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SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

SURVEY OF EXPERIENCE IN OPERATING HYDROELECTRIC PROJECTS IN COLD REGIONS

VOLUME 1-MAIN TEXT
APPENDIX A & APPENDIX B

FINAL REPORT

HARZA-EBASCO
SUSITNA JOINT VENTURE

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VOLUME 1 - MAIN TEXT

APPENDIX A & APPENDIX B

Prepared by
Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

Final Report
June 1985

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

TABLE OF CONTENTS

LIST OF APPENDICES

ACKNOWLEDGEMENTS

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1. SCOPE OF WORK

The Susitna Hydroelectric Project will be located in a region where winters are moderately severe and river and reservoir ice must be accommodated. The design and operation must consider ice effects both for the associated project structures and environmental effects on the aquatic, terrestrial, and human habitat. In particular, any changes to the natural condition of the river as regards ice must be addressed.

In an attempt to develop background on experience for existing installations in cold regions, we have made the following investigations:

A. Review of pertinent literature,
B. Mail survey, and
C. Visit to British Columbia Hydro (Vancouver) and Peace River Town.

This report contains the results of that study including recommendations for the Susitna Hydroelectric Project.

2. SUMMARY

A literature review, mailed survey and site visit have been made to evaluate the procedures adopted by operators of hydroelectric projects in cold regions similar to the Susitna Hydroelectric Project site, in response to environmental concerns. Four specific areas were addressed:

1. Reservoir and powerhouse operating procedures to mitigate ice jam related flooding,

2. The effects of reservoir ice cover and bank ice on animal crossing,

3. Management of reservoir ice cover to control cracking and the associated danger to animals, and

4. Bank erosion resulting from reservoir and river ice movement. The effect of this movement on suspended sediment and turbidity levels, including permissible turbidity levels.

The results of the study indicate that:

1. There are a few documented problems within reservoir impoundment zones. These are generally caused by animals falling through a thin reservoir ice cover or by animals losing their footing on the ice cover. An operation constraint is being used at Lucky Peak Dam to minimize deer drownings. The reservoir water level is held constant during cover formation to prevent weak spots resulting from unsupported ice or cracking which apparently occurs when the reservoir is drawn down during cover formation.

2. There are a few cases reported in Canada where ice jam flooding of towns has been attributed to upstream hydroelectric power operations.

3. Where operational procedures are in effect, they are generally directed toward protecting human life and property rather than aquatic or terrestrial habitat.

4. Operational restrictions such as those for British Columbia Hydro's Peace River project include the following:

   a. During freeze-up ice cover progression through sensitive areas on the river, flows are controlled at a high level until the cover develops sufficient strength to withstand flow fluctuations.

   b. After freeze-up, the plant can be operated freely without endangering the cover except in the frontal zone.

   c. During break-up and melt-out, flows are again maintained at high levels in the sensitive areas to erode the cover as quickly as possible. If tributary break-up appears imminent, B.C. Hydro releases are decreased in order to minimize the effect of the tributary ice surge on water levels in sensitive areas on the Peace River.

5. In other cases operational constraints are employed to prevent the formation of hanging dams in the river downstream of a hydro facility or to reduce water levels upstream of a hanging dam after it has formed. These hanging dams may result in high water levels which can reduce the plant generating capacity, endanger the powerhouse, or result in flooding of areas adjacent to the river. These types of constraints include:

   a. Inducing an early ice cover on the river upstream of known sites of hanging dams, by artificial means such as ice booms or other obstructions. When an ice cover forms, frazil ice production stops and the hanging dams, which result from frazil accumulation, are minimized.

b. Inducing an early ice cover on the river by keeping powerhouse discharges low while the ice cover forms. This may result in more rapid ice cover advance, preventing further frazil production. After the ice cover is formed, powerhouse discharges can be increased.

c. Preventing ice cover formation in sensitive areas by fluctuating discharges, continually breaking up the ice cover and keeping it downstream. This may result in higher water levels further downstream, but lower water levels in sensitive areas.

d. Reducing discharges after a hanging dam forms in order to reduce water levels upstream of the hanging dam.

6. The Canadian Electrical Association and many plant operators indicated that powerhouse operations during the winter to maintain a stable cover would be site specific and require operating experience over a number of years. Reservoir discharge, climatic conditions, channel morphology, and water temperature are all variables which must be considered.

There is an apparent disagreement between the policies suggested by 4a and 4b and the policy suggested by 5a. This results from the different objectives of the two policies. The policy adopted by B.C. Hydro would maintain power production at a reasonable rate while the ice cover forms. Since the cover is being formed at a relatively high discharge, once it is stable, the powerhouse discharge can be fluctuated within limits to meet power demands, without breaking up the ice cover and causing an ice jam downstream.

Policy 5a may be adopted where flooding induced by hanging ice dams is a problem. Hanging dams occur where an unusually large amount of frazil ice accumulates and restricts flow areas and raises water levels. These dams generally occur downstream of river reaches that do not have an ice cover. Typical locations for hanging dams are the upstream ends of reservoirs or just downstream of a rapids.

As long as the river reach is not ice covered, frazil ice may be formed and accumulate downstream at the hanging dam. Policy 5A would have the effect of reducing velocities in the normally open river reach, and would allow an ice cover to form over this reach. Once an ice cover forms, frazil production in the river reach would be stopped. This would minimize ice accumulation at the hanging dam site and result in lower water levels. Once the ice cover is formed over the reach and is stable, the flow may be increased within limits without fracturing the ice cover.

3. LITERATURE REVIEW

Several organizations have published general information and guidelines for ice considerations in the design and operation of hydroelectric and other projects. These sources were reviewed:

1. Evaluation of Ice Problems Associated with Hydroelectric Power Generation in Alaska, Final Report to the State of Alaska Department of Commerce and Economic Development by J.P. Gosink and T.E. Osterkamp, of the University of Alaska Geophysical Institute.

   The problems dealt with in this study pertained more to energy generation than to environmental concerns. There was discussion of problems related to hanging dams and ice jams which is of interest. Various methods for determining the open water reach downstream of a reservoir were discussed. A survey of hydropower plants was conducted to determine potential ice-related problems and possible solutions.

2. Course Notes for Ice Engineering on Rivers and Lakes by the University of Wisconsin, Madison in cooperation with the U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory and the University of Wisconsin Sea Grant Institute.

   The course notes include articles by leading authorities in the field of ice engineering, dealing with

   a. formation and breakup of a river ice cover and methods for analyzing and solving associated problems,

   b. ice problems at hydroelectric structures, and

   c. mechanical properties of ice and ice forces on structures.

The notes provide a good compendium of potential ice problems and engineering solutions. However, they do not deal with environmental effects other than effects of flooding on human habitation.

3. Design and Operation of Shallow River Diversions in Cold Regions by the U.S. Department of the Interior, Bureau of Reclamation REC-ERC-74-19.

   This report contains information on potential ice problems and design guidelines. Although the report is written for shallow river diversions, many of the design guidelines are applicable to hydroelectric projects as well. The report does not deal with environmental problems.

4. Winter Ice Jams on the Gunnison River, by the U.S. Department of the Interior, Bureau of Reclamation REC-ERC-79-4.

   The report details ice jam flooding problems associated with operating projects and methods used in an attempt to alleviate the problem. The flooding affected residents along the reach of the Gunnison River between Blue Mesa and Taylor Park Reservoirs. Relationships were developed between ice jam location, weather conditions and level of Blue Mesa Reservoir water surface.

5. Ice Management Manual, by Ontario Ministry of Natural Resources.

   This report includes guidelines for dealing with chronic ice problems including procedures for monitoring, predicting and acting on freeze-up and break-up ice jamming related flooding. It includes information on conditions causing ice jamming, explains causes and predictive methods for break-up, lists the data which should be collected in a monitoring program, and assesses the success rate of various remedial measures.

6. Ice Engineering by the U.S. Army Corps of Engineers, EM 1110-2-1612.

This is a very comprehensive report summarizing potential problems at all types of civil works structures including hydroelectric projects. The report provides guidance for the planning, design, construction, operation and maintenance of ice control and ice suppression measures and is used by the Corps of Engineers for their projects. The manual discusses ice formation processes, physical properties and potential solutions.

7. Behavior of Ice Covers Subject to Large Daily Flow and Level Fluctuations by Acres Consulting Services, Ltd. for the Canadian Electrical Association.

This report contains much valuable information on the types of problems encountered relative to river ice covers downstream of hydroelectric projects. An attempt was made to establish the state-of-the-art in predicting the stability of a river ice cover subject to flow and level fluctuations. Theoretical computations were made to establish stability criteria for the ice cover and to provide a means for developing guidelines for flow and level fluctuations to prevent ice cover break-up. The study concludes that:

> "...generalized criteria do not exist at present, and designs cannot be prepared for many cases of ice structure, or shoreline, interaction."

The report concludes that extensive laboratory and field studies are necessary before a generally applicable model can be formulated and that the guidelines presented in the manual can be used to establish that field program. Site specific studies would also be required.

8. Reservoir Bank Erosion Caused and Affected by Ice Cover by Lawrence Gatto for the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory.

   This report describes a survey of reservoir bank erosion problems at various places throughout the world and provides a reference list. Many photographs of existing installations are presented. Criteria for various types of erosion are presented.

9. Proceedings of the Ice Management Seminar, January 30, 1980, London, Ontario by the Ministry of Natural Resources, Southwestern Region, London, Ontario

   This report provides the experience of many Canadian and U.S. experts in the field of ice management and control. Its scope is similar to Ice Engineering by the U.S. Army Corp of Engineers (6. above) and course notes for Ice Engineering on Rivers and Lakes (2. above).

Additionally, many articles available in the general literature were consulted. Some of these were provided by participants in the mail survey described later.

4. MAIL SURVEY

A mail survey was conducted to determine the experience of operators of hydroelectric projects in cold regions. The survey was carried out by:

1. Compiling a list of operators of hydroelectric projects in cold regions,

2. Developing a concise set of questions about environmental concerns with ice,

3. Mailing the questionnaires to the operators,

4. Reviewing responses for additional contacts,

5. Mailing questionnaires to suggested additional contacts,

6. Following up by an additional mailing to non-respondents,

7. Compiling of responses, and

8. Summarizing responses.

Additionally, a copy of the survey letter was published in Fisheries, a bulletin of the American Fisheries Society (AFS, 1985). Publication of the letter was not requested. A response to this publication was received and is provided in this report.

Consulate offices representing each of the countries which experience severe northern climate conditions were contacted. Lists of names of organizations were obtained. Discussions were conducted with various consulate officials on ice management for possible leads which could be used for making contacts. In order to obtain better assurance that the questionnaire would reach the addressed person and also to obtain a faster delivery time to foreign countries, telexes or cablegrams were used. First class mail was used in the U.S. and Canada. For a list of organizations contacted refer to Appendices B-1 to B-3.

In order to obtain a full spectrum of comments, the questionnaires were sent to hydropower utilities, water supply utilities, federal and state agencies for the environment, fish, wildlife, natural resources, energy and inland waterways. In addition, questionnaires were sent to universities, research organizations (National Research Council of Canada, CRREL of the US, etc.) engineering companies located in each of the Canadian provinces and northern states in the United States involved in ice engineering, and selected concerned citizen groups. After a reasonable time lapse, follow-up letters were sent to some non-respondents. During the process of compiling the replies, telephone contacts were made in an attempt to clarify certain points.

Responses to the letter, originally mailed on October 16, 1984, which were received prior to June 1, 1985 are included in this report.

4.1 Questionnaires

The questions asked concerned ice management policies in use or being adopted by the various organizations or agencies for environmental purposes. A copy of the questionnaire is included as Appendix A-1. A summary of the questions is given below.

Question No. 1. Reservoir Operating Procedures to Mitigate Ice Jam Related Flooding:

The question asked for information on winter operating policies with respect to water surface fluctuations to control ice formation in lakes and rivers upstream and downstream of dams and hydropower plants. The general purpose of operations is to form a stable ice condition which would prevent the formation of ice jams that would lead to undesirable flooding. The water level changes could be caused by the variation of flow releases resulting from:

1. hydro-power generation,
2. domestic and industrical water supplies,
3. aquatic and fishery requirements,
4. wildlife protection,
5. water temperature control,
6. dissolved oxygen and dissolved nitrogen control,
7. flash snow melt, and
8. ice jams (backwater effect)

Question No. 2. Ice on Reservoir Banks:

The question asked for information on environmental impact on animals such as caribou, elk, bear, moose, etc. due to the formation of ice on reservoir banks due to drawdown or due to reservoir surface ice which was broken up at the banks. This ice when stepped upon by animals, may cause them to lose their footing resulting in injuries or drownings. What procedures, if any, have been taken to minimize this hazard?

