filling of the entire basin with muck and peat. The peat surface eventually grows completely out of reach of

the mineral water table, is invaded by Sphagnum mosses, and develops into ombrotrophic bog or muskeg. Because of the frequency of previous high floods, inactive delta is largely confined to the upper portion of the Athabasca Delta and even then has not evolved beyond the floating mat stage. Permanent elimination of the spring flood, however, would speed the development towards ombrotrophic bog in backswamp locations.

The time frame within which long-term succession proceeds is not well understood. It is known that the entire vegetational development took place during the past 10,000 years, but it is difficult to determine the average rate by which seral stages replace each other. From the limited data on hand, it is apparent that successional events in the delta are mainly controlled by the water regime. The vegetative replacement with decreasing water levels proceeds very rapidly in the initial stages, but more and more slowly through the shrub and forest types.

#### 2.1.2 Vegetation Monitoring Programs

Vegetation changes in the Peace-Athabasca Delta have been monitored along a series of transects established in 1968 (Dirschl, 1972). These programs monitored the immediate vegetation responses to the Bennett Dam (1968-71), the Quatre Fourches weir (1972-1975) and the Rivière des Rochers and Revillon Coupe' weirs (1976-78). There have been no vegetation monitoring studies in the Peace-Athabasca Delta since 1978. A summary of the vegetation monitoring programs since 1974 is presented in Table 2.2. The results of the studies are described below.

TABLE 2.2  
VEGETATION RESEARCH PROGRAMS IN THE PEACE-ATHABASCA DELTA SINCE 1974

DATE	AUTHOR	TITLE	FUNDING AGENCY	FIELD SEASON	PURPOSE
1975	Cordes	Vegetation change in the PA Delta, 1970--4	National & Historic Parks Branch, INAC	1974	Classify and analyze vegetation along established transects
1976	Cordes & Strong	Vegetation change in the PA Delta, 1974--5	National & Historic Parks Branch, INAC	1975	Classify and analyze vegetation along established transects
1977	Cordes & Pearce	Vegetation change in the PA Delta, 1975--6	National & Historic Parks Branch, INAC	1976	Classify and analyze vegetation along established transects
1978	Cordes & Pearce	Vegetation change in the PA Delta, 1976--7	National & Historic Parks Branch, INAC	1977	Classify and analyze vegetation along established transects
1978	Doherty	Plant succession in the northeastern portion of the PA Delta	M.Sc. Thesis, U of A	---	Study succession trends
1979	Cordes & Pearce	Vegetation change in the PA Delta, 1977--8	Parks Canada, INAC	1978	Classify and analyze vegetation along established transects

Note: PA = Peace-Athabasca; INAC = Indian and Northern Affairs, Canada



In 1974, vegetation composition along Dirschl's 1968 transects was examined by Cordes (1975). It was found that the high water levels and prolonged flooding of the period 1972 and 1974 produced a reversal of succession in vegetation cover equal to 29 percent of the total area of the transects mapped. Forty percent of the change occurred in vegetation communities established during the low water years, while 60 percent of the change took place in vegetation types present before the low water years (Cordes, 1975). Thus, with several years of flooding, plant succession reverted to more early-successional plant communities and open water. This generally confirmed the reverse successional patterns modelled for the Peace-Athabasca Delta by Townsend (1972b).

Vegetation monitoring of the established transects continued during 1975 (Cordes and Strong, 1976). With water levels returning to more average conditions that year, most reed (Calamagrostis sp.) meadows recovered to 1970 conditions, indicating that the duration and depth of flooding had not completely killed the rhizomes. Sedge (Carex sp.) meadows, located slightly lower on the contour, and therefore exposed to greater and more prolonged flooding, did not all recover. Succession was observed to be set back to immature fen and particularly whitetop (Scolochloa) in the more weakened meadows.

Water levels in 1976, the year that the weirs were completed, were approximately the same as during the previous year, and only 4 percent of the transect areas studied changed in vegetation type (Cordes and Pearce, 1977). The largest increase occurred as the

immature fen invaded mudflats exposed in 1975. Reed communities remained healthy and sedge showed a slight increase. The whitetop community continued to decrease with the lower levels. Willow (Salix sp.) dominated communities remained stable. Water levels were not high enough to flood most of the perched basins, and succession to immature fen occurred on the sparsely vegetated mudflats and ragwort (Senecio sp.).

The 1977 water regime was similar in trend to that observed in 1975 and 1976, although summer levels were approximately 0.3 - 0.6 m (1 - 2 ft.) higher. No major shifts in vegetation types were recorded in 1977 although there were species composition changes within the types and changes in vigor of some of the important species (Cordes and Pearce, 1978). Cattail (Typha latifolia) began to appear in sedge and whitetop vegetation types because of continuous rather than seasonal flooding since 1975. The high water caused flooding of reed communities along Mamawi Creek and Prairie River. Despite the somewhat higher summer water levels, the majority of perched basins in the delta were not flooded. One hundred and forty-eight perched basins were inspected by aerial survey. Forty-three percent were classified as having water levels below normal, and extensive areas of mudflats were being colonized by terrestrial vegetation types. Willows had invaded some of the sedge communities adjoining the perched basins. Cordes and Pearce concluded that the significant factors that affected the vegetation composition of the delta in the mid-1970s were moderately high water levels throughout the summer

growing season and winter, and decreased summer amplitude (lack of basin recharge).

Summer water levels in 1978 averaged 0.3 to 0.6 m (1 to 2 ft.) lower than 1977 levels and approximated those of 1975 and 1976. For the fourth consecutive year, there was no widespread overland flooding or mid-summer increases sufficient to recharge the majority of perched basins. Sixty percent of the perched basins surveyed had water levels lower than normal (Cordes and Pearce, 1979). Along the established transects, a net vegetation change of approximately 9 percent was observed, with whitetop being replaced by sedge, and sedge meadows being invaded by reed. Elsewhere there was continued evidence of immature fen persisting on some meadows weakened by the prolonged flooding of 1972-74 and subsequent grazing by bison, and weedy species (foxtail barley, sowthistle and plantain) and willow seedlings were becoming dominant.

Cordes and Pearce (1979) summarized the major vegetation changes in the Peace-Athabasca Delta from 1970 to 1978.

- The immature fen group experienced the most significant changes. It colonized the mudflats exposed by the very low 1968-1971 water levels but was then eliminated by flooding in 1972. Between 1974 and 1978, lower water levels contributed to an expansion of immature fen; although, by 1978, many areas in this group had been replaced by the more permanent vegetation types.
- The sedge and reed vegetation groups recovered much of the area they occupied before the 1972 flooding. Continued drying and a

more stable water regime were considered responsible for some deterioration of these communities and invasion by other vegetation types.

- The spruce poplar (Picea-Populus), tall willow, low willow and fen-willow groups did not change appreciably between 1970 and 1978.

### 2.1.3 Assessment of the Vegetation Data Base

The vegetation transect studies conducted between 1968 and 1978 provided a good basis for describing immediate vegetation responses to water level changes over that ten year period. However, the studies only continued for three seasons after the weirs were completed in 1976. Thus, it is not possible to document how vegetation responded to water levels on the delta since 1978.

The Wildlife Simulation Model was used by the PADIC biology subcommittee to simulate long-term vegetation responses to selected water management scenarios. The model and the vegetation changes that it predicted are discussed in Section 3.4. The model was calibrated using the vegetation map of delta prepared for the PADP Group using 1970 aerial photographs. The results of the vegetation mapping program of the 1970's were used to verify the assumptions of the model.

## 2.2 Waterfowl

### 2.2.1 Waterfowl Habitat

The Peace-Athabasca Delta is at the confluence of the four North American waterfowl flyways. It is a staging, moulting and production area of national and international significance.

It is a vital link in the migratory paths of birds nesting in the Arctic; they stop to rest here on the way north through the Mackenzie valley in the spring and south in the fall. The abundant wetland nesting habitat of the delta fosters hundreds of thousands of young ducks during years when water conditions are satisfactory (PADP Group, 1973). The Peace-Athabasca and other northern deltas are particularly important during drought years on the prairies, when waterfowl are forced to overfly traditional but temporarily dry prairie nesting grounds to seek more permanent summer waters (Townsend, 1984).

The early successional mudflat and immature fen vegetation communities that are prevalent throughout the delta provide excellent spring and fall waterfowl staging habitat. This type of habitat is maintained by fluctuating water levels and has traditionally been prevalent along the open water areas of the delta. The perched basins of the delta, which experience less water level fluctuation, have been traditionally the good habitat for waterfowl breeding.

#### 2.2.2 Waterfowl Monitoring Programs

Between 1971 and 1976, a program of waterfowl population monitoring was undertaken to document population responses to water levels resulting from regulation by the Bennett Dam and, in 1976, from the weirs on the Rivière des Rochers and Revillon Coupe (Table 2.3). Between 1971 and 1974, the surveys were conducted by Ducks Unlimited (Canada) personnel with funding from the Canadian Wildlife Service (Hennan, 1972, 1973, 1974). In 1975 and 1976, they were undertaken by the Canadian Wildlife Service and funded by Parks Canada (Hennan and Ambrock, 1977).

TABLE 2.3  
WATERFOWL RESEARCH PROGRAMS IN THE PEACE-ATHABASCA DELTA SINCE 1971

DATE	AUTHOR	TITLE	FUNDING AGENCY	FIELD SEASON	PURPOSE
1973	Hennan	PA Delta fall staging census results 1971-3	Ducks Unlimited/CWS	1971-3	To monitor waterfowl populations in the content of delta water levels
1974	Hennan	PA Delta breeding and fall waterfowl census staging results 1974	Ducks Unlimited/CWS	1974	"
1975	Hennan	PA Delta breeding and fall staging waterfowl census results 1975	CWS/Parks Canada	1975	"
1977	Hennan & Ambrock	A summary of waterfowl investigations in the PA Delta 1971-1976	CWS/Parks Canada	1976	To monitor waterfowl populations in the context of delta water levels and summarize previous studies

Note: PA = Peace-Athabasca; CWS = Canadian Wildlife Service

In 1971, after three years of low water levels, upland and aquatic vegetation had become well developed and waterfowl numbers approached what are believed to be maximum numbers for the delta without internal management. The spring-staging density averaged 19 ducks/km of wetland edge, representing a total population of approximately 400,000 to 500,000 ducks. The geese and swan population was estimated to be 150,000 (Hennan, 1972). Average breeding pair densities under these habitat conditions were estimated at 6 pairs/km, with a success rate of 3-4 broods/km. It is important to note that this success was achieved in a year of minimal summer water level increases over a rather low spring level. The abundant aquatic cover provided excellent habitat for moulting waterfowl and an estimated half-million birds utilized the delta for that purpose. The low fall water levels provided extensive mudflat-type shoreline, especially on larger lakes. In conjunction with an abundant food supply, this attracted a large fall-staging population estimated at 1.2 million ducks and 150,000 geese and swans (Hennan, 1972).

Spring water levels of 1972 were higher than 1971 and this apparently reduced both the attractiveness to staging waterfowl and the availability of good breeding (territorial and/or nesting) habitat. Average spring-staging and breeding pair densities were 11.3 birds/km and 4.4 pair/km, respectively. Early summer floods which affected parts (but not all) of the delta probably reduced nesting success. Brood production declined to approximately 1 brood/km. The water levels dropped sufficiently during late summer to provide

attractive staging habitat, but the staging population was estimated to be only half as large as in 1971.

Spring and summer Lake Athabasca water levels in 1973 were quite similar to the previous year. Although no spring-staging or breeding pair surveys were conducted, one would expect that populations were similar to 1972. With limited early summer water level increases, nesting success would have been at least equal to, and probably better than, that of 1972. Although the Lake Athabasca water level receded somewhat during late summer and early fall, levels in much of the Delta were maintained or increased by the Quatre Fourches weir. The number of ducks staging in the delta decreased by roughly 50% from 1972 and 80% from 1971 because available habitat decreased.

The record high spring water levels of 1974 left very little dry land suitable for territorial sites and nesting. No spring-staging data are available but numbers were probably very low. Breeding pair counts revealed a preponderance of divers compared to dabblers as a result of the high water conditions. Very little suitable nesting habitat was available and production was probably poor. By fall, water levels had dropped in parts of the delta to below those of 1973 and numbers of staging ducks increased by 30% over the previous year.

No spring-staging data are available for 1976. However, based on water level conditions, it is expected that the 1976 population was comparable to or somewhat below that of 1972. Breeding pair densities were low, similar to those of 1974. It should be noted that the relative numbers of dabblers and divers shifted back in favour of the



former as a result of the lower water levels. Adequate brood count data were not available but, with the absence of an early summer flood, nesting success of the small breeding population was probably high. Although there was only a limited fall water level recession, levels were already low enough to provide favourable staging conditions. The fall population census climbed back up to 70,000. Dabblers and divers were almost equally represented.

In 1976, spring-staging waterfowl densities were similar to those of 1972 and breeding pair densities were virtually equivalent to those of 1971. The production could not be assessed because of an insufficient number of surveys. However, water level increases during the nesting season were not extreme or sudden, therefore nesting success was probably quite good. Because the water level was maintained into the fall, less than optimum conditions were available for fall-staging ducks. Nevertheless, more than 60,000 ducks were counted in a single aerial survey.

Hennan and Ambrock (1977) summarized the relationship between waterfowl densities and numbers and Lake Athabasca water levels (Table 2.4). These estimates reflect the relative degree of utilization, recognizing that conditions outside of the delta, such as the continental waterfowl supply can modify the situation.

The following generalizations about waterfowl use of the delta may be drawn from the 1971 to 1976 monitoring studies:

- Highest densities of spring-staging waterfowl and duck breeding pairs occurred during low water years for the delta.

TABLE 2.4  
AN ESTIMATION OF THE RELATIONSHIP OF WATERFOWL DENSITIES AND NUMBERS TO VARIOUS WATER LEVEL REGIMES  
IN THE PEACE-ATHABASCA DELTA, 1971-76

WATER REGIME AND HABITAT	DENSITIES/km			NUMBERS
	SPRING STAGING	BREEDING PAIRS	BROODS	FALL STAGING (000's)
1. GENERALLY LOW (208.2 m [683 ft.] asl): I. Athabasca at Ft. Chipewyan				
a) No extreme early summer water level rise (following 2 or more years of low to moderate levels).	20	6+	3-4	1,000+
b) Substantial early summer floods	20	6+	1-2	
i) with fall recession				800
ii) without fall recession				700
2. GENERALLY MODERATE (208.8-209.4 m [685-687 ft.])				
a) No extreme early summer water level rise	12-13	3-5	2-3	
i) with fall recession				700
ii) without fall recession				500
b) Substantial early summer floods	12-13	3-5	1+	
i) with fall recession				500
ii) without fall recession				300
3. GENERALLY HIGH (209.4-210.0 m [687-689 ft.])				
a) No extreme early summer water level rise	3-6	2-3	1+	
i) with fall recession				300
ii) without fall recession				200
b) Substantial early summer floods	3-6	2-3	0.5	
i) with fall recession				200
ii) without fall recession				100

SOURCE: Hennan and Ambrock, 1977.

- Brood production was highest during years when breeding pair densities were high and when spring or early summer flooding did not occur.
- Numbers of fall-staging waterfowl in the delta were highest following conditions that led to a band of mudflats with seedling growth along edges of the larger shallow lakes. Low water levels for one or two summers followed by receding fall levels provided the best conditions. The least attractive condition supporting staging waterfowl resulted from summer flooding or high water on the delta which extended into the fall migration period for waterfowl.

#### 2.2.3 Assessment of the Waterfowl Data Base

The waterfowl census studies conducted between 1971 and 1976 provide a basis for discussion of how waterfowl populations relate to water levels experienced during that seven-year period. However, there is only one season of data since the weirs were completed in 1976. Thus, it is not possible to document how waterfowl populations, habitat or utilization of the delta have responded to water levels since construction of the weirs, based on field data.

A statistical analysis of waterfowl populations and Lake Athabasca water levels was prepared to determine whether there was any statistical relationship between waterfowl populations and water levels since the weirs were built. The U.S. Fish and Wildlife breeding pair transects were used as a basis for waterfowl estimates. This analysis is presented in Section 3.2.

The Wildlife Simulation Model has been used to model long-term

waterfowl responses to simulated water levels. The model and the waterfowl habitat and population changes that it predicted are described in Section 3.4.

## 2.3 Wildlife

The Peace-Athabasca Delta provides habitat for a variety of wildlife. This section of the report focuses on muskrats because they are very sensitive to water level changes. Information has been derived from field monitoring, trapping records and personal interviews of trappers. Other furbearers were examined as this report was being prepared; however, because no direct link between population and water levels occurs, other furbearers were not included in this section.

Bison and moose were covered in the PADP Group Report (1973). However, immediate adverse impacts were not predicted to occur from water level changes, and ungulates were not monitored by the PADIC program. Factors other than water levels (i.e. hunting pressure and disease) were felt to be more important determinants of population numbers. Parks Canada monitors ungulate population and habitat, particularly bison within Wood Buffalo National Park.

### 2.3.1 Muskrat Habitat in the Peace-Athabasca Delta

Of all the mammalian life in the delta, muskrat are the most directly dependent on adequate water levels for shelter as well as food. Substantial decreases in water levels, particularly over winter months will often result in high muskrat mortality rates caused by restriction of food supply, increased predation as they search for

food, stress from more frequent exposure to outside temperatures (Ambrock and Allison, 1972), and overcrowding as winter forage becomes more restricted. Low water levels, even if relatively stable, may also cause high winter mortality since water bodies may freeze to the bottom.

Ambrock and Allison (1972) reported that a minimum total depth of ice and water of 0.61 to 0.76 m (2.0 to 2.5 ft.) of water is required for muskrats to survive the winter; however, the timing of significant snowfalls and the timing of accumulated snow can have a great bearing on eventual ice thickness and water depths required to overwinter. Stelfox and McGillis (1977) found that where snow was deep, muskrats survived in areas with less than 0.3 m (1 ft.) of water and ice. Summer water levels are not as critical to muskrat since their access to food is not limited and weather conditions are not as stressful. An exception to this is when water levels rise quickly, as with overbank flooding from rivers, and flood muskrat houses, often killing many young.

Muskrat require ample emergent and submergent vegetation suitable for food, building houses and trapping snow. Significant variations in water levels during the open-water season and between years are necessary on a 3 to 5 year basis to allow reseeding of many emergent species on exposed mudflats. Large fluctuations in water levels will result in wider bands of emergent vegetation around water bodies, thus, providing more muskrat habitat than under conditions with small water level fluctuations (Poll, 1980).

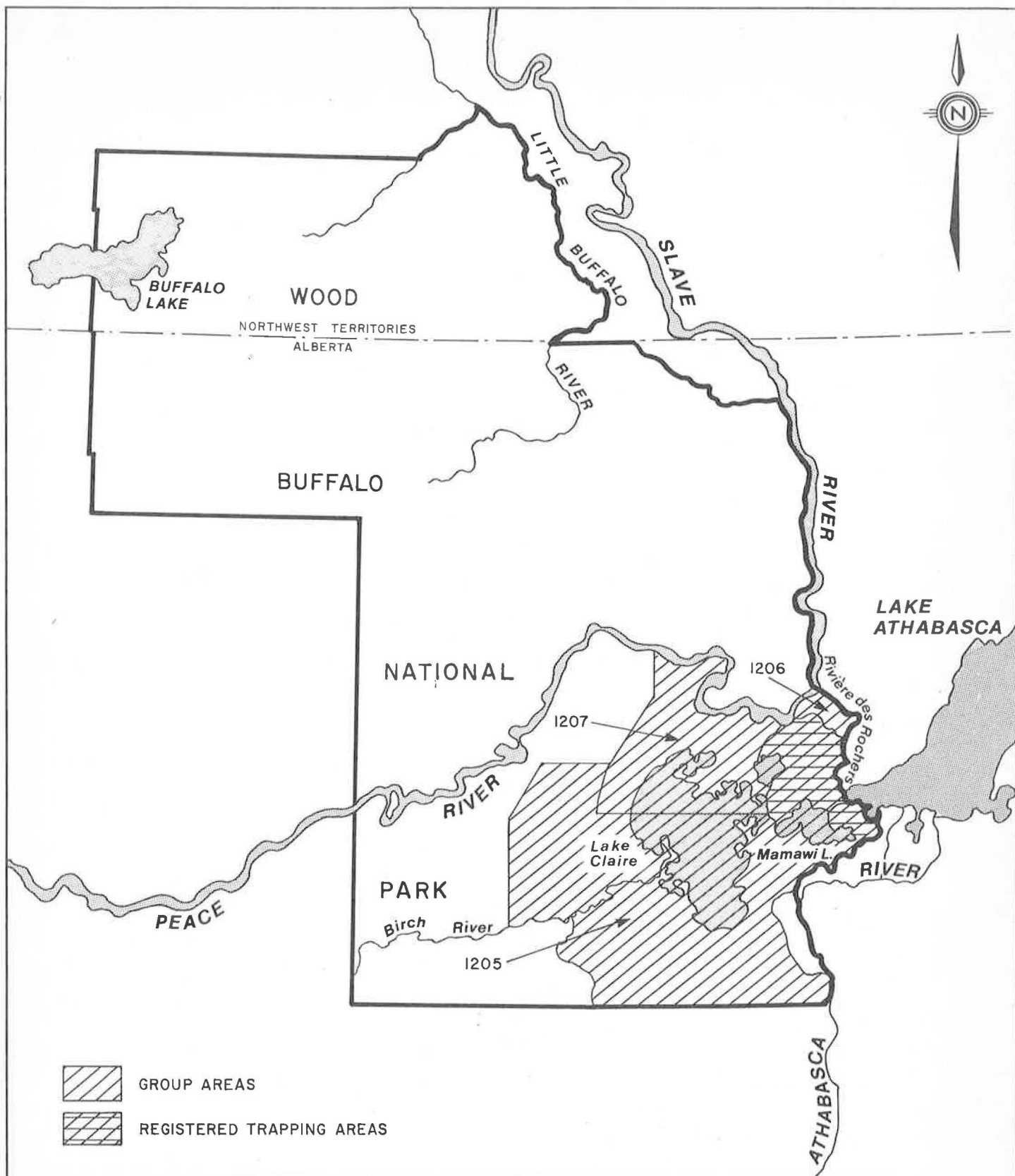
Trapping can easily remove 50% to 75% of an overwintering muskrat population (Ambrock and Allison, 1972). Such a large impact has the potential for preventing a population from peaking, shortening the duration of a peak, or hastening a population decline, and driving the population so low that it needs more time to recover than would normally be required.

Predation can also play an important role in the population dynamics of muskrat. The fur harvest records of muskrat predators (mink, fox, coyote, lynx) show that their populations depend heavily on muskrats during periods of peak abundance. The abundant food supply may allow increases in the predator populations to lag behind the muskrat population. The intense predation pressure hastens the decline in muskrat population with an effect similar to the effects of intensive trapping.

Disease and intrinsic population regulation factors also come into play at various stages of population fluctuations. These factors can affect the intensity of aggressive behavior, the effectiveness of reproductive behavior, fecundity and the ability of the population as a whole to withstand stress. These factors may enhance or retard population growth or decline irrespective of water levels.

