GULF OF ST. LAWRENCE PROJECT

AN INTERDISCIPLINARY STUDY

OF THE

GULF OF ST. LAWRENCE AREA

Prepared by: Steering Committee

Gulf of St. Lawrence Project

Bedford Institute

Dartmouth, Nova Scotia

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GULF OF ST. LAWRENCE PROJECT

Summary Statement

The objectives of the proposed study are:

(1) The understanding of the systems operating in the Gulf of St. Lawrence area in terms of physical, chemical, geological and biological oceanography;

(2) The establishment of the technological feasibility of environmental control in terms of fresh water inflow, ice cover, climate and biological productivity.

The need for such an understanding is forced upon us by the degree to which man's activities have already altered the Gulf by changing profoundly the seasonal balance of fresh water inflow through hydro-electric development, by the pouring in of pollutants of all kinds, and by unbalanced fishing pressures which have disturbed the natural system; also by the fact that we are now in a position seriously to consider environmental control in an area the size of the Gulf of St. Lawrence. It is urgent that the Gulf systems be thoroughly understood before further changes are brought about inadvertently. To do this it is necessary:

(a) To assess the extent of the changes that have already occurred in the Gulf system, particularly those due to man's activity;

(b) To shed light on the complex interaction between various parts of the system, for example between commercial fishing catches and regulation of fresh water inflow (see page 22); and

(c) To provide insight into the possibility and consequences of intentional manipulation of the system.

Several important benefits will follow from the application of the results of this study, namely:

1. The ability to predict trends in climate and biological production;

2. The control of the ice cover, at least over a longer period than the present open shipping season;

3. The maintenance of sustained yields of renewable resources;

4. The containment and restriction of pollution;

5. The development of new resources, in particular through the introduction of aquaculture;

6. In short, the unified environmental and resource management of the system.

The Project is a first serious attempt at coordination and joint operation by a diverse group of government and university agencies and industry, directed to the study of a major environmental system. The Department of the Environment is the lead agency, and participating in the Project are other Federal Departments, the Governments of Quebec and the Atlantic Provinces, eleven universities in Quebec, Ontario and the Atlantic Provinces, the National Museums of Canada, and various industrial concerns. The peak of the field research is planned to start late in 1973 and to continue for 18 months, thus spanning two winters. Certain studies, however, will start in 1972, particularly in biology and in meteorology. It is emphasized strongly that the Gulf Program is a *unit;* that is to say, no part of it is independent of the others and all parts will be synthesized into a whole system.

The program looks to the future, in an area which is now an exclusive Canadian fishing zone and the most important of our partially enclosed seas. The Gulf is the principal sea access to our largest cities and to over 60% of the population of Canada, and it supplies 40% of all Canadian fish landings. It is, therefore, highly appropriate that this Project, which will no doubt be the first of several such studies, should focus on the Gulf. It will develop expertise that could afterwards be used for the solution of similar problems across the country, for example in the Fraser Valley, in Hudson Bay, and in the Arctic Ocean.

The estimated total of new funds required is about $10 million.

SUMMARY OF NEW RESOURCE REQUIREMENTS

(Man-Years/Year and $000/Year)

Year	Man-Years	$000 O & M	$000 Capital	Total $000
1973/74	83	2885	1146	4031
1974/75	99	3386	329	3715
1975/76	89	2220	26	2246
Total	271	8491	1501	9992

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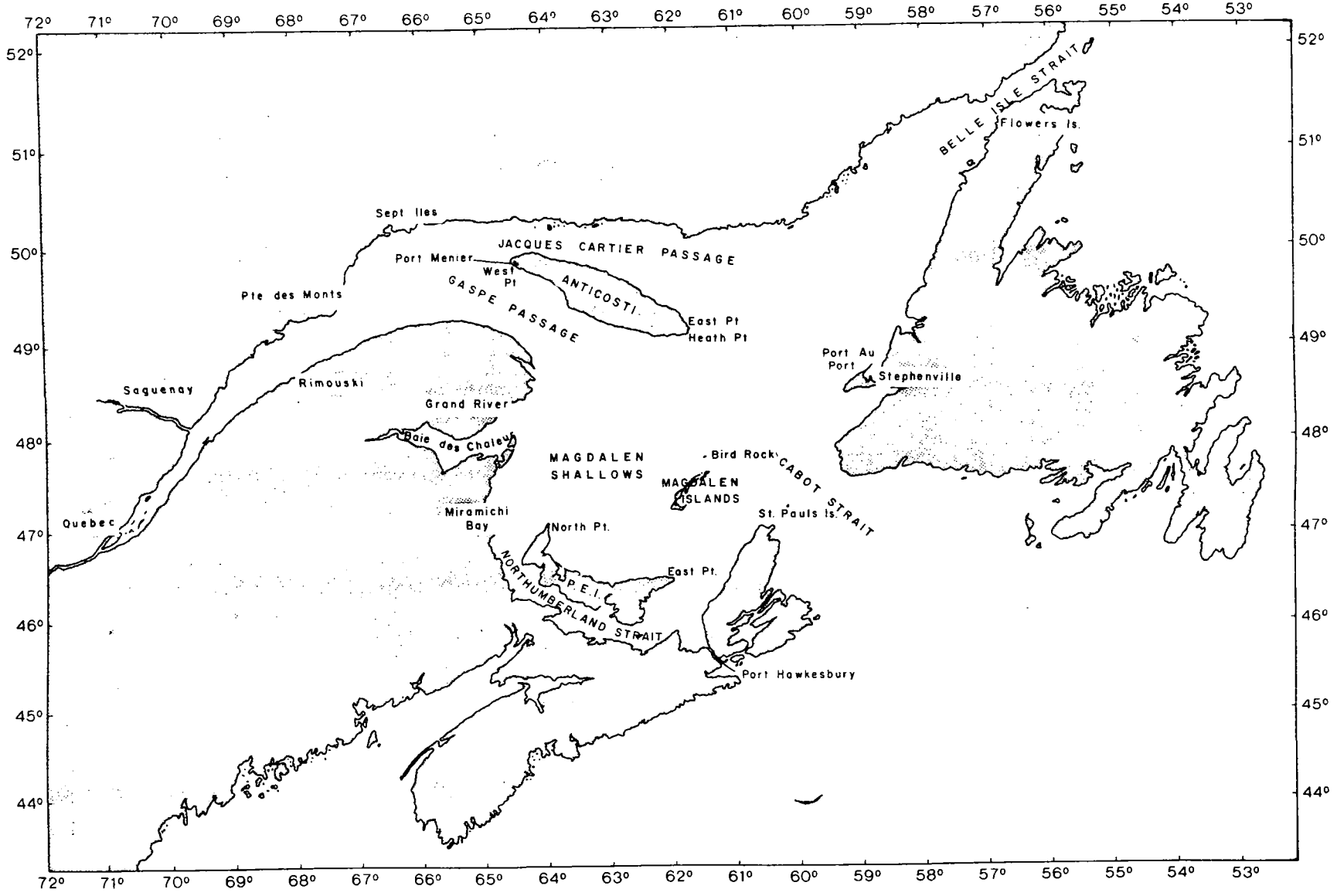

Fig. 1. Map of Gulf of St. Lawrence showing place names referred to in text.

INTRODUCTION

The Gulf of St. Lawrence, which has now been proclaimed an exclusive Canadian fishing zone, is the most important of the partly enclosed seas on the Canadian coastline. It provides the principal sea access to our largest cities and to over 60% of the Canadian population, and in addition serves major industrial regions of the United States. Forty percent of all Canadian sea fish landings by weight are produced in the Gulf, and over twenty-five percent by value. It displays conditions ranging from subtropical to subarctic. In summer, the warm waters and extensive beaches are increasingly important recreational sites, and the shallow areas form one of the world's principal sites for the harvest of lobsters, Irish moss, and oysters. In winter the ice cover provides a breeding area for Arctic seals and forms a formidable obstacle to transportation. The sea-floor offers good prospects for mineral, oil and gas exploitation. Predictably it is also used as a waste receptacle either directly or indirectly for many millions of people and much of the industrial wastes of the eastern and central United States and Canada. In short, this marginal sea, with an area about equal to that of the Maritime Provinces, has a far-reaching impact on the economic and social life of the eastern and central regions of the country.

Our past interest in the potential of the Gulf and its river systems in transportation, fisheries, minerals, and power development has led to a gradual growth of our knowledge of its physics, chemistry, geology and biology. It is from this scientific background, mostly accumulated during the past ten years, that we have now become aware of the impact of changes and the consequences of their continuation. Most importantly, we have become aware that no longer is there a possibility of effective piece-meal amelioration of local effects. We are witnessing major changes in a body of water which conditions the economic activity and the physical climate of a large part of the country and it is time we reassessed the priorities of our scientific, technological and management efforts.

With this prospect before us a group of scientists from both governments and universities have been working towards the development of a study of the entire Gulf of St. Lawrence System. The general proposal, which has been developed through discussions with about 20 different government agencies and universities, has been strongly endorsed by the East Coast Working Group of the Canadian Committee on Oceanography who believe that the Gulf of St. Lawrence provides an especially important instance of a situation where the scientific findings will have a special relevance to the definition and pursuit of Canadian social and economic goals. They concur with the view that the Gulf of St. Lawrence is a physiographic feature whose physical, chemical and biological features have a determining impact on human activities in eastern Canada, and that it is an area with great potential for change.