Question No. 3. Reservoir Management for Ice Crack Control:

The question asked for information on the method of reservoir water level fluctuation management or precautions used to control the width of opening and pattern of crack development in the ice sheet such that after snowfall with cracks covered, the traversing animals would not stumble into and be trapped in the cracks.

Question No. 4. Bank Erosion and Turbidity due to Ice Movement:

The question asked for information on problems of bank erosion caused by break-up and movement of ice floes along banks resulting in an increase of sediment in the reservoir and in the river downstream. What is the permissible degree of turbidity in parts per million or its equivalent that is acceptable for aquatic life such as salmon, trout, etc.?

Over 160 letters and telexes or cables were sent to various organizations throughout the world, of which over 80 replies were received - 50%. This is considered a good response. The list of organizations contacted is in Appendix B and correspondence received is in Appendix C.

4.2 Compilation of Responses

The replies were carefully reviewed. Only the replies which addressed the questions(s) were tabulated, the rest of the respondents normally stated that nothing is known about the queried subject. The compilation was extracted, verbatim, from the replies. Technical information in the replies is quite sparse. Many respondents suggested names of persons and organizations to contact. In general, these suggestions were followed through. The summary compilation of responses is enclosed as Appendix A-1, Canada, Appendix A-2, United States, and Appendix A-3, Europe and Japan.

Most respondents answered questions No. 2 and No. 3 together and this format was adopted in the compilation. In the summary, however, these questions were separated as far as possible.

Question No 1. - Reservoir Operating Procedures to Mitigate Ice Jam Related Flooding:

1. During freeze-up it is important that discharges remain relatively high until a stable ice cover is formed at a high enough stage and of sufficient thickness and strength to allow full flexibility of discharge throughout the winter. Thereafter, the outflow may be reduced as required. This action permits the water to flow freely under the ice cover. When short term increased discharge is necessary, it should not exceed the discharge at ice cover formation until the ice cover has had a chance to strenthen as a

result of heat loss and consolidation of ice blocks forming the initial cover. The consequences of increasing discharge over that at cover formation are the lifting of the ice cover, and a tendency to cause ice build-up. The ice build-up or hanging ice could result in increased backwater and ice jams during the break-up period.

2. During ice cover formation, the rate of freezing is monitored, and daily discharge is kept as constant as possible to reduce ice shoves at the leading edge of the ice cover and minimize flooding. If shoving should occur and water stage should increase, the discharge is moderated to reduce the hazards.

3. British Columbia Hydro attempts to coordinate ice break-up of the Peace River with the various tributaries on its river system. However, the timing and rate of break-up depend primarily on prevailing weather conditions and spring freshet flood peaks from the tributaries, and can not be controlled at the dam. Therefore, extensive field observation posts at various stations have been established to monitor ice conditions. Where necessary and feasible, operations were modified in order to minimize hazards.

4. Each plant in the Manitoba Hydro system is associated with a unique set of operating policies. These policies are usually established out of concern for the environment, but also with recognition of a preferred mode of operation for power production purposes. Attempts to mitigate effects of flooding, etc. are made. If damage should occur, however, compensation procedures are adopted.

5. Ontario Hydro states that operational procedures at dams and hydroplants are still based on operator's experience because the necessary understanding of ice jams is still not available.

6. Most respondents state that no attempts have been made to control ice levels to affect ice jamming or flooding.

7. Some respondents state that they have no written operating policy. Water levels are not regulated with effects on wildlife in mind, but only with the intent of maximum economic benefit from the power generation or the adequate water supplies for the users.

8. In other cases operational constraints are employed to prevent the formation of hanging dams downstream of a hydro project or to reduce water levels upstream of the hanging dam after it forms. Hanging dams may result in high water levels which can reduce the plant generating capacity, endanger the powerhouse, or result in flooding of areas adjacent to the river. These types of constraints include:

   - Inducing an early ice cover on the river upstream of known sites of hanging dams, by artificial means such as ice booms or other obstructions. When an ice cover forms, frazil ice production stops and the hanging dams, which result from frazil accumulation, are minimized.

   - Inducing an early ice cover on the river by keeping powerhouse discharges low while the ice cover forms. This may result in more rapid ice cover advance, preventing further frazil production. After the ice cover is formed, powerhouse discharges can be increased.

   - Preventing ice cover formation in sensitive areas by fluctuating discharges, continually breaking up the ice cover and keeping it downstream. This may result in higher water levels further downstream, but lower water levels in sensitive areas.

- o Reducing discharges after a hanging dam forms in order to reduce water levels upstream of the hanging dam.

9. The Canadian Electrical Association and many plant operators indicated that powerhouse operations during the winter to maintain a stable cover would be site specific and require operating experience over a number of years. Reservoir discharge, climate conditions, channel morphology, and water temperature are all variables which must be considered.

Question No. 2. - Ice on Reservoir Banks:

In general, all organizations take no specific actions on their reservoirs to alter the state of ice on reservoir banks for wildlife safety reasons. Two organizations indicated sporadic cases of deer drowning within ice covered drawdown zone but have no quantitative or documented information. Others reported no known problems with animal injuries or drowning as a result of reservoir drawdown.

Dr. Lennart Billfalk, Director, Vattenfall (Power Board), Sweden reports some potential problems related to the need for reindeers to pass regulated rivers have been discussed when planning for new hydro power stations and in some cases the Power Board has constructed special reindeer bridges where "natural crossings" can not be used anymore.

Mr. William M. Grove of the Union Water Power Company reports, "The nature of reservoir freezing during drawdown does not allow wet reservoir banks to exist. The drawdown is gradual thus allowing solid freezing of the water. There are no exposed areas where an animal would become entrapped in a combination of wet mire and reservoir ice. At the time of freezing, the reservoir ice has formed sufficiently to support the weight of animals. Our experience of over 100 years of operation is that we do not have migratory animals in the true sense of the word. Never have my people reported seeing moose or deer on the reservoir surface of their own accord. The deer especially are at far greater hazard from packs of predator coy-dogs that drive them on to the ice where they lose their footing and become easy prey. Bears hibernate in the winter."

Wendel J. O'Conroy, Associate Director of the United States Fish and Wildlife Service reports "There is the potential, if reservoirs freeze, for terrestial animals to become stranded on ice and become easy prey to predators. Animal loss can be prevented by predator control, fencing of reservoirs and providing access to winter feeding areas away from iced surfaces."

Question No. 3. - Reservoir Management for Ice Crack Control:

All respondents except one state that no procedures are used to control cracks in reservoir ice that might be a hazard to animals. Also most stated that no known problems with animals falling in cracks or openings along reservoirs have been documented. Many routes for migratory species do not cross existing reservoirs. Apparently, this is coincidental and not by choice of design because many of the reservoirs were in place prior to public awareness of environmental problems.

Kennebec Water Power Co., Maine states "In Maine, most large animals stay off the ice as they are unable to maintain mobility - especially the hooved animals."

At the Lucky Peak Dam, an irrigation and flood control structure in Idaho, many deer drownings occurred between its construction in 1956 and the institution of measures to minimize the problem. The reservoir is in a major migration path and, up until about 10 years ago, as many as 150-175 deer per year would drown in the reservoir. This was apparently caused by the animals crossing the reservoir when the ice cover was still thin. Pockets of unsupported ice or cracks apparently formed in the ice cover as the reservoir was being drawn down. Deer stepping on these areas would fall through the cover. Later, when the ice cover thickened, the problem ceased. The reservoir is now maintained at a stable level during cover formation to prevent the formation of these cracks or pockets. Deer drownings have reportedly been reduced to 5-10 animals per year.

At the Blue Mesa Reservoir in Colorado there has been one major incident of elk drowning during recent years. The exact cause is not known. However it appears, from the location where the elk were found, that they may have fallen through thin ice at the edge of the reservoir when the cover was first forming. It also appears that the elk do not normally travel on the reservoir and were there because of any of a number of reasons including a harsh winter and poaching hunters. The elk had apparently travelled at least a mile on the ice. The Blue Mesa Reservoir normally draws down continually through the winter by 40 to 100 feet. No measures have been instituted to control ice cover formation. Isolated instances of animals being trapped on the ice do occur and rescues have been made.

At the Revelstoke Hydrolectric Project in British Columbia, moose cross the impoundment ice with no apparent reluctance or difficulty when it is stable and generally avoid crossing when it is not. Many observations at this reservoir confirm that in almost all cases moose can climb out of the reservoir onto the ice after falling through week spots. No ice related caribou mortalities have been noted at the Revelstoke Project. Woodland caribou readily cross the reservoir during the winter when ice conditions permit, individually or in groups of up to 20 animals.

Question No. 4 - Bank Erosion Due to Ice Movement:

Permissible levels of turbidity are difficult to define and vary from province to province in Canada and from state to state in the U.S. Usually the levels are set for drinking water standards or human recreation standards and seldom for aquatic life. Manitoba has attempted stream classification applicable to fish as follows:

Class 2A - warm and cold water sport and commercial fish -
limit = 10 JTU. (Jackson Turbidity Unit)

Class 2B - warm and cold water sport and commercial fish -
limit = 25 JTU.

Class 2C - rough fish -
limit = 25 JTU.

The province of Ontario, for instance, does not permit Secchi disc readings (a turbidity indicator) to change by more than 10%. Alberta's objectives suggest changes be less than 25 JTU's over seasonal natural background level. These are drinking water standards.

The state of Michigan set maximum water surface fluctuations in impoundments for:

- o cold water rivers (salmon, char, trout, etc.) at 8"-10" per day
- o warm water rivers (bass, walleyes, etc.) at 12"-18" per day.

These criteria are based on experience in the state.

The existing practice in British Columbia is to enhance and manage fisheries in reservoirs which have suitable basic characteristics and minimal fluctuation in water levels, e.g. run-of-the-river reservoirs such as Peace Canyon development. Both BC Hydro and the resource agencies accept that reservoirs with erodible banks, large draw-down zones and high sediment levels have limitations for fisheries management.

The United States Government agencies contacted did not report turbidity standards for fish. Most agencies stated that increased turbidity during spring floods and ice movements is not within design control. In both cases the flow is relatively high. The increase in sediment gives an apparent large increase in turbidity, because of greater degree of turbulence associated with higher flow. However, turbidity changes due to project construction or due to high velocity sluice releases etc, are more critical. Some agencies stated a rule of thumb practice is to restrict a turbidity change, for cold water rivers, to no greater than 10% beyond average seasonal turbidity level for protection of aquatic life. Operational experiences gained each season, monitored by specialists, should be used to guide future operations.

No respondents report using the nephelometric method (NTU) but a few respondents stated turbidity, in the Jackson turbidity unit (JTU) using the candle turbidimeter a visual method from "The Standard Methods for the Examination of Water and Wastewater."

5. VISIT TO BRITISH COLUMBIA HYDRO AND PEACE RIVER TOWN

Mr. H.W. Coleman and Mr. Wayne Dyok visited with officials of British Columbia Hydro in Vancouver and Alberta Environment in Peace River Town. They obtained information on operating policies of the W.A.C. Bennett and Peace Canyon Project and records of the flooding of Peace River Town which was related to wintertime operations of B.C. Hydro's upstream projects. A record of their visit is contained in Appendix E.

6. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of this study are based on the literature review, mailed survey and site visit. They are:

1. Reservoir operating procedures which are in use at other projects to mitigate downstream ice jam related flooding include:

    a) Establishment of a stable ice cover on the downstream river early in the season during freeze-up. The ice cover should be high enough and strong enough to allow full flexibility of discharges throughout winter.

    b) Operational procedures may also be employed to prevent hanging dams. These include inducing an early ice cover on the river upstream of known sites by artificial means, or by keeping powerhouse discharges low while the cover forms. Hanging dams may also be prevented in sensitive areas by fluctuating discharge to keep the ice cover broken up and downstream of the area.

    c) Most utilities have no operating policies to control ice levels to affect ice jamming or flooding. A few utilities may have operating policies out of concern for aquatic life and wildlife in mind but operate with the intent of maximum economic benefit from power generation or adequate water supplies for the users. Where operating procedures are in effect they are generally directed toward protecting human life and property. If damage should occur, compensation procedures are adopted.

    d) Measures to prevent release of ice from the reservoir to the river downstream. This ice, if released, could contribute to jamming downstream.