#### 2.3.2 Review of Muskrat Trapping Records

The fur harvest records for the Wood Buffalo National Park portion of the Peace-Athabasca Delta were reviewed in the Parks Canada Fort Chipewyan office. Only those trapping areas that would be directly affected by delta water levels were included in this analysis



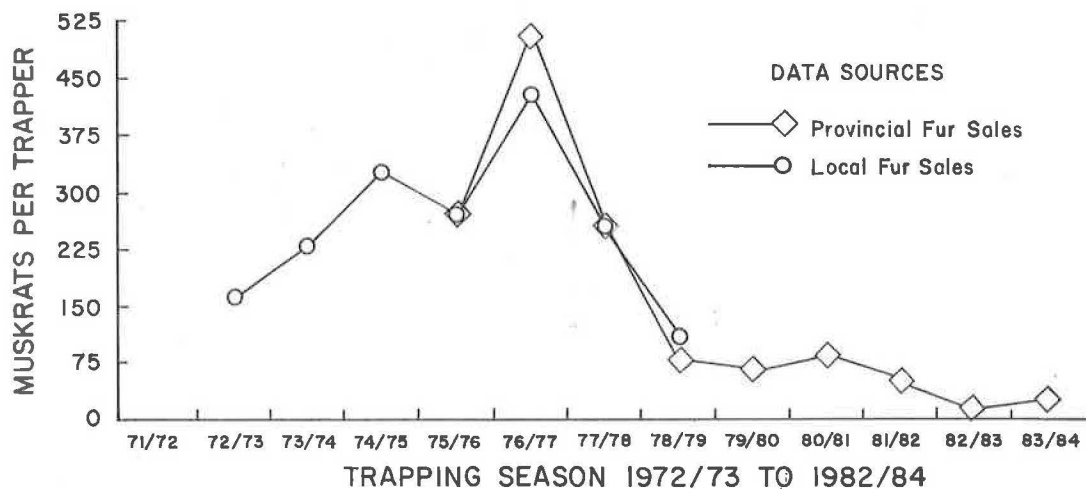
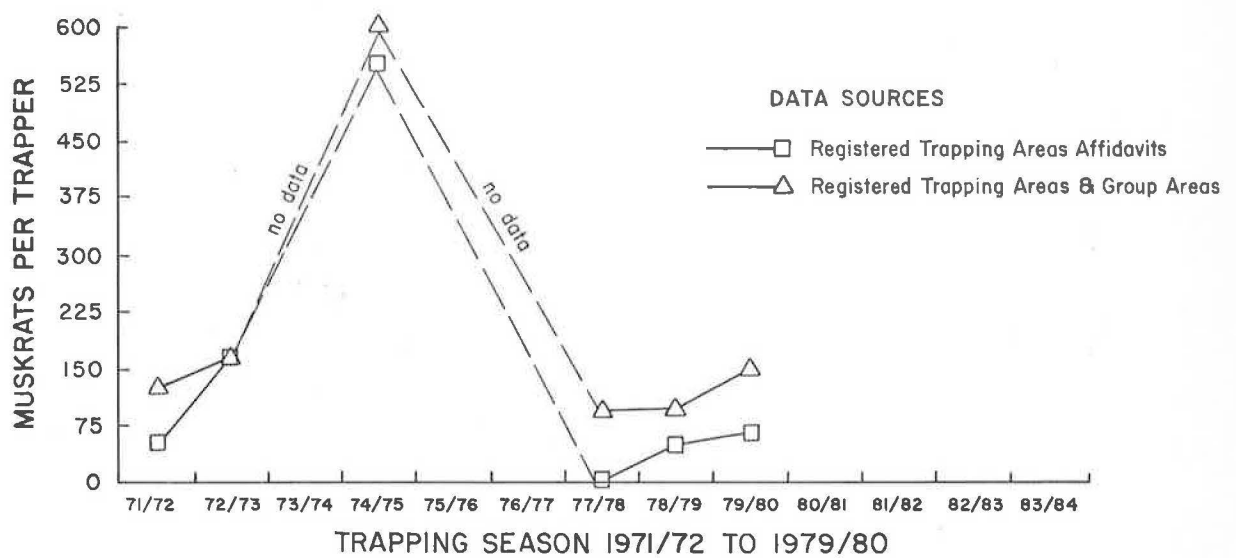
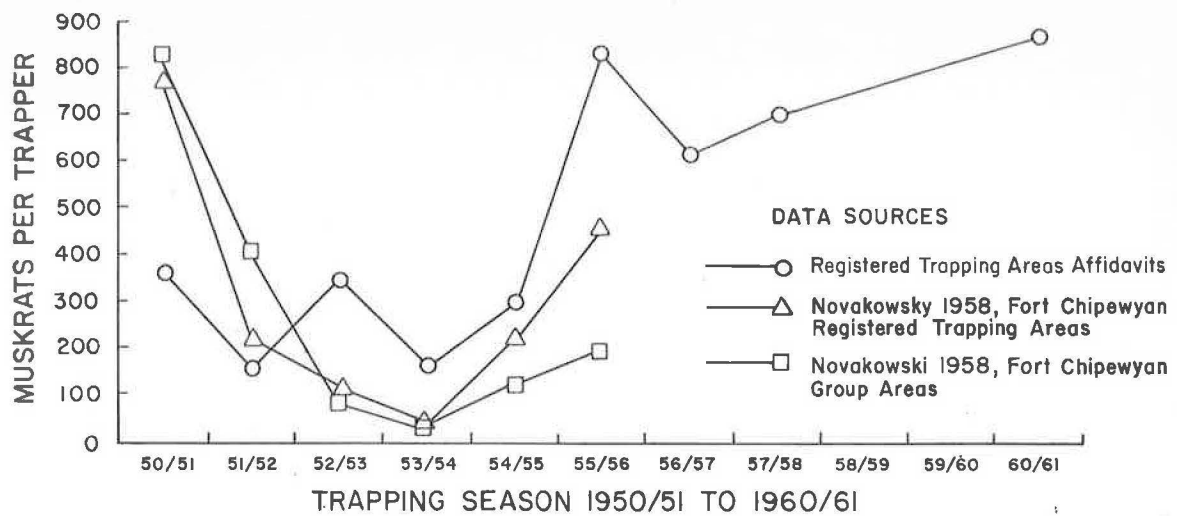
GROUP AREAS AND REGISTERED TRAPPING AREAS  
IN WOOD BUFFALO NATIONAL PARK

(Figure 2.1). The way in which the fur harvest has been recorded has varied, thus the numbers reported are not always comparable from year to year. The trends shown by the records are summarized below: -

- Trapper affidavits are available sporadically from 1949/50 to 1960/61 and from 1971/72 to 1978/79. The affidavit accuracy varies tremendously from trapper to trapper; however, they are the only data available for the 1950s.
- Records of fur sales to local buyers were recorded between 1972/73 and 1977/78. These figures would not include sales outside the community or those furs taken away for domestic or cottage industry uses.
- Records of furs sold within Alberta were kept beginning with the 1975/76 trapping season. These records were computerized beginning in 1978/79 and are current to the 1983/84 trapping season. Theoretically, the current system should keep track of all furs sold for export to or from Alberta and would only miss those used for domestic or cottage industry uses.

"Trapper success", or the average number of furs taken per trapper, provides a good indicator of the relative abundance of species taken over the years. Total fur take should not be compared from year to year because the number of affidavits submitted, number of active trappers and incentives to trap (fur prices, other employment opportunities, etc.) are variable. To calculate average trapper success, the total take for each species was divided by the number of affidavits submitted (or the number of trappers selling any





TRAPPING SUCCESS FOR MUSKRATS

fur). The Group Areas from the 1950s and 1960 pooled their fur takes so that only a few affidavits represented the catch of up to 50 or more trappers from one area. Since the number of trappers contributing was unknown, these data were excluded and only the Registered Trapping Areas (RTAs) were used to calculate trapper success for this time period.

Trapper success for muskrats varied greatly from year to year in the 1950s as it did in the post-weir period (1976 to 1984) (Figure 2-2). In 1958 Novakowski found that trappers were able to trap more muskrats annually in RTAs than individual trappers were able to trap in Group Areas. This seems reasonable since most of the RTAs are almost entirely on prime muskrat habitat whereas only portions of the Group Areas have prime muskrat habitat. Trappers in Group Areas also have greater opportunity for trapping other furbearers and may not concentrate on the muskrat harvest to the same degree as trappers from RTAs. If Novakowski's (1958) results from the Group Areas (average 105 trapper years) and RTAs (less than 20 trappers/year) are combined, then no obvious differences in the range of trapping success can be seen when compared to information collected through fur sales in the post-weir period.

When trapping success in the RTAs, the 1950s, and the post-weir period is compared, it should be noted that several methods were used to acquire fur harvest statistics in the 1970s. Thus, the 1970's data are somewhat unreliable. Nevertheless, the range of trapping success and, thus, assumed muskrat populations, do not appear to differ

TABLE 2.5  
MUSKRAT RESEARCH PROGRAMS IN THE PEACE-ATHABASCA DELTA SINCE 1974

DATE	AUTHOR	TITLE	FUNDING AGENCY	FIELD SEASON	PURPOSE
1974	Smith	Results of aerial and ground counts of muskrats in the PA Delta	CWS	1973 1974	aerial and ground inventory
1976	Smith	Results of fall ground counts of muskrat houses in the PA Delta	CWS	1975	ground survey of muskrat houses on 57 lakes
1977	Stelfox & McGillis	Muskrat monitoring in the PA Delta 1975-77	CWS; Parks Canada & PADIC	1975-7	fall counts and spring activity on 57 lakes  examined effects of water depth, snow depth, & trapping on muskrat populations
1978	Poll & Stelfox	Muskrat monitoring in the PA Delta 1977-78	CWS, Parks Canada & PADIC	1977-8	fall counts and spring activity on 64 lakes  examines effects of climate, hydrology, vegetation & trapping
1980	Poll	Muskrat monitoring in the PA Delta 1973-79,	CWS, Parks Canada	---	summarized and evaluated the findings of previous muskrat monitoring studies

Note: PA = Peace-Athabasca; CWS = Canadian Wildlife Service; PADIC = Peace-Athabasca Delta Implementation Committee

substantially between the two time periods. However, the trapping success (and inferred population) appears to remain depressed for a longer period of time during the post-weir period. Trapper success appeared to be depressed for approximately three years in the 1950s and approximately seven years in the post-weir period. Trappers reported that the muskrat population began to recover in the Birch River area during the summer of 1984, however quantitative data are not yet available to substantiate this observation.

#### 2.3.3 Muskrat Monitoring Programs

Between 1973 and 1979, five monitoring studies of muskrats were conducted for the Canadian Wildlife Service by Smith (1974, 1976), Stelfox and McGillis (1977), Poll and Stelfox (1978), and Poll (1980) (Table 2.5). The results of this five-year monitoring program were summarized by Poll (1980).

- Ground surveys of muskrat based on fall house counts conducted between 1973 and 1978 showed that muskrat populations were high in 1973, dropped slightly in 1974 and peaked in 1975. Between 1976 and 1978, fall house counts declined significantly in all parts of the delta (Table 2.6).
- The intensive flooding experienced between 1972 and 1974, and particularly the ice jam flood of 1974, filled the perched basins making more habitat available for muskrat. Poll (1980) postulated that this was a major contributor to the muskrat population increases observed between 1971 and 1974. It should be noted that the Quatre Fourches dam helped to maintain high

TABLE 2.6  
SUMMARY OF FALL MUSKRAT GROUND COUNTS FOR 31 COMPARABLE BASINS  
IN THE PEACE-ATHABASCA DELTA, 1973-78

	<u>HOUSES COUNTED</u>	<u>PERCENT CHANGE FROM PREVIOUS YEAR</u>
1973	3,128	
1974	2,794	-10.7
1975	3,353	+20.0
1976	3,064	- 8.6
1977	1,942	-36.6
1978	1,056	-45.6

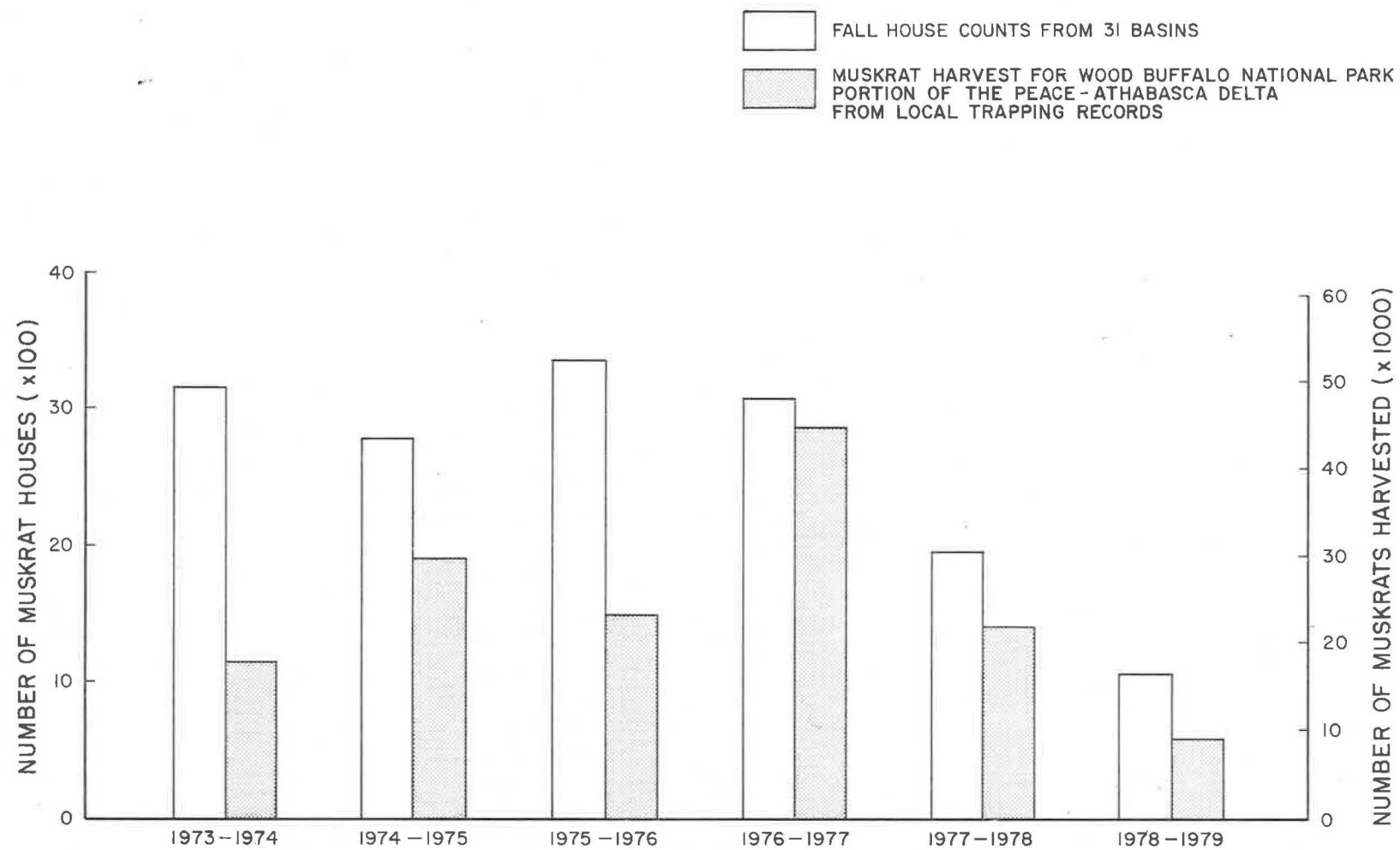
SOURCE: Po11, 1980

water levels over the 1973-74 winter.

- The stable water levels since 1975 were not sufficient to recharge perched basins, resulting in reduced water depths, -loss of emergent vegetation, and a deteriorated muskrat habitat.
- Continuous flooding of open drainage basins since 1974 reduced emergent vegetation and deteriorated muskrat habitat.
- Muskrat overwinter survival rates during this period were affected by snow cover depth, as well as trapping pressure and intraspecific strife due to the high population density. In particular, the latter two factors combined to reduce house survival rates during the high snowfall years.
- Habitat mapping conducted in 1978 revealed that muskrat habitat conditions were poor in that year. Poll (1980) concluded that this was caused by the overall stabilizing effect of the Riviere des Rochers weir.
- Fall muskrat house numbers were compared to fur harvest data for 31 delta lakes in 1973-78 (Figure 2.3). The house numbers and harvest data followed similar trends, however, it is interesting to note that the harvest peaked in 1977, the year following the peak house numbers.

#### 2.3.4 Assessment of Muskrat Data Base

Field studies of muskrats in the Peace-Athabasca Delta conducted between 1973 and 1978 provided comparable population estimates for 31 lakes in the Peace-Athabasca Delta. During this period, populations peaked in 1974, the year of maximum water levels on the delta, and



FALL MUSKRAT HOUSE NUMBERS AND MUSKRAT HARVEST, 1973-1979

FIGURE 2.3

decreased continually until 1976 as water levels decreased.

Fur trapping success was used as a general indicator of long-term population trends, bearing in mind that the method of recording trapping yield has varied considerably over the years. The trapping success statistics showed a major peak in the mid-1970s which corresponded to the population peak estimated for 1975 (Poll, 1980). This peak was comparable in magnitude to peak populations recorded in 1950s. Trapping success declined markedly after 1976 and has remained low into the 1980s. The trapping success rate for this period was no lower than has been recorded in the past; however, it appeared to have remained low for longer than any period in the past.

The Wildlife Simulation Model has been used to simulate the long-term muskrat population and carrying capacity responses to simulated water level changes. The model and changes that are predicted are discussed in Section 3.4.

## 2.4 Fish

Twenty-four species of fish have been reported for the Peace-Athabasca Delta. A checklist of species recorded by all researchers to date is provided in Table 2.7 (McCart, 1982). Goldeye (Hiodon alosoides), northern Pike (Esox lucius), lake whitefish (Coregonus clupeaformis) and walleye (Stizostedion vitreum vitreum) have been caught most frequently in the fisheries field monitoring programs in the Peace-Athabasca Delta (Table 2.8).

### 2.4.1 Fish Habitat in the Peace-Athabasca Delta

Fisheries field investigations in the Peace-Athabasca Delta have



TABLE 2.7  
FISH SPECIES REPORTED FROM THE PEACE--ATHABASCA DELTA

---

SALMONIDAE	
Shallow water cisco	Coregonus artedii
Lake whitefish	Coregonus clupeaformis
Short jaw cisco	Coregonus zenithicus
Round whitefish	Prosopium cylindraceum
Mountain whitefish	Prosopium williamsoni
Lake trout	Salvelinus namaycush
Arctic grayling	Thymallus arcticus
ESOCIDAE	
Northern pike	Esox lucius
HIODONTIDAE	
Goldeye	Hiodon alosoides
CYPRINIDAE	
Lake chub	Couesius plumbeus
Emerald shiner	Notropis atherinoides
Spottail shiner	Notropis hudsonius
Flathead chub	Platygobio gracilis
Longnose dace	Rhinichthys cataractae
CATOSTOMIDAE	
Longnose sucker	Catostomus catostomus
White sucker	Catostomus commersoni
GADIDAE	
Burbot (ling, maria)	Lota lota
PERCOPSIDAE	
Trout-perch	Percopsis omiscomaycus
GASTEROSTEIDAE	
Brook stickleback	Culaea inconstans
Ninespine stickleback	Pungitius pungitius
PERCIDAE	
Yellow perch	Perca flavescens
Walleye	Stizostedion vitreum vitreum
COTTIDAE	
Slimy sculpin	Cottus cognatus
Spoonhead sculpin	Cottus ricei

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SOURCE: McCart, 1982.

TABLE 2.8  
TOTAL NUMBER OF FISH CAPTURED DURING FIELD STUDIES IN THE PEACE-ATHABASCA DELTA IN  
1976, 1977, 1978, AND 1980

SPECIES	1976 <sup>a</sup>		1977 <sup>b</sup>		1978 <sup>c</sup>		1980 <sup>d</sup>		TOTAL	
	N	%	N	%	N	%	N	%	N	%
Cisco			8	0.08					8	0.02
Lake Whitefish	1,808	7.43	908	9.17	842	28.11	363	11.76	3,921	9.72
Round Whitefish			2	0.02					2	0.01
Goldeye	19,326	79.37	7,730	78.03	1,136	37.93	924	29.93	29,116	72.18
Northern Pike	2,525	10.37	652	6.58	470	15.69	409	13.25	4,056	10.05
Flathead Chub			190	1.92	75	2.50	9	0.29	274	0.68
Longnose Sucker	241	0.99	183	1.85	173	5.78	50	1.62	647	1.60
White Sucker	32	0.13	7	0.07	16	0.53	15	0.49	70	0.17
Burbot			61	0.62	3	0.10	46	1.49	110	0.27
Walleye	417	1.71	165	1.67	280	9.35	1,271	41.17	2,133	5.28
TOTAL	24,349	100.00	9,906	100.00	2,995	100.00	3,087	100.00	40,337	100.00

Note: a = Kristensen and Summers, 1978  
b = Kristensen, 1978  
c = Kristensen, 1979  
d = Bond, 1980

SOURCE: McCart, 1983

focused primarily upon goldeye and walleye. Both of these species have important spawning and rearing areas within the delta and both species are utilized by the local domestic and sport fishery. There is a significant commercial fishery for walleye on Lake Athabasca. A commercial goldeye fishery started in 1948 and continued until it collapsed in 1966.

Field data for other species, in particular whitefish and northern pike, have been recorded incidentally during most of the fisheries investigations. As a result, general statements can be made about the use of the delta by these species. Historically, lake whitefish have been harvested by the native people of the region for human consumption and dog food. Pike, a popular game fish, is also taken by domestic and commercial fishermen.

#### 2.4.1.1 Goldeye

The goldeye is known principally as a species of turbid rivers, feeding primarily on zooplankton and insects (Kennedy and Sprules, 1967; Donald and Kooyman, 1977b). The Peace-Athabasca Delta is a spawning and nursery area for a very significant goldeye population. Although the goldeye population declined significantly in the mid-1960s, field studies indicated that the population has been recovering (Kristensen and Parkinson, 1983). Tagging studies showed that the delta goldeye population movements are widespread throughout the Peace and Slave Rivers, Lake Athabasca, the Athabasca River and the delta itself.

Estimates for young-of-the-year production have ranged between 7 million in 1971 (a very successful year-class) and 1.5 million in

1977 (Kristensen, 1981). Since delta lakes are shallow and tend to freeze to the bottom, the population winters in the Peace and Slave Rivers, (Donald and Kooyman, 1977a), Lake Athabasca (Bond and Berry, 1980; Kristensen and Parkinson, 1983) and the Birch River (Kooyman, 1973). Although spawning appears to occur throughout the delta (Kristensen, 1981), the main spawning area is the Lake Claire-Mamawi Lake complex (Donald and Kooyman, 1977a). The distribution of young-of-the-year can be related to the distribution of spawning activity (Donald and Kooyman, 1977a) and, in many cases, with wind activity and distribution of other small or young-of-the-year fishes (Kristensen, 1981).

The spawning migration into the delta is initiated with the accumulation of goldeye in the outflow channels in March. The adult goldeye (generally six years or older) migrate up the Chena' des Quatre Fourches, Rivière des Rochers and Revillon Coupé after breakup and after the ice has cleared from the Peace River, usually in late April or early May. They migrate through Mamawi Lake and the Prairie River to reach Lake Claire. Not all fish undertake the complete journey from the Peace and Slave Rivers to Lake Claire. Many fish remain in the Mamawi Lake and Prairie River areas and a small number may spawn in the Richardson Lake and Baril Lake areas.

Spawning generally takes place during the latter half of May (Donald and Kooyman, 1977a). The actual time and place of spawning is dependent on the weather and its effect on breakup and water temperatures. When the weather is warm, breakup occurs early, and

water temperatures and other conditions for spawning develop early in the delta lakes. At such times, goldeye may enter the delta sooner and penetrate further, well into Lake Claire, utilizing a larger spawning area. Such favourable conditions, coupled with a large spawning population and an abundance of food would probably result in a successful year class, such as that which occurred in 1971.

Immature goldeye begin to migrate into the delta one or two weeks behind the adults (Donald and Kooyman, 1977a), at a time when Peace River levels may be lower and conditions for passage in the outflow channels are not as favourable (Kristensen, 1981). Both young-of-the-year and older fish use the delta waters as feeding habitat through most of the summer. Movements of goldeye back to the Peace and Slave Rivers reach a peak between mid-July and mid-August (Donald and Kooyman, 1977a). Furthermore, Bond (1980) reported a major feeding migration of immature goldeye into the lower Athabasca River before or during breakup. These goldeye were thought to be part of the goldeye population that spawns in the Peace-Athabasca Delta.

Several studies have addressed the question of the relative importance of the three major streams connecting the Peace River with the delta as migration routes for goldeye. Data from 1974 indicated that both the Chenal des Quatre Fourches and the Rivière des Rochers were used by large numbers of goldeye migrating into the Mamawi-Claire lake system (Donald and Kooyman, 1977). Kristensen and Summers (1978) and Kristensen (1981) suggested that the Rivière des Rochers and the Revillon Coupé are at least as important as the Chenal des Quatre

Fourches to the spring migration of goldeye. The relative importance of the three streams may also depend on breakup patterns on the Peace River, since ice jam location may favour access to one stream over another.

#### 2.4.1.2 Walleye

Lake Athabasca and waters associated with the Peace-Athabasca Delta support a large and important population of walleye. These fish spawn in lakes associated with the delta and in tributaries of the lower Athabasca River. Production in this area was estimated to be over 4 million young-of-the-year in 1978 (Kristensen, 1979).

Adult walleye apparently spend most of the year in the deep, cold, clear waters of the Saskatchewan portion of Lake Athabasca (Dietz, 1973). Some may overwinter in the Athabasca River (Bond and Berry, 1980), the Birch River (Kristensen, 1981) or the delta channels (Kristensen and Parkinson, 1983).

In March of each year, the walleye accumulate in Lake Athabasca near the delta, waiting for the delta lakes to open (in late April, early May) (Bidgood, 1972). Richardson Lake appears to be the best known and single most important spawning area in the delta (Kristensen, 1979). The lakes Claire and Mamawi are also very significant for walleye spawning, and probably have an overall higher walleye production than Richardson Lake (Kristensen, 1979). The relative importance of the lower Athabasca River tributaries for walleye spawning has not been studied.

