VOLUME 1 OF 2

PROPOSAL

APPENDIX A,B1,2

Alaska Power Authority

SUSITNA HYDROELECTRIC PROJECT

PROPOSAL FOR

PLAN OF STUDY

JUNE 1979

Acres American Incorporated
900 Liberty Bank Building
Buffalo, N.Y. 14202

R & M Consultants Incorporated
5024 Cordova Street
Anchorage, AK 99503

June 4, 1979
W5550.68

Mr. Eric P. Yould
Executive Director
Alaska Power Authority
333 West 4th Avenue
Suite 31
Anchorage, Alaska 99501

Dear Mr. Yould:

Proposal for the Upper Susitna River Basin Hydroelectric Power Project

We are pleased to submit herewith five (5) copies of a proposal stating qualifications and justifying selection of a team comprised of Acres American Incorporated, R&M Consultants Incorporated, Frank Moolin & Associates, and Terrestrial Environmental Specialists Incorporated (ARMT) for preparation of a detailed Plan of Study (POS) for the Upper Susitna River Basin Hydroelectric Power Project.

The general division of responsibilities proposed for preparing the POS and subsequently carrying it to fruition capitalizes on the strength and experience of its respective members. In brief, Acres, with more than 50 years experience in large hydroelectric development, particularly in northern areas, will provide overall study and project management as well as the bulk of the project engineering effort. R&M will undertake the major portion of the field engineering work to include survey, investigations and testing, and will provide a strong Alaskan presence and a firm base of operations. TES will coordinate the efforts of a team of principal environmental investigators, each one of which has been selected because of an outstanding reputation in his or her discipline, especially as it pertains to knowledge of Alaska. Frank Moolin & Associates will interject the views and recommendations of a professional construction management organization with solid Alaskan experience, and will assist in directing field work in preparation of realistic cost estimates and schedules.

Acres also brings to the Susitna project first-hand knowledge and experience in the problems of financing such a large undertaking, based on our involvement in similar large projects such as Churchill Falls.

ACRES AMERICAN INCORPORATED

Each member of the team represents a capable and experienced organization. We are convinced that the synergism associated with their assemblage provides an outstanding candidate for selection as a consultant to the State of Alaska on this important project. Together we offer a strong team with local knowledge and local presence, with a record of successful performance on large hydroelectric projects around the world and particularly in northern regions, and a depth of capability that ensures an extensive reservoir of talent is available from within our respective organizations.

In accordance with your letter of May 7, 1979, and your subsequent advice extending the closing time for this submittal, we are pleased to note as well our willingness to present our credentials in person to you and to such other individuals or agencies the State of Alaska may wish. It would be a pleasure to see you again.

We are in the business of hydroelectric development. We have been for more than 50 years. We are well aware that projects as exciting as this one are far from commonplace. They demand uncommon attention. We hope that you will find us just the group which can provide it!

Please do contact me at the number above or Col. (Ret.) C. A. Debelius at (301) 992-5300 in the event that we can provide any additional information which may help you in your choice.

Yours very truly,

for David C. Willett
Vice President

DCW/rw
Encl. (5)

Alaska Power Authority

SUSITNA HYDROELECTRIC PROJECT

PROPOSAL FOR

PLAN OF STUDY

VOLUME 1 OF 2

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APPENDIX A, B1, 2

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ACRES

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

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ACRES

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ACRES

3 - CAPABILITY AND QUALIFICATIONS

(a) Scope of Services

This proposal is submitted in response to a request from Mr. Eric P. Yould, Executive Director, Alaska Power Authority, dated May 7, 1979. The proposal demonstrates the capability and qualifications of Acres American Incorporated and its subcontractors, R&M Consultants Inc., Frank Moolin & Associates Inc., and Terrestrial Environmental Specialists Inc. to undertake complete project and financial management through commissioning of the Susitna Hydroelectric Project.

The Acres - R&M - Moolin - TES (ARMT) group brings to the Susitna Project a unique combination of capability and expertise, largely Alaska based. The group provides:

(i) A powerful design/project/construction management team experienced in studies, economic evaluation, licensing, design, financing and construction of large hydroelectric projects, particularly in northern areas.

(ii) A skilled and readily available field exploration team with facilities, personnel and equipment experienced in all aspects of hydrologic and geotechnical design and exploration, particularly in the vicinity of the Susitna site.

(iii) An exceptional team of environmental specialists with first-hand knowledge and experience of the project area.

The proposal addresses, in the manner required by the RFP, the capabilities, experience and facilities available to the group to undertake the project from initial studies through completion.

(b) Hydroelectric Engineering and Planning

Acres American Incorporated is part of the Acres group of companies, which has been responsible for the engineering and construction of more than 20,000 MW of hydroelectric capacity in all parts of the world, over a period of more than 50 years. The company is currently involved in hydro developments amounting to more than 2000 MW of installed capacity.

With a total staff of more than 1500 in offices throughout North America and overseas, the Company can call upon a wide range of skills and talents in engineering and related fields. Acres qualifications and experience is comprehensive in all aspects of planning and engineering of hydroelectric projects of all sizes. The largest of these, the Churchill Falls Development, with a total installed capacity of 5225 MW, was completed in 1976 at a total cost of $950 million, under budget and ahead of schedule. This project is located in Labrador, Canada and presented problems associated with construction in northern regions similar to those which will be encountered at the Susitna project.

Acres was also a member of the CASECO joint venture which engineered the Mica Dam Project on the Columbia River, another project similar in size and problems to the Susitna. Company hydroelectric experience is not only confined to northern areas. In contrast, the ability to deal with special problems generated by cold weather regions has also been put to good use in other regions of the world with greatly different climates. A typical example of a major project designed and built in extremely difficult conditions is the 340 MW Alto Anchicaya Project in Colombia, South America.

A detailed summary of Acres qualifications and experience in the hydroelectric field is presented in Appendix A of this proposal and summarized in the following tables.

HYDROELECTRIC POWER GENERATION

Acres has gained a leading position in the hydroelectric field and has been responsible throughout the world for over 20,000 MW of power generating facilities.

Specialists in hydraulic, geotechnical and other disciplines and a highly experienced engineering staff, form well-balanced hydroelectric project teams. Our staff of economists and environmentalists contribute to hydro developments with detailed economic comparison and environmental impact studies to ensure maximum utilization of the natural resources.

The most significant hydroelectric projects for which Acres has completed, or is currently providing services are

Project	No. of Units	Installed Capacity (MW)	Head (m)	Services
Alto Anchicaya	3	340	388.0	Engineering services
Arnprior	2	80	21.0	Project management and engineering services
Ash River	1	25	24.0	Engineering services and supervision of construction
Aslantas	3	125	100.0	Engineering services (in consortium)
Beauharnois No. 2	12	495	24.0	Engineering services
Beauharnois No. 3	10	555	24.0	Engineering services
Bersimis No. 1	8	900	239.0	Engineering services
Bersimis No. 2	5	640	112.0	Engineering services
Black River (Extension)	3	6	38.0	Engineering services
Chenaux	8	125	12.2	Engineering services
Churchill Falls	11	5,225	311.0	Technical and construction planning, engineering and estimating services, and management of construction (in joint venture as Acres Canadian Bechtel of Churchill Falls)
Chute-a-Caron (Extension)	2	100	50.0	Engineering services
Chute-des-Passes	5	750	160.0	Engineering services and site supervision
Espanola	1	8	19.5	Engineering services
Granby	2	10	7.0	Engineering services
Grand Falls	4	60	38.0	Engineering services

Hydroelectric Power Generation — 2

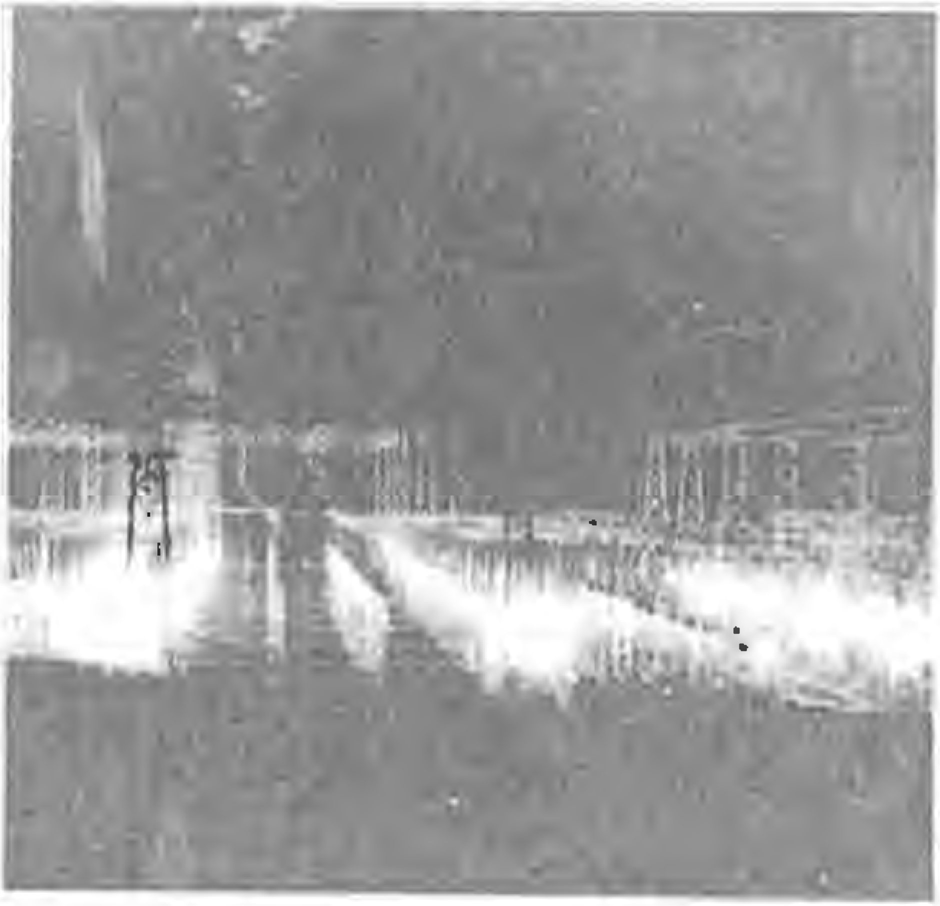
Project	No. of Units	Installed Capacity (MW)	Head (m)	Services
Grand Rapids	4	450	36.4	Engineering services
Gull Island	–	1,600	–	Engineering services
John Hart	6	125	119.0	Engineering services
Kelsey	7	224	16.8	Engineering services and site supervision
Kettle Rapids	10	1,244	30.0	Engineering services (in joint venture as Crippen Acres)
Kpong	4	160	11.8	Project management and engineering services
La Boruca	4	760	200.0	Engineering services
Ladore Falls	2	52	37.0	Engineering services and supervision of construction
Laurie River No. 1	2	5	16.7	Engineering services
Laurie River No. 2	1	5	16.7	Engineering services
Limestone Rapids	10	1,070	26.2	Engineering services (in joint venture as Crippen Acres)
Long Spruce	10	1,000	24.4	Engineering services (in joint venture as Crippen Acres)
Los Esclavos	2	13	107.0	Engineering services
Lower Notch	2	250	70.0	Engineering and project management services
Mactaquac	6	625	33.5	Engineering services and supervision of construction
Manicouagan 1	3	180	37.5	Engineering services
Manicouagan 2	8	1,000	69.7	Engineering services
Mayurakshi Reservoir	2	4	30.0	Engineering specifications co-ordination of manufacturing and supervision of inspection
McArthur Falls	8	60	7.0	Engineering services and site supervision
McCormick No. 1	2	85	37.5	Engineering services
McCormick No. 2	3	134	37.5	Engineering services
McCormick No. 3	2	120	37.5	Engineering services

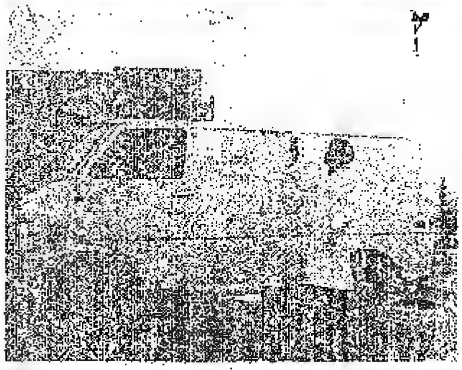
Project	No. of Units	Installed Capacity (MW)	Head (m)	Services
Nam Ngum	2	30	35.0	Project management services
Outardes	2	52	63.5	Engineering services
Pine Falls	6	85	11.3	Engineering services and site supervision
Salto Grande	12	1,620	25.0	Engineering services
Shadiwal	2	15	7.6	Engineering services
Shipshaw	12	900	63.5	Engineering services
Sirikit	3	375	76.0	Engineering services
St. Marys River	3	52	5.7	Engineering and project management
Strathcona	1	31	42.5	Engineering services and site supervision
Tarbela Extension	2	350	132.0	Engineering services and supervision of construction
Trenton Falls	1	9	82.0	Engineering services
Warsak	4	160	43.6	Engineering services and supervision of construction
Warsak (Extension)	2	83	43.6	Engineering services and supervision of construction

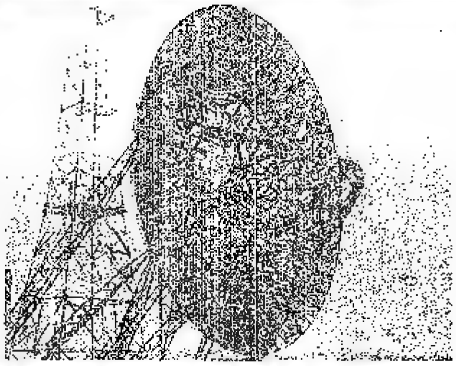
PLANNING

The staff of Acres American has a wide range of experience in the provision of consulting services to the power utility industry in the following areas:

- Load Forecasting and Market Surveys
- Long-Range Planning and Power System Studies
- Economic Analysis
- Reliability Analysis
- Mathematical Models and Computer Simulation Programs
- Switching Surges and Resonant Phenomena
- Insulation Coordination Studies
- Plant Evaluation
- Rate Studies







LOAD FORECASTING AND MARKET SURVEYS

Serving the electric power utility industry since 1924, Acres has built up a considerable body of experience in the preparation of market surveys and load forecasts. An example of Acres work in this field was the preparation of a large-scale market survey relative to the import of power from the Churchill Falls project in Canada. The area studied in that instance was the whole of the New England region together with the area serviced by Consolidated Edison Company of New York.

On a more modest scale, Acres planning engineers have prepared numerous midrange market surveys and load forecasts for urban and municipal utilities, in order to evaluate the most effective way of modernizing their distribution systems or converting to a higher voltage class.

In connection with the more detailed planning studies, Acres engineers frequently have had occasion to prepare medium and long-range projections for major utility systems both at home and overseas. Such forecasts are usually prepared in conjunction with the client's engineers and Acres own staff, and they normally include national as well as regional trends. In the case of overseas clients, often located in developing countries, a more grass roots approach is called for. In such cases, market survey techniques are employed, which are based on all necessary economic indicators, such as consumption of power per capita or per ton of manufactured product. Acres American has access, through the main Acres group of companies, to a large staff of economists well versed in the requirements of such studies.

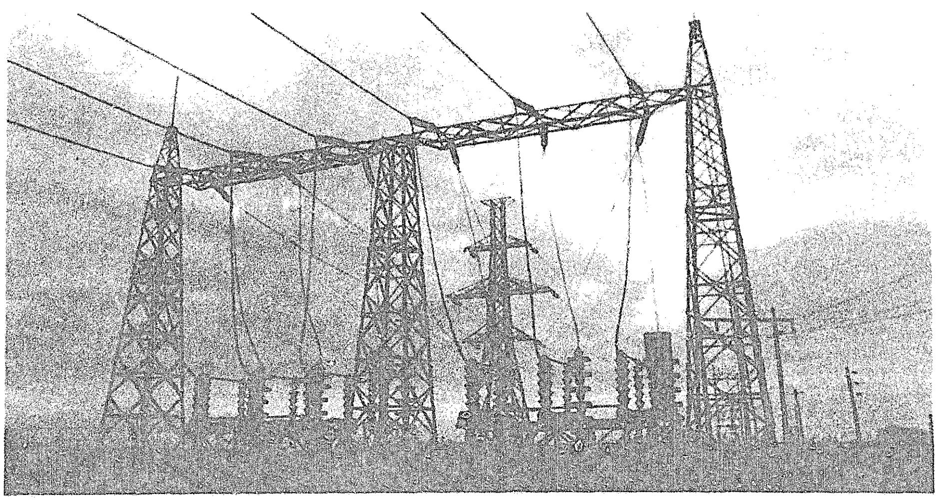
LONG-RANGE PLANNING AND POWER SYSTEM STUDIES

Acres American is in a position to provide a complete range of consulting services for long-range system planning studies. These studies, which can be done either independently or in close association with the client's engineers as required, might typically cover the following activities:

- Preparation of load forecasts and the formulation of a series of preliminary system expansion sequences
- Assembly of system data, component ratings, impedance data, and transformer tap ranges
- Conducting all necessary load flow studies to determine the timing of new plant additions, equipment ratings, transformer tap ranges, and the need for and location of VAR (voltage) control equipment
- Development of stage-by-stage single-line diagram and capital costs associated in the alternative system expansion programs
- Conducting of stability and fault level studies to modify or confirm the system configuration arrived at from load flow studies.

A recent new activity in this general sphere has been a series of studies on the economic integration of pumped storage hydro plants into existing power systems.

These studies have involved the year-by-year simulation of power system operations and determination of system operating costs for alternative system development programs. Operating costs are determined for a range of variations in key parameters, and these are combined with system capital costs to determine the total cumulative present worth cost of power supply. Comparison of the present worth costs of the various alternatives permits an easy determination of the expansion program and the pumped storage plant dimensions that minimize the power cost. It should be noted that Acres technical planning specialists and professional economists have a sound knowledge of the relevant techniques of economic analysis, particularly as they relate to electric utility problems.



LICENSING APPLICATIONS

During recent years, the Public Service Commissions in the majority of States have enacted regulations requiring utilities to secure regulatory agency approval before constructing major facilities. For example, the New York State Public Service Law on the construction of transmission lines at 100 kv and over requires utilities to file application for "Certificate of Environmental Compatibility and Public Need". Similar environmental requirements in most other states also regulate the procedures necessary for the siting of power generating plants. The application for these certificates must contain detailed information, some of which requires many in-depth studies. Acres experience in these activities enables our engineers to make valuable contributions in the following areas:

- Identification of potential sites and transmission line right-of-way, including study of alternatives
- Environmental impact statements
- Preparation of statements describing anticipated effects on local communications and the local economy
- Preparation of project descriptions and justification statements
- Assurance of compliance with local State and Federal regulations. Checking for the existence of possible conflicting cases filed by others
- Preparation of expert court testimony
- Modeling of air and water effluent dispersal by both physical and mathematical means.

EXPERT COURT TESTIMONY

During recent years, the already complex task of obtaining right-of-way for hv and ehv transmission lines has been further complicated by the need to take into account the various environmental considerations as well. In this field, as in others, Acres American has been moving with the times, and is in a position to offer the services of our professional staff, not only to prepare the detailed information necessary for the environmental impact statement itself, but to testify on behalf of the client before the County Zoning Boards, general public hearings, and the various State and other regulatory agencies.

An example of this type of service is the assistance our staff recently gave to Potomac Electric in connection with a public hearing for a 500-kv line. The testimony covered environmental considerations associated with the line and substation and included audible noise, radio and television interference, the generation of ozone and nitrogen oxides, electromagnetic radiation, electrostatic shock hazards, fuel ignition, biological effects and long-term health implications. Prior to the hearings, preparatory meetings with local regulatory and governmental authorities and health authorities were also held. Visual aids in the form of large scale charts, diagrams and architectural models and renderings were prepared and registered with the court as official exhibits.

SAFETY AND CODE REQUIREMENTS

The National Electrical Safety Code (NESC) standard covers basic provisions for the safeguarding of persons from hazards arising from the installation, operation, and maintenance of overhead supply and communication lines associated equipment. It applies to all overhead systems operated by utilities or similar systems in an industrial establishment.

The existing sixth edition of Part 2, which was approved in 1960 as ANSI C62.2–1960 and published in 1961 as NBS Handbook 81, is being revised not only to overcome many of the inadequacies but also to extend the requirements to cover system voltages in the uhv range. If the proposed seventh edition is passed, it will impose even more stringent requirements on some aspects of design, construction, and operation of overhead lines—especially the ehv lines.

As an example, Section 23 on "clearances" proposes to stipulate required electrical clearances for various switching surge factors. This requirement, if passed, could have a significant impact on ehv and uhv transmission line costs, since the proposed tower window clearances would exceed the clearances normally used by many utilities to obtain acceptable flashover probabilities.

Other items relating to potential hazards associated with higher voltages, that will be recommended by NESC, should be carefully reviewed in the light of their effect on the design, construction and operation of forthcoming overhead systems.

Acres is in a position to offer the services of senior staff members with a sound knowledge of all these considerations.

(c) Technical and Laboratory Resources Available

The ARMT team will provide a unique combination of technical, management and laboratory resources which will be particularly appropriate to the requirements of the Susitna project.

(i) Acres Resources - Project Management

Acres has successfully undertaken the complete project and construction management of numerous large hydroelectric developments, including (completion dates in parenthesis):

- Arnprior, Ontario - 80 MW, $80 million (1977)
- Churchill Falls, Labrador - 5225 MW, $950 million (1976)
- Lower Notch, Ontario - 250 MW, $60 million (1972)
- Alto Anchicaya, Colombia - 340 MW, $100 million (1975)
- Mactaquac, New Brunswick - 625 MW, $124 million (1968)

Acres responsibilities on these projects included feasibility studies, planning, power studies, design, equipment procurement, preparation of bid documents, environmental assessments, construction management, inspection and commissioning. Acres is currently providing complete project management services on the 150 MW Kpong Hydroelectric Project in Ghana and the 600 MW Cordoba nuclear power plant in Argentina.

A particularly important role of the Project Management team on the Susitna Project will be the estimates of construction cost. In this area, the Acres-Moolin team has a wealth of experience and capability for large hydroelectric projects, particularly in Alaska and similar northern areas. A detailed summary of Acres qualifications and experience in the project and construction management of large projects is presented in Appendix B1 of this proposal.

(ii) Acres Resources - Financial Management

The extent of Acres participation in the financial management of a given project can vary greatly, according to the needs and wishes of the Client. Although in many cases we have not been called upon to participate in this field of activity, in certain other cases we have taken quite major roles in the financial aspects of the project.

In the case of the Churchill Falls Development, for example, Acres was called upon to set up a special Task Force responsible for the preparation of a detailed "Bond Offering Memorandum". This memorandum, which was in fact a very substantial bound volume, outlined in great detail the various economic, technical and operational features of the project and analyzed them in terms of their relationship to the ultimate profitabilities of the completed project. The text of the document was worded in a manner appropriate to the financial community and was the basis upon which a bond offering of $500 million was successfully made. At the time of issue, this was understood to have been the largest sum of money ever raised by this method.

On perhaps a more modest scale, in terms of the total dollars involved, are the Lower Notch and Arnprior projects, owned by Ontario Hydro in Canada. The first of these, Lower Notch, was initiated in 1966. Under the terms of our contract, Acres was placed in charge of a trust fund sufficient to cover the cost of the whole contract. The degree of participation by the Owner was, in effect, confined to an overall review of acounting procedures and engineering progress. The balance of the work, from basic engineering details to the signing of contracts for both equipment and services, was left entirely in the hands of our staff. The outcome of this project was sufficiently satisfactory that in 1972 Acres was selected for a second assignment for the Arnprior Development.

A paper by J. Gavin Warnock, a member of the Acres in-house consulting panel for the Susitna project, on Design Risk and Engineering Management, may be found in the attached Appendix D. This Appendix comprises a collection of papers under the title "The Successful Accomplishment of Giant Projects".

The Acres-Moolin project management team will bring to the Susitna project a powerful combination, skilled and knowledgeable in the financing of large projects and the generation of the confidence of the investment community.

(iii) Acres Resources - Ice Engineering

The engineering and construction of the Susitna project will naturally require careful consideration of ice formation and movement processes, and the design of structures to cope with severe ice conditions. Acres has extensive experience in the appraisal of ice conditions in streams and waterways and the impact of ice forces and related factors on hydraulic structures. Ice engineering activities previously undertaken by the Company relate predominantly to Thermal Regime, Mechanical Regime, Ice Forces and Ice Navigation.

Detailed Acres experience in these aspects of project design are also presented in Appendix B1 of this proposal.

(iv) Acres Laboratory and Testing Experience

Acres is currently managing on behalf of the Corps of Engineers the 14-acre model of the Chesapeake Bay in Maryland. At its hydraulic laboratories in Buffalo, New York and Niagara Falls, Ontario, the Company has successfully completed numerous hydraulic model studies for water resources projects throughout the world. Recent studies have included diversion tunnel facilities for the Amos Dam in West Virginia, the Alto Anchicaya Project in Colombia and the Lower Churchill Falls Development in Labrador. Hydraulic model spillway studies have also been undertaken for the Alto Anchicaya project and the Lower Notch Hydroelectric Project in Ontario, Canada. Although certain studies for the Susitna project could be undertaken in the Acres Laboratory facilities, it may prove to be advantageous to locate such models in laboratories which may be available in or closer to Alaska, such as at the University of Alaska or at Corps of Engineer facilities.

Acres laboratory facilities are also available for geotechnical testing of materials. However, it is anticipated that the major portion of such testing for the Susitna Project would be undertaken at facilities owned by R&M Consultants in Alaska.

Details of Acres laboratory and testing facilities are also presented in Appendix B1.

(v) Acres Inspection and Expediting Services

Acres maintains in conjunction with its Project Management functions a comprehensive inspection and expediting service. These services are available in factories and contractors' works on behalf of in-house project groups and clients.

The Inspection and Expediting Group is able to draw upon 100 years of experience and in-house expertise in machine shop and foundry practices, electrical manufacturing and testing of engineering products. This capability covers the interpretation of plans and specifications, knowledge in the end use of equipment and broad experience in manufacturing, erection procedures and plant operation, particularly for large hydroelectric projects.

Full details of Acres Inspection and Expediting Services are presented in Appendix B1.

(vi) R&M Site Exploration and Testing Experience

(1) Introduction

R&M Consultants Inc. is an all-Alaskan multi-disciplinary consulting firm. With ten years of experience in Alaska and with modern, well-equipped facilities, R&M is uniquely qualified to provide geotechnical services for the Susitna project. Indeed, R&M is the only engineering firm in Alaska able to provide the total range of field services necessary to support a major feasibility study and license application for a project of this magnitude.

Site explorations and on and off-site testing has been accomplished throughout the State by R&M and their particular abilities and expertise in arctic and subarctic environments and in seismically active regions will be important. Even the prospect of undertaking major geotechnical investigations in support of a giant project is neither new nor formidable, for R&M played an important role as a consultant to the Alyeska Pipeline Service Company during investigations for and subsequent design and construction of the trans Alaska Pipeline system. Because The Drilling Company Inc. is an associated firm of R&M, the necessary equipment for sophisticated geotechnical investigations is not only immediately available, but also the capability to make reliable estimates of schedules and costs for field work is thereby enhanced.

(2) Surveying

Land surveying in Alaska and the Arctic is generally more complicated that elsewhere in the United States because remote locations, extreme weather conditions, elevation changes, and water to land discontinuities tend to present unusual challenges.

The combination of thoroughly trained teams, modern instrumentation, computer systems, and a company-owned aircraft permits R&M to offer a full range of survey and mapping expertise supported by extensive experience in the South-central Railbelt Area.

(3) Laboratories

For a giant hydroelectric project, it has been the experience of the Acres group that immediately available laboratory facilities are a must if scheduled tasks are to be completed -- particularly when only relatively short periods without snow cover are available. R&M has mobile testing equipment as well as four fully equipped and staffed Materials Testing Laboratories.

(4) Stream Gauging

Gathering of hydrologic data will be facilitated by R&M's ownership of stream gauging equipment. In this regard, a variety of hydrologic studies have been conducted by R&M for Alyeska Pipeline Service Company, the Alaska Department of Environmental Conservation, and others. It is R&M's unique knowledge of and experience in Alaska which has led to their development of computer applications for hydrologic analysis optimized for the Alaskan environment.

(5) Administrative Support

A detailed statement of R&M's experience and qualifications is contained in Appendix B2. While R&M's principal role druing the feasibility study period will be in the geotechnical area, this important member of the Acres team will be relied upon as well f.r a variety of other services as necessary, not the least of which is the ability to provide administrative support from Anchorage, Wasilla, and Fairbanks -- a particularly attractive combination as concurrent investigations of alternative transmission line segments are conducted. Indeed, the speed advantage (over appropriation-fettered federal management) which a private consulting team can provide will be most valuable if multitudinous tasks can be performed simultaneously.

(vii) Frank Moolin & Associates
Construction Management Experience

With specific regard to the Susitna Project, Acres will combine its project and construction management resources with those of the Frank Moolin & Associates Inc. organization. This Fairbanks-based company provides executive project and construction management services to the energy industry. Mr. Moolin, who will initially be engaged in the management of the field work aspects of the project feasibility study, has been involved in the project management of a number of major public works projects. More recently, he was project manager for the $4.3 billion pipeline portion of the Trans Alaska Pipeline and will bring to the Susitna Project a unique combination of project management skills and experience of construction of large projects in Alaskan conditions. The Moolin organization will complement the Acres team, providing local knowledge and experience which will be essential in the development of realistic cost estimates for engineering, exploration and construction of the Susitna project. A related article by Mr. Moolin on Effective Project Management Organization for Giant Projects is presented in Appendix D.

(viii) TES Environmental Expertise

Terrestrial Environmental Specialists, Inc. (TES) has performed environmental work as its pertains to all aspects of hydroelectric development. Such services as endangered species surveys, socio-economic analyses, archaeological investigations, terrestrial and aquatic ecology studies, land use analyses, and site selection surveys are notable entries on the TES experience list. Indeed, TES has either prepared or is in the process of preparing environmental assessments for five proposed hydroelectric projects and has prepared an endangered species report for the sixth. TES past experience and its strong professional staff will serve it in good stead in the management of environmental work.

Recognizing the unique nature of the project environment, TES has assembled a team of principal investigators each of whom has credentials which are second to none in his or her field. Indeed, this cast of important consultants who have agreed in advance to be a part of the ARMT team for the Susitna investigations includes distinguished professors and curators from the University of Alaska; internationally recognized private consultants such as Mr. Milo Bell whose knowledge of fish passages is unsurpassed; the Director-Designate of the Institute of Arctic and Alpine Research at the University of Colorado; an established consulting firm specializing in economic and business consultation with particular emphasis on and experience in Alaska; and a number of others whose backgrounds are equally as noteworthy.

Assuming that the Acres team is selected to undertake studies leading to FERC licensing, the environmental team conducting field investigations and analyses will be managed and coordinated by TES personnel with each special discipline being handled by principal investigators as described above. The laboratory facilities owned by R&M will be used for certain analyses.

d. STANDARD AND SPECIALIZED EQUIPMENT

(i) General

A complete list of individual equipment requirements associated with the conduct of all work necessary to secure a Federal Energy Regulatory Commission license to construct the Susitna Hydroelectric Project would necessarily be long and would likely be heavily loaded with relatively sophisticated items. It is these latter entities which deserve serious attention for their availability in Alaska is not generally widespread and even well-conceived plans to import them can prove costly -- both because transportation to and from the State is a traditional contributor to the higher cost of living and because the cost of delays on giant projects can wreak havoc with tight budgets. In addition, of course, certain modification appropriate to harsh climatic conditions, delicate terrain, and the like, add yet another increment to the expense column. We propose to satisfy virtually all major equipment requirements for which use or accessibility is demanded in Alaska by providing them from R&M's resources already in the State. To the extent that certain equipment needs do not have to be satisfied in Alaska (as would be the case for hydraulic modelling, for example), we proposed to provide them in the main from in-house resources available to Acres American Inc. or owned by Terrestrial Environmental Specialists.

The relatively short period during which conditions are favorable for field investigations of the proposed dam and reservoir site and transmission line routes creates an important constraint. To minimize its negative impacts, there is simply no alternative to identifying the equipment needs well in advance and ensuring that they are fulfilled. R&M has faced this fact on numerous occasions in the past in Alaska and, during the past ten years, has evolved a stable of equipment and a system for ensuring ready availability at the site when it is required. In short, R&M has found it prudent to become self-sufficient in terms of its total investigatory capability. We propose to offer this self-sufficiency as a unique characteristic of the team we have assembled for the work.

(ii) Geological Investigations

For the purpose of supporting further geological investigations which may be required, we are pleased to note that the Drilling Company Inc. (TDC, an affiliate of R&M) has the capability to undertake explorations requiring core recovery, core orientation, down-hole surveys, installing thermostats, thermocouples, piezometers, and other instrumentation. TDC has configured its equipment acquisition and subsequent modifications to permit maximum mobility, even in areas which are remote, roadless, and frequently fragile or starkly rugged. TDC has accomplished a variety of drilling work using rail, truck mounts, tracked carriers, trailers, all-terrain vehicles, skids, barges, airplanes and helicopters. Some major items owned by TDC include:

- CME-55 Soils Drills
- CME-45c Soils Drills
- CME-550 ATV
- Failing 1500 Rotary Drills
- Mobile B-30 Auger Drills
- Mobile B-40 Auger Drills
- Mobile B-40L
- Mayhew 1000
- Longyear Diamond Core Drills
- Nodwell-Mounted Units
- Truck-Mounted Units
- Heli-Transportable Units
- Portable Camp Facilities

(iii) Surveys

Air surveys must be conducted when environmental conditions are favorable. Acceptable periods may be few and far between since cloud cover may interfere even when snow cover and leaf cover conditions are otherwise within allowable limits. In this regard, the fact that R&M Consultants Inc. owns its own aircraft, fully equipped for aerial survey, becomes particularly significant. Other survey needs can be satisfied as well through use of R&M's modern distance measuring and position locating state-of-the-art instruments.

(iv) Access

Relative inaccessibility of proposed dam sites will not prevent the Acres team from acquiring necessary data, nor will our need to bring equipment within steep narrow canyons result in environmental damage. We are pleased to note that R&M owns a complete cableway system available for use in the field investigations of the Susitna sites. As may be seen from detailed project descriptions contained in Appendix B2, R&M designed the Thompson Pass cableway system used to advantage by Alyeska Pipeline Service Company.

(v) Material Testing

We plan to provide a system for rapid turnaround on material samples testing, for we recognize the importance of maximizing time available for investigation, preliminary analysis, and following-up leads suggested by early test results.

A cornerstone of this system is the R&M ownership of four modern materials testing laboratories in Alaska. We are prepared to absorb overload testing requirements during peak periods through round-the-clock operation of these facilities if necessary. At the same time, environmental samples will normally be analyzed in the R&M laboratories.

(vi) Stream Gauging

R&M will provide stream gauging equipment in support of continuing hydrologic investigations. In addition, we are prepared to acquire and install remote sensing devices and long-term recording apparatus, for our extensive experience in arctic and subarctic environments and our own involvement in giant projects has convinced us that the collection of site-specific data during all parts of the year is an imperative. A clear example of the importance of this point can be found in the Corps of Engineers' experiences on the Snettisham transmission line south of Juneau. The erroneous assumption that wind conditions along a mountain ridge just outside of town would replicate those in Juneau proper led to collapse of a portion of the line and two years' delay in furnishing reliable power to the marketplace. Anemometers installed after the initial diaster showed that actual wind speeds had probably exceeded design speeds by more than 100 percent.

(vii) Hydraulic Models

Acres has had extensive experience in hydraulic modelling. Not only do we currently operate the Chesapeake Bay hydraulic model for the Corps of Engineers, but we also own a well-equipped laboratory in Niagara Falls where we have modelled a variety of hydraulic structures. Our modelling experience has included extensive ice studies for extending navigation seasons on the Great Lakes as well. We will employ Acres facilities and technical expertise for modelling certain hydraulic structures.

In addition, we have verified that the use of government laboratory facilities for private investigation is possible provided costs are fully reimbursed and capacity is available. We would expect to engage the services of the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, when necessary. The newly dedicated Ice Engineering Laboratory affords excellent facilities for analysis of the effects of certain conditions (e.g. frazzile ice) which must be dealt with. While the bulk of such detailed study is more likely to occur during the final design stage, certain preliminary investigation will be appropriate during the feasibility study.

(viii) Seismic Investigations

One of the particularly crucial problems to be resolved for the Susitna project involves the proximity to known faults. Seismic investigations and subsequent detailed analysis demand the availability of modern computer facilities. Because of the crucial nature of this work, R&M will use its own computer facilities in the investigation. The Acres Geotechnical Department will independently verify the results using computer systems available to us and tapping the expertise of senior in-house Acres Consultants who faced and solved seismicity problems on the Churchill Falls project.

(ix) Miscellaneous

In addition to the ownership of or access to necessary technical equipment, we are pleased to note that all members of the proposed Acres team offer modern and efficient administrative facilities and support, designed to minimize client costs and improve our respective productivities. Thus, for example, we make extensive use of word processing equipment, telex, tie-lines, company vehicles, in-house technical library support, and the like.

Further details regarding technical and administrative support equipment may be found in Appendices B1 through B3.

(e) Major Hydroelectric Projects in North America

The climatic conditions in the area of the Susitna project are similar in severity during winter freeze-up to those at several major hydroelectric projects undertaken by Acres in Canada. The most prominent example is the Churchill Falls Development in Labrador. Others are the Kettle Rapids, Kelsey, Long Spruce and Limestone Hydroelectric Projects in Northern Manitoba. Although these sites are about 500 miles south of Susitna in latitude, they are within areas of discontinuous permafrost and close to the southern limit of continuous permafrost. Acres has also been involved in detailed studies and investigations for other major engineering projects as far north as Prudhoe Bay in connection with the petroleum industry.

This section of the proposal therefore addresses projects undertaken on the North American continent rather than the United States alone. In the United States, Acres has participated in the study, engineering, licensing and construction of numerous smaller projects involved hydroelectric generating stations, pumped storage developments, large earth dams, tunnels and other major underground excavations.

Detailed summaries of some of these projects are presented in Appendix C1 and summarized in the following tables.

REPRESENTATIVE LISTING OF ACRES PROJECTS

NORTH AMERICAN HYDRO-ELECTRIC POWER DEVELOPMENTS

DEVELOPMENT AND CLIENT	INSTALLED CAPACITY		RATED HEAD
Churchill Falls Churchill River, Labrador, Newfoundland Churchill Falls (Labrador) Corporation Limited	11 units Underground powerhouse	5,225 Mw	313 m (1,025 ft)
Bersimis No. 1 Bersimis River, Quebec Quebec Hydro-Electric Commission	8 units Underground powerhouse	900 Mw	239 m (785 ft)
Chute-des-Passes Peribonka River, Quebec Aluminum Company of Canada Limited	5 units Underground powerhouse	750 Mw	160 m (540 ft)
John Hart Campbell River, British Columbia British Columbia Power Commission	6 units	125 Mw	119 m (390 ft)
Bersimis No. 2 Bersimis River, Quebec Quebec Hydro-Electric Commission	5 units	640 Mw	112 m (367 ft)
Lower Notch Montreal River, Ontario The Hydro-Electric Power Commission of Ontario	2 units	250 Mw	70 m (230 ft)
Manicouagan 2 Manicouagan River, Quebec Quebec Hydro-Electric Commission	8 units	1,000 Mw	70 m (230 ft)
Shipshaw Saguenay River, Quebec Aluminum Company of Canada Limited	12 units	900 Mw	63.5 m (208 ft)
Outardes Outardes River, Quebec The Ontario Paper Company Limited	2 units	52 Mw	63.5 m (208 ft)
Arnprior Madawaska River, Ontario The Hydro-Electric Power Commission of Ontario	2 units	78 Mw	21 m (68 ft)

DEVELOPMENT AND CLIENT	INSTALLED CAPACITY		RATED HEAD
Chute-a-Caron Extension Saguenay River, Quebec Aluminum Company of Canada Limited	2 units	100 Mw	50 m (165 ft)
Strathcona Campbell River, British Columbia British Columbia Power Commission	1 unit	31 Mw	42.5 m (140 ft)
Black River Extensions Black River, Quebec The Pembroke Electric Light Company Limited	3 units	6 Mw	38 m (125 ft)
Grand Falls Saint John River, New Brunswick The New Brunswick Electric Power Commission et al	4 units	60 Mw	38 m (125 ft)
McCormick No. 1 Manicouagan Power Company	2 units	85 Mw	37.5 m (124 ft)
McCormick No. 2 Manicouagan River, Quebec Manicouagan Power Company	3 units	134 Mw	37.5 m (124 ft)
McCormick No. 3 Manicouagan River, Quebec Manicouagan Power Company	2 units	120 Mw	37.5 m (124 ft)
Manicouagan 1 Manucouagan River, Quebec Quebec Hydro-Electric Commission	3 units	180 Mw	37.5 m (124 ft)
Ladore Falls Campbell River, British Columbia British Columbia Power Commission	2 units	52 Mw	37 m (122 ft)
Grand Rapids Saskatchewan River, Manitoba Manitoba Hydro	4 units	450 Mw	36.5 m (120 ft)
Mactaquac Saint John River, New Brunswick The New Brunswick Electric Power Commission	6 units	625 Mw	33.5 m (110 ft)

(f) Major Hydroelectric Projects Overseas

The company has for a number of years been responsible for the complete engineering of numerous large hydroelectric projects overseas. We are currently providing comprehensive project management and engineering services to the Volta River Authority in Ghana for the $250 million, 150 MW Kpong Hydroelectric Project. This project is being financed by the World Bank and is scheduled for completion in 1982. In Iran, prior to the recent unrest, Acres had been retained to provide engineering and project management services for the $1,500 million Karun hydroelectric development. Work on this project is expected to restart in the near future.

Acres experience and accomplishments in a wide variety of conditions and circumstances overseas are considerable. A summary of more important projects is presented in the attached tables. Details of some of these projects are presented in Appendix C2.

REPRESENTATIVE LISTING OF ACRES PROJECTS

OVERSEAS HYDROELECTRIC POWER DEVELOPMENTS

DEVELOPMENT AND CLIENT	INSTALLED CAPACITY	RATED HEAD
Alto Anchicaya Anchicaya River, Colombia Corporacion Autonoma Regional del Cauca	3 units – 340 Mw Underground powerhouse	430 m
Aslantas Ceyhan River, Turkey Government of Turkey State Hydraulic Works	3 units – 125 Mw	100 m
Mayurakshi Reservoir Mayurakshi River, India Government of Canada Colombo Plan Administration	2 units – 4 Mw	30 m
Kpong Rio Volta, Ghana Volta River Authority	4 units – 160 Mw	11.8 m
Los Esclavos Los Esclavos River, Guatemala Instituto Nacional de Electrificacion	2 units – 13 Mw	107 m
Nam Ngum Nam Ngum River The Laotian National Mekong Committee	2 units – 30 Mw	35 m
Salto Grande Uruguay River, Argentina-Uruguay Comision Tecnica Mixta de Salto Grande	12 units – 1,620 Mw	25 m
Shadiwal Upper Jhelum Canal, Pakistan Government of Canada Colombo Plan Administration	2 units – 12 Mw	7 m
Sirikit Nan River Electricity Generating Authority of Thailand	4 units – 500 Mw	76 m
Tarbela Rio Indo, Pakistan Water and Power Development Authority	2 units – 350 Mw	91.4 m
Warsak Kabul River, Pakistan Government of Canada Colombo Plan Administration	4 units – 160 Mw	44 m

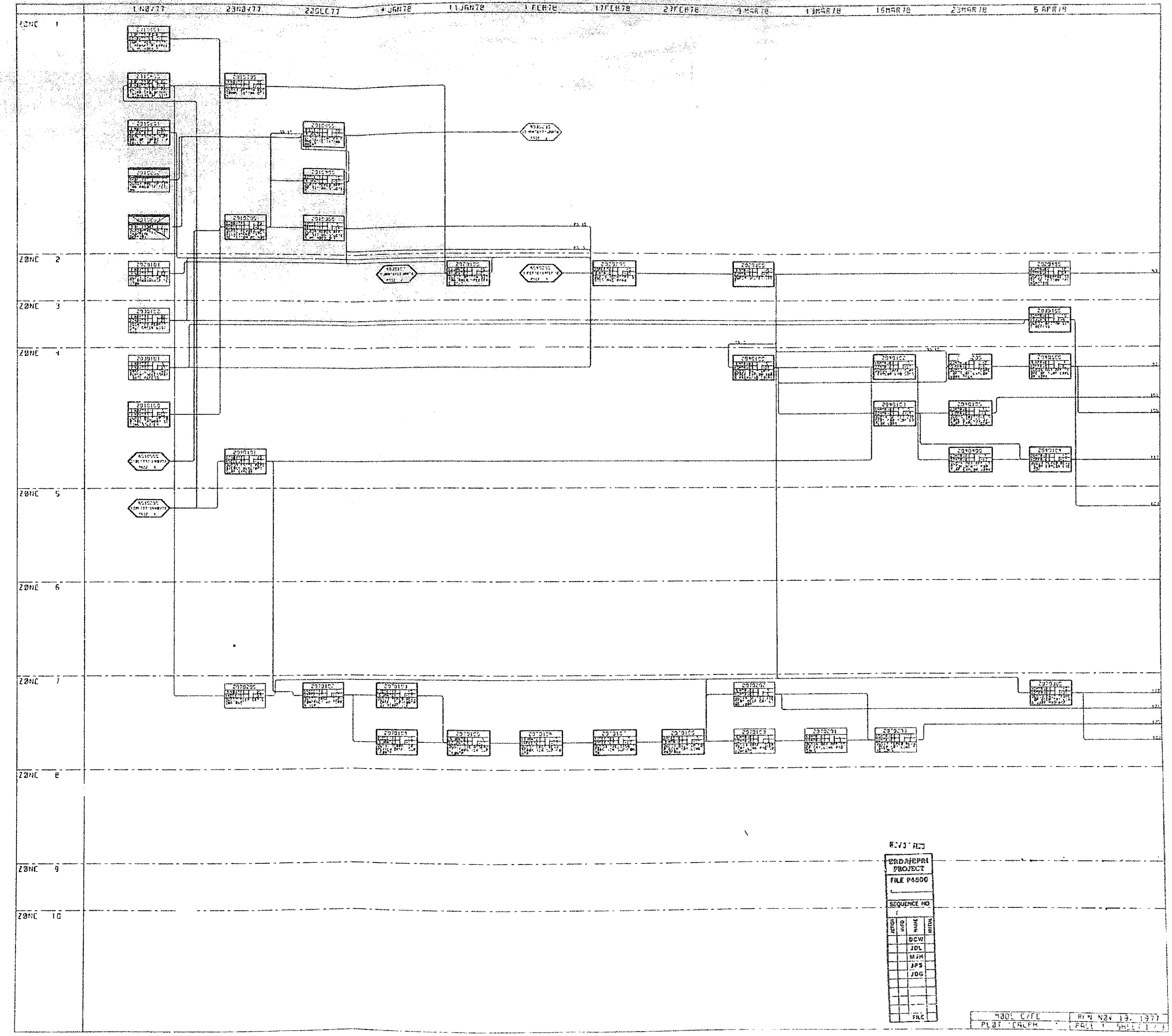
(g) Detailed Plan of Study and Licensing

(i) Plan of Study

The Acres - R&M - Moolin - TES team will provide an amply qualified group capable of preparing a comprehensive yet cost-effective plan for study of the Susitna Project. The individual members of the team, whose credentials are presented in Item 3h and Appendix E, possess a unique blend of qualifications and experience not only in engineering and environmental studies for large hydroelectric projects but also in conditions specific to the Susitna project area.

Acres American completed in 1977 the Power Alternatives Study for the 944 MW Dickey-Lincoln School Lakes Hydroelectric Project in Maine for the New England Division, Corps of Engineers. This study amounting to a total of more than $120,000 involved a detailed asessment of load growth in the six New England States and development and economic assessment of several generation expansion scenarios to meet future demands through the year 2000. Environmental assessments of each scenario were also undertaken. This study also involved participation in public hearings, and is currently still in progress with review of various state conservation policy documents and responses to comments on the draft EIS.

In the recent past, Acres American Inc. has also undertaken numerous feasibility studies for hydroelectric and pumped storage projects of all sizes. In 1978-79 the company has completed feasibility studies for ten small hydro projects in the U.S. totalling 60 MW in capacity. These studies involved conceptual designs, evaluation of alternatives, economic assessments and consideration of licensing requirements including the environmental and safety aspects. At the other end of the scale, Acres is also currently undertaking a comprehensive study of hydro and pumped storage development alternatives at Tygart Lake in West Virginia for the Pittsburgh District, Corps of Engineers and a $3.6 million study of 1000 MW underground pumped hydro and compressed air energy storage developments for Potomac Electric Power Company. This study, which is being funded jointly by the Department of Energy and the Electric Power Research Institute, required submission to DOE and EPRI of a comprehensive proposal detailing the plan of study. A segment of the detailed logic diagram for this study is attached. This logic diagram is but part of a comprehensive schedule which is updated on a monthly basis using a computerized scheduling system. Use of similar scheduling techniques would be particularly well suited to the proposed Susitna plan of study and would readily be expanded during later stages of the project to include the design and construction phases.



ERDA/EPRI PROJECT

FILE P4800

SEQUENCE NO.

ACTION	INFO	NAME	INITIAL
		DCW	
		JDL	
		MJH	
		JPS	
		JDG	
		FILE	

The PEPCO study has involved site selection, a $300,000 field drilling program and geophysical testing at the selected site in Maryland. This program is currently in progress. A detailed environmental assessment and identification of licensing requirements is also in progress as well as detailed engineering and cost studies. These studies involve numerous subcontracts to obtain the services of specialists and consultants in appropriate areas of design.

A summary of this and other major studies involving a multidisciplinary approach and requiring careful coordination of the efforts of large groups, is presented below. Details of Acres experience in such studies are provided in Appendix C.3.

Major Studies in Hydroelectric
and Related Fields

1. Project and Regional Hydro Studies

- Tygart Lake Project Hydro Power Evaluation, Pittsburgh District, Corps of Engineers
- Underground Pumped Hydro Feasibility Study, Potomac Electric Power Company, DOE, EPRI
- Pumped Storage Feasibility Study, Northeast United States
- Hydroelectric Power Generation Study, Massachusetts Municipal Wholesale Electric Company;
- Oswego River Hydro Development Study, Niagara Mohawk Power Corporation

2. Power and System Studies

- Dickey-Lincoln School Lakes Project Power Alternatives Study, New England Division, Corps of Engineers
- Vermont Power Study, Vermont Electric Cooperative
- Generation Expansion Study, Kpong Hydroelectric Project
- System Studies, Thailand

3. Pumped Storage Development Studies

- Appraisal of Sites for UPH and CAES Facilities, Boston Edison Company
- Research Priorities Study for Underground PUmed Storage, Electric Power Research Institute
- Underground Pumped Storage Study, American Electric Power Corporation

R&M Consultants are also skilled in undertaking conceptual design and other studies related to developments in the Alaskan environment. Acres and R&M have worked together on other assignments in northern regions involving hydrologic and geotechnical field work. The skills of each organization have proved to be extremely compatible and complementary in such undertakings.

Details of R&M experience in studies and exploration in the Alaska environment are presented in Appendix B2.

TES have also worked with Acres on the environmental assessment of hydroelectric projects in the U.S. The strong combination of skills and local environment expertise which TES can bring to the Susitna study will be invaluable and in many respects unique.

Details of the TES approach to the study and its specialist consultants' experience in Alaska are provided in Appendix B3.

(ii) The Application and the Licensing Process

Under the rules and regulations adopted by the Federal Energy Regulatory Commission to fulfill its responsibility vested by the Federal Power Act, the document requesting the licensing of proposed projects on the Upper Susitna River would be considered in the category of Application for License for Proposed Major Project. As such, the application document would consist of an extensive compilation of project data assembled into the appropriate FERC format in an application essentially containing summary information, and a series of up to 21 exhibits containing the details of the project proposal.

The licensing process for a major project is in fact a sort of dynamic maze whose various barriers can be erected or modified from time-to-time by a variety of Federal, state, and local agencies as well as by "interested parties". There is indeed no way to guarantee in advance that an application will eventually lead to a license.

A guarantee of success may be impossible, but failure is easily assured. A license application must pass a number of tests. To fail any one would be to fail completely for there is simply no trade-off provision in the licensing process for off-setting environmental shortcomings with economic strength or dam safety uncertainty with assured marketability or any number of items with others.

The initial preparation of the license by personnel, expert in both hydroelectric project detail and the licensing process can save costly time in avoiding application deficiency and anticipating addressing agency comment. Just as important are the follow-up services to keep the licensing consideration flowing through the network of Commission staff and Commission action. After submittal of the application, the experienced engineer would continue to provide services in the following areas, as needed:

(1) Intermittent response to Commission staff questions on the application document;
(2) Response to unanticipated Commission letters indicating deficiencies in the application;
(3) EIS support - intermittent response to questions or environmental data
- response to intervention petitions and public comments
- expert testimony if public hearing on the EIS occur
(4) Assistance in obtaining water quality certification;
(5) Assistance in responding to public and agency comments;
(6) Preparation of responses to Commission staff reviews on safety and adequacy and jurisdiction;
(7) Expert testimony in the event of a licensing hearing or conferences;
(8) Assistance as required in securing separate permits and approvals as needed from:

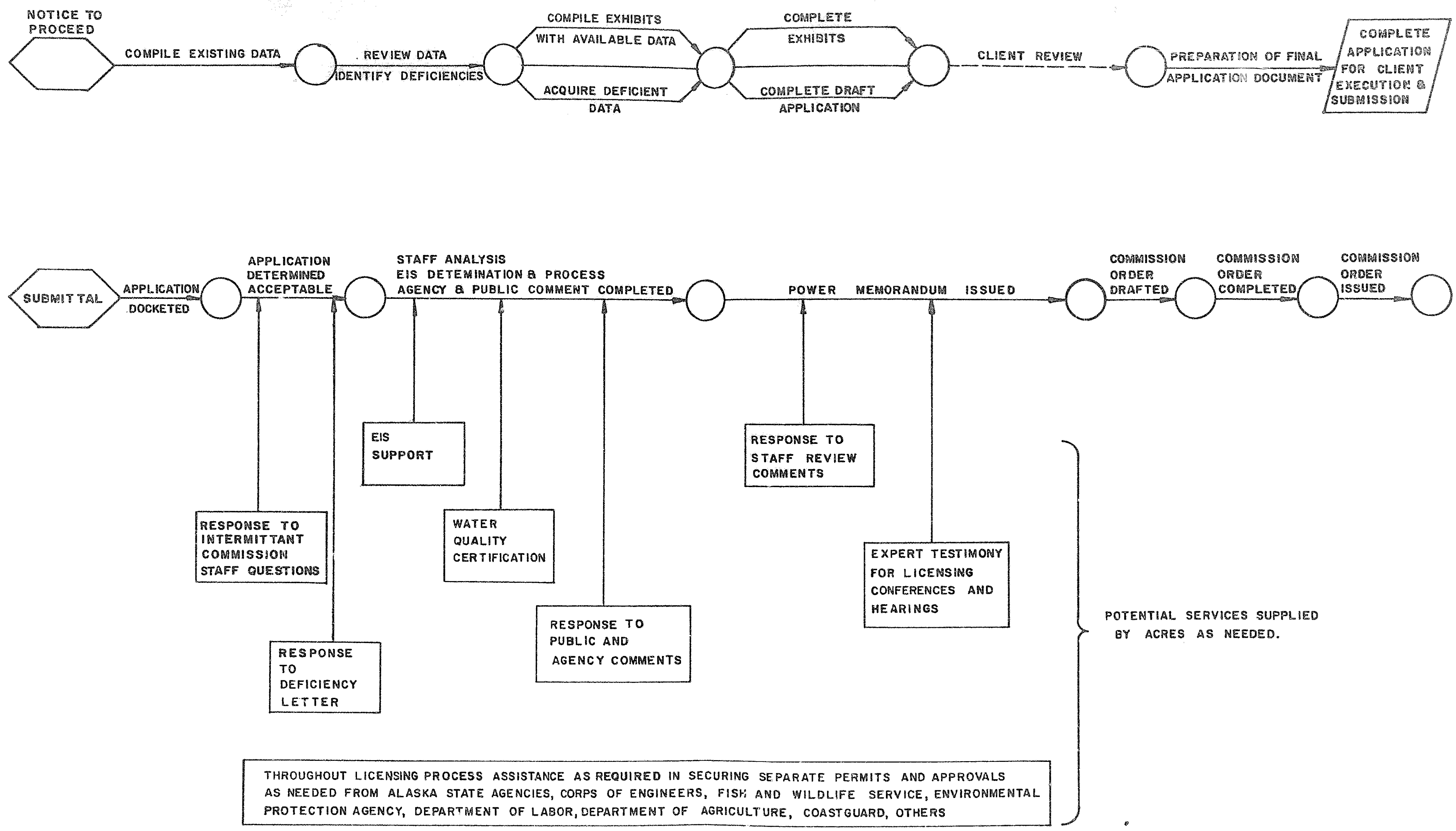
- Alaska State Agencies
- Corps of Engineers
- Environmental Protection Agency
- Department of Labor (OSHA)
- Department of Agriculture (SCS)
- Coast Guard
- Others

The attached line diagrams show the general process of the preparation of the application document and the summary FERC licensing process with the potential inputs of engineering consultant services that Acres is well qualified to provide.

Seeking to respond and lend encouragement to the recent heightened interest in hydroelectric generation and to act more promptly on all license applications, the Commission is currently carrying out a program to reform its requirements and procedures for licensing applications. The final phase of the program will deal with major unconstructed projects, such as those in the Upper Susitna. Thus, it will be important for the applicant to keep abreast of any rule changes, to take advantage of any time savings afforded by the new rules and to avoid delays caused by submittal of an application not in compliance with current rules and regulations.

?
Several of Acres current projects within the United States include preparation of FERC license and preliminary permit applications. Acres staff include several who have direct experience in current FERC regulations and the application requirements, in dealing with Commission staff and in the necessary follow-up to license application. Acres offices in Columbia, Maryland and Washington, D.C. provide convenient access to Commission offices for quick response coordination with the Commission staff.

Additionally, Acres has staff experience in working with the Corps of Engineers, who has played the major role in execution of the project studies to date.



ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SERVICES DURING LICENSING PROCESS

h. PROJECT MANAGER AND KEY PERSONNEL

(i) Introduction

The proposed organization for the preparation of the plan of study and subsequent conduct thereof is presented in Plates 1 through 4. The principal project management organization is presented in Plate 1, with succeeding plates expanding the three major areas of environmental, field work, and project engineering (including project economics).

While work necessary for successful award of an FERC license will be conducted by the project team organized as in Plate 1, it is important to note that subsequent phases of the project will necessarily demand that the team evolve through periodic metamorphosis, as detailed design and construction activities come into play. Our own experience with the successful Churchill Falls and other large hydro projects suggests -- and others knowledgeable of giant projects confirm -- that it is not enough to simply extrapolate organizational structures from normal projects to giant. The subject is discussed in some detail and skeletal organizations are shown in the enclosed article by Mr. J. G. Warnock, Vice President and Manager of Power and Heavy Civil Group, Acres American Incorporated (see Appendix D, extracted from the text, "A Multi-disciplined Study of Problems and Solutions of Successfully Accomplishing Giant Projects". Two copies of this entire text are provided with the set of five proposals furnished to Alaska Power Authority). Nor is it appropriate to defer input from the construction management expert until bids are let. Indeed, the construction manager can offer much even in the concept stage. Thus do we propose to include the firm of Frank Moolin & Associates Inc. as the fourth member of the ARMT team.

(ii) Principal Management Organization

Detailed curriculum vitae are included in Appendix E for each member of the proposed project team.

The project management workload will be divided generally as follows:

Project Manager: Mr. J. D. Lawrence will hold overall responsibility for the project. Three principal efforts will be undertaken under his direction. These include the preparation of a detailed plan of study and conduct of the study itself, early and continuing financial planning, and coordination of the activities of an external engineering board. He will be responsive to the designated representative of the Alaska Power Authority. Mr. Lawrence currently holds the position of Manager of Hydroelectric Projects in Acres American Incorporated. His extensive worldwide experience spans the spectrum from planning through direction of construction management on hydroelectric projects.

Financial Planning: Mr. J. G. Warnock will be responsible for preparation of necessary plans and comprehensive documentation for public financing of the Susitna Project. No stranger to such work, he served in this role for the Churchill Falls power development and has been intimately involved as well in the Bay of Fundy Tidal Power Study, yet another giant project still in planning.

External Engineering Board: An impartial board of eminent engineers will be formed for the purpose of providing objective professional review and advice. This group, to be nominated by Acres and agreed to by Alaska Power Authority, will be afforded broad latitude in its deliberations. At the same time, we regard it as a particularly necessary element in efforts to insure investor confidence and reduce environmental concern.

Study Director: Col. (Ret.) C. A. Debelius will be responsible to the Project Manager for the preparation of the Plan of Study and for conduct of the study itself. Col. Debelius was the Alaska District Engineer from 1973 until 1976 when his organization prepared the initial Corps of Engineers studies of the Susitna project. He personally conducted all public meetings on the subject during his tour of duty in Alaska and presented the findings and recommendations of the initial studies to the Board of Engineers for Rivers and Harbors.

In-House Review Panel: An in-house panel of experts will be formed from senior members of the Acres organization, each of whom is regarded internationally as an expert in his particular area of expertise. This team will be an in-house counterpart to the expert engineering board previously described. This group has had extensive collective experience in hydroelectric work in subarctic climates and in seismically active areas. Their involvement in the Churchill Falls Project is recounted in curriculum vitae in Appendix D. Members include Messrs. J. G. Thompson, D. C. Willett, J. G. Warnock, D. H. MacDonald (Ph.D.) and D. E. Hepburn.

Field Work: Mr. Frank Moolin, Project Manager, assisted by J. T. Minstrell of Acres American Incorporated and J. W. Rooney of R&M Consultants Inc. will be responsible for the conduct of all field work. The organization for that effort is discussed in paragraph h(iii) below.

Project Engineering: J. D. Gill will direct the Acres team responsible for all project engineering. His organization is discussed in paragraph h(iv) below.

Environmental Studies: Dr. J. W. Hayden of Acres American Inc. and Mr. J. O. Barnes of Terrestrial Environmental Specialists Inc. will be responsible for all environmental studies as well as preparation of those exhibits in the FERC license application dealing with environmental matters. The environmental organization is discussed in paragraph h(v) below.

ACRES

(iii) Field Work

The field work will be conducted primarily through the efforts and the resources of R&M Consultants Inc., with participation by certain Acres counterparts and with assistance in planning and scheduling by F. Moolin & Associates Inc. Duties and principal personnel involved are as follows:

Project Manager: F. Moolin will be responsible for the overall planning, scheduling and coordination of a large number of field activities which must be conducted concurrently to maximize opportunities available during the short season favorable to certain investigations. He will provide the interface as well for field activities of the environmental team, which will also operate in the same general area as the field work teams. Mr. Moolin is intimately familiar with the planning management of giant projects and his herculean efforts in Alaska as senior project manager on the pipeline earned him recognition as ENR's "Construction Man of the Year" in 1976. He will be assisted by Mr. J. T. Minstrell of Acres American Inc. and by Mr. J. W. Rooney of R&M Consultants Inc.

Surveys/Mapping & Real Estate: M. A. Menzies of R&M. The effort and equipment involved for this important work will be provided from the resources of R&M. Mr. Menzies has been registered as a Professional Land Surveyor in Alaska since 1965 and as a Professional Civil Engineer since 1969. He has had extensive experience in his field under the unique conditions found in Alaska and is familiar with the complications of giant project planning through his own efforts in surveying and mapping in support of the pipeline.

Hydrology: J. E. Swanson of R&M will direct hydrological investigations. He will be assisted by K. F. Litfin of Acres. Mr. Litfin will provide the necessary interface between the information needs of the project engineering team and the data collection efforts of the field team. Mr. Swanson is currently the Head of the Engineering Studies Department in R&M's Anchorage office. His own experience in hydrologic field work spans a decade in Alaska and extends geographically from Prudhoe Bay to Ketchikan.

Geology/Seismicity: Dr. J. M. Brown of R&M will direct geological investigations and seismic studies. He will be assisted by Mr. S.N. Thompson of Acres, who will provide the necessary interface with the project engineering team for data collection needs. Field work will be carried out in this discipline by R&M teams. Dr. Brown has extensive experience in the direction of geological studies in Alaska, many of which were conducted in the Southcentral Railbelt area. Thus, his direct familiarity with the proposed project site and alternative transmission corridors will be important factors in minimizing risks as the project is planned.

Site Exploration and Testing: R. L. Schraeder of R&M will direct all site exploration and testing activities. As the Vice President of Resource Exploration Corporation, an R&M Company, Mr. Schraeder manages field operations conducted within the State of Alaska. His past experience includes the direction of the activities of up to 40 field geologists on the centerline investigations conducted for the pipeline. His earlier work as a District Geologist in the Alaska Department of Highways permitted him to become thoroughly familiar with geological conditions prevalent in the Railbelt. Mr. Schraeder will be assisted by R. Henschel of Acres.

Camps, Airstrip & Access Roads: D. Nottingham of R&M will be responsible for acquiring, establishing, maintaining, and ultimately removing all facilities necessary for access and project team support. He will secure permits and ensure regulatory compliance as well. As Vice President in R&M's Anchorage office, he has gained extensive management experience in Alaska and has acquired a thorough understanding of the need for proper project planning and direction. First hand knowledge of costs associated with such work will be invaluable in preparation of a reliable estimate to be associated with the Plan of Study. He will be assisted by Mr. D. W. Lamb of Acres, who as Manager of the Transportation and Heavy Civil Engineering Division, has successfully mobilized large engineering efforts at remote sites with minimum advance notification.

(iv) Project Engineering

While all of the firms on the project team will participate in the project engineering effort, the primary role will be played by Acres, wherein extensive hydroelectric experience under arctic conditions is found. Because of the magnitude and the nature of the work, virtually the entire resources of the Acres Group (including our International and Canadian companies) will from time-to-time be called upon for contribution to successful accomplishment of the study, assistance as the license application is considered by FERC, and for involvement in detailed design and construction management if Acres is selected for such efforts. Key members of the team are shown on Plate 3 with duties as follows:

Project Engineering Manager: J. D. Gill will manage the entire project engineering effort. He will direct the activities and ensure the coordination thereof for a number of subteams. In addition, he will ensure that the field work being carried out by R&M and the environmental efforts under the aegis of TES will be responsive to the objective of acquiring the requisite FERC license. He will receive advice and assistance from F. Moolin & Associates for preparation of realistic cost estimates and schedules, tailored to the Alaskan experience. Mr. Gill is Head of the Civil/Geotechnical Department of Acres American Inc. and he offers a strong background in the conduct and management of engineering activities for hydroelectric work.

Plan Formulation: M. R. Vanderburgh plays a vital role in assisting Mr. Gill in the direction of the initial efforts in plan formulation. As a Project Manager in Acres' Hydroelectric Division, he has gained extensive experience in this unique art. He is currently involved in the project management of the Tygart Lake Hydroelectric Feasibility Study now underway for the Pittsburgh District, Corps of Engineers.

Power Studies: J. K. Landman will develop power studies including market assessment and investigation of alternatives. He has had prior experience with the Bureau of Reclamation, has been trained in the General Electric Generation Evaluation Program, and is currently involved in the Dickey-Lincoln School Lakes Alternative Study being undertaken by Acres for the New England Division, Corps of Engineers, as well as a power study for a large Cooperative in South Carolina.

Hydrology/Hydraulics: R. E. Mayer will direct hydrologic analysis and will become involved as well in the selection and design of various hydraulic features. In this latter role, he will coordinate directly with Mr. R. Shields who will be responsible for hydraulic structures as a member of the feasibility studies and design team. Mr. Mayer is experienced in hydrologic analysis and hydraulics. It is under his direction that a number of Hydrologic Engineering Center computer programs are used in project work.

Reports, Reviews, Public Participation: P. Hoover will coordinate the assembly, review, public notice, and public information programs for the feasibility study. He will also ensure all statutory and regulatory requirements for providing opportunities for public involvement are fulfilled. Mr. Hoover's most recent experience was with FERC, where he has been involved in the review of hydroelectric license applications. Prior to that assignment, he was a study manager for hydroelectric planning studies with the Corps of Engineers.

Cost Estimates and Schedules: J. T. Minstrell will direct the preparation of cost estimates and schedules for Acres. His work involves the estimation of time and costs for the study itself as well as for the actual design and construction of the project. He will provide the interface with the assistance and support of Frank Moolin & Associates, where up-to-date knowledge of current costs and Alaskan contractor capabilities is available.

Foundations/Materials: Dr. T. E. Neff will be responsible for analysis and interpretation of field investigation data and material test results. He will coordinate directly with R&M investigators and will be assisted in his endeavors by R&M foundations and materials staff. Dr. Neff's background in this type of work qualifies him well for his position on the team.

Feasibility Studies and Design: J. P. Sinclair will lead the major project engineering effort in performing technical and economic feasibility assessments. He is charged with orchestrating the concurrent efforts of small teams generally broken down by discipline. He will ensure frequent coordination of these diverse activities and will identify data gaps to be filled through coordination with field and environmental groups. In this latter regard, his responsibilities extend as well into the acquisition of special skills on inputs for which requirements were not foreseen initially. It is likely that he will call upon authorities in other project organizations (e.g. Mr. Milo Bell, with the environmental team, is well-known for his ability to design effective fish passages) whenever developing study efforts indicate a need exists. Mr. Sinclair is a Project Manager in the Hydroelectric Division of Acres American Inc., with extensive experience in feasibility assessments, and is a recognized authority on hydroelectric machinery. His subordinate teams will each be headed up by an engineer thoroughly experienced in hydroelectric work. These include:

- Civil/Structural:	Mr. P. Pal
- Ice Engineering:	Mr. R. W. Carson
- Economic Analysis:	Mr. P. H. Tucker
- Geotechnical:	Dr. S. Bahadur
- Mechanical:	Mr. P. R. Rodrigue
- Electrical:	Mr. E. N. Shadeed
- Hydraulic Structures:	Mr. R. Shields
- Transmission:	Mr. P. G. Phillips
- Access Roads and Camps:	Mr. T. W. Gwozdek

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(v) Environmental Studies

In recognition of the importance of thorough and expert environmental studies urged to date by public and private conservation interests, we recognize the necessity to field a team whose content includes a broad variety of special qualifications pertinent to the Alaskan environment as well as a management structure which has acquired special experience in environmental investigations for hydroelectric projects. Thus, we have chosen to seek the assistance of Terrestrial Environmental Specialists, Inc. (TES). TES has agreed to provide the framework, management, and a number of investigators for environmental studies. In addition, TES has also secured the agreement of leading experts to serve on the investigatory team if a study is actually conducted and to assist in the preparation of a proper Plan of Study if Acres is selected for such an assignment. The proposed organization for environmental studies appears in Plate 4. Duties are described below:

Project Administrator: J. O. Barnes (TES) will provide the overall adminstration and coordination of the environmental work on the project. Dr. J. W. Hayden will represent Acres on the environmental team, and in the interfacing with ongoing engineering work. Mr. Barnes is an environmental scientist experienced in particular in the environmental aspects of transmission line corridor selection. Dr. Hayden heads the Environmental Division of Acres American Inc. He has had extensive diverse experience in the conduct of environmental assessments. He is currently involved as the Manager of the Chesapeake Bay Hydraulic Model, where Acres has been engaged by the Corps of Engineers to conduct a variety of studies to determine the impact of changes, both man-made and naturally occurring, in the Bay's regime.