The importance of the Gulf has been recognized in other studies. The Science Council Committee on Environmental Problems, in examining the Canadian scene, recognized the System composed of the Great Lakes, the

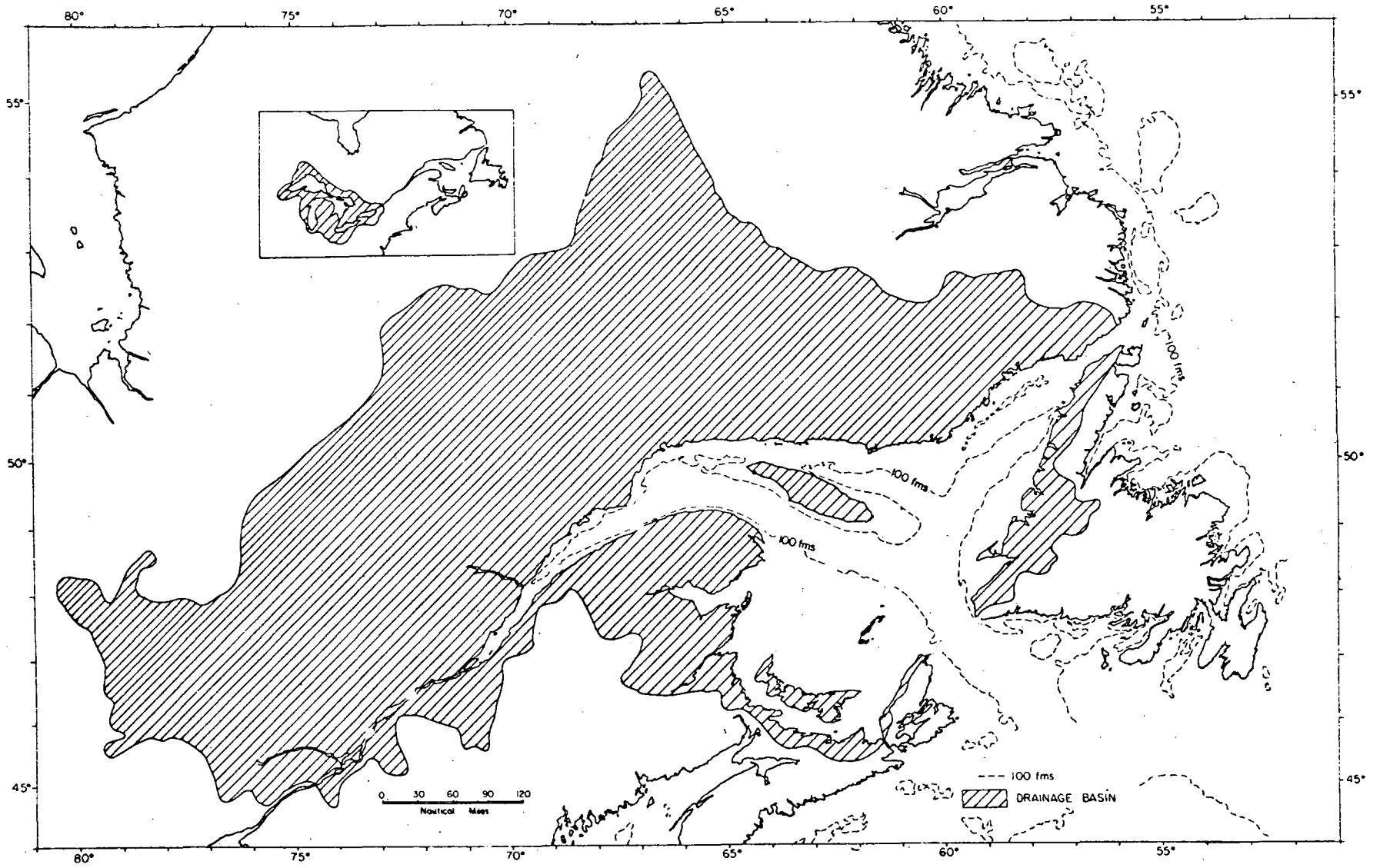

Fig. 2. Map showing Gulf of St. Lawrence drainage basin.

St. Lawrence River, and the Gulf of St. Lawrence, as being of paramount importance to Canada and recommended that a five-year major study involving the St. Lawrence System be undertaken with the aim of (a) improving our understanding of the System so that policies can be developed to ensure progressive improvement of the water and the environment within the System and thus reverse the progressive deterioration that has gone on for many decades and is now reaching a serious level; (b) developing expertise that could afterwards be used for the solution of similar problems across Canada, for example in the Fraser Valley and in Hudson Bay.

The recent Background Study for the Science Council of Canada on Marine Science and Technology identified the Gulf of St. Lawrence as one of two areas where Canadian Marine Science should be concentrated as first priority. Undoubtedly, man-made activities have already produced small scale climatic modifications in parts of the Gulf of St. Lawrence. It is probable that man could intentionally modify the climate of the entire Gulf area through control of fresh water input and ice cover. The Study on Man's Impact on Climate (SMIC) has noted that we must be cautious about proceeding with man-made attempts to alter natural conditions in areas as large as, for example, the Arctic Ocean until more scientific knowledge is acquired. It is recommended that a relatively small area such as the Gulf be studied from this point of view, an area in which we could safely proceed to attempt climate control without producing significant world-wide effects, and where the steps should be reversible at any point.

Discussion of climate control brings up at once the importance of socio-economic studies within the framework of the Gulf of St. Lawrence Project. Two steps in such a study are clearly necessary:

(1) The detailed description of the present economy and resource development of the region, including a systems analysis type of approach, which will produce an adequate model of the dynamics and inter-relations within the socio-economic system and its relation to outside influences; and

(2) The careful estimation, again using a systems approach, of the social and economic (human ecological) effects of possible man-made changes in the environment, including not only climatic control as such, but also changes in the pattern of resource development, which would follow the manipulation of the environment or the development of new basic resources.

It should be emphasized that the peak activity in the socio-economic part of the Project must necessarily come at a later stage, since it will be concerned with the possible application of the findings of the natural scientific disciplines.

It cannot be emphasized too strongly that the proposed Gulf Project is a *unit*, that is to say no part of it is independent of the others and all parts intimately concern the human population. The Study is concerned, in fact, with economic development and management in the Gulf of St. Lawrence region, which will affect the whole of eastern Canada.

The Gulf of St. Lawrence is a major natural system liable to human influences with potentially large measurable effects; it is an area claimed as an exclusive Canadian fishing zone under the Territorial Sea and Fishing Zone Act as amended; the International Convention of the Continental Shelf identified the natural resources of the sea bed and soil of the Shelf (which includes the Gulf) as belonging to the Coastal State, and for purposes of pollution control the Canada Shipping Act was amended so that Canada can exert control over the discharge of materials from ships when operating in the Gulf of St. Lawrence. Some aspects of our unilateral claim on the Gulf will probably be challenged at the next Law of the Sea Conference in 1973 or 1974. Canada's position would be greatly strengthened by demonstrable evidence that we had assumed the management responsibilities inherent in the claims. With so much at stake it is an area of special interest to Canadians.

OBJECTIVES OF THE PROJECT

A close relationship must exist between our management goals and research objectives. The defining of the one is subject to continuing modification through a feedback mechanism involving the other. In the past, the Gulf resources have been utilized in a wide variety of ways, and an implicit assumption has generally been made that there is no interaction between these various usages. It is clear that this is already an untenable assumption, and that our goal must be to manage the Gulf as a system rather than on a piece-meal basis if we are to achieve maximum overall benefits on a sustained yield basis.

In identifying the problems, it becomes readily apparent that they relate to the responsibilities of several federal departments as well as to provincial governments. The newly created Department of the Environment has major responsibilities in the Gulf and has identified six goals, as follows: to carry on established resource programs and services; to clean up and control pollution; to assess and control the environmental impact of major development; to initiate long-term environmental programs; to promote and support international environmental initiatives; and to develop an environmental information and education program. In the development of the research objectives of the Gulf study, these goals have been kept in mind.

In defining the objectives of the Gulf Project, the following elements constituted the reference framework:

(1) Protection of existing renewable resources;

(2) Efficient utilization of the existing system and its present used resources;

(3) Enhancement of utilization and the development of new resources;

(4) Socio-economic development of the area; and

(5) Canadian awareness of Canada.

1. Protection of Existing Renewable Resources

1.1 Pollution Threats

To halt and reverse the growing deterioration of the environment is an urgent challenge to modern science and technology. Correlated with increasing urbanization and industrialization, and especially with the advent of a host of new substances, many of them chemically stable and toxic at very low concentrations, is the increased evidence of serious pollution conditions in the marine environment. While we currently have but scanty information on the distribution, life history and action of most such contaminants in the sea, it is clear that as long as we continue to get 'rid' of wastes by discharging them into natural waterways, and into the air, we can expect many of them to show significant accumulations in the sea, and particularly in partially enclosed basins such as the Gulf. The sea, after all, is downstream to everywhere else. Improvements in the estimates of the levels and rates of change in such large and complex systems can be achieved, and they are basic to all other studies of the pathways and effects of pollutants, and essential to an assessment of the capacity of the environment to accept more of them. Large basins adjacent to major river systems of the world are of special concern as they may provide indices of the present state of pollution in the world oceans. The Gulf of St. Lawrence is one such area.

To date most pollutant measurements and pollution research in the Gulf of St. Lawrence have been confined to areas relatively near to urban areas or industrial operations where man-made activities have had obvious local effects. It appears to have been generally assumed that the capacity of the main body of the Gulf to accept and dispose of wastes is sufficient to keep concentrations in the environment, as well as in organisms, below unacceptable levels. In view, however, of the situation in areas like the Baltic, it is obvious that we must place the Gulf of St. Lawrence under somewhat more careful scrutiny than has been the case to date, since it receives the wastes from nearly 30 million people and their industrialized activities. What proportion of these waste products eventually reaches the Gulf, and beyond, will depend, of course, on their character, stability and behaviour.

1.2 Fishery Practices

The protection of the existing fisheries depends on more than merely a clean environment; it will require selective and controlled cropping of the resources for a sustained yield. A greatly increased understanding of the physical, chemical and biological aspects of the Gulf is essential to the maintenance of the system within a multi-use developmental framework. It may seem surprising that such basic work is still necessary in an area which has been fished so long and so successfully, but the fact remains that the start made in 1914-1915 by the Canadian Fisheries Expedition has not been followed up, even on that modest scale, until very recently. The pace of research in the physical, chemical, geological and biological oceanography of the Gulf has been considerably stepped up during the past decade, by the Fisheries Research Board, the Bedford Institute, the IBP Gulf of St. Lawrence Program and by the Quebec Provincial Laboratory at Grande Revière, but there

is still a great deal to be discovered about the circulation in the Gulf, about upwelling, about the ecosystem itself, about the growth and distribution of young fish and about the size of the fish stocks, all of which is basic to the rational and continued development of the fishery resources.