The proposed policy for operating the Susitna Hydroelectric Project contained in the report by the Alaska Power Authority (APA, 1985) contains constraints on variations in releases. These are:

a. Flows shall not vary more than ±10% from the average weekly flow at Gold Creek.

b. The maximum rate of flow change will be 10% of the average weekly flow when Watana is operating alone and 350 cfs per hour when Devil Canyon comes on line.

The first constraint generally means that water levels will not vary more than 0.4 feet throughout the week. The second constraint means that the maximum rate of water level change will be approximately 0.4 ft/hour when Watana is operating alone and 0.1 ft per hour when Devil Canyon is on line. These are based on steady state conditions. Water level fluctuations of this amount would probably be acceptable and provide ice cover stability.

If constraints such as these are adopted, it is not believed that other requirements would be necessary to provide a stable ice cover. Hanging dams causing increased water levels have not been observed in the Susitna River and so it is not believed that a policy designed to minimize these, as discussed on page 4 of this report, would be necessary.

Ice from the Watana and Devil Canyon reservoirs will not be released downstream. Powerhouse releases will be made from below the ice cover and sufficient submergence will be provided above the intake to prevent ice entrainment. There will not be releases from the spillway or cove valves during ice cover periods.

A study of attenuation of water level and discharge variations resulting from powerhouse load following may indicate that powerhouse discharges can be fluctuated more than indicated and still result in much smaller water level fluctuations at sensitive habitat areas. Additionally, experience in operating the project will allow a better estimate of feasible powerhouse discharge fluctuations.

2. All respondents except two state that their organizations take no specific actions on their reservoirs to alter the state of ice on reservoir banks for wildlife safety reasons. The Power Board in Sweden has provided reindeer bridges where "natural crossings" cannot be used.

There will be ice on the banks of the Watana reservoir to between 40 and 90 feet below the maximum operating level from the preceeding year. Devil Canyon reservoir water levels would be constant during winter and bank ice will be minimized. The ice on the shore at Watana could cause some danger to animals crossing the banks. However, it is believed the greatest danger to animals would be during the short ice cover freeze-up and melt out periods in November and May, respectively, when the ice would not support animals. There is nothing that can be done to prevent this other than attempting to rescue the animals. The freeze-up and break-up periods are also dangerous times to cross the natural river.

3. All respondents except one state that their organizations take no actions to control cracks in reservoir ice cover that might be a hazard to animals.

A policy has been instituted at Lucky Peak Dam to minimize drownings of deer. This includes keeping the reservoir water level stable during the initial ice cover formation period, to prevent cracks or pockets of unsupported ice. Reservoir drawdown to required spring levels for flood control is accomplished either before initial ice cover formation, or after the cover has thickened sufficiently that the unsupported areas would be less of a hazard. It would be impractical to institute a similar policy at Watana since this would require that releases for power be curtailed for a an indefinite period in November when energy demands are high.

4. The permissible level of turbidity in water varies from state to state in the US and province to province in Canada. Our survey indicates these levels are for drinking water standards and human recreation and not for aquatic life. Manitoba attempts to set levels applicable to fish as follows:

   Class 2A - warm and cold water sport and commercial fish -
   limit = 10 JTU. (Jackson Turbidity Unit)
   Class 2B - warm and cold water sport and commerical fish -
   limit = 25 JTU.
   Class 2C - rough fish -
   limit = 25 JTU.

   Other agencies use a rule of thumb practice to restrict a turbidity change, for cold water rivers, to no greater than 10% beyond average seasonal turbidity level for protection of aquatic life and, thereafter, apply operational experiences, gained each season, monitored by specialists, to be used to guide future operations.

The report by L. Gatto indicates that local bank erosion can be expected at Watana during the ice cover melt out period when winds may blow the ice cover against the exposed banks. This would result in local increases in suspended sediments but would not affect the sediment load of the outflow significantly.

The large amounts of bank erosion experienced at Southern Indian Lake (see papers by Newbury, Hecky, McCullough) were a result of wave action on an exposed permafrost shoreline. This is not expected at Watana or Devil Canyon because of differences in operation. The Southern Indian Lake water level is nearly constant all year and the shoreline at one level is continually exposed to erosive forces. The Watana Reservoir will be drawn down continually during the winter and soil at one time exposed to waves and above freezing water will be covered with ice and allowed to refreeze. Thus, thermal niches, as occurred at Southern Indian Lake, are not expected to occur. Some erosion of bank material and vegetation removal will occur at Devil Canyon because of thermal expansion and wind force induced "ice push" of the stable ice cover. Additionally, the Devil Canyon and Watana Reservoirs are much deeper than Southern Indian Lake. The ratio of shoreline length to volume at Southern Indian Lake is over six times that at Watana and twice that at Devil Canyon. Thus, the shoreline erosion which would occur would have a much smaller effect on suspended sediment concentrations than at Southern Indian Lake.

	Area (km^2)	Volume (10^9 m^3)	Shoreline (km)	Mean Depth (m)	Residence Time (yr)
Southern Indian Lake	2391	23.38	3788	9.8	0.72
Watana	154	11.7	295	76	1.65
Devil Canyon	32	1.35	123	42	0.16

The soils at Southern Indian Lake are predominately silty clay, with wide spread permafrost at a depth of up to 10 m. In Watana and Devil Canyon the bank soil is generally silty sands, and permafrost is discontinuous. Soils eroded from the banks of Southern Indian Lake tend to stay in suspension and contribute to high turbidity levels because of their small size and low settling velocity. Soils eroded from the banks at Watana or Devil Canyon would settle quickly and not materially affect turbidity.

REFERENCES

Alaska Power Authority, 1985, Case E-VI Environmental Flow Regime, prepared by Harza-Ebasco Susitna Joint Venture

American Fisheries Society, 1985, Fisheries, January-February 1985

APPENDIX A

SUSITNA HYDROELECTRIC PROJECT

SURVEY OF EXPERIENCE

IN OPERATING HYDROELECTRIC PROJECTS

IN COLD REGIONS

APPENDIX A-1

MAIL SURVEY QUESTIONNAIRE

Prepared By

Harza-Ebasco Susitna Joint Venture

For the Alaska Power Authority

HARZA ENGINEERING COMPANY CONSULTING ENGINEERS

October 16, 1984

Gentlemen:

We are conducting a literature search and writing to various agencies and specialists to survey the state-of-the-art in ice control engineering which affects the environment. We would appreciate any information you and/or your organization could offer or suggest names of persons and organizations which we might contact on the following:

1. Procedures or operating policies used in the control of ice levels in rivers downstream and upstream of dams and hydropower plants caused by environmental water releases and power generating flow fluctuations in order to minimize the formation of ice jams and more importantly to minimize the associated flooding.

2. Environmental impact on terrestrial animals such as caribou, elk, bear, moose, etc., due to the formation of ice on wet reservoir banks exposed by reservoir drawdown or due to reservoir surface ice which has broken up at the banks. This ice may cause the animals to lose their footing and slip into the reservoir, resulting in injuries or drownings. What procedures, if any, have been taken to minimize this hazard?

3. The method of reservoir fluctuation management or precautions used in order to control the width of opening and pattern of crack development in the ice sheet such that after snowfall with cracks covered, the traversing animals would not fall into and be trapped in the cracks.

4. Problems of bank erosion caused by break-up and movement of ice resulting in increase of sediment in the reservoir and in the river downstream. What is the permissible degree of turbidity in parts per million or its equivalent that is acceptable for aquatic life such as salmon, trout, etc.?

150 SOUTH WACKER DRIVE CHICAGO, ILLINOIS 60606-4176
TEL (312) 855-7000 CABLE: HARZENG CHICAGO TELEX 25-3540

Please send reply to the attention of: Dr. David S. Louie
Harza Engineering Company
150 South Wacker Drive
Chicago, Illinois 60606 U.S.A.

or, if you wish, send collect to one of our telex numbers: 25-4444
25-3540
25-3527

or to our cable address: HARZENG CGO.

The telephone number is 312/855-3325.

Thank you in advance for your interest and effort.

Very truly yours,

David S. Louie
Chief Hydraulic Engineer

SUSITNA HYDROELECTRIC PROJECT
SURVEY OF EXPERIENCE
IN OPERATING HYDROELECTRIC PROJECTS
IN COLD REGIONS

APPENDIX A-2
COMPILATION OF RESPONSES

CANADA

Prepared By
Harza-Ebasco Susitna Joint Venture
For the Alaska Power Authority

ALBERTA: (Question No. 1 - Page 1)

University of Alberta; Edmonton, Alberta, Canada
Professor R. Gerard, Dept. of Civil Engineering.

(Handwritten note)
I believe the releases from the Bighorn and Brazeem Dams on the North Saskatchewan are restrained to avoid downstream ice problems. Certainly those from the W.A.C. Bennet Dam of British Columbia Hydro on the Peace River are.

(Editor's note - See responses from British Columbia Hydro and Trans Alta Utilities)

Trans Alta Utilities, Calgary Alberta, Canada
Mr. R.W. Way, Manager, Generation Scheduling.

RE: CONTROL OF ICE LEVELS IN RIVERS DOWNSTREAM OF OUR DAMS. We do monitor ice levels at certain points and adjust plant operations to a degree to try to maintain ice/water levels below critical elevations. This is particularly true at our Bighorn operation on the North Saskatchewan River where problems arise as the ice pack is building past sensitive reaches of the river downstream of our development. The adjustments to plant operations are to the total daily flowby and the variation of the flow during the day.

ALBERTA: (Question No. 2 - Page 1)

Alberta Energy and Natural Resources, Fish and Wildlife Division, Dennis C. Surrendi, Assistant Deputy Minister.

In the Province of Alberta there has been limited documentation of problems between reservoirs/reservoir operations and ungulates. Most of the documentation deals with habitat loss and management following reservoir construction. The existing reservoirs in Alberta are not in the path of any major ungulate migrations which minimize the likelihood for problems although some local problems may exist which are not documented.

Edmonton Power, Edmonton, Alberta T5J 3P4;
L. M. Johnston, P.E., Environmental Manager.

Regarding sediment levels in water flowing from hydro reservoirs, neither the Alberta nor Canadian Federal Governments have definitive levels and rely on motherhood clauses based on possible impacts. Water quality from mine drainage settling impoundments are required to meet a 50 mg/l or 10 mg/l above natural background (whichever is greater) requirement for suspended solids in both Alberta and British Columbia.

Alberta, Energy and Natural Resources, Fish and Wildlife Division, Dennis C. Surrendi, Assistant Deputy Minister.

The Fish and Wildlife Division is presently developing water quality criteria for the protection of fish and other aquatic life. Suspended sediment will be one parameter for which criteria will be developed. All potential man related sources of sediment will be expected to comply with the criteria. However, until we develop our own criteria we intend to use criteria establsihed by the Inland Waters Directorate of Environment Canada which is 25 mg/l.

Alberta Environment, Environmental Evaluation Services, Environmental Assessment Division, 11th Floor, Oxbridge Place, 9820-106 Street, Edmonton, Alberta, Canada, T5K 2J6,
R. L. Stone, MCIP, Head, EIA Review Branch.

Concerning bank erosion caused by breakup of ice and its movement, any of the contacts for Point 1 would be of assistance for this topic as well. These contacts may not be able to address of the particular aspect of allowable turbidity, however, they should be aspects as related to fish may be able to be addressed by the two Hydro companies, B.C. Hydro and Trans Alta, and additional information may be obtainable from personnel of Fish and Wildlife Division of Alberta Energy and Natural Resources. A further source of information along this specific line may be Mr. Chris Katopodis, P. Eng. of the Federal Freshwater Institute in Winnipeg (located on the University of Manitoba campus).

ALBERTA: (Question No. 4 - Page 3)

Trans Alta Utilities; Calgary, Alberta, Canada
Mr. R.W. Way, Manager, Generation Scheduling

RE: BANK EROSION - Gradual ice erosion rather than break-up occurs, so this is not a problem either.

BRITISH COLUMBIA: (Question No. 1 - Page 1)

B.C. Hydro, Vancouver B.C. V6B 4T6.
W. M. Walker, Vice President & Chief Engineer.