Reports and Analysis: Dr. V. J. Lucid (TES) will provide the day-to-day direction of the environmental work, both during data collection and subsequent interpretation. He will be responsible for the content of the final environmental reports. He is currently the Director of Environmental Studies at TES, and he has had extensive experience in support of powerhouse siting and operation.

Water Quality: T. L. Smith (R&M) will provide the R&M contact on the environmental team. In addition to furnishing his own expertise in evaluation and enhancement of water quality, he will coordinate the use of R&M facilities, laboratories, and environmental staff members as required to support the effort. He holds twin masters degrees in Sanitary Engineering and Geology-Mineralogy and has conducted numerous water supply, erosion control and enviromental impact studies in Alaska.

Socio-Economic Resources: Dr. R. Gerard (TES) will coordinate socio-economic resource studies. The principal investigator for this portion of the work will be Dr. F. L. Orth whose work on economic impact and financial feasibility studies in Alaska has been extensive. He has had particular experience in developing and implementing methodologies for studies in support of the Alaskan fishery industry. His memberships have included the Alaska Fisheries Council (1977-78), Steering Committee for Bearing Sea Clam Development (1977), Executive Advisory Committee for Alaska Power Survey ([illegible]) and Faculty Fellow at the Pacific Coast Banking School, University of Washington (1973). The resources of the firm, Frank Orth & Associates, Economic and Business Consultants, will be available as appropriate in the environmental studies as well as for consultation in other studies conducted by the project engineering team (e.g. market analysis, economic evaluation).

Recreational and Cultural Resources: M. P. Killeen (TES) will coordinate activities in these two study areas. Dr. E. J. Dixon will be the principal investigator for cultural resources. Dr. Dixon is a respected archaeologist with knowledge of known and suspected earlier evidence of human settlements in Alaska. Dr. A. Jubenville will be the principal investigator for recreation resources. He holds his Ph.D. in Wildland Recreation and is currently Associate Professor of Resources Management at the University of Alaska. He has developed and conducted a number of recreation management, evaluation, and policy courses at the University level, has written texts on these subjects and has widely published other related materials.

Ecological Studies: C. A. Baumgartner (TES) will coordinate studies in ecological fields and will also serve in a quality assurance role as data and samples are conducted and evaluated. Ms. Baumgartner is an environmental scientist with a bachelor's degree in Biology and a Master's in Zoology. She has frequently been involved in the conduct of studies for power plant sites and is particularly adept at planning and organizing field data collection activities.

Fisheries Ecology: R.W. Williams (TES) will coordinate these studies. C. E. Atkinson will be the principal investigator for anadromous fisheries. His extensive work in government, industry and academe in the study of Pacific Salmon is well known. He was involved in early Susitna River studies in the mid-1950's when, as a Director of Biological Research with the Bureau of Commercial Fisheries, he did research on salmon fisheries in Cook Inlet. He has been fisheries advisor to the President of the University of Alaska, has chaired the Alaska Interagency Fisheries Committee, and has been a member of the Board of Directors, Whitney-Fidalgo Seafoods, Inc. Milo C. Bell will be the principal investigator for resident fisheries. He is internationally known for his investigations of fish facilities at hydroelectric power sites and he is perhaps the foremost authority on effective design of fish passage facilities.

Wildlife Ecology: E. T. Reed (TES) will coordinate wildlife ecology studies. Dr. B. Kessel will be principal investigator for Avian Ecology. With long experience and in-depth knowledge of Alaskan ornithology, Dr. Kessel served as Head of the Department of Biological Sciences at the University of Alaska from 1957-1966 and is currently Curator of Terrestrial Vertebrate Collections at the University Museum. S. O. MacDonald will be principal investigator for small mammal ecology. A University of Alaska graduate, he has had twenty-four years of experience in furbearing animal trapping in Minnesota and Alaska. He currently serves as a principal investigator for small mammal and bird population as a museum technician at the University of Alaska Museum.

Dr. P. S. Gibson will be principal investigator for Predatory Ecology. He is currently an Assistant Leader of the Alaska Cooperative Wildlife Research Unit at the University of Alaska. He has extensive research experience and is a recognized authority on predator-prey relationships. Dr. S. Harbo will be the principal investigator for Big Game Ecology. His extensive experience in this field is recounted in detail in his curriculum vitae.

Plant Ecology: J. W. McMullen (TES) will coordinate this activity. Dr. P. J. Webber will serve as the principal investigator. Mr. McMullen has personally conducted a report on the status of endangered plant species in the vicinity of a proposed hydroelectric facility, and has been heavily involved in botanical studies incident to other power generation projects. Dr. Webber is a Professor of Environmental Population and Organismic Biology at the University of Colorado. In September, 1979, he will become Director of the Institute of Arctic and Alpine Research at the University of Colorado. He has carried out research in his field in the arctic for 17 years.

(vi) In-Depth Capability for Follow-On Work

Preceeding paragraphs have already noted the importance of introducing construction management expertise into the planning team. As the project proceeds and a strong construction management organization evolves, Acres is prepared to offer the services of a team of skilled managers whose past involvement in large projects has seasoned them well. In particular, the following individuals will be available for in-house consultation throughout the study phase and, assuming Acres is selected to design and manage this important project, will be a part of the project management team as it evolves for construction:

John L. Owen - Project Services Manager: 20 years experience in project management and engineering primarily for power generating stations.

James E. Partridge - Planner & Scheduler: 9 years experience in planning and scheduling contract administration, and cost engineering for power generating stations.

George F. Lipsett - Manager, Materials Handling: 39 years experience in manpower economics, manpower planning, material management and labor relations related to large power generating stations and heavy industrial installations.

Robert C. Hunter - Contract Administrator: 5 years experience in contract negotiations, procurement, coordination and expediting related to large power generating stations.

Ernest J. Durocher - Senior Buyer: 12 years experience in procurement, expediting and scheduling related to power generating stations and heavy industrial installations.

W. A. Slatcher - Procurement Coordinator: 5 years experience in procurement and expediting.

Kenneth J. Owen - Engineering Coordinator: 32 years experience in project management and engineering related to large power generating stations and heavy industrial projects.

A. E. Williams - Senior Cost Engineer: 33 years experience in cost engineering, estimating, financial forecasts and analysis of power generating stations and heavy industrial installations.

John H. Saldat - Project Manager: 32 years experience in project management and engineering related to large power station development.

Terry W. Waters - Manager, Project Planning & Services: 14 years experience in engineering, contracts administration, coordination of planning and scheduling, cost control and procurement.

Keith H. Marriott - Project Contracts Administrator: 23 years experience in project management, coordination and contracts administration related to power generating stations and heavy industrial installations.

John W. McCreight - Planner/Scheduler: 11 years experience in engineering, project planning and scheduling and procurement.

Edward A. F. Welter - Project Cost Engineer: 32 years experience in multidiscipline project coordination, cost engineering, and contract administration related to power generating stations and heavy industrial installations.

J. Trevor Minstrell - Project Estimator: 28 years experience in engineering, estimating and cost engineering related to large power developments and heavy industrial installations.

Roy Oakely - Project Administration: 28 years experience in engineering, cost administration, materials management, and procurement related to power generating stations.

Albert J. Haverty - Construction Manager: 24 years experience in project management, construction management, contracts adminstration and engineering related to large power generating stations.

Howard R. Simon - Electrical Construction Supervisor: 32 years experience in electrical engineering and construction supervison of power stations and heavy industrial projects.

William N. Verlaan - Construction Cost Engineer: 21 years experience in engineering, scheduling, cost engineering, estimating and project management related to power generating stations and heavy industrial installations.

Robert H. Morris - Field Design Supervisor: 36 years experience in design engineering related to large power developments and heavy industrial installations.

Philip L. Luby - Manager, Materials Handling: 38 years experience in project management and engineering related to power generating stations and heavy industrial installations.

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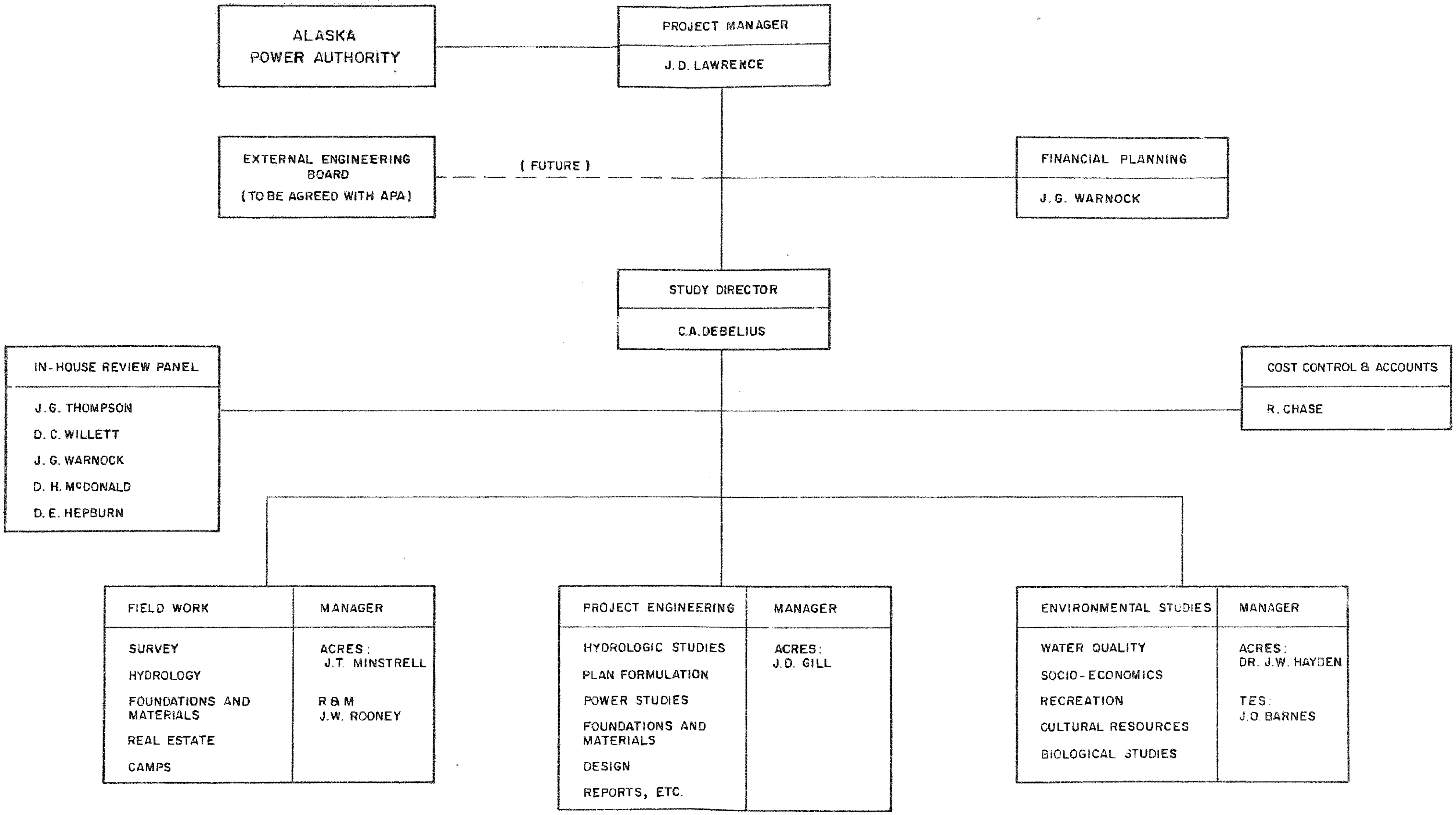
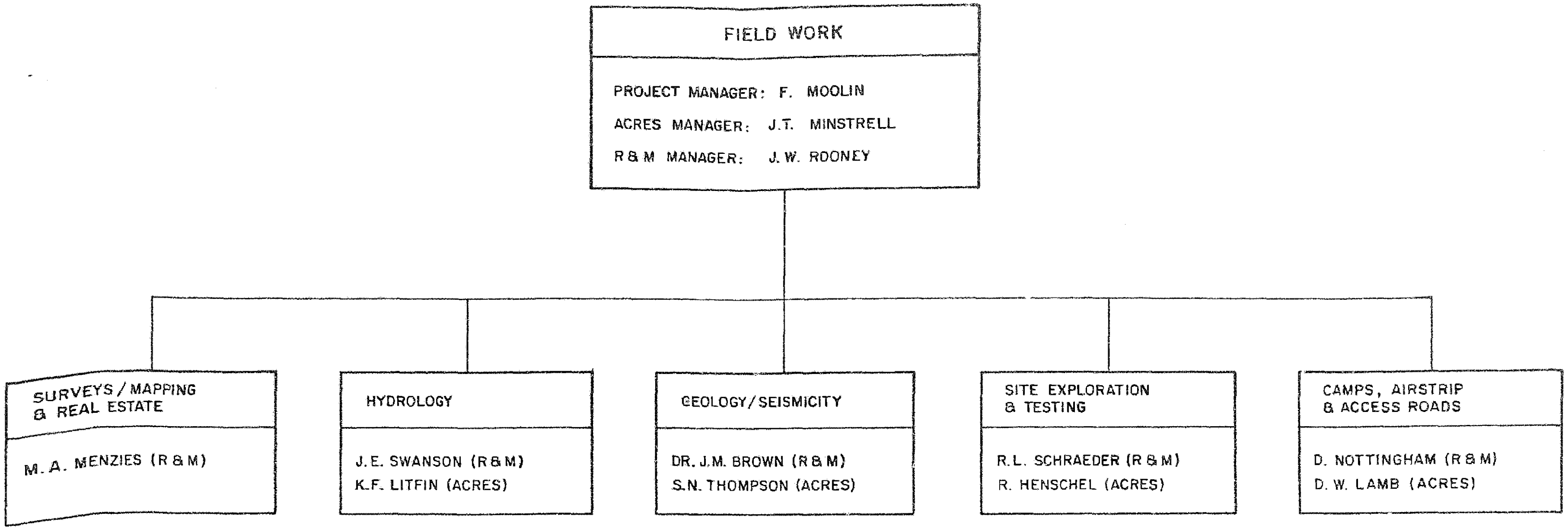


ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

PROJECT MANAGEMENT ORGANIZATION

PLATE 1



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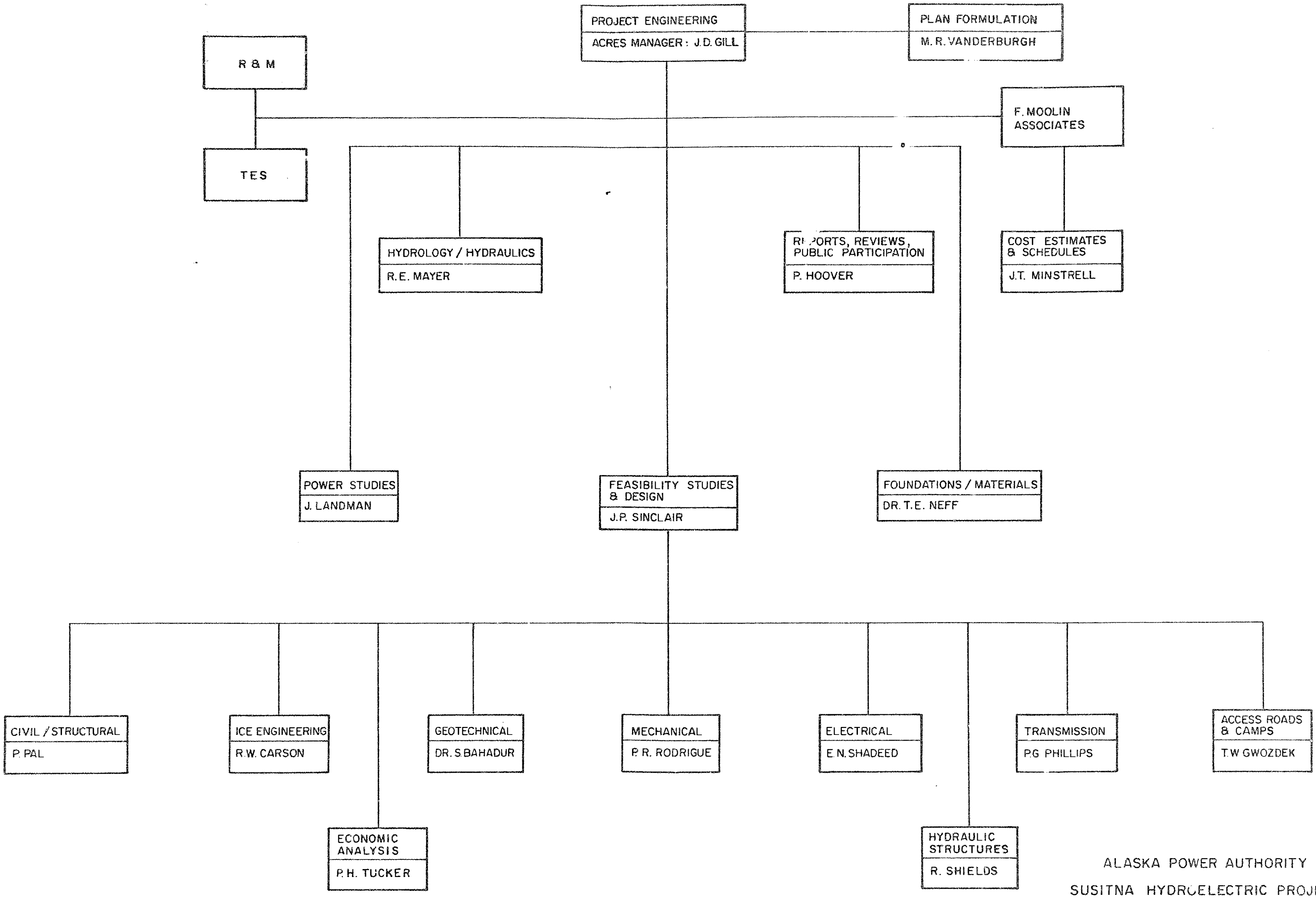
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

FIELD WORK ORGANIZATION

PLATE 2

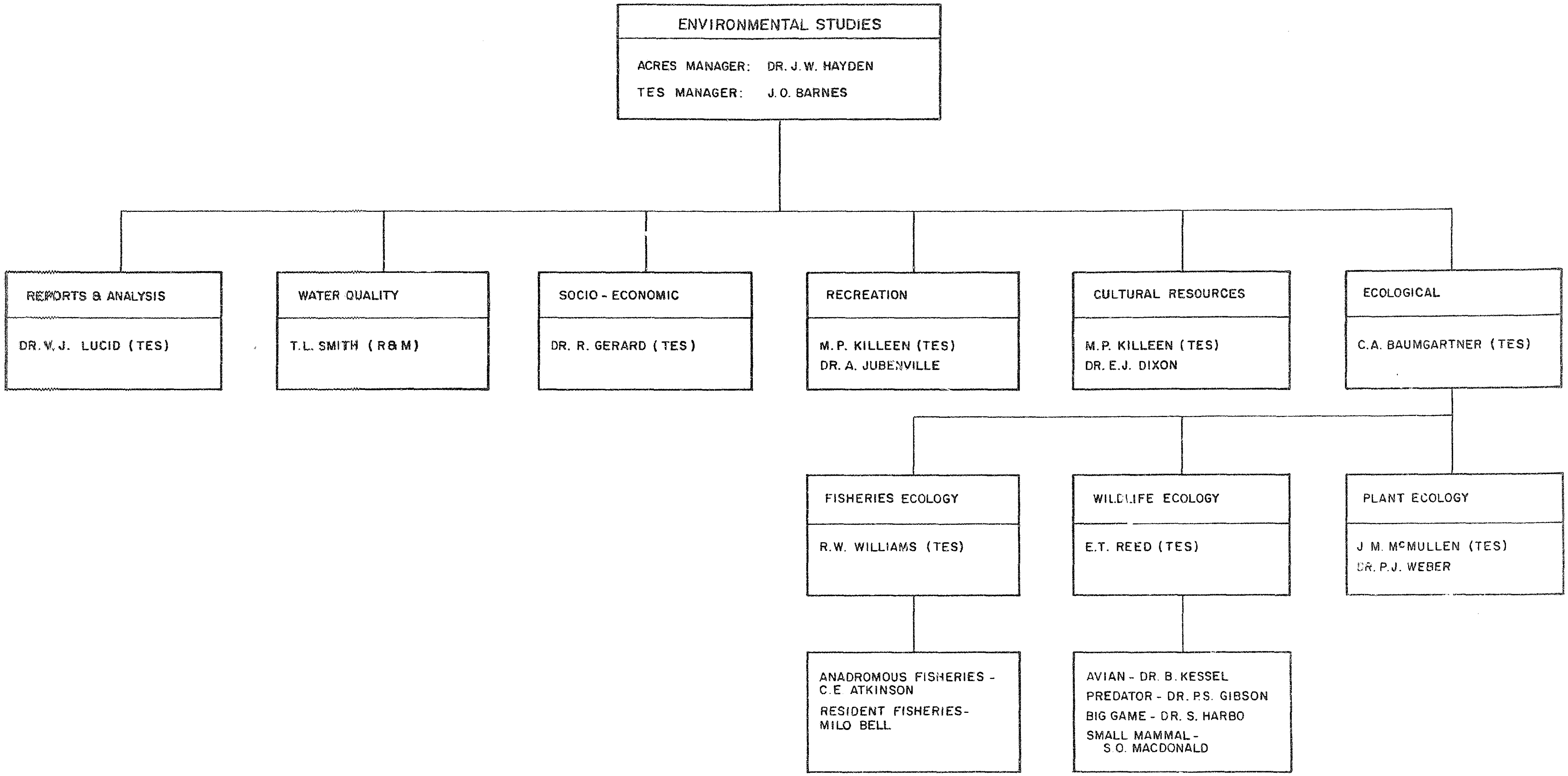


ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

PROJECT ENGINEERING ORGANIZATION

PLATE 3



ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

ENVIRONMENTAL STUDIES ORGANIZATION

PLATE 4

4 - FACTORS TO BE CONSIDERED IN DECIDING WHETHER THE STATE SHOULD TAKE OVER THE SUSITNA PROJECT

Given increasing international pressures on the costs and availability of fossil fuels, there can be little doubt that alternative means of energy production involving the use of renewable resources should be vigorously sought. It follows that the national interest will be well served if feasibility is shown and the Susitna Hydroelectric Project is ultimately constructed. In addition to the conservation of fossil fuels, however, is the important fact that the Alaskan employment picture would be greatly improved by the construction of a major project and the long-term economic outlook would be enhanced by the availability of large blocks of power at a reasonably stable price. Regardless of which route the State of Alaska chooses to follow, the proposed project should not be allowed to sink into bureaucratic oblivion. The questions of economic viability, environmental acceptability, and technical feasibility should be resolved and a decision regarding the future of the project should then be made. Factors worthy of consideration in deciding whether the State should take over the Susitna Project include:

(a) Historical experience on major water resources projects undertaken by the Corps of Engineers demonstrates that intermittent funding, frequent imposition of manpower ceilings, and other constraints imposed by the executive or legislative branches of the Federal Government tend to be extremely time consuming. Indeed, Senator Gravel (Dem., Alaska) noted in a speech just prior to his introduction of Public Law 94-578, that the average time the Corps of Engineers takes from authorization of a project to receipt of first construction funds is 18 years. This extreme length of time is not necessarily indicative of deficiencies on the part of the COE, but rather indicates that the combination of events which must take place sequentially in the bureaucratic process can lead to significant delays.

(b) Federal management will necessarily create a situation wherein national interests are always given precedence over the interests of the State of Alaska.

(c) The Corps has a solid reputation for quality engineering and construction management. A Corps-designed dam has never failed.

(d) The Corps tends to be overly conservative on large engineering projects. In this regard, for example, it is extremely unlikely that the Corps will allow the concept of a thin-arch dam to survive during the Phase I design studies.

(e) The Corps has never built a large hydroelectric dam in a subarctic environment with the attendant dangers of substantial ice buildup.

(f) On a nominal \$2 billion project, a one-year delay is equivalent to \$200 million when the interest rate is 10 percent.

(g) The national perception of Alaska may create difficult barriers to the passage of necessary authorizing legislation to provide monies for the revolving fund. In this regard, for example, Alaska is seen in the Lower 48 as a wealthy oil state whose needs for further Federal assistance are far less than those areas wherein heavy concentrations of high unemployment or low income are concentrated. In addition, the Lower 48 generally views Alaska as the last virgin land, which the remainder of the nation should put in trust to protect the environment for future generations. The recent House vote on the Alaska Lands Bill is indicative of this latter attitude. As a result, it may be difficult to get sustained Federal support for a Federal project which removes some pristine land from the domain of the untouched.

(h) Federal spending per capita in Alaska typically amounts to twice the per capita income of Alaskans. This statistic may well be cited as a defense against authorizing large sums for a revolving fund which will be tapped primarily by the State of Alaska; even though repayment would ultimately be made, the probability that large sums will be placed annually in the revolving fund is not very high.

(i) The cost of advanced engineering and development for this project will probably run about $15 million per year for a period of 4 years. This amount is more than 50 percent of the money requested for advanced engineering and design for all projects in the 1977 Federal budget. It may be difficult to sustain, in periods of tight money, such a level of funding, even if it is to be later repaid.

(j) The project will be regarded as benefiting 1/10 of 1 percent of the total population in the U.S. On the other hand, it can be argued that the nation would receive the benefit of nonrenewable resources conserved for other purposes.

(k) The State can follow a low risk path on the Phase I work if the Federal Government provides the necessary concept of relieving the State of liability for the monies expended in the event that feasibility is not shown. Accepting this low risk, nonetheless, has to be balanced against the possibility that bureaucratic delays could cost much more than the $25 million or so involved.

(l) In the event that the Federal Government does provide sufficient money to maintain the revolving fund at the required level, the State could defer a decision to proceed on its own until that point at which Federal monies dry up.

(m) The Federal hydroelectric development process is extremely cumbersome. It is time consuming, sometimes confusing, and often laced with conflicting regulatory requirements. On the other hand, it has been effective in ensuring that there is ample opportunity for consideration of all issues and for hearing the voice and arguments of the opposition.

(n) If the Corps is in fact responsible for the design of this project, the chances are great that most of the design will be done outside the State of Alaska. The Corps has a hydroelectric branch currently in Portland, Oregon; and, in addition, the work load is relatively slack at the Walla Walla District office, which has been involved over the years in a number of large hydroelectric projects. The use of a private consultant would allow the State to set specific minimum percentages of work which would have to be performed in-state.

(o) As a Federal project progresses, need for a significant change to the originally authorized purpose can result in extended delays while changes are sought to the authorization. It is reasonable to assume that the State could streamline this process if it were footing the entire bill.

(p) There is an element of State pride to be associated with undertaking this important giant project without having to rely upon the Federal government for subsidies and support. In that regard, the State of Alaska could be viewed as taking a leadership role, providing an incentive and an example for other states who may wish to have a greater hand in their own destinies.

(q) One danger associated with Federal development is that there may be strong Federal influence as customer priority preferences are set.

(r) In light of recent accelerated increases in the costs of fossil fuels, the chances that the project will be shown feasible are currently reasonably good. It follows that Alaska's expectation of having to reimburse the revolving fund for the cost of the Corps work must be correspondingly high. There is at least the chance that a private consulting team, unconstrained by certain bureaucratic layering and able to avoid the inefficiencies associated with year-to-year funding variations and uncertainties, can deliver a feasibility study and all the necessary exhibits required for FERC licensing at a markedly lower price than the $25 million (in 1977 dollars) proposed by the Corps.

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5 - SPECIAL JUSTIFICATIONS FOR SELECTION

(a) Introduction

The proposed Susitna Hydroelectric Project is extraordinary for a number of important reasons. It is, first of all, a giant project and only a relatively small number of organizations can claim experience on giant projects. Fewer still can demonstrate successful accomplishment. Secondly, the Susitna River Basin lies in an area whose extreme climatic conditions must be understood and accommodated by the designer. Nor is climate the only unique factor to be reckoned with. Seismic activity in the Southcentral Railbelt is clearly present, important anadromous fisheries depend on the lower Susitna as a spawning ground, and the project itself remains yet an embryo whose further development could follow the unusual twist whereby the State of Alaska takes over from the Federal Government. It follows, then, that the selection of a consultant to the State may be a difficult process. For the consulting firm which competes for such awesome responsibility, it is imperative that the capability must be available to carry the work not only from plan of study through FERC license award, but also to final design and construction management. Acres American Inc., together with other firms and consultants who have agreed to join its team, is prepared to provide proven capability to carry the project to successful completion.

A senior member of Acres American participated in an international conference last year in London. Giant projects were discussed and a set of six common threads were identified. Succeeding paragraphs in this section address the qualifications of the Acres team in light of each such point.

(b) Multi-disciplined Teams

The very complexity of the project demands a wide range of skills. The Acres team encompasses a far wider range of disciplines than would normally be assembled for smaller projects or for less extreme environments. More important than the presence of all necessary disciplines, though, is the fact that the team is thoroughly knowledgeable of the arctic and subarctic in general, and of Alaska in particular.

(c) Top Management Group

The top teams must be small. Their members should be capable of understanding and managing a wide variety of disciplines and functions and they must be able to compromise. The top managers proposed by Acres for this effort include in particular Mr. J. D. Lawrence, whose worldwide experience in managing all aspects of hydroelectric projects will permit him to face inevitable problems and conflicts with confidence; Mr. J. G. Warnock, whose success in securing the placement of $550 million in bonds for the Churchill Falls project ensures strong capability to guide the financial planning effort; and Col. (Ret.) C.A. Debelius, whose thorough knowledge of the project was gained first-hand when the Corps of Engineers preauthorization studies were conducted under his auspices. Each of these top managers can call upon a wealth of support from the broad-based experienced personnel available in the Acres organization. Very large hydroelectric projects, extreme arctic and subarctic conditions, remote site logistics, and a host of other capabilities are available in-house for tapping.

(d) Preplanning

The amount and range of preplanning for giant projects have typically been underestimated in the past. Every major expertise must be involved from the start. Thus do we propose to include the noted construction management firm of Frank Moolin & Associates even as the plan of study is hashed out. Thus too, do we stress early attention to planning for financing, as well as establishment of an external engineering board as soon as the study itself shall commence.

(e) Successful Organization

We regard the organization for accomplishment of the work as a critical item which impacts on both cost and quality of the ultimate product. It is imperative, in our view, that a strong local presence and adequate local facilities be included in the team. R&M provides experience in Alaska and an impressive distribution of laboratories, offices, and equipment which are immediately available for the work. Should the efforts of the Acres team in preparation of a Plan of Study be sufficient to lead to our selection, as the State's consultant, Acres American plans to establish an office in Alaska so that the bulk of the project work will be performed there and an immediate presence will be available to Alaska Power Authority for coordination.

(f) Financial Requirements

There is little doubt that if the State elects to pursue the Susitna work on its own, the resources and ingenuity of financing institutions will be taxed to the limit. It follows that strong capabilities in pursuing such matters must be a part of the team. We have already noted above the prowess of Mr. J. G. Warnock. We note as well that the firm of Frank Orth & Associates, Economic and Business Consultants, has agreed to serve as a subcontractor to TES. The Frank Orth firm has had extensive experience in financial planning in support of Alaskan enterprises.

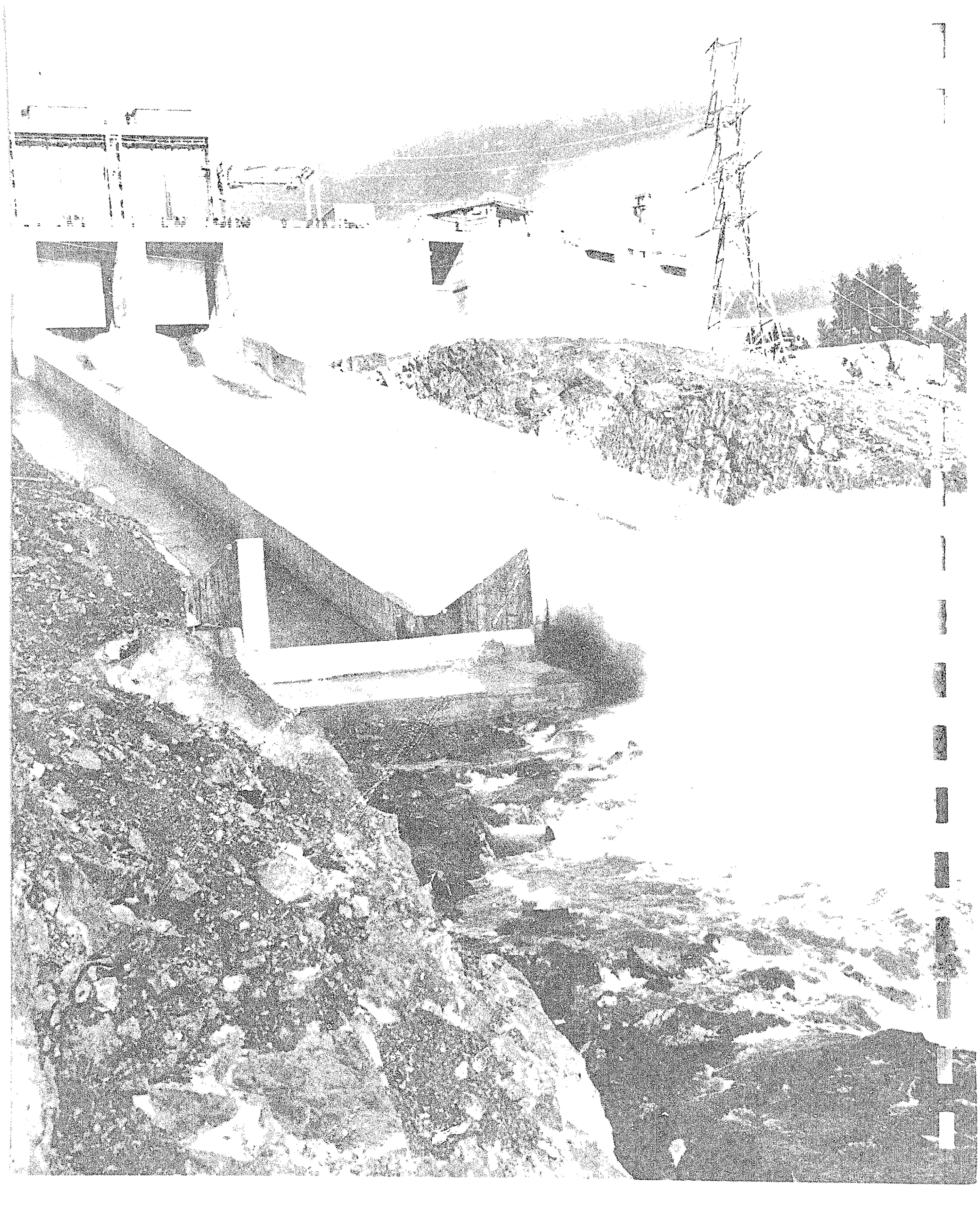
(g) Uncertainties and Risks

The shear size and scope of the Susitna project makes attention to risk reduction a necessity. Our own team includes two tiers of objective review, including an in-house review panel comprised of senior, highly-skilled and experience company officers and an external engineering board to be nominated to and agreed by Alaska Power Authority. Risk analysis is not strange to Acres, for our own efforts in risk analysis for the Arctic Gas Pipeline studies were highly commended by that organization. Most important, though, is the fact that the Acres Group was a major factor in bringing the Churchill Falls project on line ahead of schedule and under budget.

(h) Summary

In short, we are convinced that the proposed team of Acres American Inc. and its affiliates as assembled for this project provides strength, local knowledge and presence, an enviable record of successful past performance and a depth of capability which can provide an unusual measure of confidence to the Alaska Power Authority and to the State of Alaska.

VICES FOR
AND PUMPED
VELOPMENT



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A2 - ENGINEERING AND MANAGEMENT SERVICES FOR
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A3 - SELECTED PROJECT DESCRIPTIONS

ACRES

THE COMPANY

A1 - THE COMPANY

Acres American Incorporated is a consulting engineering and planning organization licensed and incorporated to perform professional engineering services under the laws of the States of New York, North Carolina, South Carolina, West Virginia, Maryland and Pennsylvania. Staff comprises professionals in the major disciplines of civil, electrical, mechanical, geotechnical, environmental, hydraulic and hydrological engineering together with technicians, draftsmen, and supporting staff totalling approximately 280. The engineering and related services are provided to utilities, government and state agencies, and industrial clients.

Acres American Incorporated, with additional offices in Columbia, Maryland, Washington, D.C., Raleigh, North Carolina, and a wholly owned subsidiary company in Pittsburgh, Pennsylvania, is a member of the Acres group which was founded in 1924 to provide engineering expertise for the development of hydroelectric resources. The resources, experience, and facilities of the entire Acres group are available, as required, to provide services necessary for the successful execution of projects on a worldwide basis.

Comprehensive company services are available, extending from preliminary hydrological, geological and feasibility investigations and economic analyses through planning, design, licensing, preparation of contract documents, drawings and specifications, evaluation of bids, contract negotiation, shop inspection, field engineering, construction supervision, project management, financial control, commissioning and initial operation. With a strength of over 1,500 engineers, specialists, and supporting staff, Acres has built up a wide range of skills to serve the power supply industry in North America, and is also structured to provide technical and planning services to other sectors of industry, including heavy civil engineering, transportation, mining, metals, fuels and other process industries.

The Company administration is based on a departmental structure, the major disciplines being electrical, mechanical, hydraulic, civil and geotechnical. Project teams, directed by an executive project manager, are staffed by engineers assigned from the appropriate departments. Specialist staff is also available from other departments of the Company to provide comprehensive service to our clients, ranging from economic analyses through quality control and commissioning services.

Specific expertise and experience are available in the following fields:

Chemical
Civil
Electrical
Environmental
Geotechnical
Hydraulic
Hydrological
Instrumentation
Mechanical
Metallurgical
Mining
Structural
Telecommunications
Thermal
Transportation
Architectural
Engineering Geology
Geographical
Meteorological
Regional and Urban Planning
Resource Conservation and Development
Economics
System Analysis

The economists include specialists in the field of:

- Agriculture
- Agribusiness
- Communications
- Economy Forecasting
- Energy Resources
- Fisheries
- Forestry
- Industry
- Mineral Resources
- Recreation
- Transportation
- Water Resources

COMPANY FACILITIES

Acres American Incorporated is one of a few consulting engineering companies in the United States that operates its own research and development laboratories in addition to providing conventional design services.

Acres' facilities include laboratories for hydraulic, fluid dynamics and thermal modelling, soil and rock mechanics and biochemical analyses. Laboratories located in Niagara Falls, Ontario and Buffalo, New York have facilities for hydraulic and chemical/physical testing. These laboratories are also available for a wide range of structural and geotechnical testing, including consolidation tests and triaxial stress-strain tests on soil, and direct shear and biaxial compression tests on soil, native rock, or concrete core samples.

Acres has extensive computer facilities comprising a GE 415 processor and its attendant data storage and input/output peripherals, two Data General minicomputers, and in-house remote terminal communication. The latter allows access via compatible systems to programs or data stored virtually anywhere in the continental United States on a time-sharing basis. Acres' in-house program library includes nearly two hundred titles, many of which are devoted to problems in energy system development and design of hydroelectric and thermal power projects.

COMPANY EXPERIENCE

In the field of power generation and related facilities, Acres has been responsible for over 20,000 MW of installed hydroelectric capacity, 65 earth- and rock-fill dams and 30 concrete dams. The largest single project engineered by Acres was the 5225 MW Churchill Falls Development in Labrador, Canada which was completed in 1976. Acres American has also carried out a number of power systems planning studies such as the Power Alternatives Study for the Dickey-Lincoln School Lakes Project for the New England Division, Corps of Engineers.

The Acres group has for many years been responsible for the feasibility assessment, design and construction supervision of a considerable number of tunnels, shafts, and caverns in hard rock. This type of work has totalled some 70 miles of tunnels, 30,000 feet of shafts, and some of the largest underground cavities in the world, including the 1,000-foot long by 150-foot high by 80-foot wide caverns 900 feet underground for power plant installation at Churchill Falls.

The Company has also been responsible for the design and supervision of construction of mine shafts, tunnels, and associated railway tunnels for pipeline and pumping stations, airport fuel systems, and right-of-way studies.

Acres is currently managing for the Corps of Engineers the 14-acre Chesapeake Bay model in Maryland. Models constructed and tested in the Buffalo hydraulics laboratory include a large (200-foot by 100-foot) hydraulic model for the Corps of Engineers to simulate ice conditions in the Little Rapids cut section of the St. Marys River; a wind tunnel model of a nuclear power plant to study the dispersion of radioactive emissions (with Calspan Corporation); aerodynamic models of electrostatic precipitators and ductwork for fossil-fired utility plants, hydraulic models of an overflow spillway structure and tunnel for energy dissipation for American Electric Power; and cooling water intakes for a nuclear power plant in New Jersey for GPU Service Corporation. Recent geotechnical testing has included triaxial and shear box strength tests for weak clay materials from an American Electric Power fly-ash retention dam in West Virginia.

Most projects undertaken in the United States have included environmental studies, impact statements, public hearings, etc., and the Environmental and Special Services group has wide experience in these areas, as well as in dealings with all levels of government and various government agencies.

Among the clients for whom Acres American Incorporated is currently providing, or has recently completed, services are:

- American Electric Power Service Corporation
- American Standard Corporation
- Appalachian Power Company
- Atomic Energy Commission (as subconsultants to United Engineers and Constructors)
- Babcock and Wilcox Company
- Bethlehem Steel Corporation
- Boston Edison Company
- California Energy Commission
- Carborundum Company
- Central Electric Power Cooperative
- Central Hudson Gas & Electric Corporation
- Cleveland Electric and Illuminating Company
- Consumers Power Company
- Department of Energy
- Dirigo Electric Cooperative
- DuPont Corporation
- Electric Power Research Institute
- Environmental Protection Agency
- Federal Energy Administration
- General Public Utilities
- Georgia Power Company
- Great Lake Carbon Corporation (subcontractors to UTRC)
- Massachusetts Municipal Wholesale Electric Company

- National Rural Utilities Cooperative Finance Corporation
- National Science Foundation
- Nebraska Municipal Power Pool
- New York State Department of Environmental Conservation
- New York State Electric and Gas Corporation
- New York State Energy Office
- Niagara Frontier Transportation Authority
- Niagara Mohawk Power Corporation
- NUS Corporation
- Ohio Edison Company
- Potomac Electric Power Company
- Precipitair Pollution Control, Inc.
- Republic Steel Corporation
- Rochester Gas and Electric Corporation
- Studebaker Worthington, Inc.
- Tennessee Valley Authority
- Turbodyne Corporation
- United Technologies Research Corporation
- Union Carbide Corporatin
- U.S. Corps of Engineers, Buffalo, New York, Pittsburgh, Savannah and Detroit Districts, New England Division and the Waterways Experiment Station
- Vermont Electric Cooperative
- Virginia Electric Power Company
- Western Precipitation Division, Joy Manufacturing Company
- Wheelabrator-Frye Company

A short selection of descriptions of large hydroelectric projects engineered in northern regions is provided in Section A3.

ENGINEERING AND MANAGEMENT SERVICES

A2 - ENGINEERING AND MANAGEMENT SERVICES FOR HYDROELECTRIC AND PUMPED STORAGE PROJECTS

GENERAL APPROACH

It is Acres philosophy that the client's "right to know" and "right to decide" is paramount, and many of the procedures that are followed have been set up specifically to ensure that the client is kept fully informed not only of the progress of the work, but also of key decisions and the impact of these decisions on the cost, schedule and ultimate success of the project.

The successful construction of a venture as large as a hydroelectric or pumped storage development, with its complex technology, large number of different tasks and long construction schedule, calls for a special combination of management techniques and engineering skills. Scores of experienced people must be brought together to form a cohesive team capable of assuming the various responsibilities and discharging them successfully.

The primary objectives of this team must be:

(a) The development of a reliable initial estimate of cost for the facility, based on sound conceptual engineering from good exploratory field data.

(b) Environmental assessment and preparation of impact statement and related licensing documents.

(c) The identification of manageable construction and equipment package and the preparation of design documents, contract drawings and technical specifications to allow successive bids to be called to a strict timetable.

(d) The finalization of engineering work after contract award, the preparation of construction drawings, and the control of design changes.

(e) The supervision of the quality and schedule of construction both in the field and in fabrication shops.

To achieve these objectives, Acres follows a carefully established series of procedures which can be adapted to suit the degree of involvement in the management of the project required by the Owner. In the past, Acres involvement has ranged from solely the engineering design and preparation of specifications to complete responsibility for the project management, including financial disbursements and contract awards. Prior to the initiation of the engineering program, it is essential for the responsibilities and relationship of the owner and consultant to be carefully defined. The Plan of Study will provide the basis for the engineering of the complete Susitna Project.

INTRODUCTION

This document has been assembled to set out the qualifications of Acres American Incorporated to provide engineering and management services for the design and construction of hydroelectric and pumped storage projects. The document not only describes the experience of the Company on past projects of a similar or related nature, but also describes the approach taken by the Company to the complex task of ensuring that a project is built on time, on budget, and to meet the client's functional requirements.

As a consulting engineering organization, a large part of this capability rests in the experience and know-how of our senior engineering and management personnel; all of the senior Acres people have held positions of responsibility from the inception through to the final commissioning of large hydroelectric and other power-related projects. The section entitled "Representative Personnel" includes summaries of the experience of a selection of those personnel who could be made available for a hydroelectric or pumped storage project.

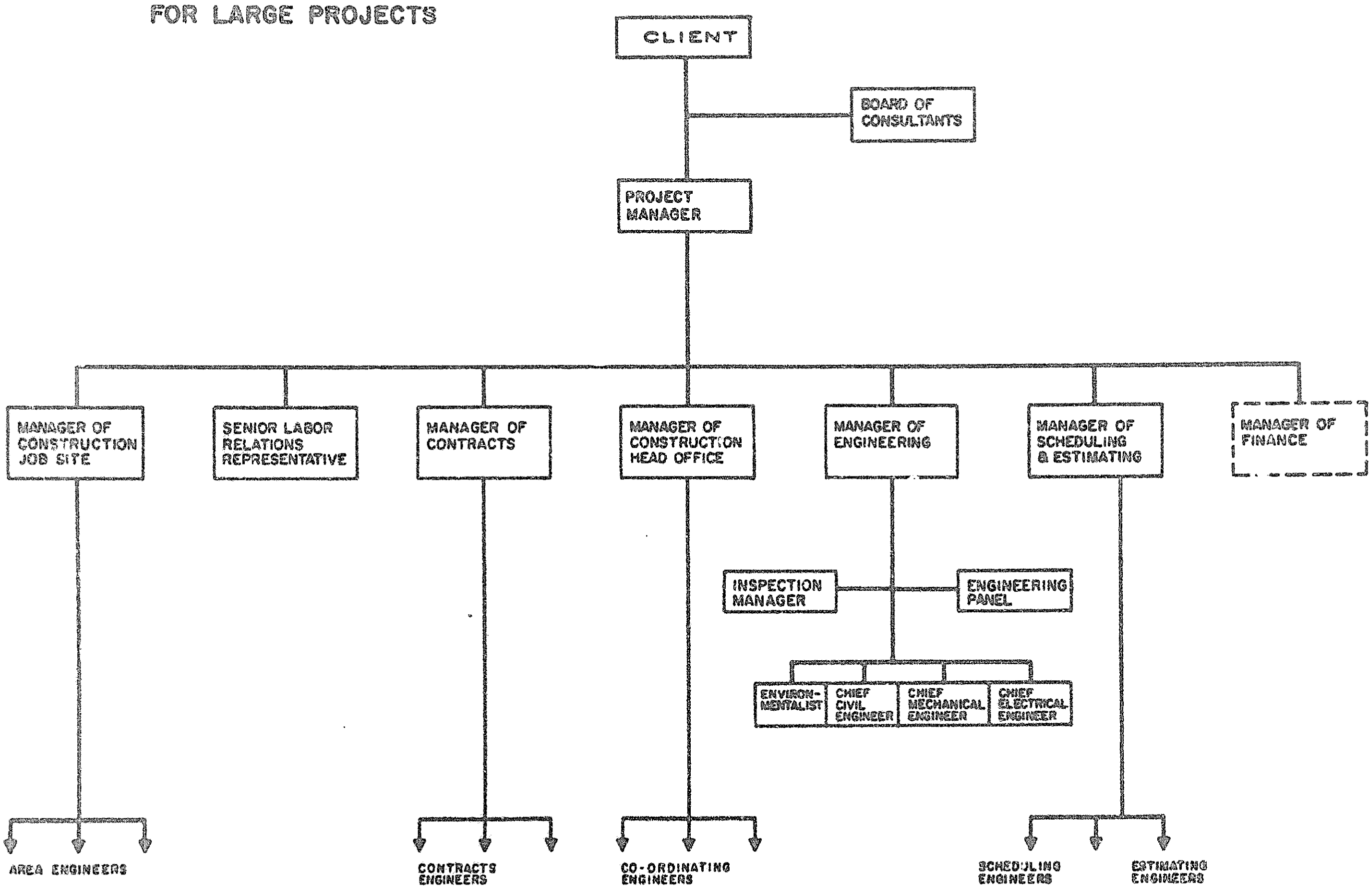
A typical outline organization structure adopted by Acres for a large project such as a hydroelectric development is set out in Chart "A". The function and responsibilities of the various positions indicated in the chart are discussed in the following sections and may be considered under the following headings:

- Engineering Management
- Construction Management
- Cost Control and Monitoring
- Quality Control and Monitoring
- Schedule Control and Monitoring

At the start of the project, scopes of work for all functions in the organization chart are prepared in as much detail as possible. From these, engineering and administrative budgets are drawn up for inclusion in the total cost estimate for the project. These budgets are monitored by means of weekly reports produced by Acres in-house cost and production control system, allowing potential overruns to be identified early and appropriate collective action taken without delay.

CHART A

TYPICAL ORGANIZATION CHART FOR LARGE PROJECTS



ENGINEERING MANAGEMENT

Many important decisions are made early in the design phase of the project and often cannot be changed later except at considerable additional cost. Acres system of design reports, or "Design Transmittals" as they are called, is aimed at ensuring that the design concepts and their implications are fully explored.

The sequence of steps in the design of a major component in the development would be typically as follows:

(a) The initial feasibility study will have established the necessity for, and a rough cost estimate of, the component.

(b) The specific scope of work for the design and specification of the component is established, an engineering budget is assigned, and overall design criteria are assembled. During this phase the applicable regulatory design and safety codes and practices are identified and continuing monitoring procedures fully coordinated.

(c) A design transmittal is prepared describing the alternatives considered, the constraints and opportunities involved, and recommending a course of design action within the context of the estimated capital and operating costs. This transmittal, which is a key document in the design phase, is circulated for comment within the Acres organization and sent to the client. Equipment suppliers are also frequently brought in for discussion at this stage. Once approved, changes can be made only by a reissu. of the document. Design transmittals are prepared for a wide range of components and, for major projects, may amount to as many as 150 transmittals for topics ranging, for example, from "Trash Handling Facilities in the Forebay" to "Powerhouse General Arrangement" and "Switchyard Insulation Levels".

(d) Next (at about 25 to 35 percent design completion) where appropriate, the contract packaging is established and "Scope Statements" are prepared, describing in detail the contents and scope of each contract related to the design transmittal.

At this point, the cost estimate for the component is keyed into the overall estimate for the project.

(e) Contract drawings (as many as five hundred for a large project) and technical specifications for the components are then prepared, and a

...s assembled for final review prior to issue for competitive ...ase would usually be undertaken concurrently with ...sessments and preparation and submission of requisite ... ...pl...cations.

(f) Once a contract reaches bidding stage, it becomes the responsibility of the construction group. However, the contractor may require additional detail drawings. For a major project, for instance, as many as two hundred detailed civil drawings and approximately an equal number of schematics, interconnections and wiring diagrams may be required in addition to the original contract drawings. A key part of this work is to ensure either that no significant changes are made to the design as set out in the contract drawings or that any changes are fully explored and reviewed with the contractor to assess impact on schedule and cost. Acres uses a system of "Design Change Memoranda" to keep track of this aspect of the work.

(g) In summary, engineering cost and quality control is effected by

- the preparation of control estimates at key stages in the development of the design

- conducting critical technical review throughout the design phase, and by the maintenance at site of a resident engineer reporting to the manager of engineering to ensure that proper tests and controls are carried out

- assigning a project monitoring group to compare the estimated and actual design man-hours expended on each phase of the work. The details of Acres control system are fully described in our "Progress and Cost Reporting System User's Manual".

ENGINEERING PANEL AND CONSULTING BOARD

It is Acres usual practice, for projects with a significant design input, to set up an in-house "Engineering Panel" comprised of senior engineers within the Company, experienced in the various areas of expertise involved in the project. The function of this panel, which is responsible only to the project manager, is to critically review the engineering designs and recommendations developed in the course of the project. Presentations are made to the panel by the project design team at appropriate times throughout the period of design development, and approval of the panel is obtained before implementation of the design.

On projects such as a major hydroelectric development, which often involve innovative thinking, it has also been Acres practice to convene a consulting board which is essentially responsible to the owner. The consulting board comprises engineers from outside the Company, eminent in their various disciplines. The consulting board would normally meet once every 3 months to review, with owner's senior staff and project team staff, such matters as major design transmittals, scheduling and financial problems, or geological and other problems encountered in the field.

Among the engineers who have served on consulting boards for Acres projects are:

Churchill Falls Development

H. E. Barnett	Project Planning and Construction
W. L. Chadwick	Power Engineering
J. B. Cooke	Hydroelectric Structures
D. M. Farnham	High-Voltage Cables — Electrical Engineering
F. B. Slichter	General Civil Engineering
R. Rhodes	Engineering Geology

Mica Creek

J. B. Cooke	Hydroelectric Structures
C. V. Davis	Hydraulic Structures

J. Gorman	Geologist
G. Watson	General Civil Engineering
Lt. Gen. R. A. Wheeler	General Civil Engineering Docks and Harbors
Lower Notch	
Professor A. Casagrande	Soil Mechanics
Dr. F. A. Nickell	Geology
Dr. R. B. Peck	Soil Mechanics
Alto Anchicaya	
Dr. D. U. Deere	Rock Mechanics
J. B. Cooke	Hydroelectric Structures

SELECTED PROJECT DESCRIPTIONS

SELECTED PROJECT DESCRIPTIONS

The following pages summarize some of the projects and studies undertaken by the Company in the United States and overseas in power generation and related fields.

HYDROELECTRIC POWER DEVELOPMENT
EARTH-FILL, ROCK-FILL AND CONCRETE DAMS

An essential part of all hydroelectric developments is the design and construction of water-retaining structures. Generally the cost of these structures form a significant portion of the total development cost. Depending on the site, the economics of the dam can determine the economic viability of the project.

Acres has successfully engineered nearly one hundred dam structures of different types on foundations ranging from tropical soils to permafrost.

The following pages give representative listings of Acres projects involving earth-fill, rock-fill and concrete dams.

EARTHFILL AND ROCK-FILL DAMS

Since 1938 Acres has been responsible for the geotechnical investigations, engineering studies, final designs, and construction supervision for over sixty earth and rock-fill dams.

These dams are of a variety of types including homogeneous section and sloping and vertical core, and their construction involved the use of fill materials ranging from marine clays and weathered clay shales to uniform fine sands utilized as impervious core materials. The construction cofferdams for these projects included earthfill, rock fill, timber crib and cellular types, some of which were designed to overcome difficult foundation problems including underseepage, while others were "closed" in extremely fast water.

Several of the dams are founded on overburden presenting stability and seepage erosion problems. These foundation conditions varied from lenses of varved clays and silts in glacial till deposits (Bersimis No. 1) to the stiff weathered crust of sensitive marine clay deposits (Bersimis No. 2). A particularly difficult foundation problem was encountered in the founding of several small dikes directly upon varved clay overburden containing extensive permafrost (Kelsey).

Seepage and the uplift pressures in a deep pervious layer were controlled by means of a grout curtain in overburden and pressure relief wells at Strathcona, and a deep cement and chemical grout curtain was employed to reduce large underseepage in alluvial sands and gravels at Lake Ste Anne.

At the Manicouagan 2 Development, the cofferdam embankment consisted of a granular fill on highly pervious alluvium. To control seepage a concrete cutoff wall was installed through the fill, well into the alluvium. The excavation for the wall was made using a bentonite slurry trench technique.

CONCRETE DAMS

In general, Canadian dam sites have crest length to height ratios which dictate the use of gravity or buttress type structures while Canada's severe winter climate and the labour/material cost balance militate against the use of highly reinforced, thin section buttress dams.

Every dam site is, however, unique. Except where the choice is obvious, Acres evaluates the relative economy and safety of the alternative types of concrete dam which could reasonably be considered. These may include gravity, hollow joint gravity, arch, arch gravity, multiple arch, buttress, massive buttress, and prestressed structures.

The choice is made with due regard to the geology, geohydrology, topography and seismicity of the site. Labour and material requirements and their cost relationships, construction schedule, and climatic conditions all have a major bearing on the final selection.

Detailed attention is given to design of the optimum concrete mix for the various parts of the structure.

Final structural analysis is carried out by digital computer. The stress/deformation characteristics of the foundations and abutments are introduced. Seepage pore pressure distributions and the effect of pressure relief systems within the dam and in the foundations are included. Thermal and shrinkage stresses within the structure as functions of the properties of the concrete mix, pour schedule, construction joint arrangement, and extent of natural and artificial cooling are determined.

In the hollow joint dam at the Manicouagan 2 development the advantages of gravity and massive buttress type structures are combined. Completed in 1965, it is believed to be the only dam of its type in North America and, with a maximum height of 345 feet, possibly the highest of its type anywhere.

Two examples of more conventional gravity dams are Bersimis 2 in Quebec and Warsak in West Pakistan. Both are briefly described in the following pages.

In all, more than 20 concrete dams designed by Acres are listed in the accompanying summary.

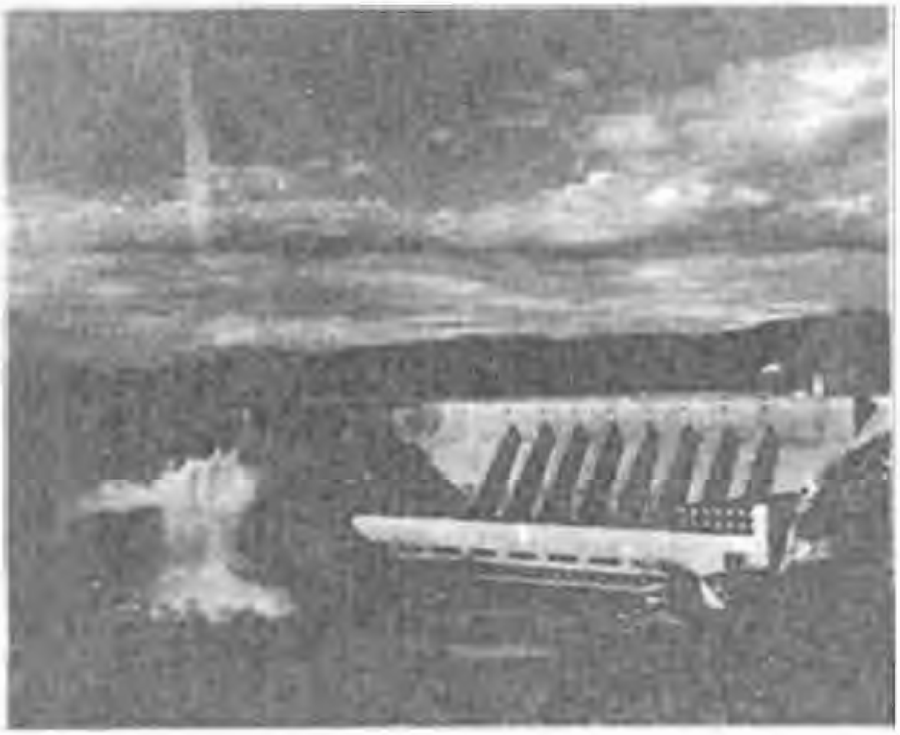
THE MANICOUAGAN 2 HYDROELECTRIC DEVELOPMENT MAIN DAM

The Manicouagan 2 Hydroelectric Development has a hollow joint gravity dam 2290 feet long and 345 feet high. The hollow joint dam was selected on the basis of an economic comparison which indicated that in comparison with a conventional gravity dam, there would be a 10% saving in concrete volume & a 7% reduction in capital cost. The high tailwater level at the site (about 100 feet above foundation level) was also a major factor favouring the hollow joint design.

A hollow joint dam is basically a gravity structure in which the transverse construction joints are formed as major cavities. At Manicouagan 2 the cavities are 16'-6" wide and the gravity blocks are 65'-6" wide so that large areas of rock are exposed at foundation level.

The hollow joints adopted at Manicouagan 2 reduced concrete quantities, and also created very effective relief of seepage pressures at the foundation and within the dam itself. As a result hydrostatic uplift forces were considerably reduced. The voids formed by the joints minimized inter-dependance of the concrete placing operations in adjacent blocks and permitted an accelerated construction schedule.

Efficient natural air cooling during construction was provided by the large area of exposed concrete at each joint, the need for artificial cooling systems being minimized as a result.



MAJOR EARTH- AND ROCK-FILL DAMS – 1

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Alto Anchicaya Power Development, Colombia	Compacted rock fill with upstream concrete face	140.3 270	m m	(460 ft h) (885 ft l)	Metamorphosed, sedimentary schist, diorite and hornfels
Amos Fly Ash Retention Dam, West Virginia, U.S.A.	Upstream compacted shale core, random and rock-fill support zone. Pressure relief system	68.6 610 2,750,000	m m m^3	(225 ft h) (2,000 ft l) (3,600,000 yd^3)	Carboniferous, sedimentary rock
Arnprior, Waba Dam Madawaska River Ontario, Canada	Earth fill, marine clay, homogeneous fill with central filter drain	18.3 1,036	m m	(60 ft h) (3,420 ft l)	Thick marine clay deposit
Aslantas Dam & Power Project, Turkey (Design only – under construction)	Compacted shale core, and support zone. Upstream and downstream weighting zones	33.6 750	m m	(110 ft h) (2,460 ft l)	Clay shale and sandstone (Flysch)
Beauharnois Power Development, Stage 3, Quebec, Canada	Forebay dike. Rock fill with thick central clay core	12 64 81,000	m m m^3	(39.3 ft h) (210 ft l) (106,000 yd^3)	Paleozoic sandstone
Bersimis No. 1 Power Development, Quebec, Canada					
Main Dam	Hydraulicly compacted rock fill with upstream rolled impervious core	64 641 2,800,000	m m m^3	(209 ft h) (2,100 ft l) (3,670,000 yd^3)	Precambrian metamorphic rock and glacial overburden
Des Roches Dam	Hydraulicly compacted rock fill with upstream rolled impervious fill core	69 335 1,100,000	m m m^3	(225 ft h) (1,100 ft l) (1,453,000 yd^3)	Precambrian metamorphic rock and glacial overburden

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Pamouscachiou Dam No. 1	Gravel with sloping rolled impervious core	19 637 221,700	m m m^3	(75 ft h) (2,090 ft l) (290,000 yd^3)	Precambrian metamorphic rock and glacial overburden
Pamouscachiou Dam No. 2	Gravel with sloping rolled impervious core	19 427 145,300	m m m^3	(62 ft h) (1,400 ft l) (190,000 yd^3)	Precambrian metamorphic rock and glacial overburden
Bersimis No. 2 Power Development Quebec, Canada					
Auxiliary Dam No. 1	Vertical marine clay core, sand support zones, local sheet pile	30 1,010 845,000	m m m^3	(97 ft h) (3,310 ft l) (1,105,500 yd^3)	Marine clay and estuarine sand
Auxiliary Dam No. 2	Vertical marine clay core, sand support zones, local sheet pile	19.5 1,195 322,800	m m m^3	(64 ft h) (3,920 ft l) (422,300 yd^3)	Marine clay and estuarine sand
Binbrook Reservoir Ontario, Canada	Control dam – Earth fill	11 701 91,700	m m m^3	(36 ft h) (2,300 ft l) (120,000 yd^3)	Stiff brown clay
Cardinal Fly Ash Retention Dam Ohio, U.S.A.	Central compacted shale core, random and rock-fill support zone. Grout curtain, pressure relief system	76.2 762 1,300,000	m m m^3	(249 ft h) (2,500 ft l) (1,703,000 yd^3)	Carboniferous, sedimentary rocks
Clarabelle Lake Dam Ontario, Canada	Control dam – Rock fill	19.8 276.5 80,280	m m m^3	(65 ft h) (905 ft l) (105,000 yd^3)	3.05 to 4.57 m of organic material plus 4.57 to 7.62 m of soft varved clay over bedrock

Major Earth- and Rock-Fill Dams — 3

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Conestogo Dam Ontario, Canada	Control dam -- Earth fill with protection thick central clay core riprap and concrete spillway section	29.3 546 458,000 72,600	m m m^3 m^3	(96 ft h) (1,790 ft l) (600.000E yd^3) (95,000C yd^3)	Dolomitic limestone with glacial till overburden
Fanshawe Dam Ontario, Canada	Control dam — Earth fill with thick clay core and concrete spillway section	30.5 655 344,250 143,700	m m m^3 m^3	(100 ft h) (2,150 ft l) (450,000E yd^3) (188,000C yd^3)	Limestone with till overburden
Grand Rapids Generating Station Manitoba, Canada	Earth fill with 30 km long, with up to 61 m deep grout curtain	33.5 25,600 7,100,000	m m m^3	(109 ft h) (83,900 ft l) (9,300,000 yd^3)	Karstic, dolomitic limestone
Horwood Lake Dam Ontario, Canada	Control dam — Earth fill with concrete sluiceway section	9.4 274 35,200 3,900	m m m^3 m^3	(31 ft h) (900 ft l) (46,000E yd^3) (5,100C yd^3)	
John Hart Development British Columbia, Canada	Main dam — Earth fill	622 83,200	m m^3	(2,040 ft l) (109,000 yd^3)	
Kelsey Generating Station Manitoba, Canada	Main dam — Rock fill with upstream impervious sloping core	36.6 291 220,000	m m m^3	(120 ft h) (955 ft l) (288,300 yd^3)	Precambrian metamorphic rock
	Cutoff dikes, two — Sand	6.1 1,189 74,400	m m m^3	(20 ft h max) (3,900 ft l total) (97,500 yd^3 total)	Permafrost

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
	Cutoff dikes, three – Clay	11.6 1,906 70,000	m m m^3	(38 ft h max) (6,250 ft l total) (91,600 yd^3 total)	
Kettle Generating Station Manitoba, Canada (In consortium)	Main dam – Earth fill	48.8 1,067 2,700,000	m m m^3	(160 ft h max) (3,500 ft l) (3,540,000 yd^3)	Precambrian rock and glacial soils
	Saddle dam – Earth fill	33.6 1,190 2,106,900	m m m^3	(110 ft h) (3,900 ft l) (2,760,000 yd^3)	
	Butnau River dam – Earth fill	18.3 3,355 1,039,800	m m m^3	(60 ft h) (11,000 ft l) (1,360,000 yd^3)	
	Reservoir dikes – Earth fill	4.6 5,490 390,000	m m m^3	(15 ft h) (18,000 ft l) (510,000 yd^3)	
Lady MacDonald Lake Dam Ontario, Canada	Control dam – Rock fill	6.4 305 19,020	m m m^3	(20 ft h) (1,000 ft l) (26,000 yd^3)	Approximately 2.13 m of organic material over bedrock
Lake St. Anne Reservoir Quebec, Canada	Main control dam – Rock fill with sloping silty core and concrete spillway section	3[illegible].4 278 449,500	m m m^3	(126 ft h) (910 ft l) (588,000 yd^3)	Precambrian metamorphic bedrock
	Cutoff dam – Earth fill	19.5 131 71,100	m m m^3	(64 ft h) (430 ft l) (93,000 yd^3)	Rock

Major Earth- and Rock-Fill Dams — 5

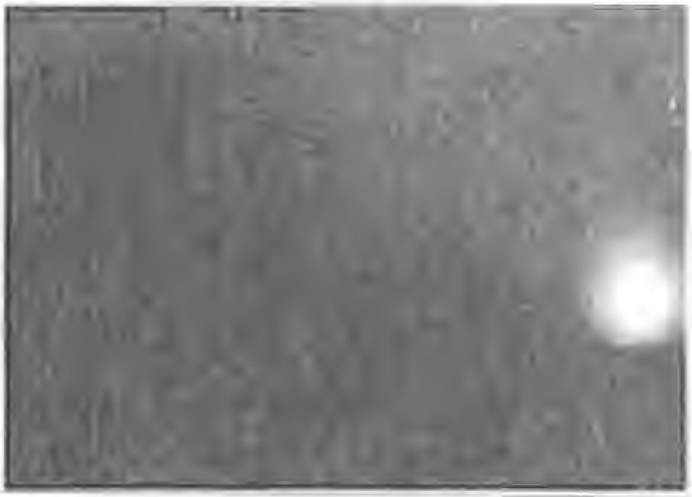
Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Laurie River No. 1 Development Manitoba, Canada	Loon River east diversion dam — Earth fill	10.7 64.1	m m	(35 ft h) (210 ft l)	
	Loon River west diversion dam — Earth fill	7.6 99.1	m m	(25 ft h) (325 ft l)	
Laurie River No. 2 Development Manitoba, Canada	Main dam extension — Earth fill	116 32,800	m m^3	(380 ft l) (43,000 yd^3)	
	Dike A — Earth fill	10.7 128	m m	(35 ft h) (420 ft l)	
	Dike B — Earth fill	10.7 134.2	m m	(35 ft h) (440 ft l)	
Limestone Generating Station Nelson River, Manitoba, Canada (In consortium)	Central core earth fill	33 538 2,200,000	m m m^3	(110 ft h) (1,900 ft l) (2,800,000 yd^3)	Ordovician limestone
Long Spruce Generating Station Nelson River, Manitoba, Canada (In consortium)	Central core earth fill	39.7 754 2,300,000	m m m^3	(130 ft h) (2,500 ft l) (3,000,000 yd^3)	Precambrian
G. Ross Lord Conservation Dam Toronto, Ontario, Canada	Earth fill	19.8 366 267,000	m m m^3	(65 ft h) (1,200 ft l) (350,000 yd^3)	Glacial deposits
Lower Notch Generating Station Ontario, Canada	Main dam — Rock fill	131.2 366 1,689,600	m m m^3	(430 ft h) (1,200 ft l) (2,210,000 yd^3)	Precambrian rock

Major Earth- and Rock-Fill Dams – 6

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
	Reservoir dikes – Rock fill	1,098 450,300	m m^3	(3,600 ft l) (589,000 yd^3)	
Mactaquac Development	Main dam – Compacted rock fill with near vertical core of impervious glacial	46.7 518 1,223,300	m m m^3	(153 ft h) (1,700 ft l) (1,600,000 yd^3)	Slate and graywacke abutments – thick clay till and gravel in riverbed
Manicouagan 1 Development Quebec, Canada	Forebay dikes – Rock fill with sheet pile diaphragm	17.1 213 10,700	m m m^3	(56 ft h) (700 ft l) (14,000 yd^3)	
Manicouagan 2 Cofferdam Manicouagan 2 Power Station Quebec, Canada	Rock fill with Icos cutoff and sheet pile membrane	37.7 155 38,900	m m m^3	(123.5 ft h) (510 ft l) (50,900 yd^3)	Grenville granite
Marietta Fly Ash Retention Dam Ohio, U.S.A.	Central compacted shale core, random and rock fill. Grout curtain and pressure relief system	10.7 137 92,000	m m m^3	(35 ft h) (450 ft l) (120,300 yd^3)	Carboniferous sedimentary rock
McArthur Falls Development Manitoba, Canada	Cutoff dikes – Earth fill (homogeneous clay)	9.15 9,760 699,570	m m m^3	(30 ft h max) (32,000 ft l total) (915,000 yd^3 total)	Glacial till and rock
Mica Development British Columbia, Canada (In consortium)	Main dam – compacted granular material with near vertical core of impervious glacial till	198 244 762 22,936,800	m m m m^3	(650 ft h) (riverbed) (800 ft h) (rock) (2,500 ft l) (30,000,000 yd^3)	Schist and gneiss abutments – granular soils in riverbed
Shand Flood Control Dam Grant River, Fergus, Ontario Canada	Homogeneous compacted clay till with key wall	24 640 411,000	m m m^3	(78 ft h) (2,100 ft l) (537,600 yd^3)	Dolomite limestone
Strathcona Development British Columbia, Canada	Main dam – Earth fill with sloping clay core, deep grout curtain and concrete spillway section	51.8 549 1,987,800	m m m^3	(170 ft h) (1,800 ft l) (2,600,000 yd^3)	Volcanic rocks and glacial till with underlying aquifer

Churchill Falls

an accomplished beginning



Introduction

The story of Churchill Falls illustrates one essential fact. Development of the requisite technology is only a preliminary. The critical ingredient is knowing how to put together the men, machines, and resources to apply that technology on a scale which challenges comparison with the Pyramids and the Great Wall of China — with the difference, pointed out by Prime Minister Trudeau, that the power project is "incomparably more useful."