Walleye spawning movements into Richardson Lake usually occur in

late April. They are associated with high water levels in the Athabasca River which cause ice lift (Bidgood, 1972; Dietz, 1973). Walleye spawn over mud substrates (Dietz, 1973). Incubation takes about 13 days, and the young fish remain in Richardson Lake until August (Dietz, 1973). Richardson Lake and other delta lakes are important nursery habitat for a number of other fish species which provide excellent feeding conditions for the piscivorous walleye. Thus, Richardson Lake walleye are characterized by fairly rapid growth (Dietz, 1973).

When they mature, the adult walleye return to Lake Athabasca, where they become widely dispersed (Kristensen and Parkinson, 1983). Dietz (1973) suggested that post-spawners divide into two major groups. One group may move eastward along the south shore of Lake Athabasca into Saskatchewan, while the other moves west and then along the north shore of the lake.

#### 2.4.1.3 Lake Whitefish

Information describing lake whitefish utilization of waters associated with the Peace-Athabasca Delta is limited. Population size is unknown, but it has been suggested that it could be 1 million or more (Smith, 1982). Overwintering occurs in Lake Athabasca, some delta channels, the Peace/Slave Rivers, and the lower Athabasca River (Bond and Berry, 1980; McCart, et al., 1982). Summer feeding areas include Lake Athabasca, delta channels, and to some extent shallow delta lakes (Kristensen and Parkinson, 1983). Spawning of whitefish in the Peace-Athabasca Delta has not been documented. A major spawning run passing up the lower Athabasca River beginning in late

August and peaking in early September was observed by Bond and Berry (1980) and a large concentration of spawning whitefish has been observed in the Athabasca River above Fort McMurray (Jones, et al., 1978). Spawning generally occurs in mid to late October. A rapid post-spawning migration back to Lake Athabasca and beyond takes place in November, although some whitefish overwinter in the Athabasca River (Bond and Berry, 1980). Incubation takes place over the winter months, with the hatch probably coinciding with peak spring flows. Young fish drift down the Athabasca River and find suitable summer feeding areas in Richardson Lake, and other lakes and channels in the delta (Dietz, 1973; McCart, 1982).

#### 2.4.1.4 Northern Pike

Although there have been no direct studies of northern pike in waters associated with the Peace-Athabasca Delta, data collected during studies of other species provides an understanding of how this species uses the delta. The northern pike is a relatively sedentary piscivorous species. It is dependent on marshy shorelines for spawning, which takes place shortly after break-up. The delta population of pike greater than 220 mm fork length was estimated at 16,300 in 1976 (Kristensen and Summers, 1978). Richardson Lake is known as a nursery area for young-of-the-year pike (Dietz, 1973). Other delta lakes and channels provide extensive spawning and rearing habitat as well (Kristensen and Parkinson, 1983). Pike overwinter in western Lake Athabasca and the deeper delta channels (Kristensen and Parkinson, 1983).



TABLE 2.9  
FISHERIES RESEARCH PROGRAMS IN THE PEACE-ATHABASCA DELTA SINCE 1974

DATE	AUTHOR	TITLE	FUNDING AGENCY	FIELD SEASON	PURPOSE
1976	Kristensen, Ott & Sekerak	Walleye and Goldeye Investigations in the PA Delta - 1975	AOSERP	1975	examine walleye & goldeye in the Athabasca River portion of the PA Delta
1977a	Donald & Kooyman	Migration and Population Dynamics of the PA Delta Goldeye Population	CWS, National & Historic Parks Branch	1971-74	examine movement and population based on field surveys
1977b	Donald & Kooyman	Food, Feeding Habitats and Growth of Goldeye ( <u>Hiodon alosoides</u> )	CWS, National & Historic Parks Branch	1971-73	examine feeding habits based on stomach contents
1978	Kristensen & Summers	Fish Populations in the PA Delta and the Effects of Water Control Structures on Fish Movements	DSS	1976	To examine fish migration on Riviere des Rochers, Revillon Coupe & Chenal des Quatres Fourches and the effect of the weirs. To obtain other information about fish movement and age on the Delta.
1978	Summers	Walleye Studies in Richardson Lake and Lake Athabasca, April-July 1977	PADIC	1977	To document the biology of spawning walleye in Richardson Lake. To determine the effect of altered water levels on the walleye.

Continued . . .

DATE	AUTHOR	TITLE	FUNDING AGENCY	FIELD SEASON	PURPOSE
					To estimate the contribution of Richardson Lake walleye to Lake Athabasca commercial fishery.
1978 & 1981	Kristensen	Investigations of Goldeye and Other Species in the Wood Buffalo National Park Section of PA Delta	PADIC	1977	<p>To determine the relative importance of Riviere des Rochers, Revillon Coupe, &amp; Chenal des Quatre Fourches to spring goldeye migration.</p> <p>To document the effects of the weirs on goldeye spring migration.</p> <p>To determine whether discrete groups of goldeye utilize the three rivers.</p> <p>To gather information about use of the delta by goldeye.</p> <p>To collect information about other species as well.</p>
1979	Kristensen	Walleye Study in the PA Delta 1978	PADIC	1978	<p>To locate spawning areas in the delta other than Richardson Lake.</p> <p>To assess their significance compared to Richardson Lake.</p> <p>To compare biological characteristics of walleye from different areas.</p>

Continued . . .

<u>DATE</u>	<u>AUTHOR</u>	<u>TITLE</u>	<u>FUNDING AGENCY</u>	<u>FIELD SEASON</u>	<u>PURPOSE</u>
1980	Bond	Fishery Resources of the Athabasca River Downstream of Fort McMurray	AOSERP	--	--
1982	McCart	Peace-Athabasca Fisheries Feasibility Studies	Alta. Env. (Slave River Studies)	none	To evaluate the effects of Slave River Dam scenarios on fish resources of PA Delta, based on existing information.
1983	Kristensen & Parkinson	Biological and Engineering Studies to Determine Fishway Designs for the PA Delta	Alta. Env. Alta. Fish & Wildlife	1980	To examine fish movements in Revillon Coupe, Rivière des Rochers and Quatre Fourches. To prepare functional engineering designs for fish passage facilities.
1985	Smith	Evaluation of Test Fishways on Rivière des Rochers in the PA Delta	Alta. Env. DFO	1984 May & June	To collect hydraulic & biological data to evaluate the performance of the prototype fishways on Rivière des Rochers.
1985	Smith	Repairs to Prototype Fishways at the Weir on the Rivière des Rochers in the PA Delta	Alta. Env. DFO	1984	To repair damages to the prototype fishways.

Note: AOSERP = Alberta Oil Sands Environmental Research Program; CWS = Canadian Wildlife Service; DSS = Department of Supply and Services; PADIC = Peace-Athabasca Delta Implementation Committee; DFO = Department of Fisheries and Oceans

#### 2.4.2 Fisheries Monitoring Programs

Five fisheries field programs have been conducted under the auspices of the PADIC since the weirs were constructed on the Rivière des Rochers and Revillon Coupe' in 1976 (Table 2.9). In 1977, a program was undertaken to determine the importance of Richardson Lake as a spawning area for walleye and the effect of altered water levels on walleye (Summers, 1978). The study found that Richardson Lake is a significant walleye spawning area; however, in 1977, it contributed only 15% of the fish caught in the Lake Athabasca commercial fishery. Therefore, a broader field study of walleye spawning throughout the delta was undertaken in the following year (Kristensen, 1979). This study confirmed that, for its size, Richardson Lake is probably the single most important water body for the production of walleye in the Peace-Athabasca Delta. However, in most years, more walleye are produced by other delta lakes, particularly lakes Claire and Mamawi. The production of walleye is more consistent in Richardson Lake than in any of the other delta lakes.

In 1977, fish movements in the vicinities of the Rivière des Rochers and Revillon Coupe' weirs were studied (Kristensen, 1981). The study focused on goldeye and concluded that, in 1977, the weirs severely impeded fish movements during parts of the spring migration of this species. Therefore, in 1979, field biological and related engineering studies were conducted to prepare functional fishway designs to aid fish passage at the weirs (Kristensen and Parkinson, 1983). Following completion of two prototype fishways (Denil and

Vertical Slot) on Rivière des Rochers, a monitoring study was undertaken in 1984 (Smith, 1985). Although no major spawning run was observed to use the fishways, mature fish were observed to use both fishways, with no strong preference for one or the other.

Several other agencies have funded fisheries research in the Peace-Athabasca Delta in the past ten years. The Federal Department of Supply and Services funded the first field study of the effects of the weirs on Rivière des Rochers and Revillon Coupé which documented blockage of the goldeye migration in 1976 (Kristensen and Summers, 1978). Under the Alberta Oil Sands Environmental Research Program (AOSERP), walleye and goldeye investigations were conducted in the delta in 1975 (Kristensen, Ott and Sekerak, 1976) and an investigation of fish resources in the lower Athabasca River was conducted in 1980 (Bond, 1980). The most extensive work on goldeye in the delta was conducted by Donald and Kooyman between 1971 and 1974 with funding from PAD Project, National and Historic Parks Branch and the Canadian Wildlife Service (Donald and Kooyman, 1977a and 1977b).

#### 2.4.3 Assessment of the Fisheries Data Base

The fisheries field program conducted under the auspices of PADIC and other agencies have been largely problem-oriented. From Kristensen's 1976, 1977 and 1981 field investigations, it is apparent that the weirs on the Rivière des Rochers and Revillon Coupé were blocking fish (primarily goldeye) movements. The PADIC fisheries monitoring program focused on this problem, and eventually culminated in the construction of the two prototype fishways on Rivière des Rochers.

Intensive biological and hydrotechnical field studies have been conducted at the Little Rapids site on the Rivière des Rochers. There are sufficient data from these studies to prepare a statistical frequency analysis of the extent of fish passage hindrance at different flows (Section 3.4). However, the results of this analysis have not been verified in the field.

There are insufficient data to prepare more than an empirical assessment of the effects of changes in water levels on fish habitat in the delta for overwintering, feeding, spawning and rearing. Relative numbers of fish species and the age class structures of goldeye and walleye have not been examined since 1979. Therefore, it is not possible to say whether there has been a shift in actual or relative numbers of fish in the delta since construction of the weirs.

### 3.0 QUANTITATIVE ASSESSMENT

#### 3.1 Hydrodynamic Model

The Hydrology Sub-Committee of PADIC used the One-Dimensional Hydrodynamic Model (hydrodynamic model) to examine the performance of the Rivière des Rochers and Revillon Coupé weirs (Alberta Environment and Environment Canada, 1985a, b). Comparative model simulations of three scenarios were conducted: the natural regime, the Bennett Dam regulated regime and the regulated regime in combination with the Rivière des Rochers and Revillon Coupé weirs. The simulation period for the analysis was 1960-1984. The actual data and detailed output can be examined in the reports prepared by the Hydrology Sub-Committee. The model results provided the hydrological input to the Wildlife Simulation Model (Section 3.3). They were also used as the basis for empirical evaluation of the long-term biological effects on various flow regimes.

The results of the modelling exercise showed that the Bennett Dam, combined with the weirs on the Rivière des Rochers and Revillon Coupé, will have the following long-term effects on the water levels of Lake Athabasca, Lake Claire, and Lake Mamawi:

- maximum mid-summer levels will be slightly lower, while average and minimum levels will be somewhat higher than the natural condition (Table 3.1);
- the variability of Lake Athabasca water levels will be significantly less than would have occurred with either the Bennett Dam or the natural condition.

TABLE 3.1  
COMPARISON OF SIMULATED WATER LEVELS IN THE PEACE-ATHABASCA DELTA (1960 TO 1984)  
USING THE ONE-DIMENSIONAL HYDRODYNAMIC MODEL

	SIMULATED WATER LEVELS (m)			DEVIATION FROM NATURAL LEVELS (m)		DEVIATION FROM BENNETT DAM (m)
	NATURAL	BENNETT DAM	WEIRS	BENNETT DAM	WEIRS	
LAKE ATHABASCA						
Maximum	209.75	209.22	209.72	-0.53	-0.03	+0.5
Minimum	207.90	207.90	208.48	0	+0.58	+0.58
Average	208.67	208.45	209.06	-0.22	+0.39	+0.61
LAKE CLAIRE						
Maximum	210.00	209.57	209.82	-0.43	-0.18	+0.25
Minimum	208.62	208.58	208.73	-0.04	+0.11	+0.15
Average	209.17	208.98	209.22	-0.19	+0.05	+0.24
MAMAWI LAKE						
Maximum	209.94	209.54	209.81	-0.40	-0.13	+0.27
Minimum	208.41	208.56	208.70	+0.15	+0.29	+0.14
Average	209.08	208.93	209.19	+0.15	+0.11	+0.26

SOURCE: Alberta Environment and Environment Canada, 1985b.



-- for Lake Claire and Lake Mamawi, the frequency and duration of water levels with the weirs in place will approximate the natural levels more closely than the level simulated for Bennett Dam regulated flows without the weirs.

The results of the hydrological modelling as they apply to the biological studies are discussed in Section 4.1.

### 3.2 Statistical Analysis of Waterfowl Populations and Lake Levels

Because only one year of post-weir waterfowl monitoring data was available, an analysis of the impact of the weirs on waterfowl populations could not be carried out. Therefore, a statistical analysis of waterfowl populations and Lake Athabasca water levels was conducted for the period 1968 to 1982 to determine whether the weirs have had a statistically significant impact on waterfowl populations. The analysis and conclusions, as prepared by the Canadian Wildlife Service for PADIC in 1984, are presented below.

Waterfowl data collected each year by the U.S. Fish and Wildlife Service from northern Saskatchewan and Alberta, southern Saskatchewan and Alberta, and from the Peace-Athabasca Delta were examined. These were the only available data which provided continuous and comparable data sets for the natural conditions period (1960-68), the Bennett Dam without weirs (1968-75) and the Bennett Dam with weirs (1976-82) periods. Water level data collected from the Lake Athabasca/Fort Chipewyan hydrological station (1960-80) were used to determine if any significant correlations existed between water levels and waterfowl

population levels during the three time periods. The data used for the analysis are provided in Table 3.2. It should be noted that this statistical analysis was conducted before the results of the one-dimensional hydrodynamic model were available.

Yearly population estimates for both dabblers and divers in each of the three periods showed that there was both a decrease in total population and a decrease in variance after the Bennett Dam was closed in 1967 (Figure 3.1). Variation in population increased somewhat after the Rochers weir was constructed in 1975, but the amplitude did not reach that of the natural conditions period.

A one-way analysis of variance (ANOVA) was performed to test the statistical significance of these trends. The results indicated that diver populations of the Peace-Athabasca Delta did not fluctuate significantly ( $p$  greater than 0.05) over the three time periods ( $F = 3.212$ ;  $df = 2, 20$ ;  $p = 0.062$ ). Similarly, no significant changes ( $p$  less than 0.05) occurred in dabbler populations ( $F = 2.838$ ;  $df = 2, 20$ ;  $p = 0.082$ ).

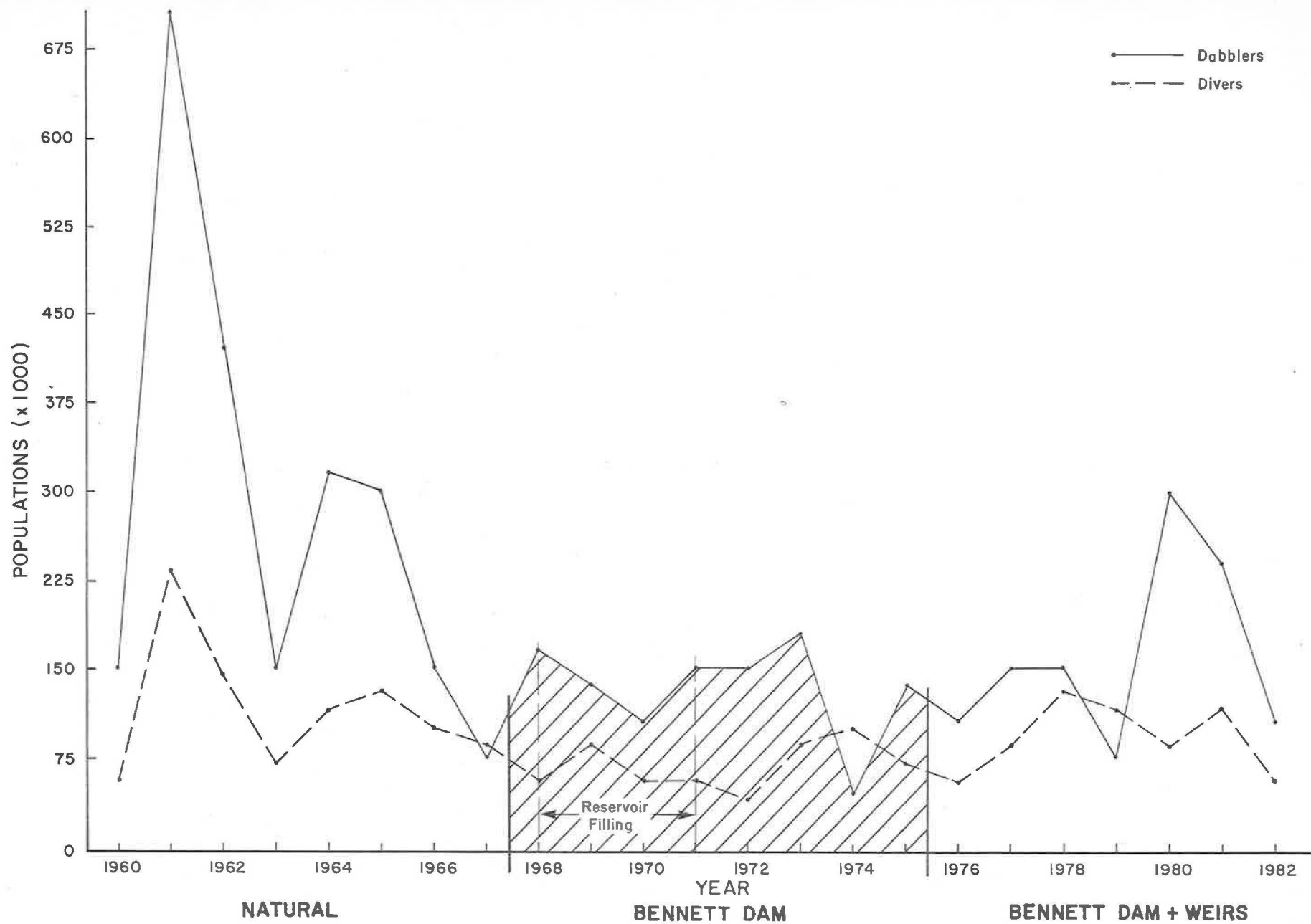
One-way ANOVAs were run on the Lake Athabasca/Fort Chipewyan hydrological data from the same time periods. A significant difference ( $p$  less than 0.05) between periods existed only when using the yearly maximum water level data ( $F = 7.901$ ;  $df = 2, 18$ ;  $p = 0.03$ ).

Pair wise multiple comparisons were performed on the recorded maximum water level data. These tests indicated that there was a significant difference ( $p$  less than 0.05) between periods 1 and 2 and between periods 1 and 3, but not between periods 2 and 3 (Figure 3.2).

TABLE 3.2  
WATERFOWL POPULATIONS AND RECORDED LAKE ATHABASCA WATER LEVELS  
(1960 TO 1982)

PERIOD	YEAR	WATERFOWL POPULATION LEVELS OF						WATER LEVELS OF			
		SOUTHERN (Alta. & Sask.)		NORTHERN (Alta. & Sask.)		PEACE- ATHABASCA DELTA		LAKE ATHABASCA AT FORT CHIPEWYAN			
		DIVER	DABBLER	DIVER	DABBLER	DIVER	DABBLER	MAY 21- MAY 31	JUNE 1- JUNE 10	MAY 21- JUNE 10	YEARLY MAXIMUM
I. Pre-Bennett Dam	1960	1,241.0	12,252.1	1,377.7	2,282.8	67.2	143.2	685.2	686.3	685.8	690.7
	1961	1,455.3	9,683.8	2,397.0	4,637.1	238.4	709.8	---	687.2	---	688.8
	1962	1,088.7	7,059.6	1,552.7	2,049.1	144.3	415.0	686.0	687.0	686.5	691.2
	1963	855.9	8,013.5	1,498.8	2,345.1	70.0	143.7	687.7	688.7	688.2	690.0
	1964	1,009.2	8,125.4	2,170.4	4,171.4	126.4	313.1	685.5	686.5	686.0	691.4
	1965	968.1	7,671.7	1,990.0	2,446.0	131.5	301.4	687.0	687.6	687.3	691.7
	1966	1,059.0	12,682.2	1,631.5	2,517.5	101.5	149.5	685.7	686.6	686.2	689.2
	1967	1,438.0	12,808.4	1,534.4	2,312.0	95.3	81.3	686.1	687.7	686.9	691.0
II. Pre-Rocher Weir	1968	788.1	8,946.4	2,258.3	2,943.1	62.2	163.2	---	---	---	685.0
	1969	1,337.5	12,262.7	1,631.4	2,418.0	83.7	132.2	685.9	685.8	685.8	686.2
	1970	1,364.8	14,891.6	1,924.9	2,646.9	62.1	110.2	684.0	684.1	684.0	685.7
	1971	1,209.4	16,291.6	1,924.9	2,646.9	64.6	157.3	684.4	684.3	684.4	687.2
	1972	1,265.7	14,817.6	2,510.8	3,398.9	49.2	145.0	686.6	686.5	686.6	689.6
	1973	1,541.4	12,578.5	2,362.2	2,798.6	89.0	178.9	685.8	686.1	686.0	687.9
	1974	1,503.7	15,085.4	2,326.7	2,621.5	104.6	51.8	689.1	689.6	689.4	689.8
	1975	2,169.3	15,258.4	2,269.3	2,604.7	74.4	133.8	685.4	685.6	685.5	688.4
III. Post-Rocher Weir	1976	2,400.3	14,608.9	1,783.9	2,153.7	60.5	103.5	686.4	686.1	686.2	689.4
	1977	2,158.0	9,963.1	1,617.6	3,238.2	91.7	157.2	686.8	687.0	686.9	688.7
	1978	1,760.7	9,195.5	2,257.2	3,959.8	136.6	148.4	---	687.2	---	688.0
	1979	2,381.0	12,394.3	3,234.9	3,582.1	119.1	79.4	687.2	687.8	687.5	689.6
	1980	2,204.2	10,188.2	1,822.8	3,330.1	94.3	294.3	684.4	684.2	684.3	685.7
	1981	1,407.9	8,396.6	2,096.8	3,058.0	123.7	242.9	---	---	---	---
	1982	1,649.1	8,871.8	1,964.5	2,709.9	59.0	99.4	---	---	---	---

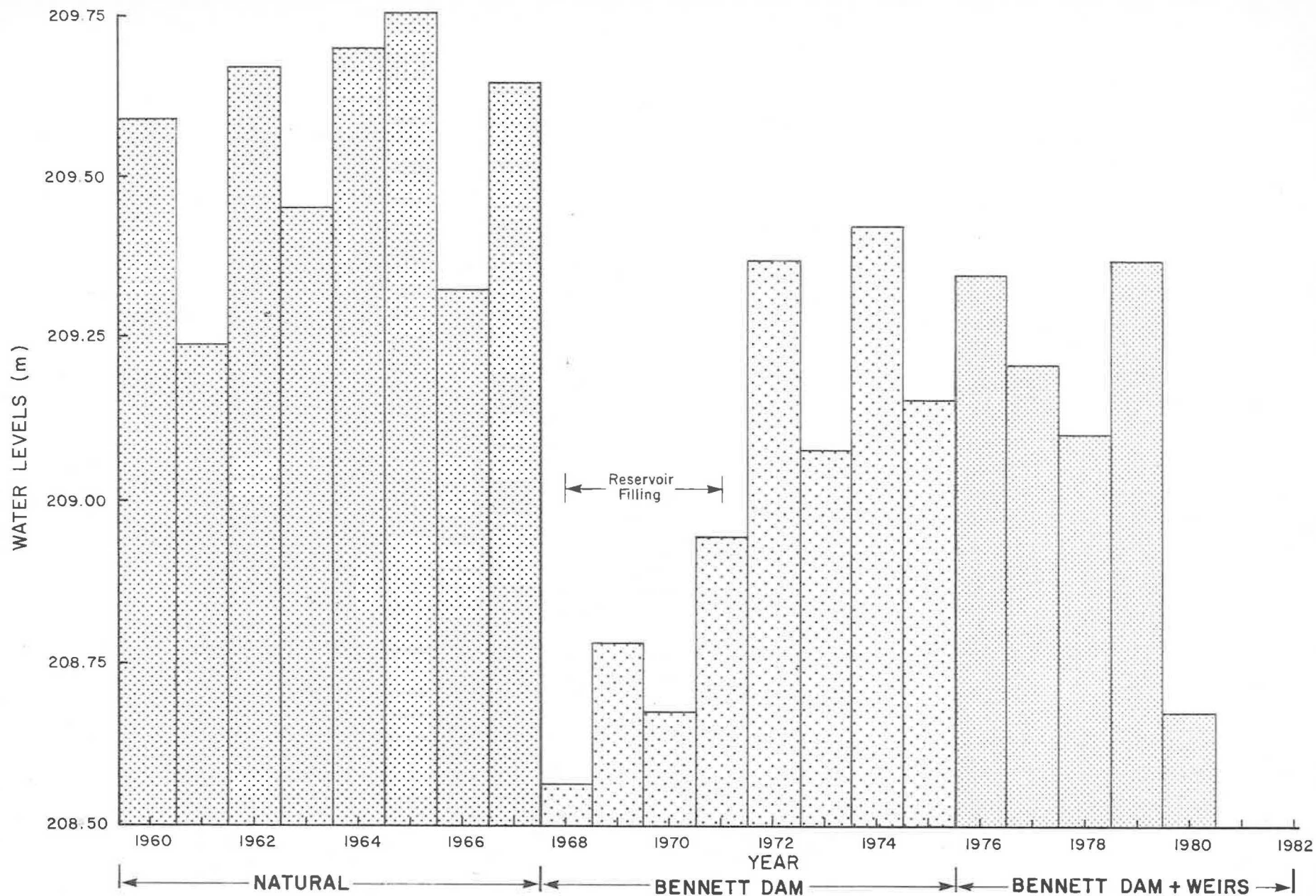
SOURCE: Dickson and Barry, 1984.