Procedures and Operating Policies Used in the Control of Ice Levels

At present, winter operation procedures for the control of ice/water levels are required only on the Peace River downstream of B.C. Hydro's two hydroelectric developments: Portage Mountain and Peace Canyon. The upstream Portage Mountain project consists of the W.A.C. Bennett Dam, Williston Lake reservoir and G. M. Shrun generating station. The installed generation capacity is 2416 MW. At normal full pool level (el. 672 m) the reservoir surface area is 1740 sq. km and the live storage is approximately 24 x 10^9 m^3 with a drawdown of 17 m. Flow releases from the Portage Mountain project discharge into the Peace Canyon reservoir. The installed generation capacity at Peace Canyon is 700 MW, and the reservoir surface area is 94 sq. km. Drawdown of the Peace Canyon reservoir is usually less than 2 m to provide pondage for the daily or weekly regulation of releases from Portage Mountain.

No special winter operation procedures for either the Portage Mountain or the Peace Canyon reservoirs have been required for ice control upstream of the dams. However, downstream of the Peace Canyon project high river stages during the winter have been experienced and are the cause of concern at flood prone areas. Two areas where the winter flood hazard is of particular concern are at the Town of Peace River, Alberta, approximately 370 km downstream of Peace Canyon, and just upstream of Taylor, B.C. approximately 100 km downstream of Peace Canyon. As a result, a joint

B.C.-Alberta Peace River Ice Task Force was formed in 1975 to monitor ice conditions and to recommend and co-ordinate operating procedures to minimize the flood hazard.

Winter operating procedures for Peace River projects, in general, emphasize power operation over ice-control, especially during December-February when the energy demand is relatively great. Nevertheless, we have been, in the past, able to provide an adequate degree of ice-related flood control, at critical times. During freeze-up, when the ice front is progressing upstream through the river reach at the Town of Peace River, relatively high, relatively constant turbine discharges at Peace Canyon are maintained, subject to limitations imposed on B.C. Hydro's integrated system by energy demands, are maintained. Because of the distance downstream from the Peace Canyon project (approximately 2 days flow travel time), hourly load/discharge fluctuations are almost completely attenuated at Town of Peace river, but daily average turbine flows are kept as constant as possible to reduce ice shoves at the leading edge of the ice cover and thereby minimize stage increase and backwater associated with ice cover formation. Relatively constant discharges are maintained from the time backwater from the advancing ice cover affects river stage at Town of Peace River, until the ice front moves upstream of the area of concern. Depending on the river discharge and the severity of the weather, the time required for an ice cover to form on the 50 km long reach could vary from a few days to 2 or 3 weeks.

During this period it is important that discharges remain relatively high so the ice cover is formed at a high enough stage and of sufficient thickness and strength to allow full flexibility of turbine discharge throughout the winter. Discharges should not exceed the formation discharge until the ice cover has had a chance to strengthen as a result of thermal penetration and consolidation of the ice blocks forming the initial cover.

The same procedure is adopted if the ice front approaches the upstream flood hazard area near Taylor. Usually, the maximum upstream advance of the ice front is downstream of Taylor, and only during severe winters is the open water reach downstream of Peace Canyon less than 100 km in length. If the ice front does reach Taylor, the hourly discharge fluctuations are not completely attenuated at this point on the river, and turbine operation may be varied to moderate shoving and stage increase at the leading edge of the ice cover.

Prior to break-up at the Town of Peace River, turbine discharges are maintained relatively high to erode and weaken the ice as much as possible. Ideally, break-up of the Peace River ice at Town of Peace River should occur before break-up of the Smoky River, a major tributary which joints the Peach River just upstream of the town. However, the time and rate of break-up depend primarily on prevailing weather conditions and spring freshet floods peaks from downstream tributaries, and cannot be controlled by increased turbine discharges. When break-up of the Smoky River appears imminent, turbine releases at Peace Canyon (as permitted by system energy demands) are reduced to maintain peak river discharges downstream of the Smoky/Peace River confluence below flood hazard levels.

BRITISH COLUMBIA: (Question No. 2 - Page 1)

B.C. Hydro,
W. M. Walker, Vice President and Chief Engineer.

B.C. Hydro presently takes no specific actions on its reservoirs to alter the state of the ice cover for wildlife safety reasons. Sporadic cases of deer drowning within ice-covered drawdown zones occur but we have no quantitative information on them. Routes for migratory species such as caribou do not cross any of B.C. Hydro's existing reservoirs.

British Columbia: (Question No. 3 Page 1)

Richard Bonar
British Columbia, Ministry of Environmental - Wildlife Branch
Revelstoke, British Columbia

(This is a summary of a conversation)

At the Revelstoke Hydroelectric project in British Columbia moose cross the impoundment ice with no apparent reluctance or difficulty when it is stable and generally avoid crossing when it is not. Many observations at this reservoir confirm that in almost all cases moose can climb out of the reservoir on to the ice after falling through weak spots. No ice related caribou mortalities have been noted at the Revelstoke project. Woodland caribou readily cross the reservoir during the winter when ice conditions permit, individually or in groups of up to 20 animals.

BRITISH COLUMBIA: (Question No. 4 - Page 1)

B.C. Hydro, Vancouver, B.C. V6B 4T6,
W. M. Walker, Vice President and Chief Engineer.

Problems of Bank Erosion. The existing practice in B.C. is to enhance and manage fisheries in reservoirs which have suitable basic characteristics and minimal fluctuation in water levels, e.g. run of the river reservoirs such as Peace Canyon. Both B.C. Hydro and the resource agencies accept that reservoirs with erodible banks, large draw-down zones and high sediment levels have limitations for fisheries management.

Manitoba Department of Natural Resources, Winnipeg, Manitoba R3E 3J5,
N. Mudry, Chief of Water Management.

This Branch operates three major flood control works; two of them have a reservoir. The reservoirs are operated for flood control during the spring and for water supply and recreation during the other seasons.

Portage Reservoir and Diversion:

When not needed for flood control, the Portage Reservoir is maintained near its full supply elevation of 869 feet. In October, the reservoir is drawn down to its winter level of about 853 feet. This takes about three weeks. The changes in water levels during the winter are very minimal and therefore the ice cover is quite stable. We are not aware of any problems with terrestrial animals.

During the spring break up period, the flows downstream in the river are controlled between 2500 and 5000 cfs. If the inflow exceeds these figures, the remainder is put into storage or is diverted out of the reservoir into Lake Manitoba via the Portage Diversion. A flow of 5000 cfs before ice in the channel has cleared out can result in ice jams. Thus to prevent ice jams which could cause overbank flows to occur, flows through the spillway control structure are limited to 5000 cfs. Under open water conditions, the minimum channel capacity of the river in this reach is about 10,000 cfs.

Shellmouth Reservoir:

During the summer, the reservoir is operated to maintain a level of between 1400.0 to 1402.5 feet. From October to April, the reservoir is gradually drawn to elevation 1391$\pm$ 3 feet depending on the estimated inflow during the spring period. The ice cover is stable and we are not aware of any problems with terrestrial animals.

During the runoff period in the spring, most of the inflow goes into storage. The release downstream in the case of ordinary floods is not great enough to cause ice jams or flood problems. However, if and when the reservoir rises above the spillway crest, discharges from the reservoir exceed the channel capacity downstream, the extent of which will depend on the magnitude of the flood.

Red River Floodway:

The Red River Floodway is an excavated channel which diverts flood waters of the Red River around the City of Winnipeg. At the point of diversion the river bed elevation is about 728 feet. The Floodway Inlet elevation is 750 feet. The amount of water to be diverted is controlled by the Inlet Control Structure located in the river downstream of the Floodway Inlet. During the break up period, the water level in the river is allowed to rise naturally to elevation 750 feet. At this point, if the ice is moving in the river then the water level is raised to at least elevation 751 feet. This is to prevent erosion at the entrance of the Floodway Inlet. However, if the ice in the river is stationary, we would delay rising the water level upstream of the Inlet Control Structure until the ice begins to move freely in the river. The objective here is to prevent ice flowing into the Floodway which could form ice jams at bridges across the Floodway and thus reduce the carrying capacity of the Floodway. Our experience to date has shown that as long as the ice is moving in the river it will not flow into the Floodway.

In addition to the above works, we also operate numerous in-channel water supply dams. During freeze up, we increase the outflow from all water supply dams until a solid ice cover forms in the river. Then the outflow is reduced as required. This action permits the water to flow freely under the ice cover. Increasing outflows beyond the original release rate at freeze-up tends to lift the ice cover which causes ice build-up resulting in increased backwater over the rest of the winter and ice jams during break up.

Manitoba Hydro; Winnipeg, Manitoba, Canada
K.J. Fallis, Executive Engineer, Corporate Planning

Each of our plants has associated with it a unique set of restrictions or operating policies. These restrictions are usually established by licence constraints which restrict such things as range of fluctuation, maximum draw down, maximum rate of discharge, etc. These are usually established out of concern for the environment, but also with recognition of a preferred mode of operation for power production purposes. In one instance these restricitons are related to the formation of slush ice on a lake immediately downstream which is traveled in winter by local inhabitants.

We attempt to mitigate the effects of flooding during the initial creation of reservoirs and compensate for damage when this occurs.

MANITOBA: (Question No. 2 - Page 1)

Manitoba Hydro; Winnipeg, Manitoba, Canada
K.J. Fallis, Executive Engineer, Corporate Planning

We have no regulation constraints established particularly for the protection of terrestrial animals. Furthermore, we are unaware of any significant impact that has occurred as the result of reservoir or river flow fluctuations. Most reservoir banks are gradual in slope and rates of change are slow. Because losses are minimal, it is our policy to compensate for such damages if and when they are shown to have occurred.

MANITOBA: (Question No. 3 - Page 1)

Manitoba Hydro; Winnipeg, Manitoba, Canada
K.J. Fallis, Executive Engineer, Corporate Planning

We have no operating restrictions designed to control the width or pattern of crack development in reservoirs. On occasion, we utilized ice booms to accelerate the formation of ice covers where velocities are critical in the formation of natural ice covers. In one location special operative techniques (controlled velocities) are utilized during the fall freeze up period to enhance the orderly formation of an ice cover. The prime consideration is to minimize the formation of hanging dams, etc. in order to maximize winter discharge capacity.

We have no knowledge of terrestrial animals being injured or drowning due to crack patterns created by reservoir operations.

MANITOBA: (Question No. 4 - Page 1)

Government of Canada, Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba, R3T 2N6,
R. W. Newbury, Hydrologic Studies.

Please find enclosed several reprints and titles of recent articles dealing with the erosion of permafrost shorelines in large northern reservoirs.

Received one article: Shoreline Erosion and Restabilization in a Permafrost-affected Impoundment. R. W. Newbury and G. K. McCullough reprinted from Permafrost: Fourth International Conference, Proceedings, ISBN 0-309-03435-3 National Academy Press, Washington, D.C. 1983. Also received 1 page listing of contents of Canadian Journal of Fisheries and Aquatic Sciences, Vol. 41, No. 4, April 1984. All articles in this issue are of Southern Indian Lake, Manitoba, Canada.

MANITOBA: (Question No. 4 - Page 2)

Manitoba Hydro; Winnipeg, Manitoba, Canada
K.J. Fallis, Executive Engineer, Corporate Planning

Bank erosion problems created by ice movement associated with development work are not considered to be particularly serious. Many of our northern rivers experience considerable erosion due to ice formation created in their natural state. Most bank erosion problems result from the inundation of new land with newly created reservoirs. In one instance this is further aggravated by the presence of permafrost which recedes, in time, after inundation.

NEW BRUNSWICK: (Question No. 1 - Page 1)

New Brunswick Electric Power Co., Fredericton, NB E3B 4X1,
Glen McCrea, Assistant Manager Plant Operations (Hydro).

I will try to answer each of your points as directly as I can although in some cases they do not directly apply to N.B. Power operation of our reservoirs along the Saint John, Tobique and Saint Croix Rivers.

The three major hydro developments in our system are located on the mainstem of the Saint John River. Storage capacities of the headponds are very small and water level fluctuation in them is insignificant. These conditions allow for the establishment of stable solid ice covers over most of the length of the headponds. However peaking operating schemes of the plants could have some effects on the formation of the ice cover in areas immediately downstream of the tailraces. In order to discourge frequent breakup during the initial freeze up process, discharges from the hydro plants are held constant, whenever possible, during this period until stable ice cover is formed.