2. Efficient Management and Utilization of the Existing System and Its Resources

2.1 Rationalization of the Fishing Industry

Economic rationalization of the fishing and processing industry requires a substantial stability in the stocks or full understanding of inherent population cycles, and a powerful short-to-long-term predictive capability. Comprehension of production processes and the technology of prediction are presently inadequate to meet these requirements.

2.2 Increasing the Existing Natural Yield of Living Resources

Only a portion of the Gulf production ends up in commercially important species but the routes producing those species vary considerably in transfer efficiency. While some gain can be achieved through utilization of less desirable species, greater potential results may be achieved through manipulation of species complexes to encourage higher production of the more desirable species while discouraging production of less desirable species. Such biological rationalization must interact with the economic rationalization (objective 2.1) but requires a far greater understanding of the ecosystem than we have today.

3. Enhancement of Utilization

3.1 Aquaculture

Canada has not seriously entered the field of marine aquaculture, and by the time she does, the supply-demand ratio may be appreciably changed. Canada should move quickly to identify unique products and develop technologies appropriate for temperate waters, such as the Gulf, to gain the best advantage in the changed market of the next decade. Much of the research information and expertise required for this type of aquaculture is inherent in objective 2.2.

3.2 Oceanographic and Climatic Modification

The Study on Marine Science and Technology for the Science Council noted that modifications of the seasonal flow ratio of the St. Lawrence and other rivers of the area appear to have had an appreciable effect on the Gulf of St. Lawrence. We quote here from that report: "It is likely that these changes have already had effects on the ice cover of the Gulf. But it is our opinion that judiciously designed engineering works could bring the ice cover fully under control. Its amount could perhaps be

determined at a political rather than a scientific level. Not only can the timing of freshwater inflow be adjusted, but the amount and nature of the flow through the Strait of Belle Isle could be controlled, as could much of the mixing between the deep saline and upper brackish water. If the most 'sensitive' features of the system can be identified and modifications made there, it is probable that the cost of control could be kept moderate.

"Control of the ice cover would provide the world's first serious test of the possibilities of deliberate climate control. Changes in the degree and timing of ice cover would affect such important, or potentially important, aspects of the Canadian economy as Gulf shipping, the New Brunswick and Newfoundland forest industry, the Gulf fishery, oil drilling in the Gulf, and the agricultural and tourist industries of Prince Edward Island.

"A theoretical study of the economic and social implications of various degrees of ice cover should be undertaken. If, as appears likely, a reduction in the ice cover would be economically and sociologically advantageous, oceanographic and technological study of the methods of controlling the ice cover should be carried out. It would then be possible to see whether the cost-benefit ratio for such an activity would be favourable. If so, we should not hesitate to carry it out.

"This study of the ice cover of the Gulf of St. Lawrence is suggested because of its immediate economic importance, the accessibility of the Gulf to present oceanographic establishments, and the fact that the present ice cover provides a convenient place for study of many of the ice problems which will be encountered in the Arctic. Of particular importance, however, will be the knowledge gained about the influence of freshwater runoff on ice formation, weather and climate. In this sense the Gulf study is an important model for what may be much more difficult and sensitive problems in Hudson Bay and in the Arctic itself."

3.3 Navigation

The Gulf is a major avenue of transportation for ships moving both to and from ports located around the Gulf of St. Lawrence, as well as 'up the River'. Ice represents a major obstacle to free flow of traffic. In addition, the extent to which Lake boats may safely extend their voyages is inadequately known. If ice cover could be reduced or eliminated, it would have a major impact on the shipping activity. More accurate knowledge of ice, tides, currents, winds and waves would permit a more economical and safer operation.

3.4 Marine Engineering

The design, construction, and maintenance of marine structures is critically dependent on environmental conditions. In the past, most activities have been undertaken on an *ad hoc* basis. There is a need for better overall background data as a guide for design criteria. Major engineering projects such as a causeway across Belle Isle Strait appear likely to be seriously proposed in the not too distant future. The need for an accurate forecast on the impact this would have on the environment is obvious.

4. Socio-Economic Development

Most scientific research has as its ultimate aim the improvement of the human situation and the happiness of mankind, although in practice the aim sometimes seems to go astray; in this sense the whole of the Gulf Program is focussed on the socio-economic results to be achieved. But part of the Program will consist of research specifically in the socio-economic field itself, and is planned in two stages:

(1) The description of the dynamics of the present level of social and economic development in the region, and the construction of models designed to estimate and predict the effects of changes in any part of it; and

(2) The consideration of the results obtained in the several scientific disciplines during the Gulf Program, in terms of the possible changes which would result from the application of the scientific findings in one or more of several possible directions.

5. Canadian Awareness of Canada

This is more difficult to put into words than the rest of the general objectives. It relates to knowledge about Canada, for its own sake, on the part of Canadians. Canadians are interested in, and can take pride in, research projects of this kind and should be kept fully informed of them. The Gulf of St. Lawrence Program is on a large national scale; it affects five provinces directly and much of the rest of the country as well. It will become part of Canadian history and will provide examples of Canadian science and technology for school and university textbooks. This is not an insignificant function.

The attainment of each of these objectives requires basic knowledge of one or more of the biological, chemical, geochemical and physical processes operative in the Gulf of St. Lawrence. While the physical sciences data constitute a common input pertinent to all the questions to be answered, the multi-disciplinary approach is the essence of the Program, and it is this approach that necessitates that all its disciplinary parts come to peak activity simultaneously.

In summary, the objectives of the proposed project are to establish the technological feasibility of environmental control and improvement, yield new insights into the present extent and potential possibilities of man-made changes in the Gulf, and provide a greatly improved information base - a requisite for rational utilization and management of Gulf resources. This will need information and scientific knowledge on the biological, chemical, physical, meteorological, social and economic characteristics of the systems operative in the Gulf of St. Lawrence, through a coordinated and intensive interdisciplinary study.

PARTICIPATION AND PLANNING

1. A list of participating agencies is given on page 49. From the first discussion of the project in 1968, Federal and Provincial Government agencies and universities have been involved, and recently the relevant industrial concerns have been brought into the picture. This cooperation has been maintained and strengthened in the present year. A Steering Committee was formally set up in February 1972, based largely on the *ad hoc* Committee that had been working at the Bedford Institute during 1971, and a Scientific Leader and Coordinator was appointed on January 1, 1972.

2. A Planning Meeting, focussed on the biological aspects of the Project, was held at Laval University, February 16-17, attended by some 80 people representing Federal and Provincial Governments and 8 universities (Laval, McGill, Montreal, Dalhousie, Quebec, Memorial, New Brunswick, Moncton). The biological program was thoroughly discussed and a beginning was made in dividing the research tasks to be undertaken between the agencies able and willing to carry them out. Standardization of techniques and sampling methods was also discussed, and steps were taken to ensure that the results from the different studies can be applied to the central focus of the Project. Firm commitments were made with the GIROQ group (Groupe Interuniversitaire de Recherches Océanographiques du Québec) regarding the work in the estuary. The biological workshop at Laval resulted in the formation of five working groups to handle the detail of planning and execution of the field work: (1) Fish Studies, (2) Pollution Studies, (3) Gaspé Current-Magdalen Shallows Production System, (4) Coastal Zone; and (5) Data Handling, each with an appointed chairman. The Fish Studies Working Group has already met in early April.

3. The GIROQ group first took shape in 1969, following earlier discussions between francophone universities in Quebec and cooperation in the field between the universities of Laval and McGill. A grant from the Canadian Donner Foundation established the group financially and made it possible for them to charter a vessel and begin research on a large scale in 1970. Another operation has also been important in planning the Gulf of St. Lawrence Project, namely the study of primary and secondary production in the Gulf carried out by McGill University under the auspices of the International Biological Program from 1969 to 1972.

4. A joint meeting in May is planned to focus on the physical oceanography, meteorological, and chemical-geological parts of the Project to carry out the same sort of exercise in the division and sharing of the research tasks involved.

5. An 'Industrial Seminar' was held at the Bedford Institute on April 13 and 14, to which some 70 guests were invited, over 50 of which accepted. This meeting, designed to introduce industrial concerns to the Project,

achieved three purposes: (1) to describe the Project in some detail to industries of potential interest (oil, shipping, marine, instrumentation, consultants, fisheries, etc.); (2) to invite participation in the field work; and (3) to make industry in general aware of the implications of the Project, in terms of climatic and productivity control, pollution, and socio-economic development. All together, 82 people took part, including 52 from industry (representing 38 organizations), 3 representatives of Provincial Governments (Quebec, Nova Scotia, P.E.I.), 23 from Federal Departments (Environment, Industry, Trade and Commerce, and Transport), and 4 from the Press. It is planned to follow up this first Seminar with others, possibly as an annual or semi-annual event.

6. An Atlas of the Gulf of St. Lawrence is planned as one way of presenting data in an effective and immediately useful manner. Apart from its immediate value in interpreting the results, the Atlas will serve as a base for the continued recording of the properties of the Gulf in decades to come; in other words, it is not planned as a one-time undertaking, but as a continuing compilation.

7. An attempt is being made ('Operation Haystack') to develop a catalogue of the large amount of unpublished and unused information and material about the Gulf that lies stored in many laboratories, libraries and museums in Canada. A circular has been sent out to over 200 people soliciting information on the whereabouts of such material, and the proposed catalogue will make it possible to use this buried information as occasion demands in the course of the Gulf Project.

8. The 'Tissue Bank', or 'Reference Collection', alluded to on page 31, paragraph viii, was discussed and planned at a meeting late in April of interested parties, representing AOL, MEL, FRB, The National Museum, the Department of Health and Welfare, and the Great Lakes Field Year. A proposal is being written, to be considered outside the Gulf Project as such, to establish an organization for this purpose on a nation-wide basis or possibly world-wide. Details of the proposal will be provided with reference to the Gulf of St. Lawrence Project, together with an estimate of the cost for the Gulf alone.