PEACE - ATHABASCA DELTA WATERFOWL POPULATIONS  
(DABBLERS AND DIVERS), 1960 - 1982

SOURCE: US Fish and Wildlife Service Data

FIGURE 3.1



ANNUAL MAXIMUM LAKE ATHABASCA WATER LEVELS  
RECORDED AT FORT CHIPEWYAN, 1960-1980

FIGURE 3.2

This suggests that there has not been a significant change in water levels since construction of the weirs and that the maximum Lake Athabasca water levels have not occurred to the high levels of the natural conditions period. This analysis was conducted independently of the Hydrology Subcommittee.

Analyses were also conducted to determine if there was any correlation between: dabbling populations in the south (Alberta and Saskatchewan) and dabbling populations in the Peace-Athabasca delta; dabbling populations in the north (Alberta and Saskatchewan) and dabbling populations in the Peace-Athabasca Delta; divers in the north (Alberta and Saskatchewan) and divers in the Peace-Athabasca Delta and; divers in the south (Alberta and Saskatchewan) and divers in the Peace-Athabasca Delta.

No significant ( $p$  less than 0.05) correlations were found except for that between divers in the north and divers in the Delta during the pre-Bennett Dam period ( $r = 0.83$ ;  $p$  less than 0.05). At this time, diver populations in both the north and the delta followed similar trends. This correlation and the lack of correction thereafter may indicate that diver populations on the Peace-Athabasca Delta declined after the Bennett Dam was completed and that these populations never recovered, even with the Rochers weir construction.

Therefore, these tests did not show that there has been a statistically significant change in the waterfowl population of the Peace-Athabasca Delta since construction of the Bennett Dam and the weirs on the Rivière des Rochers and Revillon Coupé. However, the

following shortcomings to the analysis should be considered.

- Lake Athabasca water levels do not reflect water conditions for the entire Peace-Athabasca Delta, and in particular the perched basins.
- Period 2 (1968-1975) included both filling of the Williston Reservoir (1968-1971) and the presence of the Quatre Fourches weir (1971-1974).
- The waterfowl data used in the analysis are not detailed.
- Western North American waterfowl populations have declined drastically in recent years and this may have affected waterfowl use of the Peace-Athabasca Delta.

### 3.3 Statistical Analysis of Fish Passage at the Weirs

When the weirs were constructed on the Rivière des Rochers and Revillon Coupe, it was assumed that they would not be major hindrances to migration of fish species through the delta because two other routes were available -- the Chenal des Quatre Fourches and the fish bypass channel that was constructed in conjunction with the Rivière des Rochers weir. However, observations of the Rivière des Rochers weir in 1975 suggested that the fish bypass channel was not effective in allowing spring migration of goldeye to delta lakes for spawning. Depending upon water levels and velocities, fish may have difficulty finding the entrance to the channel or navigating the narrow upstream segment where high water velocities prevailed. Subsequently, the governments of Canada and Alberta studied fish movements at the weirs, the bypass channel, and in the delta. The studies, conducted in 1976,

1977 and 1980, reported that upstream fish movements were hindered when hydraulic head over the weirs was high. Therefore, as part of the current study, the timing of goldeye migrations was examined and a frequency analysis of the hydraulic head at the weirs during the upstream spawning migration period was prepared.

### 3.3.1 Migration Period

The "migration period" was defined as the time period during which goldeye spawners have to overcome the weirs at Rivière des Rochers and Revillon Coupé to reach their spawning areas. Donald and Kooyman (1977a) reported that the earliest and latest dates for the beginning and the end of spawning migration at Chenal des Quatre Fourches in 1972-75 were May 4 and May 26, a period of just over three weeks. Kristensen and Summers (1978) gathered field data after June 3, 1976 and found that 97% were immature fish in the 1-5 year age group. They concluded that they had missed the spawning migration in that year. In 1977, migration peaks were noted in mid-May and about June 5, although large numbers of immature goldeye (particularly female six-year olds) were captured (Kristensen, 1981).

Based on these studies, it is suggested that goldeye spawning migration occurs within a time period of six weeks after ice-free conditions on the Peace River. Migrations peaked one to three weeks after ice-free conditions at Peace Point and continued for one to three weeks. Therefore, the passage period was chosen to begin with the date of ice-free conditions at Peace Point and end 42 days later (Table 3.3).

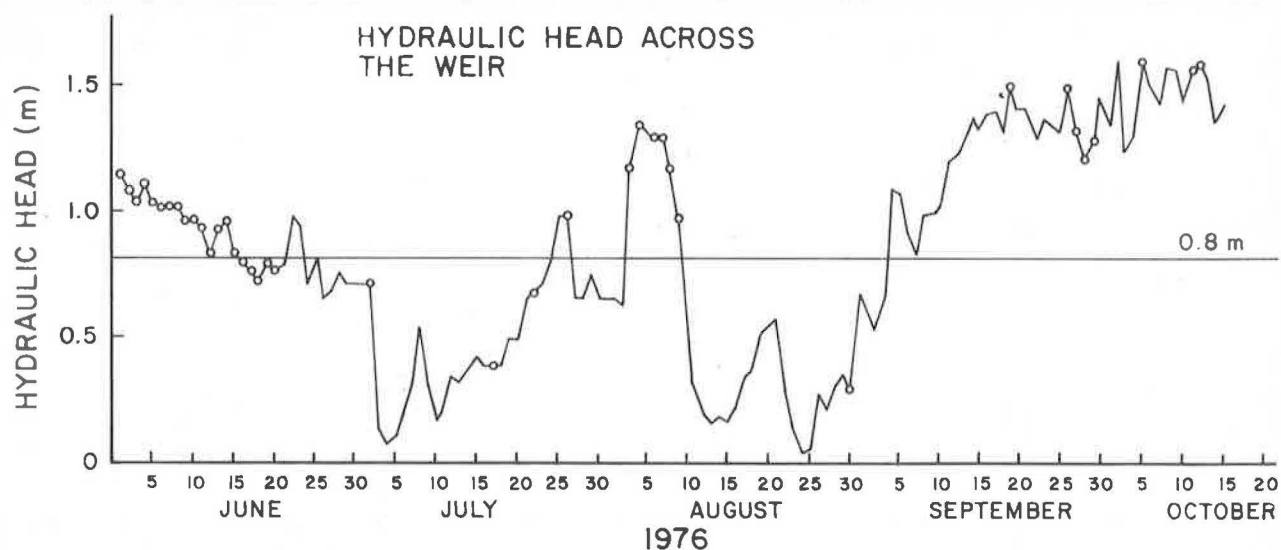
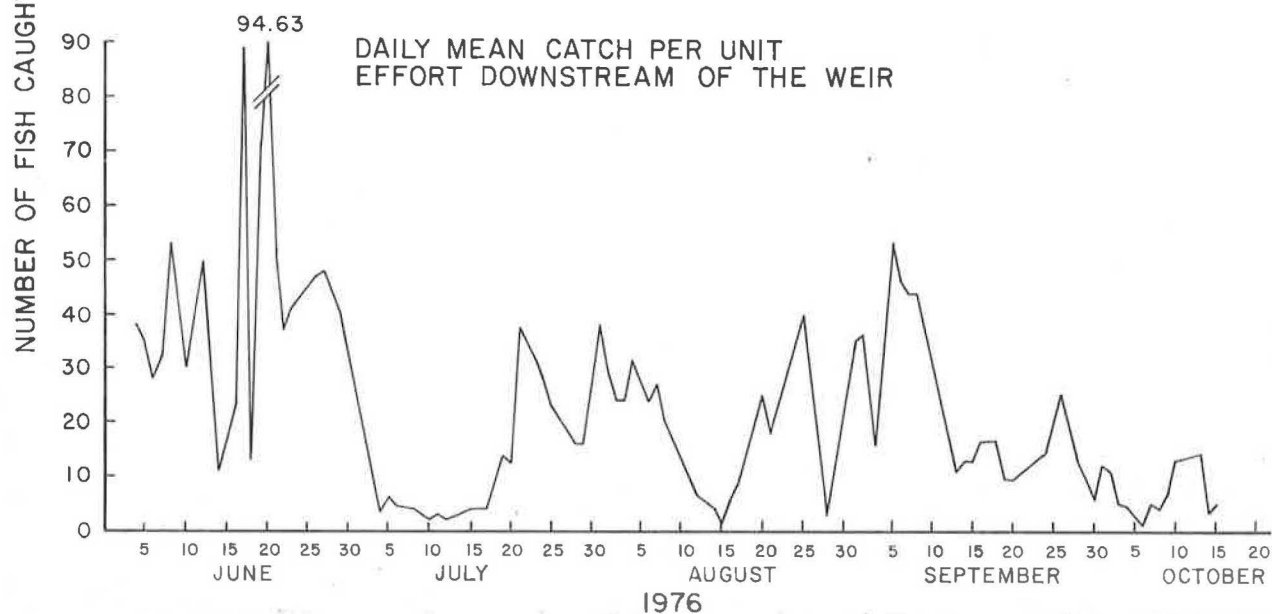
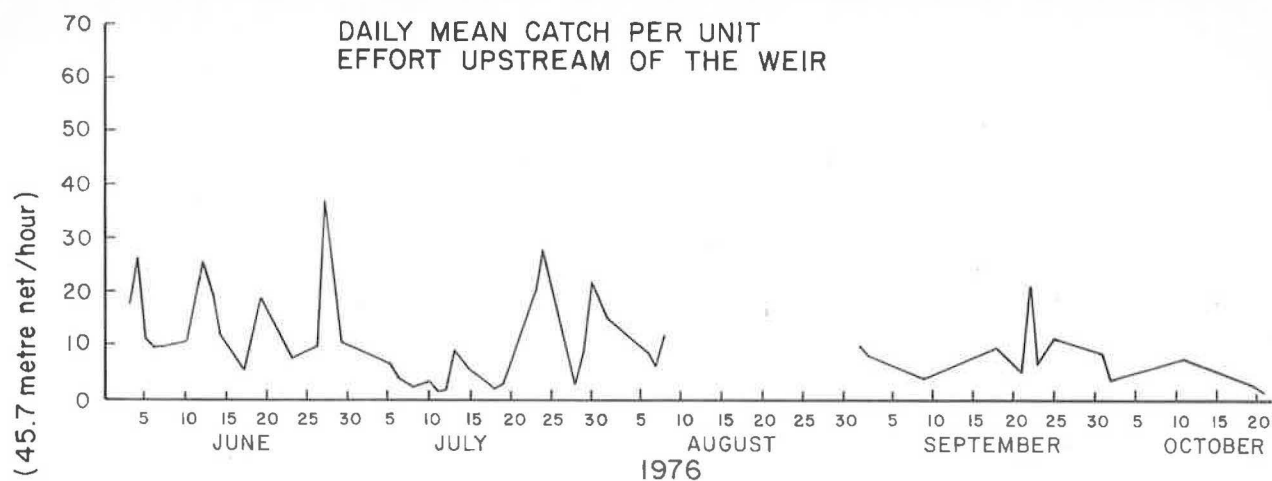


TABLE 3.3  
RECORDED AND ASSUMED MIGRATION PERIOD  
FOR ADULT GOLDEYE

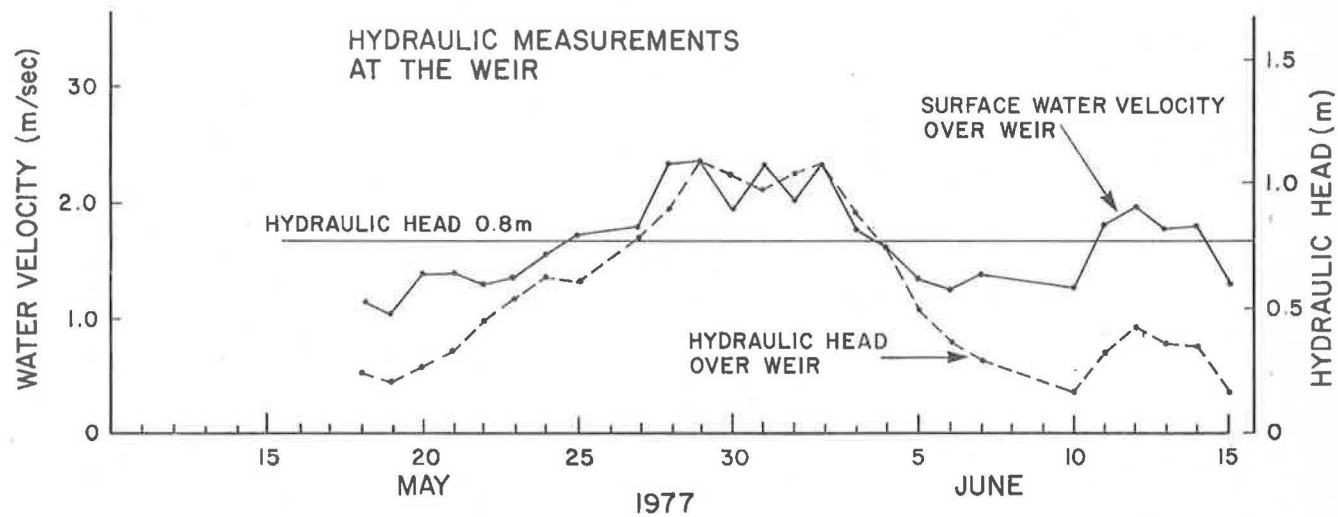
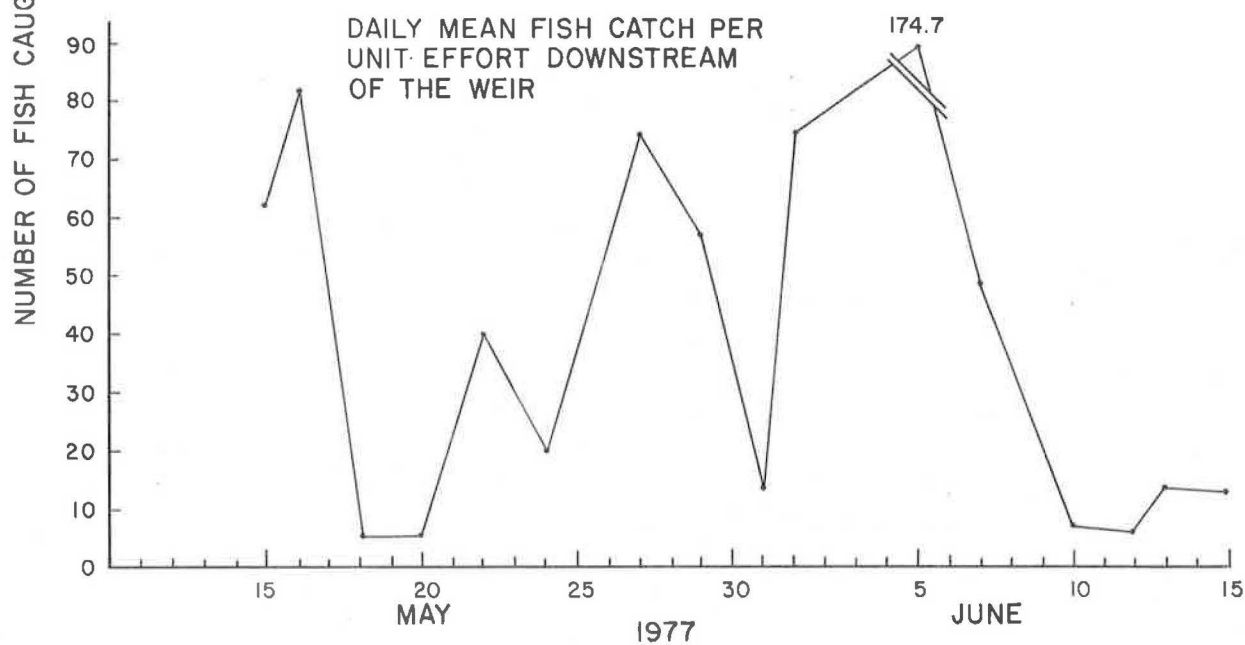
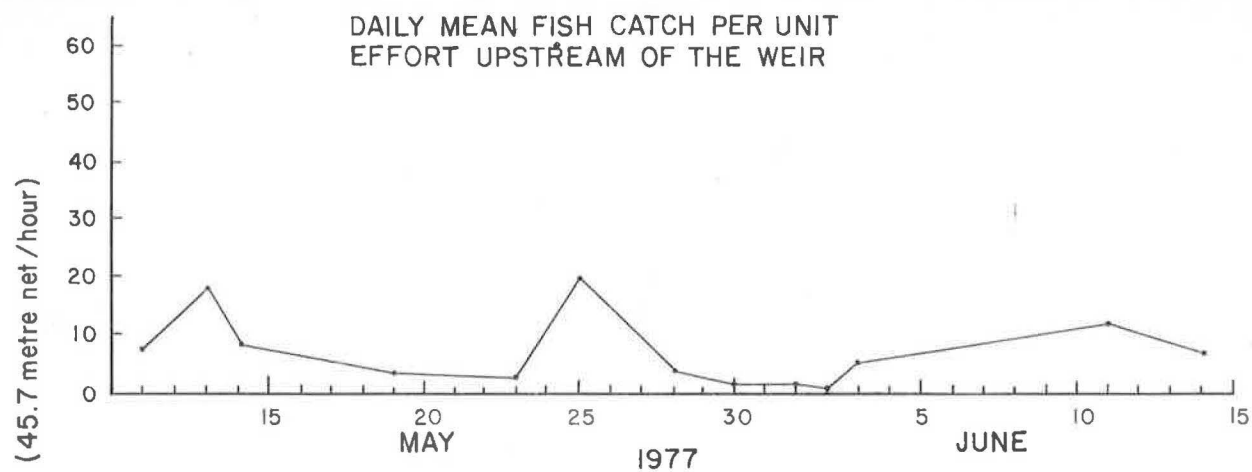
YEAR	RECORDED MIGRATION PERIOD			ASSUMED MIGRATION PERIOD	
	LOCATION	PEAK	END	BEGINNING <sup>a</sup>	END <sup>b</sup>
1960				May 09	June 18
1961				May 06	June 16
1962				May 10	June 20
1963				April 16	May 27
1964				May 10	June 20
1965				April 22	June 02
1966				May 09	June 19
1967				May 15	June 25
1968				May 03	June 13
1969				April 25	June 05
1970				May 06	June 16
1971	PR	May 12	May 20 <sup>1</sup>	April 30	June 10
1972	QF	May 21	May 26 <sup>2</sup>	May 17	June 27
1973	QF	May 11	May 26 <sup>2</sup>	May 05	June 15
1974	QF	May 11	May 26 <sup>2</sup>	May 06	June 16
1975	QF	May 14	May 26 <sup>2</sup>	May 05	June 15
1976	RRW;RCW;QF	May	June 3 <sup>3</sup>	April 28	June 08
1977	RRW;RCW;QF	May	June 7 <sup>4</sup>	April 27	June 07
1978				May 05	June 15
1979				May 15	June 25
1980	RRW;RCW	May	May 30 <sup>5</sup>	April 25	June 05
1981				May 09	June 19
1982				May 21	July 01
1983				May 12	June 22
1984				May 01	June 11

SOURCES: Kooyman (1972); Donald and Kooyman (1977a); Kristensen and Summers (1978); Kristensen (1981); Kristensen and Parkinson (1983); Water Survey of Canada (1960-84)

NOTES: PR = Prairie River; QF = Chenal des Quatre Fourches; RRW = Rivière des Rochers weir; RCW = Rivière Coupé weir; a = date of ice-free conditions on Peace River at Peace Point<sup>6</sup>; b = date 6 weeks later



FISH CATCH PER UNIT EFFORT AND HYDRAULIC HEAD AT THE RIVIÈRE des ROCHERS WEIR, JUNE - OCTOBER, 1976



FISH CATCH PER UNIT EFFORT AND HYDRAULIC MEASUREMENTS AT THE RIVIÈRE des ROCHERS WEIR, APRIL-JUNE, 1977

### 3.3.2 Relationship Between Hydraulic Head and Fish Passage

Field studies suggested that fish movements were hindered when the hydraulic head across the weirs was high (Kristensen and Summers, 1978; Kristensen, 1981). Because goldeye was by far the most common species captured, the catch rates shown in Figures 3.3 and 3.4 are essentially the same as those of goldeye.

The exact relationship between hydraulic head and the ability of fish to cross the Rivière des Rochers weir has not been documented. Based on fish caught above and below the Little Rapids weir, Kristensen and Summers (1978) and Kristensen (1981) suggested that the weir became impassable when the hydraulic head was 0.8 m (2.6 ft) or more (Figures 3.3 and 3.4). Although large scale movement through the fish bypass channel at the Rivière des Rochers weir occurred only when the hydraulic head was below 0.8 m (2.6 ft), little movement occurred during periods of high hydraulic head.

The fact that large numbers of fish were present downstream of the weir does not necessarily imply that all fish were obstructed. High numbers of fish did not always accumulate downstream of the weirs when the hydraulic head was high. Moreover, in a few instances, high numbers of fish were captured downstream of the weir when the hydraulic head was low. Kristensen (1981) suggested that some fish may prefer to remain in the large eddies downstream of the weirs, perhaps because of abundant food supplies there.



CODE	WSC GUAGE No.
QF	07NB001
E1	07NA001
E7	07NA007
E8	07NA008
EC	07M0001

HYDROMETRIC GAUGING STATIONS USED TO ESTIMATE  
HYDRAULIC HEAD AT THE RIVIÈRE des ROCHERS WEIR

### 3.3.3 Frequency Analysis of Hydraulic Head

The frequency analysis of hydraulic head at the Riviere des Rochers weir was based on recorded water level data. The results from the hydrodynamic model could not be used because there were large discrepancies between the hydraulic head computed from the simulated and from the recorded data (Alberta Environment and Environment Canada, 1985).