The completion of the largest single-site power station in the western world at Churchill Falls, on schedule, and within cost estimates offers a model of how such vast projects can be accomplished.

The Falls, the Eskers and the Estimates

Certainly it needed no flash of inspiration to see the potential power of the mighty Churchill River's spectacular tumble from the glacier-gouged Labrador plateau. As early as 1894, in the infancy of hydroelectric power generation, A.P. Low of Canada's Geological Survey suggested this new technology could be applied to provide "several millions of horsepower". With remarkable prescience, he submitted that such power, turned to heat, could be used to reduce the local iron ores.

Twenty years later, W. Thibaudeau of the Régie des Eaux of the province of Quebec, surveyed the area. He saw that the river could be diverted above the Falls, and rechannelled further to the east to increase the head of water available, from 500 ft. at the Falls and upper rapids to more than 1,000 ft. at Portage Creek.

Such bold concepts awaited full economic justification for yet another generation.

Credit for the first practical initiative is due to British Newfoundland Corporation Limited, formed in 1953 by seven major British financial, resource and manufacturing companies, including Rio Tinto-Zinc Ltd. It received a charter to explore the island of Newfoundland and Labrador for the government of Joseph Smallwood, who had just brought Newfoundland into the Canadian confederation.

The water power potential of the 110,000 square mile area was clear, but the energy available had to be quantified. In the mid-1950's it remained too remote for existing transmission techniques to deliver to available markets economically. It was accessible only by arduous canoe trip or hundreds of miles of flight by a float plane.

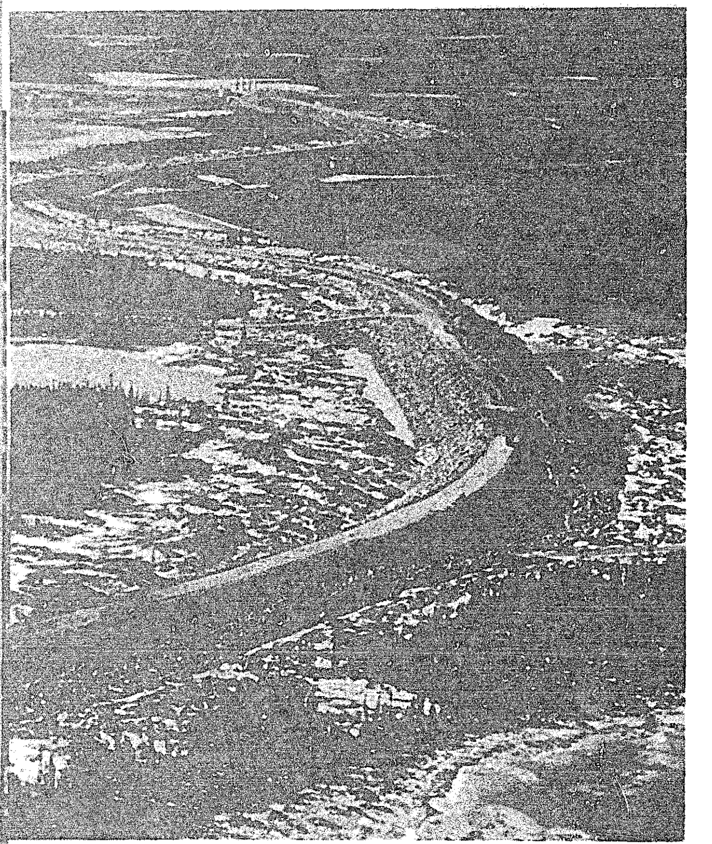
Brinco watched the opportunities for development unfold step by step. First, mining and processing of the iron ore deposits by other interests at Schefferville, Wabush and Labrador City, justified building the Quebec North Shore and Labrador Railway passing only 105 miles to the west of the Falls. Brinco added to the effort in 1960 by pushing a road from Esker, on the rail line, to the west bank of the Churchill. At Twin Falls, on the Unknown River, a few miles from Churchill Falls, Brinco built a modest 120,000 KW hydro-electric plant to serve the iron ore development and associated townsites. The harnessing of Labrador hydro power had begun.

Another link in the chain of feasibility was forged when Hydro-Québec, faced with developing the rivers of the north shore of the St. Lawrence for power, engineered and perfected a 735,000 volt Extra High Voltage (EHV) transmission system. Its successful application in carrying power from the Manicouagan River plants to Montreal in 1965 built confidence that it was the technical and economic solution to the problem of carrying Churchill Falls power to market in the developing urban and industrial centres of Quebec at reasonable cost.

An emerging counterpoint to this matching of resources to markets was the growing hunger for power of the populous U.S. eastern seaboard. Jean Lessard, then chairman of Hydro-Québec, saw the opportunity to feed this U.S. market with relatively low cost power exports. With this added to Quebec's own need, the power of Churchill Falls could be fully developed at a single stroke.

In 1961, the Smallwood government granted a Brinco subsidiary, Churchill Falls (Labrador) Corp. Ltd. (CFLCo), a 99 year lease on the hydraulic resources of the 26,000 square mile watershed of the Upper Churchill.

But what engineering enterprise could be found to determine the optimum location to utilize this potential 1,000 foot head, to create a giant power complex in the midst of the muskeg and scrubby evergreens of the Labrador plateau, and to do it with assured quality within cost and time schedules that would make the venture attractive to financial institutions. For it would require the largest amount of capital ever committed in Canada for a private project.



A general view of the dyke structure

CFLCo's answer was to bring together two highly-qualified Canadian concerns — H. G. Acres & Company Limited and Canadian Bechtel Limited.

Through its affiliation with the Bechtel organization worldwide, Canadian Bechtel was able to provide virtually unmatched resources of experience in the construction and management of vast, remote, resource projects. Acres offered a wealth of expertise and experience in hydro-electric engineering.

They formed a joint venture — Acres Canadian Bechtel of Churchill Falls (ACB) — to engineer and manage the construction of this massive hydro-electric facility. By agreement, Canadian Bechtel became managing joint venturer for the contract.

An ACB team was already surveying in the field by 1963-64 supplementing the very considerable amount of data accumulated by other engineers from firms employed earlier by Brinco. Gray Thompson, an Acres member of the team, recalls that in spite of winter temperature so frigid that the bubbles in the transit level became sluggish, the survey circuit around the v[illegible] reservoir area was closed within an accuracy of one third of a foot. This was also a tribute to previous federal government and Quebec surveys whose old bench marks were picked up by the ACB team.

Calculations were accumulated, checked and cross-checked as to the optimum site, hydrological effects of snow accumulations and the size of reservoir needed to smooth the flow of the erratic Churchill, which varied from 10,000 to 300,000 cubic feet or more per second depending on season. The project was feasible — but the resources required to build it would be enormous. Irrefutable evidence that the project would be profitable was required before a sound approach to financing could be devised.

It took two more years of negotiation, and the expenditure of $17 million on preliminary engineering, before the breakthrough that triggered the leap from concept to construction. On October 13, 1966, Hydro Quebec's Jean Lessard, signed a letter of intent assuring that the Quebec utility would purchase the bulk of electricity generated from the site. By this time, the growth of Canada's energy demand made it unnecessary to rely on export to create a market. The moment for Churchill Falls power had arrived.

It was now up to ACB to meet the challenge.

The usual procedure for a hydro-electric project in Canada would be to proceed with detailed engineering of the various components of the project, put them out to tender, receive contractors' bids, sum the bid costs and thence proceed to make the necessary capital appropriation. However, in such a massive, remote project, undertaken by a utility company with relatively little in the way of assets and financial capability, a completely different approach was required.

ACB, as engineers and construction managers, had to organize a workplace in the middle of the wilderness, devise means to bring men and machines to it, and put together the whole complex schedule for a project which would stretch over nearly a decade. The packages into which the work was divided had to be tailored to the capacities of existing contracting firms in eastern Canada. It was upon ACB's estimates of the final cost of these packages that the delicate job of financing the project had to be based.

On March 7, 1967, CFLCo signed a contract with ACB covering engineering and construction management services to the end of the project. At almost the same time, it accepted ACB's estimate of direct construction cost of $522 million for the project. To this would be added $102 million to provide for escalation arising from price and wage increases over the life of the project and $41 million as a contingency allowance, giving a total direct construction cost of $665 million. Interest charges on money borrowed during construction, administration, working capital, overhead and other expenses would bring the total project cost to $946 million. This included more than $20 million spent in early studies and work by CFLCo up to March 31, 1967. It made Churchill Falls the largest civil engineering project ever undertaken in North America to that time.

A billion dollars isn't raised quickly.

It was Oct. 30, 1968, before Brinco Chairman Henry Borden reported to a special meeting of Brinco shareholders that terms of a $100 million general mortgage bonds issue had been settled, that arrangements for bank credit ($150 million from seven Canadian chartered banks) were well underway, that an offering in the United States of half a billion dollars of first mortgage bonds had been satisfactorily completed and that an offering in Canada of $50 million in first mortgage bonds had been arranged.

During the period required to set the stage for the major financing, funds came largely from equity capital, or shares, in CFLCo subscribed by its majority shareholder — Brinco (57%) — and its minority shareholders — Hydro-Québec (34%) and the province of Newfoundland (9%). In all, $83 million was raised this way. Substantial credit also was made available to Brinco by the Bank of Montreal.

Meanwhile, work at the site had been going on for two years. First attention was given to two prime engineering challenges: to create an all-weather access road to allow heavy freight haulage to the site, and commence the enormous job of building 40 miles of dykes.

The dykes, to provide a water barrier under any temperature conditions, had to form a perfect seal with the irregular surfaces of underlying rock. They were built using glacial till and rock where available, but the principal ingredients were materials from the eskers — ridges of gravel and sand formed within or under the glaciers, which chiselled the topography of this area, and left behind when the ice melted. Virtually nothing was shipped in to build the 26-million-cubic-yard dykes. The logistics task here was moving men and equipment, but it involved some of the biggest units available.

During the first year, the master project schedule and official plan were issued. The original size of the project was increased 15%, with the addition of an eleventh turbine generating unit, and uprating each unit to 475,000 KW instead of the 450,000 KW contemplated earlier. Total plant capacity was to be 5,225,000 KW, or just over seven million horsepower. The first units were committed to deliver contract power to Hydro-Québec by May 1, 1972.

The wisdom of choosing depth of corporate experience for the management of this vast project was amply proven by the tragic event of Nov. 11, 1969. CFLCo's twin jet was approaching Wabush airport in an overcast, when it crashed into a hill, killing all six passengers: Donald McParland, 40, President and Chief Executive Officer of CFLCo; Eric G. Lambert, 46, Vice-President, Finance, for Brinco and CFLCo; John Lethbridge, 35, McParland's Executive Assistant; Fred E. Ressegieu, 56, General Manager of Acres Canadian Bechtel; J. Herbert Jackson, 42, Assistant General Manager and Manager of Construction of ACB; Arthur J. Cantle, 42, Assistant Manager of Construction, ACB; and the crew of two.

All three ACB executives were seasoned engineers. In this emergency, the resources of Bechtel's world-wide organization were combed for replacements.

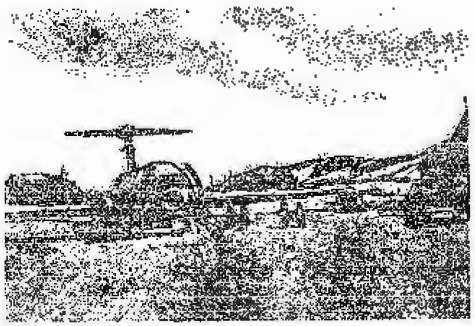
By the New Year, Steven V. White assistant to S. D. Bechtel, Jr., had stepped in to replace Ressegieu. Joseph Anderson, a Scot fresh from the Wells Hydro-Electric Project on the Columbia River, replaced Jackson in the field; Alan McConnell of Acres took over in the Montreal office.

Meanwhile after a brief period of pinch-hitting by Sir Val Duncan, chairman of the Rio Tinto organization, William Mulholland, a partner in the New York banking house of Morgan Stanley & Co., was elected president and chief executive of both Brinco and CFLCo.

Yet within a year after the tragic loss the project was well on its way to delivering first power — five months ahead of schedule!

The secret of such an achievement, is twofold, says S. M. Blair, who, as Chairman of Canadian Bechtel Limited, was chairman of ACB's Policy Board for most of the construction period. First, it was necessary to create a place to work and live productively in the wilderness; and second, to create the logistics to supply that workplace with equipment, supplies, and labour, on schedule.

Making a place for man



Most of the industrial installations built to date in the Canadian north have been transitory, such as mining or petroleum exploration camps. Generally, the facilities are temporary and the men who occupy them have little thought except to get their job done and leave.

Churchill Falls was different. The construction period was to be eight years, and the anticipated life of the station stretches toward the middle of the next century. The transition from construction camp to permanent community would be phased over the period 1971-1975.

The philosophy was this: a settled happy work force, with low turnover and a minimum of interruptions because of labour disputes, is the key to maintaining schedules and cost targets. The men should be happy *off* the job as well as *on* it. Special efforts were made to afford amenities far superior to the roughness and boredom of off-hours in a typical construction camp. Civilization must come concurrently with construction.

Even though final commitment of the project was not made until 1966, by 1967 plans for a permanent community near the power facility were drawn up. The 59 houses, four 12-unit apartment blocks and a service complex with stores, school, a hotel, theatre and indoor recreation facilities were first used by the longer-term construction staff, later by the permanent power plant operating staff.

Provision of all possible amenities began as soon as the first road camps — Esker, Bridge Camp and Mount Hyde Lake—opened. By Christmas, 1966, for instance, only two months after start of the project, John McGowan, Bona Vista Food Services manager, the caterer for the project, recalls that the Christmas dinner menu included cream of tomato soup, roast turkey with all the trimmings, and a cold buffet with salads, assorted pastries, two kinds of Christmas cake and three kinds of pie. The dinner was followed by a movie.

At the main camp, the men were housed in 20-man complexes — three trailers side by side, housing two men to a room. There were not only washrooms, but a clothes washer and dryer in most units. Janitorial services included even bed-making.

The inevitable feeling of isolation was reduced through access to the mobile radiotelephone, teletype and telegraph services that were established and linked to the continent-wide networks. At peak, the system had 1,366 telephones and 540 mobile radio units. Until the Churchill Falls airstrip was ready in 1969, scheduled flights operated from the Twin Falls airstrip, a 30 mile drive from the main camp.

When carpenter Leo Lane from Catalina, Nfld. stepped off the plane in March 1968 to become the 1,000th worker on the project, he found Hickeys and Ryans aplenty from his own province, together with Gagnons and Tremblays from Quebec: mechanics, drillers, drivers, pipe-fitters and scores of other skilled and semi-skilled trades. They were supported both on site and at the Montreal headquarters by engineers and draftsmen translating general plans and programs into detailed blueprints and schedules.

In June, 1968, the main camp became a place for women too as staff arrived to work at a new mess hall the length of a city block. Together with clerks, secretaries, nurses and teachers, they made up a group of 200 women working on the project. Their early presence on site, together with the civilized amenities, is credited with encouraging a remarkably clean, orderly, and liveable camp — "More like a town than a camp", as many workers described it.

Not that the camp lacked its lively side. A tavern (open morning and evening to accommodate shift workers) began operation in the recreation centre in late 1967, and sold four million bottles of beer in the next four years. Nor was there any lack of other recreational facilities — such as the baseball diamond, soccer field and skating rink; later the curling rink, bowling alley and swimming pool.

Geodetic survey of the intake site

Aerial view of the permanent camp site

The great majority of men on site were not ACB employees, but worked for CFLCo and the scores of contractors and suppliers. But as well as managing their accommodation at the site, ACB co-ordinated the other essentials for a happy work force: a collective master labour agreement which was signed for an eight year period (1967-1975) between an association of employers working at the site and a council of Newfoundland-based locals affiliated with international building trade and service unions.

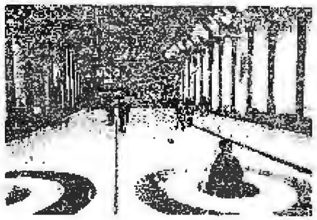
A substantial help to the general smooth running of the operation was the presence on site of full-time labour relations personnel trained to handle and resolve day-to-day problems on the spot.

ACB management is unanimous that this agreement was the single most important factor in achieving the high man-day productivity recorded during construction. The no-strike, no-lockout clause, together with an agreed formula for periodic wage adjustments, meant there was no interruption of work because of disputes, despite the many different employers on site. The 10-hour day and six-day week provided the 60-hour work week — paid at straight time and time and a half.

The massive demands of construction created needs for various

Schoolchildren beside Blueberry Lake

Swimming pool in the Town Centre



Curling rink in the Town Centre

skills, from that of the cutter clearing right-of-way for transmission lines, to the electronic expertise of the communications technician. But they all had to be able to take it: concrete pouring, for instance, continued (behind plastic shelters) even at thirty degrees below zero. Some 13 feet of snow fell each winter; clouds of black-flies were the only constant in the uncertain weather of the short summer.

At the same time that the air was filled with the roar of heavy earthmovers and the thump of blasting, a faint cry at Churchill Falls Hospital marked a new way to arrive on-site: Jeanette, daughter of school teacher John Byrne and his wife, was born March 8, 1969, with attendance of the Hospital's director, Dr. John Price of the International Grenfell Association. When a baby is born, a camp becomes a community.

Joseph Smallwood had had to make do with a shovel full of peat with caribou moss, for the official sod turning ceremony in 1967. By 1970 the principal streets of the townsite were paved and some of the glacial till was being upgraded to support the growth of lawns and gardens. Neighbours were competing to nurture sapling shade trees — a challenge in the rugged local climate.

In 1970 the field work force in Main Camp and 11 satellite camps stretching from Seahorse, at the end of the southwestward reach of the transmission corridor, to Sail Lake 200 miles distant at the north-eastern extremity of the reservoir, reached 6,245 men and women. The daily food order for this army required the delivery of 4.5 tons of meat, 2,600 dozens eggs, 3,100 loaves of bread, 13 tons of vegetables, and 2,300 gallons of milk.

The transition from camp to townsite took place smoothly over the next five years — a credit to ACB's planning.

Now home for approximately 1,000 permanent residents, Churchill Falls is one of Canada's newest northern centres. No effort has been spared to make it one of the most advanced and comfortable. To make facilities as accessible as possible during the long, cold, snowy winters, the community clusters compactly around a unique complex, the Donald Gordon Centre, grouping under one roof services such as school and stores, hotel, theatre, and sports facilities.

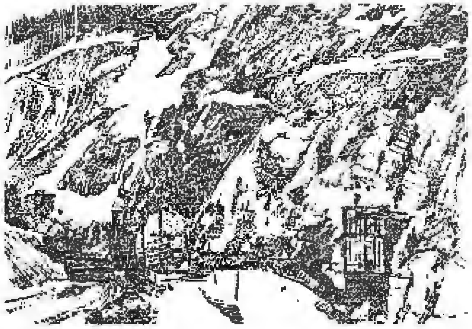
A pedestrian mall runs through the central core of the complex from the hotel to a high ceilinged concourse, which acts as the modern-day equivalent of a town square — indoors.

The Eric G. Lambert School in the Centre provided instruction in English and French. Each community facility was designed to serve several purposes. At night and on week-ends the school's resource centre becomes the community library. During week days, the movie theatre is used by the school as its auditorium and assembly hall.

The houses and apartments are grouped in a semi-circle around the Donald Gordon Centre. Houses are built on only one side of the street. This facilitates snow clearing. It also helps assure privacy — an important consideration in a small community where people see one another day in and day out at work. The use of electricity from the Falls for all heating helps make a remarkably clean place.

There is an interdenominational church, a regional hospital, a professional fire department, a small detachment of the RCMP and other amenities that go with modern civilization. Regular scheduled jet airliner service links Churchill Falls with Montreal and St John's. The community is tied in to the continental telephone network. English and French radio and television (via microwave) are provided by the Canadian Broadcasting Corporation.

Bringing the world to Churchill Falls



The management organization evolved for Churchill Falls construction was an essential pre-condition for the achievement of the project's "on-schedule, within budget" objective.

At the summit of the organizational pyramid of the ACB consortium, responsible for complete engineering and construction management, was the "Policy Board" — itself an organizational innovation. The General Manager of ACB reported monthly to this board, composed of two senior executives each from Acres and Canadian Bechtel.

The group also provided liaison with outside engineering skills embodied in a panel of distinguished international consultants and a panel of senior engineers from Acres and Canadian Bechtel.

The main functions of the ACB organization were engineering, cost control and administration, scheduling and estimating, procurement and construction. The work at the project itself was further divided into four components: water storage; power complex; switchyard and transmission lines; and support facilities.

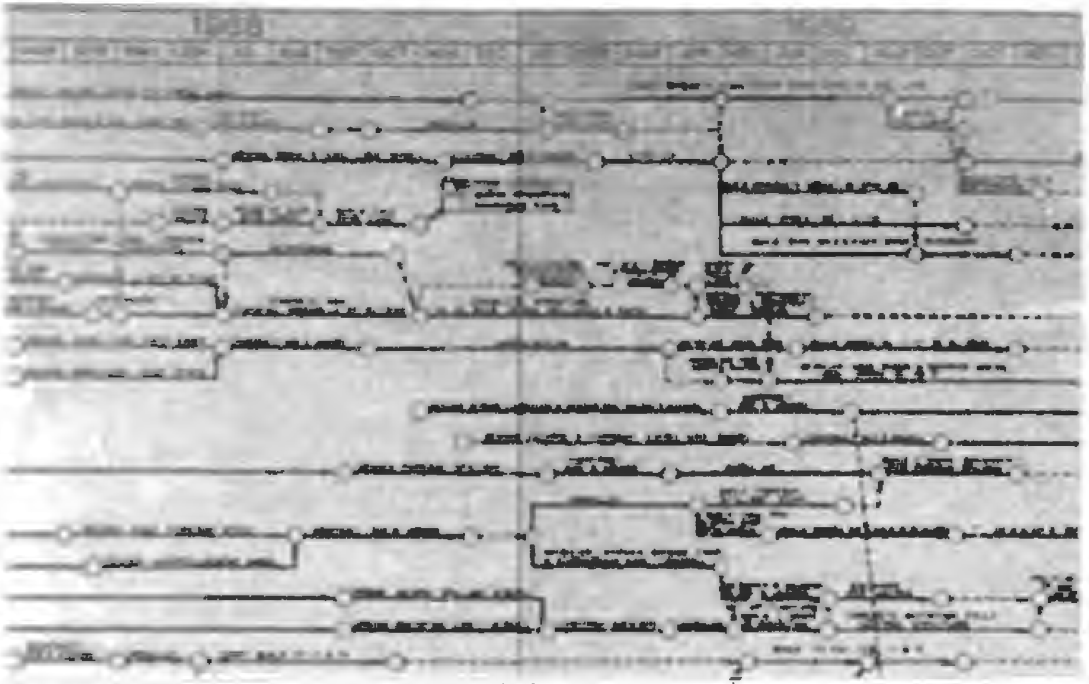
Because of the immense scope of the project, no general contractor was named. Instead, contract "packages" were developed by ACB in such a way as to encourage the widest response and competition from qualified bidders. Over 180 separate construction and service contracts were awarded, but none was for an amount in excess of $75 million. In addition, hundreds of major purchase contracts for the supply of major equipment were negotiated, mainly with Canadian firms.

It was decided early to relieve construction contractors of the responsibility for providing housing and board for their men on the site. These were provided at a stated subsidized cost per man-day by ACB. This meant the removal of a large item of uncertainty from the contractor's evaluation, thus resulting in lower and more consistent bids. In addition, the good standards of living and working conditions made an important contribution to the morale of workers on the project.

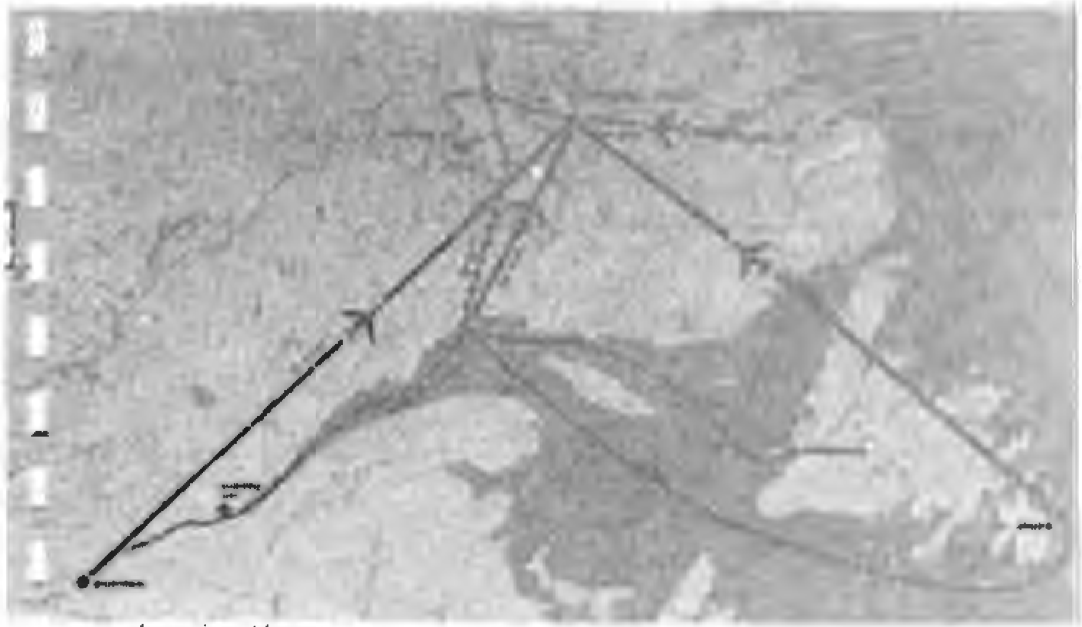
Transportation was contracted in volume packages to experienced, responsible carriers, such as Québecair and Eastern Provincial Airways. A total of 730,000 tons of material and equipment was moved to the site by air and surface transport, as well as 52,000 passengers.

The allocation of work between the different ACB divisions was as follows. Engineering, in which Acres personnel were predominant, established concepts, performed detailed design, monitored engineering assignments and obtained approvals. The remaining four divisions relied mainly on Canadian Bechtel's expertise: the Finance and Administration Divisions compiled cost data, processed progress payments and provided administrative support. The Scheduling and Estimating Division developed schedules, monitored progress and prepared control estimates for elements of the project during the engineering phase. The Operations Division covered the Contract Department, which developed contract documents, issued tenders, analyzed bids, recommended awards and organized quality control and expediting, and the Construction Department, which looked after operations on site.

One noteworthy feature of the contracting was the prevalence of the type of "consortium philosophy" inspired by the formation of ACB itself. The largest construction team on site, for instance, was Churchill Constructors Joint Venture, a consortium of six companies organized by Atlas Construction Ltd. Provision of the 11 hydro-electric generating units, a job which employed 600 men for two years at a cost of over $60 million, was contracted to The Churchill Falls (Machinery) Consortium, a joint venture of Canadian General Electric, Dominion Engineering Works Ltd. and Marine Industries Ltd. CGE and MIL divided the first 10 turbine generator contracts between them, with MIL being awarded the eleventh.



A section of the critical path which construction followed.



Logistical map of the project.

[illegible] up to 200 tons [illegible]

Of the total direct construction expenditure of $665 million, approximately $650 million — 98% — was spent in Canada, with 57% of the sum going to Canadian manufacturing industry, 17% to service industry, and 26% in direct labour costs.

But, in spite of the high Canadian component of manufacture, the consortium approach made available the best in North American and European technology. Both Canadian and French specialists, for instance, evolv[illegible] their own designs for the turb[illegible]e and generators; both groups pooled and shared their experience to the benefit of the project. Shafts for the huge units were forged in England, turbine models tested in Canada, France and Scotland, speed governors designed and built in the United States, and some transformers supplied from Sweden.

ACB's logistical management was tested to the utmost early in the project, when on May 10, 1969, a strike suspended operations on the Quebec North Shore & Labrador Railway for three months, at the peak of the heavy construction season, with 4,500 men already on site. An emergency airlift — "the biggest since the Berlin blockade" — was pulled together, with aircraft chartered from as far away as Florida and Alaska. It operated 1,153 flights from Sept Iles and Goose Bay, carrying in 650,000 gallons of fuel plus 11,617 tons of cargo, and supplies, including items as heavy as dismantled bulldozers.

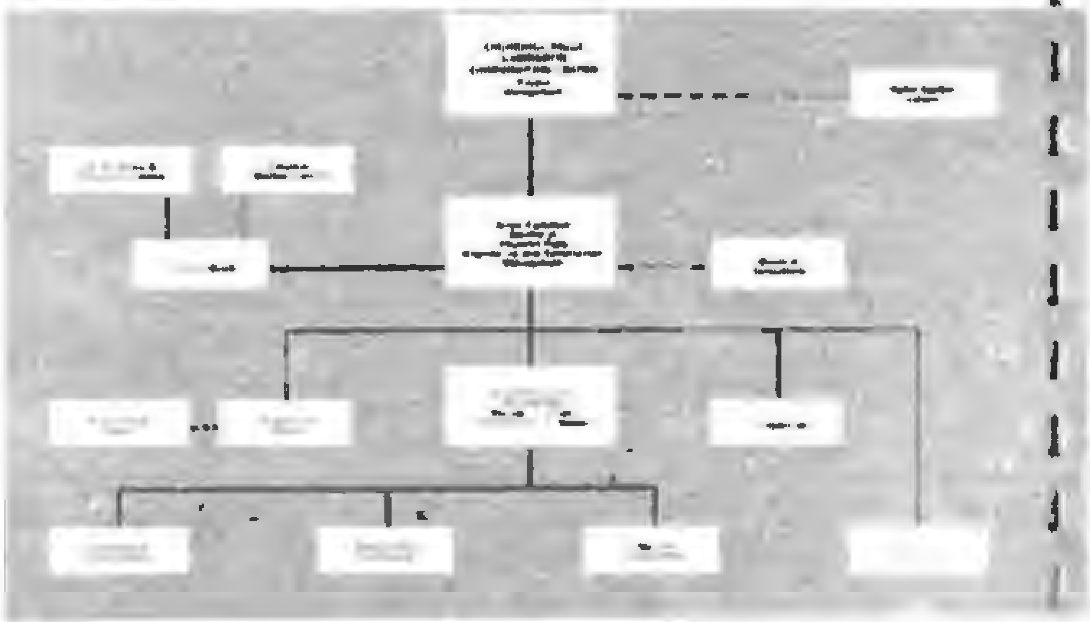
But the Churchill Falls achievement was not limited to a massive application of logistical and earthmoving skills. It involved, too, the most advanced and intensive engineering approach ever applied to a major hydro-electric project. Reliability and assured performance from the start of operation were vital to assure that power contract obligations were fully met. Features of the project had to meet the requirements of well proven experience as well as take the full cost/benefit advantages allowed by the scale of the project.

Turbines and generators were selected at the upper limits of output and size for the 1,060 ft. head. Thorough design analysis provided a high degree of confidence that all expectations would be realized. Electrical facilities made optimum use of a 230 KV/735 KV system with power carried from the underground transformers through 900 ft. long oil filled cables.

Engineering design of the excavated caverns for powerhouse, surge tank tunnels and galleries was greatly assisted by use of advanced finite element stress analysis. Close integration of engineering and construction techniques led to substantial economies.

Varied tasks demanded new engineering approaches from the massive hydraulic control gates to transport equipment specially designed for the project needs.

The gates are the crucial element in controlling the impoundment of 1,100 billion cubic feet of usable water for Churchill Falls power development. The series of reservoirs [illegible] the area of Lake Ontario are formed by the skilful use of natural land forms, supplemented with 40 miles of dykes, ranging up to 117 feet in height. The key to directing this water is [illegible] six control structures — concrete spillways with sliding gates that can be remotely controlled ele[illegible] from



the Churchill Falls control room at a distance of up to 60 miles. To make these gates operate reliably when temperatures might be 50°F. below, with five ft. of ice on the reservoir, required many man months of modelling and design effort. The installations are heated in winter both by air circulation and electric resistance heaters, and electromechanically controlled by redundant, fail-safe, supervisory control circuits.

Another unique element of the project was the design and construction of a 250-ton transporter to take the 224-ton transformers (one for each generator set) from their special rail cars at Esker to the project site.

The vehicle finally developed had tires seven feet high, and two 700-horsepower six-wheel drive tractors. Its 198 foot-long body, was articulated in order to be able to negotiate the turns in the 28 ft. wide access tunnel to the underground transformer gallery. Early Churchill Falls residents still remember turning out at the intersection of Ressegieu Drive and Esker Road to see "the awesome convoy crawl past in full glory, yellow flashers whirling, at two and a half miles an hour."

The transformer transporter was only the largest of the enormous fleet of 2,000 transport and construction vehicles at the site: 600 tracked machines, ranging from bulldozers to self propelled drills; and 1,400 wheeled vehicles, from passenger cars to fuel tankers and 50-ton dump trucks.

Nor were the transformers the only heavy equipment beyond the carrying capacity of most vehicles: the turbine runners with a casting weight of 145 tons, and a finished weight of 100 tons set for Canada a world record for the largest castings ever made in stainless steel. The two cranes installed in the power house were coupled with a massive lifting beam to handle the 655 ton rotors and giant stators for the generator units, which were assembled on site and lifted into position.

Spanning the river gorge was a highlight for the transmission line crews. Their efforts linked the power plant with the Hydro-Québec substation at Montagnais, 130 miles to the southwest. For the last span a helicopter (one of as many as seven on site) hauled 7,500 feet of half-inch nylon rope across the river from the south shore. Increasingly heavier steel cables followed until finally the complete set of conductors stretched from three sets of 100 ft. towers, 6,200 ft. apart, 1,000 ft. above the waters of the Churchill.

For each contract package, large or small, ACB's careful monitoring of cost, quality, and completion time was the essential factor in integrating every element into the smooth progress of the whole project.

Quality standards were clearly written into each contract document and purchase order, and ACB's quality control group not only monitored construction and manufacturing contracts, but also insisted that the contractors provide their own quality control systems.

Schedule control was achieved by monitoring progress on contracts every two weeks, and taking corrective action wherever possible before slippage became serious. Cost control was maintained from the initial estimate through design, and, after contract award, by monthly forecasting of final cost relative to budget. Thus, early warning of any significant variation enabled corrective measures to be taken in time to achieve control.

All this performance information would have been nearly useless unless systematized, computerized for easy retrieval, and integrated with another key factor: logistics. A given item of material for the project might meet cost, quality, and completion targets. But where was it? When was it shipped? When, and how, would it arrive on site? These were questions the Transportation Information System (TIS) used by ACB, was designed to answer. No soulless machine, TIS took the strenuous efforts of scores of men as well as masses of data processing equipment to keep tabs on the thousands of items of material in transit at any one time.

Safety beneath the shield

The heart of the Churchill Falls power plant is the great machine hall, housing the 11 generating units. Over 1000 ft. long, 81 ft. wide, and 154 ft. from floor to roof, it was carved out of the rugged granite of the Laurentian shield 900 ft. below the surface.

It might seem simpler to have sited the power plant above ground at the edge of the river. But, from the perspective of a hydraulic engineer, it is more practical to make the 11 penstocks which carry water to each turbine short and as steep as possible. When the 450 pounds per square inch pressure has spun the turbine, the spent water is discharged to a surge chamber, before flowing via two huge tailrace tunnels over a mile to the lower Churchill river.

The amount of excavation required was enormous: in addition to the penstocks and the machine hall and surge chamber a transformer gallery was excavated just above the powerhouse. And the concern of the engineers and geologists that the rock structure be "competent" to bear the blasting, tunnelling, and the surge of water, was thoroughly exercised by exhaustive drilling, sampling, and stress analysis. The area finally selected for the powerhouse had been proven to have the necessary integrity and "faultless" structure.

The first step was completion of a mile-long access road which curves down the steep slope toward the river. The second was to drive a mile deep tunnel at the end of the road, angled in to provide access to the underground works through which the heavy dump trucks were to remove much of the rock.

This accomplished, the major underground construction contract was awarded to Churchill Constructors: two contracts totalling $65.7 million, for all remaining underground excavation except completion of the tailrace tunnels; most of the concreting of the underground complex; installing of miles of embedded conduit and piping; and provision of tons of anchors and rock bolting, as well as installation of the main powerhouse cranes and gates. In excavation alone, this meant the removal of 2,300,000 cubic yards of rock. CCJV, as the consortium was called, was busy for three years at the job, employing at one time over 1,200 workers.

Safety — both for the construction crew and the operating staff who would follow them — was a prime consideration. Painstaking calculations had to take into account the changing stresses on the rock as the excavations grew in size.

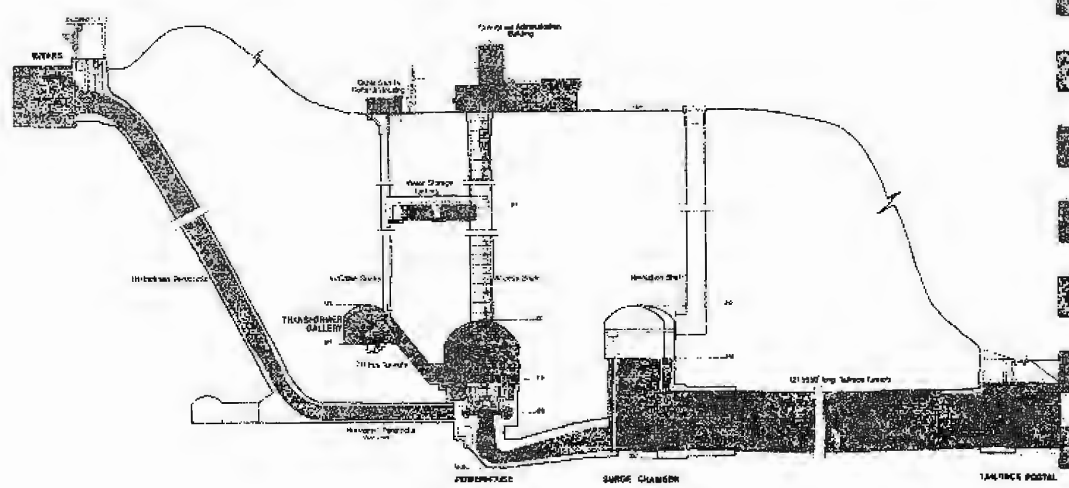
In the large chambers, excavation was carried out from the top down: first a pilot tunnel or heading was driven along what was to be the ceiling of the chamber. Then this would be "slashed" or excavated to full width. Finally the remaining layers of rock would be blasted and mucked away in a quarry-like operation.

Excavation reached its peak in June 1969: within six days 45,600 cubic yards of rock were removed, enough for 2,800 truckloads of 33 tons each.

The penstocks, on the other hand, were started from the bottom, drilled from electrically-driven climbing

Excavation of the tailrace surge chamber

The 650-ton generator for Unit #2 is positioned inside the stator.



Cross section of the underground powerhouse complex.

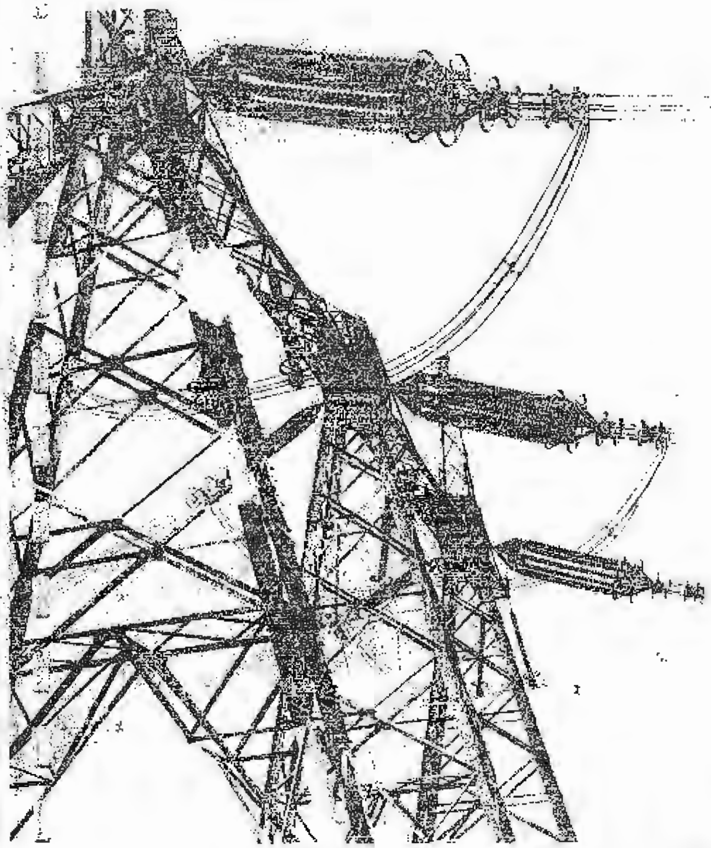
platforms known as "Alimaks" and which enabled an eight by ten foot pilot shaft 1,200 ft. to the surface to be driven without intermediate stations. Yet, such was the accuracy of surveying (in which the latest technical devices such as laser beams had been employed) that the first shaft broke surface within inches of its target.

One of the most hazardous and difficult jobs remained: slashing the 11 pilot shafts to the designed 22 ft. by 28 ft. penstock dimensions.

The "slashing" was done by six drills on outriggers, mounted on a "jumbo" — a sort of flat-car which ran on steel rails laid on the almost vertical side of the tunnel.

Day after day the same sequence went on: the drills would whine into the rock, charges would be set, the jumbo would be hauled back 45 ft., and the blast fired. As tons of rock cascaded 1,200 ft. to the bottom, the jumbo would be advanced, another 14 ft. of rail laid, and the whole process would begin all over again.

When the jumbos had finally bored their way down the shaft another hazardous job began — concreting. This was the task of covering the whole inside surface of the penstocks with a foot of concrete — to resist the rush of 400,000 gallons of water a second at full flow. The men who worked the barrel-shaped collapsible metal forms for the concrete called the frame at the top of the form "the headache rack" with good reason — even a small pebble comes down a 1,000 ft. tunnel inclined at 60 degrees like a ricocheting bullet.



Jumper arrangement for the South Bank towers, river crossing line 1

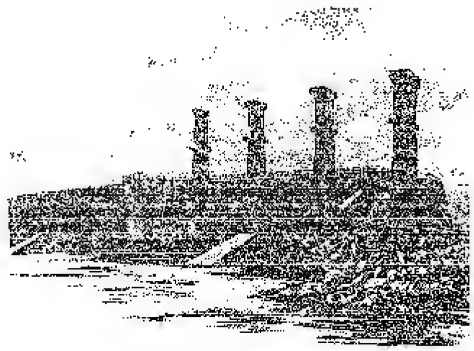
On July 13, 1970, the final blast was fired at the bottom of No. 10 penstock, marking completion — less than 34 months after it started, of the underground excavation. Some five million pounds of explosive had been used. Yet, in spite of the scale of the operation, and the great heights and other hazards involved, lost time from work accidents was substantially lower than on most excavation jobs of this type.

The final horizontal section of the penstocks, which narrowed to 14 ft. seven in. diameter, was lined with high strength steel. (The length of the costly steel lining had been minimized by careful engineering analysis and judgement of the adequacy of rock and concrete to withstand the stress. Impressive economies were achieved.)

Excellence in both design and workmanship meant that full advantage could be taken of the remarkably solid rock formation. No supporting concrete was required for the roofs of the massive underground chambers. The powerhouse ceiling finally took the form of stainless steel sheeting suspended from bolts embedded in the vaults of rock above.

Typical V-type guyed tower

Harnessing technology to improve ecology



When geologist A. P. Low climbed Labrador's Lookout Mountain in 1894, overlooking what is now the Churchill Falls power plant intake, he reported a bleak view: "over half of the surrounding country has been stripped bare by frequent fires. In the swamps and around the shores of the lakes... black spruce and larch of small size grow thickly together. On the sides of the hills these are more stunted... where the hillsides have been burnt years ago they are covered with a tangled mass of willows and alders, while the tops are coated with white moss and semi arctic shrubs."

The animals that inhabit this harsh land lead a similarly precarious existence, and large mammals, such as the black bear and caribou, are few. While the unfished lakes provide a few whoppers, the concentration of nutrients, and therefore the density of aquatic life, is sparse. Labrador's Naskaupi indians seldom visited the area, because of the scarcity of game and fish.

In working with and altering the terrain, man does not always need to oppose nature. It is, perhaps, significant that the new course along the edge of the plateau, into which the Churchill was directed, may in fact have been the original river bed before the east glaciation 20,000 years ago. Ecologically, the entire project can be studied as a model for resource development in the Canadian north.

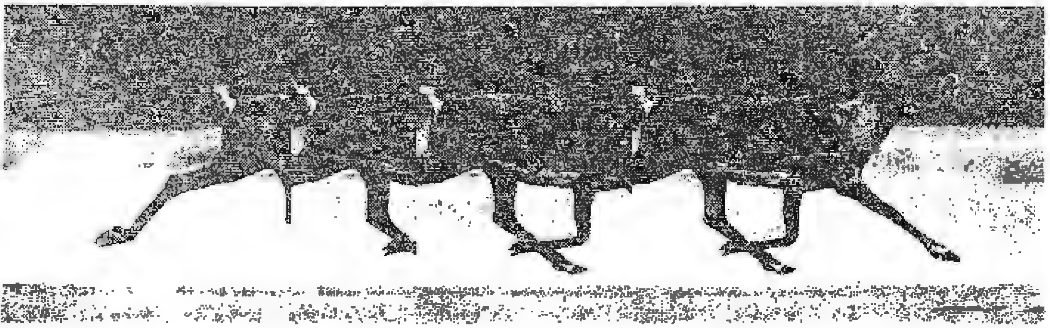
From the standpoint of conservation, the regulation of flows passing through the power development should actually help to prevent the previous harmful erosion of the banks of the lower reaches of the Churchill, by uncontrolled spring freshets.

Again, the flooding of 2,500 square miles to create the reservoirs changed the face of the countryside. However, the slowness of the process, which took place over three years, meant that harmful impact upon land animals in the region was minimized. Careful studies by biologists have concluded that some overcrowding of smaller species occurred in some limited areas such as islands which were created as the waters rose.

And the fishing should be even better than before. Not only has the aquatic habitat been greatly enlarged, but the flooding of swamp and muskeg, biologists have found, increases the volume and concentration of small organisms which are the basis of the food chain which sustains, indirectly, the larger game fish.

Of the land submerged beneath the reservoir, a survey determined that it contained 65 per cent scrub bush growing on rock scantily covered with acid soil, four per cent barren land, nine per cent burned-over areas, and 20 per cent bog. Only two per cent consisted of trees over 30 ft. high.

ACB's concern for, and interest in, the environment was clearly demonstrated by the insistence that all

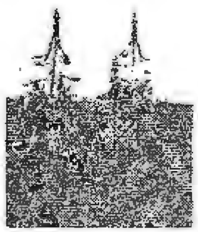


camps, even the remotest, should be equipped with sewage treatment facilities.

And the new human inhabitants, permanent and temporary, of the main camp and townsite appear to have quickly developed an awareness and appreciation of the unspoiled environment. Early issues of the weekly CFLCo paper *Churchill Falls News*, were full of suggestions for using such natural resources as caribou moss, partridge berries, and Labrador tea. And one of the hottest debates in its letters column was the vexed subject of whether female caribou have antlers. (Unlike the rest of the deer family, they do.)

It was this aspect of the project which captured the attention of Prime Minister Pierre Elliott Trudeau, when he inaugurated the development on June 16, 1972, with a speech titled "In harmony with nature."

"We should see," he said, "this gigantic installation as the unified and dynamic solution to a great many problems, using the contributions of a wide array of skills and knowledge. A truly human shape has thus been given to this source of raw energy without diminishing nature or disturbing the balance of the environment. The example of Churchill Falls shows that though man imposes his will on nature, he can do so in harmony with nature, and that this process can be noble and fruitful. *That is why I say without hesitation that our technology has produced here a masterpiece that commands double admiration.*"



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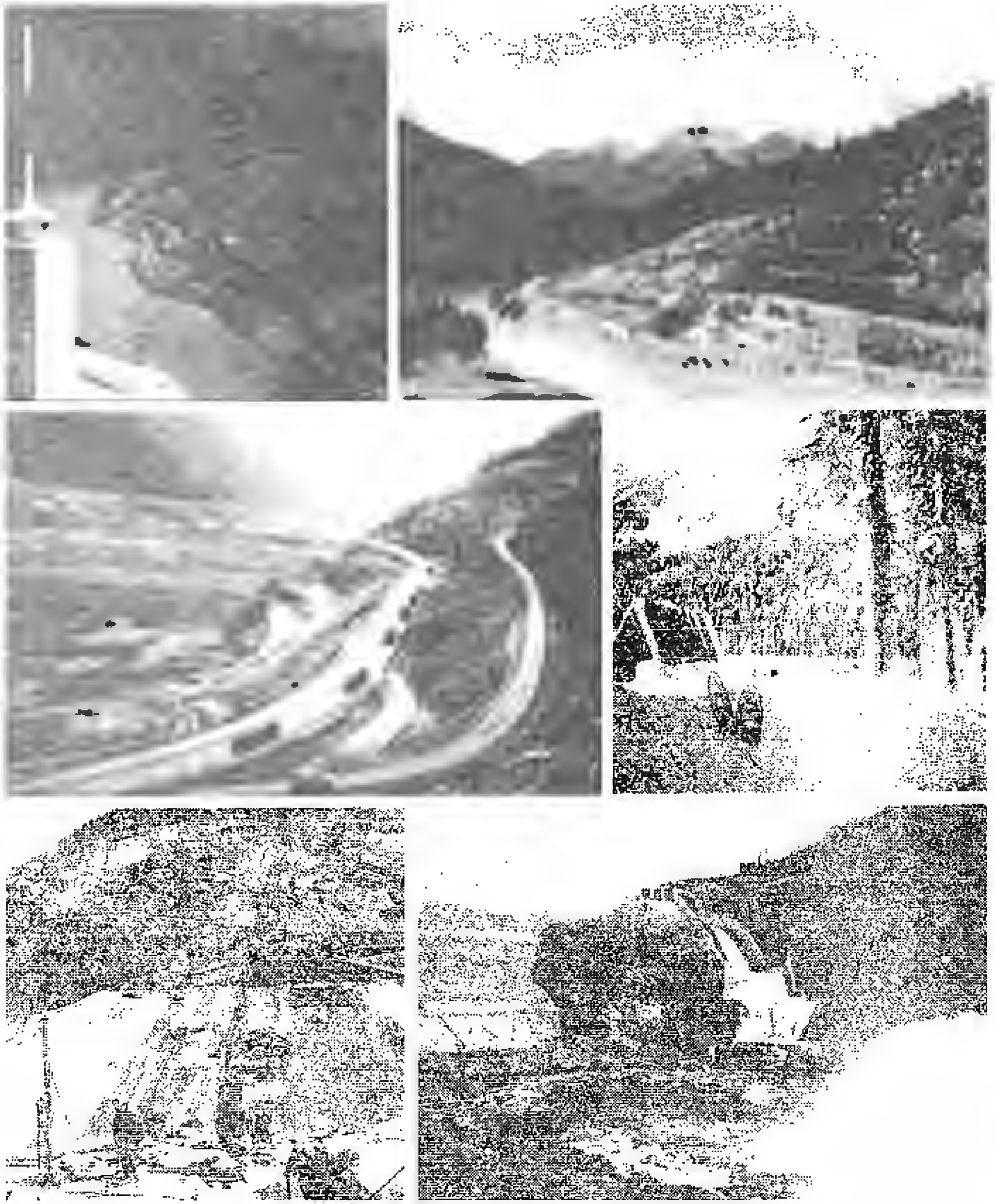

Photographs Courtesy of British Columbia Hydro and Power Authority

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Mica Storage Project

Located on the Columbia River, about 450 river km north of the Canada-United States border, Mica Dam is one of the higher earth-fill dams in the world. Completed in 1973, the dam towers 244 m above the lowest bedrock level and constitutes a major link in harnessing the water resources of the Columbia River system. A live storage capacity of $15{,}000 \times 10^6\ m^3$ is operated to tame the mighty Columbia River and provide flood protection to downstream riparian land. By 1977, 1,740 MW of hydroelectric generating capacity had been installed by the owner, British Columbia Hydro and Power Authority.

The Mica storage project was engineered by the joint-venture company CASECO Consultants Limited.

H. G. ACRES AND COMPANY LIMITED* was one of the three parent engineering companies.

*The Company was renamed Acres Consulting Services Limited in 1969.

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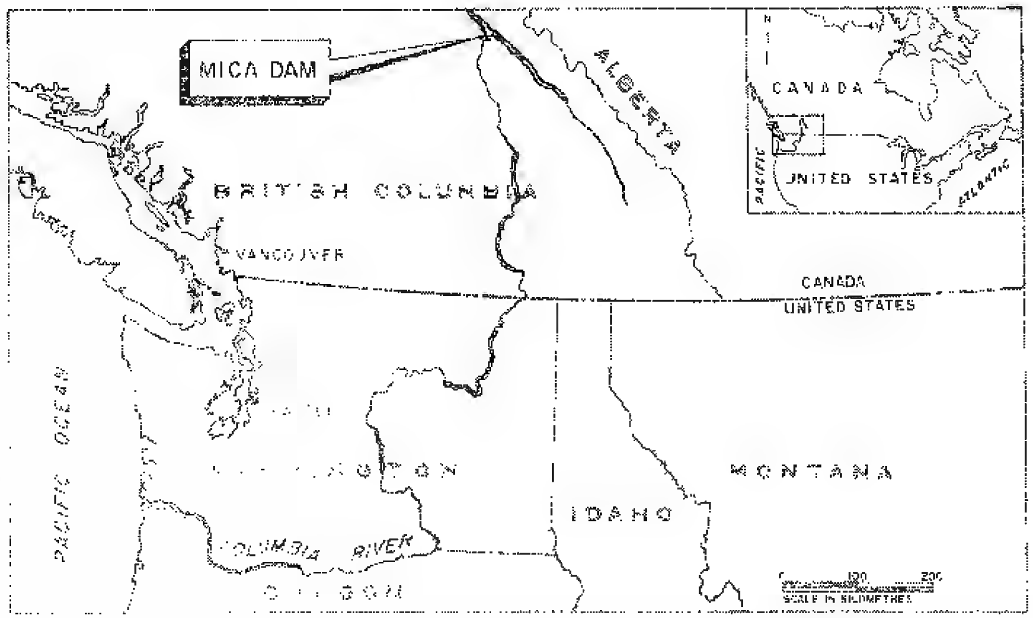


History of the Mica Storage Project

The Columbia basin is an international river system with its headwaters located predominantly in the Canadian Rockies. The Columbia River flows southward into the United States, then turns westward and ultimately discharges into the Pacific Ocean. The mean annual discharge at the mouth is 6,300 m^3/s and the system is the fourth largest in continental North America.

In the early 19th century, the Columbia River was utilized as a major trading route for the fur industry. Goods and passengers were transferred to boats just north of the present Mica damsite for the journey to the Pacific Ocean. In 1865, a brief but furious gold rush erupted as miners and adventurers streamed toward the mines south of the Mica site.

Acres has been involved in the development of the water resources of the Columbia since the early 1950's, when conceptual designs were prepared for an earth-fill dam at the present Mica site. In the late 1950's, the Company developed schemes for a site on the Columbia in the vicinity of Murphy Creek.

In 1961, three major Canadian consulting companies — H. G. Acres and Company Limited, Shawinigan Engineering Company Limited, and Crippen-Wright Engineering — formed a joint-venture company called CASECO Consultants Limited. Dr. A. W. F. McQueen of Acres was President of CASECO between 1961 and 1967. CASECO was appointed as the consulting engineers for the Mica Dam project by the British Columbia Power Commission.*

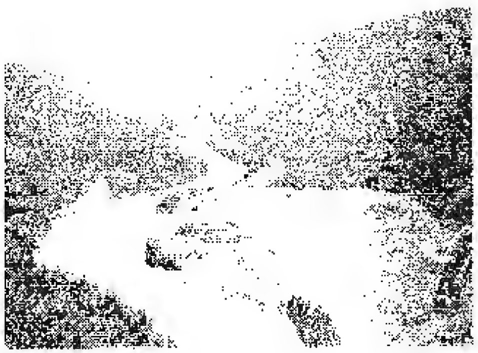
CASECO involvement in the Mica storage project included

- river basin planning studies
- engineering and construction supervision for Mica Dam and associated structures
- design of townsite
- investigation of reservoir slides
- study of the Downie slide located downstream from the site.

During the period 1961 – 1964, CASECO worked on an overall water resources development plan for the Columbia River basin in Canada. This work constituted the basis of the 1964 Columbia River Treaty between Canada and the United States. In terms of the Treaty, 3 storage dams — Mica, Duncan and Arrow — were to be built in the Canadian portion of the Columbia system.

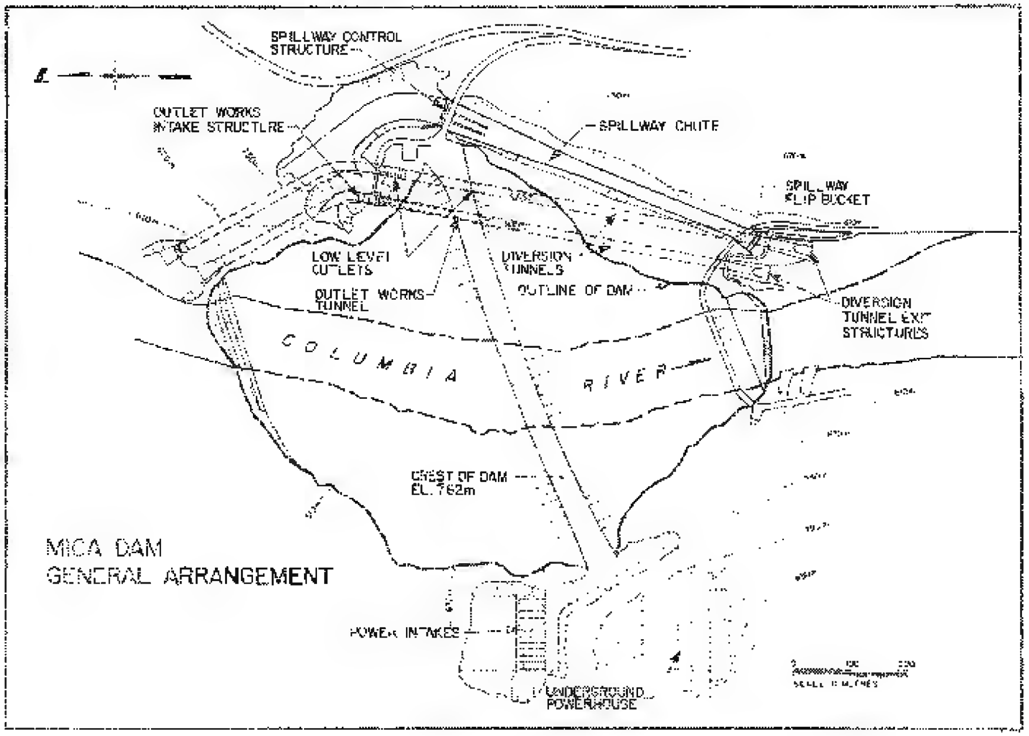
To fill key positions, CASECO initially drew senior engineering staff from the parent companies. Two senior members from each of the three engineering firms also served on a Board of Engineers for CASECO to provide technical guidance and expertise for the duration of the design and construction of the project. Dr. D. H. MacDonald and Mr. I. W. McCaig were the Acres members of the Board of Engineers for the major portion of the period between 1961 and 1978. In view of the approaching completion of the design phase of CASECO's work, Acres and Shawinigan sold their interests in the joint venture to G. E. Crippen and Associates Limited in 1967. However, as stipulated by the British Columbia Hydro and Power Authority, both Acres and Shawinigan retained technical responsibility and maintained membership on the Board of Engineers until completion of the work in 1978.

*The Commission was absorbed into the newly created British Columbia Hydro and Power Authority in 1962.



Mica Townsite

The townsite at Mica was designed [illegible] accommodate up to 4,000 people during constru[illegible] the dam. Full facilities were provided, including [illegible] shopping center, bank, recreation center, [illegible] medical clinic, police station, hotel, and [illegible] recreational facilities.



MICA DAM
GENERAL ARRANGEMENT

Main Dam

Mica Dam is located in rugged, glaciated terrain with mountains rising steeply to nearly 1,500 m above river level. During the Pleistocene epoch, Alpine and Continental glaciers covered the area with ice sheets up to 1,800 m thick. Bedrock consists generally of mica schist and granitic gneiss. The river valley beneath the dam was filled with 27 m of alluvium, underlain by up to 18 m of very dense glacial till.

Extensive field investigations were performed. Exploration was carried out over a period of 3 years by CASECO and included drilling and sampling, test pitting, trenching, seismic profiling, test fills, test blasts and pump tests. Over 2,000 drill holes, clamshell and backhoe test pits were used to confirm adequate sources of construction material.

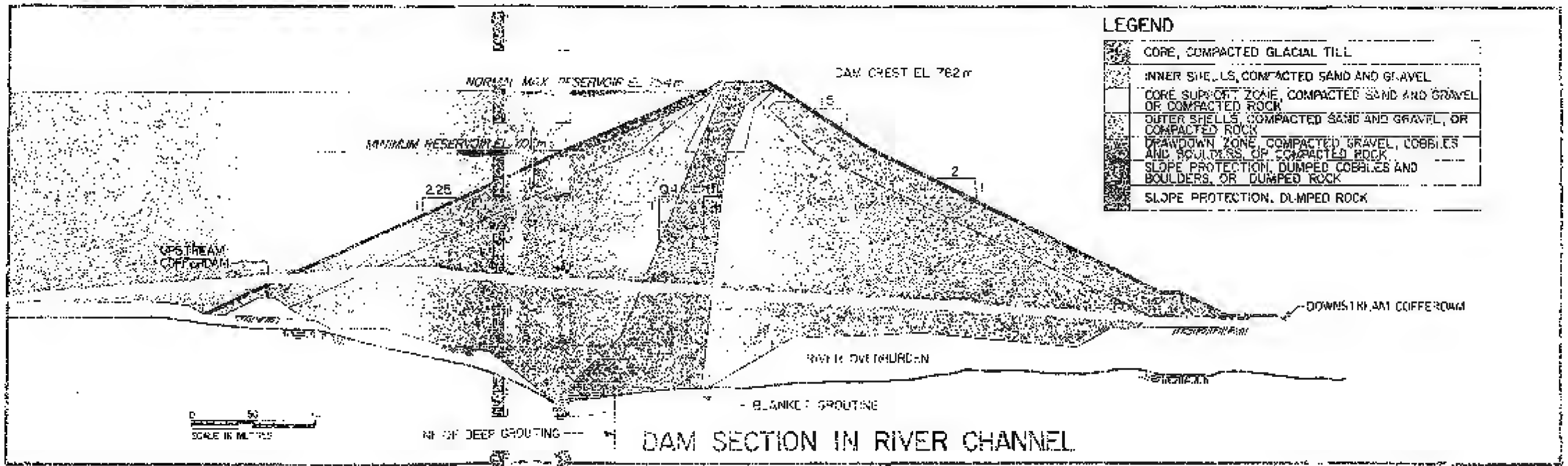
The main dam is a compacted earth-fill structure with a near-vertical impervious core of glacial till. Maximum height of the dam is 198 m above the riverbed level. The total volume of fill material is approximately 32.6 x 10^6 m^3. The inner and outer shell zones consist of sand and gravel, and rock fill, respectively. To prevent tension cracking within the shells and core zone of the dam, the following measures were incorporated in the design:

- selection of well-graded glacial till as a self-healing core material
- adoption of relatively flat slopes to minimize seismic-induced shear stresses
- upstream curvature of the dam
- high-energy compaction of fill materials
- shaping of abutments and core contact zones.

The foundation of the impervious core zone was excavated to sound rock. Overhangs and abrupt discontinuities were removed and the rock surface shaped, by blasting, to provide satisfactory contact areas with the fill. Foundation surface treatment comprised infill concrete to remove geometric irregularities, and shotcrete and slush grout to seal open joints in the bedrock surface.

Within the riverbed area, the foundation of the supporting shell zones of the dam was placed on dense alluvium. The upper stratum of silty fine sand was excavated to avoid possible liquefaction under earthquake loads.

Instrumentation of Mica Dam is extensive. To monitor the performance of the dam and check its behavior with design assumptions, a wide range of instruments was carefully selected and installed, including piezometers, movement gauges, load cells and seismic recording instruments.



DAM SECTION IN RIVER CHANNEL

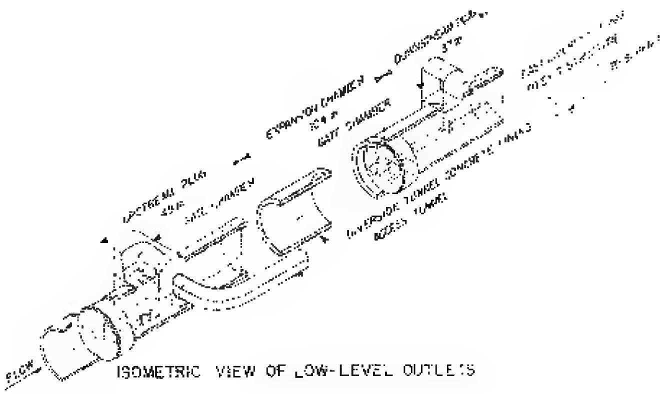
River Diversion

Diversion works consist of 2 concrete-lined tunnels, 13.7 m in diameter, each having a length of about 1,000 m. Designed as free-flow structures, the tunnels have a combined capacity of 4,250 m^3/s. Each tunnel incorporates a gated intake structure and an exit structure designed to contain the hydraulic jump.

River diversion through the tunnels was effected by 2 pairs of rock-fill dikes constructed across the Columbia River at the upstream and downstream limits of the main dam foundation area. For dewatering the dam foundation, zoned earth-fill cofferdams were constructed within these closure dikes. The cofferdams were largely incorporated into the dam embankment. Deep tube wells were installed through the river alluvium adjacent to the cofferdams for control of seepage into the core trench excavation.

Low-Level Outlets

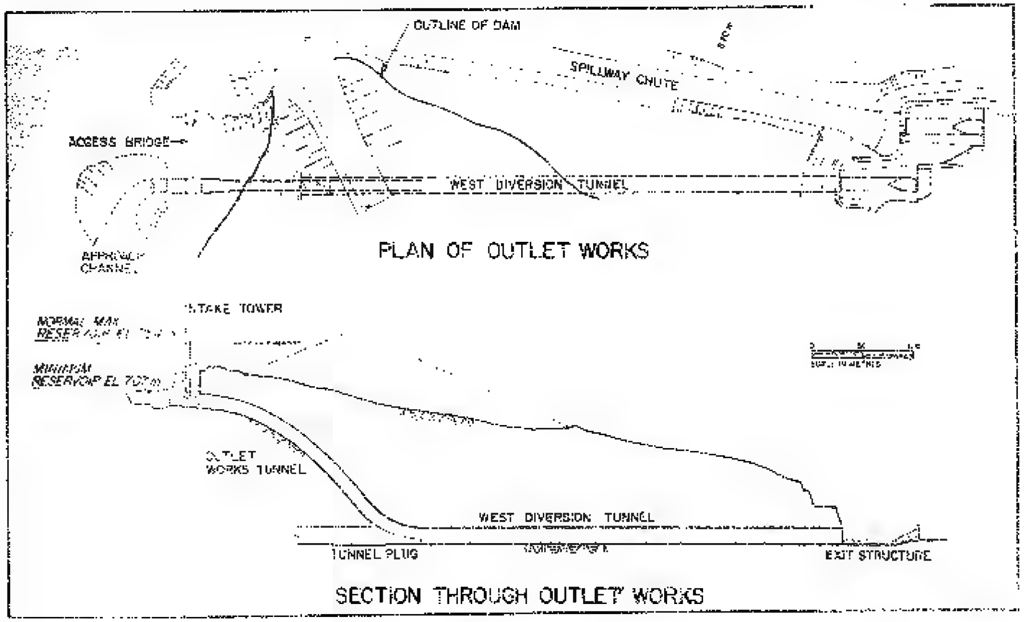
To allow flow releases during filling of the dead storage zone, a low-level outlet structure was constructed in the east diversion tunnel. This outlet employs an expansion chamber type energy dissipator which reduces the discharge head by approximately 50 percent. Extensive model tests were performed to develop the final arrangement consisting of 3 conduits and slide gates located in plugs at the upstream and downstream ends of the expansion chamber, formed by the original diversion tunnel walls.