9. The land-based resources of the Gulf coasts, such as forests, land use, and wildlife, have perhaps been underplayed in the present plan of the Project, but an inventory and general study of these resources have been under way for many years under other auspices. These resources, in fact, form part of the base of the socio-economic study.

10. One of the most important objectives of the Project is the investigation of the possibility of climatic control in the Gulf, including the control

of the ice cover in winter. It is therefore important to know as much as possible of the natural cycle of climatic change in the whole region. This lies outside the Gulf Project, and we must rely on ongoing programs outside the Gulf and on future internationally organized monitoring schemes.

11. Liaison has been established with IFYGL, the International Field Year of the Great Lakes, which has moved into the operational phase on Lake Ontario this month; also with the St. Lawrence River Working Group, a Federal-Quebec group planning an elaborate study of the river in general. The study of the fresh water inflow to the Gulf, its effects and its control form an important part of the Project and is presented in greater detail on page 22.

TIME SCALE

The scientific information required is strongly time and space dependent, necessitating a large and closely coordinated field program. Many of the parameters to be measured vary seasonally and are more or less cyclical on an annual basis; and our greatest lack is in information during the winter. The basic, high level coordinated activity must be sustained for a minimum of one cycle with some overlap. It is therefore proposed that the major field program cover an 18-month period beginning late in 1973; but because the existing level of knowledge is so fragmentary a number of preparatory studies are required in 1972 and 1973 to ensure that the major effort is focussed most effectively. The bulk of the analyses and reporting should be completed in a 12- to 24-month period following the field program.

In the following pages the project is divided into a number of programs and tasks, divided for convenience on a basis of scientific discipline.

Index of Research Operations in Relation to the Major Elements of the Project

Many operations relate to all or several of the elements, in which case they are placed here under the most relevant heading. *All* operations relate ultimately to the Socio-economic element.

	Operation Reference	
	Page	Paragraph
1. Protection of existing renewable resources	24	all paragraphs
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2. Efficient utilization of the existing system	26	4 - (a)
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3. Enhancement of utilization and the development of new resources	15	all paragraphs
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	17-18	3 - all paragraphs
	19-21	all paragraphs
	27	5 - (b)
	28	(7)
	32	(xv)
	34-41	all paragraphs
4. Socio-economic development	42-45	all paragraphs (N.B.: The whole Program relates to this element.)

PHYSICAL OCEANOGRAPHIC PROGRAM

1. General Statement

Using the background of information already obtained in the last few decades, physical oceanographic studies in the Gulf of St. Lawrence should be accelerated, coordinated between agencies in a multidisciplinary program of research and sustained over four seasons of the year, in order to better define or shed new light on:

(i) Residual circulation pattern on a seasonal basis.

(ii) Water, salt, and heat budgets on a seasonal basis.

(iii) The nature of the tidal regime, in detail, and of storm surges.

(iv) The character, behaviour, and propagation of wind, waves and swell.

(v) What proportion of energy is received from tides, the fresh water, the atmosphere as driving forces.

(vi) How much change in the circulation, the thermal regime, the tidal amplitude would be expected from closing the Strait of Belle Isle.

(vii) The average residence time in the Gulf of water from different sources.

(viii) How much change in the circulation or the thermal regime is to be expected from increasing regulation of run-off.

(ix) The relative importance of the different sources of ice in the Gulf.

(x) The areas and occurrence of gyres and of upwelling, and the precise nature of the mechanism in each case. This to start in 1972.

The following program in physical oceanography is designed to provide data from which improved models (physical and numerical) of the Gulf could be constructed as a basis for better prediction of the response of the system to possible future perturbations, either natural or man-made (both deliberate and unintentional).

2. Field Program, General

The field program is planned to cover all four seasons of the year to monitor seasonal variations, and also to cover one additional winter season because of the almost total neglect of the winter season in past projects. The proposed period of observation is roughly from December 1973 to April 1975.

For convenience the field program is divided into two categories - intermittent and continuous. The intermittent program consists of acquiring data at selected intervals (one to three months) of

time whereas the continuous program would go on without interruption.

(I) Intermittent

(a) Current measurements in Cabot Strait, Strait of Belle Isle, Gaspé Passage, St. Lawrence Estuary, and at other selected sites in the Gulf. Approximately 100 current meters would be moored to overlap in time for not less than 29 days. Meters to be moored once every three months. Program to commence in December 1973.

(b) STD (salinity, temperature and depth) measurements to be made in the sections occupied by the current meters and also on a grid of about 60-80 additional stations located to give representative coverage over the whole Gulf and estuary. The measurements in the sections should be repeated several times a few hours apart to achieve reasonable averages for at least the period of a tidal cycle.

The grid should be covered at 45-day intervals. Selected sections and stations should be occupied more frequently in order to provide additional data points over the year. Program to commence in December 1973.

(c) Tides and Water Levels. Submerged tide gauges are required at seven sites including and surrounding the Amphidromic point near the Magdalens, and should operate simultaneously for a period of three months. Program to commence in spring or summer 1974.

(d) Gaspé Current System. Special studies of this system are required to better define it and aid in determining best monitor sites for 1974. Two surveys of approximately one month duration should be carried out under maximum and minimum freshwater discharge in 1972-1973.

(e) Special studies are required in the Strait of Belle Isle to measure the heat transport through the Strait; also general physical oceanographic work is needed in the northeast Gulf area generally, with special reference to biology and fisheries. The difference in temperatures and in water mass on the two sides of the 'Esquiman ridge' appears to be very important to the fishery.

(f) Heterogeneity and Scales of Motion. Special studies (particularly in southern half of Gulf) required prior to December 1973 to define more accurately the spatial and temporal variability in currents. Approximately two months of field measurements are required.

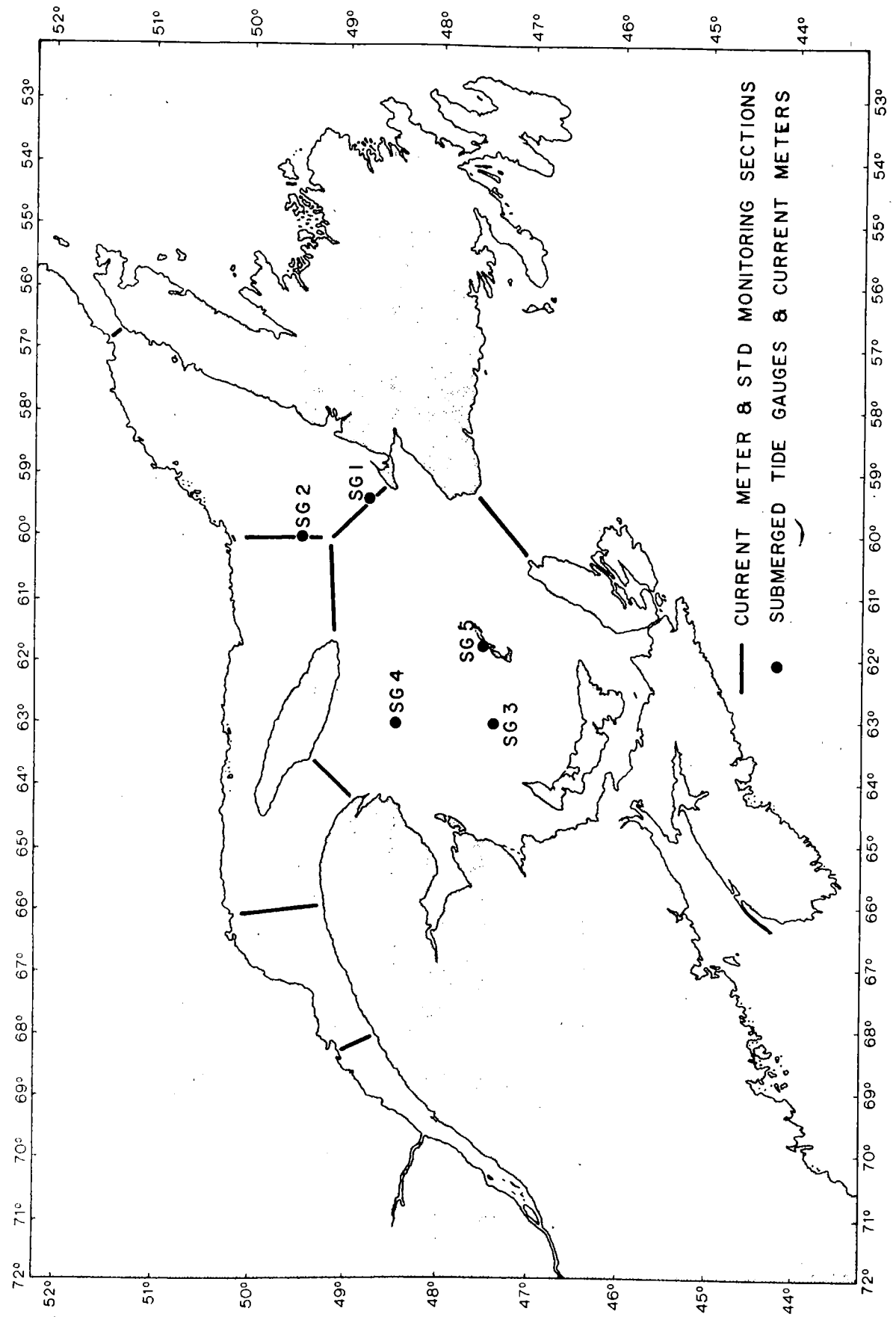

Fig. 3. Map showing location of current meter - STD monitor sections and submerged tide gauges.

(II) Continuous

(a) Water level gauging would be necessary at a network of stations to describe the fluctuations at locations characteristic of the open Gulf rather than of local harbour conditions only. Possibly six gauges in addition to existing ones would be required.

(b) Inflow from the St. Lawrence River and other representative rivers and streams around the Gulf not at present being measured should be gauged, and precipitation records kept from a grid of stations that would accurately represent the Gulf drainage basin.

(c) Wave data should be acquired from selected sites on a continuous basis as well as developing increased synoptic input from ships present in the area.