During break-up season, efforts are made not to accelerate the break-up process and let the ice covers disintegrate in place whenever possible. This will normally reduce the possibility of ice jam formation in the upper end of the headponds. However, if flow and weather conditions cause the ice covers to break prematurely, ice jams could form causing some flooding to the extreme low lying areas in the upper reach of the headpond.

The effects of the water level at the dam on the formation and releases of ice jams in these areas had been studied by "Acres Consulting Services Ltd.", of Niagara Falls, using the "ICESIM" mathematical model. Results of these studies has been used to formulate our operation strategy when an ice jam is formed in the headpond. For further information about the "ICESIM" model you may contact Mr. S. T. Lavender of Acres; telephone no. (416)354-3831.

Analysis of ice and flow records show that the construction and the operation of our reservoirs system on the Saint John River has resulted in significant reduction in ice related floods downstream of the hydro plants. It is of interest to note that since the construction of the Mactaquac dam in 1966, ice jams and ice related floods have been eliminated completely in the downstream reach; an area subjected to frequent ice jam flooding before the construction of the Mactaquac development.

NEW BRUNSWICK: (Question No. 2 - Page 1)

The New Brunswick Electric Power Commission,
Glen McCrea, Assistant Manager Plant Operations (Hydro).

We have generally very small reservoir draw-down in all of our reservoirs and most of them are in areas where wild animals do not seem to travel; therefore we have no known problems with animal injuries or drowning as a result of drawdown. Similarly we have no known problems with animals falling in cracks or openings along our reservoirs.

NEW BRUNSWICK: (Question No. 4 - Page 1)

The New Brunswick Electric Power Commission, Fredericton, N.B., E3B 4X1,
Glen McCrea, Assistant Manager Plant Operations (Hydro).

We have some bank erosion along our reservoirs; however, sediment in our reservoirs and river downstream is not identified as a problem. There is no known permissible degree of turbidity in the Saint John, Tobique, or Saint Croix River systems.

NOVA SCOTIA: (Question No. 1 - Page 1)

Nova Scotia Power Corporation, Halifax Nova Scotia,
L. R. Feetham, Manager, Hydro Power Department.

The Nova Scotia Power Corporation does not have a written operating policy for the control of ice levels in rivers where Hydro installations exist. The problem has never been a serious one due mainly to the fact that we have a maritime climate greatly affected by the close proximity of the North Atlantic. Ice covers in moving water such as canals and forebays have caused us very little problem. Anchor ice from spring backup does retard flow to one of our installations but a bypass sluice permits us to dispose of this ice in quick fashion.

Probably of more concern in Nova Scotia is a phenomenon which occurs when turbulent waters reach the freezing point; millions of ice needles form, which are referred to as Frazil Ice. This ice has, on occasion, plugged intakes and scroll cases and has to be dislodged by maintenance crews and flushed through the turbines. It does shut several of our units down for short periods of time. To my knowledge, no one has come up with a sure and fast solution to preventing it.

Bubblers are used to a fair extent upstream of spillways to keep areas clear of thick ice which might interfere with spilling or bypassing water.

I would suggest a contact with the Canadian Electric Association, who presently have a research project proposal under consideration entitled "Hydro-Power Station Operations under Conditions of Supercooled Water Supply Anchor Ice". A copy of the proposal is enclosed for your consideration.

Water fluctuations in reservoirs and headponds are the standard for operation practice and do not cause us problems.

Nova Scotia Department of the Environment, Halifax, Nova Scotia B3J 3B7,
H. T. Doane, Environmental Engineer, Water Resources Planning.

In Nova Scotia we have very few rivers that would pose a drowning threat to large mammals. Most of our rivers can be waded by a man by choosing a site within a mile of where he finds himself. These shallow rivers do not form smooth continuous ice covers such as you seem to have in mind. We do have several hydroelectric power reservoirs, but these are modified lakes, not drowned river valleys. Water levels are not regulated with effects on wildlife in mind, but only with the intent of maximum economic benefit from the power generation, or adequate water supplies for the users.

In response to your questions:

No attempts, that I know of, have been made to control ice levels to affect ice jamming or flooding. Reservoirs generally do not discharge ice and this, to some degree, reduces ice jams downstream.

There is considerable bank erosion, due in part to ice movement and freezing and thawing. It is a concern to landowners, and a lesser concern to fisheries managers, in the federal Department of Fisheries and Oceans. The principal concern by Fisheries with turbidity is the blanketing effect of silt on spawning beds. Erosion of stream banks is controlled to some extent by placement of large quarried rocks or boulders, on stream banks. Proposals to bulldoze gravel bars out of mid stream in rivers are viewed with disfavour by Fisheries and Environmental departments staff. Removal of such bars is seen by others as an answer to ice jam problems, since the bars apparently initiate ice jams.

A brief conversation with the Manager, Wildlife Resources in Nova Scotia Lands and Forests Department, Mr. Arthur Patton, failed to elicit concern about the effects of ice on wildlife, or at least any concern about reservoir management and its effects on large animals. You might wish to contact Mr. Patton or his supervisor, Merril Prime at P.O. Box 516, Kentville, N.S., B4N 3X3.

To summarize then, it appears we do not have any practices in reservoir operation that are affected by environmental protection concerns. Even this rather negative response may be of some help to you in your project I suppose.

NOVA SCOTIA: (Question No. 2 - Page 1)

Nova Scotia Department of the Environment, Water Resources Planning,
H. T. Doane, Environmental Engineer.

No procedures, that we know of, have been taken to protect large animals from ice hazards. The hazards are not perceived to be significant. No procedures are used to control cracks in reservoir ice that might be a hazard to animals.

Nova Scotia Power Corporation,
L. R. Feetham, Manager, Hydro Production Department.

I can only recall one instance where a moose went through a thin cover of flowage ice but we managed to rescue the animal.

NOVA SCOTIA: (Question No. 4 - Page 1)

Nova Scotia Power Corporation,
L. R. Feetham, Manager, Hydro Production Department.

Bank erosion has to be watched and rock rip-rap repaired or replaced on occasion. This is not a serious problem and can be classed as normal maintenance.

Nova Scotia, Department of the Environment, Water Resources Planning, Halifax, Nova Scotia, B3J 3B7,
H. T. Doane, P. Eng., Environmental Engineer,

There is considerable bank erosion, due in part to ice movement and freezing and thawing. It is a concern to landowners, and a lesser concern to fisheries managers, in the Federal Department of Fisheries and Oceans. The principal concern by Fisheries with turbidity is the blanketing effect of silt on spawning beds. Erosion of stream banks is controlled to some extent by placement of large quarried rocks or boulders, on stream banks. Proposals to bulldoze gravel bars out of midstream in rivers are viewed with disfavour by Fisheries and Environment departments staff. Removal of such bars is seen by others as an answer to ice jam problems, since the bars apparently initiate ice jams.

A call to Mr. Don Cox, of Canada Fisheries and Oceans, P.O. Box 550, Halifax, N.S., B3J 257, indicates they consider turbidity above 10 mg/L may be detrimental. Effluents regulations for the mining industry specify not more than 25 mg/L in effluent. Hatchery experience indicates 15 mg/L causes some mortaility among small fry. You could contact Mr. Cox or his colleague Mr. David Morantz for further discussion on turbidity effects on salmon and trout.

ONTARIO: (Question No. 1 - Page 1)

National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6.

The Hydraulics Division, National Water Research Institute, has been conducting research on the mechanics of ice jams for a number of years. Dr. Spyros Beltaos is the primary researcher in this area and I am enclosing several of his reports on ice jam theory which you may find useful.

Because of the complexity of the phenomenon, a complete understanding of ice jam behaviour is still not available. Therefore, many of the operational procedures at dams and hydro-power plants are still based on operatos' experience. The engineers at Ontario Hydro and Hydro-Quebec may be able to provide you with some of this operating information. They may also be able to help you with information concerning animal control.

Water Planning and Management Branch, Ottawa, Ontario K1A 0E7, J. Bathurst, Chief, Engineering and Development Division.

1. Private and public utilities would be useful sources to investigate for information of this type. We are not aware of any specific "environmental water releases" that cause ice problems and therefore require appropriate operating policies. However there are certainly control dams and power plants in this country which have operating procedures designed to discourage the formation of ice jams and minimize flooding. For example, generating flows through power plants on the St. Lawrence River, at times of ice formation, take into account the need to establish, as quickly as possible, a firm and smooth ice cover that will permit winter discharges

sufficient to regulate the level of Lake Ontario as prescribed by the International Joint Commission. Hydro-Quebec, Ontario Hydro and the New York State Power Authority would be the agencies to contact for information on this practice. It is also believed that the New Brunswick Electric Power Commission has well defined operating policies on some plants related to control of ice conditions.

Ontario Hydro, Toronto, Ontario M5G 1X6,
W. G. Morison, Vice President, Design & Construction Branch.

The objective of ice control is to maintain the capability of channels to carry the prescribed releases from reservoirs. Ontario Hydro utilizes a number of strategies to handle ice conditions on a site specific basis.

Two types of river systems are generally encountered. They are described as follows:

1. The river velocity creates a situation not conducive to ice cover formation either through structural or procedural means.

2. River velocity creates a marginal situation for ice cover formation and where structural and procedural efforts can contribute significantly to the establishment of a smooth stable ice cover.

In the first case all effort is focused toward keeping the ice moving past critical intake areas. This asumes that there is infinite storage capability downstream where the ice can be flushed, such as a large deep lake that does not freeze over in the winter season. Excavations, channels, control works, special design intakes have been constructed to facilitate this. Ice breaking boats have been commissioned. Procedures have been established to cover:

1. Fundamental principles which must be applied to circumstances as they occur in each unique combination.

2. Detailed procedures and step-by-step methods of handling a particular circumstance.

Great effort is spent in programs for observing, recording and reporting ice conditions so that:

1. Operational decisions are based on current data.

2. Management can be kept up-to-date.

3. Government agencies can be supplied with required information.

4. Future operations may be improved.

In the second case, all efforts (physical and procedural) are directed towards forming an ice cover (eg, St. Lawrence River). Velocities are controlled to encourage the formation of a smooth stable ice cover. Depending on climatic conditions, once the cover has formed, higher flows can be scheduled. Generally, short-termed power needs are sacrificed in order to ensure greater long-term production. During the ice breakup period, flows can be further adjusted to assist in wearing away the ice cover in a controlled fashion.

ONTARIO: (Question No. 2 - Page 1)

Ontario Hydro,
W. G. Morison, Vice President, Design and Construction Branch.

With respect to question 2 (ice and wildlife problems), we do not have major concerns with caribou at our facilities in Ontario.

ONTARIO: (Question No. 4 - Page 1)

Environment Canada, Water Planning and Management Branch, Ottawa, Ontario, KlA OE7,
J. Bathurst, Chief, Engineering and Development Division.

A suggested source for information is Vol. 41, number 4, Canadian Journal of Fisheries and Aquatic Services. The authors - Newburg, Hecky and others - could be contacted personally at the Freshwater Institute in Winnipeg, Manitoba. Another person to contact would be Dr. R. Baxter at the National Water Research Institute in Burlington, Ontario. Power agencies may also have information on the subject.

Permissible levels of turbidity are difficult to define and vary in this country from province to province. They can either be absolute or defined as a permissible degree of change. Usually they are given for drinking water standards and seldom for aquatic life. The province of Manitoba, however, has attempted stream classifications applicable to fish, i.e.;

Class 2A - warm and cold water sport and commercial fish - limit = 10 JTU.

Class 2B - warm and cold water sport and commercial fish - limit = 25 JTU.

Class 2C - rough fish - limit = 25 JTU.

The province of Ontario, for instance does not permit Secchi disc readings to change by more than 10%. Alberta's objectives suggest changes be less than 25 JTU's over natural turbidity. Saskatchewan also suggest less than 25 JTU's over natural.

ONTARIO: (Question No. 4 - Page 2)

The problem of erosion is much more complex than just turbidity; for example, the raising of South Indian Lake in Manitoba elevated natural mercury levels. The nature or cause of the turbidity is also important. Large colloidal particles causing the turbidity may also cause an abrasive effect on fish gills, etc.

For specific limits for particular fish, it is best to contact provincial environmental departments and federal and provincial fisheries agencies.