ISOMETRIC VIEW OF LOW-LEVEL OUTLETS

Outlet Works

The outlet works were constructed primarily to release water from live storage prior to the commissioning of the powerhouse in 1977. Released water passes through the gate-controlled conduits at the base of an intake tower into an inclined tunnel which discharges into the west diversion tunnel. The 2 fixed-wheel gates are operated by hydraulic hoists at the bottom of a dry shaft. Access to the top of the control structure is via a 2-lane bridge from the dam crest.



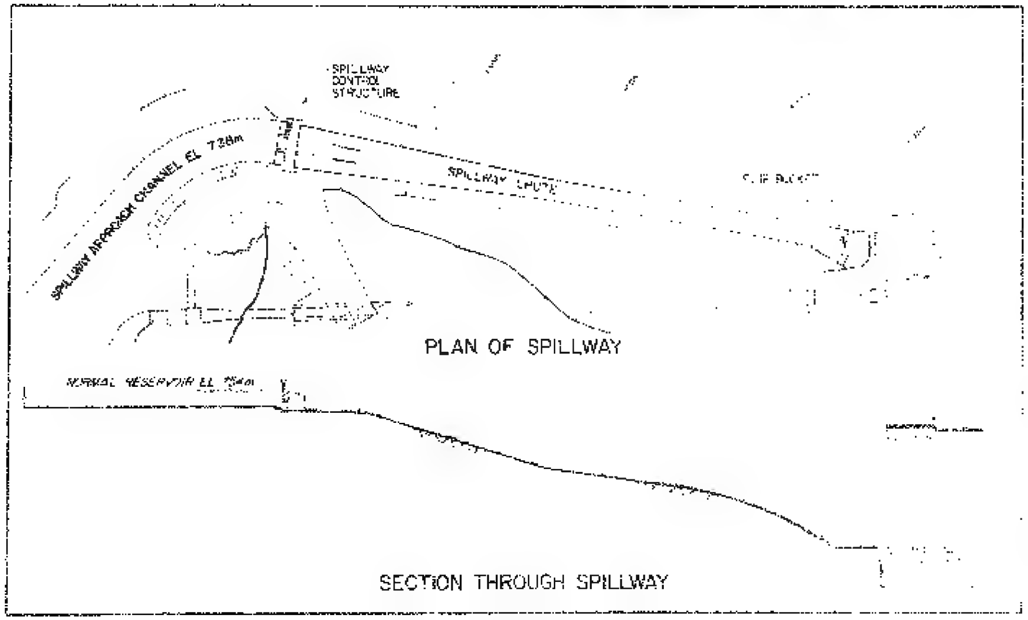
PLAN OF OUTLET WORKS

SECTION THROUGH OUTLET WORKS

Spillway

The spillway structure consists of a control structure with 3 radial gates, a 530-m long concrete spillway chute and a mass concrete flip bucket. Design capacity of the spillway is 4,250 m^3/s.

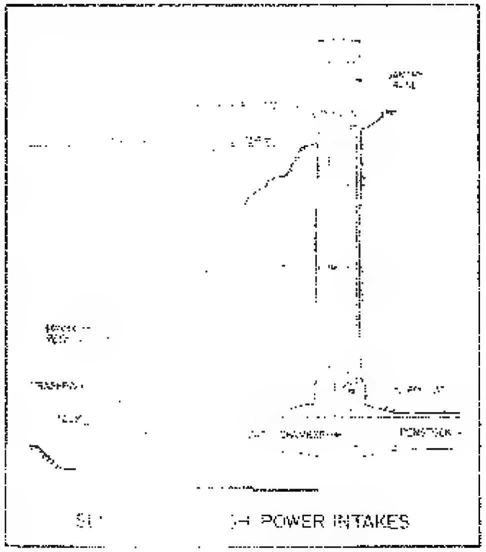
The control structure is a low overflow weir with an ogee shape. Hydraulic model tests were used to develop a unique flow surface for the flip bucket, conforming to a skew cone with an inclined axis. A transverse drainage system and longitudinal drainage gallery run beneath the full length of the spillway chute floor.



Power Intakes

The power intake structure was constructed as part of the main dam project and comprises an approach channel formed by a 76-m deep opencut rock excavation and 6 intakes. Each intake incorporates a bellmouth entrance, gate chamber and short concrete-lined stub tunnel. Flow control is accomplished by vertical fixed-wheel gates operated from 8.7-m diameter, 76-m deep gate shafts. The bellmouth entrances are covered by trashracks which are cleaned by a trash rake operated from the intake structure deck. Slip-forming methods were used to place the concrete for the face slab and gate shaft lining.

Engineering of the underground generating station at Mica was carried out by the British Columbia Hydro and Power Authority, largely subsequent to the completion of CASFCO's work on the dam and associated structures.



The Falls, the Eskers and the Estimates

Certainly it needed no flash of inspiration to see the potential power of the mighty Churchill River's spectacular tumble from the glacier-gouged Labrador plateau. As early as 1894, in the infancy of hydroelectric power generation, A.P. Low of Canada's Geological Survey suggested this new technology could be applied to provide "several millions of horsepower". With remarkable prescience, he submitted that such power, turned to heat, could be used to reduce the local iron ores.

Twenty years later, W. Thibaudeau of the Régie des Eaux of the province of Quebec, surveyed the area. He saw that the river could be diverted above the Falls, and rechannelled further to the east to increase the head of water available, from 500 ft. at the Falls and upper rapids to more than 1,000 ft. at Portage Creek.

Such bold concepts awaited full economic justification for yet another generation.

Credit for the first practical initiative is due to British Newfoundland Corporation Limited, formed in 1953 by seven major British financial, resource and manufacturing companies, including Rio Tinto-Zinc Ltd. It received a charter to explore the island of Newfoundland and Labrador for the government of Joseph Smallwood, who had just brought Newfoundland into the Canadian confederation.

The water power potential of the 110,000 square mile area was clear, but the energy available had to be quantified. In the mid-1950's it remained too remote for existing transmission techniques to deliver to available markets economically. It was accessible only by arduous canoe trip or hundreds of miles of flight by a float plane.

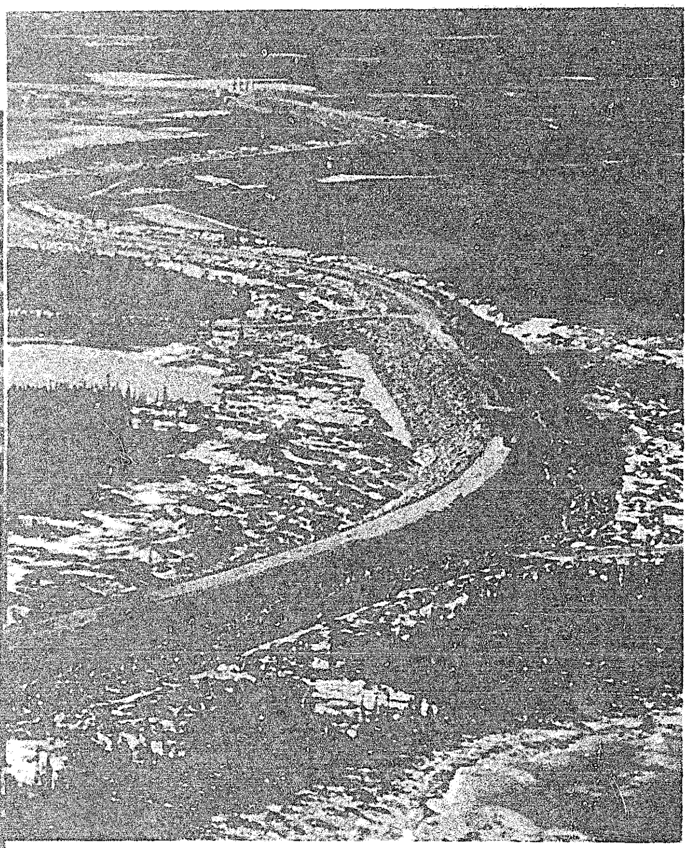
Brinco watched the opportunities for development unfold step by step. First, mining and processing of the iron ore deposits by other interests at Schefferville, Wabush and Labrador City, justified building the Quebec North Shore and Labrador Railway passing only 105 miles to the west of the Falls. Brinco added to the effort in 1960 by pushing a road from Esker, on the rail line, to the west bank of the Churchill. At Twin Falls, on the Unknown River, a few miles from Churchill Falls, Brinco built a modest 120,000 KW hydro-electric plant to serve the iron ore development and associated townsites. The harnessing of Labrador hydro power had begun.

Another link in the chain of feasibility was forged when Hydro-Québec, faced with developing the rivers of the north shore of the St. Lawrence for power, engineered and perfected a 735,000 volt Extra High voltage (EHV) transmission system. Its successful application in carrying power from the Manicouagan River plants to Montreal in 1965 built confidence that it was the technical and economic solution to the problem of carrying Churchill Falls power to market in the developing urban and industrial centres of Quebec at reasonable cost.

An emerging counterpoint to this matching of resources to markets was the growing hunger for power of the populous U.S. eastern seaboard. Jean Lessard, then chairman of Hydro-Québec, saw the opportunity to feed this U.S. market with relatively low cost power exports. With this added to Quebec's own need, the power of Churchill Falls could be fully developed at a single stroke.

In 1961, the Smallwood government granted a Brinco subsidiary, Churchill Falls (Labrador) Corp. Ltd. (CFLCo), a 99 year lease on the hydraulic resources of the 26,000 square mile watershed of the Upper Churchill.

But what engineering enterprise could be found to determine the optimum location to utilize this potential 1,000 foot head, to create a giant power complex in the midst of the muskeg and scrubby evergreens of the Labrador plateau, and to do it with assured quality within cost and time schedules that would make the venture attractive to financial institutions. For it would require the largest amount of capital ever committed in Canada for a private project.



A general view of the dyke structure

CFLCo's answer was to bring together two highly-qualified Canadian concerns — H. G. Acres & Company Limited and Canadian Bechtel Limited.

Through its affiliation with the Bechtel organization worldwide, Canadian Bechtel was able to provide virtually unmatched resources of experience in the construction and management of vast, remote, resource projects. Acres offered a wealth of expertise and experience in hydro-electric engineering.

They formed a joint venture — Acres Canadian Bechtel of Churchill Falls (ACB) — to engineer and manage the construction of this massive hydro-electric facility. By agreement, Canadian Bechtel became managing joint venturer for the contract.

An ACB team was already surveying in the field by 1963-64 supplementing the very considerable amount of data accumulated by other engineers from firms employed earlier by Brinco. Gray Thompson, an Acres member of the team, recalls that in spite of winter temperature so frigid that the bubbles in the transit level became sluggish, the survey circuit around the v[illegible] reservoir area was closed within an accuracy of one third of a foot. This was also a tribute to previous federal government and Quebec surveys whose old bench marks were picked up by the ACB team.

Calculations were accumulated, checked and cross-checked as to the optimum site, hydrological effects of snow accumulations and the size of reservoir needed to smooth the flow of the erratic Churchill, which varied from 10,000 to 300,000 cubic feet or more per second depending on season. The project was feasible — but the resources required to build it would be enormous. Irrefutable evidence that the project would be profitable was required before a sound approach to financing could be devised.

It took two more years of negotiation, and the expenditure of $17 million on preliminary engineering, before the breakthrough that triggered the leap from concept to construction. On October 13, 1966, Hydro Quebec's Jean Lessard, signed a letter of intent assuring that the Quebec utility would purchase the bulk of electricity generated from the site. By this time, the growth of Canada's energy demand made it unnecessary to rely on export to create a market. The moment for Churchill Falls power had arrived.

It was now up to ACB to meet the challenge.

The usual procedure for a hydro-electric project in Canada would be to proceed with detailed engineering of the various components of the project, put them out to tender, receive contractors' bids, sum the bid costs and thence proceed to make the necessary capital appropriation. However, in such a massive, remote project, undertaken by a utility company with relatively little in the way of assets and financial capability, a completely different approach was required.

ACB, as engineers and construction managers, had to organize a workplace in the middle of the wilderness, devise means to bring men and machines to it, and put together the whole complex schedule for a project which would stretch over nearly a decade. The packages into which the work was divided had to be tailored to the capacities of existing contracting firms in eastern Canada. It was upon ACB's estimates of the final cost of these packages that the delicate job of financing the project had to be based.

On March 7, 1967, CFLCo signed a contract with ACB covering engineering and construction management services to the end of the project. At almost the same time, it accepted ACB's estimate of direct construction cost of $522 million for the project. To this would be added $102 million to provide for escalation arising from price and wage increases over the life of the project and $41 million as a contingency allowance, giving a total direct construction cost of $665 million. Interest charges on money borrowed during construction, administration, working capital, overhead and other expenses would bring the total project cost to $946 million. This included more than $20 million spent in early studies and work by CFLCo up to March 31, 1967. It made Churchill Falls the largest civil engineering project ever undertaken in North America to that time.

A billion dollars isn't raised quickly.

It was Oct. 30, 1968, before Brinco Chairman Henry Borden reported to a special meeting of Brinco shareholders that terms of a $100 million general mortgage bonds issue had been settled, that arrangements for bank credit ($150 million from seven Canadian chartered banks) were well underway, that an offering in the United States of half a billion dollars of first mortgage bonds had been satisfactorily completed and that an offering in Canada of $50 million in first mortgage bonds had been arranged.

During the period required to set the stage for the major financing, funds came largely from equity capital, or shares, in CFLCo subscribed by its majority shareholder — Brinco (57%) — and its minority shareholders — Hydro-Québec (34%) and the province of Newfoundland (9%). In all, $83 million was raised this way. Substantial credit also was made available to Brinco by the Bank of Montreal.

Meanwhile, work at the site had been going on for two years. First attention was given to two prime engineering challenges: to create an all-weather access road to allow heavy freight haulage to the site, and commence the enormous job of building 40 miles of dykes.

The dykes, to provide a water barrier under any temperature conditions, had to form a perfect seal with the irregular surfaces of underlying rock. They were built using glacial till and rock where available, but the principal ingredients were materials from the eskers — ridges of gravel and sand formed within or under the glaciers, which chiselled the topography of this area, and left behind when the ice melted. Virtually nothing was shipped in to build the 26-million-cubic-yard dykes. The logistics task here was moving men and equipment, but it involved some of the biggest units available.

During the first year, the master project schedule and official plan were issued. The original size of the project was increased 15%, with the addition of an eleventh turbine generating unit, and uprating each unit to 475,000 KW instead of the 450,000 KW contemplated earlier. Total plant capacity was to be 5,225,000 KW, or just over seven million horsepower. The first units were committed to deliver contract power to Hydro-Québec by May 1, 1972.

The wisdom of choosing depth of corporate experience for the management of this vast project was amply proven by the tragic event of Nov. 11, 1969. CFLCo's twin jet was approaching Wabush airport in an overcast, when it crashed into a hill, killing all six passengers: Donald McParland, 40, President and Chief Executive Officer of CFLCo; Eric G. Lambert, 46, Vice-President, Finance, for Brinco and CFLCo; John Lethbridge, 35, McParland's Executive Assistant; Fred E. Ressegieu, 56, General Manager of Acres Canadian Bechtel; J. Herbert Jackson, 42, Assistant General Manager and Manager of Construction of ACB; Arthur J. Cantle, 42, Assistant Manager of Construction, ACB; and the crew of two.

All three ACB executives were seasoned engineers. In this emergency, the resources of Bechtel's world-wide organization were combed for replacements.

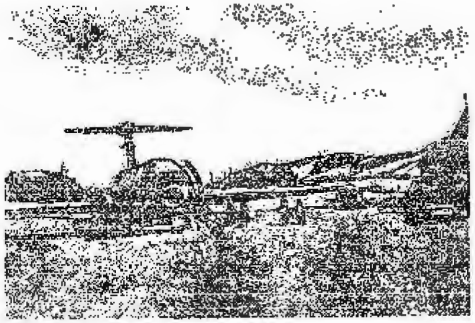
By the New Year, Steven V. White assistant to S. D. Bechtel, Jr., had stepped in to replace Ressegieu. Joseph Anderson, a Scot fresh from the Wells Hydro-Electric Project on the Columbia River, replaced Jackson in the field; Alan McConnell of Acres took over in the Montreal office.

Meanwhile after a brief period of pinch-hitting by Sir Val Duncan, chairman of the Rio Tinto organization, William Mulholland, a partner in the New York banking house of Morgan Stanley & Co., was elected president and chief executive of both Brinco and CFLCo.

Yet within a year after the tragic loss the project was well on its way to delivering first power — five months ahead of schedule!

The secret of such an achievement, is twofold, says S. M. Blair, who, as Chairman of Canadian Bechtel Limited, was chairman of ACB's Policy Board for most of the construction period. First, it was necessary to create a place to work and live productively in the wilderness; and second, to create the logistics to supply that workplace with equipment, supplies, and labour, on schedule.

Making a place for man



Most of the industrial installations built to date in the Canadian north have been transitory, such as mining or petroleum exploration camps. Generally, the facilities are temporary and the men who occupy them have little thought except to get their job done and leave.

Churchill Falls was different. The construction period was to be eight years, and the anticipated life of the station stretches toward the middle of the next century. The transition from construction camp to permanent community would be phased over the period 1971-1975.

The philosophy was this: a settled happy work force, with low turnover and a minimum of interruptions because of labour disputes, is the key to maintaining schedules and cost targets. The men should be happy *off* the job as well as *on* it. Special efforts were made to afford amenities far superior to the roughness and boredom of off-hours in a typical construction camp. Civilization must come concurrently with construction.

Even though final commitment of the project was not made until 1966, by 1967 plans for a permanent community near the power facility were drawn up. The 59 houses, four 12-unit apartment blocks and a service complex with stores, school, a hotel, theatre and indoor recreation facilities were first used by the longer-term construction staff, later by the permanent power plant operating staff.

Provision of all possible amenities began as soon as the first road camps — Esker, Bridge Camp and Mount Hyde Lake—opened. By Christmas, 1966, for instance, only two months after start of the project, John McGowan, Bona Vista Food Services manager, the caterer for the project, recalls that the Christmas dinner menu included cream of tomato soup, roast turkey with all the trimmings, and a cold buffet with salads, assorted pastries, two kinds of Christmas cake and three kinds of pie. The dinner was followed by a movie.

At the main camp, the men were housed in 20-man complexes — three trailers side by side, housing two men to a room. There were not only washrooms, but a clothes washer and dryer in most units. Janitorial services included even bed-making.

The inevitable feeling of isolation was reduced through access to the mobile radiotelephone, teletype and telegraph services that were established and linked to the continent-wide networks. At peak, the system had 1,366 telephones and 540 mobile radio units. Until the Churchill Falls airstrip was ready in 1969, scheduled flights operated from the Twin Falls airstrip, a 30 mile drive from the main camp.

When carpenter Leo Lane from Catalina, Nfld. stepped off the plane in March 1968 to become the 1,000th worker on the project, he found Hickeys and Ryans aplenty from his own province, together with Gagnons and Tremblays from Quebec: mechanics, drillers, drivers, pipe-fitters and scores of other skilled and semi-skilled trades. They were supported both on site and at the Montreal headquarters by engineers and draftsmen translating general plans and programs into detailed blueprints and schedules.

In June, 1968, the main camp became a place for women too as staff arrived to work at a new mess hall the length of a city block. Together with clerks, secretaries, nurses and teachers, they made up a group of 200 women working on the project. Their early presence on site, together with the civilized amenities, is credited with encouraging a remarkably clean, orderly, and liveable camp — "More like a town than a camp", as many workers described it.

Not that the camp lacked its lively side. A tavern (open morning and evening to accommodate shift workers) began operation in the recreation centre in late 1967, and sold four million bottles of beer in the next four years. Nor was there any lack of other recreational facilities — such as the baseball diamond, soccer field and skating rink; later the curling rink, bowling alley and swimming pool.

Geodetic survey of the intake site

The great majority of men on site were not ACB employees, but worked for CFLCo and the scores of contractors and suppliers. But as well as managing their accommodation at the site, ACB co-ordinated the other essentials for a happy work force: a collective master labour agreement which was signed for an eight year period (1967-1975) between an association of employers working at the site and a council of Newfoundland-based locals affiliated with international building trade and service unions.

A substantial help to the general smooth running of the operation was the presence on site of full-time labour relations personnel trained to handle and resolve day-to-day problems on the spot.

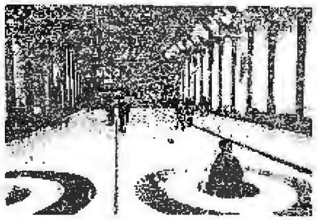
ACB management is unanimous that this agreement was the single most important factor in achieving the high man-day productivity recorded during construction. The no-strike, no-lockout clause, together with an agreed formula for periodic wage adjustments, meant there was no interruption of work because of disputes, despite the many different employers on site. The 10-hour day and six-day week provided the 60-hour work week — paid at straight time and time and a half.

The massive demands of construction created needs for various

Aerial view of the permanent camp site

Schoolchildren beside Blueberry Lake

Swimming pool in the Town Centre



Curling rink in the Town Centre

skills, from that of the cutter clearing right-of-way for transmission lines, to the electronic expertise of the communications technician. But they all had to be able to take it: concrete pouring, for instance, continued (behind plastic shelters) even at thirty degrees below zero. Some 13 feet of snow fell each winter; clouds of black-flies were the only constant in the uncertain weather of the short summer.

At the same time that the air was filled with the roar of heavy earthmovers and the thump of blasting, a faint cry at Churchill Falls Hospital marked a new way to arrive on-site: Jeanette, daughter of school teacher John Byrne and his wife, was born March 8, 1969, with attendance of the Hospital's director, Dr. John Price of the International Grenfell Association. When a baby is born, a camp becomes a community.

Joseph Smallwood had had to make do with a shovel full of peat with caribou moss, for the official sod turning ceremony in 1967. By 1970 the principal streets of the townsite were paved and some of the glacial till was being upgraded to support the growth of lawns and gardens. Neighbours were competing to nurture sapling shade trees — a challenge in the rugged local climate.

In 1970 the field work force in Main Camp and 11 satellite camps stretching from Seahorse, at the end of the southwestward reach of the transmission corridor, to Sail Lake 200 miles distant at the north-eastern extremity of the reservoir, reached 6,245 men and women. The daily food order for this army required the delivery of 4.5 tons of meat, 2,600 dozens eggs, 3,100 loaves of bread, 13 tons of vegetables, and 2,300 gallons of milk.

The transition from camp to townsite took place smoothly over the next five years — a credit to ACB's planning.

Now home for approximately 1,000 permanent residents, Churchill Falls is one of Canada's newest northern centres. No effort has been spared to make it one of the most advanced and comfortable. To make facilities as accessible as possible during the long, cold, snowy winters, the community clusters compactly around a unique complex, the Donald Gordon Centre, grouping under one roof services such as school and stores, hotel, theatre, and sports facilities.

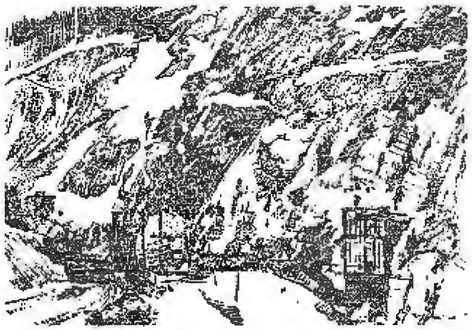
A pedestrian mall runs through the central core of the complex from the hotel to a high ceilinged concourse, which acts as the modern-day equivalent of a town square — indoors.

The Eric G. Lambert School in the Centre provided instruction in English and French. Each community facility was designed to serve several purposes. At night and on week-ends the school's resource centre becomes the community library. During week days, the movie theatre is used by the school as its auditorium and assembly hall.

The houses and apartments are grouped in a semi-circle around the Donald Gordon Centre. Houses are built on only one side of the street. This facilitates snow clearing. It also helps assure privacy — an important consideration in a small community where people see one another day in and day out at work. The use of electricity from the Falls for all heating helps make a remarkably clean place.

There is an interdenominational church, a regional hospital, a professional fire department, a small detachment of the RCMP and other amenities that go with modern civilization. Regular scheduled jet airliner service links Churchill Falls with Montreal and St. John's. The community is tied in to the continental telephone network. English and French radio and television (via microwave) are provided by the Canadian Broadcasting Corporation.

Bringing the world to Churchill Falls



The management organization evolved for Churchill Falls construction was an essential pre-condition for the achievement of the project's "on-schedule, within budget" objective.

At the summit of the organizational pyramid of the ACB consortium, responsible for complete engineering and construction management, was the "Policy Board" — itself an organizational innovation. The General Manager of ACB reported monthly to this board, composed of two senior executives each from Acres and Canadian Bechtel.

The group also provided liaison with outside engineering skills embodied in a panel of distinguished international consultants and a panel of senior engineers from Acres and Canadian Bechtel.

The main functions of the ACB organization were engineering, cost control and administration, scheduling and estimating, procurement and construction. The work at the project itself was further divided into four components: water storage; power complex; switchyard and transmission lines; and support facilities.

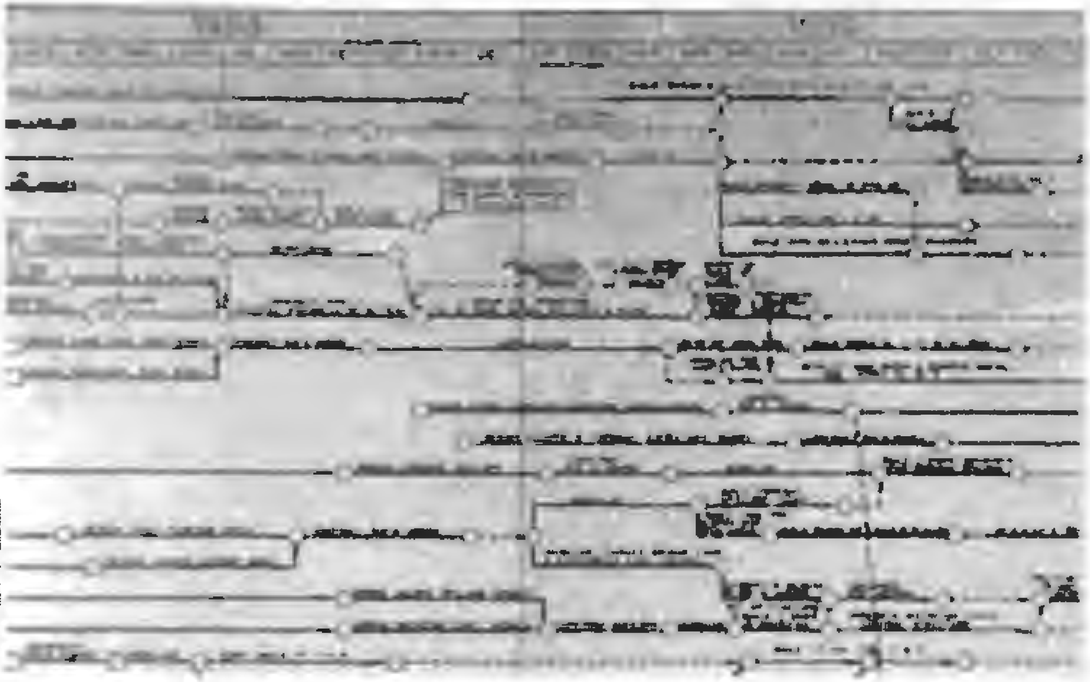
Because of the immense scope of the project, no general contractor was named. Instead, contract "packages" were developed by ACB in such a way as to encourage the widest response and competition from qualified bidders. Over 180 separate construction and service contracts were awarded, but none was for an amount in excess of $75 million. In addition, hundreds of major purchase contracts for the supply of major equipment were negotiated, mainly with Canadian firms.

It was decided early to relieve construction contractors of the responsibility for providing housing and board for their men on the site. These were provided at a stated subsidized cost per man-day by ACB. This meant the removal of a large item of uncertainty from the contractor's evaluation, thus resulting in lower and more consistent bids. In addition, the good standards of living and working conditions made an important contribution to the morale of workers on the project.

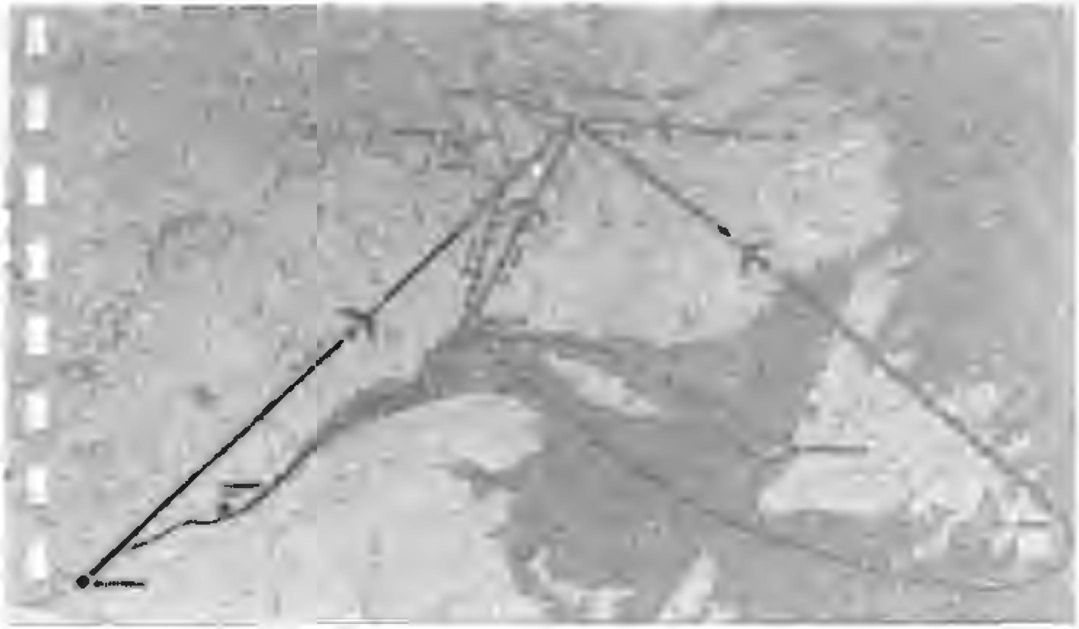
Transportation was contracted in volume packages to experienced, responsible carriers, such as Québecair and Eastern Provincial Airways. A total of 730,000 tons of material and equipment was moved to the site by air and surface transport, as well as 52,000 passengers.

The allocation of work between the different ACB divisions was as follows. Engineering, in which Acres personnel were predominant, established concepts, performed detailed design, monitored engineering assignments and obtained approvals. The remaining four divisions relied mainly on Canadian Bechtel's expertise: the Finance and Administration Divisions compiled cost data, processed progress payments and provided administrative support. The Scheduling and Estimating Division developed schedules, monitored progress and prepared control estimates for elements of the project during the engineering phase. The Operations Division covered the Contract Department, which developed contract documents, issued tenders, analyzed bids, recommended awards and organized quality control and expediting, and the Construction Department, which looked after operations on site.

One noteworthy feature of the contracting was the prevalence of the type of "consortium philosophy" inspired by the formation of ACB itself. The largest construction team on site, for instance, was Churchill Constructors Joint Venture, a consortium of six companies organized by Atlas Construction Ltd. Provision of the 11 hydro-electric generating units, a job which employed 600 men for two years at a cost of over $60 million, was contracted to The Churchill Falls (Machinery) Consortium, a joint venture of Canadian General Electric, Dominion Engineering Works Ltd. and Marine Industries Ltd. CGE and MIL divided the first 10 turbine generator contracts between them, with MIL being awarded the eleventh.



A section of the critical path which construction followed.



Logistical map of the project.

A [illegible] 200 foot long [illegible] transporter moves loads of up to 250 tons to the job site.

Of the total direct construction expenditure of $665 million, approximately $650 million — 98% — was spent in Canada, with 57% of the sum going to Canadian manufacturing industry, 17% to service industry, and 26% in direct labour costs.

But, in spite of the high Canadian component of manufacture, the consortium approach made available the best in North American and European technology. Both Canadian and French specialists, for instance, evolved their own designs for the turbine and generators; both groups pooled and shared their experience to the benefit of the project. Shafts for the huge units were forged in England, turbine models tested in Canada, France and Scotland, speed governors designed and built in the United States, and some transformers supplied from Sweden.

ACB's logistical management was tested to the utmost early in the project, when on May 10, 1969, a strike suspended operations on the Quebec North Shore & Labrador Railway for three months, at the peak of the heavy construction season, with 4,500 men already on site. An emergency airlift — "the biggest since the Berlin blockade" — was pulled together, with aircraft chartered from as far away as Florida and Alaska. It operated 1,153 flights from Sept Iles and Goose Bay, carrying in 650,000 gallons of fuel plus 11,617 tons of cargo, and supplies, including items as heavy as dismantled bulldozers.

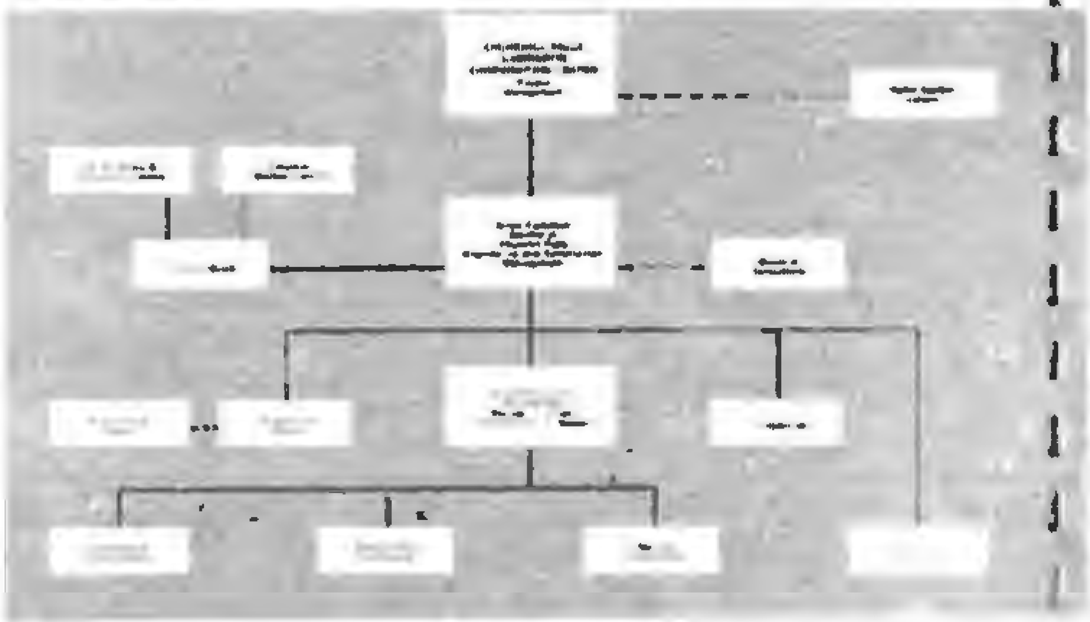
But the Churchill Falls achievement was not limited to a massive application of logistical and earthmoving skills. It involved, too, the most advanced and intensive engineering approach ever applied to a major hydroelectric project. Reliability and assured performance from the start of operation were vital to assure that power contract obligations were fully met. Features of the project had to meet the requirements of well proven experience as well as take the full cost/benefit advantages allowed by the scale of the project.

Turbines and generators were selected at the upper limits of output and size for the 1,060 ft. head. Thorough design analysis provided a high degree of confidence that all expectations would be realized. Electrical facilities made optimum use of a 230 KV/735 KV system with power carried from the underground transformers through 900 ft. long oil filled cables.

Engineering design of the excavated caverns for powerhouse, surge tank tunnels and galleries was greatly assisted by use of advanced finite element stress analysis. Close integration of engineering and construction techniques led to substantial economies.

Varied tasks demanded new engineering approaches from the massive hydraulic control gates to transport equipment specially designed for the project needs.

The gates are the crucial element in controlling the impoundment of 1,100 billion cubic feet of usable water for Churchill Falls power development. The series of reservoirs, a third the area of Lake Ontario, are formed by the skillful use of natural land forms, supplemented with 40 miles of dykes ranging up to 117 feet in height. The key to directing this water is just six control structures — concrete spillways with sliding gates that can be remotely controlled electrically from



the Churchill Falls control room at a distance of up to 60 miles. To make these gates operate reliably when temperatures might be 50°F. below, with five ft. of ice on the reservoir, required many man months of modelling and design effort. The installations are heated in winter both by air circulation and electric resistance heaters, and electromechanically controlled by redundant, fail-safe, supervisory control circuits.

Another unique element of the project was the design and construction of a 250-ton transporter to take the 224-ton transformers (one for each generator set) from their special rail cars at Esker to the project site.

The vehicle finally developed had tires seven feet high, and two 700-horsepower six-wheel drive tractors. Its 198 foot-long body, was articulated in order to be able to negotiate the turns in the 28 ft. wide access tunnel to the underground transformer gallery. Early Churchill Falls residents still remember turning out at the intersection of Ressegieu Drive and Esker Road to see "the awesome convoy crawl past in full glory, yellow flashers whirling, at two and a half miles an hour."

The transformer transporter was only the largest of the enormous fleet of 2,000 transport and construction vehicles at the site: 600 tracked machines, ranging from bulldozers to self propelled drills; and 1,400 wheeled vehicles, from passenger cars to fuel tankers and 50-ton dump trucks.

Nor were the transformers the only heavy equipment beyond the carrying capacity of most vehicles: the turbine runners with a casting weight of 145 tons, and a finished weight of 100 tons set for Canada a world record for the largest castings ever made in stainless steel. The two cranes installed in the power house were coupled with a massive lifting beam to handle the 655 ton rotors and giant stators for the generator units, which were assembled on site and lifted into position.

Spanning the river gorge was a highlight for the transmission line crews. Their efforts linked the power plant with the Hydro-Québec substation at Montagnais, 130 miles to the southwest. For the last span a helicopter (one of as many as seven on site) hauled 7,500 feet of half-inch nylon rope across the river from the south shore. Increasingly heavier steel cables followed until finally the complete set of conductors stretched from three sets of 100 ft. towers, 6,200 ft. apart, 1,000 ft. above the waters of the Churchill.

For each contract package, large or small, ACB's careful monitoring of cost, quality, and completion time was the essential factor in integrating every element into the smooth progress of the whole project.

Quality standards were clearly written into each contract document and purchase order, and ACB's quality control group not only monitored construction and manufacturing contracts, but also insisted that the contractors provide their own quality control systems.

Schedule control was achieved by monitoring progress on contracts every two weeks, and taking corrective action wherever possible before slippage became serious. Cost control was maintained from the initial estimate through design, and, after contract award, by monthly forecasting of final cost relative to budget. Thus, early warning of any significant variation enabled corrective measures to be taken in time to achieve control.

All this performance information would have been nearly useless unless systematized, computerized for easy retrieval, and integrated with another key factor: logistics. A given item of material for the project might meet cost, quality, and completion targets. But where was it? When was it shipped? When, and how, would it arrive on site? These were questions the Transportation Information System (TIS) used by ACB, was designed to answer. No soulless machine, TIS took the strenuous efforts of scores of men as well as masses of data processing equipment to keep tabs on the thousands of items of material in transit at any one time.

Safety beneath the shield

The heart of the Churchill Falls power plant is the great machine hall, housing the 11 generating units. Over 1000 ft. long, 81 ft. wide, and 154 ft. from floor to roof, it was carved out of the rugged granite of the Laurentian shield 900 ft. below the surface.

It might seem simpler to have sited the power plant above ground at the edge of the river. But, from the perspective of a hydraulic engineer, it is more practical to make the 11 penstocks which carry water to each turbine short and as steep as possible. When the 450 pounds per square inch pressure has spun the turbine, the spent water is discharged to a surge chamber, before flowing via two huge tailrace tunnels over a mile to the lower Churchill river.

The amount of excavation required was enormous: in addition to the penstocks and the machine hall and surge chamber a transformer gallery was excavated just above the powerhouse. And the concern of the engineers and geologists that the rock structure be "competent" to bear the blasting, tunnelling, and the surge of water, was thoroughly exercised by exhaustive drilling, sampling, and stress analysis. The area finally selected for the powerhouse had been proven to have the necessary integrity and "faultless" structure.

The first step was completion of a mile-long access road which curves down the steep slope toward the river. The second was to drive a mile deep tunnel at the end of the road, angled in to provide access to the underground works through which the heavy dump trucks were to remove much of the rock.

This accomplished, the major underground construction contract was awarded to Churchill Constructors: two contracts totalling $65.7 million, for all remaining underground excavation except completion of the tailrace tunnels; most of the concreting of the underground complex; installing of miles of embedded conduit and piping; and provision of tons of anchors and rock bolting, as well as installation of the main powerhouse cranes and gates. In excavation alone, this meant the removal of 2,300,000 cubic yards of rock. CCJV, as the consortium was called, was busy for three years at the job, employing at one time over 1,200 workers.

Safety — both for the construction crew and the operating staff who would follow them — was a prime consideration. Painstaking calculations had to take into account the changing stresses on the rock as the excavations grew in size.

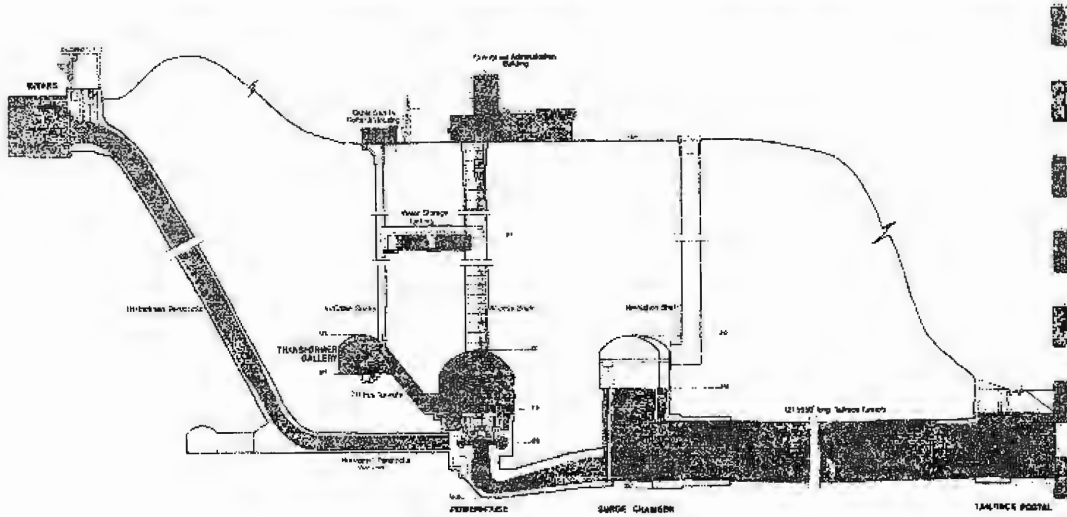
In the large chambers, excavation was carried out from the top down: first a pilot tunnel or heading was driven along what was to be the ceiling of the chamber. Then this would be "slashed" or excavated to full width. Finally the remaining layers of rock would be blasted and mucked away in a quarry-like operation.

Excavation reached its peak in June 1969: within six days 45,600 cubic yards of rock were removed, enough for 2,800 truckloads of 33 tons each.

The penstocks, on the other hand, were started from the bottom, drilled from electrically-driven climbing

Excavation of the tailrace surge chamber

The 650-ton generator for Unit #2 is positioned inside the stator.



Cross section of the underground powerhouse complex.

platforms known as "Alimaks" and which enabled an eight by ten foot pilot shaft 1,200 ft. to the surface to be driven without intermediate stations. Yet, such was the accuracy of surveying (in which the latest technical devices such as laser beams had been employed) that the first shaft broke surface within inches of its target.

One of the most hazardous and difficult jobs remained: slashing the 11 pilot shafts to the designed 22 ft. by 28 ft. penstock dimensions.

The "slashing" was done by six drills on outriggers, mounted on a "jumbo" — a sort of flat-car which ran on steel rails laid on the almost vertical side of the tunnel.

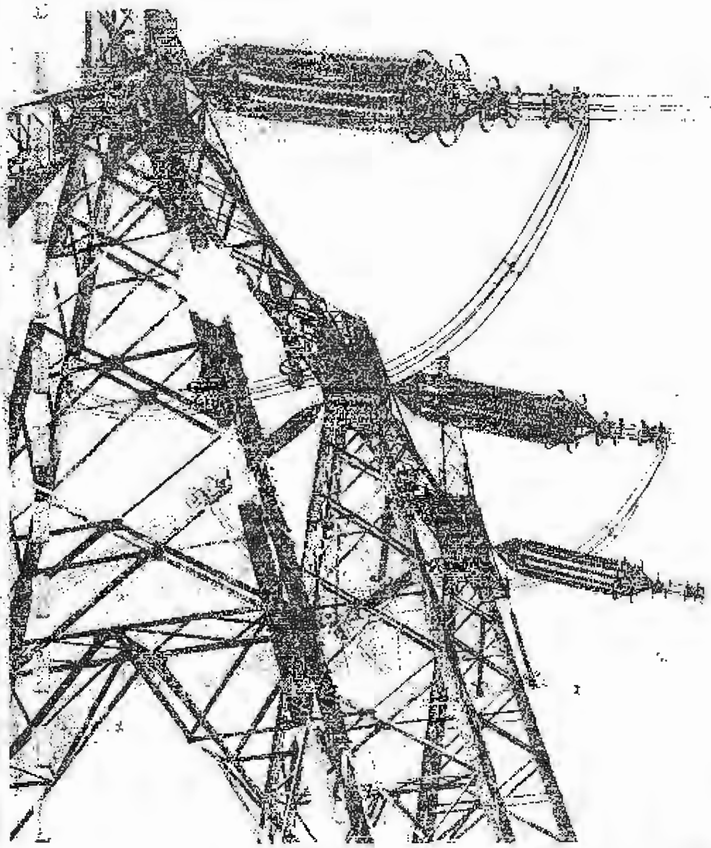
Day after day the same sequence went on: the drills would whine into the rock, charges would be set, the jumbo would be hauled back 45 ft., and the blast fired. As tons of rock cascaded 1,200 ft. to the bottom, the jumbo would be advanced, another 14 ft. of rail laid, and the whole process would begin all over again.

When the jumbos had finally bored their way down the shaft another hazardous job began — concreting. This was the task of covering the whole inside surface of the penstocks with a foot of concrete — to resist the rush of 400,000 gallons of water a second at full flow. The men who worked the barrel-shaped collapsible metal forms for the concrete called the frame at the top of the form "the headache rack" with good reason — even a small pebble comes down a 1,000 ft. tunnel inclined at 60 degrees like a ricocheting bullet.

On July 13, 1970, the final blast was fired at the bottom of No. 10 penstock, marking completion — less than 34 months after it started, of the underground excavation. Some five million pounds of explosive had been used. Yet, in spite of the scale of the operation, and the great heights and other hazards involved, lost time from work accidents was substantially lower than on most excavation jobs of this type.

The final horizontal section of the penstocks, which narrowed to 14 ft. seven in. diameter, was lined with high strength steel. (The length of the costly steel lining had been minimized by careful engineering analysis and judgement of the adequacy of rock and concrete to withstand the stress. Impressive economies were achieved.)

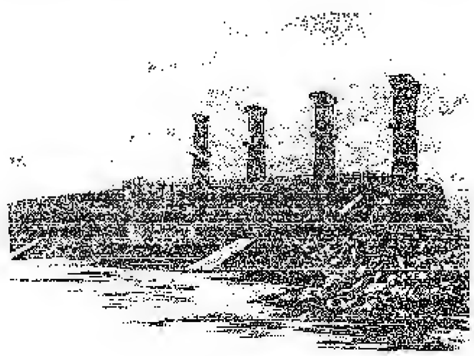
Excellence in both design and workmanship meant that full advantage could be taken of the remarkably solid rock formation. No supporting concrete was required for the roofs of the massive underground chambers. The powerhouse ceiling finally took the form of stainless steel sheeting suspended from bolts embedded in the vaults of rock above.



Jumper arrangement for the South Bank towers, river crossing line 1

Typical V-type guyed tower

Harnessing technology to improve ecology



When geologist A. P. Low climbed Labrador's Lookout Mountain in 1894, overlooking what is now the Churchill Falls power plant intake, he reported a bleak view: "over half of the surrounding country has been stripped bare by frequent fires. In the swamps and around the shores of the lakes... black spruce and larch of small size grow thickly together. On the sides of the hills these are more stunted... where the hillsides have been burnt years ago they are covered with a tangled mass of willows and alders, while the tops are coated with white moss and semi arctic shrubs."

The animals that inhabit this harsh land lead a similarly precarious existence, and large mammals, such as the black bear and caribou, are few. While the unfished lakes provide a few whoppers, the concentration of nutrients, and therefore the density of aquatic life, is scarce. Labrador's Naskaupi indians seldom visited the area, because of the scarcity of game and fish.

In working with and altering the terrain, man does not always need to oppose nature. It is, perhaps, significant that the new course along the edge of the plateau, into which the Churchill was directed, may in fact have been the original river bed before the last glaciation 20,000 years ago. Ecologically, the entire project can be studied as a model for resource development in the Canadian north.

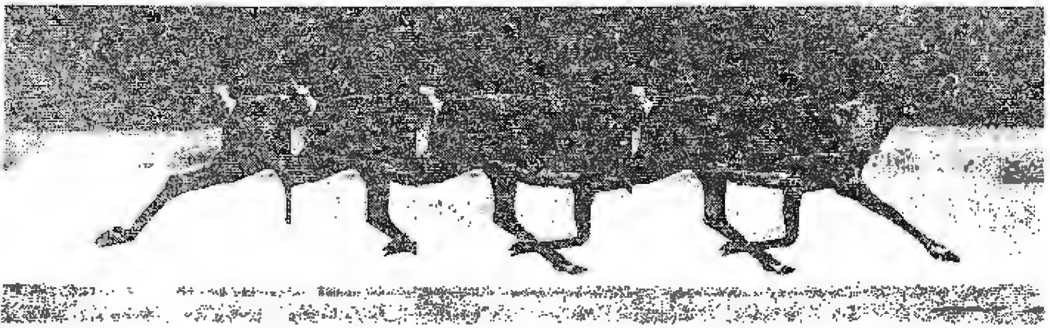
From the standpoint of conservation, the regulation of flows passing through the power development should actually help to prevent the previous harmful erosion of the banks of the lower reaches of the Churchill, by uncontrolled spring freshets.

Again, the flooding of 2,500 square miles to create the reservoirs changed the face of the countryside. However, the slowness of the process, which took place over three years, meant that harmful impact upon land animals in the region was minimized. Careful studies by biologists have concluded that some overcrowding of smaller species occurred in some limited areas such as islands which were created as the waters rose.

And the fishing should be even better than before. Not only has the aquatic habitat been greatly enlarged, but the flooding of swamp and muskeg, biologists have found, increases the volume and concentration of small organisms which are the basis of the food chain which sustains, indirectly, the larger game fish.

Of the land submerged beneath the reservoir, a survey determined that it contained 65 per cent scrub bush growing on rock scantily covered with acid soil, four per cent barren land, nine per cent burned-over areas, and 20 per cent bog. Only two per cent consisted of trees over 30 ft. high.

ACB's concern for, and interest in, the environment was clearly demonstrated by the insistence that all

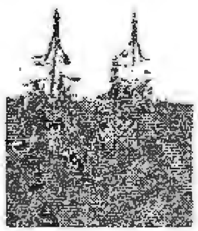


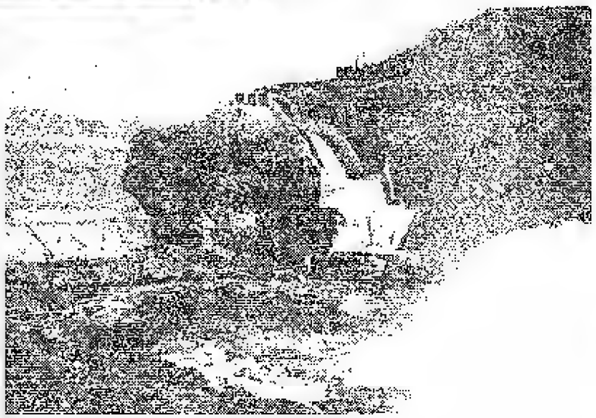
camps, even the remotest, should be equipped with sewage treatment facilities.

And the new human inhabitants, permanent and temporary, of the main camp and townsite appear to have quickly developed an awareness and appreciation of the unspoiled environment. Early issues of the weekly CFLCo paper *Churchill Falls News*, were full of suggestions for using such natural resources as caribou moss, partridge berries, and Labrador tea. And one of the hottest debates in its letters column was the vexed subject of whether female caribou have antlers. (Unlike the rest of the deer family, they do.)

It was this aspect of the project which captured the attention of Prime Minister Pierre Elliott Trudeau, when he inaugurated the development on June 16, 1972, with a speech titled "In harmony with nature."

"We should see," he said, "this gigantic installation as the unified and dynamic solution to a great many problems, using the contributions of a wide array of skills and knowledge. A truly human shape has thus been given to this source of raw energy without diminishing nature or disturbing the balance of the environment. The example of Churchill Falls shows that though man imposes his will on nature, he can do so in harmony with nature, and that this process can be noble and fruitful. *That is why I say without hesitation that our technology has produced here a masterpiece that commands double admiration.*"





Photographs Courtesy of British Columbia Hydro and Power Authority

Mica Storage Project

Located on the Columbia River, about 450 river km north of the Canada-United States border, Mica Dam is one of the higher earth-fill dams in the world. Completed in 1973, the dam towers 244 m above the lowest bedrock level and constitutes a major link in harnessing the water resources of the Columbia River system. A live storage capacity of $15{,}000 \times 10^6$ m^3 is operated to tame the mighty Columbia River and provide flood protection to downstream riparian land. By 1977, 1,740 MW of hydroelectric generating capacity had been installed by the owner, British Columbia Hydro and Power Authority.

The Mica storage project was engineered by the joint-venture company CASECO Consultants Limited.

H. G. ACRES AND COMPANY LIMITED* was one of the three parent engineering companies.

*The Company was renamed Acres Consulting Services Limited in 1969.

Acres Consulting Services Limited
5259 Dorchester Road
Niagara Falls, Ontario
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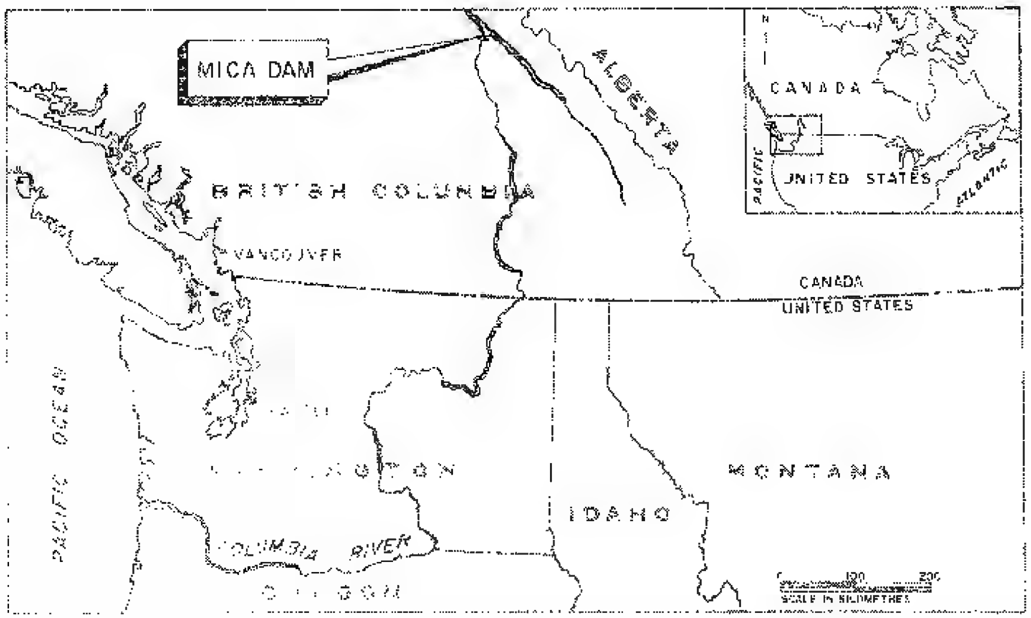
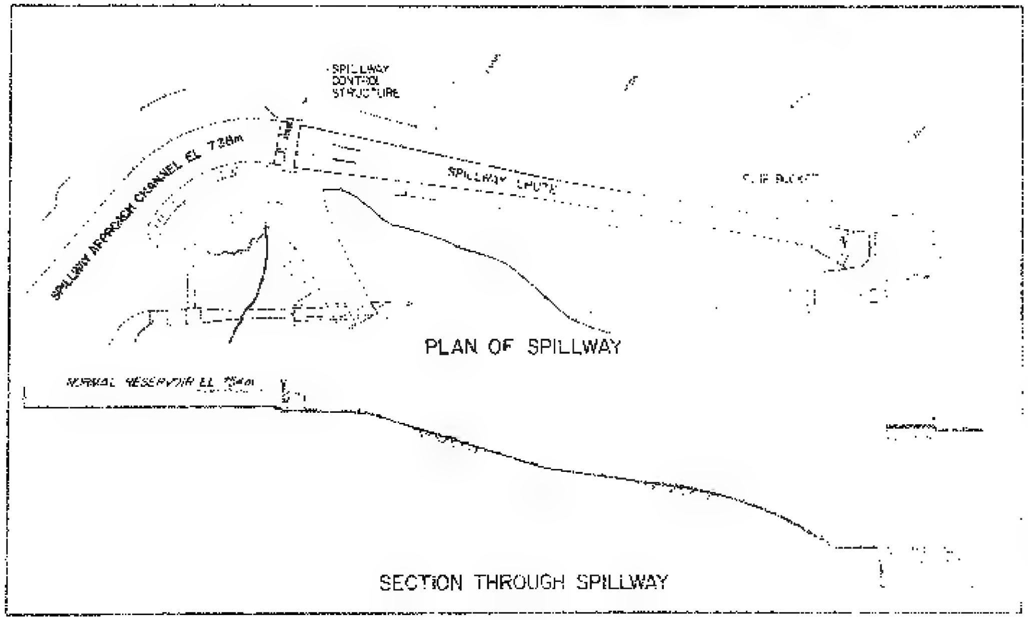
L2E 6W1



Spillway

The spillway structure consists of a control structure with 3 radial gates, a 530-m long concrete spillway chute and a mass concrete flip bucket. Design capacity of the spillway is 4,250 m^3/s.

The control structure is a low overflow weir with an ogee shape. Hydraulic model tests were used to develop a unique flow surface for the flip bucket, conforming to a skew cone with an inclined axis. A transverse drainage system and longitudinal drainage gallery run beneath the full length of the spillway chute floor.



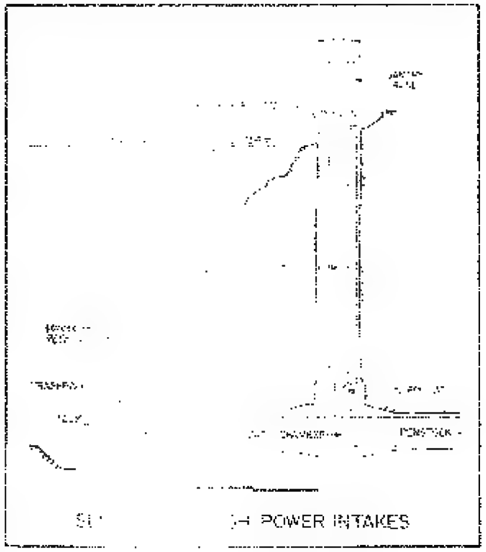
PLAN OF SPILLWAY

SECTION THROUGH SPILLWAY

Power Intakes

The power intake structure was constructed as part of the main dam project and comprises an approach channel formed by a 76-m deep opencut rock excavation and 6 intakes. Each intake incorporates a bellmouth entrance, gate chamber and short concrete-lined stub tunnel. Flow control is accomplished by vertical fixed-wheel gates operated from 8.7-m diameter, 76-m deep gate shafts. The bellmouth entrances are covered by trashracks which are cleaned by a trash rake operated from the intake structure deck. Slip-forming methods were used to place the concrete for the face slab and gate shaft lining.

Engineering of the underground generating station at Mica was carried out by the British Columbia Hydro and Power Authority, largely subsequent to the completion of CASFCO's work on the dam and associated structures.



[illegible] POWER INTAKES

MICA DAM PROJECT STATISTICS

General

Drainage basin area	21,250 km^2
Mean annual discharge	590 m^3/s
Reservoir storage – total	25,000 x 10^6 m^3
– live	15,000 x 10^6 m^3
Full supply level	754 m
Maximum tailwater level	576 m

Dam – Compacted Earth Fill, Near-Vertical Impervious Core

Height above bedrock	244 m
Crest – elevation	762 m
– length	792 m
– width	34 m
Base width	945 m
Volume	32.6 x 10^6 m^3

Diversion Tunnels – Two Concrete-Lined Tunnels

Diameter	13.7 m
Length – west	893 m
– east	1,036 m
Gate sill elevation	567 m
Design discharge	4,250 m^3/s
Number of vertical fixed-wheel gates	4

Spillway – Gated Chute with Flip Bucket

Number of radial gates	3
Gate dimensions	12.8 m high by 12.2 m wide
Gate sill elevation	742 m
Design discharge	4,250 m^3/s

Low-Level Outlets – Three Conduits Located in East Diversion Tunnel

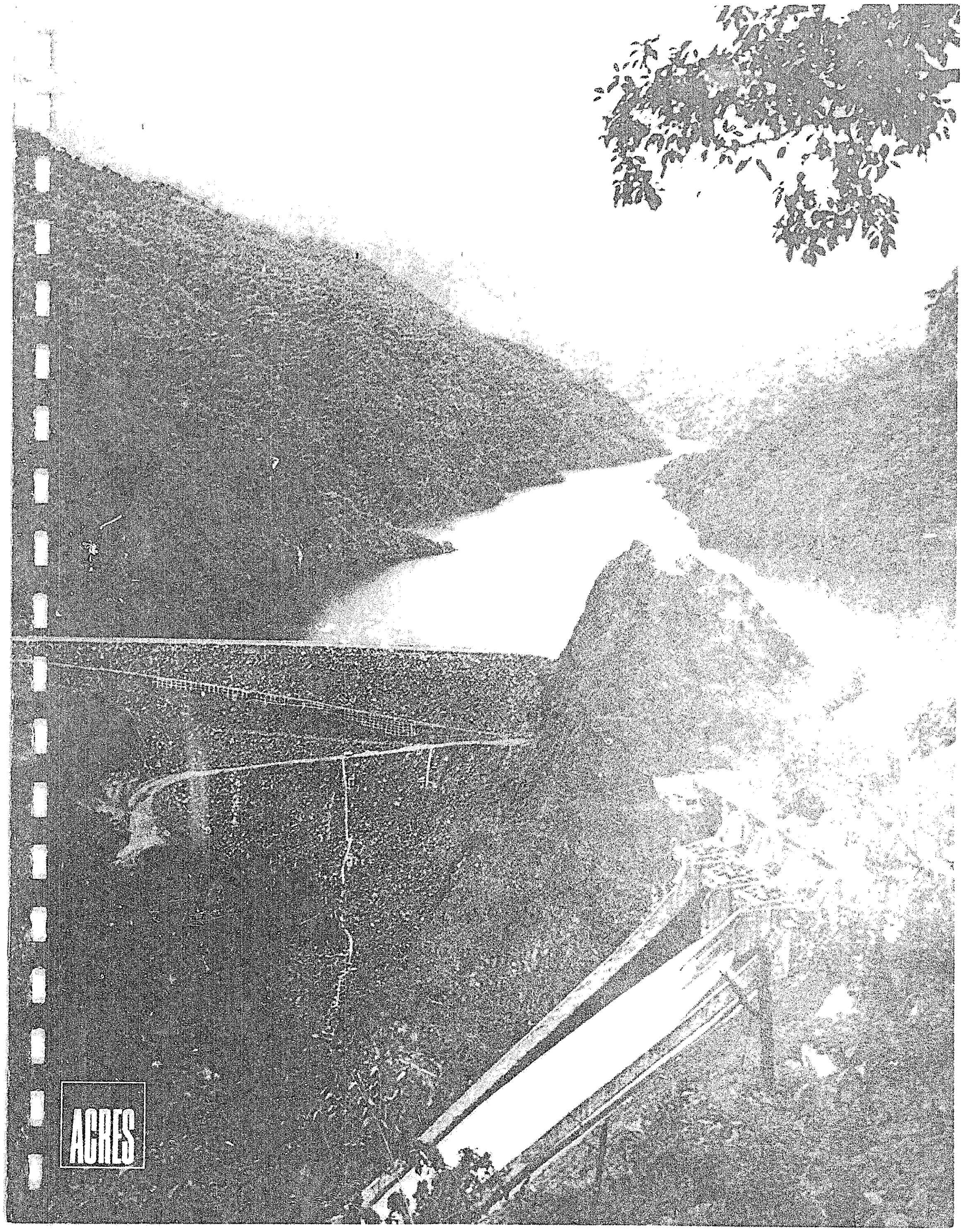
Conduit dimensions	2.3 m by 3.5 m
Maximum design head	174 m
Number of vertical slide gates	9
Design discharge capacity	850 m^3/s

Outlet Works – Concrete-Lined Tunnel Linking to West Diversion Tunnel

Number of intake conduits	2
Dimensions of intake conduits	3 m by 5.5 m
Number of vertical fixed-wheel gates	2 control, 1 guard
Inclined tunnel diameter	11 to 9 m
Design discharge capacity	1,060 m^3/s

Power Intakes – Six Individual Intakes

Intake conduit dimensions	5.3 m by 6.7 m
Maximum design head	68 m
Number of vertical fixed-wheel gates	6 control, 1 guard
Tunnel diameter	6.7 m
Total design discharge capacity	1,700 m^3/s

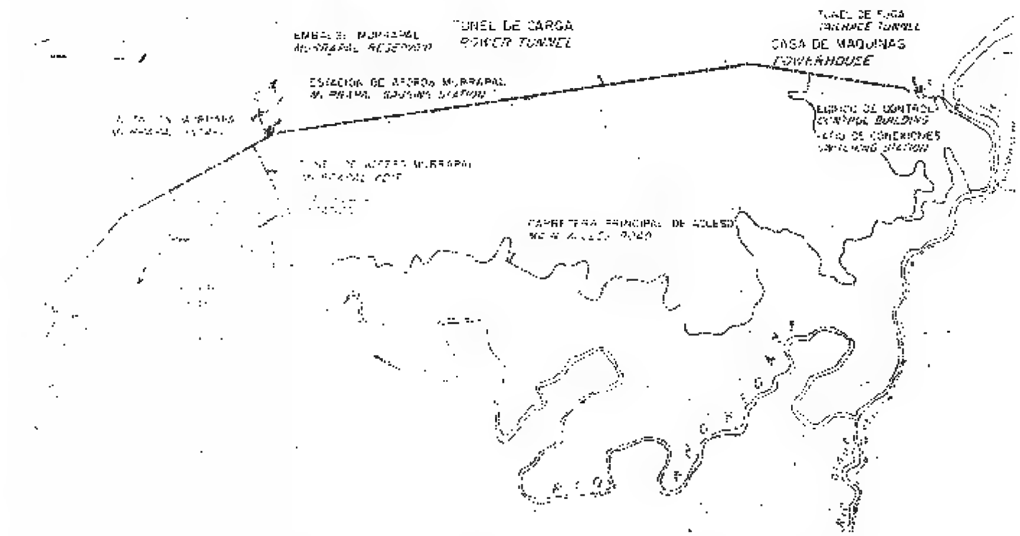

ACRES

Cat. No. 2214

ALTO ANCHICAYA HYDROELECTRIC PROJECT

In the tropical rain forest of South America's Western Cordillera, the CVC of Cali, Colombia, owns and operates the world's highest concrete-faced rock-fill dam and a 340-MW underground power facility.

Acres International Limited
Consulting Engineers
5259 Dorchester Road
Niagara Falls, Canada

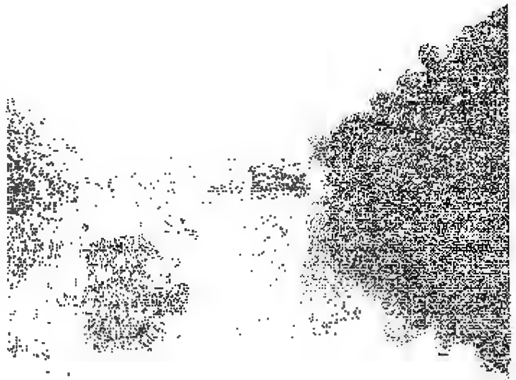


DISPOSICION GENERAL DEL PROYECTO
GENERAL ARRANGEMENT OF PROJECT

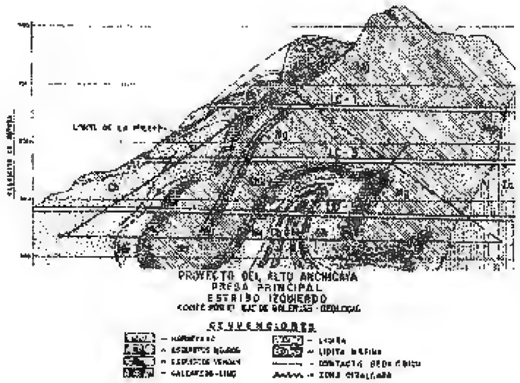
The Corporación Autónoma Regional del Cauca (CVC) of Cali, Colombia, with the help of its consultants and contractors, has completed the construction of the Alto Anchicayá hydroelectric project, including a 140-m high concrete-faced rock-fill dam, 8-km power tunnel, and 340 MW underground power station. The site is on the rugged Pacific slope of the Western Cordillera of South America, an area of precipitous mountains covered by tropical rain forest.

The CVC's engineering consultant, from the inception of the feasibility studies through detail design and construction, was Acres International Limited of Canada. The contractors for the major civil works were ICA of Mexico.

Slopes in the area of the project are very steep. Vertical cliffs are common. From its headwaters in the Farallones de Cali to its mouth near Buenaventura (a straight-line distance of only about 60 km) the river drops almost 3,000 m, and river gradients of 6 percent are found downstream from the damsite. Precipitation is very heavy, averaging about 4,800 mm per year near the powerhouse site, with 200 to 300 mm of rain even in the driest months. These features, which are favorable to hydroelectric development, made access very difficult in the early days. Men with picks and shovels hacked a 13 km trail over the slippery slopes, built a camp with planks sawn by hand in the jungle, dismantled the drilling equipment, and carried it, lashed to long poles, to the damsite to explore the rock in the dam foundations. When the track had been completed, [illegible] and horses were able to undertake the [illegible] and equipment. Finally, when [illegible] of the project had been confirmed, [illegible] the major task of building [illegible] roads to serve for the construction [illegible] of the project. Two years later, [illegible] road was completed, the trip from [illegible] to the damsite was finally reduced [illegible] 5 hour trudge on foot or muleback [illegible] minute drive.