The hydraulic head over the Rivière des Rochers weir was estimated from Water Survey of Canada records in the delta area (Figure 3.5). Daily water levels from the hydrometric stations on either side of the weir were used to calculate the hydraulic head directly:

$$H_0 = E7 - E8 \quad (1)$$

where:

$H_0$  = hydraulic head (m) over the Rivière des Rochers weir

$E7$  = water level (m) recorded at Rivière des Rochers east of Rivière des Rochers weir site (07NA007)

$E8$  = water level (m) recorded at Rivière des Rochers west of Rivière des Rochers weir site (07NA008)

A complete record for a 42-day passage period over 9 years (1976-84) is 378 values for  $H_0$ . Using (1) only 82 values for  $H_0$  could be computed directly from recorded data. This represents 22% of a complete record. The record was completed through correlations between water levels recorded at different stations during the passage period. The following correlations were derived:

$$E7 = 1.034 E8 - 7.305 \quad (2) \\ (r = 0.985, N = 640, SE = 0.020 \text{ m})$$

$$E8 = 0.972 E1 + 5.827$$

$$(r = 0.999, N = 139, SE = 0.002 \text{ m}) \quad (3)$$

$$E1 = 660 + 0.040713QF^{0.52389}$$

$$(r = 0.999) \quad (4)$$

$$H_0 = 167.417 - 0.802 E1$$

$$(r = -0.983, N = 82, SE = 0.018 \text{ m}) \quad (5)$$

where:

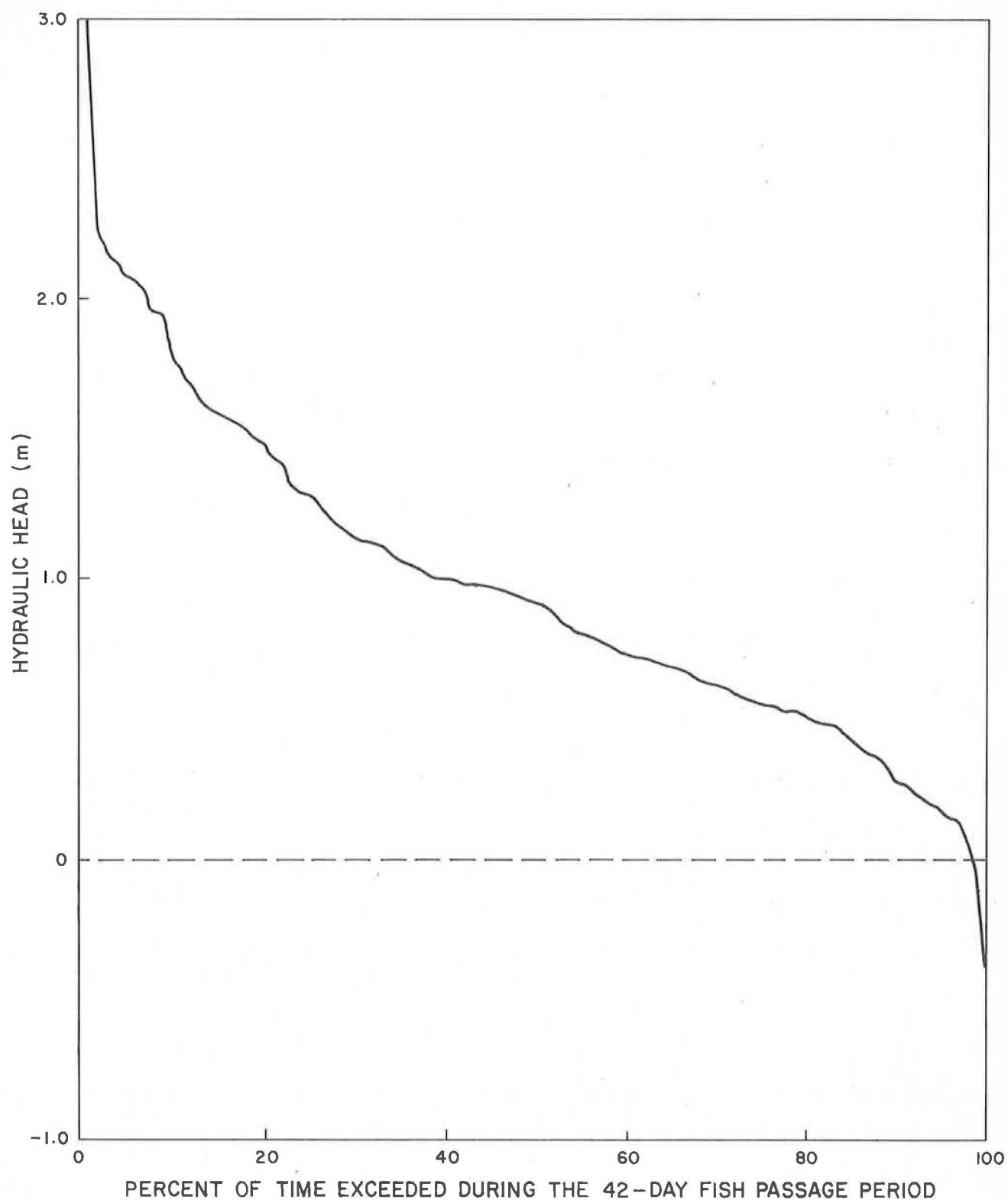
EC = water level (m) recorded at Lake Athabasca at Fort Chipewyan Water Survey of Canada gauge (07MD001)

E1 = water level (note: meters in equations 3 and 5; feet in equation 4) recorded at Rivière des Rochers above Slave River Water Survey of Canada gauge (07NA001)

QF = daily discharge (ft<sup>3</sup>/s) recorded a day later at Slave River at Fitzgerald Water Survey of Canada gauge (07NB001)

For the passage period, values for E7 were compiled using recorded water levels or estimates from (2). Except for four values in 1982, the record for E7 was completed. Similarly, values for E8 were compiled using recorded water levels estimates from (3) when E1 was available or from (4) and (3) when E1 was not available. Appendix A indicates which values of E7 or E8 were estimated (E) from the above correlations. Hydraulic head  $H_0$  was calculated from (1) and is listed in Appendix A.

A frequency analysis of daily hydraulic head was performed to provide the percent time that a given hydraulic head was exceeded during the 42-day passage period (Figure 3.6). Table 3.4 lists a range of hydraulic heads and the corresponding percent time that the head was not exceeded. In terms of fish passage, if the selected hydraulic head was not exceeded, the weir would be passable for fish.



FREQUENCY-DURATION CURVE FOR HYDRAULIC HEAD  
OVER THE RIVIÈRE des ROCHERS WEIR, APRIL-JUNE, 1976 - 84

FIGURE 3.6



TABLE 3.4  
FREQUENCY OF PASSABLE CONDITIONS AT RIVIÈRE DES ROCHERS WEIR  
FOR SELECTED HYDRAULIC HEADS AND SELECTED DELAY PERIODS

PASSABLE HYDRAULIC HEAD (m)	PERCENT TIME NOT EXCEEDED (i.e. PASSABLE)		
	NO DELAY <sup>a</sup>	THREE-DAY DELAY <sup>b</sup>	SEVEN-DAY DELAY <sup>b</sup>
1.5	81		
1.0	61	68	
0.9	49		
0.8	44	50	59
0.7	36		
0.6	28		
0.5	19	26	

<sup>a</sup> from Figure 3.6

<sup>b</sup> from Tables 3.5 and 3.6

TABLE 3.5  
FREQUENCY OF PASSABLE AND IMPASSABLE CONDITIONS AT RIVIÈRE DES ROCHERS WEIR  
WITH A HYDRAULIC HEAD OF 0.8 m OR LESS CONSIDERED PASSABLE<sup>a</sup>

YEAR	3-DAY DELAY														P	I
	CONSECUTIVE 3-DAY INTERVALS OVER THE 42-DAY PASSAGE PERIOD															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
1976	P	I	I	P	P	P	P	P	I	I	I	I	I	I	6	8
1977	P	P	I	I	I	P	P	P	P	P	I	I	P	P	9	5
1978	P	P	P	I	I	I	I	P	P	P	P	P	P	P	10	4
1979	I	P	P	P	P	P	P	P	P	P	P	P	P	P	13	1
1980	I	I	I	I	I	I	I	I	I	I	I	I	I	I	0	14
1981	P	P	P	P	P	P	P	P	P	P	P	P	I	I	12	2
1982	?	P	P	P	I	I	I	I	P	P	I	I	I	I	5	8
1983	I	I	I	I	I	I	I	I	I	I	I	I	I	I	0	14
1984	I	I	I	I	I	I	I	P	P	P	P	P	P	P	7	7
P/I	4/4	5/4	4/5	4/5	3/6	4/5	4/6	6/3	6/3	6/3	4/5	4/5	4/5	4/5	62	63
%P	50	56	44	44	33	44	44	67	67	67	44	44	44	44	50	50

YEAR	7-DAY DELAY							
	CONSECUTIVE WEEKS OVER THE 6-DAY PASSAGE PERIOD							
	1	2	3	4	5	6	P	I
1976	P	P	P	P	I	I	4	2
1977	P	I	P	P	P	P	5	1
1978	P	I	I	P	P	P	4	2
1979	P	P	P	P	P	P	6	0
1980	I	I	I	I	I	I	0	6
1981	P	P	P	P	P	P	6	0
1982	P	P	I	P	P	I	4	2
1983	I	I	I	I	I	I	0	6
1984	I	I	I	P	P	P	3	3
P/I	6/3	4/5	4/5	7/2	6/3	5/4	32	22
%P	67	44	44	78	67	56	69	41

Note: a = Values for hydraulic head were used from Appendix A  
 ? = Insufficient data  
 P = Passable conditions  
 I = Impassable conditions

TABLE 3.6  
FREQUENCY OF PASSABLE AND IMPASSABLE CONDITIONS AT RIVIÈRE DES ROCHERS WEIR  
WITH THREE-DAY DELAY<sup>a</sup>

YEAR	IF PASSABLE HYDRAULIC HEAD 1.0 m														P	I
	CONSECUTIVE 3-DAY INTERVALS OVER THE 42-DAY PASSAGE PERIOD															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
1976	P	P	P	P	P	P	P	P	P	P	I	P	P	P	13	1
1977	P	P	I	I	I	P	P	P	P	P	P	I	P	P	10	4
1978	P	P	P	I	I	I	I	P	P	P	P	P	P	P	10	4
1979	I	P	P	P	P	P	P	P	P	P	P	P	P	P	13	1
1980	P	I	I	I	I	I	I	I	I	I	I	I	I	I	1	13
1981	P	P	P	P	P	P	P	P	P	P	P	P	P	I	13	1
1982	?	P	P	P	P	I	I	I	P	P	P	P	I	I	8	5
1983	I	P	P	P	P	P	P	P	P	P	I	I	I	I	10	4
1984	I	I	I	I	I	I	I	P	P	P	P	P	P	P	7	7
P/I	6/2	7/2	6/3	5/4	5/4	5/4	5/4	7/2	8/1	8/1	6/3	6/3	6/3	5/4	85	40
%P	75	78	67	56	56	56	56	78	89	89	67	67	67	56	68	32

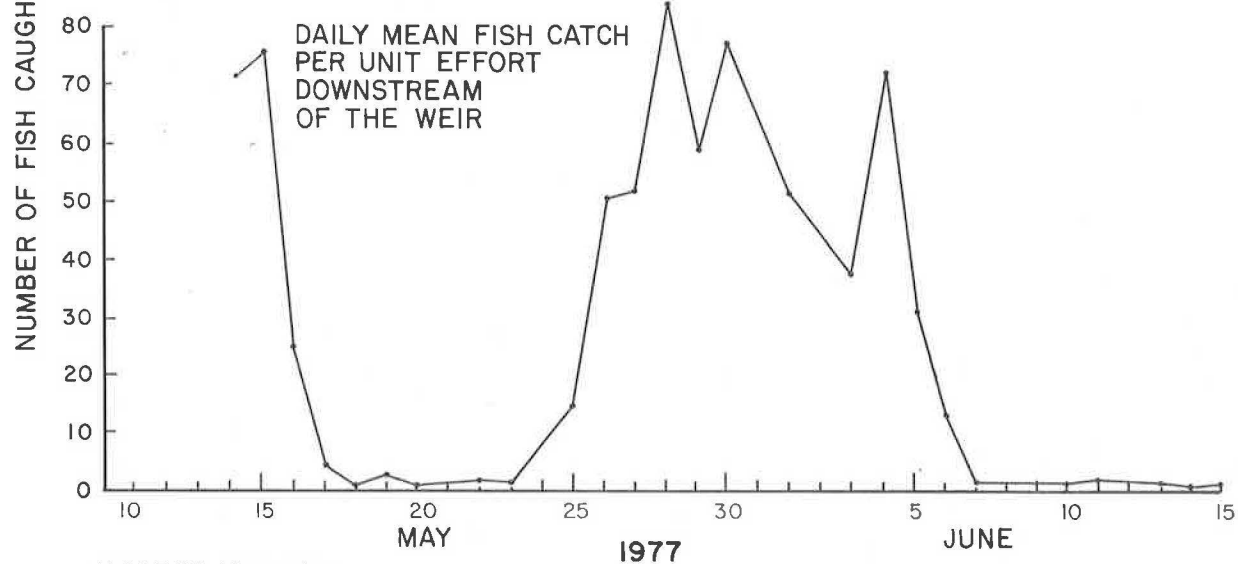
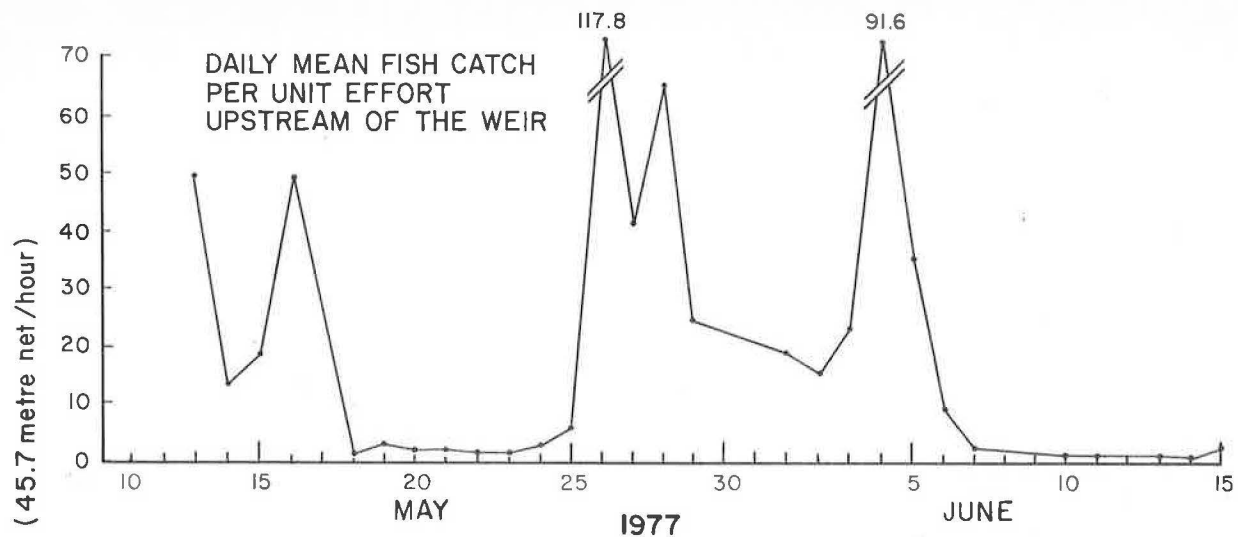
YEAR	IF PASSABLE HYDRAULIC HEAD 0.5 m														P	I
	CONSECUTIVE 3-DAY INTERVALS OVER THE 42-DAY PASSAGE PERIOD															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
1976	P	I	I	I	I	I	I	I	I	I	I	I	I	I	1	13
1977	P	I	I	I	I	P	P	P	P	I	I	I	I	P	6	8
1978	P	P	I	I	I	I	I	I	I	I	I	I	I	I	2	12
1979	I	P	P	P	P	P	P	P	P	P	P	P	P	P	13	1
1980	I	I	I	I	I	I	I	I	I	I	I	I	I	I	0	14
1981	P	I	I	I	I	I	P	I	P	I	I	I	I	I	3	11
1982	?	P	P	I	I	I	I	I	I	I	I	I	I	I	2	11
1983	I	I	I	I	I	I	I	I	I	I	I	I	I	I	0	14
1984	I	I	I	I	I	I	I	P	P	P	P	I	P	I	5	9
P/I	4/4	3/6	2/7	1/8	1/8	3/7	3/6	3/6	4/5	2/7	2/7	2/8	2/7	2/7	32	93
%P	50	33	22	11	11	22	33	33	44	22	22	11	22	22	26	74

Note: a = Values for hydraulic head were read from Appendix A  
 ? = Insufficient data  
 P = Passable conditions  
 I = Impassable conditions

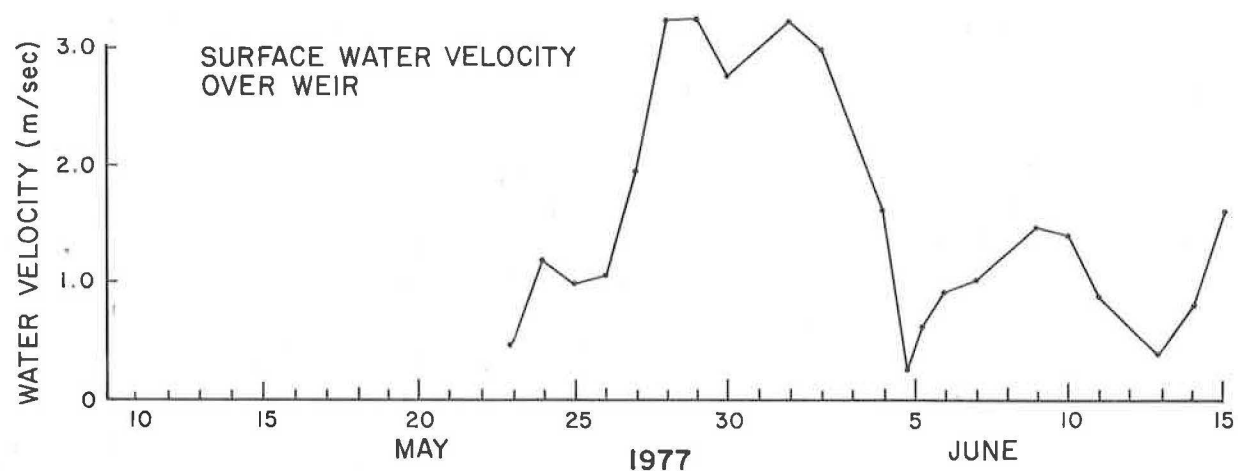
If a three-day delay is assumed to be tolerable to goldeye spawners, the 42-day passage period can be divided into 14 consecutive three-day intervals. Appendix A was used to calculate the three-day intervals during which  $H_0$  was higher than three selected hydraulic heads: 0.5 m (1.6 ft), 0.8 m (2.6 ft) and 1.0 m (3.3 ft). If the selected hydraulic head was not exceeded, the weir was assumed to be passable for fish. The results are summarized in Tables 3.5 and 3.6. It should be noted that the passable hydraulic head of 0.8 m (2.6 ft) was suggested for the Rivière des Rochers weir by Kristensen and Summers (1978) and Kristensen (1981).

The overall percent time that the weir was passable by goldeye was higher using the three-day intervals than one-day intervals and was higher still for the seven-day interval. The percent time that the weir was passable during each three-day and seven-day interval is detailed in Tables 3.5 and 3.6. It is worth noting that the highest percentages of time the weir was passable occurred in the 8th to 10th three-day intervals or three to four weeks after ice-free conditions on the Peace River. The peak and end of goldeye spawning migration usually occurs during this time (Table 3.3). If critical hydraulic head of 0.8 m is assumed, Table 3.5 shows that goldeye would have been unable to negotiate the weirs in 1980 and 1983. They would have been able to negotiate the weirs in the remaining years during parts of the migration period.

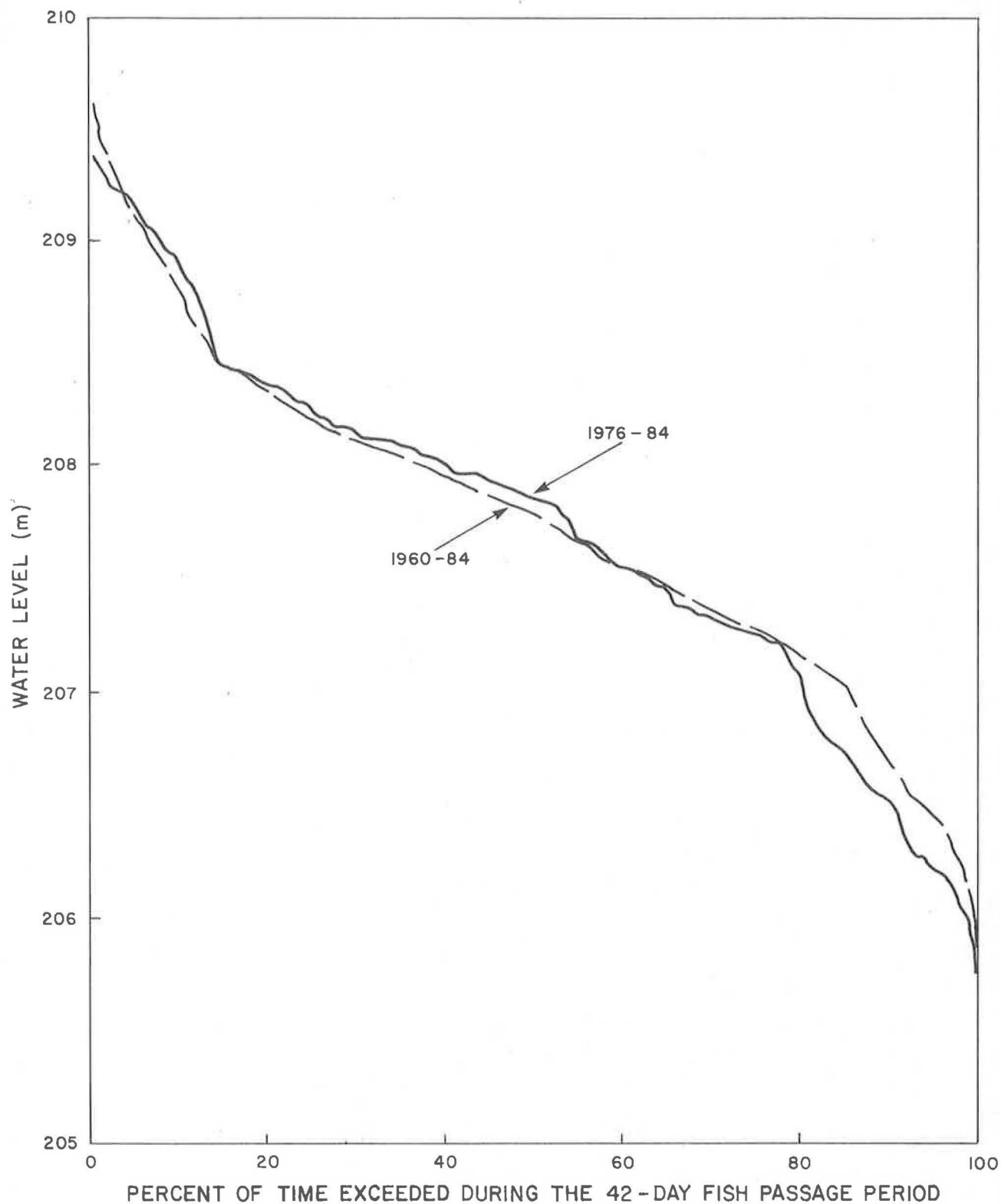
A hydraulic head frequency analysis, similar to the one conducted for the Rivière des Rochers weir, could not be carried out at the



CURRENT DIRECTION



FISH CATCH PER UNIT EFFORT AND HYDRAULIC  
MEASUREMENTS AT THE REVILLON COUPÉ WEIR,  
MAY AND JUNE, 1977



WATER LEVEL FREQUENCY-DURATION CURVES  
FOR RIVIÈRE des ROCHERS ABOVE SLAVE RIVER,  
APRIL-JUNE, 1960-84 AND 1976-84

Revillon Coupe' weir, because water level data are lacking during the fish migration period. Field studies suggest that the Revillon Coupe' weir hinders fish migrations to a much lesser extent than the Rivière des Rochers weir (Kristensen, 1981) (Figure 3.7). Based on recorded water levels by Alberta Environment at Rivière des Rochers and Revillon Coupe' weirs during the open-water period the hydraulic head at Revillon Coupe' weir is on average 0.47 m (1.5 ft) lower than the corresponding head at Rivière des Rochers weir.

Water level frequency-duration curves at E1 for the assumed 42-day fish passage period were derived to compare the post-weir period (1976-84) with a longer period of record (1960-1984) (Figure 3.8). Both duration curves were based on recorded water levels for 1976-84, with missing data estimated as described in Section 3.2.2.3. The duration curve for 1960 to 1984 was based on simulated water levels from the one-dimensional hydrodynamic model for 1960-75 (Bennett Dam with weirs scenario; Alberta Environment and Environment Canada, 1985b). The curves for the two time periods match closely, particularly for water levels higher than 207.0 m (679 ft). This corresponds to hydraulic heads at the weir of less than 1.4 m (4.6 ft) which are of interest for fish passage (equation 5). Therefore, it is suggested that the conclusions regarding fish passage are representative of the longer term situations.

#### 3.4 Wildlife Simulation Model

The Wildlife Simulation Model was used to assess how different

water level regimes could affect long-term changes in the vegetation communities and wildlife populations of the Peace-Athabasca Delta. The model was developed during the PADP study (Townsend, 1972b). For the purposes of this report, it was run using the simulated water levels from the hydrodynamic model (Section 3.1) as input (Alberta Environment and Environment Canada, 1985b). The results of the modelling exercise provide an estimate of the long-term effectiveness of the Rivière des Rochers and Revillon Coupe'weirs.