(d) Meteorological information is also required for the oceanographic program and is identified in a subsequent section (see p. 34).

(e) Currents, temperature and conductivity to be measured continuously at two sites in Belle Isle Strait. Program to commence in December 1973.

3. Tidal Field Work Requirements for the Gulf Program

The field requirements for further studies in the Gulf of St. Lawrence consist of the installation and operation of temporary tide gauges at strategic locations which are not covered by permanent stations and of submerged gauge stations distributed around the semidiurnal amphidrome centered near the Magdalen Islands. Some current measurements will be associated with the latter gauges.

Three months of synoptic observations by all these gauges would be considered ideal although from an operational point of view, one month at most might be feasible. In contradiction to normal hydrographic practice, the gauges should be established (as far as it is possible) on the open coast, facing the sea, so that the genuine oceanic tide can be measured without disturbances from bay resonance, fresh water outflow, etc. In spite of the difficulty, it is felt in particular that a gauge should be re-established on St. Paul Island during part of the Gulf year since that station would measure the Atlantic tide entering the Gulf.

The establishment of temporary gauge stations is recommended at the following locations:

Code Name	Location	No. of Gauges
T.G. 1	St. Paul Island	1
2,3	The southeastern and southwestern extremities of Anticosti (vicinity of East Point and West Point)	2
4,5	Two points on Quebec north shore exactly north of the aforementioned locations	2
6,7	Eastern and northwestern tips of Prince Edward Island (vicinity of East Point and North Point)	2
	Total	7

Submerged gauges:

S.G. 1	48°50'N 59°20'W	1
2	49°30'N 60°00'W	1
3	47°25'N 63°00'W	1
4	48°30'N 63°00'W	1
5	47°35'N 61°50'W (just west of Magdalen Islands)	1
	Total	5

A current meter should be associated with each of the submerged gauges to measure the current near the bottom: number of current meters required - 5.

It is felt that simultaneous meteorological ovservations should be taken from floating platforms or if not feasible, on shore, in the vicinity of S.G. 3 and 4, T.G. 3 and 6. The latter requirement is flexible and can be integrated with the metorological needs of other undertakings and the facilities available to the Atmospheric Environment Service.

These tidal observations will be submitted to a standard harmonic analysis and most probably to more sophisticated techniques of analysis. They will allow the redrawing of more accurate cotidal charts in the Gulf; they will help in the calibration of a numerical model of the Gulf. The residues will be of use in the study of mean sea level changes, water level transfers, storm surges; they will be scrutinized for the possible presence of edge waves although such waves are highly unlikely to occur in the Gulf.

4. Gulf of St. Lawrence Wave Climate

The sea state of the Gulf of St. Lawrence is one of the properties to be investigated during the Gulf Year. It will be used to provide a wave climate for the Gulf Year, to determine the wave energy distribution with respect to time and space, and to form the basis of a statistical analysis of both long term and extreme sea state distributions.

Wave information is very relevant to all activities on and adjacent to large bodies of water. It is perhaps particularly important for the Gulf because it represents the junction of two cargo-handling waterborne transport systems, namely, that from the Great Lakes and that from the Oceans. Regulations exist based partly on wave information restricting the use of Great Lake carriers in the Gulf. The following is a quotation from a recent paper by J. Ploeg of the National Research Council:

> *The wave conditions in the Upper Gulf are generally considered to be comparable to those of the Great Lakes. The inland water limits therefore include the Upper Gulf. The Lower Gulf of St. Lawrence, however, is exposed to ocean swell with much longer wave periods than can be expected in the inland waters. Vessels designed for operation within the inland water limits are currently not allowed to navigate the Lower Gulf.*
>
> *The four navigation seasons are now as follows:*
>
> | | |
> |---|---|
> | *May 1 - September 15* | *(Mid-summer season)* |
> | *September 16-September 30* | *(Summer season)* |
> | *April 16 - May 1* | *(Intermediate season)* |
> | *October 1 - October 31* | |
> | *November 1 - April 15* | *(Winter season)* |
>
> *Each season has its own load lines and it would be of considerable advantage to the shipping companies to extend any one season by only one or two weeks. A change in the load line, allowing one inch more draft for a typical 700 ft. bulk carrier, represents an additional cargo of approximately 100 tons.*

The considerable development of harbours and coastal protection work by the Department of Public Works in the Gulf requires special input with regard to wave information. Ship design for all types of vessels using the Gulf is dependent on adequate wave information.

4.1 Establishing a Wave Climate

A wave climate study of the Gulf should be considered in two stages. The first is to verify already developed wind-wave models with existing wave observations, and second, to establish, for the Gulf year, a system into which all existing observational methods are incorporated, so as to ensure as complete a coverage as possible.

The first stage can be started immediately by making use of the results of work already available:

1. "The comparison of five years hindcase wave statistics in the Gulf of St. Lawrence and Lake Superior"; by C. Quon, F.K. Keyte and A. Pearson; BIO Report 63-2; December 1962.

2. "Wave climate study - Great Lakes and Gulf of St. Lawrence"; by G.W.T. Ashe and J. Ploeg; N.R.C. Mech. Eng. Report MH-107A.

3. "Wave climate of the Canadian Atlantic Coast and Continental Shelf - 1970"; by H.A. Neu, AOL Report 1971-10, December 1971.

4. Data recently acquired by the Wave Climate Study (WCS) group centered in Ottawa.

There are four methods of obtaining wave information. These are: hindcasting from wind observations, direct measurement with wave gauges, visual observations from ships and aerial surveying. Each one of these methods in itself is insufficient to provide a comprehensive wave climate. Hindcasting does not provide reliable data without verification through field observations. Direct surveying of the entire area would require at least 15 to 20 gauges and even then the measurements would lack directions; their locations would be limited by their transmitter range; and their operational life is frequently short; ice also presents additional problems and hazards for measuring. Visual observations from ships prove very effective, but there is insufficient coverage available, particularly during the winter season. Aerial surveys are restricted to fairly clear, good weather.

It is felt that the integration of all four methods in one survey system would provide the greatest chance of obtaining accurate results. Each would contribute its share of inforamtion to a common mosaic of data; each would supplement and cross-check the others.

4.2 Survey Requirement

The collection and correlation of data from four survey methods will be, in terms of time and effort, the most demanding part of the investigation. The Maritime Forces Weather Office in Halifax provides this service for the Atlantic Ocean on a 24-hour basis. An extension of this service to include the Gulf area would indeed be the most rational solution to the problem.

The Wave Climate Study (WCS) will participate in the Gulf Program and offers the instrumentation and support for three wave measurement stations. Each installation will be comprised of a Waverider accelerometer buoy sea unit telemetering information to a shore- (or ship-)based receiver up to 20 miles distant. The support from the WCS will be for installation and instructing the operators of the receiving unit. This follows the usual WCS practice, where local operators, lighthouse keepers, etc., are responsible for the changing of the magnetic data tapes and their dispatch to Ottawa. Auxiliary support from other operating units in the Field Year is required to provide ship time for installation, routine maintenance, inspections and removal of the sea units. The positioning of the buoys can be arranged to coincide with other environmental installations providing that they are representative of wave conditions in the Gulf.

Each government ship cruising the Gulf will be asked to provide reliable wave information every three hours on the hour to Maritime Forces Weather Office in Halifax. Merchant vessels and larger fishing boats operating in the Gulf should contribute and their survey effort should be compensated. Survey aircraft, while in flight, should supply wave data every 50 miles to the Maritime Forces Weather Office.

FRESH WATER INFLOW TO THE GULF

The importance of the fresh water run-off has without doubt been underestimated until quite recently. Modifications of the natural seasonal run-off, which have already been brought about on a very considerable scale, cause significant changes in the temperature and salinity of the surface water and in the pattern of water circulation, including the all-important matter of the bringing of nutrient-rich deep water to the surface by the processes of entrainment and mixing. From the climatic point of view, this causes a moderating influence on the temperature of the surface, producing a positive heat input in winter and a negative input in summer to the lower atmosphere.

To quote from a recent paper by Mr. Hans Neu (AOL):

"It has been estimated that at the seaward end of the estuary, the ratio between the fresh water and the sea water involved in the estuarine circulation is 1 to 30, i.e. one part of fresh water brings nearly 30 times as much sea water into circulation. This ratio increases seaward. With regard to the estuary, it implies that reducing the fresh water flow by 3000 to 4000 m^3/sec would deprive the system of a sea water inflow of about 100,000 m^3/sec. Because of its tremendous capacity for both storage and transport of heat energy, reductions of this nature will influence the climate of the estuary, including the Gulf of St. Lawrence.

"The fresh water run-off into the estuary is already being modified for the purpose of power generation and in order to divert water into other drainage systems. Under natural conditions, i.e. before the turn of the century when the regulation commenced, the ratio between the spring-summer run-off and the winter run-off was approximately 3 to 1. Since then, this ratio has been modified to about 1.6 to 1. The regulation of the Great Lakes, the Ottawa River, and the Chicago Diversion, along with other rivers, are examples of such modifications.

"The scope of these regulations has now been greatly increased and at present huge water storage schemes such as the Manicouagan power development are under construction or in the design stage. Their ultimate aim is to achieve a 1 to 1 ratio between the summer and winter flow for optimum power production."

The effect of these changes, in terms of climatic and water production, are to be taken seriously. A further study of this phase of the Gulf mechanism will be undertaken during the Gulf Program, including the measurement of the inflow and seasonal variations in streams, not at present monitored.

CHEMICAL AND GEOLOGICAL PROGRAM

1. General Statement

The Gulf of St. Lawrence is a dynamic system in both chemical and geological terms. Many fundamental processes of chemical and geological additions and losses to and from the region are operating within today's temperate climate. In the past the region was influenced by periods of both warmer and colder climates resulting in conditions substantially different from the current quasi-equilibrium state.

It is fortunate, however, that from present studies an understanding can be gained of past climatic effects and the capability to predict the future can be developed. From observations of the present inputs, transport and losses from the Gulf System and studies of past circumstances through chemical and geological examinations of sediment cores, further environmental changes occasioned by man's activities may be predicted. Without such studies, however, it is apparent that the effects of modification of the area cannot be foretold.