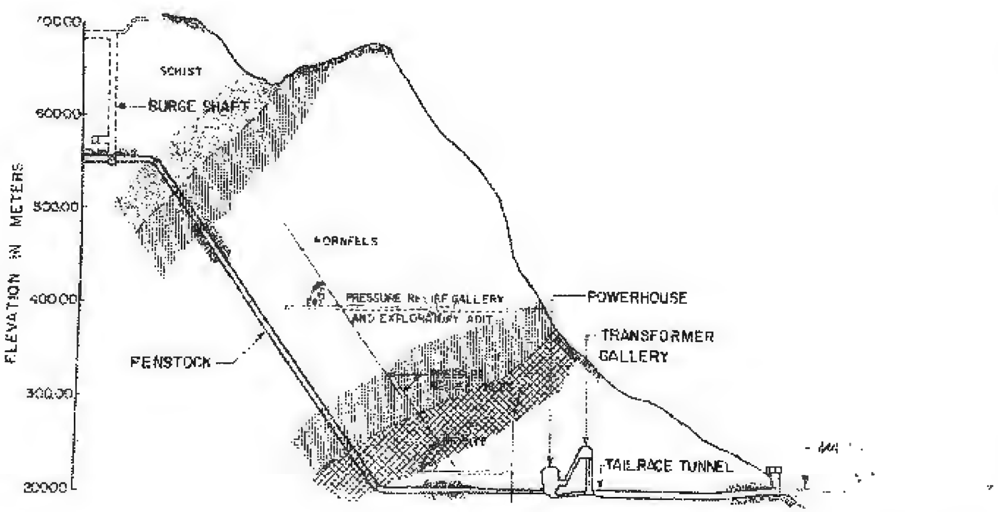


The earliest evaluations of the power potential of the upper reaches of the Anchicayá River were hampered by the complete absence of maps and even of aerial photographs (because of almost continuous cloud cover). Hardy pioneer engineers located the site of the Alto Anchicayá dam in the 1950's after arduous weeks of work in the jungle. These explorations resulted in in-house studies and a preliminary report on the economic feasibility of upstream developments which was submitted to the management of CVC in October 1966. In April of the following year, Acres International Limited, Consulting Engineers of Niagara Falls, Canada was retained to assist the hydroelectric department of CVC in the performance of a full-scale feasibility study, including site surveys, investigations of foundations, construction materials and earthquake risk, geologic and topographic mapping, hydrological, electrical system, and economic studies, preliminary designs and costs estimates, and all the related activities of such a study. A mixed team of Colombians and Canadians completed the work in a year, and the feasibility report was submitted to the Executive Director of CVC in April of 1968. It was concluded that the installation of 340 MW of capacity at Alto Anchicayá, with a load factor of 0.59, would contribute 1,760 GWh to the CVC system in the average year, and that a financial rate of return of 14 percent could be expected, based on energy sale prices in effect at the time.



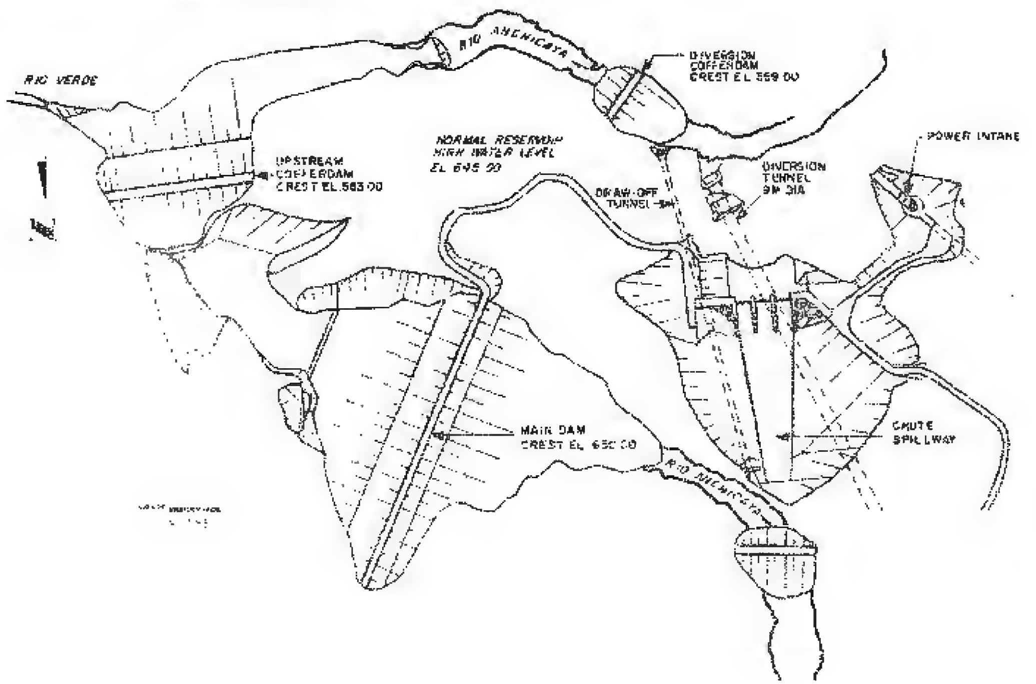
The subsequent period was spent in obtaining financing for the construction of the project. The Inter-American Development Bank and the Government of Canada agreed to cooperate. Meanwhile, detailed investigations and studies continued to refine the engineering designs and insure that the optimal structures would be built.

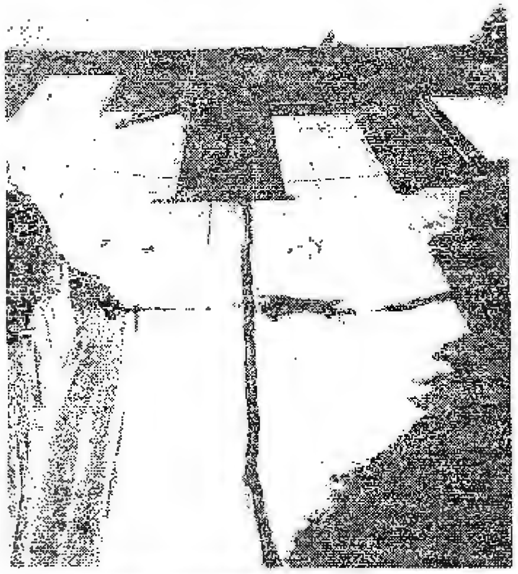
A comparison of all the applicable alternative types of dams was made and it was determined that the most economical would be a compacted rock-fill dam with an impervious membrane formed on its upstream face by cast in situ concrete. Since this would be the highest such dam ever constructed, great care was required in the design of each of its components and in the selection of materials and methods of construction. A finite element deformation analysis of the dam body and the concrete face was performed, and the assistance of three special consultants (Dr. D. H. MacDonald, Dr. D. U. Deere and Mr. B. J. Cooke) was obtained to advise on the selected design, its detailed fitness for the site, and the materials and method of construction. At the same time, the final location, orientation, shape and details of the underground powerhouse, surge shafts and penstocks, and of the tunnel and its construction portals and intakes were fixed. By September of 1969 the data had been prepared for the main civil contract tenders. This contract was ultimately awarded to the Mexican firm of Ingenieros Civiles Asociados (ICA).



The left abutment of the dam was formed by a narrow sharp-crested ridge, around which the river formed a deeply incised horseshoe loop. In the complex folded schist bedrock within this ridge, a thick layer of strong chert provided a firm foundation for the upstream concrete diaphragm. An elborate system of tunnels and drill holes was installed within the ridge to control the seepage flows and pressures generated by the deep reservoir on its upstream side. (Similar but less extensive measures were also required on the right abutment.)

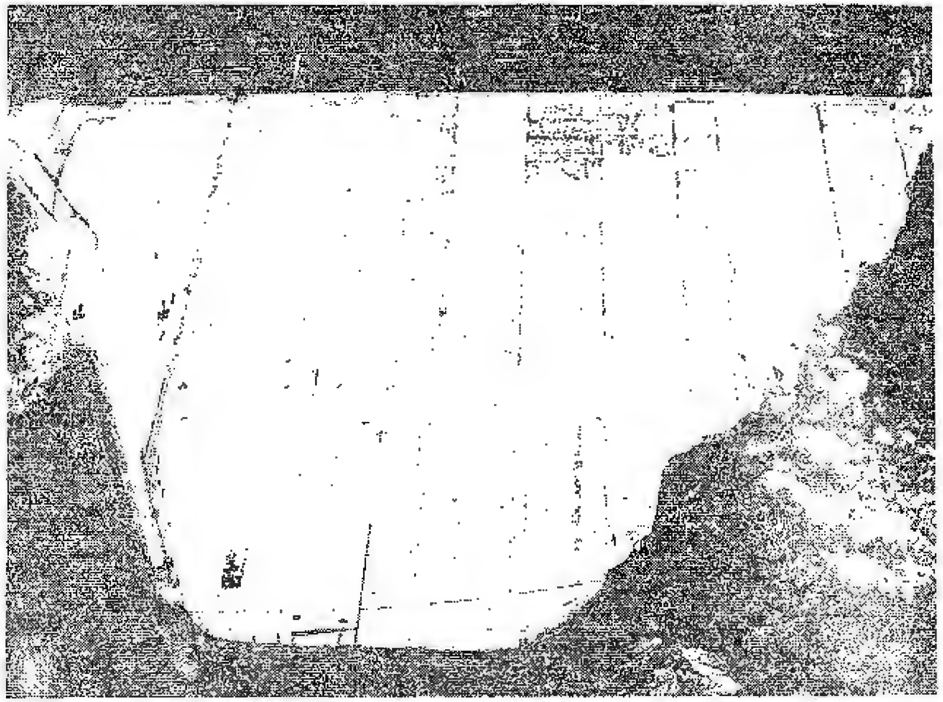
The siting of the spillway and the diversion and outlet tunnels also took advantage of the presence of this ridge to achieve the necessary water releases over the shortest practical path. In this area the bedrock consists of hornfels, a hard but fractured rock formed from the schists in the vicinity of a large body of diorite (an igneous intrusive rock).



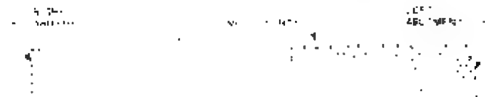


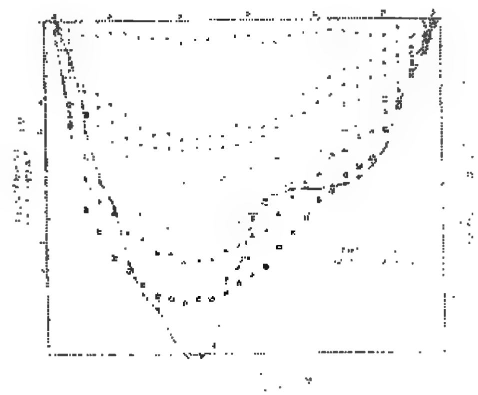
In order to control the ultimate deformation of the concrete face of the dam, great care was required in the design and construction of the rock fill in the body of the dam, including the selection of rock types, particle sizes and compaction methods. Only diorite and hornfels were permitted. They were obtained from quarries near the damsite and from the spillway excavation. The rock was dumped on the fill, sluiced, and spread in 60-cm layers with four passes of a 10-ton vibratory roller. Numerous tests were made to insure that the required density was being obtained, as too low a density might have permitted excessive deformation of the fill and hence of the upstream concrete diaphragm.

The concrete face itself was slip formed on top of a special bedding layer of finer-grained rock fill. Again, careful detailed control was exercised to achieve the desired quality of the concrete and correct installation of all the design details. The thickness of the concrete slab varies from 30 cm to 70 cm.



The 8.3-km long power tunnel was routed to take advantage of the terrain to provide adequate cover while permitting the use of intermediate construction adits and a small intake to pick up the inflow from the Murrapai tributary. Because the ground above the tunnel was inaccessible to drilling equipment, no subsurface investigations had been carried out along the line of the tunnel. The geological conditions had been deduced from geological mapping of the soils and rock outcrops alone. These predictions turned out to be quite dependable. The tunnel passes through all three rock types (schists, hornfels and diorite), but excavation was delayed because of geological conditions on only one occasion.



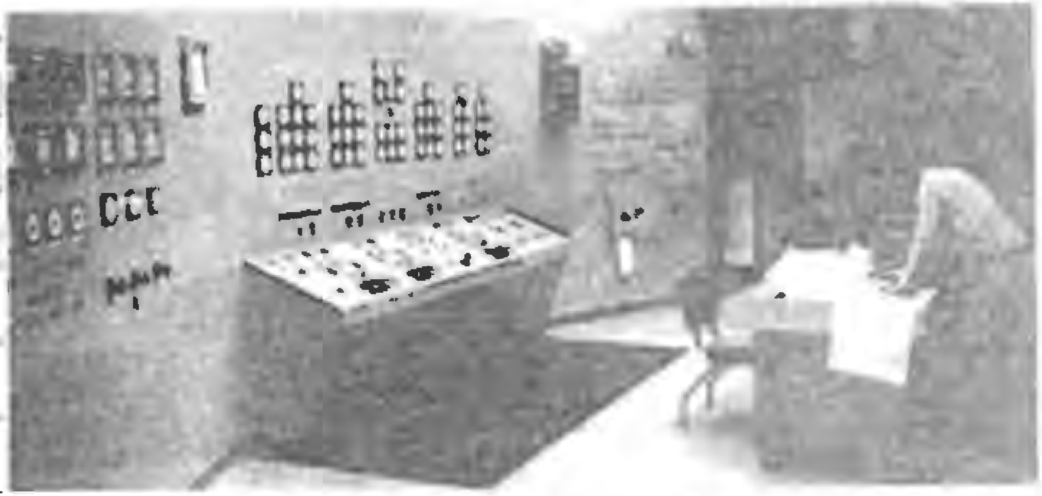


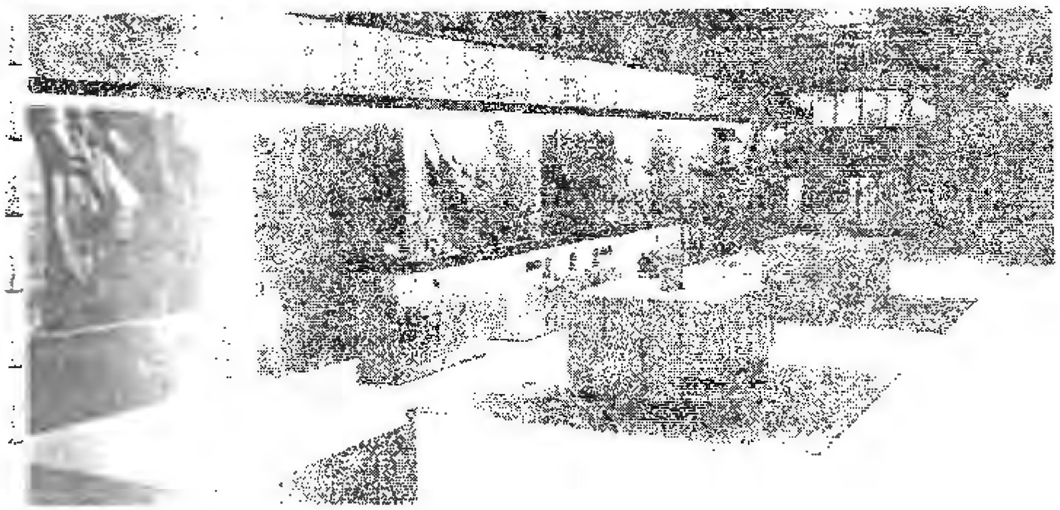
The layout of the underground structures in the powerhouse area was such as to take maximum advantage of the distribution of different types of rock. The whole powerhouse cavity is in a body of diorite. Local narrow zones of sheared and weathered rock had been discovered in exploratory drill holes and tunnels, and design details and construction methods had been adapted to accommodate them. The control room and erection bay are located at one end of the powerhouse, adjacent to the access tunnel. Three vertical-axis Francis type turbines were installed, rated at 160,000 mhp under a head of 400 m and a unit speed of 450 rev/min. The generators are rated at 126 MVA, 13.8 kV, 60 Hz, 90 percent power factor. Transformers are located in a separate underground gallery which also houses the crane to operate the draft tube gates.

The absence of level ground in the area led to extensive studies prior to selecting the final location for the switching station. A two-level scheme was finally selected to be constructed on compacted rock fill on the riverbank, with suitable protection from erosion. From here the power is transmitted to the substations which serve Cali, 60 km away, by a double circuit 230-kV transmission line, each circuit of which is designed for the entire generating capacity of the powerhouse.

The diversion tunnel gate at the damsite was closed on July 29, 1974 to permit the installation of a permanent concrete diversion tunnel plug. The project was formally inaugurated by the President of the Republic in a ceremony on July 31.

In 1976 Acres was honored by The Association of Consulting Engineers of Canada with its Award of Excellence in the category of civil engineering for its work on this project.





ALTO ANCHICAYA HYDROELECTRIC PROJECT STATISTICS

Long-term average flow	56.7 m^3/s
Firm flow	20 m^3/s
Drainage area	520 km^2
Reservoir live storage	30,000,000 m^3
Dam type: compacted rock fill with concrete upstream diaphragm	
– height	140 m
– volume of dam and cofferdams	2,705,000 m^3
– open excavation	219,000 m^3
– galleries	28,000 m^3
– grouting and drainage holes	71,000 m
Spillway type: gated chute with flip bucket	
– number of gates	3
– gate dimensions	13.5 m high x 13.67 m wide
– crest length	41 m
– design discharge	4,600 m^3/s
Power tunnel type: concrete-lined horseshoe	
– dimensions	6.2-m diameter x 8.3 km long
Power tunnel surge tank type: circular shaft with lower and upper expansion chambers	
– shaft dimensions	6.2-m diameter x 140 m high
– lower chamber dimensions	8-m diameter x 25 m long
– upper chamber dimensions	8-m diameter x 78 m long
Pressure tunnel type: concrete-lined inclined circular	
– design head for transient conditions	560 m
– dimensions	4.5-m diameter x 480 m long
Penstocks: steel lined	3 of 2.3-m diameter x 48 m long
Powerhouse type: underground	
– volume of cavity, approximate	37,000 m^3
– dimensions	62 m long x 20 m wide
Access tunnels—total length	390 m
Units type: vertical-axis Francis type turbines	
– number of units	3
– total installed capacity	340 MW

STURGEON POOL DAM
PHASE I – STRUCTURAL EVALUATION

P5006.01

Location Wallkill River, New York

Client Central Hudson Gas & Electric Corporation

Year 1978

Structural evaluation of a 110-foot high concrete gravity dam on the Wallkill River north of Poughkeepsie, New York. The dam, which went into service in 1923, is founded on horizontally interbedded layers of shale and sandstone. The dam provides the storage pond for Central Hudson's 15,000 kw Sturgeon Pool hydroelectric plant. The evaluation includes a geological appraisal of the rock foundation, an inspection of the dam itself and a stability analysis of the structure.

Owner	Manitoba Hydro
Consortium	Crippen Acres Limited
Location	Churchill River, Manitoba
Value	Missi Control — \$53,000,000 South Bay Channel — \$69,000,000 Notigi Control — \$27,000,000

The project involved direction of investigations, preparation of contract documents and all engineering designs for control structures, dams and channels for diverting the Churchill River into the Nelson River to augment the power generated at hydroelectric plants on the latter river. There are principal structures at three separate locations.

At Missi on Southern Indian Lake the outflow of the Churchill River is controlled by a spillway and two earth-fill dams. The spillway is a concrete structure (33,000 yd^3) with six 40-ft high by 40-ft wide crest gates and a total discharge capacity of 154,000 cfs. The structure also incorporates a hydraulically driven generating unit to provide local power heating and gate operation. The earth-fill dams have a maximum height of 50 ft and a total volume of 400,000 yd^3.

The Churchill River waters are diverted out of Southern Indian Lake into the Nelson River Basin via a 6-mile long channel excavated at South Bay. This channel is designed for a flow of 30,000 cfs and is mainly in permafrost-affected soft clays and silts, and involved a total of 10,500,000 yd^3 of excavation.

The diversion flows into the Nelson River via the Burntwood River are controlled by a spillway and earth-fill dam at Notigi. The spillway is a concrete structure (15,000 yd^3) with three 40-ft wide by 40-ft high crest gates to regulate flows to a licensed maximum of 30,000 cfs. The earth-fill dam has a volume of 475,000 yd^3 and a maximum height of 120 ft.

AMOS DAM, STAGE 3

P3826.04
P3826.05

Location: **Charleston, West Virginia**

Client: **Appalachian Power Company**

Associate Consultant: **Woodward-Clyde Consultants**

Year **1976**

Value **$11,000,000**

Design and construction supervision of the Stage 3 dam raising the Stage 2 dam to a total height of 250 feet.

The decision to undertake the Stage 3 raising was made prior to completion of the Stage 2 raising. This phase of the project consequently required detailed coordination between site and design office activities to insure safe and economic construction. Considerable use was made of bottom ash material from the John E. Amos coal-fired generating plant in drainage and filter zones in the dam.

ACRES

Location	**Charleston, West Virginia**
Client	**Appalachian Power Company**
Associate Consultant	**Woodward-Clyde Consultants**
Year	**1974**
Value	**$9,000,000**

Field exploration, design and construction supervision of the Stage 2 dam, raising the Stage 1 dam to a height of 220 feet and extending into the adjacent valley. The dam retains fly ash slurry from the John E. Amos thermal generating plant and comprises an upstream impervious zone of compacted clay from excavated overburden or quarried shale materials, and downstream zones of compacted sandstones, siltstones, shales and sand and gravel drains. The embankment is designed for a further 30 feet raising.

The project also incorporates an additional vertical concrete service spillway structure and a tunnel moled through the right abutment, also intended for use as an emergency spillway. Hydraulic model tests were conducted to prove the adequacy of the design.

AMOS DAM P2593

Location Charleston, West Virginia

Client Appalachian Power Company

Associate Consultant Woodward-Moorehouse and Associates, Inc.

1970

Value $3,000,000

Field exploration, design and construction supervision of an earth and rock-fill dam (170 feet high designed to be raised to an ultimate height of 235 feet) for the retention of fly ash slurry from the John E. Amos thermal generating plant.

The dam comprises a zoned design incorporating compacted clay shale, excavated from an adjacent quarry, as the impervious membrane. The balance of the dam is constructed of sandstone with varying proportions of shale selectively excavated from the quarry.

The project incorporates a vertical concrete drawoff structure and associated floating skimmer, and a free-overflow emergency spillway.

CARDINAL DAM

P3134

Location Steubenville, Ohio

Client Buckeye Power Company
Ohio Power Company

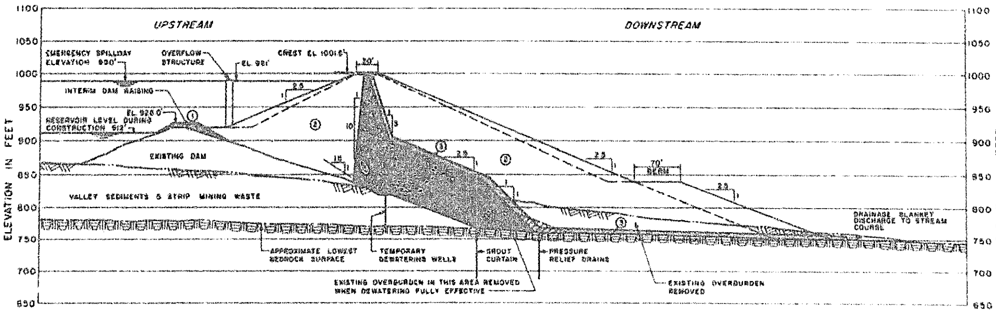
1973

Value $3,100,000

Field exploration, design and construction supervision of the raising of the existing earth and rock-fill dam to an ultimate height of 260 feet for the retention of fly ash slurry from the Cardinal thermal generating plant.

The dam is of zoned design, constructed primarily of mine waste from a nearby waste tip. Additional material was obtained from a major excavation for the emergency spillway. Construction included the provision of a well-point type dewatering system for the foundation excavation, and shallow cement grouting in the abutments of the existing dam.

The project incorporates a vertical concrete drawoff structure and associated skimmer, together with multiple fly ash discharge pipelines from the power plant to the relocated pond.



LEGEND

(1) IMPERVIOUS FILL (2) RANDOM FILL (3) FILTER ZONE & DRAINAGE BLANKET

APPENDIX B1

PROJECT AND CONSTRUCTION
MANAGEMENT SERVICES

ICE ENGINEERING CAPABILITIES

INSPECTION AND EXPEDITING
SERVICES

LABORATORY AND TESTING
FACILITIES

PROJECT MANAGEMENT SERVICES

CONSTRUCTION MANAGEMENT

Contractual Arrangements

For a project as large as a hydroelectric or pumped storage development, it is essential that a decision be made at a very early stage as to the type of construction contract (or contracts) which are to be let. Possible arrangements range from turnkey, through one general contractor, to separate contracts for the major structures and equipment. The type of contractual arrangements will have a major effect on the type of construction management organization to be set up.

Construction Supervision

Acres usually organizes the field supervision operation in accordance with the natural divisions in the project, such as upper reservoir and intake, power plant and conduits, lower reservoir, transmission, support facilities, etc. A typical organization is shown in Chart "A".

Each division is headed by a construction manager who operates with a great degree of autonomy and reports to the manager of construction located at the site. Each division has its own complement of contract engineers, area engineers, surveyors, scheduling engineers and cost engineers. In order to maintain uniformity in dealing with the contractors, a central management core reporting directly to the manager of construction operates as a staff group and deals directly in a staff capacity with its opposite number in the separate divisions. Each group is responsible for the supervision of individual contractors and for the coordination of all contractors. The group is responsible for the basic project layout and, in practice, to establish control points from which each contractor is obligated to set out and control his own work. The engineers maintain a continuous watch over contractor quality and progress. They are in constant contact with the design office regarding shipments of owner-supplied equipment, they assist in expediting where required, and they release owner-supplied equipment to the contractor for installation. In addition, when the contractors advise that their work is complete, the group can, if appropriate, accept the work on behalf of the owner and authorize final payment to the contractors.

Working under Acres surveillance, the contractors are responsible for labor supply and operation of construction equipment, and supply and installation of materials not provided by the owner.

The extent of Acres involvement in the financial management of the contracts can be arranged to suit the requirements of the owner. In previous work, the Company's responsibilities have ranged from complete to minimal involvement in this field of activity.

On-Site Quality Control

The basic philosophy behind on-site quality control is that nothing gets done by contractor or supplier/installer without the approval of Acres or its designated representative. On civil engineering work, this involves examination of foundations and approval by the engineers of the quality of the foundations before any earthwork or concreting can be done.

As the job progresses, engineers constantly check quality of concrete both at the mixing plant and in the forms, gradation of fill materials in dike work, embedment, alignment and job interfaces with other contractors before allowing any one contractor to proceed. Contracts are generally so worded that the engineer may request any contractor to redo suspect work. In the event that such work is proven unacceptable, repairs or modifications are made at the contractor's expense, but if proven acceptable, the expense of replacement is borne by the project.

Quality assurance is injected at the earliest possible stage. For example, all elements used in the manufacture of concrete are pretested before the materials arrive at the mixing plant. The product is again tested as it leaves the plant, and finally tested in place. Similarly, borrow pits are investigated for dike materials, and tests are taken before and after placement. Nuclear densometer compaction tests are used to check the compaction of dikes and the results correlated with laboratory tests made on the materials used in the dikes.

Laboratory work is contracted out to firms specializing in this type of work. These firms report directly to the Acres engineers in charge of the separate areas, rather than through their company offices. Fabricated items which require on-site welding are subjected to nondestructive testing, and again this testing of on-site welding is contracted out to specialists in the X-ray or ultrasonic fields. A complete record is retained by the engineers of X rays taken on all site welding on the penstocks, scroll cases or other critical components requiring field welding.

In the electrical and mechanical fields, suppliers of all major electrical equipment are contractually obliged to have representation at the site, at the project's expense, to ensure that their equipment is properly assembled and connected to the system. All control and protection circuits are checked to minimize the possibility of troubles during the commissioning stage. As-built drawings are kept up to date and the originals modified as required.

COST CONTROL AND MONITORING

Management Cost Control and Information System

Objectives — The purpose of Acres management cost control and information system is to provide current and factual information on all cost aspects of the project, so that control can be exercised at responsible management levels. The system is not restricted to reporting only cost information, but is more heavily directed toward looking ahead to the future. By tracking each work unit from its inception in the engineering design phase through to completion of construction, and by a process of continuous forecasting of each work unit in detail, as to both cost and time, unfavorable trends and variances are highlighted well in advance, thereby enabling corrective action to be taken without delay.

Basic Principles — To achieve this objective, the system revolves around several principal elements. These are the construction cost estimate, responsibility reporting, cost estimating and budgetary control and, finally, the recording of costs, as incurred, by contract package.

The construction cost estimate is a detailed evaluation of construction, engineering and management costs, based on preliminary or conceptual designs defining the entire scope of the project, and is prepared with cost information and prices current at the time of project inception. In addition to the estimate of costs to design and construct the project, the construction cost estimate includes, as separate items, allowances for contingency and escalation.

The Control System

Engineering Design Phase — The design of each contract package is initiated through the issuance of an engineering work authorization which indicates the scope of design work to be carried out. Once approved, the work authorization constitutes the authority to proceed with the assignment, and it authorizes a specific amount of funds to be spent in designing the facility.

On receipt of the work authorization, the design office proceeds with preliminary activities including studies of alternatives, formulation of a general arrangement, and design requirements as described in the section entitled "Engineering Management".

When preliminary design is essentially complete, the scope statement is prepared, describing the scope of the contract package. The report also includes estimated quantities based on engineering documents. Once the findings of this report are accepted, the design office proceeds with the detail design.

When detail design is progressing, monthly forecasts of eventual construction costs are prepared to reflect all changes in current designs. When detailed design is mainly complete, a final report known as the technical package is issued, providing a draft of all technical specifications, drawings, and a listing of individual units of work within the contract package, as well as estimated quantities. The report includes the second control estimate of the work based on the units of work at prevailing prices. This cost estimate affords a final opportunity to consider changes in the scope of the package before sending it out for competitive bidding.

Bidding Phase — During the bidding period, a final control estimate known as the engineer's estimate is prepared, based on the information in the bid documents which are sent out to potential contractors. This is a detailed estimate which takes into account the current site conditions and current cost trends, and also serves as an independent measure of the total cost and individual work items against which to review the reliability of bids submitted.

Upon receipt of bids, an analysis is made with respect to the corresponding control budget, with the latest estimate of costs and with respect to all other bids received.

Construction Period — Once the award is approved, primary responsibility for control shifts to the manager of construction, who exercises control over schedules, quantities of work, cost and quality within the limits of the contract. As described in the section dealing with construction management, the manager of construction has a primary responsibility to ensure that the contractor performs the work within the terms of the contract document. Control is exercised by senior engineers assigned to each major contract or series of minor contracts. The senior engineer is responsible for field surveillance and supervision over actual measurements of work performed, and the continual forecasting of quantities and cost to contract completion. Monthly, quantity and cost forecasts are used as a means to update plans and initiate remedial action when work falls behind schedule, or when cost overruns become apparent. The engineers in the field issue weekly and monthly reports, including quantitative and cost data reflecting work actually completed and forecasted future work relative to each work unit within the contract.

The information contained in these reports is subjected to a detailed review each month by the construction manager and his staff and is finally reviewed by the project manager before being channeled into the final reports which are transmitted to other senior management levels.

Major Equipment and Materials – Major items of electrical equipment and some bulk materials are often purchased directly by the owner and installed by contractors. Typical examples are transformers, switchgear, cable and transmission line conductor and hardware.

Cost control is maintained in much the same manner as for construction contracts by comparing cost estimates with the related control budget, and by means of competitive bidding procedures and bid analysis.

Control Over Management and Engineering Costs – The construction cost estimate includes an estimate of the cost of management and engineering design services for the project. This estimate is based on the number of employees required to perform the design requirements for each facility and the classification of employees required to provide other management services.

Detailed management budgets are prepared annually for each department and are supported by details of salary costs and other expenses. When approved, the budget forms a basis of comparison with actual costs.

Management Reporting System

The management reporting system provides standard accounting statements normally used for business operations and other analysis type reports which provide information in the amount of detail pertinent to the management level for which each report is intended. The reports compare costs and forecast information to control budgets from the time design activities commence until construction has been completed.

Various types of financial reports are used, three of the more important types are described below.

Unawarded Work – Throughout the engineering design phase, forecasts showing the timing of planned costs are reported by contract package for comparison with the original planned rate of future expenditure, the control budget, and the percentage of design work completed. Estimated final variances and the effect on the contingency allowance are shown on the reports and are further analyzed in other reports within the system.

Awarded Work — Once contracts and purchases are awarded, the award value becomes the plan against which actual performance is measured. Costs for each contract and all major purchases are reported for the month and cumulative to date, in comparison with the award value.

Project Status Report — This report summarizes monthly selective information from the management information system into a one-stage presentation of current cost and forecast information in comparison to the overall plan, and provides a means of evaluating actual performance at key stages of work progression.

SCHEDULE CONTROL AND MONITORING

Contract Document Requirements

Acres takes great care in specifying the schedule requirements in contract documents. Key dates which the contractor must meet are listed, but within this framework the contractor is given freedom to plan the work. Bidders are not given copies of the planning schedule for the particular contract; contractors must submit with their bids a preliminary schedule covering initial operations in detail and the remainder of the work in summary form. A specified number of days after award of contract, usually 45 or 60, the successful bidder must submit a completely detailed schedule for the whole contract. These schedules are calendar-scaled CPM networks, except on very small contracts when bar charts are permitted.

Monitoring

The project must also be controlled during design and construction. Regular monitoring, by comparing actual progress to the schedule, enables effective control to be maintained.

Each monitor includes a computer printout, float trend charts, and a narrative which highlights items requiring attention, gives reasons for any delays, and outlines corrective action that should be taken. Progress is plotted on the network diagrams and these are issued once a month for each facility, again staggered to level work load.

The printout produced by the computer has a variety of possible formats. Tabulation can be done for several levels of summarization tailored to the needs of the user, and also by responsible agency.

Float Trend Charts

The need for fast reference to float trend is recognized by the use of the "float trend chart". This is a simple graph showing the value of available float plotted against a calendar scale. At a glance, it is possible to see if the situation is good but slipping, late but improving, late and getting worse, or (and there have been many) on time and steady. Float is calculated relative to milestones which are important key events such as award of contract, completion of construction, or an important intermediate event like completion of excavation of the first two penstocks.

Testing

A great variety of physical, electrical and mechanical testing must be carried out during the various manufacturing processes. Manufacturers are required to give advance notice of all tests. These are witnessed by the inspectors, and engineering department representatives from Acres are called in to witness specific tests of major importance. Test results are submitted along with QAR.

Plant Evaluation

When considered desirable, the Acres Inpsection Department carries out an inspection of the plant of the low bidder, prior to contract award, to determine the suitability of the manufacturing facilities. There is, of course, no need to do this when the successful bid has been submitted by a company whose plant is already well known to the project management.

QUALITY ASSURANCE

Basic Function and Approach

Acres quality control staff covers off-site manufacturing of major equipment and material throughout North America and Europe. The location of manufacture is governed essentially by the successful bidder. Quality control on site is the responsibility of the assistant project manager (construction) and his staff, who are resident on site.

The basic approach on the subject is one of quality assurance throughout the manufacturing progress, rather than merely control by inspection on completion of the finished article. It is very easy to reject completed work if it does not meet the specification, but this can have an extremely adverse effect on schedule if the component is a major one (such as a turbine runner) or if the reject rate is high for a large number of small articles (such as transmission line insulators). Also, when available time for manufacture is limited or work is running behind schedule, there is often a tendency on the part of the supplier to sacrifice quality for speed. Because of this potential conflict between quality and schedule requirements, additional emphasis is placed on the fact that specified quality must be attained before the product is accepted and released for shipping, and it is the supplier's duty to devise a means of achieving this within the time available.

Staff

Quality assurance within Acres is the responsibility of the manager of technical services and his quality reporting assistants. Acres staff consists of a supervising inspection engineer and inspection coordinators, while the actual inspection work in the manufacturing plant is sometimes assigned to specialist agencies. Each coordinator handles a particular type of work appropriate to his training and experience within the following broad divisions:

- Civil, Structural and Mechanical
- Electrical
- Turbines and Generators

Assignment to Agencies

Although Acres is in a position to carry out most quality assignments with its own staff, it sometimes becomes advantageous, in the case of an overseas supplier for example, to assign some of this work to local agencies.

Once a contract has been awarded or an order placed (depending on the size of the equipment or amount of material), the manufacturing location is known and the Acres supervising inspection engineer is then in a position to consider suitable inspection agencies. The choice of agency is largely governed by the type of work to be inspected, since many agencies have specialized fields. individual inspectors with appropriate experience are interviewed in most cases by the Acres supervising inspection engineer who, in turn, recommends to the owner the assignment of the most suitable candidate as the quality assurance inspector.

Reporting

The inspectors are charged with submitting quality assurance reports for each plant visit. However, if the inspector is resident or makes several visits in 1 week, a weekly quality assurance report (QAR) for each contract is sufficient. Handwritten copies of the QAR are dispatched simultaneously to the inspector's agency office and to the Acres Inspection Department.

The QAR contains the following information:

- Details of work inspected
- Defects found which can be repaired
- Rejected items
- Results of tests
- Status of manufacturer's design and material procurement
- Status of material delivery
- Status of manufacture.

Relationships with Engineering Departments

The function of the quality assurance staff is to ensure strict conformance to the specifications.

Preparation of the latter is an engineering responsibility and the inspection group has no authority to allow any departure from specification. The inspection group does, however, have an opportunity to review specifications prior to contract award to ensure that impracticable requirements are not being asked for, and group personnel can recommend changes in the specifications at this stage.

FINANCIAL MANAGEMENT

The extent of Acres participation in the financial management of a given project can vary greatly, according to the needs and wishes of the client. In the majority of cases we have been called upon to take little or no participation in this field of activity. In certain other cases however, we have taken major roles in the financial aspects of the project.

In the case of the Churchill Falls development, for example, Acres was called upon to set up a special task force responsible for the preparation of a detailed "Bond Offering Memorandum". This memorandum, which was in fact a very substantial bound volume, outlined in great detail the various economic, technical and operational features of the project and analyzed them in terms of their relationship to the ultimate profitabilities of the completed project. The text of the document was worded in a manner appropriate to the financial community and was the basis upon which a bond offering of $500 million was successfully made. At the time of issue this was understood to have been the largest sum of money ever raised by this method.

On a more modest scale in terms of the total dollars involved, are the Lower Notch and Arnprior projects for Ontario Hydro. The first of these, Lower Notch, was initiated in 1966. Under the terms of our contract, Acres was placed in charge of a trust fund sufficient to cover the cost of the whole contract. The degree of participation by Ontario Hydro was, in effect, confined to an overall review of accounting procedures and engineering progress. The balance of the work, from basic engineering details to the signing of contracts for both equipment and services, was left entirely in the hands of our staff. The outcome of this project was sufficiently satisfactory that in 1972 Acres was selected for a second assignment for the Arnprior development.

PROJECT MANAGEMENT ORGANIZATION

Typical organization charts for the overall, conceptual engineering, contractor selection and commissioning phases of large projects are presented in the following charts.

ACRES

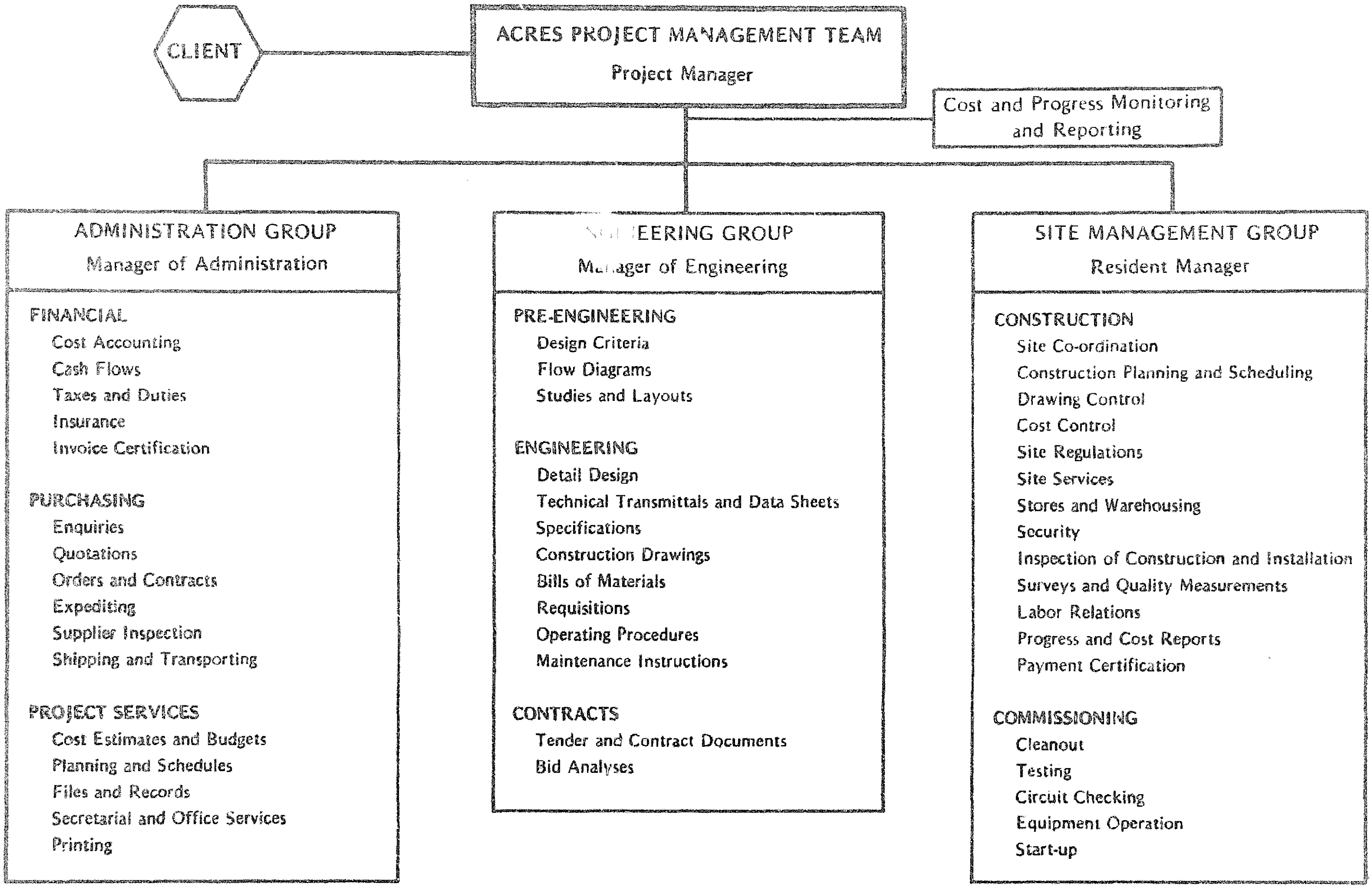


CHART 1 – THE PROJECT MANAGEMENT

OVERALL ORGANIZATION

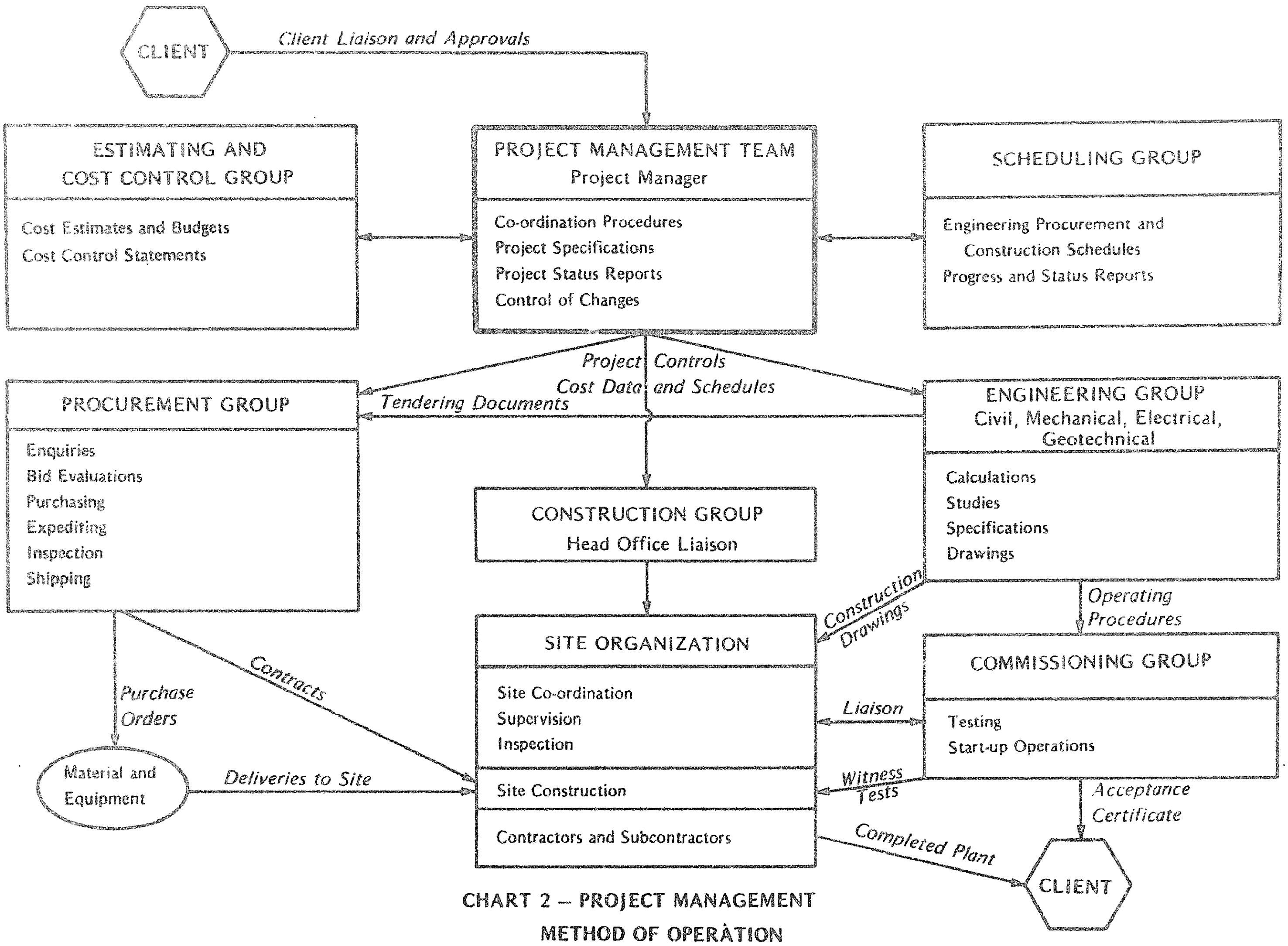


CHART 2 – PROJECT MANAGEMENT METHOD OF OPERATION

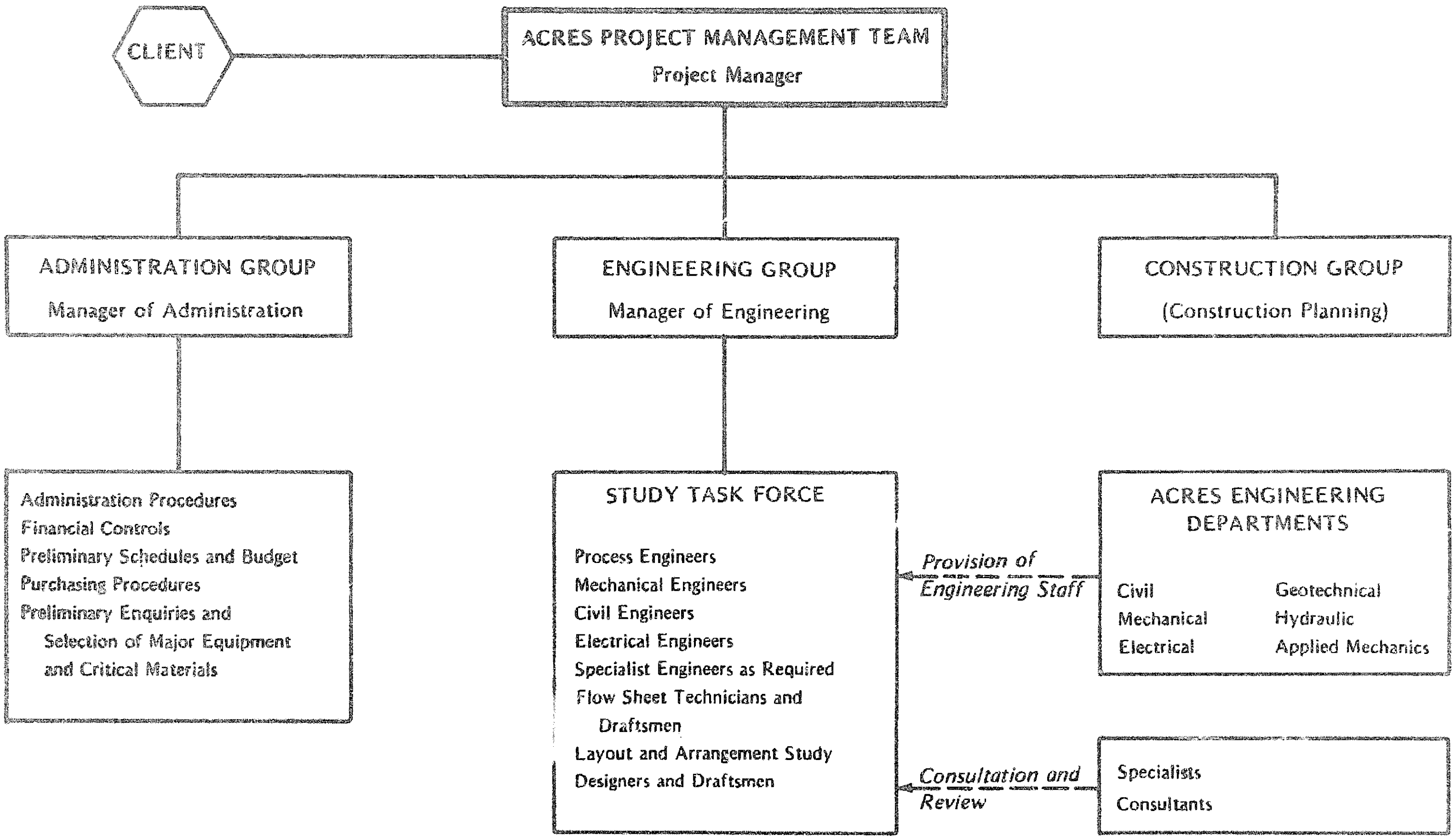


CHART [illegible] – PROJECT MANAGEMENT

PHASE 1 – CONCEPTUAL AND DEVELOPMENT ENGINEERING

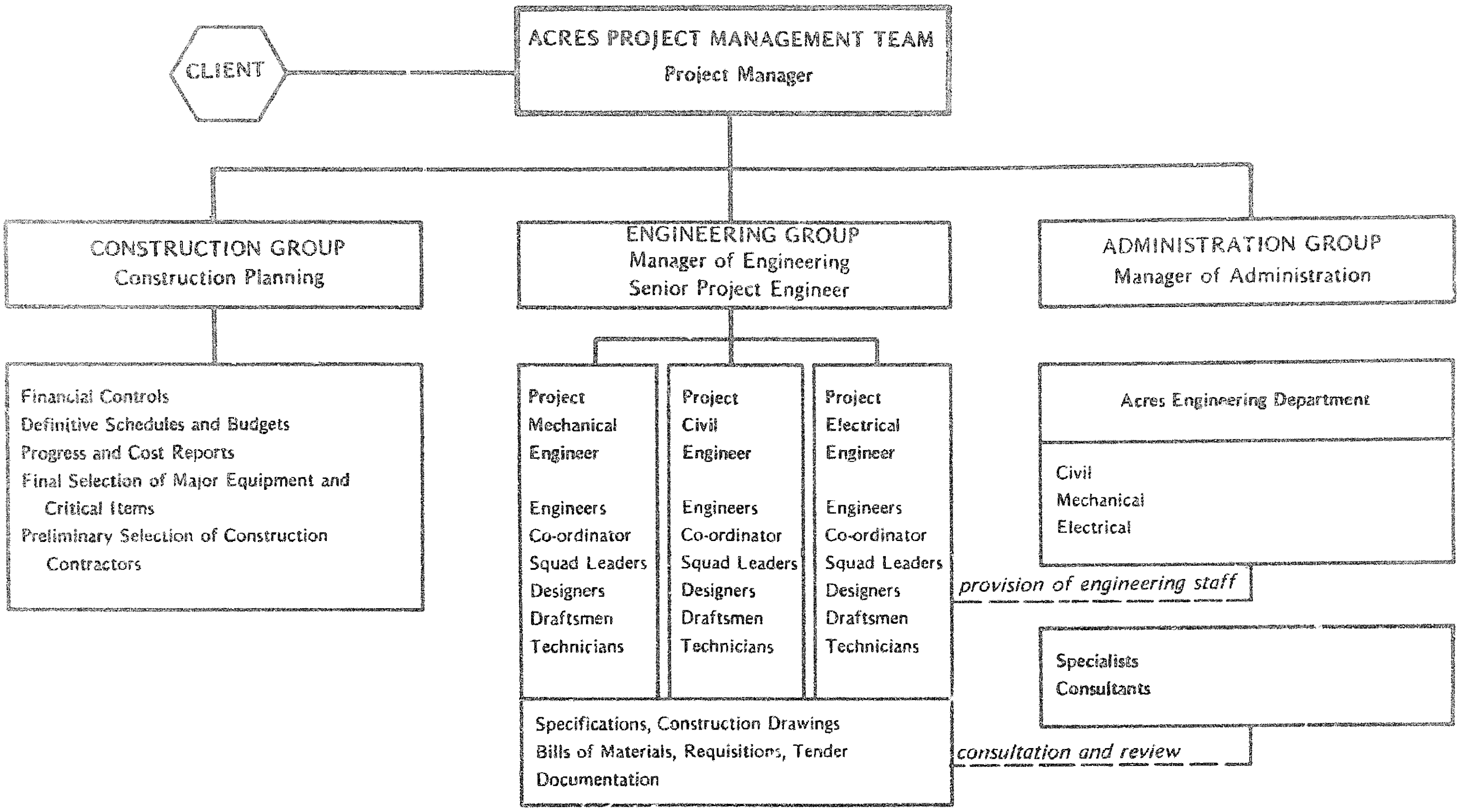


CHART 4 – PROJECT MANAGEMENT

PHASE 2 – PRODUCTION ENGINEERING

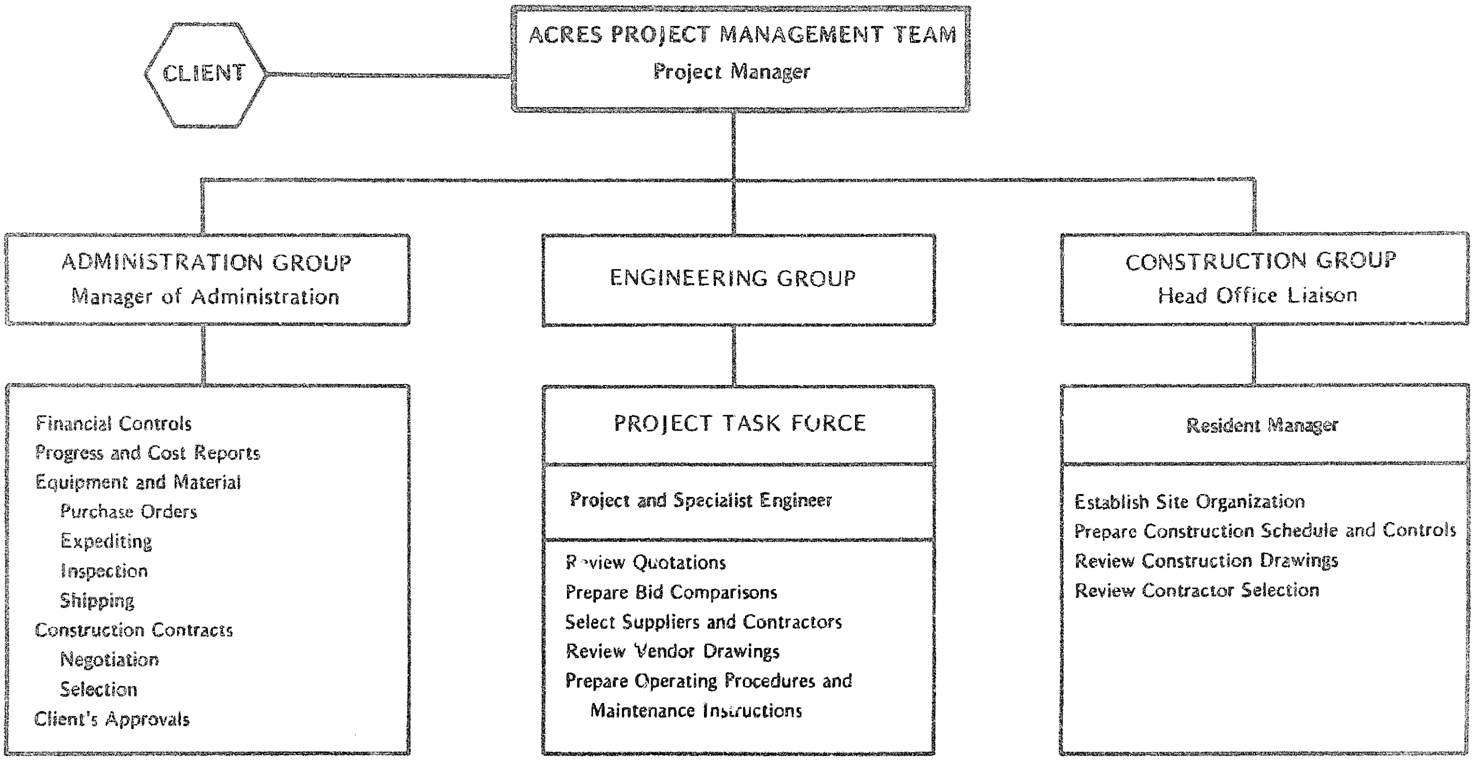


CHART 5 – PROJECT MANAGEMENT

PHASE 3 – CONTRACTOR SELECTION

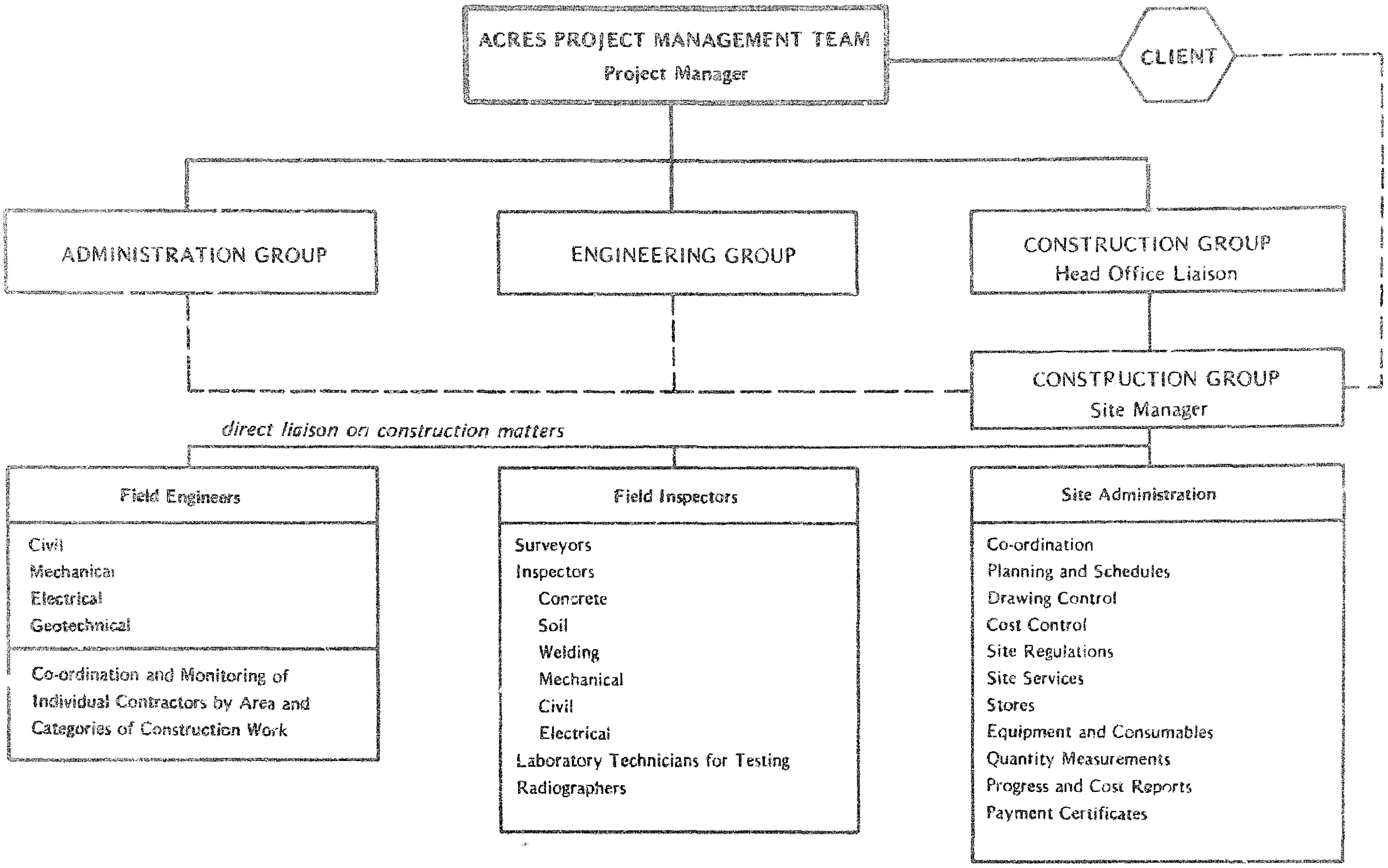


CHART 6 – PROJECT MANAGEMENT
PHASE 4 – CONSTRUCTION

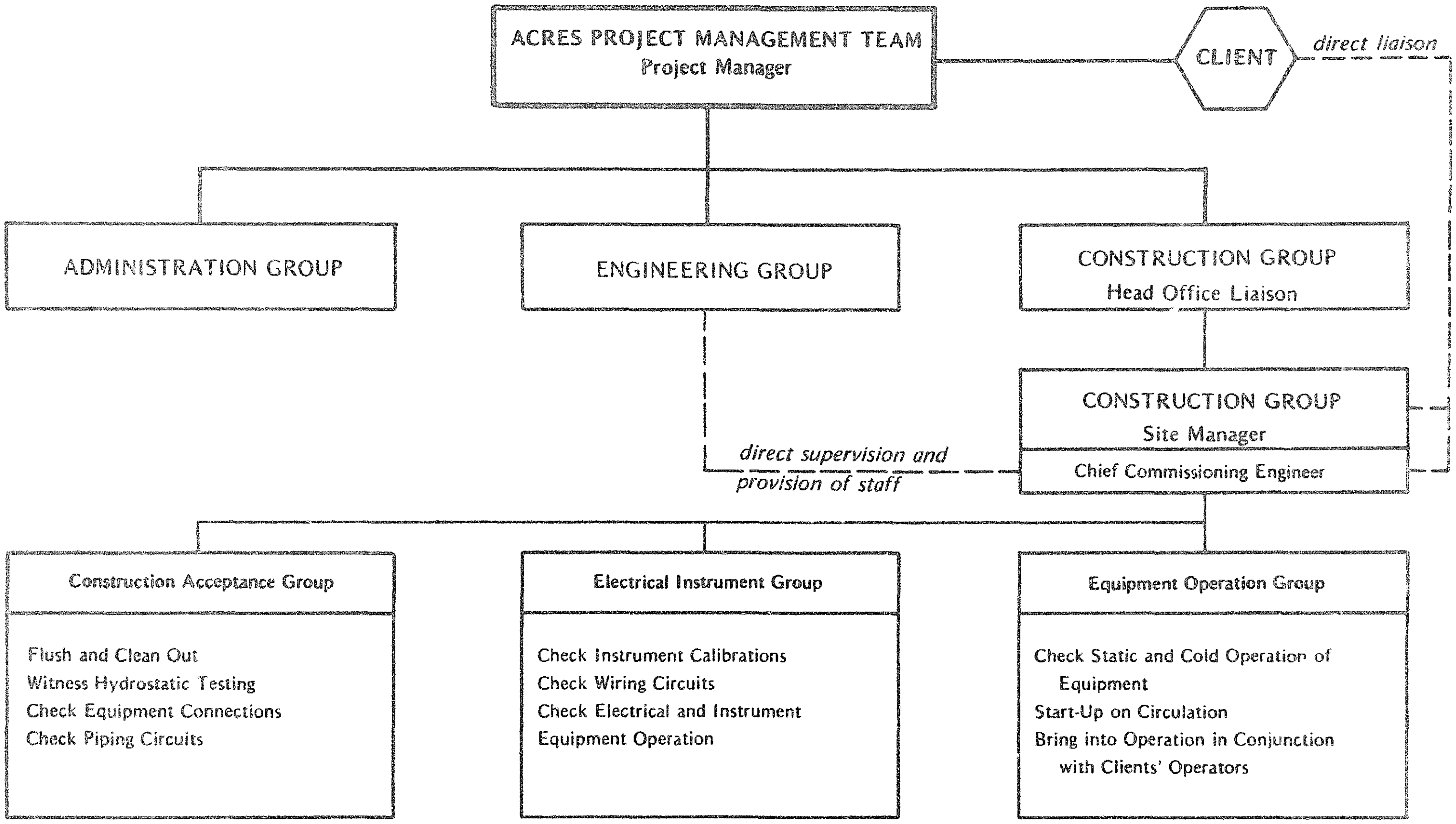


CHART 7 – PROJECT MANAGEMENT

PHASE 5 – COMMISSIONING

PROJECT MANAGEMENT

CLIENT	PROJECT DESCRIPTION AND EXTENT OF SERVICES
Ministry of Transport and Communications Department of River Transport Republic of Peru	Construction management of ports on the Amazon River at Iquitos, Pucallpa and Yurimaguas.
National Harbours Board	Management of Fairview container terminal, Halifax, Nova Scotia.
'arbours Board	Design and construction management for marine container terminal at Saint John, New Brunswick. Approximate capital cost $35 M.
ort Limited	Project management services for the proposed Eddy Point common-user oil dock, Nova Scotia. Estimated capital cost $50 M.
Imperial Oil Enterprises Limited	Design, procurement and construction management of a refinery sour water stripper unit using Imperial's process design at Sarnia, Ontario.
Centrais Electricas Brasileiras South America	Management of planning, design, construction supervision, testing and start-up of thermal electric power station at Belem, Para, Brazil. In association with SELTEC of Rio de Janeiro. Approximate capital cost $12 M.
Corporacion Autonoma Regional del Cauca	Alto Anchicaya project, Colombia, South America. Project management in combination with client's representatives.
Churchill Falls (Labrador) Corporation Limited	Churchill Falls hydroelectric development. Complete project management in association with Canadian Bechtel Limited. Approximate capital cost $665 M.
Iron Ore Company of Canada Limited	Partial project management for the Humphrey Mine rail tunnel and ore-handling facility and automatic mine railway, Labrador City, Labrador. Approximate capital cost $18 M.
Pilkington Brothers (Canada) Limited	Complete project management for a float glass production unit added to an existing plant at Scarborough, Ontario. Approximate capital cost $35 M.
Construction Aggregates Limited	Design, purchasing, construction management and supervision of a road-base aggregate plant near Port Mellon, British Columbia. Approximate capital cost $5 M.

CLIENT	PROJECT DESCRIPTION AND EXTENT OF SERVICES
Construction Aggregates Limited	Conceptual design, preliminary and final engineering, budgetary appropriation and project control estimates, purchasing and construction management and supervision of a concrete and road-base aggregate plant near Victoria, British Columbia. Approximate capital cost $10 M.
The Kingdom of Laos The Laotian National Mekong Committee	Engineering management and supervision of design, construction and initial operation of the Nam Ngum hydroelectric development, north of Vientiane, Laos. Approximate capital cost $29 M.
The Hydro-Electric Power Commission of Ontario	Project management for the Arnprior hydro-electric development. Approximate capital cost $79 M.
The Hydro-Electric Power Commission of Ontario	Project management for the Lower Notch hydroelectric development.
The Manitoba Hydro-Electric Board	Kelsey hydroelectric development. Partial project management. Approximate capital cost $44 M.
Atomic Energy of Canada Limited Comision Nacional de Energia Atomica	Project management and construction supervision for Cordoba 600-MWe CANDU nuclear power generating station, Argentina. Approximate capital cost $600 M.
Imperial Government of Iran Ministry of Energy Khuzestan Water and Power Authority	Project definition, preliminary and feasibility studies for multimillion dollar hydroelectric and irrigation projects. Approximate capital cost $1.5 billion.
State Organization of Electricity Republic of Iraq	Planning, design and construction supervision of 400-kV ac supergrid system. Approximate capital cost $300 M.
Volta River Authority	Engineering, construction supervision and planning for Kpong 160 MW hydroelectric project, Ghana. Approximate capital cost $240 M.

SCHEDULING SERVICES

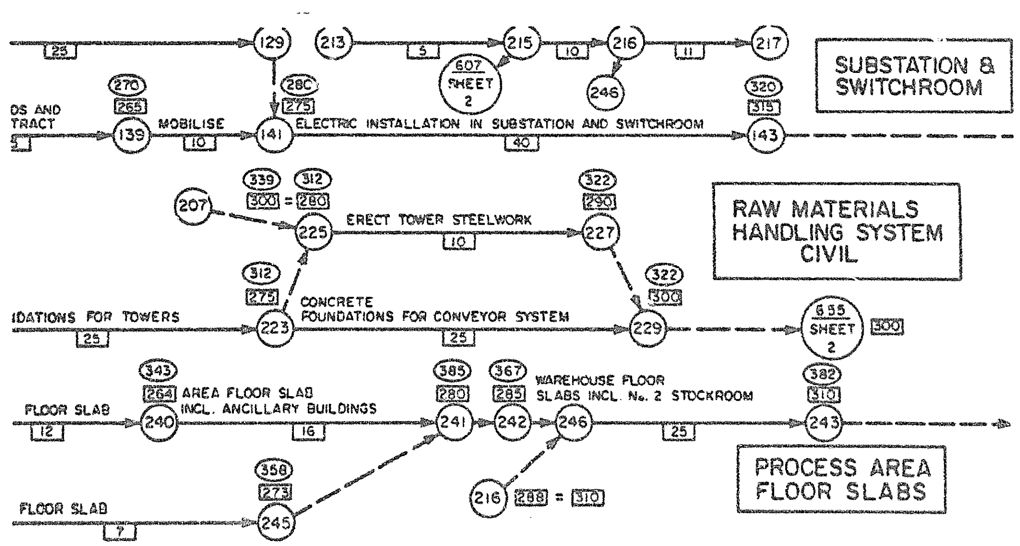
Acres scheduling staff has extensive experience in applying modern computerized techniques as well as other manual and graphic methods to the planning and monitoring of projects, both for in-house assignments and directly for clients.

Design schedules are vital to our projects to ensure timely completion. Schedules interface directly with Acres computerized "Progress and Cost Control" system, which is an system for project management to control both the duration and expense of services to our clients.