Ontario Hydro, Toronto, Ontario, M5G 1X6,
W. G. Morison, Vice President, Design and Construction Branch.

With respect to problems of such erosion caused by the breakup and movement of ice, little information is available. While some evidence of earth breaking away from the shore as the ice breaks up has been noticed there is no formal documentation.

In respect to turbidity changes as result of bank erosion, etc., a rough rule of thumb is to restrict a change of no greater than 10% beyond existing conditions for protection of aquatic life.

QUEBEC: (Question No. 1 - Page 1)

Universite Laval, Department of Civil Engineering, University City, Quebec GIK 7P4,
Dr. Bernard Michel, Professor.

It is extremely difficult to get information in this field. Here are some comments.

Hydro power operations. No firm would admit it is causing any jam or modifying the ice cover. Example; (New Brunswick Power Commission - Case in court - flooding by ice jams in the Mattakwac reservoir - B. C. Hydro - flooding downsteam of Peace River).

Quebec (Question No. 1 Page 2)

Societe d'Energie de la Baie James
Montreal, Quebec
Onil Faucher, Chief of Environmental Studies Department

... we will briefly describe the principal observations and measures that we carried out at the La Grande Complex and, on the other hand, we will give a specific answer to your questions...

Since the LG 2 powerhouse and other works of the Complex have been put in operation, the downstream part of the La Grande River presents an increase and a regularized flow and since the electric demand is more important in winter the flow is also more important in winter. In general, this flow increase does not cause ice jams downstream from LG 2 powerhouse but has a tendency to increase water levels that, due to the steepness of the river banks, do not cause inundation.

However, this winter flow increase causes ice-cover instability in front of the Chisasibi community. This is the most important repercussion since some Chisasibi cree trappers cross the River on the ice-cover to get to their hunting territories. The unstable ice-cover, at that spot, reduces the period while trappers can safely cross the river. Nevertheless, to counteract this problem, SEBJ built at the site of the future LG 1 powerhouse, a bridge that allows cree trappers to cross safely the river.

Quebec (Question No. 1 Page 3)

Specific answers to your questions

Procedures or operating policies used in the control of ice levels

From a technical point of view, the La Grande Complex works operating modalities have been optimized to reduce all inconvenients related to the ice-cover instability or to the formation of frasil ice. Nevertheless, in particular for the diversion zone, some environmental criteria have been included in the optimization of operationg modalities of the La Sarcelle (discharge of Opinaca reservoir) and Brisay (discharge of Caniapiscao Reservoir) regulaiton works in order that the ice condition on the path of diverted waters be stable enough to stop the formation of ice jams and consequently stop supplementary inundation due to the increase of water levels. Furthermore, in these areas, some environmental works (canalization, construction of protection dykes and bunds) were carried out to control the water flow and by doing so reduce the inundated surfaces.

QUEBEC: (Question No. 2 - Page 1)

Universite Laval, Department of Civil Engineering, University City, Quebec GlK 7P4,
Dr. Bernard Michel, Professor.

Environment Canada has given many contracts to study the effects of ice on animal crossings in ship's tracks.

Societe d'Energie de la Baie James
Montreal, Quebec
Onil Faucher, Chief of Environmental Studies Department

Environmental impact on terrestrial animals

In the La Grande Complex, the formation of the ice-cover or the breakage of the ice-cover due to the drawdown effect has caused no impact on the various animal population such as caribou, moose, wolf, etc. The animal the most liable to use the bare reservoir zones are caribous. Even if caribou is found in the Caniapiscau, Laforge diversion, LG 4 and LG 3 regions, the reservoirs are not used as a migration zone. On the other hand, in some sectors, the edge of the reservoir forms an ecotone zone that is used by small mammals or by predators.

Quebec (Question No. 3 Page 1)

Sociele de'Energie de la Baie James
Montreal, Quebec
Onil Faucher, Chief of Environmental Studies Department

Method of reservoir fluctuation management

Since the reservoirs are not used by the fauna and since they are not used as migration path, no precaution or reservoir fluctuation management is needed to control the width of opening and pattern of crack development in the ice sheet.

Hydro-Quebec
Montreal, Quebec
Jean-Claude Rassam, Division Chief

In response to your letter dated January 16, 1985 to Mr. J. G. Dussault, and which was forwarded to us on March 19, we are pleased to provide you with two examples with ice management cases that affects the environment.

In the case of the Eastmain - Opinaca diversion of the La Grande system (James Bay Project), the level of Lake Sakami is maintained at its highest level from the beginning of the winter in order to allow free access of the beavers to their huts. More details on the subject could be found in the E.O.L. diversion report which is to be requested from Mr. Marc Drouin of the Societe d'Energie de la Baie James, 850 est de Maisonneuve, Montreal, Quebec.

QUEBEC: (Question No. 4 - Page 1)

Universite Laval, Department of Civil Engineering, City University, Quebec G1K 7P4 Canada,
Dr. Bernard Michel, Professor.

J. C. Dionne, one of my colleagues at Laval is studying very seriously this question. Included is a copy of one of his recent papers to set you on the way.

Included with this letter, is a publication for reference:

Dionne, J. C. 1984. An estimate of ice-drifted sediments based on the mud content of ice cover at Montmagny, Middle St. Lawrence Estuary. Mar. Geol., 57:149-166.

Societe d'Energie de la Baie James
Montreal, Quebec
Onil Faucher, Chief of Environmental Studies Department

Bank erosion and water quality

On the shores of the La Grande Complex reservoirs, bank erosion is a minor phenomenon and in general the principal erosion agent is not ice action but the combined effect of wind and waves.

On the other hand, downstream from LG 2, La Grande River bank erosion is much more important since the combined effect of level variation resulting from flow control and waves form the principal erosion agent.

As far as turbidity in the reservoir is concerned, it can increase by a few parts per million during the first few years of operation. In the La Grande River, the active shores give more sediments to the river and turbidity can increase by some 10 ppm mostly during summer and fall but these turbidity conditions do not affect the fish population characteristics of this northern milieu (whitefish, walley, pike, etc.).

In conclusion, we have to recall that the integration of environmental consideration in the conception of works in La Grande Complex allowed to benefit from, to reduce or minimize the ice effect on the environment.

SASKATCHEWAN: (Question No. 1 - Page 1)

Saskatchewan Power Corporation, Regina, Saskatchewan S4P 0S1
R. J. Stedwill, Manager, Environmental Studies.

Procedures or operating policies used in control of ice upstream and downsteam of hydroelectric facilities is normally facility specific; and in the case of Saskatchewan Power Corporation operations, these are worked out on an annual basis with the Saskatchewan Water Corporation. These procedures are also dependent on existing water conditions and forecasts.

A contact person within the Saskatchewan Water Corporation is:

D. Richards,
Saskatchewan Water Corporation,
3rd Floor,
2121 Saskatchewan Drive,
Regina, Saskatchewan.
S4P 4A7

Saskatchewan Parks & Renewable Resources, Box 3003, Prince Albert SK S6V 6G1,
B. L. Christensen, Fish Habitat Protection, Coordinator.

Saskatchewan currently has only two major hydro-electric generating stations; a third is scheduled to come on stream toward the the end of 1985. Although both the existing hydro-electric reservoirs are subject to winter drawdowns, we are not aware of any adverse environmental effects caused by fluctuating ice levels or formation of ice jams downstream.

SASKATCHEWAN: (Question No. 2 - Page 1)

Saskatchewan Power Corporation,
R. J. Stedwill, Manager, Environmental Studies.

At this point in time, injuries or drownings of animals due to poor ice conditions has never been a problem to my knowledge.

SASKATCHEWAN: (Question No. 4 - Page 1)

Saskatchewan Parks and Renewable Resources, Fisheries Branch,
Prince Albert, SK, S6V 6G1, Canada,
B. L. Christensen, Fish Habitat Protection Coordinator.

"Saskatchewan currently has only two major hydro-electric generating stations; a third is scheduled to come on stream toward the end of 1985. Although both the existing hydro-electric resevoirs are subject to winter drawdowns, we are not aware of any adverse environmental effects caused by fluctuating ice levels or formation ice jams downstream."

Saskatchewan Power Corporation, Regina, Saskatchewan, S4P 0S1,
R. J. Stedwill, Manager, Environmental Studies.

"Point No. 4"

In response to this particular question, I believe the actual impact of turbidity in the water on fish "directly is not as severe as the impact which affects the fish indirectly. Silting of fish rearing grounds and feeding areas are far more significant than direct exposure.

Cole (1941), Van Oosten (1945), and Wallen (1951) suggest that fish could be harmed in exceptionally turbid waters under very unusual conditions; however, Pentelow (1949) has noted that sea trout regularly pass up a river through china clay with no apparent harm.

It should also be noted that scouring of river edges and increased turbidity is a natural phenomenon and reservoirs upstream of dams do, in fact, reduce turbidity levels during the spring run-off as well as at other times of the year.

Should you require any further elaboration on these points, feel free to contact this office.

Saskatchewan Environment, Regina, Canada S45 OBl,
H. S. Maliepaard, Executive Director, Environmental Information.

A review of the limited number of environmental impact assessments which have been carried out for reservoir development in Saskatchewan revealed that duration of ice cover and timing and amount of winter drawdown were the major concerns. These concerns related more to the fisheries resource than to terrestrial animals. Bank erosion was a recognized problem not only with ice break-up and movement in the spring, but also with wave action during the summer months. Some studies suggested that sediment levels downstream of the dam might even be reduced from that which naturally occurs.

SUSITNA HYDROELECTRIC PROJECT
SURVEY OF EXPERIENCE
IN OPERATING HYDROELECTRIC PROJECTS
IN COLD REGIONS

APPENDIX A-3
COMPILATION OF RESPONSES

UNITED STATES

Prepared By
Harza-Ebasco Susitna Joint Venture
For the Alaska Power Authority

MAINE: (Question No. 1 - Page 1)

Kennebec Water Power Co., Waterville, Maine 04901,
Allen J. Carson, River Engineer.

We control only the headwaters of the Kennebec River; therefore the operating policies of Central Maine Power Company on downstream plants might shed some light on your request.

MAINE: (Question No. 1 - Page 2)

Union Water Power Company; Lewiston, Maine
William M. Grove, Agent and Engineer

The winter operating procedure on the Androscoggin River is one of run-of-river at all hydro power stations. This allows a steady formation of ice both above and below the station. Above the station of course, the slowed velocity of water freezes more quickly and to a greater depth than below the station where the velocity is inherently greater. We have a greater problem of ice jamming that is created more from natural causes than from power station operation. This river has several natural constrictions in the form of 'doubling bends' that restrict river flows and act as gathering areas for tributary ice discharges created by unseasonable freshets. Power stations on this river are well separated from these problem areas and cannot be considered to be a contributing factor to flooding.

MAINE: (Question No. 2 - Page 1)

Maine Department of Inland Fisheries and Wildlife,
Frederick B. Hurley, Jr., Director, Bureau of Resource Management.

We apparently experience few problems with animals slipping into reservoirs or through cracks in the ice. At least to the best of my knowledge at this time it has not been identified as a problem so no policies or measures have been developed to deal with it.

MAINE: (Question No. 2 - Page 2)

Union Water Power Company; Lewiston, Maine
William M. Grove, Agent and Engineer

In response to your questionnaire regarding state-of-the-art in ice control, please accept my apology for not responding more promptly. In general we find little natural peril for terrestrial animals and in fact can find some benefit from reservoir drawdown. More on this later. Specifically I will answer the survey in order of presentation.

The nature of reservoir freezing during drawdown does not allow wet reservoir banks to exist. The drawdown is gradual thus allowing solid freezing of the water. There are no exposed areas where an animal would become entrapped in a combination of wet mire and reservoir ice. At the time of freezing, the reservoir ice has formed sufficiently to support the weight of animals. Our experience of over 100 years of operation is that we do not have migratory animals in the true sense of the word. Never have my people reported seeing moose or deer on the reservoir surface of their own accord. The deer expecially are at far greater hazard from packs of predator coy-dogs that drive them on to the ice where they lose their footing and become easy prey. Bears hibernate in the winter.

In addition to the above there are advantages to reservoir shore ice formation. It shields the reservoir surface from freezing temperatures thus allowing open water to the many wildlife who depend upon water for their very existence. We have otter and muskrat and mink who could not exist without the formation of ice shelves for access. These shelves provide protection against their natural enemies and the harsh New England weather that is their habitat.