Some of the ways by which chemical substances are added to the Gulf can be straightforwardly defined. Dissolved and solid substances enter by way of the rivers, by direct precipitation in the area, by exchange between the waters and the atmosphere, by resuspension of sediment and by inward transport of sea water in the Belle Isle and Cabot Straits. Transport within the Gulf occurs by way of physical transfer in solution, by exchange between solution and suspended material, by mass transfer of suspended matter from one area to another, by incorporation in the biomass, and by interaction of dissolved and particulate material with ice. Finally, there are losses from the Gulf system itself through sedimentation, through air-sea exchange and again in solution and suspended forms through the Belle Isle and Cabot Straits. Quantitative estimates of input, transport and loss must be affected by seasonal variations which are likely to be very marked, particularly with respect to the contributions of rivers to the chemical and geological environment of the Gulf.

One aspect of chemical studies in the Gulf which requires special mention is pollution. Few pollution studies, restricted to oil, pesticides and limited research on heavy metals, have been performed. The studies in themselves have been useful but uncoordinated. Within the general framework of a systems approach, as described above, further pollution research would yield valuable predictive information, and the results would be meaningful and useful when further substances considered as hazardous to man and/or other forms of life are brought to light. An understanding of their behaviour within the Gulf could be inferred (or in some cases actually deduced with considerable confidence) from the geochemical balance model.

In view of the lack of past data on these subjects the chemical program will, in the main, be starting from scratch. Some analytical geochemical studies of the sediments of the Gulf of St. Lawrence have

been carried out, but a greatly enlarged program is now needed specifically to take into account transport mechanisms of pollutants in critical areas.

2. Field Program

It is essential that all studies be pursued throughout the year (with the obvious exception of ice research), commencing late in 1973 and proceeding through April 1975. Most of the work is planned on a project basis - the need for continuous or intermittent observations being apparent within each project. The projects are here classified into seven broad areas, with the various subprojects listed as considered necessary for the accomplishment of the objectives.

(1) Pollution Studies

(a) A survey of pollutants in the dissolved and particulate state within the Gulf of St. Lawrence. These studies will embrace the whole of the Gulf, the St. Lawrence estuary and river together with the major river systems draining into the Gulf. Emphasis will be given to the boundary regions of Belle Isle and Cabot Straits.

(b) Grab samples of sediments will be examined from the major sedimentary regimes in addition to samples collected in those areas adjacent to potential pollution sites, e.g., St. Lawrence estuary, Miramichi, Bay of Chaleur, and Port Hawkesbury regions.

Pollutants to be examined within the above projects will include oil and petroleum residues, heavy metals including Hg, Pb, As, and Cd, pesticides and other organic pollutants, and probably NTA.

(2) Atmospheric Chemistry

(a) A limited number of precipitation stations will be established within the Gulf system to determine the general pattern of chemical additions to the Gulf through this mechanism. Samplers will be designed for snow collection to enable the relative contributions of snow and rain to be determined. Species to be investigated in the normal atmospheric chemistry program will include the standard ions, CO_3, HCO_3", SO_4", Cl', Na^+, K^+, Mg^{++}, together with determinations of pH and conductivity.

(b) The concentrations of pollutants in precipitation are likely to be low, and therefore large rainfall collectors may be required to permit the determination of heavy metals, organic pollutants and other pollutants as they arise. Feasibility studies will be necessary during late 1973 and early 1974 to ensure that collection techniques are adequate, particularly for snow, and that the geographical coverage of the area is sufficient.

(c) Stations will be established on a limited basis throughout the Gulf system to monitor air quality and air pollution, and for air-sea exchange purposes.

(d) It is proposed to establish a high-volume sampler (24-hour values on Grindstone Island.

It is believed that under (b) and (c) approximately six stations will be satisfactory although additional sites may be established to examine local pollution sources. Determinations of atmospheric particulate concentrations will be performed in addition to specific chemical constituents such as Pb, Hg(?) and Cd.

It should be emphasized that very little research has ever been undertaken on surface uptake of air pollution at distances of a few hundred kilometres from sources. The work described here is designed to help meet one of the objectives of the Gulf Program, but it is also of fundamental interest to the international scientific community. Recommendations that such studies be undertaken have been made recently by WMO, GESAMP, SCOPE, the IAMAP Commission on Atmospheric Chemistry and Global Pollution, and the IAMAP-IAPSO-SCOR Working Group on Air-Sea Interactions. Regional and global budgets of air pollution are at present very uncertain because of inadequate information on the rates of transfer from the atmosphere to the oceanic reservoirs.

Concerning absorption at the water surface, the determination of the flux of pollutants through the air-sea interface is a micrometeorological problem. It has never been done successfully but there is wide international interest in attempting an experiment. The basic requirement is the measurement of the vertical profile of a pollutant over the water, together with an indirect estimate of the diffusivity obtained from concurrent measurements of the fluxes and profiles of heat and/or water vapour. Such experiments could not be repeated continuously over the 18 months of the Gulf Program, or even continuously over a few weeks.

Some preliminary attempts to measure the fluxes of pollutants are planned for the IFYGL. Provided that a fixed tower is available, these types of experiments should be repeated in the Gulf.

It is proposed also to use Gulf Program aircraft for occasional supplementary monitoring of air pollutants in the troposphere.

(3) Organic Chemistry

A primary source in maintaining continuity of life in any water body is the organic matter in solution. The molecular nature of this dissolved material remains largely unknown and, unfortunately, is currently being modified by man's continued dumping of organic wastes into the oceans. Three areas of study are, therefore, recognized within this category of investigations:

(a) Examination of the spatial and temporal variations in total organic carbon, hydrogen and nitrogen. Areas to be covered will include the Gulf, the boundary regions of Belle Isle and Cabot Straits, Bay of Chaleur

and major river systems, particularly those in proximity to pulp and paper mill activities and major centres of population.

(b) Qualitative and quantitative analyses of the various compounds constituting the dissolved organic carbon (e.g. lipids, carbohydrates, amino acids).

(c) Identification of specific organic indicator compounds which reflect the influence of man's activity on the organic regime of the Gulf. In this context pulp and paper mill activity results in the addition of wood and its byproducts into the oceans. Degradation of these substances may lead to the presence of compounds that are characteristic of this modification of the chemical composition of the dissolved organic matter.

(4) Inorganic Chemistry

The understanding of pollutant behaviour, particularly the heavy metals, will be as complete as our understanding of the geochemical behaviour of metals in the Gulf environment. Some metals, other than those already identified as pollutants, are biologically essential and these will also require study within the Gulf system. A continuing comprehensive program must, therefore, be initiated in the Gulf regions, preferably as soon as possible, to establish the sources and sinks of various inorganic constituents, together with investigations of the major transport mechanisms in the area.

(a) The following elements will be examined in the Gulf of St. Lawrence, the rivers of the bordering provinces and the St. Lawrence estuary: Mg, Ca, Li, Al, Si, Sr, Fe, Cu, Ni, Cr, and Zn. Quantities present must be examined both in solution and suspension throughout the system and, thus, the variability of suspended matter in the rivers and Gulf must also be assessed.

Concerning the variability of the suspended matter:

(i) The relation between the suspended matter distribution and physical parameters, S, T, σ_t, O_2, should be stressed. This brings up the necessity of routine simultaneous observations (by STD, transmissionometer, water samples and current meters at least in the estuary), and therefore involves cooperative programming with physical oceanographers.

(ii) Attempts will be made at measuring precisely the vertical gradients of dissolved constituents as well as particulate matter near the boundaries (both the sea surface and the bottom interface), to assess the importance of diffusion processes. Methods of study need to be defined and perhaps special equipment developed for this purpose.

(iii) There is a fairly large biomass of filterfeeders, some of them vertical migrants (e.g. euphausids, mysids); these must play a role in the redistribution of the suspended matter. Analyses of biological material should be performed to elucidate this mechanism.

Also important, and not yet attempted, would be a detailed study of the chemistry and mineralogy of the fine re-suspendable (<10 μ) material, fractioned in selected subsizes. Comparison with the suspended load should yield interesting information.

(b) In sedimentary material a fairly comprehensive study of the occurrence of these elements has already been made. Some additional grab samples and sedimentary cores will be taken to complete this research and to establish any recent changes which may be occurring. Interstitial water samples released from sediments collected in the major sedimentary regime of the Laurentian Trough will be obtained in studies of the exchange reactions occurring at the sediment-water interface. Further laboratory studies in support of this program will constitute an important part of this effort.

(c) A study of the fractionation and diffusion processes related to the importance of ice as a transport mechanism within the Gulf will be undertaken. This project will be related to the atmospheric chemistry studies in terms of the deposition of trace metals and some non-metals (by snow particularly) but will also embrace the extent to which concentrations of gases essential to living processes, such as oxygen, carbon dioxide and nitrogen, are modified by ice cover.

(5) Physical Chemistry

(a) Control of the chemical properties of a water body, be it the Gulf of St. Lawrence, an inland lake or the open ocean, is related to the fundamental physical chemical properties of the system. These properties, e.g., pH and temperature, influence solubility of most substances of interest, the absorption/desorption and solution at boundary zones and the capability of the system to accept or reject the products of man's activities. Engineering modifications to the area will have a profound effect on these basic variables, and hence on the system as a whole.

Studies of seasonal variations in pH, alkalinity and total CO_2 in water samples will serve to describe the CO_2 system within the Gulf. Measurements of calcium and magnesium will indicate the precipitation cycle of carbonate deposits.

(b) An important factor in world climate modification is the change in CO_2 content of the atmosphere resulting from the consumption of fossil fuels. An intensive world-wide study of these temporal variations is about to be established and it is proposed to establish a Canadian station in the Gulf of St. Lawrence area. CO_2 measurements will be made on a continuous basis to permit the evaluation of diurnal and seasonal influences and, together with previous work, to help elucidate the part played by the oceans in the global CO_2 cycle.