In carrying out feasibility studies, scheduling is used as an aid in the preliminary planning of a project to establish project milestones and assess the overall cost ramifications of changes in project duration.

An overall project control schedule is essential to construction or project management to ensure coordination of all aspects of detailed schedules such as engineering, procurement and construction requirements, including consideration of required milestone dates, equipment needs, long-delivery items, seasonal difficulties, manpower limititations, work-area congestion, etc. The continuous involvement of a scheduler during project planning and execution ensures that both project management and the client are aware of the status of the work and the effect that any actions or decisions will have on the expected completion date.

In addition to applying critical path network analysis and resource allocation techniques, Acres has developed a standard approach to analyzing the risks associated with schedule development. Because of the lengthy duration and tremendous cost of many of today's undertakings, it is vital that not only a project's expected duration but also its potential variability be known as precisely as possible. Acres risk analysis provides an effective framework for quanitatively assessing the potential variablity of a schedule or cost estimate and its associated liability or contingency requirements.



COMPUTING SURVEYS

ICE ENGINEERING

Acres has extensive experience in appraising ice conditions in streams and waterways and in designing structures to cope with severe ice conditions. Four main areas of investigation are prominent in the projects which have been carried out. These relate to Thermal Regime, Mechanical Regime, Ice Forces and Ice Navigation.

THERMAL REGIME

The evaluation of heat transfer and temperature changes affecting lakes and streams is fundamental to appraisal of the ice conditions which will prevail. Much of this work has been carried out to predict dates of freeze-up, ice thicknesses, outflow temperatures or rates of ice production associated with reservoirs and the natural and man-made channels of northern hydroelectric power developments. These studies are complemented by Acres work on thermal input to the Great Lakes and dispersion of waste heat from thermal power stations.

MECHANICAL REGIME

Flow mechanics and the mechanics of materials determine the form which ice will take in the location of interest. The combined thermal/mechanical development of an ice cover on flowing water may involve

- growth of sheet ice over quiescent areas
- ice crystal formation at the surface of rapidly flowing water
- transport and deposit of frazil ice crystals and slush ice at the surface and under an established ice cover
- growth of border ice along stream banks
- progression of the ice cover upstream by arching or thickening and ice staging
- consolidation, shoving and freezing of the cover under hydraulic and wind loads
- erosion and melting of selective channels through the established cover
- break-up, melting and dispersal of the ice, sometimes involving jamming, during warming weather and increasing flows
- on lakes and at sea, the effects of the wind dominate in establishing a mechanical regime involving sheet ice, pressure ridging and rafting, and high pile-up on headlands. Tidal areas are subject to special ice forms.

Projects in which the mechanical regime was a principal factor have primarily been those in which changes to a river channel were proposed, an ice jamming problem was analyzed, or the effectiveness and effects of ice control measures were evaluated.

ICE FORCES

Forces imposed on structures or ice control works such as booms are related to the mechanical ice regime, the physical properties of ice and the setting in which interaction with the ice occurs. Forces may involve

-- thermal expansion of the sheet ice

-- impact of floes of sea ice several miles in extent

-- wind and water forces on an ice jam

-- the weight of grounded ice ridges.

Projects in which ice forces have been prominent among the governing design criteria are

-- offshore drilling platforms and light piers

-- bridge caissons in water depths of up to 100 feet

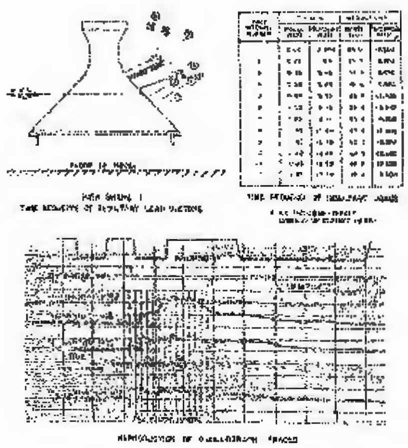
-- spillway piers and gates

-- flood control gates

-- ice control booms.

Methods of determination of ice forces have included scale model simulation of ice loading situations and the application of finite element methods and advanced concepts of fracture mechanics.

DYNAMOMETER AND MODEL PIER

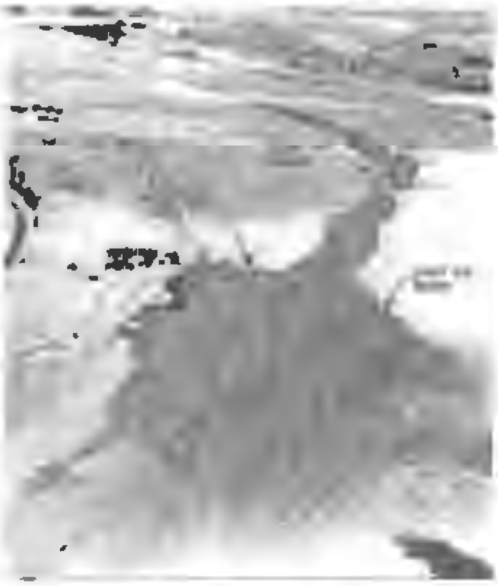


LOAD SEQUENCE FOR A WIDE FLOE

ICE NAVIGATION

Studies of prevailing ice conditions and the ability of various classes of vessels to cope with them have been central in a number of navigation projects. Although specialized vessels can make passage through polar seas, ice in temperate latitudes remains a very serious seasonal hindrance to more conventional vessels.

Ice navigation studies have been oriented to appraisal of new routes and to seeking means of extension of the navigation season on existing routes. Data from systematic aerial reconnaissance of ice conditions in most Canadian waters provide a statistical basis for analysis. Field surveys, hydraulic model tests and computer simulation are employed in resolving specific questions.



The methods used in ice engineering studies include mathematical analysis, computer simulations, field observations and hydraulic model tests. Ice studies have been an important part of the work of Acres laboratories since pioneering work in deriving impact loads using structural/hydraulic models began in 1963. They continue to be prominent in the international work of the company. The following table gives a summary of key projects and clients.

PRINCIPAL ICE ENGINEERING PROJECTS

Project Number	Project	Client	Description
P4298	Saint John River Flooding (1976)	The New Brunswick Electric Power Commission	A study of the events leading to ice jam flooding on the Saint John River in the spring of 1976.
P4226	Bell Island Oil Storage Project (1976)	Wabanex Ltd.	A study of the effects of sea ice conditions on the feasibility of supertanker navigation to a major crude oil storage facility in Conception Bay, Newfoundland.
P3901	Gull Island Hydro Electric Project (1975)	Gull Island Power Company	Field observations, analysis and hydraulic model studies to evaluate the effect of severe winter ice conditions on river diversion.
P3855	St. Mary's River Ice Model (1975)	United States Army Corps of Engineers	A research and study program to develop feasible solutions to problems created by the frequent ice build-up in the narrow navigation channels on the St. Mary's River.
P3912	Limestone Generating Station - Nelson River (Manitoba) (1975)	Manitoba Hydro	Calculations to predict the ice regime and flow levels during construction of the project.
P3885	Northern Staging Area (1975)	Northcan/Canadian Arctic Gas	Study of flooding related to ice jamming of potential wharf sites on the Hay River and Upper Mackenzie River.
P3663	Churchill River (1975)	Manitoba Hydro	Calculations to predict the ice regime and flow levels following diversion of power flows through the Rat River – Burntwood River system.[8]

[8]Lavender, S. T., and J. E. Cowley. Convective Heat Transfer at an Ice Water Interface, NRC Research Seminar on the Thermal Regime of River Ice, Laval University, 1974

ACRES

Project Number	Project	Client	Description
P3396	Lake Erie – Niagara Ice Boom (1974)	International Niagara Board of Control	Extended study of the environmental effects of use of the ice boom at the head of the Niagara River.[5,6]
P3495	System study to extend the winter navigation season on the St. Clair and Detroit rivers (1974)	United States Army Corps of Engineers	Study of the ice problems encountered by shipping during winter navigation and evaluation of alternative measures for extending the ice season.
P3344HM	St. Lawrence Marine (1973)	CECOP Company Limited	Feasibility and hydraulic model study for constructing a terminal for tankers. Included were simulations of the effects of both tidal current and winds on ice movements and mathematical simulation of vessel delays caused by ice conditions.[7]
P3176	Arnprior Generating Station (1972 – 1975)	Ontario Hydro	Design of ice boom and other control works. Basic data were derived from detailed ice observations employing air cushion vehicles and from hydraulic model tests.
P2999	Long Spruce Generating Station (1971)	Manitoba Hydro	Calculations to predict the ice regime and flow levels during construction of the project.
P2904	Study of Lake Erie Ice Boom (1972)	Water Survey of Canada	Study of the effect of the Lake Erie ice boom on ice retention and dissipation in Lake Erie.
P2614	Offshore Structure Study (1971)	Bow Valley/Acres Santa Fe – Pomeroy	Feasibility study of exploratory drilling platforms to be used in the Beaufort Sea.
P2330	Arctic Marine Terminal Module (1970)	Van Houten Assoc. Inc. for Esso Research and Engineering Company	Review of the proposed design for a marine terminal module to be used for the collection of environmental data and as a loading terminal for ice-breaking oil tankers.
R40	Study of Offshore Drilling Structures (1970)	Acres Limited	Conceptual engineering studies for offshore oil drilling platforms operating in slow-moving pack ice.
P2084	Study of the Effects of Thermal Inputs to the Great Lakes (1970)	Government of Canada Department of Energy, Mines and Resources	Study of the sources, amounts and results of heated effluent discharges into the basin of the Great Lakes.
P2113	Ice Forces Measuring Systems (1969)	Government of Canada Department of Transport	Design, Supervision of installation and commissioning of a system for measuring ice forces on lighthouses of various shapes.
P1140	Mactaquac Hydro Electric Project (1969)	The New Brunswick Electric Power Commission	Study of the mechanism of ice jams in the Saint John River above the Mactaquac Hydro-Electric Power Development.

[5] Acres Report published by the International Joint Commission, 1974.

[6] Rumer, R. R., C. H. Atkinson, and S. T. Lavender. Effects of Lake Erie–Niagara River Ice Boom on the Ice Regime of Lake Erie. Third International Symposium on Ice Problems, Hanover, New Hampshire. 1975.

[7] Cowley, J. E. Quantitative Application of Ice Climate Data to Winter Navigation Studies.

Project Number	Project	Client	Description
P2065	Evaluation of Ice Research Benefits (1969)	Government of Canada Department of Energy, Mines and Resources	Studies of the theory and nature of ice, its effect on various structures, the economics of ice control and preparation of a program for ice research.[4]
P1432	Kettle Rapids Generating Station (1968)	Manitoba Hydro	Studies of the ice break-up in the Nelson River and the passage of ice through the powerhouse openings during construction. (Included field observations, physical modeling and analytical assessment.[3])
P1520	Churchill Falls Power Project (1968)	Churchill Falls (Labrador) Corp.	Study of the mechanism of formation, nature and behavior of ice covers in a reservoir system and prediction of its effects on operation.
P1000	Northumberland Strait Causeway (1967)	Government of Canada	Measurement of the forces exerted by ice floes on fixed structures in the field in conjunction with an extensive scale model study of ice forces on various pier shapes.[2]
R53	Development of Model Ice Material (1966)	Acres Limted	Development of model ice material for use in a structural hydraulic model.
P1111	McCormick Dam Project No. 3 (1965)	Manicouagan Power Company	Prediction of ice formation in the forebay and winter water temperatures due to sequential development of upstream reservoirs.
P867	Mactaquac Hydro-Electric Project (1962)	The New Brunswick Electric Power Commission	Prediction of ice conditions and the risk of ice jamming in the city of Fredericton following dam construction.
P826	Grand Rapids Generating Station (1960)	Manitoba Hydro	Study of ice conditions in Cedar Lake and prediction of winter temperature in the forebay. Probability analyses were made on the formation of ice cover in the forebay channel and of ice jams in the tailrace.
P776	Outardes and McCormick Power Development (1959)	Manicouagan Power Company	Study of the frazil ice conditions in the McCormick forebay.[1]
P724	Kelsey Generating Station (1957)	Manitoba Hydro	Study of the ice conditions to be expected in the forebay of the power station.
P608	Bersimis 1 Power Station (1955)	Quebec Hydro	Investigation of the formation of an ice cover in the forebay channel and the effect of heat storage in the water of the Lac Casse Reservoir.

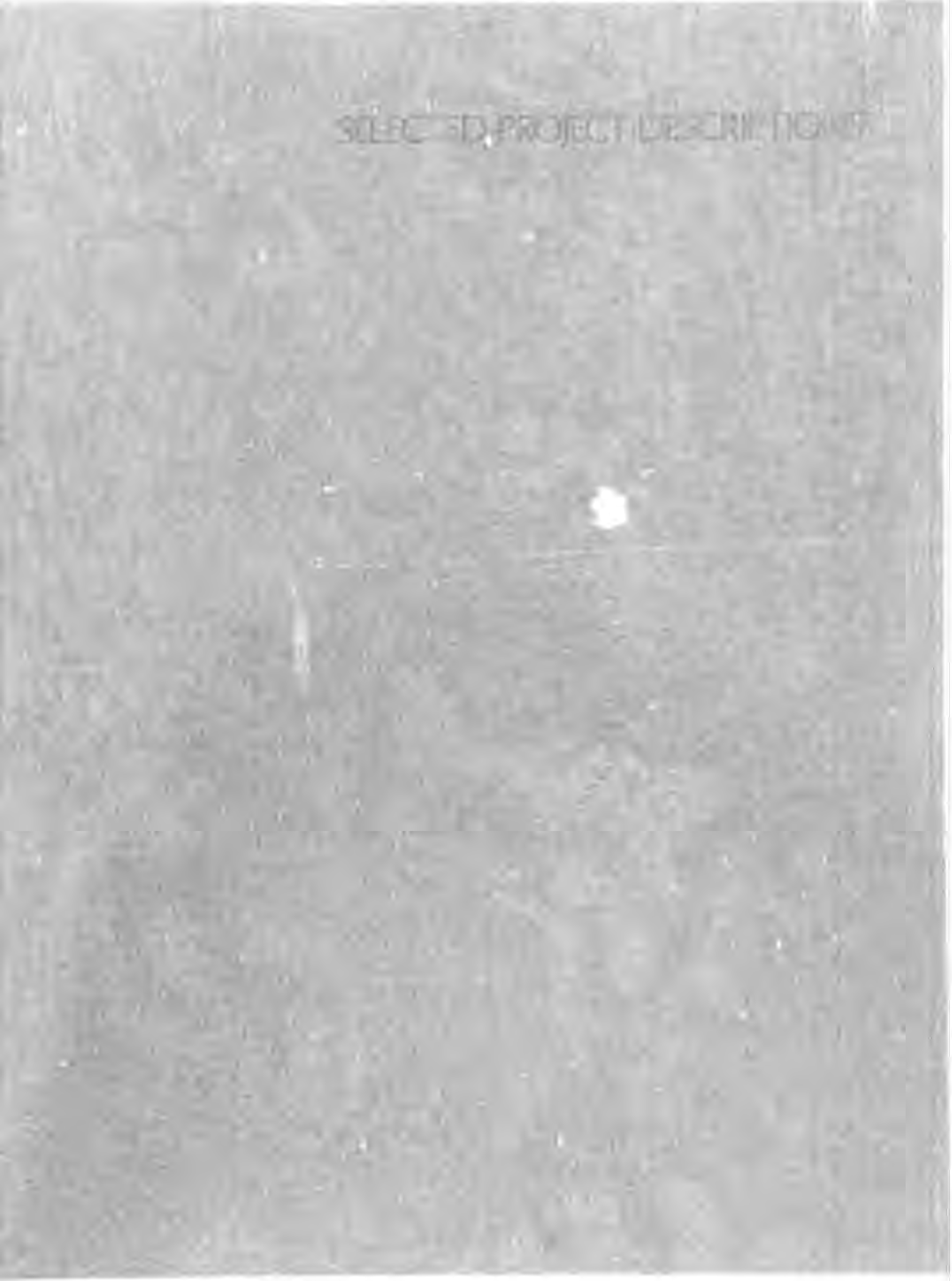
[1] Erickson, O. M., R. N. Millman and R. L. Clinch. Ice Problems at McCormick Dam – Tests on a Pilot Bubbler System.

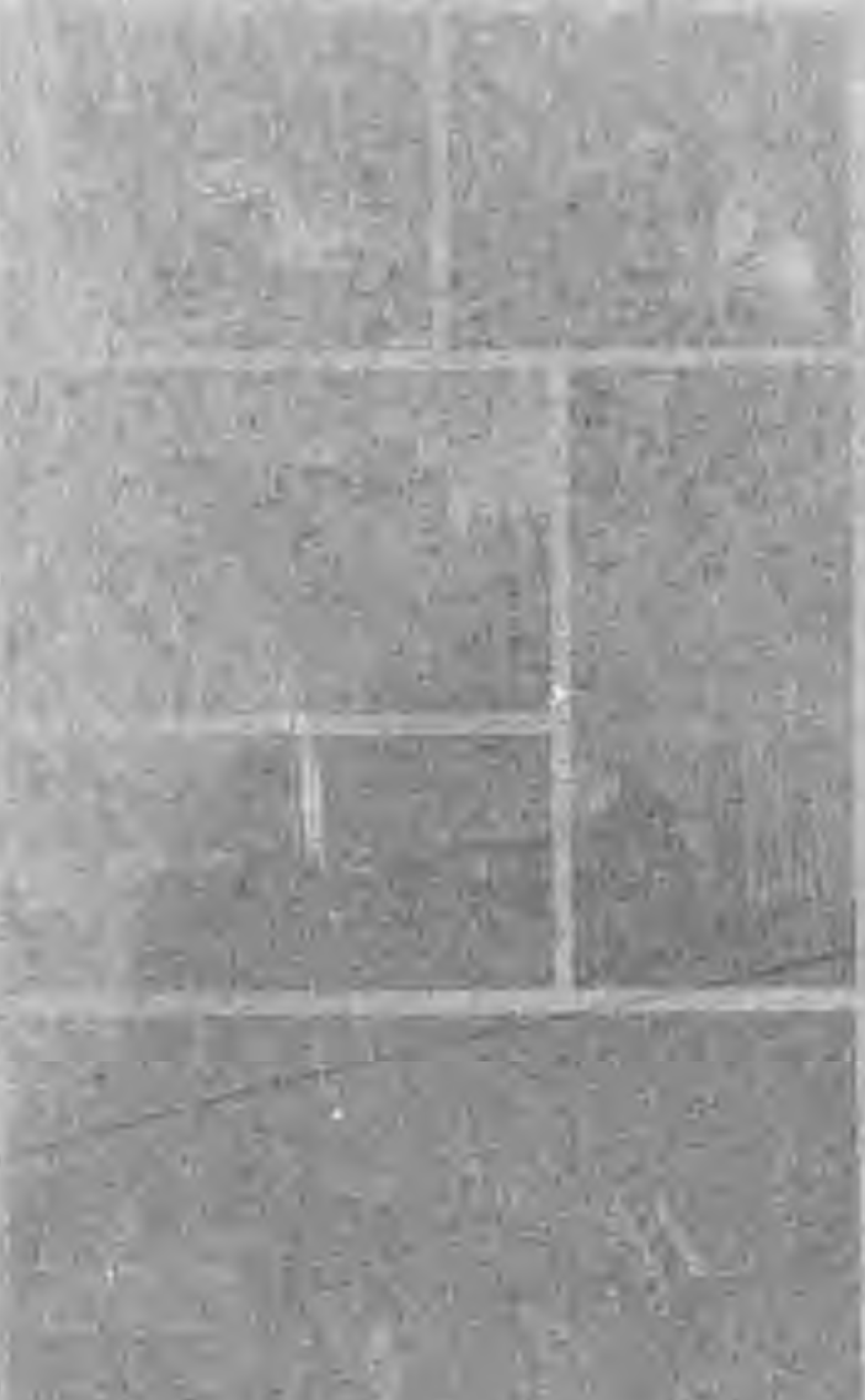
[2] Cowley, J. E. Ice Model Studies for the Northumberland Strait Crossing.

[3] Macdonald, E. G. and H. R. Hopper. Hydraulic Model Simulation of Ice Jamming During Diversion of the Nelson River. Awarded the Keefer Gold Medal of the Engineering Institute of Canada for 1972.

[4] Reprinted and published by the Department of Public Works of Canada.

SELECTED PROJECT DESCRIPTIONS





GULL ISLAND HYDROELECTRIC PROJECT
ICE STUDIES

P3901.11

Location Churchill River, Labrador

Client Gull Island Power Company

1975

Field surveys were undertaken to establish the interrelationship of the hydraulic, hydrologic and ice regimes of the natural river. Observations of development and dissipation of the ice cover and water levels were made in a 25-mile reach of the Churchill River from Gull Lake to about 20 miles upstream of the site of the proposed Gull Island power project over two winters, 1974–1975 and 1975–1976. Heavy ice conditions with staging in excess of 20 feet above the summer rating prevail in the lower reaches of the study area.

Hydraulic model tests of the river diversion planned for the project and ice stability analyses were combined in assessing the best approach to ice handling during construction. The requirements for regulating upstream water levels to maintain a stable ice cover were determined. It was concluded that the benefits of upstream control would not justify the cost of regulating gates. Cofferdam heights to allow for uncontrolled ice staging through the tunnels were established.

ST. MARY'S RIVER ICE MODEL

P3855

Location Sault Ste. Marie, Michigan

Client U.S. Corps of Engineers

1975

This project was part of a research and study program to develop feasible solutions to problems created by frequent ice buildups in the narrow channel between Sault Ste. Marie, Michigan and the area below the Little Rapid Cut area of the St. Mary's River, Michigan.

Broken and frazil ice float downstream into the cut. The resulting ice jams restrict commercial vessel passage and prevent regular ferry transportation to and from the mainland for the two hundred families who live on Sugar Island,located in the channel.

The model, verified against field observations, simulated the effects of relocating the ferry crossing, widening of the riverbed, the use of ice control booms and ice harvesting methods, the creation of ice-flow diversions and ice suppression systems.

The model riverbed and shoreline forms a Y shape in an area 120 feet by 200 feet, includes a model vessel, and utilizes specially treated polypropylene pellets to simulate ice.

The influence of discharges from power canals and industry, the effects of changes in ice supply due to vessel passage, the effects of size, various wind conditions and the impact of vessel size and speed on ice jamming and accumulation were studied.

Remedial measures recommended as a result of the study and put into service in the winter of 1975/76 have proven highly successful.

ST. CLAIR-DETROIT RIVER SYSTEM STUDY P3495

Location St. Clair and Detroit Rivers

Client U.S. Army Corps of Engineers

1973

A study to determine what enabling measures would be necessary to extend the navigation season between Lake Huron and Lake Erie. Ice conditions, climatological and hydrological conditions, hydraulic characteristics of channels, and operating characteristics of vessels were investigated and the information used to develop design criteria for enabling measures.

Vessel operating capabilities in ice covered waters were developed as the key factor in the study. Design winter conditions were established from analyses of available data and problem reaches in the area were defined by relating these conditions to the vessel operating capability.

The enabling measures recommended included ice-breaker assistance, ice booms, pile clusters and air bubbler systems. These measures would permit year-round navigation.

Capital costs and annual operating costs for the selected scheme were developed.

A complete environmental assessment evaluating all relevant environmental, social and recreational factors in the study area resulting from the extended season navigation was also undertaken.

SITE INVESTIGATIONS FOR DEVELOPMENT OF A ST. LAWRENCE MARINE TERMINAL — P3344H

Location — Grande Ile, St. Lawrence Estuary, Quebec

Client — CECOP Company Limited:
Ashland Oil Canada Limited
New England Petroleum Company Limited

In support of a study of the feasibility of constructing a terminal for 300,000-dwt tankers at Grande ile, site investigations were carried out to establish:

- tidal current conditions
- ice conditions
- local bathymetry
- geological conditions

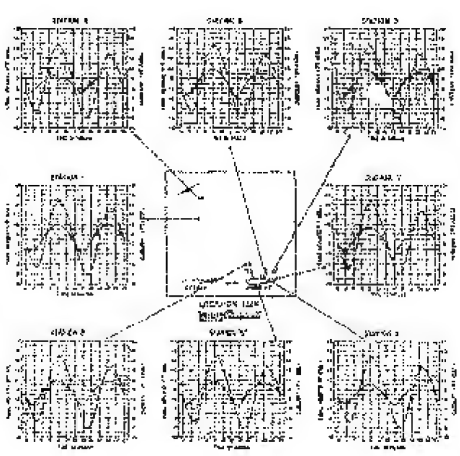
The field investigations supplemented analyses of regional and local climate, ice conditions, bathymetry, clearances, tides and currents along the approach route. They provided the more detailed knowledge required in the vicinity of the proposed terminal.

The tidal range at Grande Ile varies from 4 to 19 feet. The structure of adjacent tidal flows was established by measurement, over a period of 18 days of velocity and temperature/salinity relationships throughout the depth of the estuary at 8 stations. Details of surface eddies were established from shipboard observations, time-lapse aerial photography and simulation of flows in a hydraulic scale model.

Ice conditions were evaluated by field observations, aerial reconnaissance and mapping, and by detailed analyses of Ice Central records.

Bathymetry and underwater geologic structure were established by sounding and seismic surveys.

Geological conditions were established by reconnaissance, mapping, drilling, and laboratory analysis of samples.



HYDRAULIC MODEL STUDY FOR
A ST. LAWRENCE MARINE TERMINAL

P3344HM

Location Grande Ile, St. Lawrence Estuary, Quebec

Clients CECOP Company Limited
Ashland Oil Canada Limited
New England Petroleum Company Limited

In support of a study of the feasibility of constructing a terminal for 300,000-dwt tankers at Grande Ile, a hydraulic model study was undertaken to establish

the effects of various structural alternatives on tidal currents in the approaches to the ship berths. The tidal range at the site is 18 feet and currents of up to 3 knots are experienced in the area.

the effectiveness of various alternatives for protecting the berths against floating ice fields without causing unfavorable changes in currents.

The model reproduced an area 1.3 by 2.6 miles at a scale of 1:200. A radio-controlled model of a 300,000-dwt vessel of 1,200 foot length and 50-foot draft was employed. The effect of tidal currents and winds on ice movements was simulated. Different arrangements of ice booms and ice control structures placed at each end of the docking area were compared. Skimming booms which restricted longshore ice movement without appreciable influence on strong tidal currents proved the most effective.

ICE STUDIES FOR EXPLORATORY DRILLING SYSTEM P2614

Location Beaufort Sea

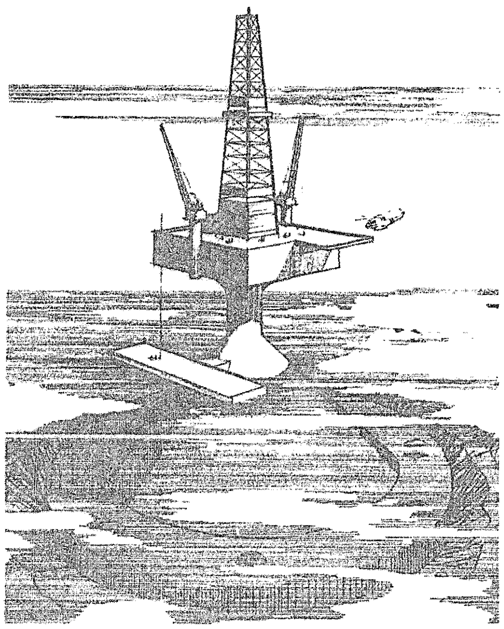
Client Arctic Petroleum Operators Association

1971

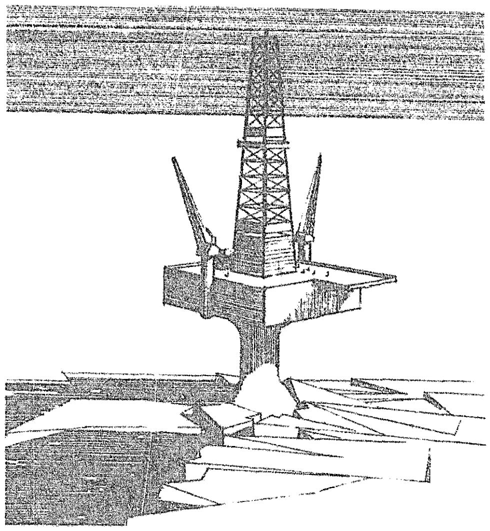
As part of an investigation of potential methods of exploratory offshore drilling in the Beaufort Sea, one area of major concern was the potential for ice damage to the drill platform.

An extensive review of available data from observations of the ice pack, controlled field testing and laboratory testing, as well as various theoretical analyses, were used to determine design loads for various structure types during both summer and winter conditions.

As part of this ice study the existing ice reconnaissance data was analyzed, and maps prepared with contours indicating annual periods with various probabilities of exceedance for a range of ice conditions. These maps give a picture of the ice conditions over the area of interest, in terms that can readily be translated into the statistics, describing the frequency distribution for the number of days available for various types of platforms. The analysis included consideration of forecasting ability, and required monitoring to ensure that a well could be safely abandoned ahead of incoming ice and then continued after the ice moved out.



Summer Loading



Winter Operation

Location Saint John River, New Brunswick

Client The New Brunswick Electric Power Commission

1969

Study of the mechanism of ice jam formation in the Saint John River above the Mactaquac hydroelectric power development to determine what operation schedules of this and associated developments might reduce or eliminate the formation of ice jams and the resulting flooding and loss of power production during the spring ice break-up.

The work included the assessment of the value of mathematical and physical models for the simulation of dynamic ice regimes. This portion of the study indicated that simulation by means of mathematical methods is possible and that physical models are of limited usefulness due, mainly, to their inability to reproduce thermal effects.

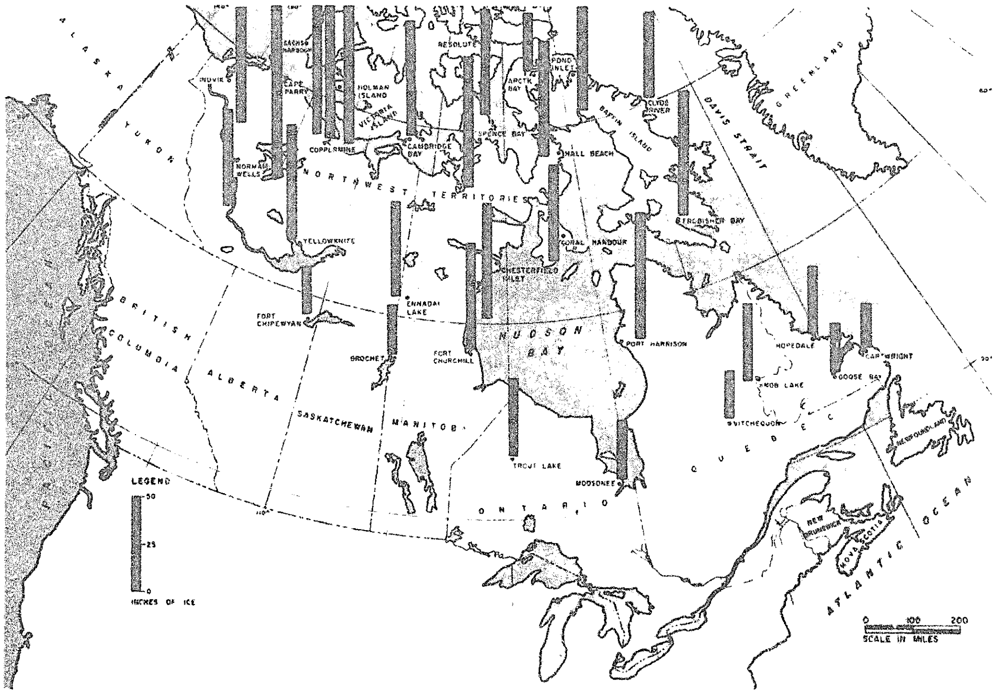
The work also included an outline of the field work that must be undertaken to obtain the data for the development of a working mathematical model of the ice regime.

EVALUATION OF ICE RESEARCH BENEFITS P2065

Client Government of Canada
Department of Energy, Mines and Resources

1969

Studies of the theory and nature of ice formation, the growth and decay of ice cover, the physical properties of ice, and the effects of ice on water control structures and waterways; evaluations of the economic aspects of ice effects on water control structures, water supply systems, navigation, climate ecology and water quality; reviews of the methods and economics of ice control; and preparation of a program for ice research, based on the greatest potential benefit scale.



Ice Thickness In Canada
(March 1966)

ARCTIC MARINE TERMINAL MODULE P2330

Location North Coast, Alaska

Client Van Houten Associates, Inc. for
Esso Research and Engineering Company

1969 – 1970

Independent review of the proposed design for a marine terminal module to be used initially for the collection of environmental data and possibly later as a mooring-loading terminal for ice-breaking oil tankers.

Location Northumberland Strait between New Brunswick and Prince Edward Island

Client Northumberland Consultants Ltd.
for Government of Canada

1967 – 1968

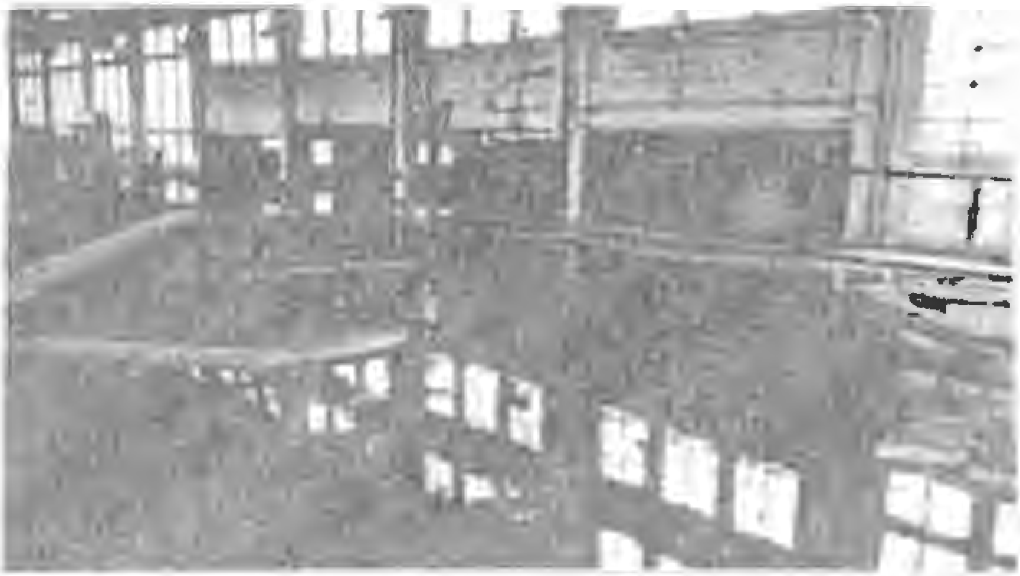
Engineering services were provided for the construction, calibration and testing of hydraulic models and apparatus to determine environmental changes which may have occurred to the tidal regime of the strait following the construction of a major crossing structure, and to investigate ice and wave forces likely to be encountered by the piers of the proposed crossing.

Tidal Model Study

The tests were conducted on a model having a vertical scale of 1:64 and a horizontal scale of 1:6400, and investigated the effects on the tidal regime of the strait that would have resulted from the construction of various types of structures.

Ice Floe Model Study

Tests were conducted on a model having a scale of 1:60; used a substance of special formulation which had appropriate mechanical properties to simulate the action of ice at the scale of the model and a dynamometer of special design which measured the forces on the model piers. The tests determined the magnitude and direction of the forces due to ice floes on the piers of bridge-type structures and the mechanics of the break-up of ice floes.



Ice Floe Forces Apparatus

The apparatus consisted of a pair of hollow steel panels with relatively flexible walls and containing a pattern of hydraulic flat jacks equipped with pressure-sensing devices that produced oscillographs of the forces exerted by ice at various elevations over various periods of time on the vertical faces of the pier. The tests determined the forces exerted by a large ice floe when driven by strong winds against the end of a pier at Port Borden, Prince Edward Island.

Flume Model Study

The tests were conducted at a scale of 1:20 in the 65-foot long wave flume of Acres Laboratory, Niagara Falls, and were used to determine the most economic combination of dike freeboard, dike slope, primary precast concrete armor units and secondary riprap requirements to protect the rock-fill core of the causeway section of the crossing from the combined effects of a 20-foot design wave, currents resulting from partial closure of the strait that is affected by 8-foot tides, and the movement of large ice floes.

Wave Action Model Study

The tests were conducted on a model having a scale of 1:60 with a working basin 60 feet long by 20 feet wide. The model was equipped with two pneumatic wave generators, each 10 feet long, which were capable of simulating the three-dimensional action of wave trains and tidal currents on submerged structures; and it was used to determine the effects of wave action and tidal currents on the causeway ends and on the bridge piers.

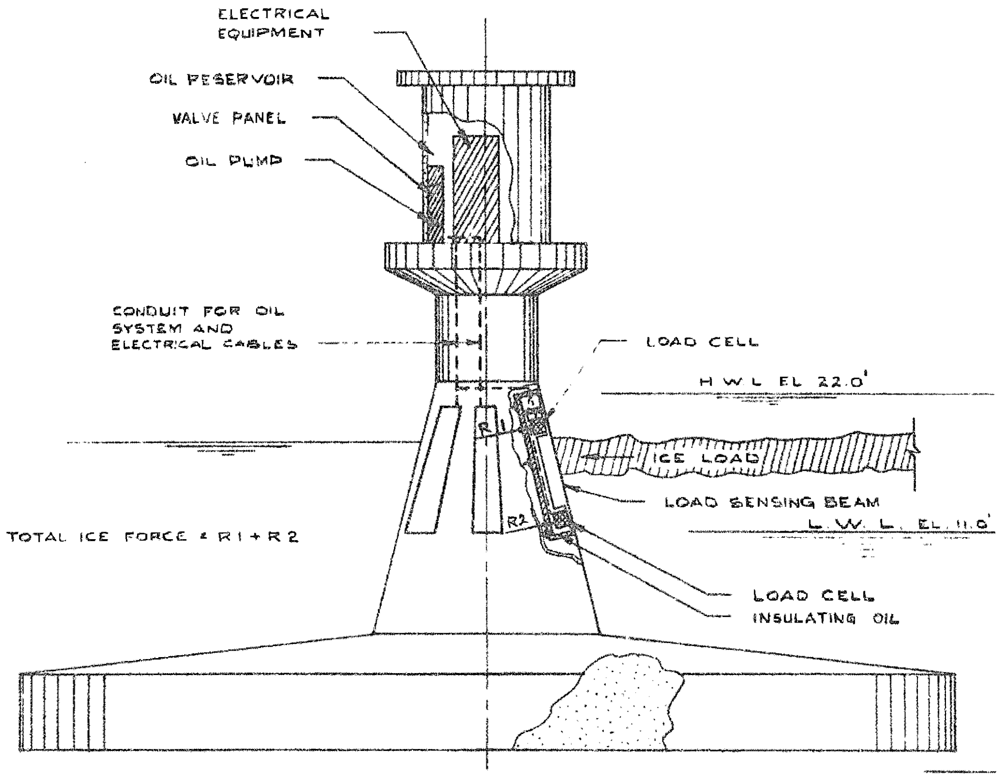
Wave Amplitude Test Apparatus

The measuring apparatus consisted of an electronic circuitry cabinet and an electrode probe mounted on a mast, 50 feet in length, that was anchored to the ocean floor 1 mile from the shore. The sensing devices on the mast were connected by a seven-conductor submarine cable to a power source and chart recorder located on the shore. The apparatus was capable of measuring waves having a maximum amplitude of 20 feet, and was used to determine the amplitudes, lengths and patterns of the waves in the strait.

Client Government of Canada
Department of Transport
Works Branch

1969

Analysis of the characteristics of three given shapes for lighthouses, evaluation of the feasibility of developing systems for measuring ice forces on each of the lighthouse shapes, studies of the forms and characteristics of measuring components and systems, selection of a system most suitable for each lighthouse shape, and preparation of preliminary designs and cost estimates for each recommended system.



Ice Force Instrumentation

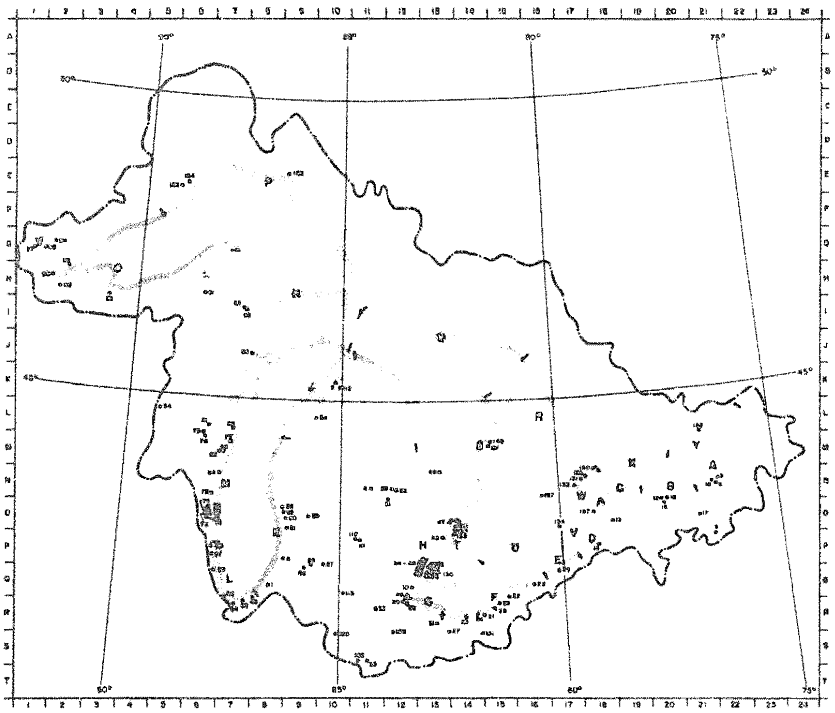
THERMAL POLLUTION STUDY P2084

Location Great Lakes Basin, Canada

Client Government of Canada
Department of Energy, Mines and Resources

1969

Survey of the sources of heated effluent discharges into the basin of the Great Lakes, Canada; forecasts of the amounts and patterns to the year 2000 of artificial thermal inputs; computation of resulting temperature changes using four mathematical models of transporation and diffusion; analysis of the effects of the thermal inputs on evaporation, ice, climate, ecology and economic factors; and preparation of a schedule of recommendations covering the nature and economic value of further research.



LAKESHORE SECTIONS AND LOCATIONS OF EXISTING AND COMMITTED THERMAL GENERATING STATIONS

KETTLE GENERATING STATION

Location Nelson River, Manitoba

Owner Manitoba Hydro

Consortium Crippen Acres Limited

1971

Value $220,000,000 (Approximate capital cost)

Engineering for a complete hydroelectric power development having twelve generating units, each with a rating of 104 Mw under a design head of 98.5 feet.

The main dam (earth fill)/spillway/powerhouse structure of the development is approximately 5,586 feet long, and the reservoir dikes have a total length of approximately 35,000 feet.

The work included extensive studies of the probable effects of ice jams on the heights of cofferdams required for the various stages of river diversion during construction. The studies focused primarily on the scheme for Stage II diversion through the partially constructed powerhouse intake. This scheme involved raising the water level and maintaining a stable ice cover immediately upstream from the site, in order to prevent ice from jamming in the narrow flow passages. The ice studies included field surveys to establish the natural ice regime of the Nelson River and simulation of ice jams in a 6-mile reach of the river, using an 85-foot long hydraulic model, to determine the minimum height of the upstream cofferdam.

Actual operation in the field during diversion was in accordance with the results of the ice model studies in all major respects. A stable ice cover was successfully formed at the recommended level, and was maintained until late spring when the weakened ice cover was safely sluiced through the control structure.

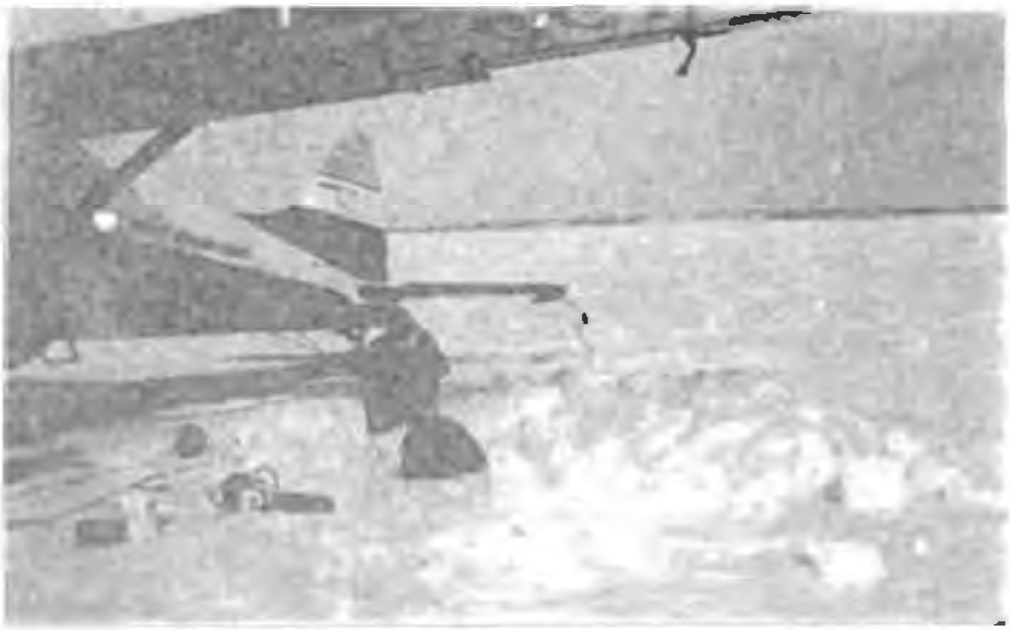
Location	Churchill River Labrador, Newfoundland
Project Managers	Acres Canadian Bechtel of Churchill Falls
Owner	Churchill Falls (Labrador) Corporation Limited

Due to the northerly climate of Labrador, design problems related to ice were encountered in virtually every flow reach upstream and downstream of the Churchill Falls powerhouse. Frazil ice dams and spring ice jams observed in the natural regime had to be eliminated or bypassed through careful design in order to maintain flow to the powerhouse and avoid increase in tailwater levels.

An extensive field survey of ice thicknesses, water temperatures, flow velocities and bottom profiles was conducted through two winters on the large natural lakes, Michikamau, Lobstick, Sandgirt and Jacopie, which were joined to form the principal reservoir (2,200 square miles) and on the connecting channels between them, as well as on the Churchill River downstream of the powerhouse. These data were used to document the existing regime and to supply data for design calculations.

Thermal and mechanical analyses were applied to various schemes for channel, dike and control structure designs in order to decrease frazil production and ice jam formation to a level where energy production and structure security would not be affected.

In the initial years of operation of the Churchill Falls development, the ice control measures adopted in the design have proven to be effective, and ice has not been a problem.



ARNPRIOR GENERATING STATION ICE STUDIES

P3176

Location Madawaska River, Ontario

Client Ontario Hydro

1972 – 1975

The Arnprior Generating Station has been built within the town of Arnprior on a reach of the Madawaska River which was historically subject to active ice jamming. Extensive investigations were carried out to establish the mechanisms controlling the natural ice regime so that the effects of peaking operation of the power station could be predicted.

Field surveys of natural river conditions were carried out over two winters. Surveys included periodic measurement of flow velocities, ice thickness and extent, and of the depth and form of frazil ice accumulation. A two-man hovercraft permitted observations to be taken in areas which would otherwise have been too hazardous to reach. Flows, water and air temperatures and the overall ice configuration were monitored daily.

Analysis of the field data and hydraulic model studies permitted establishment of the ice conditions to be expected after completion of the project. The tailrace improvements incorporated in the design will result in a significant reduction in the severity of ice conditions in the downstream reaches of the river.

Client Government of Canada
International Niagara Board of Control

The Lake Erie - Niagara River ice boom was originally installed in 1964 to control the amount of ice leaving Lake Erie in the winter season in order to minimize ice jamming and ice handling problems in the Niagara River, particularly at the power utilities intake structures. The boom is effective in attaining this objective, but caused concern over other possible environmental effects. Of particular interest was the effect of increasing the volume of ice in Lake Erie during the winter season and prolonging the period of ice cover at the end of the ice season. Prolongation of the ice cover is a possible factor in extending the spring inversion phenomenon which leads to air quality problems in the Buffalo area.

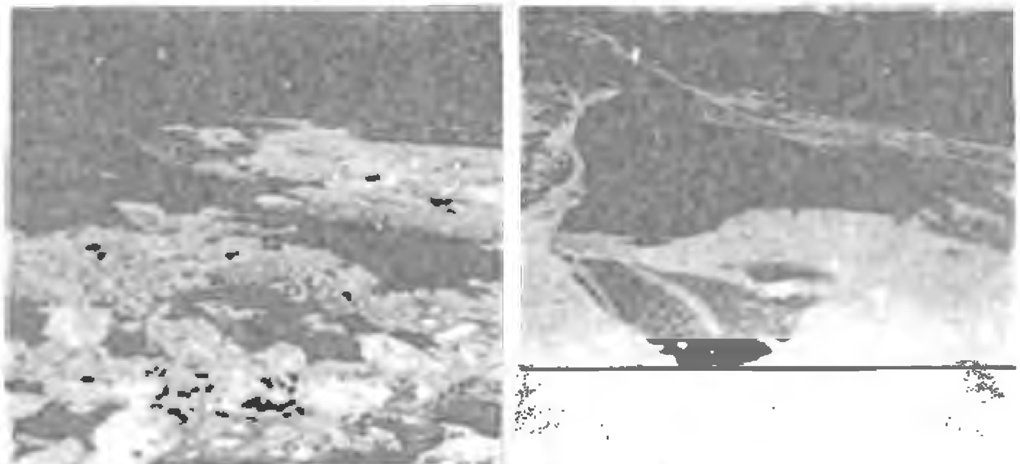
The specific objectives of this study were:

To determine to what extent, if any, the ice boom affects the thickness or extent of the ice field or changes the rate of dissipation of ice in Lake Erie and, hence, has any effect on navigation, recreation, weather, or other environmental considerations.

To determine criteria which would be used annually to establish a date for removal of the boom, which would minimize the impact of ice flows on intakes for power plants and shore property along the entire Niagara River without appreciable adverse effects on the other interests.

The report presented the results of an intensive study of the current state of knowledge of the ice dissipation process in Lake Erie and the possible boom effects on this dissipation process.

The investigation involved a detailed examination of the historical record of ice growth and dissipation in Lake Erie for preboom and postboom years. A statistical analysis was made of water temperature data proximate to the ice boom for preboom and postboom years. Ice melt mathematical models were reviewed and a simplified simulation of the ice dissipation process in Lake Erie was developed.



Photographs courtesy of the Power Authority of the State of New York

Location Conception Bay
Newfoundland

Client Wabanex Energy Corporation

1976

An underground oil storage facility including a deep-water port has been proposed for the abandoned Wabana Iron Mine on Bell Island, Conception Bay, Newfoundland. As part of the feasibility study for the project, an investigation was conducted of the ice conditions in Conception Bay and their relation to navigation by both supertankers and smaller tankers.

Historical ice data were collected, collated and compared with comments of experienced mariners operating in the bay. This analysis produced statistics on the frequency and duration of ice conditions of various severities. The statistics were related to the ice navigation capabilities of supertankers and smaller tankers to obtain a quantified assessment of potential delays to both classes of vessel.

Related studies of currents, meteorological conditions and the biology of the area are being carried out to form a complete package suitable for terminal design and approval under the TERMPOL code.

Client Petro-Canada
Arctic Pilot Project

The Arctic Pilot Project was initiated by Petro-Canada to assist in the development of the natural gas resources of the Canadian Arctic. The project included the drilling and completion of a subsea well and flow line, the installation of a gathering and transmission system, and the installation of a liquefaction system with related marine transport facilities.

The Acres study was concerned with ice management problems at Bridport Inlet, Melville Island, which is the proposed northern LNG terminal. The study included the identification of potential ice management problems and the documentation of the present operators of ships and terminals in ice-infested waters.

A number of potential solutions were investigated, such as icebreaker tug support, bubbler systems, thermal discharge systems, surface heat control, ice removal and ice diversion systems. These solutions were assessed in terms of cost, effectiveness, reliability, environmental and other effects, with the result that several were recommended for implementation.

The study also included an outline of possible field or laboratory programs which may be needed for further design data.

INVESTIGATION OF 1976 ICE JAM ON THE SAINT JOHN RIVER

P4298

Location Saint John River, New Brunswick

Client The New Brunswick Electric Power Commission

1976

In April 1976 major ice jams formed above the head ponds of each of the three power developments on the Saint John River-Mactaquac, Beechwood and Grand Falls. Flooding occurred in the towns of Ste. Anne de Madawaska, Perth-Andover, Hartland and Woodstock. A study was undertaken which

- documented the meteorologic, hydrologic and ice events prior to and during the 1976 spring breakup
- placed the 1976 events in historical perspective with meteorologic, hydrologic and ice conditions of previous years
- assessed the reason for the severity of the 1976 jams and determined the extent to which changes in the operation of the power developments might lessen the impact of ice jams.

Extensive backwater calculations were made to facilitate analysis of the ice jam movements to determine the effectiveness of various possible power development operating procedures.

REPRESENTATIVE PERSONNEL

CHARLES H. ATKINSON — ICE ENGINEERING EXPERIENCE

Education	University of Durham, Newcastle, England B.Sc. (Honours) Civil Engineering, 1953
Professional Associations	Association of Professional Engineers, Ontario — Member American Society of Civil Engineers — Member International Association for Hydraulic Research — Member American Water Resources Association — Member Canadian Society for Civil Engineering — Member Engineering Institute of Canada — Member

1976 Manager, Environmental and Special Studies Division, Acres Consulting Services
1974 Executive Engineer, Acres Consulting Services

Evaluation of the causes of the 1976 ice jam floods on the Saint John River, New Brunswick.

Analysis of the effects of the Niagara ice boom on the ice regime of Lake Erie and on the local environment.

Technical review of ice engineering aspects of the Company's projects, 1968 to 1973.

Responsible for extensive ice studies for detail design, evaluation of the power potential of the entire Churchill River basin, mathematical simulation of flood hydrographs, and statistical synthesis of streamflow data of the Churchill Falls power project, Labrador.

Direction of the engineering services provided for the Northumberland Strait Crossing project, New Brunswick—Prince Edward Island, involving investigation of major ice problems.

1956 — 1963 Head, Hydrological Department, Aluminum Company of Canada Limited

Responsible for ice handling for the hydroelectric power system in Quebec, which has a total installed capacity of 2,600 Mw (including 750-Mw Chute-des-Passes and 900-Mw Shipshaw).

Technical Publications
Related to Ice Engineering

The Determination of Ice Forces on Small Structures
Presented to the Eastern Snow Conference, February 1971 (coauthor)

Measurement of Ice Forces Against a Lightpier
Presented at Conference on Port and Ocean Engineering Under Arctic Conditions, Technical University of Norway, August 1971.

Effects of Lake Erie — Niagara River Ice Boom on the Ice Regime of Lake Erie
Presented at Third International Symposium on Ice Problems, Hanover, New Hampshire, 1975 (coauthor)

JAMES E. COWLEY — ICE ENGINEERING EXPERIENCE

Education	University of Alberta at Edmonton B.Sc. Civil Engineering, 1960 Queen's University, Kingston, Ontario M.Sc. Civil Engineering (Hydraulics), 1962
Professional Associations	Association of Professional Engineers, Ontario — Member American Society of Civil Engineers — Member

1975 Head, Hydraulic Department, Acres Consulting Services

Technical review of the ice engineering aspects of the Company's projects, including

- evaluation of the causes of the 1976 ice jam floods on the Saint John River, New Brunswick
- design of the 1,680-MW Gull Island hydroelectric project, Labrador
- design of the 78-MW Arnprior hydroelectric project, Ontario
- hydraulic model studies of ice conditions affecting navigation in St. Marys River at Sault Ste. Marie, Michigan
- responsible for hydraulic studies, including analyses of regional climatology, measurement of tidal currents and evaluation of ice conditions, and hydraulic model tests of currents and ice movements for a proposed port to handle 300,000-dwt tankers. Ship delays due to ice in the 625-mile inland approach route were calculated
- study of water supply alternatives for Lost River, Alaska (latitude North 65.5 degrees)
- survey of the needs for marine environmental data in the northwest Atlantic for Nova Scotia Research Foundation
- studies and definition of the hydraulic design criteria for a technical and economic feasibility study on development of tidal power sites on the Bay of Fundy
- supervision of field measurements and design, construction and testing of three hydraulic models to investigate effects of tide, wave and ice action on proposed Northumberland Strait crossing structures.

Technical Publications
Related to Ice Engineering

A Model Study of Ice Navigation in the St. Marys River
Presented at the Rivers '76 Symposium, Fort Collins, Colorado, August 1976.

Quantitative Application of Ice Climate Data to Winter Navigation Studies
Second Canadian Hydrotechnical Conference, May 1975.

Ice Model Studies for the Northumberland Strait Crossing
Eastern Snow Conferences Annual Meeting, Boston, February 1968.

Navigation Delays Due to Ice Conditions — Analysis and Case Studies
Fourth International Conference on Port and Ocean Engineering under Arctic Conditions, September 1977 (coauthor).

A. B. (GUS) CAMMAERT — ICE ENGINEERING EXPERIENCE

Education	University of Waterloo, Waterloo, Ontario B.A.Sc. Civil Engineering, 1968 Cambridge University, England Ph.D. Structures, 1971
Professional Associations	Association of Professional Engineers, Ontario — Member Engineering Institute of Canada — Member Canadian Society for Civil Engineering — Member

Experience

1976 —Acres

1976 Engineering Specialist, Technical Development Department

Research and development in the Canadian offshore engineering industry, including marketing studies, specialist projects on ice mechanics and ice-structure interaction, design techniques for offshore structures, and arctic transportation.

In-house review of simulation techniques for navigation delays due to ice conditions.

Inventory of cold regions engineering research capabilities.

Study of ice management techniques for LNG terminal at Melville Island in the Canadian Arctic Study included identification of potential ice management problems, assessment of possible solutions, and recommendation for solution implementation.

1971 —1976 Faculty of Engineering and Applied Science, Memorial University of Newfoundland

1975 Associate Professor
1971 Assistant Professor

Research into instrumentation of offshore structures; design and construction of small offshore platform to monitor wave and ice forces and to test instrumentation systems.

Project coordinator of study to investigate feasibility of Strait of Belle Isle crossing. Study included ice formation, thickness and movement, iceberg tracking and grounding, bathymetric data, tide and current data, and transportation analysis.

Research director for study on northern housing and municipal services for Royal Commission on Labrador.

Coauthor of report on design guidelines for ice forces on marine structures. Review of literature on ice pressures and analysis of existing design codes. Recommendations for Canadian design practice.

Project supervisor for instrumentation project on line forces and fender deflections for berthed supertankers at Come-by-Chance wharf, Newfoundland.

Scholarships and Awards

Athlone Fellowship 1968
National Research Council Bursary 1970

Technical Publications

Navigation Delays Due to Ice Conditions – Analysis and Case Studies by J. E. Cowley and A. B. Cammaert, presented at the Fourth International Conference on Port and Ocean Engineering Under Arctic Conditions, St. John's, Newfoundland, September 1977.

CARL P. S. SIMONSEN

ICE ENGINEERING EXPERIENCE

Education	University of Manitoba B.Sc. Civil Engineering, 1964 University of Strathclyde, Scotland M.Sc. Hydraulic Engineering, 1965 Postgraduate Diploma, Industrial Management, 1966
Professional Associations	Association of Professional Engineers, Manitoba – Member Engineering Institute of Canada – Member American Society of Civil Engineers – Member

1973 Head, Hydraulic Department, Acres Manitoba Limited

Supervision of a study of ice handling during construction of the proposed 1,100-Mw Limestone Generating Station on the Nelson River, Manitoba

Coordinating and supervision of the hydraulic designs and model studies for the Churchill River diversion project, Manitoba. This interbasin diversion project involves a 6-bay control structure (154,000 cfs), a 3-bay control structure (30,000 cfs), a 6-mile excavated channel, and approximately 250 miles of natural river channel. Winter flow conditions and ice effects are the major source of complexity on this project.

Coordinating of the hydraulic design and direction of hydraulic model studies for the 1,000-Mw, 10-unit Long Spruce Hydro-Electric Power Development.

S. THOMAS LAVENDER | ICE ENGINEERING EXPERIENCE

Education
University of Waterloo, Waterloo, Ontario
B.Sc. Mechanical Engineering, 1962
University of Wales, University College of Swansea, U.K.
M.Sc. Civil Engineering, 1968

Professional Associations
Association of Professional Engineers, Ontario — Member
Institution of Water Engineers, U. K. — Member

1974 Hydraulic Specialist, Acres Consulting Services

Principal investigator in the following ice engineering projects:

- evaluation of the causes of the 1976 ice jam floods on the Saint John River, New Brunswick

- prediction of ice effects on the performance of the flow diversion channels from the Churchill River to the Nelson River in Manitoba

- studies of ice handling during construction of the Gull Island Project on the Churchill River, Labrador, and the Long Spruce Project on the Nelson River in Manitoba.

Project Engineer for the following studies:

- Measurement of Ice Forces on Lightpiers, Department of Transport, Canada

- Saint John River Ice Study, The New Brunswick Electric Power Commission

- Development of testing methods and equipment for a structural/hydraulic model of ice loads on a pier.

Technical Publications
Related to Ice Engineering

Convective Heat Transfer at an Ice Water Interface
NRC Research Seminar on the Thermal Regime of River Ice, Laval University, 1974. S. T. Lavender and J. E. Cowley.

Effects of Lake Erie — Niagara River Ice Boom on the Ice Regime of Lake Erie
Third International Symposium on Ice Problems, Hanover, New Hampshire, 1975 (coauthor).

DAVID L. R. CRONIN ICE ENGINEERING EXPERIENCE

Education	University of New Brunswick, Fredericton, New Brunswick B.Sc. (Honours) Civil Engineering, 1966 University of Alberta, Edmonton, Alberta M.Sc. Civil Engineering, 1968 McMaster University, Hamilton, Ontario M.B.A. 1974
Professional Associations	Association of Professional Engineers, Ontario – Member American Society of Civil Engineers – Associate Member

1968 Hydraulics Engineer, Acres Consulting Services

Load cell instrumentation and telemetry for analysis of ice loads on lightpier in St. Lawrence River, including automatic all-weather camera system.

Technical Publications
Related to Ice Engineering

Measurement of Ice Forces Against a Lightpier
Conference on Port and Ocean Engineering under Arctic Conditions, Trondheim, Norway, August 1971 (coauthor).

The Determination of Ice Forces on Small Structures
Eastern Snow Conference, Fredericton, New Brunswick, February 1971 (coauthor).

BRUCE I. McCLENNAN — ICE ENGINEERING EXPERIENCE

Education	University of Waterloo, Waterloo, Ontario B.A.Sc. Civil Engineering, 1972 M.A.Sc. Civil Engineering, 1973
Professional Associations	Association of Professional Engineers, Ontario – Member Association of Canadian Underwater Councils – Member Professional Association of Diving Instructors – Member

1974 Senior Hydraulic Engineer, Acres Consulting Services

Analysis of conditions leading to ice jam flooding on the Saint John River, New Brunswick in April 1976.

Study of the effects of sea ice on navigation to a proposed major oil storage depot at Bell Island, Newfoundland.

Maximum probable flood study using a snowmelt simulation model for Gull Island Hydro-Electric Development.

Mathematical model study of bouyant jets from submerged thermal diffusers, including development of a general computer program for the analysis of head losses and costs of diffuser systems.

Development of an unsteady river backwater system; development of a one-dimensional, unsteady, nonuniform mathematical model; research into semi-implicit solutions of two-dimensional free surface flow using data generated from a physical model.

RICHARD F. WALDEN ICE ENGINEERING EXPERIENCE

Education McMaster University, Hamilton, Ontario
B.Eng. Civil Engineering, 1970
M.Eng. Civil Engineering (Hydraulics), 1973

Professional Associations Association of Professional Engineers, Ontario — Member

1972 Hydraulic Engineer, Acres Consulting Services

Model study of the level regulation requirements for maintenance of stable ice conditions upstream from the diversion tunnels at the Gull Island Hydroelectric Project (diversion designflow 210,000 cfs).

Operation of a hydraulic ice model to determine the effect of ice action on alternative designs for a proposed supertanker port in the St. Lawrence River.

Technical Publications
Related to Ice Engineering

Programming the Equations of Unsteady Flow
Master thesis, McMaster University, Hamilton, Ontario, 1973

WILLIAM POULIER — ICE ENGINEERING EXPERIENCE

Education	University of Edinburgh, Scotland B.Sc. Civil Engineering, 1938
Professional Associations	Association of Professional Engineers, Manitoba – Member Association of Professional Engineers, British Columbia – Member Institution of Civil Engineers

1973 Hydraulic Department Coordinator, Acres Manitoba Limited

Study of the winter regime of the Rat River Waterway from South Indian Lake to Notigi Control Structure for the Churchill River Diversion, Manitoba. The study was undertaken to establish the extent and nature of ice cover at various stages of winter and, consequently the total head losses in the waterway corresponding to the various ice extents.

Study of the winter regime of the Burntwood River Waterway from Notigi Control Structure to the confluence with the Nelson River for the Churchill River Diversion, Manitoba. The study was undertaken to establish the water surface profiles in the waterway at various stages of ice cover development and regression, accounting for local inflow, effects of storage in the waterway, and the dynamic collapse of ice dams.

J. B. FITZPATRICK ICE ENGINEERING EXPERIENCE

Education City and Guilds, U.K.
Mechanical, 1957
O.N.C. Mechanical, 1957

1976 Oceanographic Technologist, Acres Consulting Services

Field survey of ice stability and river flow conditions during diversion of the Nelson River for construction of the Kettle Rapids power project.

RICHARD W. CARSON — ICE ENGINEERING EXPERIENCE

Education — University of Manitoba
B.Sc. Civil Engineering, 1970
M.Sc. Water Resources Development, 1973

Professional Associations — Association of Professional Engineers, Manitoba – Member
Canadian Society for Civil Engineering – Member

Experience

1976 – Acres

1974 – 1976 Senior Engineer, Crippen Acres Engineering

Lower Nelson River – Development of river ice observation programs for each winter of 1974 to 1978. This included planning of water level gauge and ice drilling locations, as well as hydraulic interpretation of the data obtained.

Limestone Generating Station – Development of a computer model of river ice processes on the Nelson River for the purpose of preliminary prediction of ice conditions and required cofferdam heights during the construction period of an 1,100-MW hydroelectric plant.

Development of a program for and supervision of a detailed hydraulic model study of the river ice development to determine safe winter diversion procedures during the construction of Limestone generating station.

Churchill River Diversion,Missi Falls Control Structure – Analytical and hydraulic model studies of ice passage through the control structure.

Churchill River Diversion, South Bay Channel – Design of an excavated channel which is required to pass 30,000 cfs under winter conditions.

Development of backwater relationships for the diversion route under open-water and ice-covered conditions.

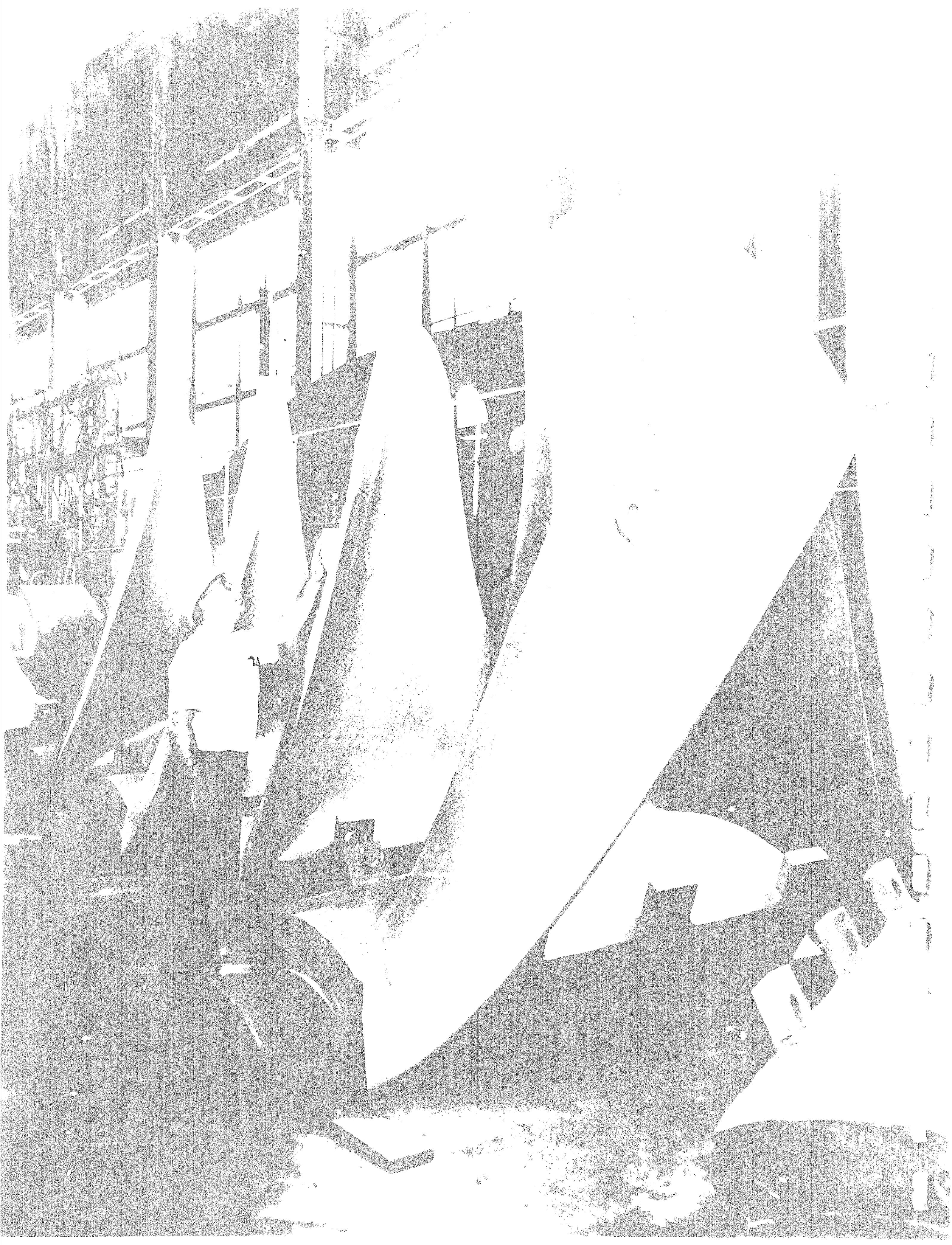
Churchill River Diversion, Burntwood River – Development of a computer model of ice processes to study the effects of ice formation on the winter performance of the Churchill River diversion route downstream of the Notigi control structure.

Lake Winnipeg Regulation – Development of a scheme of reducing Lake Winnipeg outflows in late fall to form a competent ice cover on the natural and excavated channels between Lake Winnipeg and the Jenpeg control structure.