This reservoir system has been in operation continuously for over 100 years and we have not observed any calamity to wildlife that has not occurred in non reservoir conditions.

In the case of migrating caribou where thousands of animals constituting tons of hoof striking force on any questonably frozen surface, it is a lot to expect that the ice surface will always support them under all conditions or that some interruption in the ice surface will not create some hazard. Wind blown ice gives little if any traction to cloven hooved animals. Similarly hazardous conditions exist in drifted snow fields and concealed brooks and streams.

Having observed winter conditions first hand, it seems somewhat facetious consider that any manipulation of reservoir levels could or would affect formation or ridges or cracks that would be any more or less hazardous than naturally frozen lakes.

MAINE: (Question No. 3 - Page 1)

Kennebeck Water Power Co., Waterville, Maine, 04901,
Allen J. Carson, River Engineer.

I am not aware of any environmental impacts as a result of reservoir drawdowns.

In Maine, most large animals stay off the ice as they are unable to maintain mobility - especially the hooved animals.

Union Water Power Company; Lewiston, Maine
William M. Grove, Agent and Engineer

The formation of ice cracks/ridges is far more severe on natural lakes where the only relief for ice pressure is the formation of ridges. The very nature of reservoir operation relieves these pressures as the reservoir is drawn. The formation of these ridges is practically non existent on our reservoirs. Our reservoirs do not fluctuate as such. The draw is continually downward and does not reverse itself until the spring fill period has started. Reservoir fluctuation is annual in that the reservoirs are filled once in the spring and drawn over the rest of the year reaching their lowest level on the last day of March (average).

MAINE: (Question No. 4 - Page 1)

State of Maine, Department of Environmental Protection, Bureau of Land Quality Control, Augusta, Maine,
Dana Paul Murch, Hydropower Coordinator.

In response to your question on turbidity, I am enclosing a copy of the State Laws classifying inland and tidal waters. Basically, there are five classifications of inland waters: A, B-1, B-2, C and D. Class A standards specify that "there shall be no disposal of any matter or substance in these waters which would impart... turbidity...other than that which naturally occurs in said waters." The standards for all other classifications specify that "there shall be no disposal of any matter or substance in these waters which imparts...turbidy...which would impair the usages ascribed to these classifications.

State of Maine, Department of Inland Fisheries and Wildlife, Augusta, Maine 04333,
Frederick B. Hurley, Jr., Director, Bureau of Resource Management

"Item No. 4 regarding turbidity is also best answered by the Department of Environmental Protection pursuant to their overall jurisdiction under State Water Quality Classification. Again, our Department has no established accepted or "permissable" degree of turbidity for waters containing salmonids."

Kennebec Water Power Co., Waterville, Maine 04901. Allen J. Carson, River Engineer.

MAINE: (Question No. 4 - Page 2)

We have had erosion of embankments due to spring break-up, but attempt to keep reservoir levels below full pond at break-up to minimize impacts. The Maine Department of Environmental Protection maintains standards for water quality classifications.

MAINE: (Question No. 4 - Page 3)

Union Water Power Company; Lewiston, Maine
William M. Grove, Agent and Engineer

The reverse is true at so called break-up time. This peroid is marked by a closing of the reservoir discharge gates thereby stilling the reservoir waters from any flow. As the reservoir rises, the ice that was formed during the drawdown period and which is still in place along the shore, merely falls into place with the rising water level. This prevents movement from wind and restricts any subsequent shore line damage. While there are years that late melting ice fields can create problems when the wind blows, this is not different from natural lakes that have problems annually and can create severe shore line damage. Therefore, there is virtually no problem beyond what occurs naturally in the way of turbidity. My biologists tell me that this is a non problem and therefore has not been worthy of study. Downstream of the reservoir is much the same as above. Since the gates have been closed except for minimum flow requirements, there is insufficient flow to create river bank erosion. Any shore ice melts rather uneventfully as nature takes its course.

MONTANA: (Question No. 1 - Page 1)

Montana Environmental Quality Council, State Capitol, Helena,
Montana 59620,
Howard Johnson, Environmental Scientist.

Thank you for your letter requesting information on ice-control engineering and related environmental problems in Montana. Although ice jams and flooding are concerns in the lower Yellowstone River basin, I am not aware of specific concerns or work related to impacts on terrestrial animals.

NEBRASKA: (Question No. 1 - Page 1)

Nebraska Public Power District, Environmental Affairs, Columbus, Nebraska 68601,
Eric N. Sloth, Division Manager.

At Gentleman Station, a 1300 MW total coal fired steam electric generating station on the south shore of Sutherland Reservoir, warm water recirculation to the water intake structure occurs during the winter months to minimize icing conditions. Other than that we have no procedures or operating policies used in the control of ice levels in rivers downstream and upstream of dams and hydro-plants in our system.

NEBRASKA: (Question No. 4 - Page 1)

Nebraska Public Power District, Environmental Affairs, Columbus, Nebraska 68601,
Eric N. Sloth, Division Manager.

The Nebraska Water Quality Standards state that turbidity caused by human activity shall not impart more than a 10 percent increase in turbidity, as measured in Jackson Turbidity Units, to the receiving water.

OREGON: (Question No. 1 - Page 1)

Pacific Power & Light Co., Portland, Oregon 97204,
S. A. deSousa, Manager, Civil Engineering.

Pacific does not operate any project at which ice formation in the river is of any conseqence. There is one small reservoir within Pacific's system that periodically freezes over, but no special procedures are required for operation during such occasions.

U.S. ARMY CORPS OF ENGINEERS: (Question No. 1 - Page 1)

Department of the Army, Detroit District, Corps of Engineers, Carl Argiroff, Chief, Planning Division.

Concerning the control of ice in rivers downstream and upstream of dams and power plants, we have both studies and practical experience in stabilizing ice covers to allow passage of vessels and still maintain a stable flow of water for hydropower and prevent the formation of ice jams, through the use of floating log ice booms. Work in this area has been done primarily on the St. Marys River at Sault Ste. Marie, Michigan, on the Niagara River at Buffalo, New York, and along the St. Lawrence River. Activities on the St. Marys River included a model study followed by a demonstration program to test an ice boom's effectiveness at the head of the Little Rapids Cut just downstream of the Soo Locks and Government and private hydropower facilities at Sault Ste. Marie, Michigan. This work was done during the Congressionally authorized Great Lakes - St. Lawrence Seaway Navigation Season Extension Program which was concluded in September of 1979. A photocopy of the Little Rapids Cut model study is available at a cost of $52.00. The boom proved so successful that it is now part of our normal operations activities. However, the effects of the boom on water levels, flows, and ice cover continue to be analyzed and a report is released annually by our Great Lakes Hydraulics and Hydrology Branch. Should you desire specific details on operating procedures or policies associated with the ice boom, please contact Mr. Jim Bray, Soo Area Engineer, U. S. Army Corps of Engineers, St. Marys Falls Canal, Sault Ste. Marie, Michigan 44783; telephone number (906) 632-3311.

In an effort to control ice problems on the St. Marys River, the present Lake Superior regulation plan, Plan 1977, contains a requirement limiting the discharge through the Lake Superior control structures (three power plants, navigation locks, and compensating works) into the St. Marys River to 85,000 cfs from December through April. This limitation was set as a "safe" maximum as a result of past experiences with flooding due to ice jamming in the Soo Harbor and the lower St. Marys River, caused in part when higher flows are discharged.

There is also an ice boom placed annually at the head of the Niagara River by permission of the Intenational Joint Commission. The ice boom accelerates the formation of, and stabilizes the natural ice arch that forms near the head of the Niagara River every winter. The boom reduces the severity and duration of ice runs from Lake Erie into the Niagara River, and lessens the probability of large-scale ice blockages in the river which can cause reductions in hydropower generation and flooding of shoreline property along the Niagara River. Additional information on this ice boom can be obtained from Colonel Robert R. Hardiman, Buffalo District Engineer and Chairman of the International Niagara Working Committee of the International Niagara Board of Control. Colonel Hardiman can be reached at this address:

U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

U.S. ARMY CORPS OF ENGINEERS: (Question No. 2 - Page 1)

Department of the Army, Detroit District, Corps of Engineers, Carl Argiroff, Chief, Planning Division.

The Detroit District is involved in the operation of only one reservoir; the Lake Winnebago Pool on the Fox River in Wisconsin...Under the plan of operation, the pool is not drawn down until a substantial ice cover has been established. Thus the banks are not exposed when the pool level is drawn down. With this method of operation, we do not experience adverse effects on wildlife using the pool for watering; not are we aware of problems for wildlife relating to cracks in the ice cover.

U.S. ARMY CORPS OF ENGINEERS: (Question No. 4 - Page 1)

Department of the Army, Detroit District, Corps of Engineers, Carl Argiroff, Chief, Planning Division.

The Detriot District does not have any studies on the problems of bank erosion caused by break-up and movement of ice and increased sediment in reservoirs. However, during the Great Lakes and St. Lawrence Seaway Navigation Season Extension Program, a study on "Shoreline Conditions and Bank Recession along the U. S. Shoreline of the St. Marys, St. Clair, Detroit and St. Lawrence Rivers" was conducted as part of an investigation of the effects of ice caused erosion on these rivers. The Environmental Protection Agency has also funded some research of sedimentation in the Winnebago Pool in Wisconsin. For information on turbidity effects on aquatic life, you may wish to contact the U. S. Fish and Wildlife Service and Region 5 of the Environmental Protection Agency.

U.S. DEPARTMENT OF THE INTERIOR: (Question No. 2 - Page 1)

U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.
W. O'Connor, Associate Director.

There is the potential, if reservoirs freeze, for terrestrial animals to become stranded on ice and become easy prey to predators. Animal loss can be prevented by predator control, fencing of reservoirs and providing access to winter feeding areas away from iced surfaces.

U.S. DEPARTMENT OF THE INTERIOR: (Question No. 4 - Page 1)

U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 20240,
W. O'Connor, Associate Director.

Problem of bank erosion caused by the break-up and movement of ice resulting in an increase in sediment.

Biologically, salmon and trout are very sensitive to stream turbidity. Sensitivity varies with life stage, time of year, water temperature and other factors.

SUSITNA HYDROELECTRIC PROJECT
SURVEY OF EXPERIENCE
IN OPERATING HYDROELECTRIC PROJECTS
IN COLD REGIONS

APPENDIX A-4
COMPILATION OF RESPONSES

EUROPE AND OTHER COUNTRIES

Prepared By
Harza-Ebasco Susitna Joint Venture
For the Alaska Power Authority

EUROPE: (Question No. 1 - Page 1)

IVO Consulting Engineers; Helsinki, Finland
Sune Norrback, Executive Vice President

Operating policies

We have successfully tested the maintaining of steady discharge in a river in Northern Finland to obtain early ice formation. The early ice formation is essential to minimize the formation of frazil ice. The steady discharge was obtained with a hydro power plant which has a large reservoir. This method is promising, but its application in practice is rather difficult. The electricity production requirements are often opposite to the ice formation operating policy.

EUROPE: (Question No. 2 - Page 1)

Republic Osterreich, Bundesministerium fur Land - and Forstwirtschaft,
F. Schmidt (AUSTRIA).

(From a translation by H. A. Wagner). The water levels do not fluctuate noteworthy, so that the reservoir banks will not be covered unduly with ice. Also, extreme periods of frost do not occur in Austria. However, the reservoirs in the high mountains are regularly covered with ice and the river banks are partly covered with heavy ice, due to often changing water levels. No problems, as mentioned in your letter, are known in Austria, due to the fact that few animals live in the high mountains especially during the winter. Besides, migrations don't occur.

Vattenfall, Vallingby, Sweden,
Dr. Lennart Billfalk, Director.

I have contacted the Environment and Concession Department within our company. As far as they know there are no injuries or drownings of animals reported as a result of icing of banks or shore cracks in the ice covers. Some potential problems related to the need for reindeers to pass regulated rivers have been discussed when planning for new hydro power stations and in some cases the Power Board has constructed special reindeer Bridges where "natural crossings" cannot be used any more.

EUROPE: (Question No. 3 - Page 1)

IVO Consulting Engineers, Helsinki; Finland
Sune Norrback, Executive Vice President

Reservoir fluctuation management

The crack development is not a problem in our country. Warm water flowing from a reservoir has weakened the ice cover in Northern Finland.