(6) Nutrient Chemistry

(a) It is likely that the Gulf system has, up to now, escaped

the fate of inland water bodies which have become seriously contaminated with detergents--particularly phosphate. One objective of the present study will be to determine the variability of phosphate concentrations, both spatially and temporally as part of a continuing study of nutrient levels in the Gulf. Seasonal (year-round) data are particularly desirable in view of the limited information current available from the winter. For the spring and summer, an excellent start has been made by the McGill IBP project.

(b) Of particular interest physically, chemically and biologically is the region east of the mouth of the Saguenay River, where upwelling is believed to occur. It appears to be one of the most nutrient-rich zones in the Gulf system and as such requires some local intensive study. Continuous observations of nutrients in conjunction with biological studies of phytoplankton and zooplankton occurrence in the area will be performed. It should be noted that the GIROQ group is planning for this summer (1972) an intensive survey of the physical factors involved by various methods, including wind stress measurements, STD sections, self-recording current meters; observations of chemical parameters could be done simultaneously with the cooperation of the Bedford Institute. This would be a chance to test methods to be used later in the Gulf Program.

(7) Paleoclimatic Studies

With the aid of C^{14} measurements sedimentary deposits in the Gulf of St. Lawrence depict the climatological record prevailing in the area from the time of the Late Pleistocene. Planktonic species, in particular, are excellent indicators of past climate variation related to advances and retreats of glaciers. Changes in the abundance of cold and warmer water species can be used to show climate changes, the influence of continental ice sheets and the extent of run-off from the drainage areas. Any proposed future modification of the climate of the area must, of necessity, rely very heavily on paleoclimatic studies for the purpose of prediction of the effects of modification. See the 'SMIC' Report, listed in 'Background literature', below.

The research will be conducted in four phases:

(a) Seasonal distribution of living planktonic foraminifera in the Gulf of St. Lawrence;

(b) Distribution of foraminifera in sediment cores;

(c) Petrological and sedimentological studies of cores;

(d) Examination of the distribution of molluscs in cores and shoreline Pleistocene deposits.

BIOLOGICAL PROGRAM

(1) General Statement

Until very recently our knowledge of the biological oceanography of the Gulf of St. Lawrence was fragmentary. Much progress in our understanding of primary and secondary production has been made by the Canadian IBP program in the Gulf (McGill University Group), but that program was necessarily restricted in scope and did not include the tertiary level of production, nor problems related to the fishery. The biological program of the Gulf Project should aim at picking up the momentum generated by IBP while redirecting the emphasis to give early answers to problems concerning important aspects of the management of the renewable resources of the Gulf system. Attention should be focussed on the following questions:

(i) What are the current abundance levels of the exploitable fish resources of the Gulf? What are the most probable short-term trends in these abundances? What level of continuing inventory is necessary and what is the most efficient method for achieving it?

(ii) What are the principal factors controlling the nutrition, mortality and dispersal of larval fish on the spawning banks and elsewhere? How much of this kind of information is required for prediction of recruitment to the fishery?

(iii) What are the current contamination levels, at representative points in the food web, of substances known to be toxic to life? What pollution levels are experienced by the people living in the Gulf region? Can carefully documented samples of tissue be preserved for future analysis of the substances not known to be toxic at present, or of toxic substances for which present analytical technology is inadequate? By what pathways and with what intensity are pollutants transferred through the food web? By what pathways are stable compounds removed from the Gulf?

(iv) What is the mechanism connecting the high phytoplankton production in the St. Lawrence estuary with the secondary production at the Magdalen Islands? To what extent is this phytoplankton production, which feeds an important nursery ground, dependent on the flow of the St. Lawrence River and other major rivers on the north shore?

(v) What is the productivity of the seaweeds in selected areas of the Gulf? What is the potential for direct use by man and what is the importance of seaweeds in the food chains leading to commercially important species?

(vi) What are the current abundance levels of exploitable invertebrates in the Gulf? What are the most probable short-term trends in these abundances? What levels of fishing pressure can be sustained by these populations?

(vii) What is the status of sea mammals and sea birds in the trophic ecology of the Gulf, especially as competitors with man or with commercial fish species for food, or as predators on commercial species?

(viii) What is the part played by the hyperbenthos in the whole ecosystem, and what are the relations between planktonic and benthonic production?

(ix) What are the most promising approaches to long term management and what kinds of information would be required to implement them? What are the relative cost-benefits and socio-economic advantages of the various options?

(x) What are the most promising approaches to augmenting natural production through aquaculture?

(2) Specific Tasks

The following list of specific tasks is designed to provide information relevant to these basic questions listed above. For convenience we distinguish between field programs, laboratory studies and theoretical analysis. The main program should begin in 1973 but in some instances it is essential that preliminary data be collected in 1972.

(a) Field Studies

(i) Inventory of the more abundant and economically important pelagic and demersal fish. Preferred sampling frequency -- four surveys per year. Both traditional and acoustic methods should be used to estimate stock sizes. These two methods should be run in parallel in a sufficiently large number of instances that a thorough comparison may be made between them. Fish egg surveys should be continued and intensified as a further aid to stock assessment for some species. Work on age structures and growth rates of the stocks should be continued and increased. In cases in which it is important to recognize different populations of the same species and their migrations, these surveys should be supplemented by tagging programs and studies of biochemical genetics. Preliminary trials in 1972.

(ii) Extensive study should be made of stomach contents in a range of age groups of all commercially important fish species in the Gulf. Particular attention should be given to those species thought to utilize a common food resource - e.g. herring and mackerel, American plaice and cod. Preliminary data required in 1972.

(iii) A broad study should be made of the ecology of larval fish; for instance, the condition factor achieved in nature by larvae of important fish species should be measured as a possible tool in prediction of recruitment. This will clearly require study of the zooplankton in the

vicinity of feeding larvae. For each year class, the variation in condition factor within and between sampling stations should be assessed; these results to be compared with those from parallel laboratory studies. To begin in 1972.

(iv) A determined effort should be made to develop sampling techniques adequate for inventory of juvenile fish. A systematic search should be made in all types of environment within the Gulf to try to locate the juveniles of those species whose habitat before their recruitment into the fishery is at present unknown.

(v) A detailed study should be made of the quantitative changes in nutrients, phytoplankton and zooplankton along a transect from the St. Lawrence estuary to the Magdalen Islands. This transect should be repeated from five to ten times throughout the year. The constancy of the geographical boundaries of this production system should be investigated by repeated mapping of chlorophyll concentration using either shipborne or airborne techniques.

(vi) Attention should be paid to the productivity and general biological conditions in the northeast part of the Gulf, which has been conspicuously neglected hitherto.

(vii) A thorough study should be made of the population ecology of euphausiids and pelagic amphipods and their status in the trophic ecology of the Gulf. High priority should be given to the development of adequate acoustic equipment for census of euphausiids and pelagic amphipods in the field, and for studying the spatial structure of the populations. To begin in 1972.

(viii) A reference collection of animal and plant tissues should be established for analysis in pollution investigations. This should consist of a set of carefully documented samples of organisms collected from several environments of the Gulf (pelagic, benthic, inshore, offshore, intertidal, hinterland), representing all size ranges and all functional groups of the ecosystem. Samples of human tissues should be included. A small portion of each sample should be analyzed immediately for substances known to present a pollution hazard. The remainder of each sample should be preserved in the best possible manner for analysis in the future for substances not known at present to be hazardous to health.

The importance of this scheme should be given some emphasis; it is for long-term use and it may well develop into a nation-wide enterprise. The cost, furthermore, will be considerable. For both these reasons it is being described in a separate brief at present in preparation.

(ix) The mechanism and transfer coefficients of pollutants within the food web and environment should be investigated for a specific compound or family of compounds for which there is available a simple and rapid analytical technique, such as the mercury compounds and pesticides.

(x) The abundance and productivity of seaweeds should be measured in selected areas of the Gulf; their importance to man and to the production system should be investigated. Information is needed here on the freshwater run-off and nutrients carried by it.

(xi) Present work on the abundance and growth rate of selected exploitable invertebrates within the Gulf should be intensified; for instance, on the shrimp *Pandalus borealis*.

(xii) Most of the work mentioned above should be done also in the St. Lawrence estuary (age structures and stomach contents of fishes, larval and juvenile fish studies, nutrients and plankton production, pollutants in plankton and benthos, seaweed surveys, and work on exploitable invertebrates).

(xiii) The biological significance of eddies in water structure should be evaluated. Initially, this can probably be done most readily by investigation of phytoplankton dynamics, using airborne methods to locate possible gyres.

(xiv) The food requirements of the sea mammal and sea bird populations of the Gulf should be studied to evaluate their impact as food competitors or predators on commercial species. For instance, as a start, investigation should be made of the food requirements and thermal economy of the three important species of seals (harp, harbour and grey seals). There is some indication that the food requirements may be significantly lower than present estimates.

(xv) Experiments in aquaculture are needed in the Gulf region. Species to be considered should include the edible mussel, *Mytilus edulis*, other molluscs, shrimps and anadromous fishes. Attention should be paid, for instance, to the very successful Swedish work on the artificial propagation of salmon.

(b) Laboratory Studies

In addition to laboratory analysis of samples collected in the field program, the following laboratory studies should be carried out:

(i) A thorough study should be made of the feeding behaviour of larval fish. The condition factor achieved in the laboratory under optimal feeding conditions should be measured and compared with condition factors for specimens caught in the field.

(ii) The growth rates and food requirements of euphausiids should be studied.

(iii) The growth rate of pandalid shrimps should be studied to aid determination of sustainable yield from census data. Growth rate, food requirements and optimal growing conditions should be determined for

molluscs of potential importance for commercial exploitation and for aquaculture.

(iv) The physiological ecology of important phytoplankton species should be determined on monocultures initially, and subsequently on mixed culture. The effect of certain pollutants on phytoplankton productivity should be evaluated.

(v) The physiological ecology of important copepod species should be studied.

(c) Theoretical Studies

(i) The significance of year class dominance within and between species in the pelagic fishery should be evaluated, to determine under what conditions the fluctuations in annual yield might be minimized.

(ii) The significance of all aspects of spatial and size structure of populations for the dynamics of ecosystems should be explored. The dependence of this organization on the physical structure of the environment should be assessed.