Development of backwater relationships through this reach under winter conditions.

Technical Publications

Ice Processes During Construction of Limestone Generating Station
Proceedings of the Third National Hydrotechnical Conference, May 1977 (coauthor).



INSPECTION, EXPEDITING AND QUALITY ASSURANCE PROCEDURES

INSPECTION AND QUALITY ASSURANCE PROCEDURES .... SECTION 1

FORMULA FOR OPERATION .... SECTION 2

PART ONE - QUALITY ASSURANCE PLAN .... SECTION 3

PART TWO - EXPEDITING PLAN .... SECTION 4

ORGANIZATION CHART .... SECTION 5

TYPICAL REPORTS - TURBINES AND AUXILIARIES .... SECTION 6

SELECTED LISTING OF PROJECTS .... SECTION 7

ACRES

QUALITY ASSURANCE PROGRAM

This program is applicable to Thermal, Hydro and Industrial projects in conformance with:

ANSI-N45-2-1971

DND-1015

MIL-Q-9858A

DND-1016

MIL-Q-45208A

ASNT-SNT-TC-1A Supp. A, B, C, D and E

ASQC-C1

ASME Code Section VIII

ASME Code Section IX

ASME Code Section III

ASME Code Section II Parts A and B

CSA Z299.1

CSA Z299.2

CSA Z299.3

CSA Z299.4




SECTION 1
QUALITY ASSURANCE PROCEDURES

ACRES

QUALITY ASSURANCE PROCEDURES

INTRODUCTION

The Acres Quality Assurance Department is engaged in the provision of high-quality inspection and expediting services in factories and contractors' works on behalf of in-house project groups and/or outside clients.

The nature of this work necessitates particular emphasis on capability, conformance and reliability.

The procedures are set out in two parts, namely, Part One – Quality Assurance Plan and Part Two – Expediting Plan as shown in the succeeding index.

(a) Inspection, Witness Testing and Progress Reporting.

(b) Expediting, Measuring and Control of the procurement progress.

In the Acres concept therefore, one man will not carry responsibility for both functions because of the conflict of interest—that of meeting schedule commitments and at the same time being required to reject work which fails inspection.

OBJECTIVE

The objective of Acres Quality Assurance Management is to provide a service which ensures that products, services and processes will conform to contractual requirements, codes, specifications, procedures and approved drawings.

POLICY

To achieve this objective it is the policy of Acres Quality Assurance Department to establish and maintain an effective Quality Assurance program planned and developed in conjunction with other management functions. Determination of conformance of work to contract requirements shall be made on the basis of objective evidence of quality and quantity.

ACRES AMERICAN INCORPORATED

Consulting Engineers
The Liberty Bank Building, Main at Court
Buffalo, New York 14202

Telephone 716-853-7525

Other Offices: Pittsburgh, Pa.; Raleigh, N.C.; Washington, D.C.

ASSOCIATED INSPECTION AUTHORITIES

To provide inspection and/or expediting services outside the continental limits of North America, Acres may, with the approval of the purchaser, delegate responsibilities to firms with whom they have been associated and whose services have previously been rendered with satisfactory results in respect to similar equipment.

In the event of such delegation, the firm selected will perform services on behalf of and will report to Acres who will, in turn, report to the purchaser in a manner so arranged as to avoid undue reporting delays or other complications.

PREAWARD EVALUATION

Included in this brochure will be found various standard Acres forms in current use. When requested by the client, surveys such as outlined in these documents have been found to be extremely revealing and useful when completed at the proper time, usually prior to the award of an order or contract, and they assist in determining the probable outcome of quality and adherence to schedules.

REPORTS

Acres Inspection and/or Expediting reports are prepared and issued to the client as required, on an agreed schedule. These scheduled reports are distributed to all interested parties in accordance with a prearranged distribution list as directed by the client.

VALIDITY

In order to function as a bonafide extension of the clients' Purchasing or Engineering departments, external or in-house, the program is initiated by the following documents:

(a) Submission and approval of estimated costs.

(b) Assignment for Quality Assurance and/or Expediting services.

(c) Advice to the vendor that Acres Quality Assurance Department is authorized to inspect and/or witness tests on behalf of the client; copies to Acres.

(d) Purchase orders on prime vendor(s) and amendments. (Suborders will be secured directly from the prime vendor.)

(e) Updated field and shop schedules, critical path diagrams and bar charts as available.

(f) Copies of technical correspondence altering quality, quantity and intent of purchase agreements during the life of the assignment.

RESPONSIBILITY

Clearly the responsibility for meeting quality and the delivery schedule is that of the vendor. This program is not intended to replace the vendor's duties in this respect.

However, the overall project responsibility is that of the client or project manager. The Acres Quality Assurance program is designed to assist the client or project manager in meeting the stipulated on-stream schedule and to ensure maximum usage after start-up.

SECTION 2
FORMULA FOR OPERATION

FORMULA FOR OPERATION

GENERAL

The need for Quality Assurance is obvious. Quality Assurance guarantees that each project will meet quality and delivery schedules and yet this important factor is often overlooked in initial planning stages. In many instances, Quality Assurance is not implemented until serious product failure has resulted in costly delays.

Acres Quality Assurance Department, established in 1966, has in-depth capability in inspection, progress reporting, and expediting. As an extension of the Consulting Engineering and Project Management services, the department is able to provide complete control and supervision over manufacturing of engineering products for thermal, hydraulic, petrochemical and industrial projects.

SCOPE

The scope of services may vary from a nominal advisory function to complete involvement in project undertakings, including review of procedures and specifications, preaward evaluation of contractor's facilities, shop inspection, progress reporting, expediting of information and equipment, and site inspection during erection and commissioning.

BACKGROUND

Our background represents 100 years of experience in machine shop and foundry practices, electrical manufacturing and testing of engineered products. It covers expertise in the interpretation of plans and specifications, knowledge in the end use of equipment, and broad experience in manufacturing, erection procedures and plant operation.

Our department is able to draw from in-house expertise in the various disciplines in science and engineering when specialized technical knowledge is required. This guarantees that materials, components and supplies meet contract stipulations.

EXPERIENCE

Our specialists have wide experience in: nondestructive testing of raw materials; fitting of machinery; static and dynamic balancing; assessment of vibration and noise level of rotating equipment; static, hydrostatic, and gas testing of pressure vessels and containers; functional, applied and induced potential, impulse, resistance, impedance, ratio, polarity, temperature and operational testing of electrical equipment.

EFFECT

The client can be certain that materials are supplied, and engineered products are built in the shops in accordance with the requirement of purchase documents, specifications, data sheets, approved procedures, drawings, and applicable codes and standards. Deviations are immediately disclosed and brought to the attention of the client, his delegate, or the engineer. By immediate initiation of corrective action, cumulative errors are avoided and schedules are maintained.

Effective monitoring of manufacturer's quality control at the proper stage during manufacture ensures that the capital and human resources invested in the preparation of designs, specifications, and detail drawings will not be wasted. It guarantees that custom-built equipment exactly meets design standards or agreed changes and, therefore, gives maximum usage after start-up. It minimizes site erection time since tolerances and clearances are held to design limits so that components fit on assembly at site.

DEDICATION

Acres Quality Assurance policy is dedicated to a "Zero Defect" concept and, while this may be difficult to achieve in full measure, deviations are evaluated on the basis of their overall effect upon the equipment and the project, and the concept does achieve a high degree of quality and reliability.

PARTICIPATION

Continuous participation in, and association with, modern engineering, manufacturing methods, and quality control techniques place the Acres Quality Assurance Department in a position of importance in the successful completion of construction projects.

As an added service to our clients, Acres includes a material review facility whereby engineers and inspectors may trade information as to the suitability and acceptability of raw materials or finished parts.

SECTION 3
PART ONE
QUALITY ASSURANCE PLAN

ACRES

PART ONE

QUALITY ASSURANCE PLAN

General

The Quality Assurance program, together with associated procedures and contractual documents, is designed to ensure that clients' quality requirements are recognized by the vendor and that consistent and uniform control of this quality is adequately maintained. The Quality Assurance program is assisted by formal written procedures approved by the engineer and/or client, and provides competent personnel and sufficient inspection coverage throughout all phases of the work furnished and performed by others in order to ensure conformance with contract requirements.

The Quality Assurance program is established to meet the requirements outlined in the different national and international standards, codes, specifications and other customer requirements.

The Quality Assurance program is adjusted to suit the complexity of products, quantity under process, reliability and interchangeability requirements, and production techniques. It includes provision for assurance of prompt detection of discrepancies and for timely and effective action.

Validity

Part One of the Quality Assurance document describes the procedures and formalities in force within Acres to ensure that the contract requirements are being met and therefore reliability of equipment in service will be achieved.

The Quality Assurance Department of Acres

- constitutes a divisional organization for quality, directions and quantity follow-up of products for the client;
- solicits and coordinates activities in the shops in order to create and maintain an optimum quality level for the products consistent with the ruling specifications, codes and drawings;
- is responsible for ensuring that products comply with quality requirements of applicable standards.

These general directions imply that the Acres Quality Assurance Department

- reviews the manufacture of products during development and production stages, and continuously monitors established routine for changes in quality;

- is responsible for ensuring that in-plant inspection of products during production stages is carried out satisfactorily by certified and responsible inspectors;

- is responsible for ensuring that established inspection routines and procedures concerning special processes are maintained;

- is responsible for ensuring the calibration and inspection of gages and instruments is being followed satisfactorily;

- is the coordinating influence for the client for failure reporting and, with the cooperation of the engineer and the necessary records, for analyzing the quality situation and initiating necessary corrections;

- reviews and comments on the specified requirements, and alerts the client or engineer at an early stage if there are prerequisites for obtaining an acceptable product;

- deals with faults which are discovered during inspection, on an individual basis, according to the seriousness of their effect.

Workmanship

Every employee of the Acres Quality Assurance Department is responsible within the framework of his capability for:

- the correctness of his work and statements made in his report;

- receiving documentation from the vendor and ensuring that it is representative of the material offered and that the material is of acceptable quality;

- ensuring that faults are discovered and reported on a timely basis;

- ensuring that reasonable measures are taken by the contractor to prevent repetition of such faults.

The above implies that the Acres Inspector is responsible for ensuring that:

- obvious defects at the beginning and/or throughout the manufacturing phases are corrected, and that parts are carefully checked against applicable drawings, procedures and specified requirements;

- checking takes place to the extent necessary or as reasonably judged necessary, to ensure compliance with all nondestructive, procedural and operational testing.

Inspection Equipment

The Acres Inspector will normally use instruments, measuring tools, tapes, rules, straightedges, gage blocks, meters, controllers and gages which are supplied by the contractor or vendor and are known to conform to applicable standards and maintained in good condition.

X-ray, ultrasonic, magnetic particle, dye penetrant, resistance, temperature and high-potential testing, due to the sophisticated nature of some of this equipment and attending regulations, will be witnessed by the Acres Inspector in conjunction with the contractor's or vendor's personnel and in accordance with the restrictions imposed on outside inspectors by the suppliers and the ruling safety regulations.

In cases where the contractor or vendor does not maintain suitable test equipment or measuring devices, the Inspector may require him to obtain outside assistance to satisfy the requirements of the contract.

Manufacture and Assembly

To ensure satisfactory operation at the site, all equipment is assembled either into one unit or subassembled units. This enables the Inspector to check the various fitting practices, tolerances and operating clearances as stipulated in the contract or specifications. The Inspector witnesses all static and hydrostatic testing and all functional and operational tests.

Inspection Procedure

Inspection procedures require:

> Monitoring of manufacturing processes and preparation for shipment; witnessing of tests as may be required by the codes of specifications;
>
> Procurement from the vendor and confirmation of necessary details regarding production, welder qualifications, material test reports, repair procedures and dimensional details.

Deviations, concessions and any other matters requiring engineering judgment are reported to the engineer or purchaser as required for approval.

Acres releases equipment from the factory, but final acceptance of the product is at the jobsite.

Conditions affecting delivery, installation, performance or reliability will be detected and corrected before such problems or difficulties have had time to produce a chain reaction.

Quality Assurance Testing

In the initial contact Acres informs all suppliers—and through them, all relevant subcontractors, of their inspection and testing interest, and establishes inspection stages and/or tests to be witnessed under the specifications. At the agreed stages and on completion of manufacture, Acres performs the agreed inspection.

Destructive testing to cover physical properties such as tensile, yield point, elongation, reduction of area, impact and hardness will be witnessed in the vendor's laboratory. Nondestructive testing of ferrous and nonferrous metals for surface and internal defects, as provided by the ruling specification, codes and standards, using techniques as provided by the vendor or as occasion demands, will be witnessed. Inspection reports are issued after each visit or series of visits as may be appropriate or required.

The Inspector may waive inspection or witnessing of tests on minor items, repetitious procedures or certain rolled material when he feels that testing would generate more accurate results during manufacture. Under these circumstances, Acres accepts the original manufacturer's test certificates.

Test certificates are checked and evaluated in order to determine that the results obtained by the supplier, in his inspection, are valid and objective.

Additional testing, outside of the normal requirements, that may be deemed necessary are subject to the written approval of the purchaser, if any additional cost to him would thereby be incurred.

At any time during the manufacture of equipment or materials at the vendor's premises or those of subcontractors, Acres, whenever necessary, exercises the right on behalf of the purchaser to reject components or manufacture on grounds of faulty workmanship. In the event of such rejection having an effect upon the stipulated contract or purchase order completion date, Acres immediately informs the engineer and the purchaser of the occurrence and the reasons for such rejection; otherwise the full information is presented in the subsequent routine report.

In the event of sufficiently serious defects being found in materials or components being manufactured or submitted for inspection or test, Acres requires the vendor to submit to the purchaser his proposals, with appropriate sketches, for repairs. Immediately following, and if necessary during any such repair, Acres reinspects the affected material or equipment and indicates whether manufacture and/or testing can continue.

In the case of certain contracts, it may be necessary to station a resident inspector in the vendor's premises in order to carry out effective inspection. Such action is taken only with the approval of the purchaser.

Particular attention is given to ensuring that all equipment and components are of the highest standard commensurate with specifications, standards, safety requirements and client's Quality Assurance requirements.

When manufacturing procedures that have not been previously used are involved, Acres will witness, at the supplier's premises or at such testing laboratories as may be agreed, such type tests as may be required to demonstrate the suitability of the process for the duty it will have to perform in service. Documentation is then issued to verify that manufacturing has complied with the specified type tests.

Nonconforming Material

By definition, nonconforming material is that which, in the raw or finished condition, whether purchased or manufactured by a vendor, shows faults or which does not conform to the specification or good workmanship.

Nonconforming materials which have been detected shall be reported to the client or engineer, stating the type of fault or appearance of the fault, and measures to be taken by the vendor to salvage or correct the condition.

Nonconforming material which has been detected, where the fault is of such type that an acceptance should be considered is reported to the engineer or client and the vendor's quality control. The material is accepted only after written approval is received from the engineer or client.

A complicated fault detected during final inspection of a completed component or product is immediately brought to the attention of the vendor. A decision is then made on the remedial action to be taken.

Documentation

The contractor or prime vendor is responsible for and required to draw up complete inspection and Quality Assurance records covering all technical stipulations, deviations, test data, certification and dimensional details, and submit copies of such records to Acres through their visiting Inspector.

Copies of technical correspondence between the contractor and the engineer need to be forwarded to the Quality Assurance Department of Acres in order to maintain up-to-date information regarding the progress of approvals and/or changes to the specified requirements of the contract to ensure that the group always has applicable and complete information.

Work instructions and special procedures need to be forwarded to the Quality Assurance Department in order that the Inspector may ensure adherence.

Packing and Transport

On completion of manufacture and following the satisfactory conclusion of all final inspections and tests, Acres will, whenever required or considered necessary, check the transport and shipping arrangements previously proposed for each different type of equipment involved. Acres also checks, as required before shipping, the packaging of the various items, the location of material lists and the application of case markings. Handling and distribution is supervised as necessary. If also relevant, Acres ensures that the work of forwarding or shipping agents is carried out in a timely and efficient manner and, if specifically required and whenever possible, Acres will arrange for a final inspection of the equipment to be made on board the carrier in which it is to be transported.

Management Audit

The Head of the Acres Quality Assurance Department is kept informed of the quality level and trends in the various vendor's factories, and advises client, vendor and engineer of the quality when required.

Periodic meetings between representatives of the client, engineer and vendor are attended by the Head of the Quality Assurance Department to assist in the resolution of deviations and production problems and the preparation of special procedures.

The Head of the Quality Assurance Department functions as a part of the material evaluation board, and liaison with the various engineers is normally through this channel. The Head of the Quality Assurance Department acts on behalf of the Project Manager in reviewing the technical aspects of specifications to ensure that testing and acceptance standards meet the requirements and intent of the client and the present day codes.

SECTION 4
PART TWO
EXPEDITING PLAN

ACRES

PART TWO

EXPEDITING PLAN

General

Procurement is one of the most significant phases of project execution, and is a key factor in timely completion. If the project manager loses the initiative in procurement his efforts to maintain close control over the other functions could result in costly project delays.

Closely related to procurement is the expediting function which is primarily time oriented in relation to planning and scheduling, and bears a direct relationship to project completion. Expediting of equipment and information includes a close liaison between contractor, engineers, project management and purchasing. If implemented during placement of an order or contract, this liaison provides a flow of information between interested parties with a view to avoiding predictable delays in the performance of a contract and smooths the exchange of information on schedules, updatings, and approvals to ensure that construction programs are maintained on schedule.

Expediting, as covered herein, is the practice of making direct contact with all prime vendors on a regular itinerary, through visits to their offices and shops, and in certain cases those of subvendors, to witness at first hand that supplies are true to schedule, deliveries are realistic and shop conditions are adequate.

Expediting is concerned with everything in the procurement chain and visiting Expediters are responsible for ensuring that schedules are maintained.

The Acres Expediting Program pays particular attention to identifying in advance any potential threats to the project construction schedule, and reports risks due to shop overloading, quality control, labor contract disputes, approvals, advance ordering, past performance, labor qualification, management attitudes, production problems and remedial actions, etc. With such current and factual information the contract manager is in a position to make accurate, decisive and effective judgments to restore and situation which may threaten the achievement of his objective. Penalty or bonus clauses in contract documents are ineffectual and, at best, cause only minor inconvenience to the contractor as compared to the loss in revenue to the client from a delayed project.

Validity

Part Two of the Quality Assurance Document describes the procedures and formalities in force within Acres to ensure that contract requirements are being met, and therefore on-stream schedule dates will be maintained.

While the expediting plan is concerned with everything in the chain of procurement from the preparation of designs to the loading of completed equipment, its attention and reporting is focussed on what remains to be accomplished, and the difficulties anticipated which actually threaten the project objectives.

Included in the plan is the careful evaluation of the bidder's ability to schedule and control production.

Workmanship

Every employee of the Acres Quality Assurance Department Expediting task force is responsible within the framework of his capability for:

— the correctness of his work and statements made in his reports;

— receiving documentation from the bidder or vendor and ensuring that it is representative of the actual shop conditions;

— reviewing production schedules and relating these to site requirements.

Familiarization

The Expediter obtains approved drawings to ensure his familiarity with the general arrangement of the equipment, and maintains in his possession a copy of the latest revision or a conformed specification, the purchase order and amendments, in order to be fully conversant with the equipment for which he has responsibility.

The Expediter examines all information and technical data relating to the order, and satisfies himself that no conflict or confusion exists and that information is complete in all respects to enable the vendor to proceed in the most expeditious manner.

Performance

Evaluating the vendor's ability to perform the work and checking the validity of his delivery promises includes the following:

— review engineering, purchasing and manufacturing facilities, resources, floor space, equipment, handling gear, scheduling practices, reporting methods and means of quality control;

— investigation of the labor situation to determine if the union contract is up for renewal, whether a strike is imminent and if the local labor market is adequate in the event that additional skilled help is required;

— investigation of capacity and flexibility of the shop for present and future work, policies regarding shift work and overtime, extra machining capacity or machining limitations, assembly and test facilities, storage;

— investigation of quality control system—who is responsible—are suborders inspected at source or on arrival in the shops? What nondestructive testing facilities are in regular use? Are engineering instructions issued to those who require them to carry out the specified requirements?

- investigation of extent of manufacturing performed in the vendor's plant;

- investigation of adequacy of shipping preparations and loading practices.

The above implies that the Expediter is responsible for ensuring:

- critical path and network diagrams are being followed to the extent necessary or as reasonably judged necessary to ensure adherence to the project schedule;

- avoiding as far as possible "late start" operation to prevent procurement problems;

- constant review of the shop loading for conditions affecting manufacturing operations, such as alternative facilities, in the event of a breakdown of a critical machine tool or interference from other clients scheduled ahead of the order;

- that production is following an orderly installation sequence;

- formal acknowledgment that all information is in the hands of the vendor;

- early identification of any bottlenecks or risks which may delay the work, and what steps may be taken by the vendor should they occur;

- pirated materials to fill a need on earlier schedules;

- that he is guided mainly by what he sees with his own eyes, and does not depend on hearsay or conjecture when vital portions of a project are at stake;

- a constant alert for solving problems on a piece by piece basis rather than an overall solution.

The intensity of the expediting effort varies with the circumstances surrounding each contract; however, for critical items, all necessary factory visits will be made to check progress.

Where progress is found to be falling behind the agreed schedules, Acres will work directly with the supplier and, through him, with any of his subsuppliers at the highest managerial level in a maximum effort to reestablish the agreed schedule.

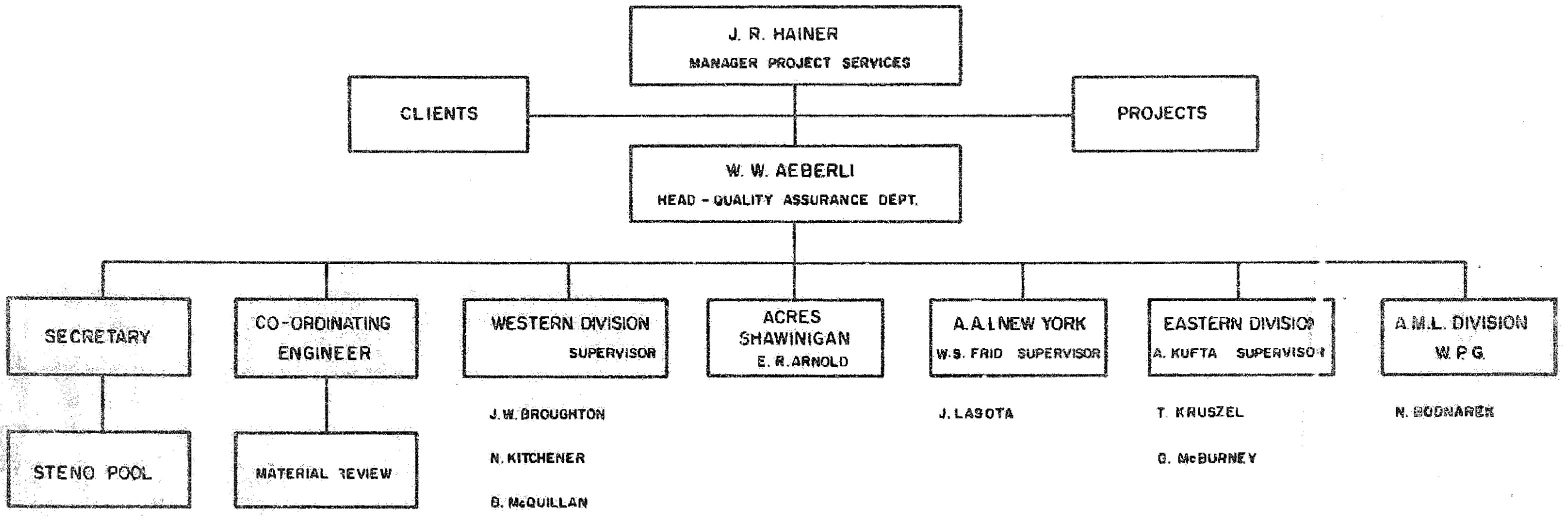
Acres representatives ensure that proper marking, tagging or coding identification is attached to the equipment, and that bundles or packages are dispatched to the site in such a manner as to achieve easy identification and prevent unnecessary sorting. If part shipments or shipments of semicompleted assemblies are acceptable to the client or site, then, by agreement, the Expediter arranges these matters as quickly as the need becomes apparent.

If the Expediter, in visiting the shops, finds that quality is far below specified standards and codes, he alerts the client, registers an objection with the vendor, and takes whatever action is deemed necessary to correct the condition in the best interest of the client.

SECTION 5
ORGANIZATION CHART

ACRES

QUALITY ASSURANCE DEPARTMENT ORGANIZATION



SECTION 6

TYPICAL REPORTS -
TURBINES AND AUXILIARIES

ACRES

ACRES

Inspection Report
Quality Assurance Department
Product Verification/Procedure Compliance

TO: Ao
Comandante Mario Guarita
C A E E B
Director Comercial
Av. Rio Branco, 135-140 and. N e s t a

DATE September 29, 1976
FILE No. P.4390.00
REPORT No. 23
SPECIFICATION No. M - 2

CLIENT: Companhia Hidro Eletrica Do Sao Francisco
PROJECT: Salvador Bahia Phase I
EQUIPMENT: Turbines and Auxiliaries
CONTRACT/P.O. No.: T-19440

VENDOR: Pneumafil Corporation
LOCATION: Charlotte, North Carolina
SHOP ORDER: 7-12533
CONTACT: U. Burtt; J. Swett
CONTRACTED DELIVERY DATE: 2 sets-Oct 5/76; 1 set-Dec 3/76
LATEST PROMISE: To Schedule
PRESENT STATUS: To Schedule

SUBVENDOR:
LOCATION:
P.O. No.:
CONTACT:
CONTRACTED DELIVERY DATE
LATEST PROMISE:
PRESENT STATUS:

PLANT VISIT [X] TELEPHONE CONTACT [ ] PERIOD OF REPORT: Aug. 25/76 TO Sept. 29/76

SUMMARY

INSPECTOR W.S. Frid

ENGINEERING: Complete. Shop drawings revised for welding of support angles for filter media because of accessibility problems.

MATERIALS: All cutting, forming and detailing for seven units complete. Filter media complete for seven units. Cream colored paint for top coat due on the afternoon of September 29, 1976.

PRODUCTION: Assembly and welding complete for two units. Dimensions satisfactory; welding very good. One series of stich welds missing. Vendor tends to overweld. Paint inspection waived.

DELIVERY: Both filters to be export crated and shipped to Savannah, Ga. by October 5, 1976. The media will be in place. Shipping specifications received. Units No. 3, 4 and 5 will ship in December.

DOCUMENTS:

See body of report

DISTRIBUTION

W.W. Aeberli - 1	C A E E B - 2	A.J. Cipriani - 1
J.W. Broughton - 1	C H E S F - 2	E. Jensen - 1
N.J. Kitchener - 1	W.M. Sybert - 1	E. Smith - 1
	W.S. Frid - 1	W.J. Dixon - 1

This report concerns a plant visit to Pneumafil Corporation in Charlotte, North Caroline, on September 29, 1976, for the purposes of expediting and inspecting the generator air intake filters ordered by Turbodyne for the Salvador Bahia Phase I Program.

A - ENGINEERING

All engineering for this contract is complete. The design is for a standard filter as shown in the catalogue. The only differences are various dimensions and these drawings have been approved by Turbodyne. The interface of the flange between Pneumafil and Koppers has been approved by Turbodyne.

During the visit, we noted that the flange, which connects to Kopper's equipment, is bolted. The discharge flange is a blank flange and we are unaware of the next mating piece. Since there are no holes, it was assumed that this flange might be bolted to the next piece of equipment. We attempted to contact Mr. Cipriani and were unsuccessful. We contacted his assistant, Mr. Tuttle, who agreed to check the type of connection and advise Pneumafil later in the day. Obviously, if the joint is to be a welded connection, then we do not want the flange coated with the one-part epoxy primer and the two-part polyester epoxy cover coat. Mr. Tuttle agreed to advise Pneumafil, who will tape this flange to prevent corrosion during shipment.

B - MATERIALS

All structural and filter materials for seven units are on hand. All of the structural and plate materials for seven units have been cut, formed and detailed.

The one-part epoxy primer is on hand. The cream colored top coat is due on the afternoon of the date of this visit.

C - PRODUCTION AND INSPECTION

Assembly and final welding of the first two generator intake filters has been completed. We conducted a thorough dimensional check and found no discrepancies. The overall dimensions are all to drawing tolerances and the layout and punching of the flange is correct.

On Unit No. 1, we noted that one long top plate was deflected approximately 3/8 inch, for a length of approximately 2-1/2 feet. However, due to the extreme lightness of the material, we could see no way that the vendor could correct the situation. Since the deflection is on the blank flange, it is unlikely that it will be noticable after installation.

All of the welding of the corners is satisfactory and the unit appears watertight. The welding of the plate splices is via the new automatic equipment, which makes use of two formed joints and places a full penetration bead along the V-joint. The quality of this weld is excellent.

All structural welding is staggered stitch welding. Without exception, the drawing specifies this welding to be 1 inch in length on 6-inch centers. We noted that the vendor has tended to greatly overweld these units. While most of the stitch welds tend to be closer to 7/8 inch than 1 inch, the majority of the areas were welded on 3, 4 or 5-inch centers, with the average tending to run between 3 inch and 4 inch. We pointed out to Mr. Swett and Mr. Burtt that this over reinforcing could be serious if this were a high temperature application. Further, this is a considerable waste of manpower and weld material. A third reason for objection is that customer inspectors at site could examine these units, lacking drawings, and decide that the welds are insufficient because some will be 1 inch at 5 or 6 inch, instead of 1 inch at 3 inch. The vendor agreed with our criticisms and assured us that the future units will be welded 1 inch at 6 inch.

As we examined the interior, we found one filter support angle which was still only tack welded. It was one of the short angles and seven welds were missing. This was brought to the attention of the area foreman, who added these welds prior to our departure. The drawings show the filter support angles to be welded 1 inch at 6-inch centers staggered. However, because of the length of the top flange, the vendor has been able to weld on only one side. The inner shield guns will not permit access to the other side. Engineering was consulted and they instructed Production to weld 1 inch at 3 inch, and to weld the end of these supports solid. We concur that this is structurally sound and that the missing welds are not significant.

The filter support plates at the top of the units have been stitch welded on both sides, even though the drawing shows them to be stitch welded on one side.

In general, we were very pleased with the quality of the work and advised Mr. Schaaf and Mr. Burtt that end product inspection is all that will be required for future units.

Still to be completed is the painting, and it was scheduled to start on the morning of September 30, 1976. We have waived inspection of the painting because of the automatic paint system that is used by Pneumafil, and because the paint is the standard product which they use every day.

Mr. Burtt requested permission to manufacture Units No. 3, 4 and 5 in December 1976. We consulted with Mr. Schaaf and learned that this is satisfactory. Mr. Burtt has been so advised, and so our next visit will be for inspection of Unit No. 3 for Salvador Bahia Phase I and both of Salvador Bahia Phase II.

The filters will be installed in the shells before shipment. The filter units will be totally boxed and export skidded.

D - DELIVERY

Mr. Cannon of Turbodyne has instructed Pneumafil to use the Port of Savannah for shipment. Pneumafil will forward both filters on October 5, 1976, and Mr. Cannon stated this will be more than adequate time to meet the boat in Savannah. However, Mr. Cannon did not advise when the date would be, except that it would be sometime in the week of October 11, 1976.

E - ADDENDUM

Late in the afternoon of September 29, 1976, we were advised by Mr. Schaaf, that Pneumafil have permission to manufacture Units No. 3, 4 and 5 and ship them in the month of December. He emphasized that this does not apply to Units No. 6 and 7 which must be held until July 1977. We telephoned Mr. Burtt, who expressed his satisfaction.

Mr. Tuttle contacted Mr. Burtt and advised him that the blank flange is to be painted, since the filter remains within the High Bay and there is no connection at the blank end.

W.S. Frid

WSF/smj W.S. Frid

SECTION 7

SELECTED LISTING
OF PROJECTS

ACRES

SELECTED LISTING OF PROJECTS

Brascan Limited — Light Servicos de Electricidade
Brazil, South America

Inspection, consultation and testing of castings, machining and balancing of one 88,000-hp impulse and one 140-inch diameter pump impeller, manufactured from 13 per cent chrome and 4 per cent nickel. P2415

British Columbia Hydro & Power Authority
British Columbia

Inspection and witness testing of distribution transformers, two 130-ton powerhouse cranes, T/L Hardware, conductor and cable. P3430

Centrais Eletricas do Para, S.A.
Brazil, South America

Inspection, testing and expediting of all equipment originating in North America for the 50-Mw Belem thermal station. P2278

Churchill Falls of Labrador Corporation
Labrador, Canada

Inspection of materials, castings and components for five turbines built by Dominion Engineering Works, Lachine. Engineering liaison and reporting on the manufacture of spiral casings manufactured by Marine Industries Limited, Sorel, Quebec for the 5,225-Mw generating station. P1521

Cochin Pipeline
Dome Petroleum

Inspection/expediting of pumping station equipment for London and Sarnia stations. P2905

Corporacion Autonoma Regional del Cauca
Colombia, South America

Inspection and expediting at factories in North America, Switzerland and Japan to provide overseas monitoring and testing of all equipment and materials for the entire 370-Mw Alto Anchicaya Generating Station. P1630

Dow Chemical of Canada Limited
Sarnia, Ontario

Inspection and testing of two 50-Mw gas turbines and generators, two 250,000-pound waste heat boilers and one 60/80/100-Mva power transformer. P2784

General Electric Company
Greenville, South Carolina

Survey, evaluation and report on the manufacturer's quality control program for manufacture of gas turbines. P2997

Imperial Oil Enterprises Limited

Inspection of all equipment for sour water stripper. P3875

Iron Ore Company of Canada
Humphrey Mine

Inspection of mechanical, electrical equipment and conveyor systems for the new crushing facility. P2599

Manitoba Department of Agriculture
and Conservation — Red River —
Floodway Inlet Control Gates
Winnipeg

Inspection and liaison during the manufacture of the two submersible sector gates, guides and hydraulic servomechanisms. P940

Manitoba Hydro
Grand Rapids Turbine No. 4.

Inspection and progress reporting during the casting and repair of components, machining and testing of one 150,000-hp Kaplan turbine in Lachine, Quebec, Canada, and Milwaukee, Wisconsin, U.S.A. P1282

Manitoba Hydro
JENPEG Generating Station

Inspection of powerhouse cranes and hatch covers for bulb turbines. P3846

Manitoba Hydro
Kelsey Generating Station

Inspection and expediting of the turbine, gates and powerhouse extension for Unit 6. Rectification of leakage between headblocks 5 and 6 and, at a later date, inspection, expediting and testing of the turbine, gate hoists, generator and excitation equipment for Unit 7. P2728, 1620

Manitoba Hydro — Crippen Acres Limited
Missi Falls

Inspection of House Service Unit. P3669

Manitoba Hydro — Crippen Acres Limited
Kettle Rapids and Long Spruce
Generating Stations

Inspection, expediting and liaison in connection with shop manufacture of all mechanical and hydraulic equipment for construction of the 1,500-Mw and 1,150-Mw generating stations. P3598, 1432

Merz and McLellan Consulting Engineers
Newcastle, England

Inspection, expediting and testing of power generators for Furnas project in Brazil, electrical components for Capetown, South Africa and Cogolex, Paris, France. P2949

Metropolitan Toronto — R. L. Clark Filtration
Plant, Mimico, Ontario

Site inspection during the installation of all mechanical and ventilation equipment and installation of inlet structures, gates, screens, pumps and piping for the raw water, filtered water and backwash facilities. P966

Metropolitan Toronto Conservation Authority

Inspection and expediting in the shops during manufacture of control gates, embedded parts and hoists for Finch Dam. P1304

Niagara Mohawk Power Corporation
New York State

Inspection and expediting in the shops during the manufacture of all materials and equipment for electrostatic precipitators, waste water control and coal handling facilities to control pollution of the environment at Dunkirk Thermal Station.
P2789, 2788, 2722

Ontario Hydro — Arnprior Generating Station
Arnprior, Ontario

Inspection, expediting and witness testing of all mechanical, electrical and structural equipment. P3176

Ontario Hydro — Lower Notch Generating Station
Cobalt, Ontario

Inspection, expediting, monitoring of repair procedures and testing in various shops during the manufacture of all mechanical, hydraulic and electrical equipment for the construction of the 220-Mw generating station. P1661

Petrofina Canada Ltd.

Inspection/expediting of all equipment for sour water stripper.
P3668

Pilkington Glass
Scarborough, Ontario
SC2 and SC3

Inspection, expediting and liaison in connection with all mechanical and electrical equipment for both Float Glass plants.
P2004, 1227

Queen's University
Kingston, Ontario

Inspection and testing during the fabrication of breaching, ducts and expansion joints for conversion of central heating plant.
P1918

Sirikit Power Station

Inspection control metering and relay equipment. P3322

Societé de Traction et de Electricité
Brussels, Belgium

Inspection, expediting and testing during the manufacture of the pump turbines for the 500-Mw Coo Trois Ponts pumped storage installation at Ardennes. P1869

Sydney Steel Corporation Limited
Sydney, Nova Scotia

Reheat furnace — inspection and expediting of equipment and instrumentation. P3186

Thyssen Mannesmann — Petrofina
Montreal, East, Canada

Inspection and expediting of all mechanical and electrical equipment and instrumentation entering into the construction of a refinery expansion project. P2769

Turbodyne/Worthington
United States

Inspection and expediting of large gas turbines, modular boilers, silencers, castings, forgings and electrical equipment for Northern States Power, Southern California Edison, Algeria, Oklahoma, Saskatchewan, Braintree and Houston. P3419

LABORATORY SERVICES

Our modern laboratory is equipped for

- biological analysis and bioassay
- chemical and physical analysis of solids, liquids and gases
- physical modeling to scale
- soil and rock mechanics testing
- hydraulic, aerodynamic, civil and architectural design evaluation.

Skilled and experienced technologists, with expertise in sampling, analysis and evaluation, work with engineering specialists. Standard commercial equipment, supplemented by special equipment designed by and manufactured specifically for Acres, is used for sampling and testing on site and in the laboratory.

Procedures for sampling and analysis are updated regularly to incorporate the most advanced methods. Programs are written for and run on the Acres computer to facilitate and accelerate the calculation of the test results. Standardized reports are prepared and documented to fulfill the requirements of the client and of government agencies.

Test results are used to establish design criteria for conceptual and remedial engineering. Often, these design criteria are confirmed and modified by physical testing on scale models.

FLUID DYNAMICS LABORATORY

The laboratory is equipped to operate models using liquids or gases as the testing media in closed-circuit tests. Modern electronic instruments are used to control the flow of fluids, measure the rapidly varying pressures of these fluids, and record the resulting strains in a model structure.

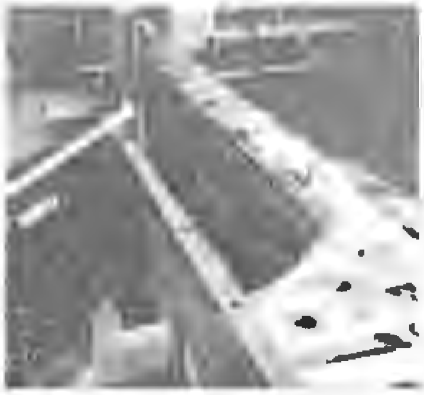
Designs can be confirmed or modified after observing the results of tests which simulate prototype conditions. These studies give assurance of the prototype's proper operation, and often result in considerable savings in construction and operating costs.

Recent advances in theoretical hydrodynamics and computer techniques developed from years of physical testing and field experience have alleviated the need for physical testing on surge tanks

HYDRAULIC MODELING

Tests on models of complex hydraulic systems such as spillways, control and diversion structures and tunnels for hydroelectric developments are used to optimize designs, calibrate structures, and investigate energy losses, flow patterns, air entrainment, cavitation, bed erosion, energy dissipation and hydraulic loading.

Spillway



Diversion Tunnel

Control Structure

ICE MODELING

The build-up of ice can cause considerable problems in the effective operation and stability of hydraulic structures. Model testing using simulated ice is conducted to develop methods and operating procedures to minimize the effect of this hazard.

Model of the upstream rapids and inlet to the Kettle Rapids Generating Station on the Nelson River, Manitoba

WAVE ACTION AND TIDAL CURRENT MODELING

Models of coastal regions in which wave trains and tidal currents are reproduced to scale are used to determine the effects of topographical changes on coastal erosion and wave loading.

Model of a proposed causeway structure for the Northumberland Straits Crossing between New Brunswick and Prince Edward Island

FLUID-DYNAMICS LABORATORY

AERODYNAMIC MODELING

Test models of large gas systems, such as electrostatic precipitators, are used to determine the location of guide vanes, to check flow distribution and generally to refine the original design.

Model of hot electrostatic precipitator and ductwork at Niagara Mohawk, Dunkirk, New York

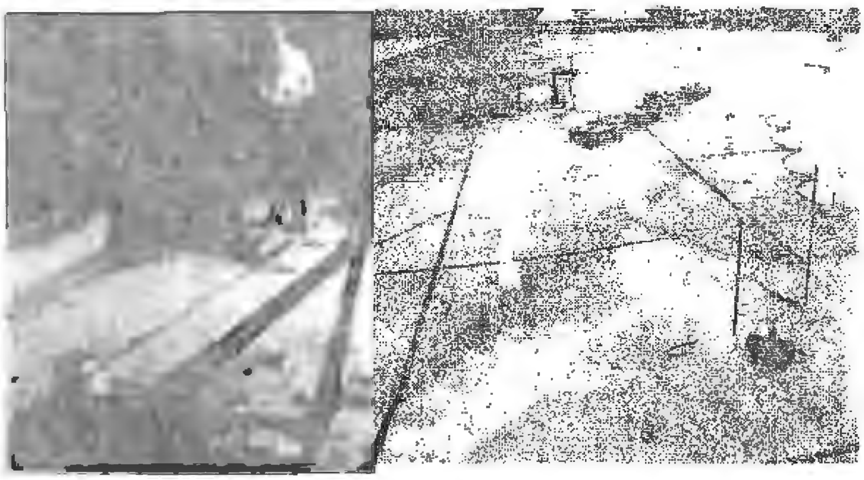
THERMAL DIFFUSION MODELING

The physical modeling of warm-water discharges was used to determine the effect on receiving water ambient temperatures.

Model of Oswego Harbor and Niagara Mohawk's Steam Station cooling water system, Oswego, New York

NAVIGATION CHANNEL MODELING

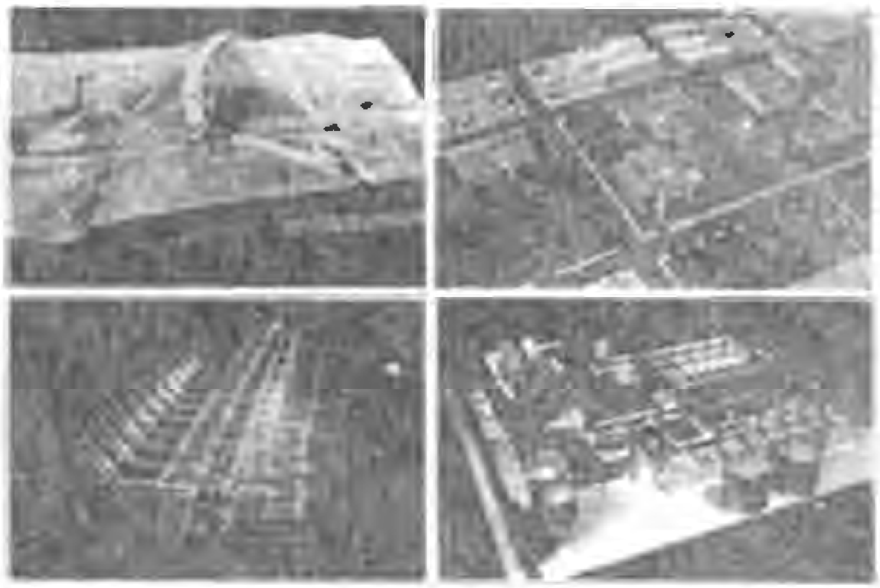
Model studies of ship navigation problems are conducted to improve and stabilize the flow conditions in the navigation channels. Radio-controlled ships are used to gauge the degree of improvement obtained.



PHYSICAL MODELING

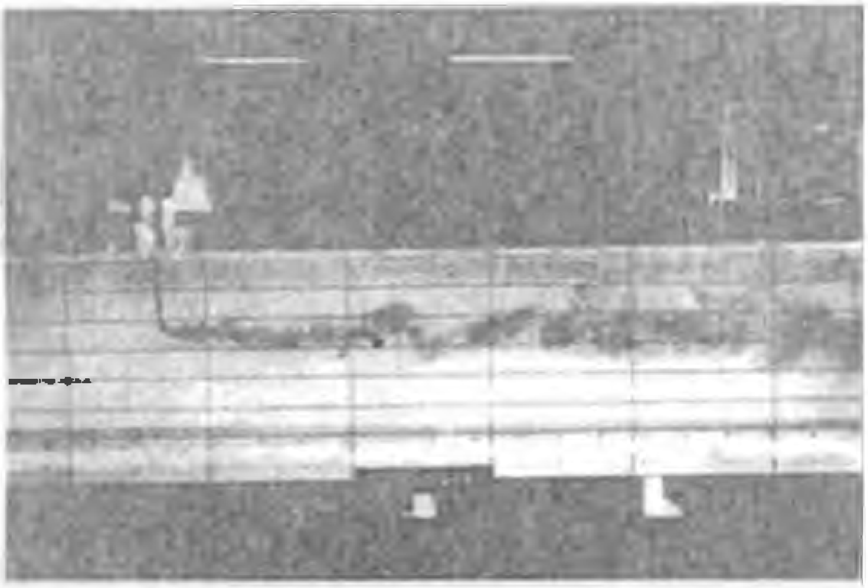
Scale models are prepared of river basins, canals, dams, townsites, airports, buildings, equipment, piping, and other structures and facilities.

Many are used as three-dimensional architectural, structural and mechanical design tools. Other models are used in the fluid dynamics and environmental laboratories to simulate the hydraulic and aerodynamic conditions that provide data for detail design.



HYDRAULIC MODELING OF THE ATMOSPHERE

Simulation of inversions and other meteorological phenomena is difficult to obtain by aerodynamic modeling. Acres has designed and successfully developed a hydraulic model that simulates the atmosphere with stratified layers of varying brine concentrations. The model is used for prediction of stack plume behavior during various meteorological conditions.



ODOR TESTING

Odors are measured, and control systems for their elimination are developed. One typical project required the measurement of odor causing constituents in a starch plant emission, review of various control systems and testing and performance evaluation of the most promising prototype. Another project involved measuring the odor strength of various foundry vents and calculating the distance downwind required to dissipate the odor by dilution.

SOUND AND VIBRATION MEASURING

Experienced staff and detection equipment are available for field surveys and studies of sound and vibration problems.

The deleterious effects of excessive noise on health, safety and working efficiency are now well known. Legislation to control ambient noise in industry has led to extensive research in abatement measures. Recent legislation has also been enacted to control noise in both urban and rural environments to minimize disturbance of natural systems and people. Acres has specialist experience in sound-level measurement, and analysis for the development of sound and vibration absorption and attenuation systems.

PHYSICAL AND CHEMICAL ANALYSES

Solid, liquid and gaseous samples taken in the field are usually analyzed for physical and chemical characteristics at the Niagara Falls laboratory. When sampling is a remote location, determinations are done in the field on portable equipment taken to the site. Equipment is available for performing tests to ASTM or other standards.

AIR POLLUTION CONTROL STUDIES

Environmental engineers and technicians are available to

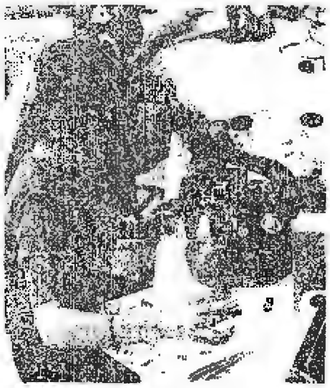
- perform field surveys to EPA standards utilizing EPA sampling trains
- develop feasible schemes for emission control
- determine operating costs and investment costs
- provide selections and recommendations
- provide engineering and designs
- provide supervision of construction
- provide performance testing and operational efficiency evaluation.

ENVIRONMENTAL LABORATORY

BIOLOGICAL ANALYSES

Our capability in field sampling, design input and computer analysis is backed by a comprenensive laboratory facility. Our biological laboratory is fully equipped to handle collection, sorting and identification of fish, planktonic and benthic samples. Work undertaken has included a large volume of sample analyses from a variety of water and benthos types, classification and identification of lichens, and tissue preparation and analysis for concentrations f contaminants.

The biological and chemical laboratories frequently work together on one project with interpretations being made on the basis of combined data. Raw data are fed directly to a computer for maximum efficiency in summarizing and carrying out statistical analyses.



BIOASSAY FACILITY

The laboratory includes a bioassay facility to handle toxicity testing as well as a radioassay facility for uptake work and a controlled temperature room. Toxicity tests can be carried out on a wide range of effluents, including those with a high BOD requiring special handling.

ENVIRONMENTAL LABORATORY

EMISSION SURVEYS

Stack gas streams are sampled and analyzed for the various constituents, including dry particulates, wet particulates, SO_2, SO_3, NO_x, hydrocarbons, heavy metals, etc. Equipment and specialist staff are provided by Acres laboratories.

Stack Sampling Platform
Niagara Mohawk Huntley Station
Buffalo, New York

Sampling of SO_2 and SO_3

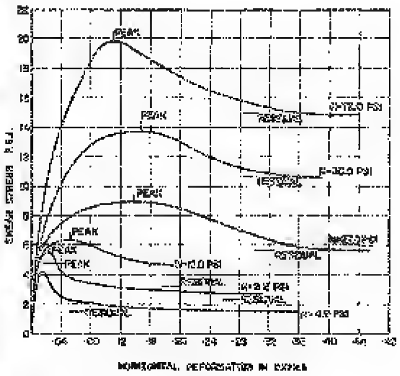
AMBIENT AIR SAMPLING SURVEYS

Mobile sampling of stack plumes, episode sampling, design of ambient sampling stations, planning of systems for data collection, and computer processing of information from sampler/analyzers and meteorological instrumentation are provided.

DIRECT SHEAR TESTING

Direct shear testing machines are used primarily to determine the stress-deformation behavior and shear strength of soil or rock along existing geological planes of weakness.

These machines are equipped to provide both stress and strain rate-controlled loading on predetermined planes. Direct shear testing also allows the measurement of residual as well as peak shear strengths.

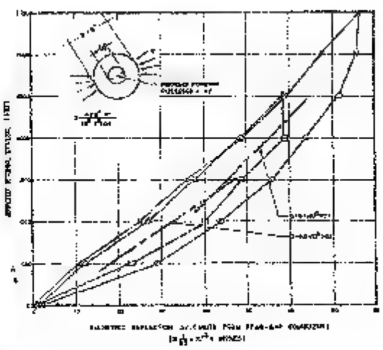


Direct Shear Test Results
Highly Plastic Clay

BIAXIAL COMPRESSION TESTING

Biaxial compression apparatus, designed and built by Acres to apply pressures up to 10,000 psi, is used to determine the modulus of elasticity of 6-in. diameter rock or concrete cores obtained from field overcoring tests.

Biaxial compression testing is used in conjunction with field overcoring tests to measure the in situ stresses present in a rock or concrete mass.



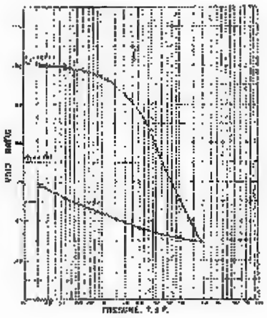
Biaxial Test Results
Granitic Gneiss

CONSOLIDATION TESTING

Consolidation test apparatus is used to determine the stress-deformation-time characteristics of undisturbed soil samples.

The rate and magnitude of settlement of foundations can be predicted from these results.

The equipment is suitable for testing 1.5- to 3-in. diameter samples. Apparatus has been developed for testing 24-in. diameter samples of fine rock fill.



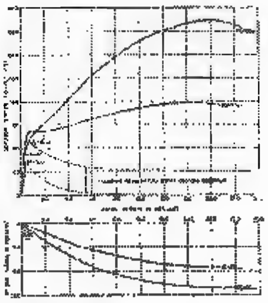
Consolidation Test Results
Lacustrine Clay

TRIAXIAL TESTING

Triaxial testing apparatus is used to determine the stress-deformation behavior and shear strength of natural and compacted soils when subjected to various stress conditions.

Stress or strain rate-controlled axial loading of cylindrical samples is applied in either compression or tension, and can be used for long-term creep tests.

Drained tests with volume change measurements or undrained tests with pore water pressure measurements can be performed.



Consolidated Drained Triaxial Test Results
Estuarine Clay

INSTRUMENTATION LABORATORY

Acres Instrumentation Laboratory services include inspection and checkout of purchased equipment, site supervision and commissioning, and testing and troubleshooting of new and existing instrumentation systems.

In addition to utilizing off-the-shelf instruments, Acres has the expertise and facilities to modify or custom-fabricate specialized instrumentation designed for particular applications.

The following are some of the types of services our Instrumentation Laboratory has provided to meet client requirements.

Research and Development

- Ice force measurement
- Hydraulic thermal dispersion models
- Precipitator models
- On-line data processing for experimental testing.

Pollution Control Monitoring Systems

- Power plant precipitators
- Ash removal systems
- Neutralization facilities
- Sour water strippers
- Chemical processes.

Process Monitoring and Control Systems

- Ore crushing and milling
- Direct-reduction steel plant
- Rolling mill installations
- Pickle line installations
- Silicon carbide plant
- Wire drawing plant.

GEOTECHNICAL LABORATORY

BOREHOLE PHOTOGRAPHY

In many engineering projects it is sometimes necessary to know more about in situ rock conditions than can be determined from normal coring operations. Questions arise such as the reasons for lost core, orientation and openness of joints, or the presence of voids or solution features in soluble rock.

They can be answered using Acres borehole camera which photographs the walls of drill holes ranging in diameter from "N" size to 6 in., and to depths of up to 1,500 ft. The equipment is operated in the field by our experienced geotechnical staff. Data obtained on color film can be viewed by geologists. If necessary, our computer program can produce an output listing the depth, dip and azimuth of geological features.

This equipment and associated geotechnical engineering services are available to organizations involved in underground or surface works in rock.

BLAST MONITORING

Blasting operations in close proximity to human beings and structures can range from being hazardous at one end of the spectrum to uneconomical and time consuming at the other. The use of appropriate monitoring equipment in conjunction with design of blasting patterns, can result in the most economical and safe solution.

Acres staff has extensive experience in the design and supervision of delicate blasting operations for rock excavations immediately adjacent to operating power stations, tunnels and other large structures in North and South America. We have also developed instrumentation to monitor underwater blasting shocks. Our current equipment includes a Sprengnether VS-1200, 3-axis seismograph which is capable of monitoring air shocks as well as ground motions.

CHESAPEAKE BAY HYDRAULIC MODEL P4655

Location Annapolis

Client U.S. Army Corps of Engineers
Baltimore District and Waterways Experiment Station

Year 1977–1980

The Chesapeake Bay hydraulic model was completed in May 1976 and covers an area of some 8 acres housed in a 14-acre shelter. The model is built to a horizontal scale of 1 ft. = 1,000 ft. and a vertical scale of 1 ft. = 100 ft. and is representative of the Chesapeake drainage basin covering 64,170 square miles and a water surface area of 4,300 square miles with a tidal shoreline of 7,300 miles. The model is used to study:

- salinity distribution and saltwater intrusion
- mechanics of estuary flooding
- effects of upstream impoundment and basin diversions
- effects of navigation projects and channel geometry
- circulation and upwelling current patterns
- site locations for sewage and other outfalls, port facilities
- waste assimilation capacity of the bay
- shoaling characteristics of the bay and tributaries
- sources of ship handling problems
- tidal flooding and effect of storm surges.

By applying the knowledge gained from the Chesapeake Bay study and the hydraulic model, plans can be formulated that will insure a balanced approach to developing the Bay's resources while protecting the quality of the environment.

Acres is under contract to the U. S. Corps of Engineers for the total maintenance and operation of the facility and will be responsible for conducting an extensive series of studies over a prolonged period.

Client U.S. Corps of Engineers

Location Sault Ste. Marie, Michigan

This project was part of a research and study program to develop feasible solutions to problems created by frequent ice build ups in the narrow channel between Sault Ste. Marie, Michigan and the area below the Little Rapid Cut area of the St. Marys River, Michigan.

Broken and frazil ice float downstream into the cut and the resulting ice jams restrict commercial vessel passage and prevent regular ferry transportation to and from the mainland for the two hundred families who live on Sugar Island located on the east side of the cut.

The model was verified against field observations and employed to simulate the effects of relocating the ferry crossing, widening of the riverbed, the use of ice control booms and ice harvesting methods, the creation of ice-flow diversions and ice suppression systems.

The model forms a Y shape in an area 120 feet by 200 feet and includes a scaled riverbed, shoreline and model vessels, and utilizes polypropylene pellets to simulate ice.

It was also used to study the influence of discharges from power canals and industry, the effects of changes in ice supply due to vessel passage, various wind conditions and the impact of vessel size and speed on ice jamming and accumulation.

Remedial measures recommended as a result of the study were constructed and in service in the winters of 1975—1977.

LOWER NOTCH GENERATING STATION
MODEL STUDIES

P1661HM

Location Montreal River, Cobalt, Ontario

Client The Hydro-Electric Power Commission of Ontario

1969

The engineering services provided for this 340,000-hp hydro-electric power development included the construction and testing at Acres Laboratory of a hydraulic model (scale 1:64) of the spillway, chute and flip bucket (50,000 cfs) to determine the design criteria for the structure, the extent of possible erosion below the flip bucket, the possibility of cavitation damage to concrete surfaces, the spillway rating curves, the flip bucket jet trajectories, and the flow patterns in the forebay for various flow ratings.

SIRIKIT POWER DEVELOPMENT P1616HM
Hydraulic Model Studies

Location Bangkok, Thailand

Client Electricity Generating Authority of Thailand (EGAT)

1969 – 1971

The design, supervision of construction, calibration and testing of a hydraulic model, to investigate the effects on irrigation and navigation resulting from various arrangements and operation schedules of the Sirikit Power Development. Of particular interest was the simulation of the operation of the power station at various plant factors in conjunction with two major irrigation diversion structures planned downstream.

The model reproduces flows in the 300 km of the Nan River immediately below the development (down to Phichit). It is of the fixed-bed type and is built to scales of 1:40 vertically and 1:600 horizontally. The fl capacities of the model are 5.3 litres per second to simulate a maxi m discharge from the power plant of 800 cubic metres per second, and 19.8 litres per second to simulate flood flows in the river of up to 3,000 cubic metres per second.

APPENDIX B2

QUALIFICATIONS STATEMENT
AND RESUMES FOR
R&M CONSULTANTS, INCORPORATED

ACRES

organization

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

R&M CONSULTANTS, INC.

CONSULTANTS IN ENGINEERING AND EARTH SCIENCE

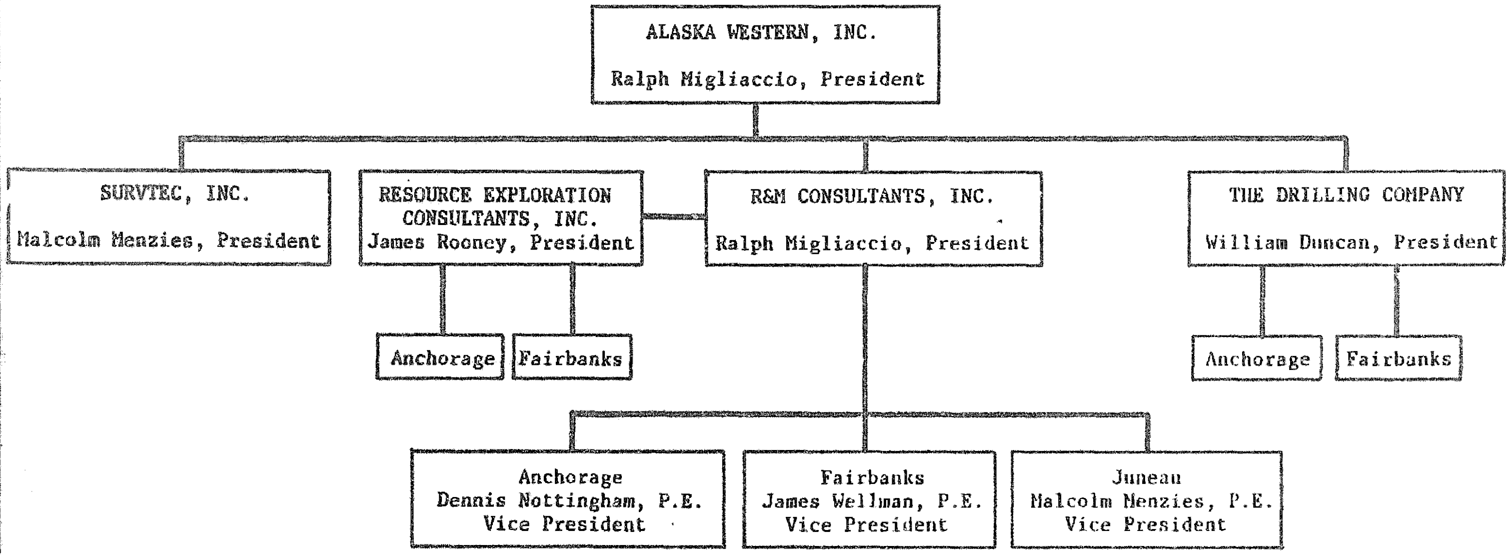
R&M Consultants, Inc., is an all-Alaskan multidiciplinary consulting firm with offices in Anchorage, Fairbanks and Juneau. Services provided cover a wide variety of engineering and earth science disciplines, including general civil engineering, structural engineering, sanitary engineering, geotechnical engineering, materials engineering, systems engineering, surveying, geology, engineering geology, hydrology and forestry. Such a range of services allows many projects to be completed entirely "in-house" - from work plan development through the construction management and inspection phases - thus eliminating the coordination and cost inefficiencies of having various phases accomplished by different firms.

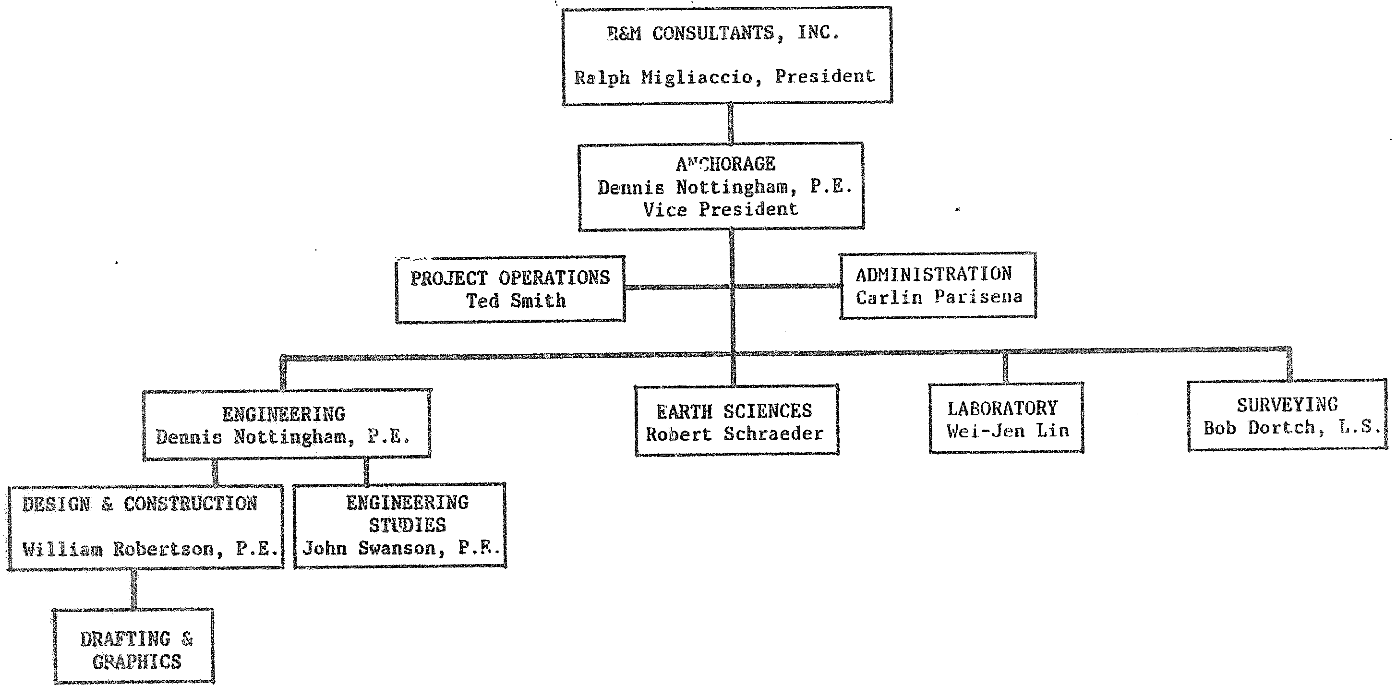
Since R&M's inception in 1969, we have successfully completed hundreds of projects, large and small, in both the urban and rural settings of Alaska. We are known for our considerable field experience in the remote regions of the state, as well as in many of our villages, and have earned a good reputation for completion of projects on time and within budget.

Over the years, we have established working relationships with a wide variety of clients in both the governmental and private sectors, and understand their needs, requirements, and expectations. Our knowledge about the unique conditions of the north gained from much practical field experience, has been very important in producing sensible, cost effective designs - especially on "fast track" projects. We specialize in "fast track" projects, and have the depth in personnel to accommodate those client needs.

R&M Consultants has three affiliated firms which serve to further expand the services that can be offered. Survtec, Inc., provides surveying and drilling services to the construction industry. Resource Exploration Consultants, Inc., supplies mining and resource exploration expertise for our clients. The Drilling Company, Inc., furnishes drilling services of all kinds for the entire range of client needs - for those requiring a subsurface soils investigation as well as firms demanding large, complicated exploration projects. Thus, R&M Consultants, Inc., in conjunction with its affiliated companies, provides a wide variety of highly qualified experienced professionals with access to the necessary equipment and appropriate facilities enabling us to successfully complete a project in a timely manner and within budget, despite size of the job.

The following descriptions of some of our past projects have been included to demonstrate the broad capabilities of our firm, and performance of our staff. They represent only a small portion of our total experience.


ALASKA WESTERN, INC.
Ralph Migliaccio, President
SURVTEC, INC.
Malcolm Menzies, President
RESOURCE EXPLORATION CONSULTANTS, INC.
James Rooney, President
Anchorage
Fairbanks
R&M CONSULTANTS, INC.
Ralph Migliaccio, President
THE DRILLING COMPANY
William Duncan, President
Anchorage
Fairbanks
Anchorage
Dennis Nottingham, P.E.
Vice President
Fairbanks
James Wellman, P.E.
Vice President
Juneau
Malcolm Menzies, P.E.
Vice President


R&M CONSULTANTS, INC.
Ralph Migliaccio, President
ANCHORAGE
Dennis Nottingham, P.E.
Vice President
PROJECT OPERATIONS
Ted Smith
ADMINISTRATION
Carlin Parisena
ENGINEERING
Dennis Nottingham, P.E.
EARTH SCIENCES
Robert Schraeder
LABORATORY
Wei-Jen Lin
SURVEYING
Bob Dortch, L.S.
DESIGN & CONSTRUCTION
William Robertson, P.E.
ENGINEERING STUDIES
John Swanson, P.E.
DRAFTING & GRAPHICS

project description

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

SLOPE STABILITY STUDIES CONDUCTED BY
R & M PERSONNEL

CLIENT:

Alaska Department of Highways

- Simpson Hill Slope Failure, Richardson Highway;
- Canadian Border Slide, Alaska Highway;
- Pillar Mt. Slide, Kodiak Island;
- Keystone Canyon Rock Fall, Richardson Highway

U.S. Geological Survey

- Post Earthquake Assessment - Old Valdez "Effects of the Earthquake of March 27, 1964 at Valdez, Alaska," H.W. Coulter and R.R. Migliaccio, 1966 (U.S.G.S. P.P. 542-C).

Alyeska Pipeline Service Company

- Route Slope Stability Parameter Assessment Task Group; (See attached Project Data Sheet)
- Terminal Site - Participated in design and stabilization of rock slopes;
- Solifluction Analysis & Recommendations "Solifluction and Related Mass Wasting Processes, 1974"
- Ft. Liscum Slide "Engineering Geology of the Fort Liscum Landslide, Port Valdez, Alaska, 1970"

Insurance Company of North America

- Lake Silvas Slide - evaluation/provide expert witness

SLOPE STABILITY ASSESSMENT TASK GROUP
GEOTECHNICAL ENGINEERING
-TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Allen Stramler, Engineering Coordinator

Acting on a recommendation by Dr. R.B. Peck, Alyeska Pipeline Service Company (Alyeska) formed a slope stability assessment task group in 1973 to consider, on a mile-by-mile basis, the parameters governing the stability of natural slopes along the proposed 760 mile pipeline alignment. Two R&M members of the five man task group were R.A. Migliaccio and J.W. Rooney.

The principal function of the task group was to establish the specific basis for analysis of the stability of each signficant slope under conditions judged by the group to be critical. Dr. Peck envisioned the work of the task group to consist of the following steps:

1. Examine the proposed layout of the pipeline on a mile-by-mile basis, considering each significant slope.
2. Agree on the geological features and engineering properties of the subsoil which are considered representative for each slope.
3. Consider carefully the conditions that are likely to prevail at any time, or times, which would prove critical with respect to stability.
4. Determine what constraints there may be upon the shape of the surface of sliding, and determine the shape, or shapes, that should be considered in the analyses.
5. Propose the appropriate physical parameters for use in the stability analyses.

The responsibilities of the task group did not include the actual performance of slope stability analyses. However, the results of the task group's study provided the basis for the best possible estimate of the stability of the slopes that could be obtained by the conventional analytical procedure making use of the results of soil and geological exploration, testing, and theory.

A number of personnel with R&M Consultants participated in this lengthy study and in the development of the final report.

R&M CONTACT:

Ralph Migliaccio, Anchorage Office, James W. Rooney, Anchorage Office

ROCKSLOPE DESIGN, DOCUMENTATION, DEWATERING, AND REINFORCEMENT, VALDEZ PIPELINE TERMINAL, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Michael C. Metz, Geotechnical Engineering

R&M provided a resident geologist who engaged in full-time consulting services for a period of three years. Activities began with geologic investigation of bedrock conditions by surface mapping and subsurface drilling and coring of bedrock. This geotechnical data was then used in the design effort to produce an extremely conservative design for the rockslopes and their reinforcement, such that the rockslopes would be stable during the design contingency earthquake (0.6 g lateral acceleration). A conservative design was required because of the height of the rockslopes (up to 230 feet) and their proximity to vital facilities of the terminal complex. Geotechnical input also included draft and revision of rock work specifications including drilling, blasting, and rock bolting techniques. During construction, activities included daily site inspections to document geotechnical conditions, to insure that excavation conformed to design, and to monitor the contractor's QC documentation. Also, as excavation progressed, unfavorable geotechnical conditions were encountered which required field modification of slope and reinforcement design. Encountered groundwater pressures also required the design of a weephole, inclined drain, and interceptor trench dewatering system for each rockslope, and the design and installation of a piezometer network for groundwater observation. R&M personnel prepared technical reports on these matters for governmental agency review.