V. S. T., Ltd, Consulting Engineers, Reykjavik, Iceland, Sigmundur Freysteinsson.

Problems with turbidity due to erosion by ice are irrelevant compared to other sediment problems.

Republick Osterreich, Bundesministerium Fur Land-und Forstwirtschaft, F. Schmidt (English translation of Schmidt's letter by H. A. Wagner).

Subject: Preventive measures to avoid harmful influences on the environment by formation of ice in rivers and reservoirs.

A sudden drift of ice, which collects on the reservoir does not occur. Measures to avoid bank erosion will be taken only in extreme flooding situations. The continuous natural exit of the ice does not cause bed or bank erosion and does not influence the living conditions of the animals. Possible local damages of the banks after periods of frost have to be repaired.

Repairs which will cause noteworthy water pollution will be performed during favorable high downstream water levels (above middle water). The upper limit for insoluble matter in water is 30 mg/L or a minimum visibility of 1 m.

The Swedish State Power Board, Alvkarleby Laboratory, S-810 71 Alvkarleby, Sweden,
Dr. Lennart Billfalk, Director.

...Bank erosion in connection with the movement of ice is a common phenomenon in North Swedish rivers. Normally the load of suspended particles is far below the amount causing damage to fish. The kind of soil, dominating in northern Scandinavia, consists of comparatively coarse particles, and problems only arise in connection with construction work.

I have not been able to trace any publications on the Swedish experiences in the above fields. The work most frequently referred to with respect to the 1st topic (i.e. question 4) is a report by the European Inland Fisheries Advisory Commission (EIFC). The English title is unknown to me, but the Swedish translation indicates that it is an interim report dealing with fine particulate solids and fishery."

Swiss National Committee on Large Dams, c/o Ingenieurburo fur bauliche Analgen, der Stadt Zurich, Postfach 6936, CH-8033 Zurich, Tel (01) 435-2603,
R. Bischof, Secretary,

Also your questions Nr. 4 seems to make no important problems in our country, since we have had a three day symposium on reservoir sedimentation in October 1981 at the Swiss Federal Institute of Technology in Zurich and nobody reported on increase of sedimentation in the reservoir due to ice action.

APPENDIX B

SUSITNA HYDROELECTRIC PROJECT
SURVEY OF EXPERIENCE
IN OPERATING HYDROELECTRIC PROJECTS
IN COLD REGIONS

APPENDIX B-1
ORGANIZATIONS CONTACTED

CANADA

Prepared By
Harza-Ebasco Susitna Joint Venture
For the Alaska Power Authority

ALBERTA

- ALBERTA ENERGY AND NATURAL RESOURCES
  Petroleum Plaza, South Tower
  9915 - 108th Street
  Edmonton, Alberta T5K 2C9, Canada

  Attention: Mr. D.C. Surrendi
  Asst. Deputy Minister Fish & Wildlife

- ALBERTA ENERGY AND NATURAL RESOURCES
  Petroleum Plaza, South Tower
  9915 - 108th Street
  Edmonton, Alberta T5K 2C9, Canada

  Attention: Mr. R.D. McDonald, Exec. Dir.
  Scientific & Engineering Services

- ALBERTA ENVIRONMENT
  Oxbridge Plaza
  9820 - 106th Street
  Edmonton, Alberta T5K 2J6, Canada

- TRANSALTA UTILITIES CORPORATION
  Box 1900
  Calgary, Alberta T2P 2M1, Canada

  Attention: Mr. W. Nieboer
  Vice President of Engineering

- EDMONTON POWER
  10250 - 101st Street
  Edmonton, Alberta, Canada

  Attention: Chief Engineer

- Prof. R. Gerard (Chairman)
  Department of Civil Engineering
  University of Alberta
  Edmonton, Alberta, T6G 2G7

- Response received see Appendix A-1

ALBERTA

NORTHWEST HYDRAULIC CONSULTANTS
4823-99 Street
Edmonton, Alberta, T6E 4Y1

Attention: R. J. Cooper, President

BRITISH COLUMBIA

MINISTRY OF ENERGY, MINES & PETROLEUM RESOURCES
Parliament Buildings
Victoria BC, V8V, 1X4, Canada

Attention: Mr. Bill Bachop, Director
Information Services

o MINISTRY OF ENVIRONMENT
Parliament Buildings
Victoria BC V8V 1X4, Canada

Attention: Mr. R. Cameron, Director
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MINISTRY OF ENVIRONMENT
Environmental Management Division
Parliament Buildings
Victoria, BC V8V 1X4, Canada

Attention: Mr. A. Murray
Asst. Deputy Minister

MINISTRY OF ENVIRONMENT
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Attention: Mr. D.J. Robinson
Director of Fish & Wildlife

o B.C. HYDRO
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Attention: Mr. W.M. Walker
Vice President and Chief Engineer

o B.C. HYDRO
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Hydrologist

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  Attention: Director

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  Attention: Mr. R.B. Chenier
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  Engineering and Construction

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Attention: Mr. Hayden
Director of Fisheries Management

DEPARTMENT OF NATURAL RESOURCES
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MANITOBA

- WESTERN REGION FISHWATER INSTITUTE
  Department of Fisheries and Oceans
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  MANITOBA HYDRO
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  Attention: Dr. R.W. Newbury

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- DEPARTMENT OF NATURAL RESOURCES
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- NEW BRUNSWICK DEPARTMENT OF THE ENVIRONMENT
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  Coordination of Information

- NEW BRUNSWICK ELECTRIC POWER COMMISSION
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  General Manager

- NEW BRUNSWICK DEPARTMENT OF FISHERIES
  Kings Place
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  Attention: Director

UNIVERSITY OF NEW BRUNSWICK
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NEWFOUNDLAND & LABRADOR

- NEWFOUNDLAND & LABRADOR HYDRO
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Attention: Director

MINISTRY OF NATURAL RESOURCES
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Attention: Mr. Doug Cuthbert and Mr. G. Tsang

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- MARITIME ELECTRIC CO. LTD.
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o SOCIETE D'ENERGIE DE LA BAIE JAMES
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HYDRO-QUEBEC
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- CANADIAN WILDLIFE SERVICE
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- INLAND WATER DIRECTORATE
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  Engineering & Development Division

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  Attention: Dr. G. L. Robins, Director

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  Attention: Chief Engineer

- o NATIONAL RESEARCH COUNCIL
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  Attention: Chief Engineer

- o DIVISION OF WATER PLANNING
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- o HYDRAULICS LABORATORY
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- o CANADIAN COAST GUARD
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  Attention: Mr. Charles Lawrie

SUSITNA HYDROELECTRIC PROJECT
SURVEY OF EXPERIENCE
IN OPERATING HYDROELECTRIC PROJECTS
IN COLD REGIONS

APPENDIX B-2

ORGANIZATIONS CONTACTED

UNITED STATES

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Harza-Ebasco Susitna Joint Venture

For the Alaska Power Authority

IDAHO

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MAINE

UNIVERSITY OF MAINE
Department of Zoology
Orono, ME 04469

Attention: Dr. Terry A. Haines
Field Research Unit

o MAINE DEPARTMENT OF INLAND FISH & GAME
Augusta, ME 04330

Attention: Director

o CENTRAL MAINE POWER CO.
Edison Drive
Augusta, ME 04336

Attention: John Arnold, Environmental Effects Coordinator

o UNION WATER POWER CO.
150 Main Street
Lewiston, ME 04240

Attention: William Grove, Agent and Engineer

o KENNEBEC WATER POWER CO.
8 Water Street
Waterville, ME 04901

Attention: Alan Corson, Chief Engineer

GREAT NORTHERN PAPER CO.
Millinocket, ME 04462

Attention: Paul Firlotte, Power Systems Manager

BANGOR HYDRO-ELECTRIC CO.
33 State Street
Bangor, ME 04401

Attention: Doug Morrell, Hydraulic Engineer

o Response received see Appendix A-2

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Woodland, ME 04694

Attention: Kenneth Gordon

- DEPT. OF ENVIRONMENTL PROTECTION
  State of Maine
  State House Station 17
  Augusta, ME 04333

MASSACHUSETTS

- COOPERATIVE FISH RESEARCH UNIT
  University of Massachusetts
  Amherst, MA 0 003

  Attention: Dr. Boyd Kynard

MICHIGAN

- o U.S. ARMY CORPS OF ENGINEERS
  Detroit District
  477 Michigan Avenue
  Detroit, MI 48226

  Attention: Mr. Carl Argiroff
  Chief Planning Division

- o MICHIGAN DEPARTMENT OF NATURAL RESOURCES
  Lansing, MI 48924

  Attention: Director

MINNESOTA

NORTHERN STATES POWER COMPANY (MINN.)
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Minneapolis, MN 55401

Attention: Chief Engineer

MINNESOTA DEPARTMENT OF CONSERVATION
St. Paul, MN 55101

Attention: Director

MONTANA

- o STATE OF MONTANA ENVIRONMENTAL QUALITY COUNCIL
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  Helena, MT 59620

  Attention: Dr. Howard E. Johnson

  DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
  Engineering Bureau
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  Attention: Richard Bondy, Chief

- o DEPARTMENT OF FISH, WILDLIFE & PARKS
  Resource Assessment Unit
  Helena, MT 59620

  Attention: James A. Posewitz, Leader

  MONTANA POWER COMPANY
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  Attention: Mr. Robert Periman
  Manager, Hydro-Engineering

- o DEPARTMENT OF HEALTH & ENVIRONMENTAL SCIENCES
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  Attention: Mr. Don Willems

  MONTANA POWER COMPANY
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  Attention: Mr. R. J. Labrie
  Senior Vice President, Engineering

NEBRASKA

- NEBRASKA PUBLIC POWER DISTRICT
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  Larry Kuncl

NEW HAMPSHIRE

o COLD REGION RESEARCH AND ENGINEERING LABORATORY
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NEW HAMPSHIRE FISH & GAME DEPARTMENT
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Attention: Director

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
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Attention: Mr. D. N. Merrill
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NEW YORK

ST. LAWRENCE SEAWAY DEVELOPMENT CORPORATION
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Attention: Mr. John B. Adams III
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NIAGARA MOHAWK POWER CORPORATION
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CONSOLIDATE EDISON COMPANY OF NEW YORK, INC.
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OREGON

- PACIFIC POWER & LIGHT COMPANY
  Public Service Building
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  Attention: Chief Engineer

  PORTLAND GENERAL ELECTRIC COMPANY
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  Attention: Chief Engineer

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Attention: Dr. Ernest D. Salo

- WASHINGTON STATE GAME DEPARTMENT
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  Attention: Director

- WASHINGTON STATE DEPARTMENT OF FISHERIES
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  Attention: Director

WYOMING

WYOMING GAME & FISH DEPARTMENT
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Attention: Director

UNITED STATES FEDERAL GOVERNMENT

- U.S. FISH & WILDLIFE SERVICE
  Washington, D.C. 20013

  Attention: Director

- NATIONAL MARINE FISHERIES SERVICE
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  Attention: Director

  AMERICAN FISHERIES SOCIETY
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  Attention: Executive Director

- U.S. ARMY CORPS OF ENGINEERS
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SUSITNA HYDROELECTRIC PROJECT
SURVEY OF EXPERIENCE
IN OPERATING HYDROELECTRIC PROJECTS
IN COLD REGIONS

APPENDIX B-3
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EUROPE AND JAPAN

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EUROPE & JAPAN

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  Attention: Thor Gudjonsson, Director

  NORDURLAX HATCHERY
  Laxamyri
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  Attention: Dr. Tumi Tomasson

- o SWEDISH STATE POWER BOARD
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  WATER RESOURCES AND ELECTRICITY BOARD
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  Attention: Dr. E. V. Kanavin

- o INSTITUTE OF HYDRO ENGINEERING
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- o THORODDSEN AND PARTNERS
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- o VERSUCHSANSTALT FUR WASSERBAU UND KULTURTECHNIK
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o Response received see Appendix A-3

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Attention: Director

DEPARTMENT OF ENERGY AND INDUSTRIES
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Attention: Director

DEPARTMENT OF ELECTRIC SUPPLIES
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EUROPE & JAPAN

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Direction Generale
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Attention: William Varoquaux, Chef

Adjoint du Service des Etudes Economiques Generales

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o GERMAN ASSOC. FOR WATER DEVELOP. AND ADVANCEMENT OF CULTURE
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