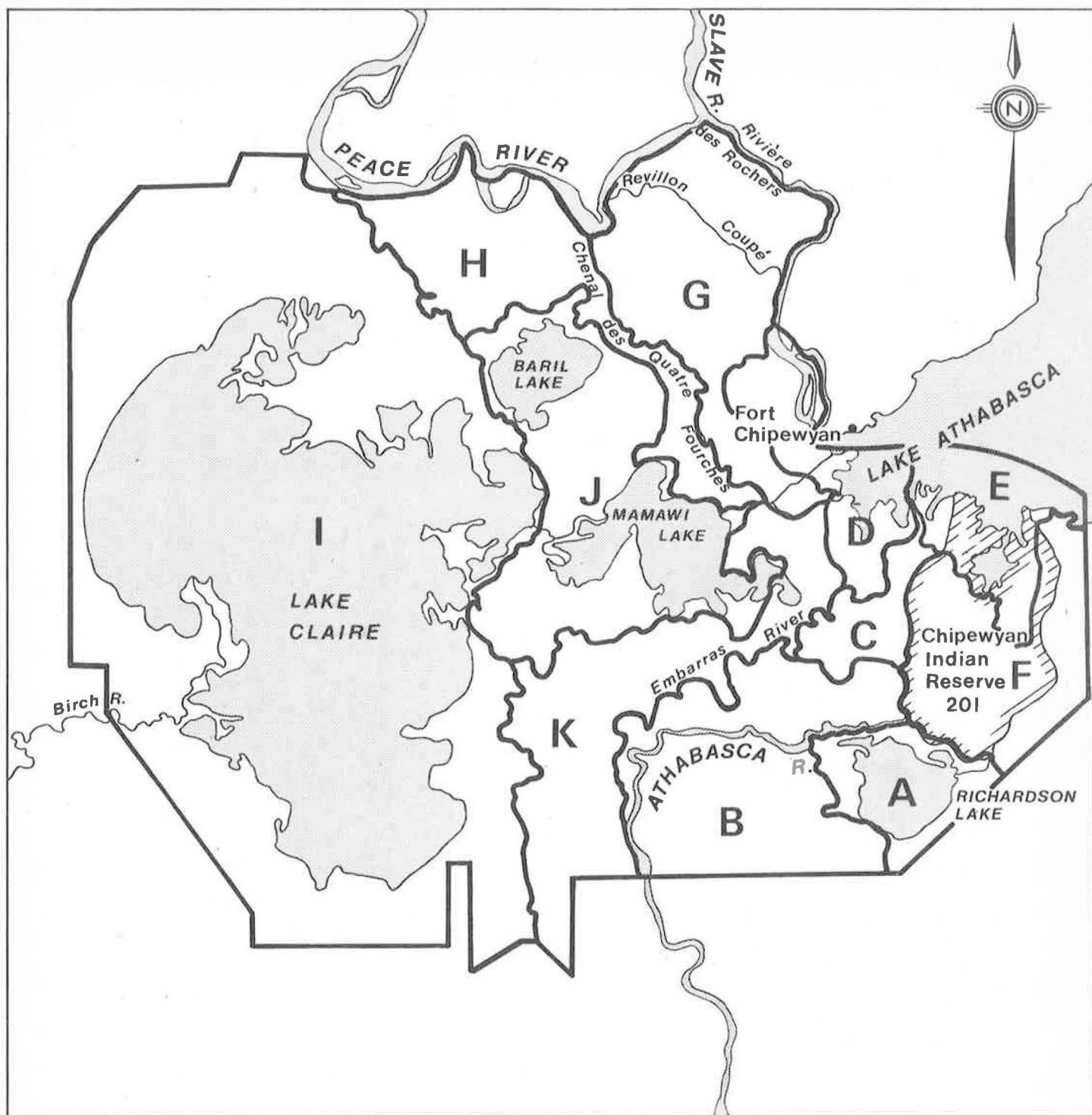
#### 3.4.1 General Description of the Model

The Wildlife Simulation Model was developed to translate effects of water level fluctuations on the Peace-Athabasca Delta into wildlife habitat and population changes. A detailed description of the model can be found in Townsend (1972b).

Acreages and shore lengths of 11 major vegetation types (Section 2.1, Table 2.1) were mapped using measurements from 1970 aerial photographs and 1970-71 engineering surveys as the data base. The starting populations of muskrats and optimum densities of waterfowl were derived from population censuses conducted for the PADP Group (1973).

The computer model was designed to accept water levels for five time periods for each year simulated. "Rules of change" were built into the model to simulate effects of Lake Athabasca water level fluctuations on water levels in both the open drainage basins and perched basins of the delta and the resultant increases or decreases in vegetation types, wildlife habitats and wildlife populations.





GEOGRAPHICAL SUBDIVISIONS OF THE PEACE-ATHABASCA DELTA  
USED FOR THE WILDLIFE SIMULATION MODEL

The computer program was designed to compute the acres of each habitat type, total miles of perched basin shoreline, wildlife numbers and wildlife carrying capacities for each year simulated and tabulate average values for the entire simulated period.

#### 3.4.2 Major Assumptions of the Model

The Peace-Athabasca Delta is an extremely complex ecological area. Therefore, a number of assumptions were used to develop the Wildlife Simulation Model. These are described in Townsend 1972b and summarized below.

##### 3.4.2.1 Geographical Subdivisions

The delta was divided into ten subdivisions (Figure 3.9). A solution was executed for each subdivision as a single unit and these were summed to compute a solution for the entire delta.

##### 3.4.2.2 Time Periods

The five time periods for water level input were based on the seasonal activities of wildlife and the vegetation growing seasons. The five time periods used for all model runs were 1 = May, 2 = June, 3 = July 1 to August 14, 4 = August 15 to October 14, and 5 = October 15 to April 30.

##### 3.4.2.3 Open Water and Perched Basin Water Level Fluctuations

The available topographical data were used to construct a mathematical contour map of the delta. The total acreage of each subdivision was allocated to either open drainage or perched basins. The model allowed each subdivision to have between 5 and 7 perched basins. Thus, at least 50 perched basins were modelled for the entire delta.

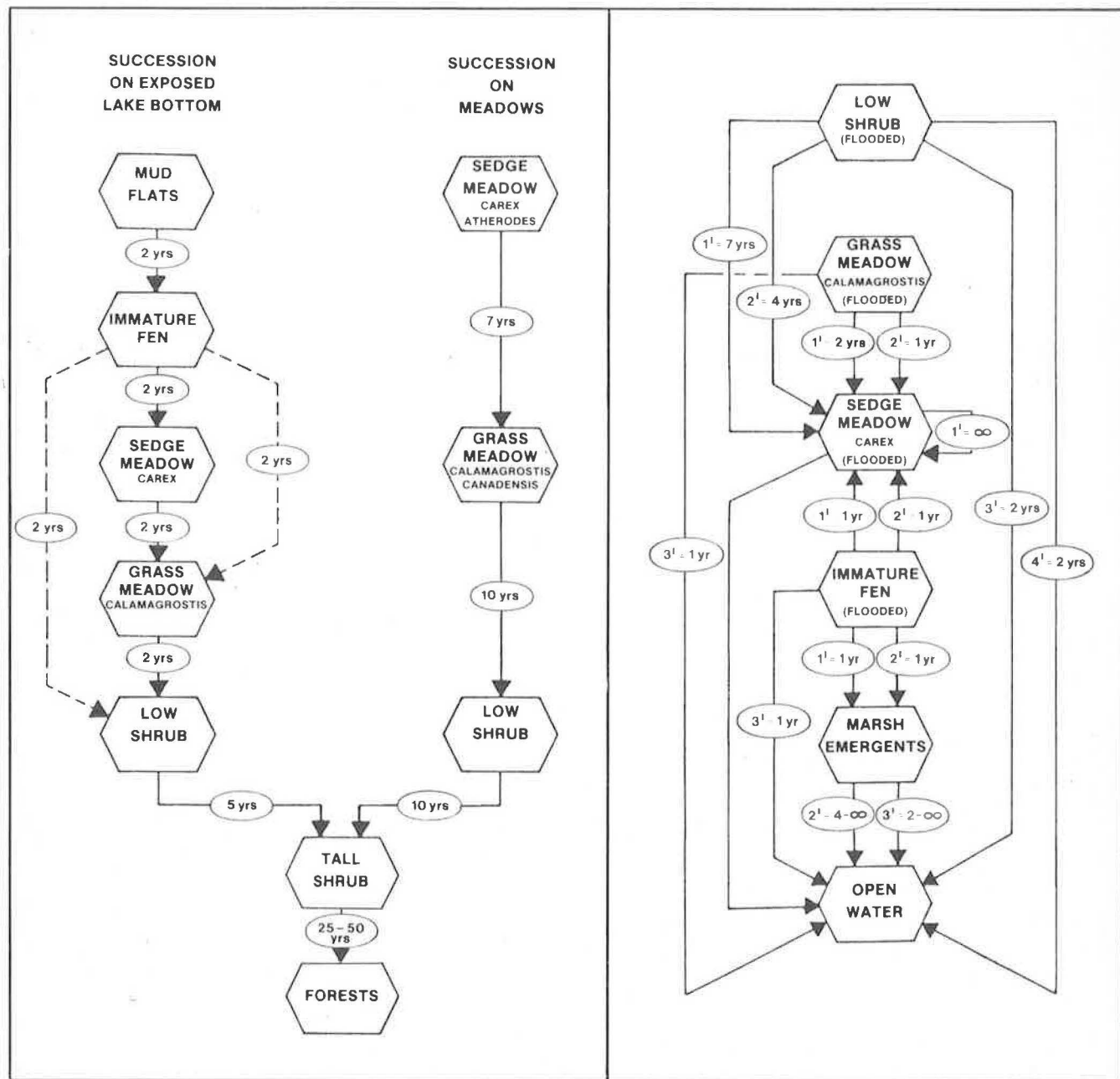
The Lake Athabasca levels entered for each simulated year were adjusted by a constant for each subdivision to account for the slope of the delta. These constants, in feet, for each subdivision were as follows: A = 3.2, B = 4.6, C = 1.7, D = E = 0.0, F = 1.9, G = H = IJ = 0.0, K = 3.2. The converted levels became the open drainage water levels for the subdivision.

Each perched basin in the model was assigned a defined "spill" elevation, "full" elevation, and "basin bottom" elevation. If the open drainage water level exceeded the "spill" elevation, the perched basin was assumed to be flooded to the open drainage water level. During a later time period, if the open drainage water level became less than the perched basin "spill" level, the perched basin level was lowered to the defined "full" level. Subsequent years of "no flooding" caused the water level in the perched basin to decline by a constant percentage of acres flooded and basin shore lengths: A = 8%, B = 7%, C = D = E = 12%, F = 10%, G = H = 7%, IJ = 12%, K = 7%. These losses represented evaporation and seepage.

Within each time period, water levels were considered to fluctuate within the open drainage basin according to the values read into the model. There were no water level fluctuations in perched basins unless the basin was flooded within the time period, because fluctuations in small perched basins were considered to be negligible for ecological purposes.

#### 3.4.2.4 Vegetation Succession Rules of Change

Following the initial allocation of vegetation types to contour



Conditions of declining water levels.

Conditions of prolonged flooding.

SUCCESSTION TRENDS USED BY THE WILDLIFE SIMULATION MODEL

FIGURE 3.10

levels, the vegetation succession rules of change were used to calculate the vegetation types present on each contour of open drainage and perched basin of for each subdivision. Plant succession was advanced, retarded or remained the same depending on the water levels during time periods 2 and 3. The vegetation succession rules, illustrated in Figure 3-10, represent, in a much simplified way, the extremely complex ecological processes of the Peace-Athabasca Delta.

#### 3.4.2.5 Waterfowl Production and Staging Rules of Change

Waterfowl production was simulated as a function of shoreline habitat available during time period 1 and water level fluctuations occurring during time periods 1 and 2. Optimum production per mile of shoreline vegetation type for dabblers and divers was defined as follows:

<u>Shoreline Type</u>	<u>Dabblers</u>	<u>Divers</u>
Mudflats	24.9	0.0
Immature fen	27.9	8.3
Meadow	48.9	19.3
Low Shrub	27.9	31.9
Tall Shrub	36.0	42.4
Deciduous	16.8	38.5
Coniferous	9.9	34.1
Rock Outcrop	2.7	0.0

Increasing water levels during nesting were assumed to affect optimum survival values as follows: less than 0.5 foot = 100%, 0.5-0.9 foot = 75%, 1.0-1.9 feet = 50%, greater than 1.9 feet = 0%.

Decreasing water levels were assumed to have the following effect on survival: less than 1.0 foot = 100%, greater than 1.0 foot = 75%.

Waterfowl fall staging habitat was simulated by summing the number of acres of mudflat and first-year immature fen available during period 4.

#### 3.4.2.6 Muskrat Population Rules of Change

Starting numbers for muskrat populations were defined for each subdivision of the delta based on 1971 population surveys and estimates: A = 1000, B = 9200, C = 1500, D = 400, E = 200, F = 15000, G = 2300, H = 1800, IJ = 1700, K = 3200. The sex ratio was assumed to be 1 to 1.

Optimum muskrat production from spring to fall was assumed to be 14 young per female. Rising water levels during time periods 1, 2, and 3 were assumed to reduce optimum production by the following percentages: less than 1 foot = 0%, 1 foot = 7.5%, 2 feet = 15%, 3 feet = 30%, +4 feet = 50%. Spring and summer mortality of adults was assumed to be 5% and was taken just prior to the breeding season. The fall population size was calculated as adults plus young. The survival of muskrat population over the winter was determined by the depth of flooding of emergent vegetation. Muskrats were assumed to have a maximum density of 10 per acre of emergents, with deepest emergents being allocated first, and shallowest last. The percentage surviving the winter (time period 5) was assumed to vary with water depth as follows: less than 0.6 feet = 0%, 0.6-1.0 feet = 30%, 1 foot = 40%, 2 feet = 50%, +3 feet = 70%. Spring trapping was assumed to take 50%

of the population surviving the winter.

### 3.4.3 Major Assumptions Used for the Model Runs

#### 3.4.3.1 Water Management Scenarios Modelled

The hydrodynamic model was used to simulate three water management scenarios for the Peace-Athabasca Delta: natural regime, regulated Bennett Dam regime, and the regulated regime in combination with the Rivière des Rochers and Revillon Coupe' weirs (Section 3.1). The water level outputs from these three scenarios were input to the Wildlife Simulation Model to allow the same scenarios to be modelled.

#### 3.4.3.2 Time Sequences

The daily water levels simulated by the hydrodynamic model for the period 1960-1984 provided the water level input from the Wildlife Simulation Model. Thus, it was assumed that past water levels represented water levels that could reasonably be expected to occur in the future. This does not imply that past sequences of water level fluctuations will be faithfully repeated; however, it assumes that they form one plausible set of conditions that could occur. The Wildlife Simulation Model required every water level in a set to be exactly defined and the output of the hydrodynamic model satisfied that requirement.

Different sequences of the same water level data were found to provide different results from the Wildlife Simulation Model, because the ecological parameters were serially related to water level events spanning more than one year. Thus, two sequences of water level data were assembled for input to the model. The Delta 1 sequence comprised

the string of water levels from 1960 through 1984, repeated twice, to provide input for a 50-year run. The Delta 2 sequence began the series with 1971, continued through 1984, was followed by 1960 through 1984, and then repeated 1960 through 1970, to also provide a 50-year run.

#### 3.4.3.3 Water Level Input

The hydrodynamic model was developed to simulate water levels for Lake Athabasca and the major lakes of the Peace-Athabasca Delta. The Wildlife Simulation Model which was developed earlier accepts only Lake Athabasca levels, adjusting these where necessary by a constant to provide the open drainage basin levels for each of the ten subdivisions of the delta. To take advantage of the available simulated Lake Claire levels, the Wildlife Simulation Model was run using these levels for subdivisions H and IJ, representing the Claire-Mamawi area. The results of the Lake Claire Simulation for Subdivision H and IJ were manually combined with the simulation using Lake Athabasca levels for the rest of the delta. Lake Athabasca water levels from reach 150, and Lake Claire levels from reach 550 were used (Alberta Environment and Environment Canada, 1985a, b)

The daily levels were averaged for each ecological time period, and the maximum and minimum levels for each period were expressed as departures from the mean. These data were input to the Wildlife Simulation Model. The departure values represented water level fluctuations within each time period. The use of each pair of values for each time period in every year differed from the approach taken for earlier runs where average fluctuations for each time period were



TABLE 3.7  
RESULTS OF THE WILDLIFE SIMULATION MODEL DELTA 1 TIME SEQUENCE  
USING LAKE CLAIRE LEVELS FOR SUBDIVISIONS H and IJ  
AND LAKE ATHABASCA LEVELS FOR REMAINING SUBDIVISIONS

	AVERAGE ANNUAL PRODUCTION	AVERAGE ANNUAL DEVIATION FROM SIMULATED NATURAL REGIME	
	<u>SIMULATED NATURAL</u>	<u>SIMULATED WEIRS</u>	<u>SIMULATED BENNETT DAM</u>
<u>Habitat Acres</u>			
Open Water	547,350	+ 2%	-15%
Productive Habitats <sup>a</sup>	335,514	-11%	-10%
Shrubs and Forests	591,387	+ 4%	+20%
Fall Waterfowl Staging Habitat	43,045	-38%	-17%
<u>Shoreline Miles</u>			
Perched Basin	5,824	-17%	-41%
<u>Animal Numbers</u>			
Dabblers	210,632	- 1%	-23%
Divers	91,827	+ 6%	- 6%
Ducks	302,461	+ 1%	-17%
Muskrats (spring)	20,485	- 8%	-26%
Muskrats (fall)	67,011	0	-18%
Carrying Capacity Muskrats	67,372	- 1%	-15%

Note: a = Emergents, mudflat, immature fen and meadows, all  
of which are early successional habitat types.

TABLE 3.8  
RESULTS OF THE WILDLIFE SIMULATION MODEL DELTA 2 TIME SEQUENCE  
USING LAKE CLAIRE LEVELS FOR SUBDIVISIONS H and IJ  
AND LAKE ATHABASCA LEVELS FOR REMAINING SUBDIVISIONS

	AVERAGE ANNUAL PRODUCTION	AVERAGE ANNUAL DEVIATION FROM SIMULATED NATURAL REGIME	
	<u>SIMULATED NATURAL</u>	<u>SIMULATED WEIRS</u>	<u>SIMULATED BENNETT DAM</u>
<u>Habitat Acres</u>			
Open Water	558,157	+ 1%	-16%
Productive Habitats <sup>a</sup>	324,122	-10%	- 8%
Shrubs and Forests	591,972	+ 4%	+20%
Fall Waterfowl Staging Habitat	42,898	-39%	-18%
<u>Shoreline Miles</u>			
Perched Basin	5,719	--17%	-41%
<u>Animal Numbers</u>			
Dabblers	207,629	-- 2%	--21%
Divers	91,044	+ 7%	- 7%
Ducks	298,672	+ 1%	-17%
Muskrats (spring)	10,852	-19%	+18%
Muskrats (fall)	36,214	-13%	+27%
Carrying Capacity Muskrats	56,436	0	- 8%

Note: a = Emergents, mudflat, immature fen and meadows, all of which are early successional habitat types.

calculated by summing the respective values from all years and dividing by the number of years (Townsend, 1972b).

#### 3.4.4 Results and Discussion

The results of the Wildlife Simulation Model runs, using Lake Claire levels for subdivisions H and IJ and Lake Athabasca levels for the other eight subdivisions were summarized as deviations from the simulated natural conditions. The results using the Delta 1 time sequences for water level input are presented in Table 3.7 and using the Delta 2 sequences in Table 3.8. With the exception of muskrat populations, there was little difference in the results of the Delta 1 and Delta 2 sequences. Therefore, the following discussion is based primarily on the Delta 1 simulation runs. It should be emphasized that the model was used to predict long-term trends. The results do not reflect present conditions in the delta.

The following long-term trends in vegetation types were predicted by the Wildlife Simulation Model:

- Open water areas under the simulated weir regime would increase slightly (+2%) over the natural condition. This is in contrast to the 15% decrease that would occur under the simulated Bennett Dam regime.
- Productive habitats would decrease by the same magnitude for both scenarios (simulated weir regime - 11%, simulated Bennett Dam regime - 10%)
- Shrub and forest communities would increase 4% over the natural conditions under the simulated weir regime, whereas

the increase would be 20% under the simulated Bennett Dam regime.

Although productive habitats were predicted to decrease by the same amount for both scenarios, the causes would be different. Under the simulated weir regime, the loss would be caused by reduced annual water level fluctuations; whereas under the simulated Bennett Dam regime, it would be caused by an increase in shrub and forest communities and a loss of open water.

The Wildlife Simulation Model predicted that there would be a long-term decrease in available fall waterfowl staging habitat under the simulated Bennett Dam regime (17% less than the simulated natural condition). However, fall staging was predicted to decrease even more under the simulated weir regime. This is because the weirs would cause fall water levels to decrease more slowly than under either the natural or Bennett Dam regimes, leaving less available staging habitat.

Although the length of perched basin shoreline would be less under the simulated weir regime than the natural regime (-17%), there would be considerably more than under the simulated Bennett Dam regime (41% less than the simulated natural regime). This implies that the wildlife habitat for these species that inhabit the perched basins would be considerably better under the simulated weir regime than under the simulated Bennett Dam regime.

Waterfowl production estimates for the simulated weir regime approximate natural conditions, and would be substantially better than the simulated Bennett Dam regime. This reflects the greater length of

perched shoreline caused by the weirs and reduced fluctuation in water levels during the nesting season caused by the Bennett Dam. It should be noted that this reflects available habitat only and does not take into account external influences on waterfowl numbers.

Muskrat production would be higher for the simulated weir regime than for the simulated Bennett Dam regime. This was partly a result of the relative length of perched basin shoreline miles for the two regimes and the higher overwinter water levels on the main lakes which continue to prevent winter freeze-out. The Delta 2 sequence resulted in a much lower muskrat population than the Delta 1 sequence. It is suggested that muskrat production for the simulated natural regime may have been underestimated, particularly for the Delta 2 sequences, because topographic information describing overflow characteristics along the major river levels is lacking. This type of flooding is suspected to play an important role in the natural regime particularly of the perched basins.

## 4.0 DISCUSSION

### 4.1 Water Levels in the Peace-Athabasca Delta

Water levels in the Peace-Athabasca Delta have been below the long-term average since 1976, when the Rivière des Rochers and Revillon Coupe' weirs were completed. An analysis of water yields from the major rivers contributing to the delta showed that for the past 10 years flows in the three major contributory basins have been somewhat below those recorded prior to weir construction (Table 4.1). Moreover, since 1980, the three basins have yielded 10% less water than in the period between 1960 and 1979. This must be considered when examining short-term biological changes on the delta.

The results of the hydrodynamic model simulations for lakes Athabasca, Claire and Mamawi for the natural regime, the regulated regime, and the existing regulated regime with weirs are provided in Figure 4.1. The hydrographs indicate that Bennett Dam regulation without the weirs results in significantly lower summer peak levels than would occur under the natural regime, but low levels experienced in the late winter are approximately the same. The hydrographs show that although the weirs significantly restore the summer peak levels in the delta, winter levels are increased thereby producing a lower amplitude between the summer peaks and the winter lows in comparison to the natural regime. This effect was predicted by the PADP Group in 1973.