In all, six different rockslopes were designed, excavated, reinforced and documented, as follows:

1. Powerhouse and Vapor Recovery Backslope
2. West Manifold Rockslope
3. Ballast Water Treating Backslope
4. Vapor Recovery Westslope
5. East Tank Farm Step
6. West Tank Farm Step

Slope angles varied from steep slopes of 1 horizontal to 4 vertical to more gentle slopes of 1 horizontal to 1 vertical. Reinforcing techniques used included tensioned, fully-grouted Dywidag rockbolts, wire mesh, toe buttresses, and shotcrete. All slopes possess a dewatering system with installed piezometers to monitor groundwater conditions.

R&M CONTACT:

Jim McCaslin Brown, Anchorage Office

CONSTRUCTION INSPECTION OF BEDROCK CONDITIONS, BLASTING, AND STABILITY KEYSTONE TUNNEL BYPASS PROJECT, VALDEZ

CLIENT:

State of Alaska, Department of Transportation and Public Facilities, Division of Highways

CLIENT CONTACT:

Mr. William Slater, Chief Geologist

Consultant services began after serious slope stability problems halted construction on this project. Initial R&M work involved participation in redesign of the rockslopes. Periodic inspections were performed after construction recommenced to examine excavated rockslopes and blasting results in order to maximize stability and safety. A stability analysis was conducted for the partially excavated rockslope west of the Lowe River. This analysis and other geologic data provided input for a Value Engineering study of alternatives for continuing the Bypass Project beyond the first construction season.

R&M CONTACT:

Jim McCaslin Brown, Head, Earth Science Department, Anchorage Office

REINFORCED EARTH EMBANKMENTS
ALYESKA PIPELINE TERMINAL, VALDEZ, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. M. C. Metz, Geotechnical Engineering

Two large embankments at the Valdez Pipeline Terminal were found to present severe limitations if constructed as conventional rockfill embankments, due to space and economic considerations. R&M personnel determined site and foundation conditions for the proposed Reinforced Earth Embankments and cooperated with Alyeska Engineering during review of the Reinforced Earth design for the East and West Tank Farm embankments. Efforts included review of earthwork specifications and recommendations on internal and basal drainage blankets of free-draining material to maximize embankment stability.

R&M personnel also performed daily construction inspection of materials and workmanship as the construction progressed, and monitored Quality Control personnel and documentation.

R&M CONTACT:

Jim McCaslin Brown, Project Manager, Anchorage Office

CONSTRUCTION MATERIAL SITES
ALYESKA PIPELINE TERMINAL
VALDEZ, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. M.C. Metz, Geotechnical Engineering

Material requirements for the Valdez Terminal construction reflected the complexity of the terminal plant facilities. During the three year period of construction, requirements existed for numerous types of rock-fill and earth-fill products including concrete aggregates. R&M personnel were active in all phases of acquisition of these materials.

Potential on-site bedrock sources were investigated by diamond drilling and laboratory testing of the recovered cores. Several of these sources, including one major quarry, were developed and rock-fill products were produced. Select (high-quality) rock-fill products were produced by crushing and screening plants, while non-select rock-fill products were often pit-run material. In both cases, R&M personnel engaged in quality control functions to insure that the rock-fill products satisfied required specifications.

On-site sources of fine-grained, relatively impermeable earth-fill were required for surface sealing of containment dikes. Surface and subsurface investigations combined with laboratory testing and site conditions, such as length of haul and accessibility, were used to delineate suitable sources. These sources were within glacially deposited silty gravels.

No on-site sources of sands and gravels existed which were suitable for coarse and fine concrete aggregates. Because of this, off-site existing gravel pits owned by private firms and the State of Alaska were investigated. These were located at some distance from the terminal in the flood plain of the Valdez Glacier stream. Site selection among these commercial pits involved visual inspection of pit walls, laboratory testing of bulk samples, and examination of past production records. In addition, R&M performed the required laboratory testing and prepared a concrete mix design as well as a shotcrete mix design.

R&M CONTACT:

Jim McCaslin Brown, Head, Earth Science Department, Anchorage Office

GRAYWACKE QUARRY-EXPLORATION, DEVELOPMENT AND PRODUCTION ALYESKA PIPELINE TERMINAL, VALDEZ, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. M. C. Metz, Geotechnical Engineering

The rockfill requirements for construction of the Alyeska Pipeline Terminal required 1.5 million cubic yards of competent rock for select rockfill products in excess of that obtainable from the rock excavations required by the facilities design. R&M personnel were major participants in all phases of the life of the quarry. These included site reconnaissance, exploration, development, excavation design, production and restoration.

A site evaluation reconnaissance based on surface geologic mapping located four potential sites. These were explored by diamond drilling (NX-Coring). Cores were logged in the field, including such parameters as rock type, fracture spacing, and Rock Quality Designator (RQD).

Selected cores underwent soundness (resistance to chemicals) and abrasion tests (resistance to physical forces) to determine the competence of the rock at the various potential sites. The best quarry site was then selected based upon the results of drilling and testing, accompanied by standard economic considerations such as length of haul, access to the site, and excavation methods.

A development Mining Plan was then drafted for the quarry which included design of the rock cuts for the proposed excavation, design of drainage measures both surface and subsurface, and design of haul roads. In addition, restoration plans with a Visual Impact Engineering report were included. An oral presentation by R&M personnel based on this document plus submittal of the document by Alyeska to the federal and state reviewing authorities resulted in the appropriate permits and notices-to-proceed.

R&M personnel monitored rock quality and excavation during production of the quarry to insure that the proper rock products were produced and that the resultant rock slopes were stable and safe during the life of the quarrying operation.

R&M CONTACT:

Jim McCaslin Brown, Head, Earth Science Department, Anchorage Office

SITE ANALYSIS AND ALTERNATIVE
LAND USE PLANS FOR FEDERAL EXCESS LANDS

CLIENT:

Cook Inlet Region, Inc.

CLIENT CONTACT:

Mr. Carl Marrs, Land Manager, 1211 W. 27th Avenue, Anchorage, Alaska.

R&M carried out an extensive site analysis and land use planning effort to provide Cook Inlet Region, Inc., an overview of the development potential and land use alternatives for several Federal Excess Land sites being considered by the Native corporation for selection under the Native Land Claims Settlement Act.

The planning process consisted of two steps. Initially a site evaluation criterion was developed to screen all potential sites. Factors considered in the criterion included access to the site; availability of utilities; land terrain; soil conditions; vegetation type and density; flood, earthquake, and avalanche potentials; zoning and other comprehensive planning considerations. An extensive literature search and interpretation of aerial photos provided the data needed to develop the parameters used to make the first phase selections. Sites determined to have development potential in the first phase were then subjected to the second phase process which developed land use alternatives for those sites.

R&M CONTACT:

Mr. Theodore Smith, Project Manager, Anchorage Office.

SITE EVALUATION FOR PROPOSED ALTERNATE U. S. COAST GUARD LORAN "C" STATIONS

CLIENT:

17th Coast Guard District, Juneau, Alaska

CLIENT CONTACT:

Mr. H. McPherson, Contracting Officer

R&M produced comprehensive site evaluations for proposed alternate Loran "C" Stations at Tok, Carroll Inlet, and Annette Island, Alaska. Comprehensive evaluations were also produced for sites at Sitkinak, Chiniak and Narrow Cape, Alaska, on Kodiak Island. Site surveys were performed at each site to produce the boundary and contour maps needed to develop the site layout plans and drainage systems. Extensive subsurface soils investigations were conducted to gather information needed to make recommendations on structural foundation designs, potential material source locations, sewage and solid waste disposal site locations, water supply well locations, and to evaluate potential problems with local groundwater conditions. Local climatic conditions and seismic probability were included in the evaluation process.

R&M CONTACT:

Mr. Mal Menzies, Vice-President and Project Manager, Juneau Office.

PRELIMINARY HYDROLOGIC STUDIES
ALCAN GAS PIPELINE PROJECT
DELTA JUNCTION TO THE CANADIAN BORDER

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Mark Luttrell, Senior Environmentalist, Gulf Interstate Engineering Company

This study was initiated by field reconnaissance of the proposed route using aerial and on-the-ground observation techniques. The field work was supported by office investigation using existing topographic maps and aerial photographs. The office review entailed a literature search of pertinent documents and analysis of the drainage basins involved, leading to the development of a computational method to obtain design discharge values. All the drainage basins were classified. The studies isolated fish streams, areas of aggradation, scour, outburst flood potentials, and general ground water conditions along the pipeline alignment between Delta Junction and the Canadian Border.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDROLOGY AND RIVER HYDRAULICS STUDY
KUPARUK RIVER AND COASTAL PLAIN STREAMS
NORTH SLOPE, ALASKA

CLIENT:

Atlantic Richfield Company

CLIENT CONTACT:

Steve Jones; Atlantic Richfield Company

This project consisted of conducting a complete hydrological analysis of the Kuparuk River and provide baseline design parameters for a proposed bridge and pipeline crossing. An estimate of flood discharges was made utilizing the Corps of Engineers (HEC-I) Flood Plain Hydrology Computer model. Following the preliminary office analysis, an extensive field program was conducted during the spring breakup flood to obtain data for the calibration of the computer model and interpretation of river behavior.

Flood plain delineation, Flood water elevations, water velocities and depth of scour were determined for the Kuparuk River in the vicinity of the proposed crossing.

Three small Coastal Plain streams were investigated for providing a water supply for camp and drill rig usage. The quantity and quality of the water was determined, and the duration of time that each stream flows sufficiently to provide a water supply was identified.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDROLOGY STUDY
KUPARUK RIVER
PRUDHOE BAY, ALASKA

CLIENT:

Atlantic Richfield Company

CLIENT CONTACT:

Mr. Stan Caldwell, Senior Project Engineer

For Atlantic Richfield's Kuparuk River crossing and Kuparuk Development Area, R&M performed a hydrology study which included a flood hazard analysis utilizing the Corps of Engineers' HEC-1 and HEC-2 computer models. This study, which consisted of both office analysis and field investigation, developed estimated discharges, water surface profiles, and scour depths for 25-, 50-, 100-, and 200-year recurrence intervals. Additionally, a water supply analysis was performed for the proposed "development area," to determine the feasibility of supplying water for a permanent camp of approximately 200 people.

The lack of base-line data, coupled with the extremely difficult field logistics, required both the technological ability to develop the computer analysis and the field experience to perform the in-stream work.

R&M CONTACT:

John E. Swanson, Project Manager

HYDROLOGY STUDY
PROPOSED NEW CAPITAL SITE
WILLOW, ALASKA

CLIENT:

Capital Site Planning Commission

CLIENT CONTACT:

Mark Fryer; Mark Fryer and Associates

As a portion of the initial physical planning effort for the proposed new capital site, R&M performed a hydrology and flood hazard study. The site is traversed by one major stream, Deception Creek, and the study included an estimate of the flood discharge for this creek as well as a general hydrologic review of the entire capital site study area. The review entailed compilation and analysis of precipitation and snowpack data available for the area, as well as analysis of the stream flow records for streams having similar hydrologic characteristics within this region. Drainage patterns were studied as they related to erosion potential, and recommendations were made concerning control of storm water runoff, icing hazards, and land use.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

RIVER MONITORING PROGRAM
ALCAN GAS PIPELINE PROJECT
DELTA JUNCTION TO THE CANADIAN BORDER

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Walfred Hensala, Environmental Coordinator

During the Spring of 1977, R&M monitored the break-up conditions in the five major rivers along the proposed gas pipeline route between Delta Junction and the Canadian Border. While the results of this effort were qualitative in nature, they provided valuable insight into the characteristics of these streams. Following the break-up period, a limited amount of in-stream work was performed in order to prepare a preliminary estimate of scour potential.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDRAULIC DESIGN CRITERIA
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A. Condo, Arctic/Civil Engineering Supervisor

R&M developed the design criteria for basic hydraulic structures required to intercept and route flows from defined drainages and surface runoff from undefined drainages across the pipeline workpad. Drainage structure selection criteria was developed based on varying soil types, thermal state of the soils, terrain, types of flow and configuration of the workpad. Design procedures permitted selecton of the most suitable drainage structure. Tables and charts were developed for sizing the most economic structures for the anticipated design discharge, as determined in the hydrology study of small drainage basins. The resulting manual enabled field construction personnel to specify and design the most suitable structures for differing or unusual field conditions during construction. This manual was ultimately incorporated into the erosion control manual used to restore the workpad and other work sites after construction.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDROLOGY STUDY OF SMALL STREAMS
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. A. Condo, Arctic/Civil Supervisor

R&M selected the computational method used to estimate the surface runoff for the small drainage basins intercepted by the pipeline right-of-way. The study included surveying several discharge computational methods, evaluating the available data and computing the design discharges for all runoff intercepting the 760-mile long pipeline alignment. Following this, preliminary recommendations for drainage structures were made. The initial design was accomplished in the office, with all results tabulated by computer, and the final design requirements were verified in the field before and during the construction process. R&M's overall participation in this effort extended over a four-year period and was expanded to include responsibility for various phases of erosion control and revegetation.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

GENERAL ENGINEERING AND GEOLOGICAL CONSULTING SERVICES
ALCAN GAS PIPELINE PROJECT

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Mr. John Viehweg, Chief Engineer

Testimony for F.P.C. hearings, chaired by Judge Litt in Washington, D.C., was prepared and presented. Subsequently, numerous short technical reviews have been conducted to establish background data for other hearings as well as for use in design planning. These reviews have included the geologic evaluation of various pipeline routing possibilities and the analysis of design and construction practicality. Conditions considered have included soil and permafrost conditions, frost heave potential, drainage characteristics, compatibility with existing and proposed man-made facilities, and natural hazards. Structure design, performance, and cost criteria relating to special northern environmental constraints, have also been reviewed.

R&M CONTACT:

Ralph Migliaccio, Fairbanks Office.

PRELIMINARY CENTERLINE SOIL INVESTIGATION
DELTA JUNCTION TO THE CANADIAN BORDER
ALCAN GAS PIPELINE PROJECT

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Don Nicol, Senior Engineer, Gulf Interstate Engineering Company

This program was designed and conducted to meet the need for preliminary soils, ground water and related data along the proposed route of the ALCAN Gas Pipeline. During the peak period of activity, seven rotary drill rigs were working two shifts per day spread out over as much as thirty miles of line. An extensive communication system involving portable radios and couriers was utilized to maintain close field coordination and sufficient logistical support including the transportation of large quantities of soil samples. Special care and equipment was necessary to maintain frozen and unfrozen samples in their natural thermal state during transport from the field to the testing laboratory in Fairbanks.

The field and laboratory data from this program is scheduled for use in the development of initial design concepts and in planning subsequent programs.

R&M CONTACT:

Robert L. Schraeder, Anchorage Office.

GEOTECHNICAL INVESTIGATION - PILLAR MOUNTAIN SLIDE
KODIAK ISLAND, ALASKA

CLIENT:

State of Alaska, Department of Highways

CLIENT CONTACT:

William Slatter, Chief Geologist, Department of Highways, College, Alaska

R&M Consultants, Inc. performed a geotechnical review of the Pillar Mountain slide on Kodiak Island, Alaska. Extensive surveys of the slide area were performed to determine correct placement of a monitoring network to warn of any further slide movement during future construction efforts. Project was performed in 1972.

R&M CONTACT: Mr. Jim Rooney, Vice President, Anchorage Office

GEOTECHNICAL INVESTIGATIONS, 17 PROPOSED SCHOOL SITES,
LOWER KUSKOKWIM SCHOOL DISTRICT
BETHEL, ALASKA

CLIENT:

Lower Kuskokwim School District

CLIENT CONTACT:

Mr. Dave Chauvin, Contract Manager, L.K.S.D., Anchorage, Alaska

Complete geotechnical investigations for seventeen villages in the Lower Kuskokwim School District (Bethel, Alaska area) were conducted in January and February of 1979. Three drill rigs were utilized to accomplish the fieldwork. One drill rig was mounted on an all terrain Nodwell; two were skid mounted and transported from site to site by Caribou or Sky Van aircraft. Test holes at each site were drilled to depths of 30 feet with split spoon and core barrel sampling. Many of the sites were underlain by permafrost. Soil profile temperatures were monitored at each site with thermistor strings. Field logistics and soil sample shipping were coordinated in Bethel. All soil samples were maintained in their original thermal state while being returned to Anchorage for laboratory testing. Foundation recommendations and other site geotechnical parameters were presented in a final report for each site. Foundation recommendations included conventional shallow footings, piles and refrigerated (passive) shallow foundations.

R&M CONTACT:

Dennis Nottingham or Gary Smith, Anchorage Office

GEOTECHNICAL INVESTIGATIONS
ALASKA STATE HIGHWAY SYSTEM
LIVENGOOD TO THE CANADIAN BORDER SEGMENT

CLIENT:

Alaska Department of Highways, Juneau, Alaska

CLIENT CONTACT:

William Slater, State Geologist or Doyle Ross, State Materials Engineer, Department of Transportation, Douglas, Alaska

R&M personnel have extensive supervisory and field experience on the Alaska Highway System. Specific studies that our personnel have participated in along the Livengood to the Canadian Border segment include centerline soil investigations, material site exploration, quarry exploration, and construction quality control. Some special studies also in this area include "An Investigation of the Canadian Border Slide," "Research on Aggregate Degradation," and "Routing Studies to Avoid Problem Areas."

Various personnel have acted in different highway department capacities including State Soils Engineer, State Foundation Geologist, District Geologist, District Materials Engineer, Field Geologist, and Materials Technician.

R&M CONTACTS:

J.W. Rooney; R.R. Migliaccio; R.L. Schraeder; W.T. Phillips; and D. Nottingham; Anchorage Office

ENVIRONMENTAL ASSESSMENT PROGRAM - PHASE I
SOURCE DOCUMENT NO. 3
GEOTECHNICAL STUDIES - GEOLOGIC MATERIALS AND
HAZARDS ANALYSIS

CLIENT:

State of Alaska, Capital Site Planning Commission

CLIENT CONTACT:

Dr. Charles Behlke, CSPC Chairman, Geophysical Institute, University of Alaska, Fairbanks.

During September and October, 1978, R&M geologists spent one month in the field at the proposed new State Capital at Willow. This field investigation, performed for the Capital Site Planning Commission, was part of an investigation which applied the techniques of terrain unit analysis to a 100 square mile area. These procedures allowed the collection of considerable geotechnical data to be used for environmental assessment of the Capital Site for evaluation of geologic materials hazards.

Initial stages of data collection produced preliminary terrain and slope analysis maps of the planned development area of the capital site by air-photo interpretation. This was followed by field work. Initial efforts utilized helicopter-supported field crews with hand tools. This effort, which involved study of over 150 locations, was directed toward gathering ground-truth, validating the maps, and gaining a better understanding of on-site vegetation, soil, and water conditions. Detailed subsurface work consisted of backhoe test pits and four 100-foot deep drill holes, and took place within specific development areas to support the planning efforts at the Commission. These areas included the town center, airport site, power plant site, water well development area, and four residential areas. The backhoe operation was confined to areas with existing trails and the drilling operation used helicopter-transported drills.

The field-checked Terrain Unit Map with associated tables, field logs, and laboratory data is a convenient vehicle for storing and presenting considerable geologic and engineering data concerning the soils, bedrock, and groundwater for the 100 square mile development area. A Geologic Materials Map was derived from the Terrain Unit Map to describe the construction use and foundation suitability of the soils and bedrock. An Erosion Potential Map was derived from the Slope Map and the Terrain Unit Map. This described the potential for erosion during development and construction activities based upon topographic and soil conditions.

A final derivative map describes the type and severity of various geologic hazards. Hazards documented included permafrost thaw-settlement, settlement, slope stability, seismic ground shaking, seismic ground fracturing, and seismic liquefaction. The ground fracturing hazard is related to the Castle Mountain Fault in the area near the Little Susitna River at the east end of the capital site. A statistical study of the seismicity of the capital site was performed. One conclusion reached was that the capital site is in a somewhat less seismically active area than either Fairbanks or Anchorage.

R&M CONTACT:

Jim McCaslin Brown or Robert L. Schraeder, Anchorage Office

GEOTECHNICAL INVESTIGATION AND TERRAIN ANALYSIS
SOUTH WILLOW CAPITAL SITE

CLIENT:

State of Alaska, Capital Site Planning Commission

CLIENT CONTACT:

Mr. R. Moorehouse, Planner

A preliminary site evaluation was performed to obtain data required for the physical planning and design tasks of the client's Phase 1 Planning Process.

The terrain unit method of terrain analysis was employed during the geotechnical investigation of the South Willow Capital Site.

This method of investigation employs remote sensing techniques (specifically air photo interpretation) to define landforms and landform types within the study area. Eight terrain units were identified within the designated development area of the South Willow site. These terrain units were then investigated in the field by standard surface geology mapping methods supplemented by the subsurface soils techniques of drilling and sampling. Information thus obtained was augmented with local Electromagnetic (EM) Resistivity Surveys.

This information combined with laboratory testing of selected soil samples, and preliminary engineering evaluations produced a terrain analysis of the designated development area. Documents produced included:

- Slope Identification Map - Scale 1:24,000
- Terrain Unit Map - Scale 1:24,000
- Terrain Unit Evaluation Table
- Slope Analysis Map - Scale 1:6,000
- Geotechnical Limitations to Building Construction Map -Scale 1:6,000

R&M CONTACT:

Jim McCaslin Brown, Anchorage Office

THOMPSON PASS CABLEWAYS
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Taylor Rigging Company

CLIENT CONTACT:

William Taylor

Construction of the trans Alaska pipeline presented many diverse engineering problems including the movement of pipeline and related construction equipment to each site. At Thompson Pass, a particularly steep mountain face compelled the use of hi-lines for the transportation of materials and the construction operation. Designed by R&M to serve as overhead cableways, the two hi-line spans were 1,000 and 1,450 feet and each possessed a 20 ton load capacity. Representing some of the longest span structures built in Alaska, the hi-lines were each supported by two steel towers with a maximum height of 170 feet. The moveable towers supported track cables anchored to post-tensioned concrete deadmen.

R&M CONTACT:

Dennis Nottingham, Project Manager, Anchorage Office.

GULKANA RIVER PIPELINE BRIDGE
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Jim A. Maple, Supervisor Structural Analysis

The original engineering design plans for the Alyeska Pipeline Service Company hot oil pipeline crossing of the Gulkana River involved a buried underwater crossing. Alyeska's decision to bridge the river avoided innumerable associated problems and provided R&M's senior structural design engineers with some specific challenges. The bridge represents an imaginative approach to the sensitive problems of permafrost, ecology, time and materials limitations, as well as aesthetics.

A tied-arch design was developed for the bridge superstructure and construction was accomplished with steel available to the project. The 400 foot long bridge has a substructure composed of specially designed H-piles driven into permafrost. Bridge loads are transferred to the H-piles by supporting piers made from 48" and 18" diameter surplus project pipe. Project design and construction of the $2 million bridge was completed within a six month period.

R&M provided the following services:

- Schedule Control Services
- Design Drawings and Engineering Documents
- Environmental Assessment Including Subsurface Investigation
- Fabrication Quality Control
- Logistics Control
- Construction Inspection

R&M designers won a fifth place award for the bridge superstructure design and third place award for the pile foundation design in the James F. Lincoln Arc Welding Foundation, 1976 Awards Program for Improvement Through Welding.

R&M CONTACT:

Dennis Nottingham, Project Manager, Anchorage Office

YUKON RIVER BRIDGE

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

The involvement of R&M in design and construction of this 2300 foot orthotropic steel pipeline/highway bridge spanning the Yukon River was significant. Mr. Dennis Nottingham was originally in charge of design for this nationally significant structure while employed by the State of Alaska and won Lincoln Arc Welding honors for his contribution. Following his employment with R&M, this firm became a consultant to Alyeska Pipeline Service Company relating to this structure. Interaction with government review officials, analysis of substructures, review of pipeline erection procedures and design of new barrier railing were part of these efforts. Knowledge of ice forces, and analysis based on design of this structure and many previous large highway crossings was used to develop river ice and drift design criteria for all pipeline bridges with river piers on the Trans-Alaska Pipeline.

R&M CONTACT:

Dennis Nottingham, Project Manager, Anchorage Office

SAXMAN DAM
KETCHIKAN, ALASKA

CLIENT:

U.S. Public Health Service

CLIENT CONTACT:

John DeLapp

In order to provide an adequate water supply for the City of Saxman, near Ketchikan, the U.S. Public Health Service contracted with R&M to perform the design of a dam, reservoir, and treatment system. This included preliminary hydrologic and geologic investigations at the site, design of the dam and its appurtenant structures, and design of the access road, transmission line, and pipeline between the dam and the existing system.

Several alternative systems were investigated, and recommendations were made to U.S.P.H.S., based on the on-site investigations and on previous experience with similar projects in southeast Alaska.

R&M CONTACT:

Dr. Daniel Smith, Project Manager

JAMES W. ROONEY, P.E. PRINCIPAL/VICE PRESIDENT

Current Responsibilities

Vice President and Principal-in-Charge, Anchorage Office, R&M Consultants, Inc.

Alaskan Task Assignments

R&M Consultants, Inc.:

Special Consultant to Trans Alaska Pipeline System and gas pipeline study groups.

Consultant, for the coordination and supervision of field investigations and geotechnical studies for the Trans Alaska Pipeline System; involvement has been continuous since early 1969.

Geotechnical Engineer, assisted in the evaluation of pipeline alignment, general soil conditions, and preliminary review of slope performance of critical segments along the Trans Alaska Pipeline route.

Geotechnical Engineer, selected as special task group member by Dr. R. B. Peck for detailed review and identification of slope stability problems associated with construction programming along the Trans Alaska Pipeline route.

Project Consultant, visual impact engineering and site restoration projects for the Trans Alaska Pipeline.

Evaluation of a small dam failure in Anchorage, Alaska, and retained as a third party to review a number of geotechnical and civil design related project failures.

Expert review on legal case concerning 1) Construction claims associated with pavement materials at Barrow, Alaska, 2) a major landslide and powerhouse failure in Ketchikan, Alaska, and 3) the failure of large multi-plate highway culverts in Juneau, Alaska.

Project Geotechnical Manager for U. S. Coast Guard Loran "C" Stations at Ketchikan, Kodiak, and Tok, Alaska.

Performance of soils engineering and foundation studies in Anchorage, Wasilla, Palmer, Fairbanks, Juneau, Kenai, Cordova, Valdez, and many Alaskan locations throughout the Trans Alaska Pipeline route.

Evaluation of a construction excavation slope failure in weathered bedrock which partially undermined an existing three story structure on the University of Alaska - Fairbanks campus, included the design of a braced bulkhead retaining wall for temporary support through construction period.

Selected as Project Geotechnical Consultant for the Northwest Alaskan Natural Gas Transmission System by Fluor Engineering and Constructors. Involved in coordination of and supervision of field and office geotechnical studies for the chilled gas pipeline alignment.

State of Alaska, Department of Highways:

Project Design Engineer, responsible for a number of highway design projects in Southeast Alaska.

Design Engineer, directed a special study involving construction of a four-lane highway adjacent to the Juneau-Douglas High School. Effort included evaluation of settlement and highway embankment slope stabilization related to previous boat harbor construction and hydraulic fill placement adjacent to structure.

Valdez District Materials Engineer, responsible for project materials and soil investigations for district projects; programs included evaluation and design recommendations for cut slopes of up to 300' in height in soils and rock containing both frozen and thawed conditions.

Valdez District Materials Engineer, conducted special study and prepared remedial design for a major embankment failure involving gravel fill on thawed clay soil.

State Soils Engineer, responsible for review of soil conditions and specific geotechnical studies for general soil investigations on highway projects throughout the State.

State Soils Engineer, supervised and directed a number of special studies on soils and construction materials and assisted in the review of project construction materials and soil conditions.

State Soils Engineer, directed investigation of a major 55' high rock-fill embankment failure on disturbed frozen foundation material along a section of the Alaska Highway.

<u>Task Assignments Performed Outside Alaska</u>

Soil Testing Services, Iowa City, Iowa:

Senior Engineer, responsible for project operations at branch office of Soil Testing Services in Iowa City, Iowa. Projects involved major foundation investigation programs for highways, buildings, small dams, and industrial sites.

Project Soils Engineer, providing services for two major interstate highway projects involving special design considerations for deep cuts and fills in potentially unstable soils; evaluation and recommendations for staged construction, sub-drains, instrumentation and monitoring controls for these projects. Also involved in the evaluation of bluff instability and erosion problems above the Burlington Railroad alignment along the Mississippi River near Ft. Madison.

Education

B.S., 1962, Civil Engineering, Wayne State University.

M.S., 1967, Civil Engineering, Wayne State University.

Registrations/Certifications

Professional Engineer (Civil), 1964, Alaska, 1967, Iowa.

Professional Land Surveyor, 1972, Alaska.

Professional Affiliations

Member, American Society of Civil Engineers.

Member, National Society of Professional Engineers.

Member, Transportation Research Board.

Past Assistant Chairman, Soil Mechanics and Foundations Committee, American Society of Civil Engineers, Iowa Section.

Former Member, Anchorage Municipality Geotechnical Commission.

Instruction

Instructor (Evening Course) - University of Alaska, School of Engineering, Department of Civil Engineering, "Pavement Design."

Workshop Topic Chairman, Transportation Corridors - Design and Construction. Joint U.S. - Canadian Northern Civil Engineering Research Workshop. Edmonton, Alberta, March, 1978.

Publications

Davison, B.E., Nottingham, D. and Rooney, J.W., "Chilled Pipeline Frost Heave Mitigation Concepts." Pipelines in Adverse Environments, Proceedings of the ASCE Pipeline Division Specialty Conference, January, 1979.

Davison, B.E., Rooney, J.W., and Bruggers, D.E., "Design Variables Influencing Piles Driven in Permafrost." A.S.C.E. Cold Regions Specialty Conference, Anchorage, Alaska, May, 1978.

Vita, C.L. and Rooney, J.W., "Seepage - Induced Erosion Along Buried Pipelines." A.S.C.E. Cold Regions Specialty Conference, Anchorage, Alaska, May, 1978.

Davison, B.E., and Rooney, J.W., "Arc Welding Applied to Arctic Foundations," Consulting Engineer, December, 1977.

Wang, Dr. W., Rooney, J.W., and Davison, B.E., "Simpson Hill Cut, Copper River Basin, Alaska - A Case History of Slope Stability in Frozen Cohesive Soil." Thirtieth Canadian Geotechnical Conference, Saskatoon, Saskatchewan, October, 1977.

Davison, B.E., and Rooney, J.W., "Use of Thermal Piles for Offshore Frozen Embankments." Fourth International Conference on Port and Ocean Engineering Under Arctic Conditions, Memorial University of Newfoundland, St. Johns, Newfoundland, Canada, 1977.

Rooney, J.W., Nottingham D., and Davison, B.E., "Driven H-Pile Foundations in Frozen Sands and Gravels." Second International Symposium on Cold Regions Engineering, University of Alaska, College, Alaska, 1976.

Rooney, J.W., and Atkins, J.T., "Servicing in Northern Communities" (abstract). Forum - Canadian Institute of Planners - Annual Conference, Winnipeg, June, 1976.

Migliaccio, R.R., and Rooney, J.W., "Engineering Geologic and Subsurface Soil Investigations for the Trans Alaska Pipeline System" (abstract). Proceedings - Symposium on Cold Regions Engineering (Vol. I), University of Alaska, College, Alaska, June 1971.

Rooney,, J.W., "The Influence of Sampling and Disturbance on the Shear Strength of Saturated Cohesive Soils," Master's Essay submitted to College of Engineering, Wayne State University, June, 1967.

Klausner, Y., and Rooney, J.W., "Design and Construction of a Device for the Pure Deviatoric Loading of Soils." National Science Foundation Science Teaching Equipment Development Program Grant, Wayne State University.

<u>Awards</u>

1976 Lincoln Arc Award for H-Pile Foundation Design.

Awarded Membership in Chi Epsilon, National Honorary Civil Engineering Fraternity.

MALCOLM A. MENZIES, P.E., L.S. VICE PRESIDENT

Current Responsibilities

Principal and General Manager, Juneau Office, R & M Consultants, Inc.

Alaskan Task Assignments

- R&M Consultants, Inc.

Location Engineer, responsible for locating 55 miles of secondary road from Livengood to the Yukon River for the Trans Alaska Pipeline.

Project Manager, supervised engineering and environmental analysis for the Juneau-Douglas waste water treatment facility.

Project Manager, supervised site reconnaissance, evaluation, location surveys, and soils investigation for the U. S. Coast Guard's 17th District Loran 'C' Sites at Shoal Cove, Tok, and Narrow Cape, Alaska.

Project Manager, supervised quality control and construction management services provided to the City and Borough of Juneau for repaving improvements to the Juneau International Airport and pavement construction, Wrangell Airport.

Project Manager, currently responsible for supervising R&M's portion of a joint venture effort with Richardson Associates and TAP, Inc., to update the Juneau International Airport Master Plan for the City and Borough of Juneau.

Project Manager, supervising feasibility studies, surveys, and preliminary designs for the sawmill and port development proposed by the Alaska-Juneau Timber Corporation.

Project Manager, supervised special studies to evaluate natural resource sites throughout Southeast Alaska for multiple land use as construction material sources and at the same time provide environmental improvements.

Project Manager, supervised 155 mile Native Land Selection Cadastral Engineering project at Unalakleet, Alaska for the Bureau of Land Management.

Project Manager, currently supervising Native Land Selection Cadastral Engineering project in the Craig-Klawock area of Southeast Alaska for the Bureau of Land Management.

Project Manager, responsible for site evaluation, complete design, and construction management for a 310 unit mobile home park at Switzer Creek near Juneau, Alaska.

Project Manager, responsible for planning, design, and construction management of several projects throughout Alaska. Projects range from land development through to solid waste management and slope stability studies.

State of Alaska, Department of Highways, Juneau District

Area Resident Construction Engineer, responsible for protecting the State's interest in highway construction maintenance and design projects.

Project Construction Engineer, responsible for making certain that highway projects were constructed in accordance with the plans and specifications.

District Location Engineer, responsible for highway location surveys throughout Southeast Alaska.

Project Survey and Design Engineer, responsible for obtaining necessary preconstruction surveys and developing designs for specific highway projects in Southeast Alaska.

Project Right-of-Way Engineer, researched and made recommendations concerning highway right-of-ways for specific projects within the district.

Southeastern Consultants; Juneau, Alaska:

Partner in a firm which specialized in land surveys and civil engineering throughout Southeast Alaska.

Education

B.S., 1963, Civil Engineering, Chicago Technical College, Chicago, Illinois.

Special Studies in Surveying, U. S. Army Engineering Center, Fort Belvoir, Virginia.

Registrations/Certifications

Professional Engineer (Civil), 1969, Alaska, Washington.

Professional Land Surveyor, 1965, Alaska.

Professional Affiliations

Member, American Society of Civil Engineers.

Past State Treasurer, Alaska Society of Professional Engineers.

Past Chairman, Alaska Section, American Congress of Surveying and Mapping.

Board of Directors - Alaska Society of Professional Land Surveyors.

Member - American Society of Photogrametry.

Member - Canadian Institute of Surveying.

Member, American Congress of Surveying and Mapping.

Member, Alaska Society of Professional Land Surveyors.

Member, City and Borough of Juneau Planning Commission.

Member, Juneau Chamber of Commerce.

DENNIS NOTTINGHAM, P.E. VICE PRESIDENT

Current Responsibilities

Engineer specializing in structural, foundation, and marine design and analysis.

Vice President, Anchorage Office, R&M Consultants, Inc.

Alaskan Task Assignments

R&M Consultants, Inc.:

Design Engineer, developing ice force criteria for the design of major river structures along the Trans Alaska Pipeline.

Design Engineer, developing designs for several hydraulic and winch operated State Ferry System ramps.

Design Engineer, developing vehicle transfer barge-bridge systems for Hoonah, Metlakatla, and Kake.

Certified Scuba Diver, performing an underwater materials source investigation in conjunction with construction of the Juneau Outerdrive Road.

Design Engineer, designing a 2-1/2 million gallon earth fill dam in Juneau.

Design Engineer, designing six highway interchange structures in Anchorage.

Project Director, North Slope Haul Road Maintenance Camp Study for the Alaska Department of Transportation and Public Facilities. Responsibilities included directing planning studies and design/build contract preparations for the location of road maintenance facilities along this 360 mile arctic road. Efforts involved the "fast track" organization to examine a wide variety of environmental, geological, engineering, architectural and policy parameters. Results of these efforts were published in a planning report of 500 pages which took only three months to prepare.

Design Engineer, participating in the structural design for three all-wood pedestrian over-passes and seven bicycle trail stream crossings in Anchorage.

Engineer, involved in slope stability studies and landslide hazard recommendations.

Engineer, participating in several hydrology and hydraulic studies.

Structural Design Engineer, involving structural design review and special consulting for the Trans Alaska Pipeline System.

Structural Engineer, including conceptual and structural design for an oil pipeline bridge required by Alyeska Pipeline Service Company to span the Gulkana River.

Design Engineer, designing a system of overhead cableway highlines for use in material transportation up a steep mountain face during construction of the Trans Alaska Pipeline. The highlines span 1,450 and 1,000 feet, have a 20 ton load capacity, and are some of the longest span structures built in Alaska to date.

Project Engineer for design of lightering system for tour ships and related dock facilities for City of Juneau.

Analysis of ice loads and report on the exposed Nikiski Products Pipeline across Turnagain Arm, Alaska.

Project Manager, Design Engineer, performing the design for FAA Radar sites at Kenai and Fairbanks; aspects supervised included subsurface investigations, foundation, road, structural, water and sewer design, and surveying. This fast track project was completed within 30 days, to include the preparation of 15 detailed engineering drawings.

Project Engineer for design of a reinforced earth/prestressed concrete bridge over Campbell Creek at Arctic Boulevard, Anchorage, Alaska.

Project Engineer for design of steel and concrete dock and marine boat lift system in Petersburg, Alaksa.

State of Alaska, Department of Highways:

Design Engineer, designing many varied bridges for areas throughout Alaska.

Design Engineer, designing a 407 foot two-hinged steel arch bridge at Hurricane Gulch.

Design Engineer, designing the American Institute of Steel Construction award winning Chulitna River Bridge.

Engineer, performing the structural analysis and design check for the Sitka Harbor Bridge, the first cable-stayed bridge in the United States.

Design Engineer, performing design services for 220 foot span composite continuous steel plate girders for approximately one-half mile of bridges crossing the Copper River at Flag Point.

Design Engineer, performing design and project coordination services for the Yukon River Bridge--a 2,280 foot steel orthotropic structure with 410 foot main spans.

Certified Scuba Diver, providing underwater inspection services for foundation construction for the Sitka Harbor Bridge.

Certified Scuba Diver, providing underwater inspection services for the Juneau-Douglas Bridge.

Bridge Design Engineer, participated in bridge reconnaissance studies for Chilkat and Copper River Highways.

Engineer, participating in and conducting extensive structural inspection of bridges and marine facilities to include evaluation of earthquake destruction, normal deterioration, and other damage.

Design Engineer, designing a large concrete dock-type parking structure in Ketchikan.

Engineer, participating in scuba diving operations to locate abandoned artesian drill holes within the Kenai River.

Private Consultant:

Design Engineer, designing many docks, marine structures and facilities, airplane hangers, floating boat shelters, boat houses, riverboats, private homes, bridges, and a variety of other structures.

Design Engineer, participating as a co-designer of a marine highway auto-ferry transfer bridge with associated mooring dolphins at Cordova.

Certified Scuba Diver, participating in both major and minor salvage operations.

University of Alaska, Juneau-Douglas Community College:

Instructor, teaching mathematics, engineering and science courses.

Task Assignments Performed Outside Alaska

Montana Highway Department:

Design Engineer, designing various types of structures including continuous plate girder bridges, pre-stressed concrete bridges, retaining walls, composite girder bridges, interstate highway grade separation and interchange structures.

Montana State University:

Graduate Assistant Instructor, teaching courses in civil engineering.

Education

B.S., 1959, Civil Engineering, Montana State University

M.S., 1960, Civil Engineering, Montana State University.

Registration/Certifications

Professional Engineer, 1963, Alaska.

Professional Land Surveyor, 1973, Alaska.

Certified Scuba Diver, 1971.

Publications

Davison, B.E., Dennis Nottingham, J. W. Rooney, and C. L. Vita. Chilled Pipeline Frost Heave Mitigation Concepts, ASCE Pipeline Specialty Conference, New Orleans, January, 1979.

Davison, B.E., William Graham, Dennis Nottingham, and J. W. Rooney. Through Ice and Snow --- Timber Piles in Permafrost, AE Concepts, American Wood Preservers Institute, July - October, 1978.

Hartig, E.P., Dennis Nottingham, J.E. Swanson, B.C. Tisdale. Reburial Considerations for an Exposed Pipeline, A.S.C.E. Pipeline Specialty Conference, New Orleans, January, 1979.

Nottingham, Dennis, 1960. "Experimentation testing of a saddle type concrete hyperbolic paraboloid under four loading conditions," Masters Thesis, Montana State University.

Nottingham, Dennis, 1972. Baby It's Cold in Wood Preserving, April, American Wood Preservers Institute.

Nottingham, Dennis, and Roy Peratrovich, Jr. 1977. The 24-Hour Campbell Creek Bridge in AE Concepts in Wood Design, September-October, American Wood Preservers Institute.

Rooney, J.W., Dennis Nottingham, and B. E. Davison. 1976. Driven H-Pile Foundation in Frozen Sands and Gravels in Proceedings of the Second International Symposium on Cold Regions Engineering, Fairbanks. University of Alaska. 24p.

Awards

Award given in 1970 from the National Lincoln Arc Welding Design Contest for co-design of a marine highway auto-ferry transfer bridge and associated mooring dolphins at Cordova.

First place award of $10,000 given in 1976 from the National Lincoln Arc Welding Design Contest for design of the Yukon River Bridge.

Ideal Cement Company Graduate Study Fellowship.

Morrison-Maierle College Scholarship (Montana State University).

Most Beautiful Bridge Award to the Alaska Department of Highways from the American Institue of Steel Construction for design of the Chulitna River Bridge (D. Nottingham chief designer).

Shared fifth place award, James F. Lincoln Arc Welding Foundation, 1976 Awards Program for Improvement Through Arc Welding, Design of Gulkana River Pipeline Bridge.

WILLIAM E. DUNCAN

CURRENT RESPONSIBILITIES

President, The Drilling Company, Inc.

WORK DESCRIPTION

The Drilling Company, Inc.:

Responsible for management of contract drilling firm offering services via 18 drilling units to Alaska's engineering, construction and mining industries.

R&M Consultants, Inc.:

Laboratory Manager, responsible for all phases of soil laboratory operations.

Supervise quality control and material inspection on numerous construction projects within Alaska.

Responsible for soils investigations for foundation studies, construction inspection and materials testing.

Alaska Department of Highways:

Construction inspection of bridges and related highway buildings.

Set-up quality control on construction of new highway construction projects.

Training of engineering technicians and inspectors as related to quality control of highway materials.

EDUCATION

Florida State University
University of Alaska

ROBERT L. SCHRAEDER SENIOR ENGINEERING GEOLOGIST

Current Responsibilities

Associate of R&M Consultants, Inc.

Head, Earth Science Department, R&M Consultants, Inc.

Vice President, Resource Exploration Corporation, management of field operations conducted within the State of Alaska.

Professional Experience

1965	Staff Geologist, Alaska Department of Highways, Valdez.
1965-1969	District Geologist, Alaska Department of Highways, Valdez.
1969-1970	Acting District Materials Engineer, Alaska Department of Highways, Valdez
1970-Present	Senior Geologist, R&M Consultants, Inc.

Directly Related Task Assignments

R&M Consultants, Inc.:

Supervisory Geologist, supervision of the centerline soils investigation for the Trans Alaska Pipeline. This involved establishing the procedures, standards and lines of communication necessary to direct the activities of up to 40 field geologists, and to coordinate their efforts with the needs of management and other involved groups. This project involved various levels of activity over a period of approximately seven years, and a multimillion dollar budget. Products included preparation of published borehole logs, drilling location maps and supporting information in a format suitable for presentation to government review agencies.

Supervisory Geologist, supervision of the preliminary centerline soils investigation for the proposed Northwest Alaskan Gas Pipeline between Delta Junction and the Canadian Border. Tasks were essentially the same as for the TAPS (above) except that supervision of seven double shifted drill rigs was also included. This task involved as many as 50 personnel of varying job descriptions and was further complicated by the ex remely short time available for mobilization and the urgent ne d for the finished product.

Supervisory Geologist, supervised preparation of terrain unit maps and associated landform profiles for the TAPS project. These maps were developed by intensive use of photogeologic interpretation combined with extensive field checking and incorporation of all soils information available from the drilling program, published sources, and personal knowledge of the area.

Senior Geologist/Associate, managed and directed work of the R&M Houston office. Primary duties were: liaison with Alyeska Geotechnical Engineering and the numerous other consultants involved in the project, review of proposed design documents for compliance with design criteria and government stipulations, writing and reviewing design mode justification documents prior to submittal to the agencies, writing requests for Notices to Proceed and answers to agency questions and objections, performing duties attendant with the R&M position on the Alyeska construction mode selection committee, supervising other geotechnical personnel in the Houston office.

Supervisory Geologist, supervised preparation of preliminary Terrain Unit Maps for the proposed Northwest Alaskan Gas Pipeline. The project involved photo interpretation, a literature search and field checking.

Supervisory Geologist, assisted in the design of and data gathering for the TAPS Soil Data Bank.

Supervisory Geologist, supervised the design and implementation of resistivity surveys along selected segments of the TAPS. These surveys were used to extend the information in hand to other, less understood segments of the alignment, and to increase the confidence level of sub-soil interpretations.

Geotechnical Consultant, temporary duty in the Alyeska Houston Office. Duties included membership on the Alyeska Construction Mode Committee. This committee was responsible for the application of government stipulations and APSC design criteria to the collected geotechnical data to develop a construction mode listing for the entire pipeline route. Also included were extensive design review duties. These reviews included inspection of essentially all pertinent geotechnical parameters which might affect the integrity of the pipeline. Other duties involved monitoring of field data flow from Alaska to Houston, assisting on numerous short term task forces, and liaison between project personnel the R&M Houston Consultant Group and the Alyeska Hoston Group.

Supervisory Geologist, supervision of the day-by-day operation of the R&M Fairbanks Geotechnical Section. This included normal management duties as well as scheduling and implementation of all projects.

Geotechnical Consultant, participated in the foundation drilling program and materials source reconnaissance for two school buildings in Ketchikan Alaska. This project involved use of tripod and cat head wash boring tools which were hand carried to the drilling sites in dense vegetation.

Geotechnical Consultant, supervised the development of numerous reports such as slush flow avalanche studies, solifluction studies, slope stability studies and bedrock mapping projects.

Geologist, Member of the Site Study Task Force, North Slope Haul Road Maintenance Camp Study for the Alaska Department of Transportation and Public Facilities. Participated in the field investigation of all potential maintenance camp sites along the 360 mile road. Performed preliminary examination of all potential camp sites and described their physical parameters, including road maintenance, siting, climate, and geotechnical parameters as well as environmental, historical, and archaeological considerations.

State of Alaska, Department of Highways

District Geologist, performed route reconnaissance for various proposed routes including the Chitina to McCarthy Road, the Lake Louise Reroute and Extension, The Tasnina Pass segment of the Copper River Highway and other short realignment proposals.

District Geologist, directed and performed centerline soils investigations of the Chitina to McCarthy Road, various segments of the Glenn, Richardson and Tok Highways, the Lake Louise Road, and the Valdez to Ft. Liscum Road.

District Geologist, directed and performed borrow and quarry site investigations of the Lake Louise Road, the Chitina to McCarthy Road, the west end of the Copper River Highway, the Tasnina Pass area, and segments of the Richardson, Glenn and Tok Highways.

District Geologist, participated in setting-up and monitoring the Chitina permafrost insulation test section.

District Geologist, responsible for preparing and administering the budget and the day-by-day activities of the Geology group of the Materials Section, Valdez District.

Acting District Materials Engineer, direction of the geology, materials testing and construction materials inspection for the Alaska Department of Highways, Valdez District.

District Geologist, directed and performed seismic and resistivity surveys for bridge sites, borrow sites, cut sections and centerline investigations of segments of the Lake Louise Road, the Valdez to Ft. Liscum Road, and the Tasnina Pass section of the Copper River Highway.

Other Alaskan Experience:

Geologist, participated in stratagraphic geologic studies for Gulf Oil Corporation in the area north of the Brooks Range, Alaska.

Geologist, participated in research on Ice Island ARLIS II in the Arctic Ocean for the Office of Naval Research.

Geologist, teaching Assistant, University of Alaska, assisted in teaching the Mining Short Courses.

Research Assistant, investigations in geochemical research for the University of Alaska.

Education

M.S. Geology, University of Alaska

Registration/Certification

Registered Professional Geologist, California (1971)

JIM McCASLIN BROWN, Ph.D. SENIOR ENGINEERING GEOLOGIST

Current Responsibilities

Senior Engineering Geologist, specializing in projects requiring expertise in rock mechanics, structural geology, groundwater monitoring and control, bedrock mapping, and airphoto interpretation.

Alaskan Task Assignments

R&M Consultants, Inc.:

Operations Coordinator for the Northwest Alaskan Pipeline Company centerline soils investigation along the Alaska Highway from Delta Junction to the Canadian Border. This investigation performed in the spring of 1979 for Fluor-Northwest Inc., utilized 5 drillrigs, thermistor installations, and geophysical methods to obtain geotechnical data required for the Federal Energy Regulatory Commission permitting processes, and for design and financing purposes. The operations coordinator was responsible for sample storage and shipping; scheduling of the downhole permafrost density and moisture content determination by gamma-gamma response and neutron-thermal-neutron response techniques; thermistor installation; resistivity surveys employing Geonics EM 31 resistivity units to locate anomalies prior to drilling; scheduling of special drilling techniques for large sample recovery for frost heave studies; and final environmental inspection of drill sites.

Field Supervisor for resistivity survey of selected sites along the Northwest Alaskan Pipeline Company gas line route from Eielson Air Force Base to Livengood. The geophysical traverses totaled about 20 miles in length and were performed for Fluor-Northwest Inc. by a five man party utilizing the Geonics EM 31 and EM 34 survey units to measure ground resistivity, and to allow subsequent interpretation of subsurface conditions such as soil type and unfrozen versus frozen thermal state.

Project Geologist, Preliminary Site Investigations for 16 proposed high school sites at villages within the Lower Kuskokwim School District. Through the use of available well log data combined with airphoto and topographic map interpretation described the soils, permafrost, and seasonal frost conditions likely to prevail at the proposed school sites. Also responsible for a discussion of the regional geology, permafrost, and seismic conditions.

Senior Engineering Geologist, responsible for the preparation of terrain unit maps based upon published soils data and air photo interpretation as a part of a number of projects in southcentral and western Alaska. These terrain unit maps and non-plastic soil cements; and developing structures and methods to control erosion, stream siltation and surface runoff.

Project Geologist, responsible for the 1977 Terrain and Geotechnics Investigation of the South Willow Capital Site. This surficial geology and subsurface soils investigation, using the terrain unit method of terrain analysis, provided geologic data and engineering evaluation of the geotechnical conditions at the designated development area. This information was required for the initial physical planning and design tasks of the State of Alaska Capital Site Planning Commission.

Project Geologist, responsible for the 1978 Geotechnical Studies - Geologic Materials and Hazards Analysis of the new State Capital Site at South Willow, Alaska. This investigation, applying the techniques of terrain unit analysis to a 100 square mile area, was performed as part of the Environmental Assessment Program - Phase 1. These techniques allowed the collection of considerable geotechnical data to be used for an environmental assessment of the Capital Site.

Project Manager, rock slope stability consultant to the Alaska Department of Highways on the Keystone Tunnel Bypass Project. Services provided included construction inspection of bedrock conditions, blasting, and slope stability. Performed a stability analysis of the partially excavated rock slope west of the Lowe River. Participated in a Value Engineering Study of alternative plans for continuation of the project.

Project Geologist, responsible for the geologic reconnaissance, terrain unit mapping, and soils investigation portions of the Goose Bay - Point MacKenzie Highway Corridor Route Reconnaissance. This study performed for the Matanuska - Susitna Borough defined possible highway route corridors, evaluated geologic and soil conditions along each corridor, and estimated construction costs for roads within each corridor.

Project Geologist, responsible for the field investigation and site analyses of the Quarry Site Selection Study, for the University of Alaska Seward Marine Shore Station.

Senior Engineering Geologist, participated in a mile-by-mile frost heave potential assessment of the Northwest Alaska Pipeline Company gas line route from Prudhoe Bay to the Alaska Border.

Project Manager, provided geologic documentation of the cathodic protection borings at the Alyeska Pipeline Terminal in Valdez.

U. S. Geological Survey:

Geologist, investigated the structure and stratigraphy of the southern part of Kodiak Island, the Trinity Islands, and Chirikof Island, Alaska.

University of Alaska:

Research Assistant, investigated bedrock and ore deposits of the Fairbanks Mining District, Alaska.

Pan American Petroleum Corporation:

Junior Geologist, assisted in the field exploration for petroleum in Interior Alaska.

Task Assignments Performed Outside Alaska

Indiana University/Purdue University; Indianapolis, Indiana:

Assistant Professor of Geology, responsible for conducting research in structural geology and teaching graduate and undergraduate level courses in structural geology and air-photo interpretation.

Saint Louis University; St. Louis, Missouri:

Assistant Professor of Geology and Geological Engineering, teaching graduate and undergraduate level courses in structural geology, mineralogy and petrology.

University of Wisconsin; Madison, Wisconsin:

Instructor, teaching courses in structural geology.

Teaching and Research Assistant, instructing courses in introductory geology, and researching rock deformation.

Ontario Department of Mines; Ontario, Canada:

Senior Assistant Geologist, investigated the structure and stratigraphy of iron deposit formations in the Lake St. Joseph area of Northern Ontario.

Education

B.S., cum laude, 1960, Geology, University of Alaska.

M.S., 1963, Geology, University of Alaska.

Ph.D., 1968, Geology, (Metallurgical Engineering minor), University of Wisconsin, Madison.

Registrations/Certifications

Registered Professional Geologist, 1978, Oregon.

Certified Engineering Geologist, 1978, Oregon.

Certified Professional Geological Scientist, 1978, Association of Professional Geological Scientists.

Professional Affiliations

Member, Geological Society of America.

Member, Alaska Geological Society.

Member, American Institute of Mining, Metallurgical, and Petroleum Engineers.

Past President, Vice President, and Secretary-Treasurer, 1970-1973, Indiana Geologists.

Member, Valdez City School Board, 1975-1976.

Member, Association of Professional Geological Scientists.

Publications

Brown, J. M. 1963. "Bedrock geology and ore deposits of the Pedro Dome Area, Fairbanks Mining District, Alaska." University of Alaska, Fairbanks. M.S. thesis. 125 p.

Brown, J. M. 1967. The Grenville Front south of Coniston, Ontario in Geology of Parts of Eastern Ontario and Western Quebec: Guidebook for Fieldtrips, Fall meeting of the Geological Association of Canada and the Mineral Association of Canada. pp. 11-12, pp. 280-283.

Brown, J. M. 1968. "Nature and origin of the Grenville Front, SE of Sudbury, Ontario." University of Wisconsin, Madison. Ph D. thesis. 250 p.

Brown, J. M. 1970. Deformation and Movement Within Mylonitic Rocks of the Grenville Front, Southeast of Sudbury, Ontario (Abstract). Geological Society of America, North-Central Section. pp. 378-379.

Brown, J.M., et al. 1975. Design Considerations for the Rock Slope at the Powerhouse and Vapor Recovery Building, Valdez Terminal. Rock Slope Stability Report RSS-001. Alyeska Pipeline Service Company. 175 p.

Brown, J.M., 1977. Terrain and Geotechnical: in Natural Site Conditions, Background Report No. 4, State of Alaska, Capital Site Planning Commission. pp. 1-20.

Brown, J.M., Davison, B.E., and Schraeder, R.L. 1978. Geologic Materials and Hazards Analysis in New Capital City Environmental Assessment Program - Phase 1, Source Document No. 3 Geotechnical Studies - State of Alaska, Capital Site Planning Commission. 195 p.

Brown, J.M., 1978. Quarry Site Selection Study in Pre-design Investigation Seward Marine Shore Station Erosion Control Project. Prepared for the University of Alaska. R&M Consultants, Inc., Anchorage. pp 1-14.

Brown, J.M., et. al. 1979. Goose Bay to Point MacKenzie Route Reconnaissance. Prepared for the Matanuska - Susitna Borough, Palmer, Alaska. R&M Consultants, Inc., Wasilla. 68 p.

Brown, J.M., Dalziel, I.W.D., and T. E. Warren. 1969. The *structural and metamorphic history of the rocks adjacent to the* Grenville Front near Sudbury, Ontario, and Mount Wright, Quebec in Age Relations in High Grade Metamorphic Terrains. H. R. Wynne-Edwards, ed. Geological Association of Canada. Special Paper No. 5. pp. 207-224.

Brown, J.M., and R.B. Forbes. 1961. A Preliminary Map of the Bedrock of the Fairbanks Mining District, Alaska. Alaska Division of Mines and Minerals. Inv. Report 194-1.

Smith, T.L., Brown, J.M. et al. 1977. Energy Conservation Technology Study -- Identification of Environmental Impacts of Energy Conservation Technologies for Proposed New Capital Site at Willow, Alaska. *Prepared for the Alaska Division of Energy and* Power Development and the U. S. Energy Research and Development Administration. R&M Consultants, Inc., Anchorage. 59p.

Awards

Listed in American Men of Science - 12th ed., 1971.

WEI-JEN LIN

MATERIALS ENGINEER
LABORATORY MANAGER

Current Responsibilities

Laboratory Manager and Project Manager for geotechnical engineering investigations and construction quality control/assurance.

Alaskan Task Assignments

R&M Consultants, Inc.:

Design and field testing of construction work pad test sites near Fairbanks and Glennallen for Alyeska Pipeline Service Co.

Quality and quantity control for preparation of foundation soils in permafrost areas for schools in Fairbanks, Alaska.

Direct and review Portland concrete mixture designs and various types of asphaltic concrete mixture designs for both private and governmental organizations.

Calibration and assistance in setting-up hot-mix plants for asphaltic concrete paving, including the recently developed Shearer process drum-dryer plant in 1973 at the Nome Airport.

Evaluation of deteriorating pavement systems at Bethel, Fairbanks and Juneau airports.

Design and set-up quality control programs on construction of new paving system for streets and airports for Bethel and Juneau, Alaska, in 1971 and 1972 respectively.

Supervised construction quality control programs for portions of the Chena River Flood Control project at Fairbanks, Alaska.

Supervise quality control and materials inspection on numerous building construction projects throughout Alaska.

Design and supervise test programs for frozen gravel compaction studies.

Conducted asphaltic concrete paving inspection and testing training classes for Alaska Division of Aviation in 1972.

Served as expert witness in court case concerning Barrow Airport construction.

Task Assignments Outside Alaska

Geo-Testing, Inc.; San Rafael, California:

Laboratory Engineer, responsible for all phases of soil laboratory operations.

Laboratory tests including high pressure consolidation, triaxial compression, and permeability determinations for foundation and design of large earth dams, and monthly control testing during construction.

Research and development of special soil testing equipment to be manufactured and marketed by Karol-Warner, Inc.

Soil Testing Services of Iowa, Inc.; Iowa City, Iowa:

Materials Engineer, responsible for all phases of soils and materials laboratory operations and for supervision of field inspections.

Engineering and execution of test programs to solve special problems encountered in construction, such as trouble shooting for concrete strength deficiencies.

Conducting pile and footing load tests for high load capacities, and assisting in programming all laboratory tests for computer analysis.

Training of engineering technicians and inspectors.

Twin City Testing & Engineering Laboratory, Inc.; St. Paul, Minnesota:

Civil Engineer, responsible to the Chief Engineer for special projects, including supervision of assigned personnel.

Personally perform as well as supervise the testing of soils and construction materials by others.

Calibration of ready-mix conrete and asphalt hot plants.

Improvising apparatus such as asphalt tile indentations devices and designing performance evaluation test methods for same; setting-up Troxler nuclear density moisture gage calibrations and test procedures.

Supervised development and verification programs for new construction products such as a steel bar joist, O-ring seals for vitrified clay pipes, curtain wall systems, and for portable dish antennas for the Army Signal Corps.

Performed many production plant inspections on laminated wood structures, creosote treated wood products, fabricated structural steel, pre-stressed concrete products, as well as concrete and asphaltic concrete batching facilities.

Education

B.S., 1953, Civil Engineering, Chen-Kung University, Taiwan, Republic of China.

1954 Graduate, ROTC Aircraft Maintenance School, Republic of China.

M.S., 1957, Civil Engineering (Soil Mechanics & Highways), University of Minnesota.

Postgraduate studies in Highway and Airport Pavement Design, University of Minnesota.

Postgraduate studies in Arctic Engineering at the University of Alaska.

Registrations/Certifications

Civil Defense Fallout Shelter Analyst, 1963 and 1966.

Civil Defense Blast Shelter Analyst, 1964.

Professional Affiliations

Member, American Society of Civil Engineers.

Supporting Member, Transportation Research Board.

Member, American Concrete Institute.

Member, American Society for Testing and Materials.

JOHN E. SWANSON, P.E. HYDROLOGIST/SENIOR ENGINEER

Current Responsibilities

Hydrologist, specializing in hydraulic and hydrologic investigation and design.

Head, Engineering Studies Department in R&M's Anchorage office.

Alaskan Task Assignments

R&M Consultants, Inc.:

Senior Engineer, participating in preparation of plans and specifications for a water supply dam and treatment facilities in Ketchikan.

Project Manager, supervising a comprehensive hydrologic investigation of the Kuparuk River, near Prudhoe Bay. This study included flood hazard analysis, water supply investigations, and design recommendations. The Corps of Engineers' HEC-1 and HEC-2 computer programs were utilized extensively.

Senior Engineer, coordinating design efforts for an erosion control and shore protection project at the University of Alaska's Marine Shore Station in Seward.

Project Engineer, prepared a hydrologic design program for all small drainage areas along the 789 mile Trans Alaska Pipeline route.

Project Engineer, participated in preparation of the hydraulic design criteria for all cross-drainages along the Trans Alaska Pipeline.

Senior Engineer, participated in the preparation of erosion control procedures for use on the Trans Alaska Pipeline.

Senior Engineer, participated in the field investigation and design of the Lake Nunavaugaluk Sockeye Rearing Facility for the Alaska Department of Fish and Game.

Project Engineer, responsible for the preliminary hydrologic reconnaissance along the proposed Northwest Gas Pipeline route.

Senior Engineer, participated as an expert witness in the review of the Silvis Lake dam failure and landslide at Ketchikan.

Senior Engineer, performed flood hazard study for design of a University of Alaska, Anchorage, building complex.

Senior Engineer, performed flood hazard and drainage investigations for builders and developers in the Anchorage area.

Project Manager, supervising an exploratory drilling program and water supply study for a proposed fish hatchery at Hidden/Skilak Lakes on the Kenai National Moose Range.

Project Manager, conducting a "208" Water Quality Study to identify and implement the best management practices to control soil erosion and sedimentation during the construction and operation of roads, pipelines and railroad lines in Alaska.

Project Manager, supervising preparation of a hydrology and drainage study for the proposed capital site near Willow.

Project Manager, supervising a tidal scour analysis for a pipeline crossing Turnagain Arm.

Civil Engineer, member of the Site Study Task Force, North Slope Haul Road Maintenance Camp Study for the Alaska Department of Transportation and Public Facilities. Participated in field reconnaissance of potential maintenance sites, and development and review of the site selection criteria. Took part in final site evaluation and selection. Participated in meetings with numerous state and federal agencies, as well as Alyeska Pipeline Service Company, in order to obtain input from all affected parties.

Alaska Department of Highways:

Highway Engineer, organizing and developing the Departments' first Hydraulic Design Unit.

Highway Engineer, compiling and editing the Hydraulics Manual for use by the Department and other agencies throughout the State.

Highway Engineer, responsible for a major hydrologic investigation on the Copper River near Cordova; work included stream gaging, data reduction and analysis, flood wave time-of-travel studies, and final design recommendations for seventeen major bridge sites.

Project Engineer, in charge of a three-million dollar urban road construction project in Ketchikan, which included two major bridge structures in addition to sewer, water, and electrical utilities.

Project Engineer, in charge of an eight-mile paving and resurfacing project near Ketchikan.

Task Assignments Performed Outside Alaska

California Department of Water Resources:

Construction Inspector, supervising the installation of water pipe for the California Water Project, including laying of pipe, backfilling, and related operations.

Education

B.S., 1965, Civil Engineering, San Jose State College.

M.S., 1970, Engineering Management, University of Alaska.

Postgraduate coursework in river mechanics.

Postgraduate coursework in coastal engineering.

Registrations/Certifications

Professional Engineer, 1969, Alaska.

Land Surveyor, 1972, Alaska.

Professional Affiliations

Member, American Society of Civil Engineers.

Member, ASCE Water Resources Planning and Management Division, Water Laws Committee

Member, National Society of Professional Engineers

Member, Alaska Water Management Association

Member, Water Pollution Control Federation

Publications

Hartig, E.P., D. Nottingham, J.E. Swanson, B.C. Tisdale. 1978. "Reburial Considerations for an Exposed Pipeline." Presented at the A.S.C.E. Pipeline Division Speciality Conference, New Orleans, January, 1979.

Swanson, J.E. 1970. "Flood Control and Floodplain Management, A Review Of Some Recent Problems and Their Solutions". Master's thesis, University of Alaska, Department of Engineering Management, Fairbanks.

______________, ed. 1971. Hydraulics Manual. State of Alaska, Department of Highways.

BRENT T. DRAGE, P.E. HYDROLOGIST/SENIOR ENGINEER

Current Responsibilities

Hydrologist, specializing in hydraulic design, river mechanics, ice engineering, sedimentology, riverine regime analysis, and northern hydrological evaluation and assessment.

Senior Engineer responsible for project management on hydraulic and general civil engineering projects.

Alaskan Task Assignments

R&M Consultants, Inc.

Hydrologist, conducted an extensive hydrological study of the Kuparuk River and Coastal Plain watershed on the North Slope, for Atlantic Richfield Company. Utilized the Corps of Engineers' Floodplain Hydrology (HEC-1) and Floodplain Hydraulics (HEC-2) computer programs for the analysis.

Project Engineer, responsible for design of 2 miles of reconstruction for the Old Seward Highway in Anchorage. Carried the project through the preliminary design and location study, public hearings and final design.

Project Engineer, in charge of site selection, site engineering, soils investigation, surveying and road design for housing projects at five villages in the Aleutian Islands.

Hydrologist, reviewed the bank erosion problem at the village of Noatak and provided recommendations to the State of Alaska for locating future school facilities.

Permit application specialist, have prepared several permit applications for bridges, waterway encroachments and marine facilities for clientel to be presented to the U.S. Army Corps of Engineers.

Project Manager for conducting a feasibility study for crossing the Kuparuk River with a bridge capable of supporting 1200 ton building modules and resisting severe ice and flood forces while meeting present environmental and governmental concerns. Client was ARCo Oil and Gas Company.

Project Engineer, responsible for route selection and performing the preliminary design of a submarine pipeline across the Kuparuk River. Prepared permit for submission to U.S. Army Corps of Engineers. Client was ARCO Oil and Gas Co.

Hydrologist, participated in a water availability study for a proposed fish hatchery at Upper Trail Lake on the Kenai Peninsula. Client was Alaska Department of Fish and Game.

Hydraulics Engineer, designed the spillway geometrics for Saxman Dam to adequately convey the design flood flow. Client was U.S. Public Health Service

Alyeska Pipeline Service Company

Senior River Engineer, responsible for the design, maintenance and monitoring of river and stream crossings for the Trans Alaska Pipeline System preceeding, during and following the operational start-up.

Hydraulic design and site selection for several permanent access bridges.

Woodward - Clyde Consultants

Project Engineer, developed and implemented a hydrology program for a multi-disciplinary project to determine guidelines for mining gravel from rivers and floodplains in Alaska, for the U.S. Fish & Wildlife Service.

Prepared a hydrological assessment of the National Petroleum Reserve - Alaska for an environmental impact statement on the exploratory drilling program.

Provided hydrological input on the Oil Spill Contingency Plan for the Trans Alaska Pipeline System.

Consultant, for the development of a winter water supply project for oil drilling rigs on the North Slope for BP Alaska, Inc.

Schlumberger Offshore Services

Field Engineer, in charge of performing oil well logging in the Prudhoe Bay and Cook Inlet oil fields. Interpretation of the logs to determine geological formations, location of oil and gas reserves, and the quantity of fossil fuels contained within the reserves.

Institute of Water Resources, University of Alaska

Research Assistant involved in hydrologic research projects. A major project investigated the current methods of peak flood determination in northern sparse data regions. Completed thesis research on the hydraulic characteristics of northern braided rivers.

Canadian Task Assignments

Northwest Hydraulics Consultants, Ltd.

Conducted an extensive river ice research program on the Mackenzie River to determine the effects of spring break-up on proposed wharf structures and pipeline crossings.

Hydraulic Engineer, participated in the river engineering data collection and design for the proposed Arctic Gas Pipeline.

Consultant, participated in a multi-discipline task force assigned to select the route and prepare preliminary testimony for the proposed Beaufort-Delta oil pipeline from the Mackenzie Delta to Edmonton, Alberta.

Hydraulic Engineer for the Trans Alaska Pipeline System, conducted river surveys, collected hydraulic data and prepared field data reports for the major and minor river crossings along the pipeline route. Participated in the hydraulic design of major river crossings. Computed 'Standard Project Flood' water levels, flood limits, velocities and scour depths.

Hydraulic Engineer, design of hydraulic structures and river training works, river surveys, bathymetric surveys, and preparation of proprietory reports for projects in western Canada.

Education

B.S., 1969, Civil Engineering, Utah State University

M.S., 1977, Civil Engineering, University of Alaska

Registrations/Certifications

Professional Engineer (Civil), Alaska, 1975

Professional Engineer (Civil), Alberta, Canada, 1974

Publications

Drage, B.T., and Carlson, R.F., "Hydraulic Geometry Relationships for Northern Braided Rivers." Third Canadian Hydrotechnical Conference, Laval University, Quebec, May, 1977.

Drage, B.T., "Hydraulic Engineering Investigation into the Braided Rivers of the Eastern Brooks Range, Alaska." Masters Thesis submitted to the College of Engineering, University of Alaska, Fairbanks, 1976.

Drage, B.T., and Nuttall, J., "Mackenzie River Ice Break-Up." Presented at ASCE Hydraulics Division, 23rd Annual Specialty Conference, Seattle, Washington, 1975.