The summer peak levels simulated for Lake Claire, with weirs in

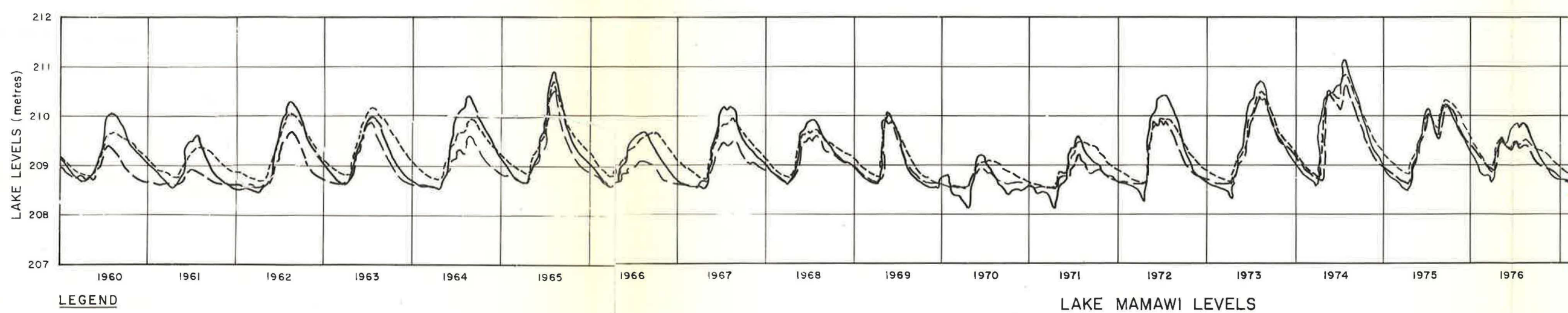
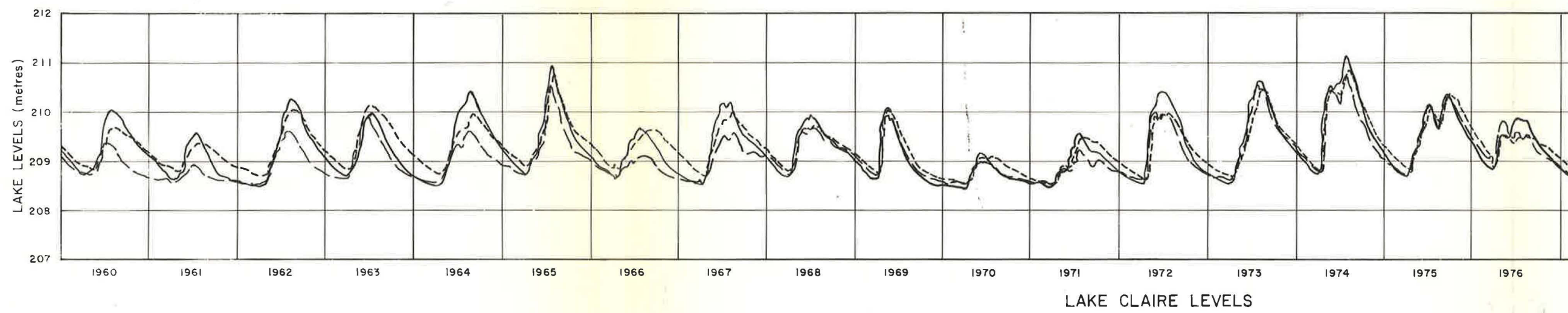
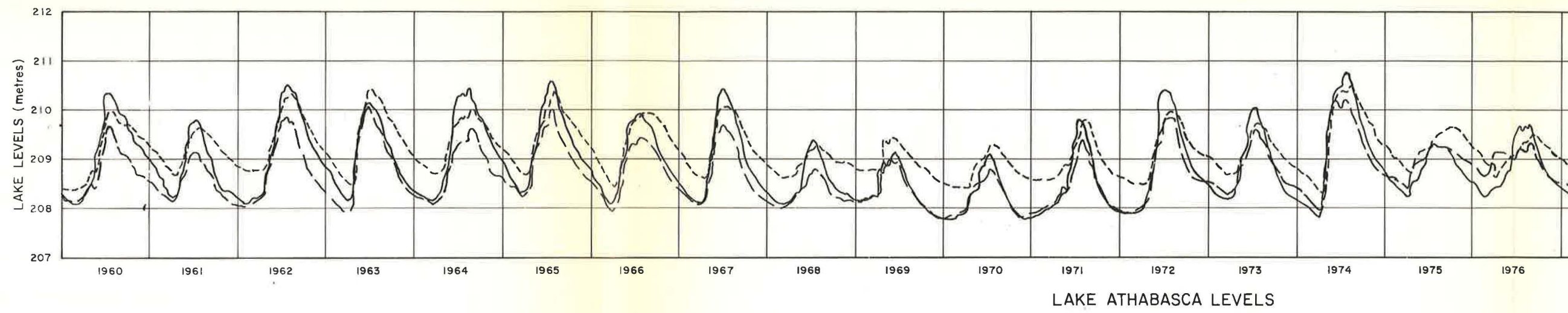
TABLE 4.1  
MEAN ANNUAL DISCHARGES RECORDED IN THE  
CONTRIBUTORY BASINS  
1976 - 1985 (m<sup>3</sup>/s)

YEAR	PEACE <sup>a</sup>	ATHABASCA	FOND DU LAC
1960 -- 75	2281	699	283
1976 -- 85	<u>2001</u>	<u>658</u>	<u>279</u>
Difference (%)	-12%	-6%	-2%
1960 -- 1979	2260	698	299
1980 - 1985	<u>1800</u>	<u>602</u>	<u>276</u>
Difference (%)	-20%	-14%	-8%

Note: a = Discharge data for the Peace River do not include 1968 - 71,  
when the Williston Reservoir was being filled.

Source: Inland Waters Directorate 1985ca, cb, G. Morton, personal  
communication





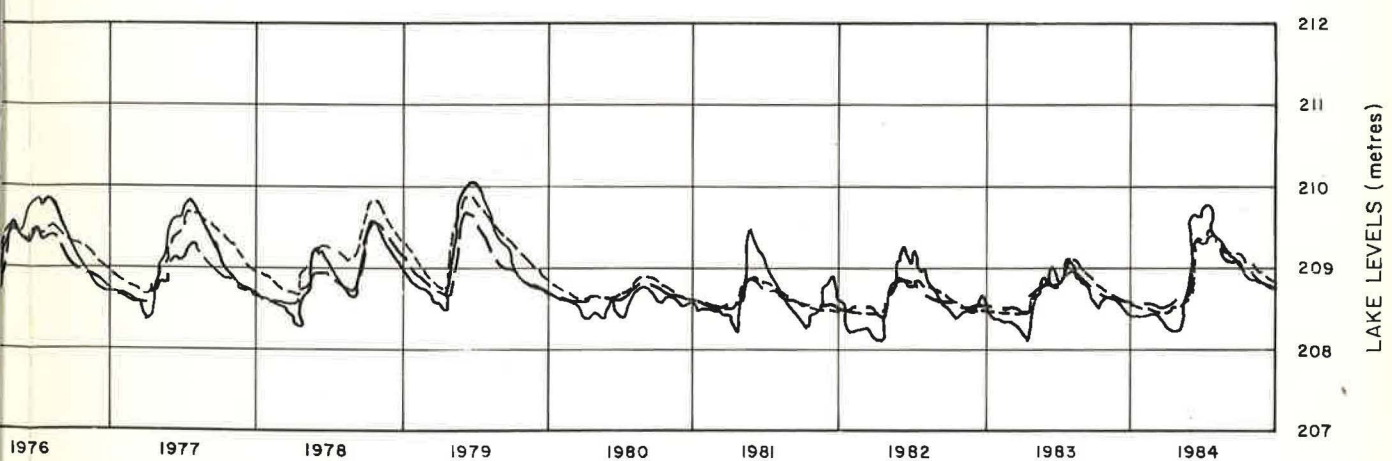
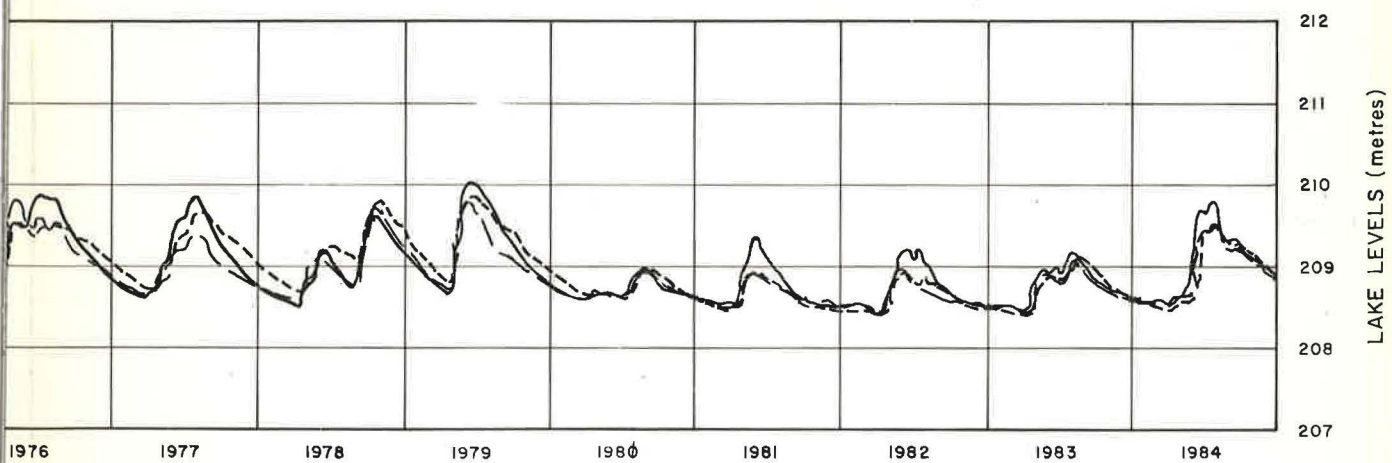
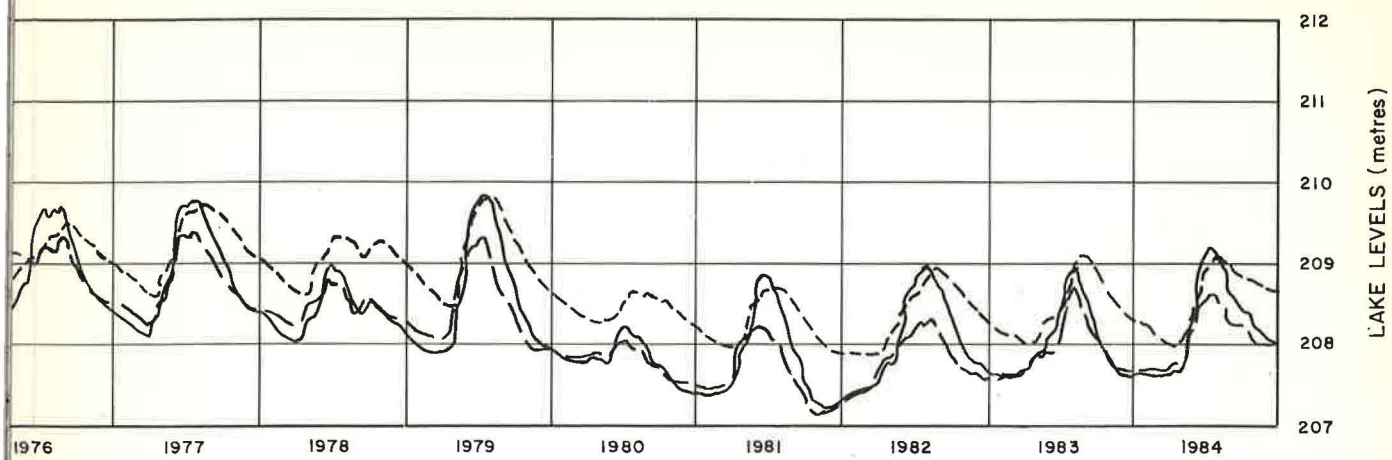
**LEGEND**

— NATURAL

- - - BENNETT DAM, NO WEIRS

- . - BENNETT DAM WITH WEIRS





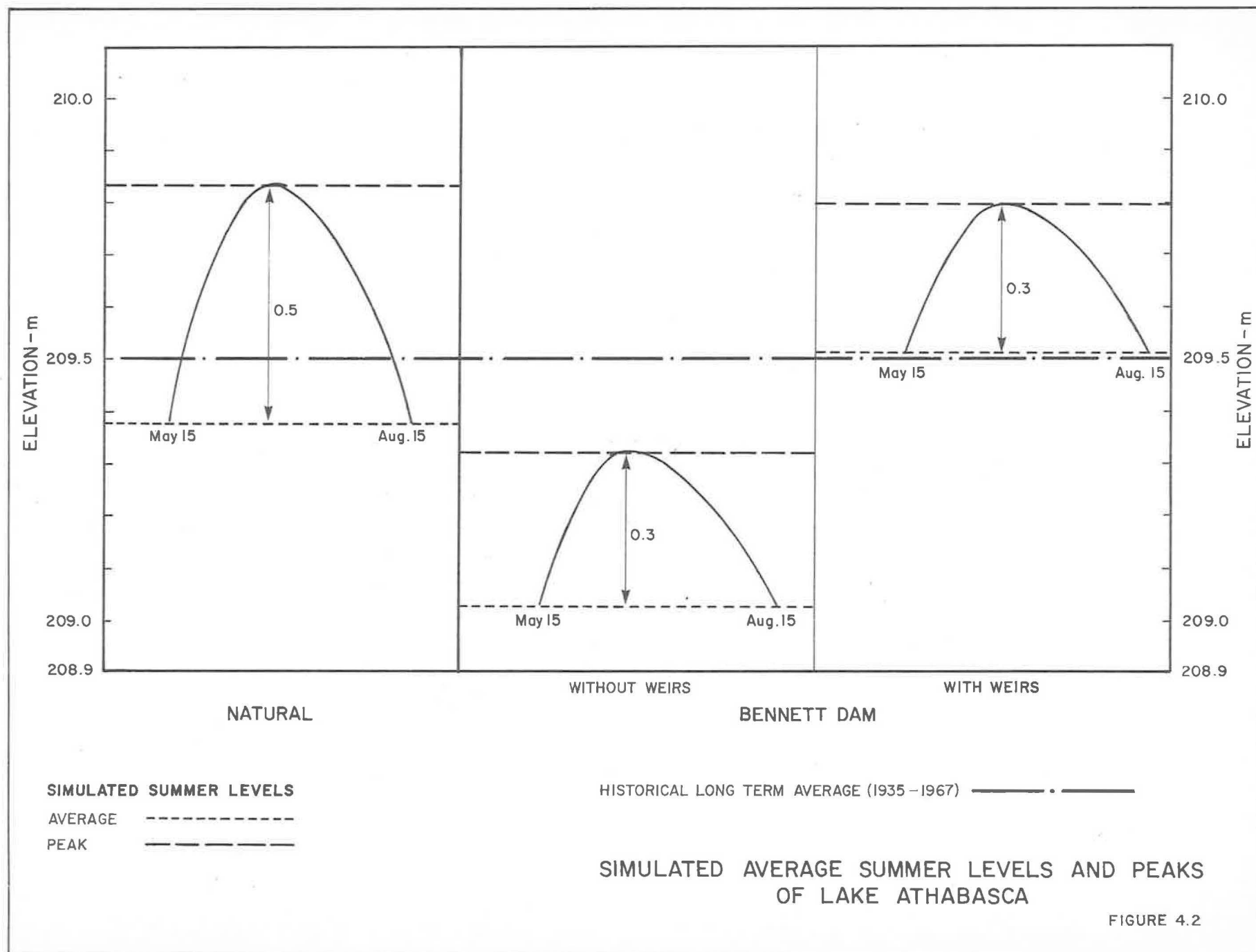
COMPARATIVE WATER LEVEL SIMULATIONS  
FOR LAKES ATHABASCA, CLAIRE AND MAMAWI

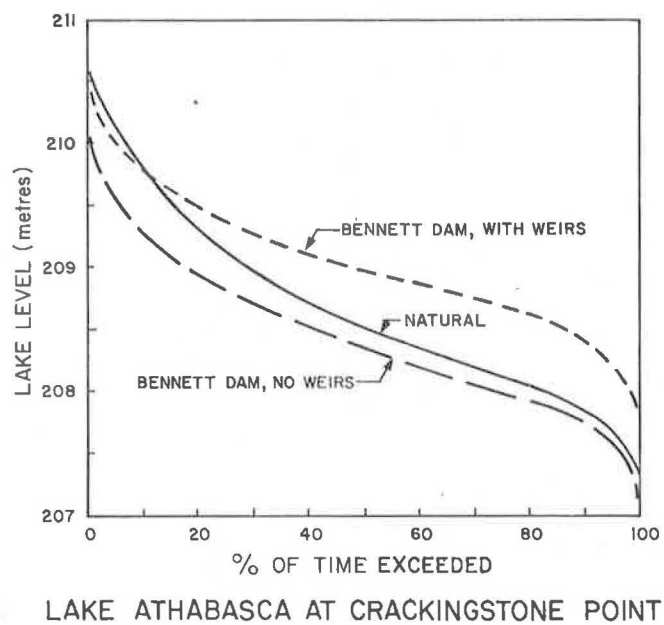
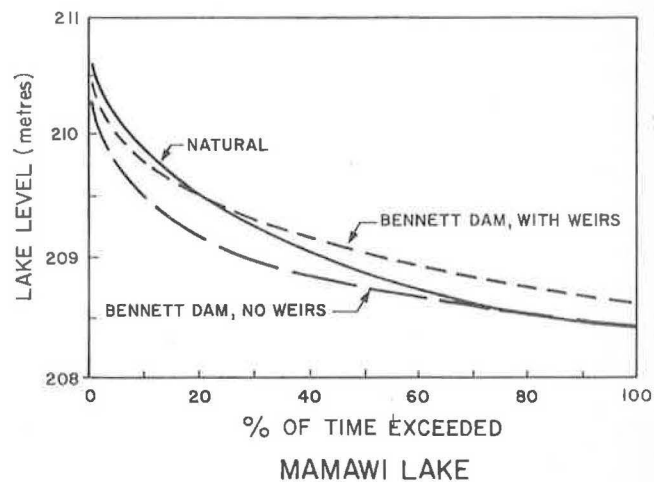
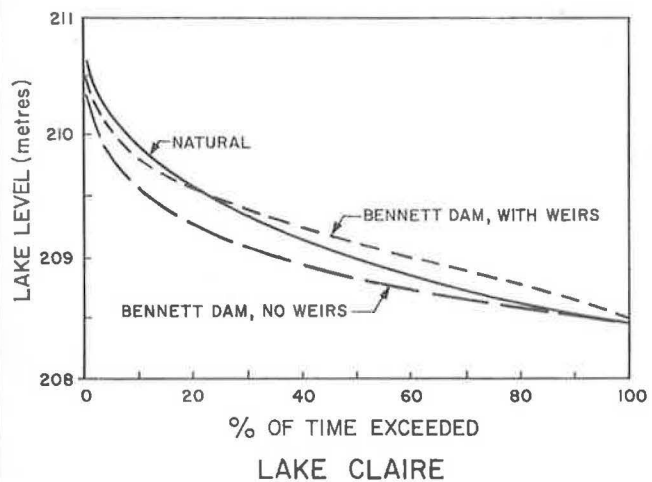
FIGURE 4.1

place, are about 0.2 m lower than the simulated natural levels. Both the minimum and mean water levels are higher than natural by about 0.1 m. Average summer peak levels on Mamawi Lake, with weirs in place, are about 0.1 m lower than natural, while minimum and mean water levels are both higher than natural by about 0.1 m. The mean amplitude of annual levels on Lakes Claire and Mamawi has been reduced by about 0.3 m.

Average summer Lake Athabasca peak levels, simulated with weirs in place, match the simulated natural levels within 0.1 m; while minimum and mean annual water levels are higher than natural by about 0.6 m and 0.4 m, respectively. The mean amplitude of annual levels with the weirs is reduced by about 0.6 m from natural conditions. With the weirs in place, average summer growing season (15 May - 15 August) levels on Lake Athabasca are raised by about 0.1 m above the natural average (Figure 4.2), and the mean amplitude of summer levels is reduced by about 0.2 m for both the Bennett Dam without weirs and the Bennett Dam with weirs. When compared to the long term summer average Lake Athabasca level, the simulated natural levels are slightly lower and the simulated levels with the weirs are slightly higher.

Curves illustrating the duration of daily water levels for lakes Athabasca, Claire and Mamawi are provided in Figure 4.3. The curves show the percentage of time that specific levels are equalled or exceeded -- based on the simulated data. The duration curves, like the hydrographs, illustrate the significant reduction in amplitude of annual water levels that has resulted from weirs.





WATER LEVEL DURATION CURVES  
FOR LAKES ATHABASCA, CLAIRE AND MAMAWI

The duration curves for lakes Claire and Mamawi indicate that with the weirs the peak levels above elevation 209.6 m are not being attained as regularly as with the natural regime. This suggests that the perched basins are being replenished less frequently with the present regime. However, during the percentage of time that elevation 209.6 m is exceeded (less than 20%), peak levels are restored to within 0.2 m of the natural regime. If the weirs had not been constructed, elevation 209.6 m would be achieved approximately 18% less frequently. Furthermore, at 209.6 m most of the perched basins that are recharged by overland flooding from the delta lakes would have their supplies replenished.

The duration curves show that the peak Lake Athabasca levels are virtually restored. That is, under the existing regime, lake levels above elevation 209.9 m are exceeded only 1-2% less frequently than under the natural regime. During this percentage of time (less than 10%), peak levels are restored to within 0.1 m.

From a biological perspective, the water levels in both the open drainage and perched basins should be considered. The open drainages are those lakes, rivers, streams or creeks which are interconnected by channels in which water flows. Lakes Claire, Mamawi and the Quatre Fourches channels are typical examples. Perched basins, in contrast, are depressions which have no channel or stream to drain them. These depressions, which vary in size, are only filled by local snowmelt, rain or by overland flooding from adjacent lakes, streams or rivers.

The hydrodynamic model simulated water levels in the open drainage portion of the delta. Although the peak water elevation simulated could be applied to the perched basins, the usefulness of these data was limited because the fill elevations of most perched basins have not been surveyed. The recession of water from the perched basins is primarily by evaporation or groundwater movements, factors that are not included in the hydrodynamic model.

The source of the flood waters to fill the perched basins is important when measures to restore water levels and habitat on the delta are considered. Perched basins on the delta can be grouped into four regions based upon the source of their flood waters: Peace River wetlands; Lake Claire and Mamawi wetlands; Athabasca River wetlands; and Lake Athabasca wetlands. The Rivière des Rochers and Revillon Coupe' weirs have directly affected wetlands in the Lake Athabasca and lakes Claire and Mamawi regions only. Monitoring data and modelling simulations suggest that perched basins along the Peace River have been recharged less frequently since construction of the Bennett Dam as spring floods have been reduced substantially.

Extensive flooding of the perched basins of the delta has not occurred since 1976, although there was some flooding in 1979. Localized flooding of some perched basins in the Birch River drainage basin occurred in 1984 and 1985 (Redhead, pers. comm.). The hydrodynamic model showed that a peak elevation of 210 m, which is necessary to recharge many of the higher perched basins, was barely reached in 1979 with the weirs in place. According to the model

results, 1979 was the only year since completion of the weirs that this critical level may have been exceeded under natural conditions. The model results indicate that natural peak summer levels were closely restored by the weirs.

#### 4.2 Vegetation

Vegetation communities on the Peace--Athabasca Delta have developed and changed in response to water level fluctuations. The most dynamic communities and those most susceptible to changes caused by water level fluctuations are the early successional communities located adjacent to the water's edge. These include the immature fen and sedge meadow communities.

Vegetation succession in the delta has not been monitored since 1978, thus there are no field data to document how vegetation communities have responded to the low water levels of the early 1980s. However, based on the results of the studies completed to 1978, it is reasonable to predict that around the edge of open water areas the general succession trend of immature fen to sedge meadow or willows has continued during the recent low water period and that the littoral vegetation communities have become more stable as the amplitude of annual water level fluctuations has decreased.

Field observations in 1978 indicated that the perched basins along the Peace River and at higher elevations in the delta were becoming drier. With the exception of some recent flooding in the Birch River basin, many perched basins in the delta have not been inundated since

1974. Thus, as the perched basins have continued to become drier, it is likely that the early successional communities have been replaced by more permanent species, such as willow and poplar.

The long-term vegetation trends resulting from the weirs have been predicted as deviations from the natural condition using the Wildlife Simulation Model. With the weirs, productive habitat was predicted to decrease by 11%, while there would be a slight increase in both open water and shrub/forest communities (+2% and +4%, respectively). With the Bennett Dam, productive habitat was predicted to decrease by a similar amount (-11%); however, this decrease would be attributed to a significant increase in shrub/forest communities (+20%) and a significant decrease in open water (-15%).

#### 4.3 Waterfowl

Generally, waterfowl production on the Peace-Athabasca Delta was found to be better when summer flooding did not occur (Hennan and Ambrock, 1977). Because only one season of waterfowl monitoring was conducted since completion of the weirs, waterfowl population changes in the post-weir period cannot be evaluated. It can be assumed that since water levels have remained relatively constant, conditions have been favourable for production. However, the extensive loss of perched based shoreline during the recent dry years, particularly along the Peace River and at higher elevations, may have reduced overall waterfowl production.

The statistical analysis comparing waterfowl data to water levels



for the period 1960 to 1980 showed no significant differences among waterfowl populations for the pre-dam, post-dam, and post-weir periods. Thus, it appears that the fluctuations in the waterfowl populations within the first four years following weir construction were within the range experienced before weir construction.

The long-term waterfowl production trends resulting from the weirs were calculated as deviations from the natural condition using the Wildlife Simulation Model. It is predicted that long-term waterfowl production under the weir water level regime should approximate the natural conditions and be substantially better than with the Bennett Dam only. However, it should be noted that these predictions are based on available habitat and do not take fluctuations in the continental waterfowl population into consideration.

The Wildlife Simulation Model predicted that with the weirs fall staging waterfowl habitat would decrease by 38% from the natural condition. This is far more than the decrease predicted for the Bennett Dam only (-17%), and would result from the slower decrease in fall water levels caused by the weirs.

#### 4.4 Muskrats

Trapper success rates (1930 to 1984) and population estimates (1973 to 1978) indicated that the Peace-Athabasca Delta muskrat populations peaked in response to the high 1974 water levels and that numbers have declined since completion of the weirs in 1976. There are a large number of factors that can affect the muskrat population. The

water level in the Peace-Athabasca Delta is the most important factor because it sets the physical limit to the abundance of muskrats through the availability of suitable habitat. Water levels appear to establish the range within which the muskrat population can fluctuate and regulate numbers only when the population meets or exceeds the capacity of the habitat.

When historical muskrat populations (trapper success) were compared with Lake Athabasca water level data for the period 1950 to 1984, it was evident that high water levels (which flooded at least 50% of the perched basins) always preceded peak muskrat numbers. It was also evident that in equally as many occasions, water levels rose high enough to flood approximately 50% or more of the perched basins without a corresponding detectable increase in the muskrat population. In some cases, muskrat numbers remained relatively constant or increased slightly from the previous year, but in more cases the numbers actually declined despite seemingly better habitat conditions. This may indicate that flooding of perched basins by high water is necessary to provide good habitat for muskrat populations, but good habitat does not automatically mean the population will expand. Other factors, such as trapping, predation, and disease can reduce population numbers.

The open drainage areas in the delta typically provide marginal muskrat habitat. Since the weirs were installed, water levels in the open drainage areas have increased in both summer and winter over pre-weir, post-Bennett Dam levels (except 1974) although the range between summer and winter levels has been reduced. This should have

resulted in a reduction in winter muskrat mortality caused by isolation from food sources or winter freeze-out and a reduction in summer mortality caused by flooding of muskrat houses. However, open basin muskrat populations declined.

If it is assumed that the low water levels of the late 1970s-early 1980s resulted primarily from natural conditions, as is suggested by the hydrological model, then it follows that the muskrat populations will recover to some degree if and when water levels return to higher levels. Observation by local trappers in the Birch River area indicated that water levels have been higher in this part of the delta since 1983 and the muskrat population appeared to be recovering. However, it should be remembered that, historically, the extreme water level fluctuations have produced excellent muskrat habitat on the delta.

#### 4.5 Fish

Fish studies in the Peace-Athabasca Delta since completion of the weirs in 1976 have focused on the effects of the Rivière des Rochers weir on goldeye migration. Field studies have shown that the weir impeded migration of spawning goldeye in some years. Statistical analysis of hydraulic head at the weir between 1976 and 1984 during the goldeye migration period showed that goldeye could cross the Riviere des Rochers weir 50% of the time and that, in two of the nine years, the weir would have been impassable at all times. Two assumptions were used in this analysis: first, spawning goldeye can wait three days below the weir and still spawn successfully and, second, goldeye can

migrate upstream past the weirs when the hydraulic head over the weir is less than 0.8 m. There are insufficient data to assess whether the impediment caused by the weir has had a significant effect on the goldeye population of the delta.

There are no data to verify if other major fish species of the delta (walleye, whitefish, and pike) have been adversely affected by the changed water levels in the delta. A major concern for all species is the effect that more stable summer water levels may have on shoreline vegetation and invertebrates, the major food sources for young fish. Higher winter water levels are likely to have enhanced the suitability of delta channels for overwintering. A reduction in spring peaks may have reduced both spawning habitats and entrapment losses for northern pike.

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Biological Monitoring Programs

Most of the PADIC biological monitoring programs ended in 1978, thus, the effects of the weirs were only monitored for the first two years after they were completed. These monitoring data, alone, are not sufficient to evaluate the success of the remedial measures, however, the monitoring programs did document the following biological trends:

1. The succession of immature fen to sedge meadow continued as water levels dropped between 1976 and 1978. It is likely that this trend continued during the lower water period of the 1980s.
2. Studies between 1971 and 1975 showed that spring and fall staging densities of waterfowl were highest under low water levels that exposed extensive areas of mudflats. Brood production was high when spring and summer flooding did not flood nests. However, persistent low water levels can cause entire perched basins to dry out, thereby reducing overall waterfowl production of the delta.
3. Muskrat populations were observed to decline as water levels dropped between 1976 and 1978. Although populations were not monitored after 1978, the low trapper success rate of the late 1970s and early 1980s indicated that muskrat populations continued to decline as water levels dropped. Local trappers observed that muskrat populations recovered in the Birch River basin as water levels rose in this basin in 1983.

4. The Rivière des Rochers weir was observed to impede the goldeye spawning migration in 1977 and 1980 when the hydraulic head exceeded 0.8 m. However, the effect that this had on goldeye spawning success has not been documented.

## 5.2 Quantitative Analyses

When sufficient data were available, quantitative methods were used to relate water levels to habitat conditions and populations. The results of these analyses are as follows:

1. A statistical analysis of waterfowl numbers and Lake Athabasca water levels showed no significant difference in waterfowl numbers before or after the dam and weirs were completed.
2. A frequency analysis of hydraulic head at the Rivière des Rochers weir showed that, on average in any given year, goldeye can successfully pass over the weir 50% of the time during the critical 42-day migration period, if it is assumed that the critical hydraulic head is 0.8 m. Based on this analysis, goldeye would have passed over the weir during part of the migration period in seven years and would have been blocked by the weir for the entire migration period during two years since completion of the weirs in 1976.

## 5.3 Simulation of Wildlife Habitat

The Wildlife Simulation Model developed by Townsend (1972b) for the PADP Group was used to simulate long-term changes in the wildlife

habitat of the delta for the natural condition, with Bennett Dam only and with Bennett Dam plus weirs. The model was run using Lake Claire and Lake Athabasca water levels which were simulated by the one-dimensional hydrodynamic model. The following conclusions can be drawn from these modelling exercises:

1. Productive habitats would decrease from the natural conditions by approximately 10% both with the Bennett Dam only and with the Bennett Dam plus weirs; however, the causes of the decrease would be different. With the weirs, the decrease in productive habitats would be caused by a slight increase in both the open water and forest/shrub communities; while with the dam only, the decrease in productive habitats would be caused by a significant increase in the area of shrub/forest communities and a significant decrease in open water area.
2. Waterfowl production with the weirs was predicted to be significantly better than with the dam only and would approach the natural condition. This is based upon both open water and perched basin conditions. The analysis is independent of variations in the continental waterfowl population.
3. Waterfowl staging habitat was predicted to be significantly worse for the weir regime than for either the natural condition or the Bennett Dam. This is because the weirs tend to elevate fall water levels, thereby decreasing available staging habitat.

#### 5.4 Success of the Weirs in Restoring Water Levels

The weirs have produced water levels on the delta similar to those predicted by the PADP Group (1973) (Alberta Environment and Environment Canada, 1985a). However, in the ten years since the weirs were constructed, water levels have been lower than average, largely as a result of low water yields from the contributory basins. The weirs, and the resulting water levels, have had the following effects on the biological communities of the delta:

1. The depressed water levels of the past decade have caused a decrease in the productive wetland habitat of the delta, particularly in the perched basins. Without the weirs, the extent of productive habitat would have decreased even more. Declining wildlife populations should partially recover when water levels return to average conditions.
2. The weirs have mitigated many of the long term biological impacts caused by the Bennett Dam and created a situation substantially closer to natural conditions than would have existed if they had not been built. However, the weirs will not restore the biological communities to natural conditions.
3. The reduced frequency of flooding of the perched basins at higher elevations will result in altered habitats in these wetland areas. The loss of perched basins along the Peace River will result in permanent loss of some wetland habitats in some years.



4. The weirs may block segments of the goldeye population migrating from the Peace River into the delta lakes. The effect that this may have on the goldeye population of the delta has not been documented.

#### 5.5 Recommendations for Ongoing Biological Monitoring in the Peace-Athabasca Delta

The Peace-Athabasca Delta is an area of national and international ecological significance. Regular monitoring of the biological effects of the Bennett Dam and the weirs is important to ensure that the weirs are maintaining reasonable water levels for the ecological balance of the delta, to record the rate of biological changes in the delta in response to water level changes and to provide the data base for predicting biological changes for water management projects in other deltaic environments. Further work is particularly important because the monitoring studies to date have only recorded the response of biological communities to below average water levels.

A long-term biological monitoring program should be established to measure ecological changes throughout the delta. If such a program is to succeed, monitoring responsibility must be clearly assigned to appropriate agencies along with reporting procedures. The critical components of this program are as follows:

1. Water levels in June and September should be measured in representative perched basins within the various hydrological regions within the delta. These regions could be lakes Claire and

Mamawi, Peace River, Athabasca River, Birch River and local internal runoff. The sites chosen should be coordinated with the vegetation monitoring program recommended below.

2. Vegetation mapping of selected areas should be carried out at regular intervals and coordinated with "1" above. Methods should be comparable to those used by the PADP Group (1973) and sites should include areas influenced by open water and the perched basins. This information would be used to assess wildlife habitat changes in response to actual water level fluctuations to calibrate the Wildlife Simulation Model.
3. A fisheries sampling program should be carried out to document the age structure and compile life tables for the major fish species of the delta. This would allow assessment of the responses of fish populations to past changes in water levels. For goldeye, it would provide data that could be used to evaluate the impact of hydraulic head at the weirs on spawning migrations and ultimately spawning success. The program should be designed to provide the baseline for future monitoring and should allow data to be comparable to previous studies as well.

#### 5.6 Recommendations Regarding Future Water Management in the Peace-Athabasca Delta

Based on the results of the one-dimensional hydrodynamic model, the results of biological monitoring programs in the delta and the wildlife simulation model runs, the following recommendations are made

regarding future water management in the Peace-Athabasca Delta:

1. The existing Rivière des Rochers and Revillon Coupe weirs should remain, as they appear to be doing a reasonable job of restoring water levels on the delta. However, biological monitoring should continue to ensure that the weirs will perform adequately at higher water levels.
2. The decision to build a fishway at the Rivière des Rochers weir site should not be made until the effect of the weirs on the goldeye population of the delta lakes has been determined. Therefore, a sampling program to document the age structure of the delta goldeye population should be undertaken.

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APPENDIX A

Appendix A. Water levels east of (E7) or west of (E8) Rivière des Rochers weir and hydraulic head (H<sub>0</sub>) during the passage period. Values are from recorded data or from correlation estimates (E).

Year	Date		E7 (m)	E8 (m)	H <sub>0</sub> (m)	Year	Date		E7 (m)	E8 (m)	H <sub>0</sub> (m)	
1976	April	28	208.822	208.440 E	0.382	1977	May	10	208.937	207.610 E	1.327	
		29	208.809	208.277 E	0.532			11	208.998	207.809 E	1.189	
		30	208.785	208.055 E	0.730			12	208.718	208.085 E	0.633	
	May	1	208.733	207.910 E	0.823		13	208.767	208.286 E	0.481		
		2	208.761	207.785 E	0.976		14	208.895	208.405 E	0.490		
		3	208.672	207.681 E	0.991		15	208.959	208.432 E	0.527		
		4	208.657	207.658 E	0.999		16	209.050	208.481 E	0.569		
		5	208.706	207.681 E	1.025		17	209.026	208.591 E	0.435		
		6	208.739	207.681 E	1.058		18	209.050	208.781 E	0.269		
		7	208.654	207.741 E	0.913		19	209.062	208.849 E	0.213		
		8	208.791	207.853 E	0.938		20	209.075	208.802 E	0.273		
		9	208.803	208.076 E	0.727		21	209.041	208.671 E	0.370		
		10	208.892	208.176 E	0.716		22	209.020	208.538 E	0.482		
		11	208.843	208.218 E	0.625		23	209.053	208.455 E	0.598		
		12	208.831	208.218 E	0.613		24	209.129	208.438 E	0.691		
		13	208.843	208.179 E	0.664		25	209.053	208.366 E	0.687		
		14	208.815	208.132 E	0.683		26	208.992	208.268 E	0.724		
		15	208.898	208.111 E	0.787		27	208.989	208.179 E	0.810		
		16	208.943	208.111 E	0.832		28	209.105	208.156 E	0.949		
		17	208.940	208.127 E	0.813		29	209.309	208.182 E	1.127		
		18	208.858	208.120 E	0.738		30	209.267	208.105 E	1.162		
		19	208.950	208.167 E	0.783		31	209.139	208.011 E	1.128		
		20	209.001	208.203 E	0.798		June	1	209.093	207.999 E	1.094	
		21	208.977	208.173 E	0.804			2	209.230	208.114 E	1.116	
		22	208.959	208.099 E	0.860			3	209.050	208.114 E	0.936	
		23	208.953	208.031 E	0.922			4	209.068	208.271 E	0.797	
		24	208.946	207.987 E	0.959			5	209.111	208.526 E	0.585	
		25	208.922	207.972 E	0.950			6	209.203	208.730 E	0.473	
		26	208.882	207.921 E	0.961			7	209.279	208.938 E	0.341	
		27	208.946	207.910 E	1.036		1978	May	5	208.971	208.932 E	0.039
		28	208.898	207.881 E	1.017				6	209.029	209.021 E	0.008
29	208.907	207.839 E	1.068	7	209.120	209.210 E			-0.090			
30	208.956	207.830 E	1.126	8	209.209	209.338 E			-0.129			
31	209.157	207.921 E	1.236	9	209.044	208.989 E			0.055			
June	1	209.029	207.949 E	1.080	10	209.026			208.789 E	0.237		
	2	208.886	207.889 E	0.997	11	208.971			208.348 E	0.623		
	3	208.754	207.785 E	0.969	12	208.928			207.975 E	0.953		
	4	208.931	207.895 E	1.036	13	208.928			207.697 E	1.231		
	5	208.959	207.972 E	0.987	14	208.928			296.534 E	1.394		
	6	208.931	207.963 E	0.968	15	208.943			207.406 E	1.537		
	7	208.913	207.930 E	0.983	16	208.989			207.364 E	1.625		
	8	208.946	207.981 E	0.965	17	208.986			207.367 E	1.619		
1977	April	27	209.035	209.089 E	-0.054	18			208.959	207.398 E	1.561	
		28	208.913	208.802 E	0.111	19	208.943	207.409 E	1.534			
		29	208.855	208.351 E	0.504	20	208.977	207.409 E	1.568			
		30	208.767	207.972 E	0.795	21	208.995	207.376 E	1.619			
		May	1	208.818	207.681 E	1.137	22	209.093	207.359 E	1.734		
2	208.818		207.471 E	1.347	23	209.172	207.522 E	1.650				
3	208.806		207.338 E	1.468	24	208.901	207.567 E	1.334				
4	209.062		207.525 E	1.537	25	208.822	207.632 E	1.190				
5	208.953		207.652 E	1.301	26	208.694	207.676 E	1.018				
6	208.788		207.629 E	1.159	27	208.776	207.794 E	0.982				
7	208.751		207.572 E	1.179	28	208.861	208.085 E	0.776				
8	208.776		207.563 E	1.213	29	208.946	208.303 E	0.643				
9	208.873		207.567 E	1.306	30	208.977	208.410 E	0.567				
					31	209.023	208.449 E	0.574				

## Appendix A Continued

Year	Date		E7 (m)	E8 (m)	H <sub>0</sub> (m)	Year	Date		E7 (m)	E8 (m)	H <sub>0</sub> (m)
1978	June	1	209.014	208.428 E	0.586	1980	April	25	208.092 E	207.128 E	0.964
		2	209.041	208.419 E	0.622			26	208.122 E	207.315 E	0.807
		3	209.001	208.372 E	0.629			27	208.157 E	207.252 E	0.905
		4	209.053	208.360 E	0.693			28	208.254 E	207.119 E	1.135
		5	209.056	208.354 E	0.702			29	208.168 E	206.873 E	1.295
		6	209.023	208.307 E	0.716			30	208.252	206.658 E	1.594
		7	209.062	208.339 E	0.723		May	1	208.290 E	206.580 E	1.710
		8	209.087	208.339 E	0.748			2	208.289 E	206.508 E	1.781
		9	209.132	208.370 E	0.762			3	208.135 E	206.305 E	1.830
		10	209.184	208.416 E	0.768			4	208.189 E	206.237 E	1.952
		11	209.087	208.378 E	0.709			5	208.249 E	206.190 E	2.059
		12	209.078	208.396 E	0.682			6	208.339 E	206.208 E	2.131
		13	209.102	208.435 E	0.667			7	208.347 E	206.260 E	2.087
		14	209.142	208.428 E	0.714			8	208.437	206.320 E	2.117
		15	209.132	208.351 E	0.781			9	208.464	206.386 E	2.078
1979	May	15	209.146 E	205.803 E	3.343			10	208.362	206.337 E	2.025
		16	209.150 E	205.895 E	3.255			11	208.373	206.329 E	2.044
		17	209.115 E	205.907 E	3.208			12	208.387	206.324 E	2.063
		18	209.160 E	206.251 E	2.909			13	208.354	206.278 E	2.076
		19	209.202 E	209.617 E	-0.415			14	208.345	206.209 E	2.136
		20	209.196 E	209.462 E	-0.266		15	208.358	206.176 E	2.182	
		21	209.227 E	209.290 E	-0.063		16	208.276	206.104 E	2.172	
		22	209.253 E	209.216 E	0.037		17	208.438	206.031 E	2.407	
		23	209.277 E	209.110 E	0.167		18	208.297	206.047 E	2.250	
		24	209.207 E	209.068 E	0.139		19	208.298	206.063 E	2.235	
		25	209.215 E	209.024 E	0.191		20	208.143	206.116 E	2.027	
		26	209.318 E	208.953 E	0.365		21	208.297	206.122 E	2.175	
		27	209.269 E	208.798 E	0.471		22	208.349	206.220 E	2.129	
		28	209.204 E	208.653 E	0.551		23	208.536	206.379 E	2.157	
		29	209.191 E	208.642 E	0.549		24	208.821	206.591 E	2.230	
		30	209.350 E	208.727 E	0.623	25	208.550	206.600 E	1.950		
		31	209.291	208.864 E	0.427	26	208.487	206.536	1.951		
	June	1	209.282	209.024 E	0.258	27	208.413	206.467	1.946		
		2	209.336	209.172 E	0.164	28	208.281	206.336	1.945		
		3	209.494	209.235 E	0.259	29	208.302	206.310	1.992		
		4	209.453	209.187 E	0.266	30	208.374	206.331	2.043		
		5	209.373	209.142 E	0.231	31	208.309	206.238	2.071		
		6	209.372	209.131 E	0.241	June	1	208.337	206.262	2.075	
		7	209.380	209.170 E	0.210		2	208.359	206.321	2.038	
		8	209.407	209.218 E	0.189		3	208.451	206.511	1.940	
		9	209.421	209.269 E	0.152		4	208.331	206.537	1.794	
		10	209.457	209.317 E	0.140		5	208.293	206.604	1.689	
		1981	May	9	208.504	208.316 E	0.188	10	208.504	208.135 E	0.369
				11	208.498	207.940 E	0.558	11	208.498	207.940 E	0.558
				12	208.468	207.933 E	0.535	12	208.468	207.933 E	0.535
				13	208.525	207.969 E	0.556	13	208.525	207.969 E	0.556
14				208.603	207.853 E	0.750	14	208.603	207.853 E	0.750	
15				208.559	207.923 E	0.636	15	208.559	207.923 E	0.636	
16				208.501	207.942 E	0.559	16	208.501	207.942 E	0.559	
17				208.516	207.968 E	0.548	17	208.516	207.968 E	0.548	
18				208.527	207.968 E	0.559	18	208.527	207.968 E	0.559	
19				208.507	207.901 E	0.606	19	208.507	207.901 E	0.606	
20				208.511	207.854 E	0.657	20	208.511	207.854 E	0.657	
21				208.562	207.858 E	0.704	21	208.562	207.858 E	0.704	
22				208.665	207.936 E	0.729	22	208.665	207.936 E	0.729	

## Appendix A Continued

Year	Date	E7 (m)	E8 (m)	H <sub>0</sub> (m)	Year	Date	E7 (m)	E8 (m)	H <sub>0</sub> (m)
1981	May	23	208.564	207.870 E	1982	June	18	208.587	207.907 E
		24	208.555	207.844 E			19	208.612	207.834 E
		25	208.572	207.855 E			20	208.752	207.675 E
		26	208.571	207.892			21	208.670	207.573 E
		27	208.755	208.092			22	208.533	207.584
		28	208.579	208.051			23	208.587	207.589
		29	208.614	208.114			24	208.565	207.509
		30	208.712	208.168			25	208.572	207.425
		31	208.676	208.155			26	208.578	207.374
							27	208.642	207.360
	June	1	208.580	208.055			28	208.671	207.367
		2	208.632	208.108			29	208.702	207.384
		3	208.590	208.127			30	208.580	207.271
		4	208.575	208.104		July	1	208.740	207.187
		5	208.585	208.033					1.553
		6	208.887	208.169	1983	May	12	208.235	207.344 E
		7	208.922	208.309			13	208.130	207.237 E
		8	208.788	208.242			14	208.115	207.237 E
		9	208.684	208.182			15	208.094	207.246 E
		10	208.669	208.131			16	208.082	207.255 E
		11	208.679	208.067			17	208.302	207.264 E
		12	208.662	207.989			18	208.260	207.273 E
		13	208.601	207.869			19	208.273	207.282 E
		14	208.571	207.732			20	208.284	207.291 E
		15	208.549	207.579			21	208.237	207.299 E
		16	208.574	207.452			22	208.243	207.308 E
		17	208.522	207.305			23	208.246	207.317 E
		18	208.520	207.214			24	208.292	207.324 E
		19	208.559	207.190			25	208.333	207.331
1982	May	21	-	208.034 E			26	208.226	207.317 E
		22	-	208.076 E			27	208.281	207.326 E
		23	-	208.076 E			28	208.353	207.393 E
		24	-	208.085 E			29	208.476	207.491 E
		25	208.569	208.176 E			30	208.397	207.493 E
		26	208.638	208.238 E			31	208.410	207.520
		27	208.658	208.162 E		June	1	208.431	207.542
		28	208.573	208.064 E			2	208.448	207.521
		29	208.585	207.969 E			3	208.390	207.467
		30	208.628	207.874 E			4	208.327	207.353
		31	208.565	207.661 E			5	208.317	207.306
	June	1	208.640	207.619 E			6	208.314	207.332
		2	208.511	207.544 E			7	208.246	207.335
		3	208.606 E	207.481 E			8	208.335	207.344
		4	208.697 E	207.482 E			9	208.516	207.402
		5	208.574 E	207.274 E			10	208.389	207.271
		6	208.630 E	207.187 E			11	208.454	207.142
		7	208.602 E	207.162 E			12	208.359	206.943
		8	208.539 E	207.265 E			13	208.343	206.782
		9	208.544	207.402 E			14	208.376	206.672 E
		10	208.569	207.522 E			15	208.404	206.639 E
		11	208.646	207.596 E			16	208.264	206.599 E
		12	208.713	207.641 E			17	208.395	206.672 E
		13	208.721	207.601 E			18	208.352	206.745 E
		14	208.676	207.709			19	208.556	206.908 E
		15	208.588	207.826 E			20	208.538	206.971 E
		16	208.688	207.884 E			21	208.398	206.894 E
		17	208.625	207.921 E			22	208.362	206.786 E

## Appendix A Continued

Year	Date		E7 (m)	E8 (m)	H <sub>0</sub> (m)	Year	Date	E7 (m)	E8 (m)	H <sub>0</sub> (m)
1984	May	1	208.126	207.065 E	1.061					
		2	208.034	206.592 E	1.442					
		3	207.954	206.205	1.749					
		4	208.012	206.476 E	1.536					
		5	208.292	206.583 E	1.709					
		6	208.217	206.600 E	1.617					
		7	208.231	206.654 E	1.577					
		8	208.327	206.725 E	1.602					
		9	208.349	206.778 E	1.571					
		10	208.348	206.810 E	1.538					
		11	208.314	206.819 E	1.495					
		12	208.292	206.846 E	1.446					
		13	208.331	206.838 E	1.493					
		14	208.333	206.838 E	1.495					
		15	208.356	206.838 E	1.518					
		16	208.370	206.891 E	1.479					
		17	208.317	206.891 E	1.426					
		18	208.056	206.810 E	1.246					
		19	207.928	206.751 E	1.177					
		20	207.867	206.707 E	1.160					
		21	207.829	206.810 E	1.019					
		22	207.814	207.294 E	0.520					
		23	208.205	207.458	0.747					
		24	208.451	207.975	0.476					
		25	208.565	208.234	0.331					
		26	208.555	208.321	0.234					
		27	208.518	208.352	0.166					
		28	208.544	208.358	0.186					
		29	208.542	208.350	0.192					
		30	208.597	208.315	0.282					
		31	208.710	208.300	0.410					
	June	1	208.481	208.197	0.284					
		2	208.425	208.023	0.402					
		3	208.536	207.990	0.546					
		4	208.565	207.974	0.591					
		5	208.644	208.012	0.632					
		6	208.837	208.216	0.621					
		7	208.834	208.312	0.522					
		8	208.782	208.291	0.491					
		9	208.655	208.147	0.508					
		10	208.568	207.995	0.573					
		11	208.728	208.081	0.647					