METEOROLOGICAL PROGRAM

1. Land-Based Synoptic Weather Observing Program (Additional to Present Operating Network

1.1 Preamble

Although land-based synoptic weather stations are not entirely representative of conditions over the Gulf, they do provide valuable clues. An operational network already exists, as well as an efficient system for station inspection, data collection, quality control and data retrieval. The operational management of the system is shared by the AES Regional Offices in Moncton and Montreal.

The existing network has been examined in the light of the special requirements for the Gulf Program, and a few additions are proposed below. It is well known, for example, that the present wind observations at Port Menier, Anticosti, are affected by very local channelling and are not representative of over-water condition.

1.2 Program

(a) New Locations (hourly reporting)

In addition to the existing network of stations around the Gulf at least two more are required reporting on an hourly basis, one on the west coast of Newfoundland, and one on the eastern end of Anticosti Island. It is proposed to locate these at:

(1) Flowers Island, NW Newfoundland

(2) Heath Point , Anticosti, P.Q.

(b) New Locations (climatological)

Three stations are proposed that would be equipped with Automatic Climatological Stations. These would be located at:

(1) St. Paul's Island

(2) Bird Rock

(3) Port au Port Peninsula, near Lourdes, Newfoundland

The program would include:

Pressure	continuous
Temperature	continuous
Relative humidity	continuous

Precipitation	continuous
Wind	continuous

This type of installation would require frequent visits by a technician to ensure that the quality and continuity of the records were properly maintained.

(c) Existing Locations (additional Facilities

(1) House Harbour (airport site), Grindstone Island

(2) Port Menier, Anticosti Island

Installation of recording thermometers, Type 45B.

(d) New Location (wind measurement only)

West Point, Anticosti Island

Installation of a recording thermometer, Type 45B.

2. Water Budget Studies

In contrast with IFYGL, water budget studies during the Gulf Year are of secondary interest in comparison with heat budget and circulation studies. The meteorological requirements can be fully met by a few supplementary synoptic network precipitation stations (see section on Land-Based Synoptic Weather Observing Program) and by the evaporation estimates included in the heat balance program.

3. Surface Wind Stress Field

3.1 Preamble

In order to understand or to model numerically the currents in the Gulf, the surface wind stress field must be known. The characteristic response times range from about a day to two weeks. The required spatial resolution consists of about 10 grid points. These estimates are derived from preliminary examination of the Gulf circulation, which is rather complex due to the irregular shoreline, the presence of Anticosti Island, and the channels created by the St. Lawrence River, the Strait of Belle Isle and Cabot Strait.

Determination of the surface wind stress field is also required for the Wave Climate Study and for the Tidal Gauge Experimentation, both described in the Physical Oceanographic Program, above.

Three approaches could be used to estimate the wind stress field:

(a) Establishment of a network of 10 buoys, each measuring the wind and the air-water temperature difference. It is operationally not feasible to maintain such a network for 15 months, particularly during periods when the Gulf contains ice.

(b) Inference from the geostrophic or gradient wind, based on atmospheric pressure measurements, and the stability of the air. Because of channeling effects (e.g., in the St. Lawrence River and around Anticosti Island), however, the geostrophic wind is likely to be a poor predictor of surface stress. In any event, the technique should not be used without rather detailed feasibility studies.

(c) Inference from the network of shore-based and island anemometers, supplemented by intermittent observations from ships, towers, and winter-time ice-based stations. This technique, as in the case of (b) above, should not be used without rather detailed feasibility studies.

3.2 Program

3.2.1 Feasibility Studies

A large number of ship observations of wind in the Gulf are contained: (a) in ship logs on file at the Bedford Institute, (b) in the Oceanographic Data Centre in Ottawa, (c) at AES Headquarters in Toronto. These data require careful quality control, based on a knowledge of the height and exposure of each anemometer. The data should then be used to derive empirical relations with: (a) observations from shore-based stations, (b) the geostrophic or gradient wind derived from the pressure field (the Ice Central has a historical file of daily mean 1000 mbar pressure charts).

3.2.2 Ship Anemometer Inspection and Installation

The Halifax Port Meteorological Officer will inspect all meteorological equipment on DOE and chartered ships to be used during the Gulf Year. New instruments will be installed, and others relocated, if found necessary.

3.2.3 Gulf Year Program

(a) Additional anemometers will be operated for short periods from towers and stable platforms, the locations being determinted from the feasibility studies. For the latter half of the period, AES will provide two Bedford-type stable platforms and associated meteorological instruments. It is likely that two additional deep-water meteorological buoys will be required (a responsibility of Bedford Institute or through a University contract), but no firm statements can be made until the feasibility studies have been completed.

(b) Additional anemometers will be operated for short periods on the ice in winter. This will be arranged through a university contract.

(c) Using all available data and empirical relations, AES will produce three-hourly estimates of wind stress for 10 grid points for all periods within the Gulf Year designated by MSB to be of special interest.

4. Radiation Program

4.1 Preamble

Daily solar radiation estimates are required for biological productivity investigations, and for heat budget studies, with a spatial resolution of about 4-8 grid points. Net all-wave radiation estimates over the water are required in order to close the heat-balance equation. A spatial resolution of 10 grid points is indicated.

The present network of radiation stations is completely inadequate for these purposes. There is a good network of sunshine recorders but it is not possible to infer the radiation terms for the number of hours of sunshine except on days when skies are clear. During cloudy conditions the solar radiation and the net all-wave fluxes cannot be predicted from sunshine records.

It is clearly impossible operationally to organize radiation programs at a network of 10 over-water towers. The measurements require careful supervision and can only be done at manned stations. Supplementing a proposed small shore-based network, therefore, information is required on the distribution of cloudiness across the Gulf, which will have a profound influence on the downward solar and long-wave radiation fluxes. In addition, the water (or snow/ice) surface skin temperature distribution is required in order to infer the upward long-wave radiative flux. Finally, the surface albedo can be estimated from values given in the literature. The predictions from semi-empirical methods must, of course, be compared occasionally with values observed on ships.

4.2 Program

4.2.1 Shore-Line Stations

(a) Total downward short-wave radiation is presently measured at Charlottetown. A downward long-wave sensor will be added by AES.

(b) Downward short-wave and long-wave sensors will be installed at three new stations - one on Anticosti, one on Grindstone and one on the west coast of Newfoundland.

(c) A downward short-wave radiation sensor is being installed at Sept Iles in 1972-1973. A downward long-wave sensor will be added for the Gulf Year.

4.2.2 Ship Stations

Downward short-wave and long-wave sensors will be installed on all capital ships participating in the Gulf Year Project.

4.2.3 Aircraft Observations

(a) Infrared surveys of the Gulf surface skin temperatures using the Ice Recco aircraft and an additional aircraft to be chartered when the Ice Recco aircraft are not available.

(b) Installation on the Ice Recco and chartered aircraft of upward and downward pointing all-wave radiation sensors.

4.2.4 AES will provide estimates of net short-wave and net all-wave radiation for 10 grid points.

5. Heat Budget Studies

5.1 Preamble

The heat budget of the Gulf requires measurements *inter alia* of the net radiation (this program is described above) and of monthly estimates of sensible and latent heat transfer across the air-water interface, with a spatial resolution of 10 grid points.

Empirical methods can be applied, based on: (a) air-water temperature and humidity differences, and (b) either a transfer coefficient, or a wind and an associated empirical constant. In order to apply these methods continuously over the 15 months of the Gulf Year, feasibility studies are required immediately to seek relationships between shipboard and land- or island-based meteorological observations. There is a further need to determine the empirical constants, which cannot be obtained from a literature review. Instead, more detailed measurements from ships or towers are required over periods ranging from one week to a month in each season. These estimates are still subject to considerable uncertainty, particularly in a region as complex as the Gulf. There is thus a further requirement for direct measurements of the fluxes obtained by eddy correlation techniques from a tower or an aircraft over periods ranging from a day to a week.

Direct flux measurements from an aircraft serve another purpose, which is of far more importance than that of 'calibrating' the empirical formulae. When there is a partial cover of ice over the Gulf, most of the heat losses to the atmosphere occur through the open leads. These losses can be very great, and they are of critical importance in determining the thermal and ice regimes of the Gulf and in developing simulation models. Only direct measurements obtained from an aircraft can reveal the flux strengths and spatial variability during such conditions. In this connection, the Institute of Oceanography, University of British Columbia, has developed a capability to make such aircraft measurements.

5.2 Program

5.2.1 Feasibility Studies

A large number of weather observations from ships in the Gulf are on file, and there is an urgent need to commence studies of land-water relations amongst the various meteorological elements. This work will be a responsibility of AES.

5.2.2 Gulf Year Program

The program listed elsewhere under 'Surface Wind Stress Field' applies here also. The ART and radiation programs described under 'Radiation Program' are also particularly relevant. In addition, university contracts for eddy correlation direct flux measurements, and for ice studies, are proposed.

6. Ekman Boundary Layer Program

6.1 Preamble

In order to define the surface meteorological fields over the Gulf region it would be advantageous to be able to map the Ekman boundary layer fields (i.e. wind and temperature distributions up to about 500 m). This could be done by aircraft, tethered balloons and/or special radiosonde observations and such a program would be useful to the climatic modification, surface wind stress and heat budget programs. The boundary layer data, coupled with the surface flux data, would be useful for parameterization studies for GARP.

6.2 Program

The program should consist of tethersonde sites on Anticosti, Grindstone and near Stephenville (for example). The equipment could not be operated continuously but could be operated for periods of a few weeks in each season. The standard rawinsonde data for Sept Iles, Stephenville, Sable Island and Caribou would also be useful for background data.

7. Climatic Modification

7.1 Preamble

One of the objectives of the Gulf Year is to determine through simulation models how best to 'manage' the resources of the Gulf. In this connection, it is important to note that simulated changes in ice cover, fresh-water input, salinity distribution, etc., imply an associated modification of the atmosphere and thus of climate. The ocean and the atmosphere are strongly coupled, often in non-linear ways that are not immediately obvious. The atmosphere and the Gulf waters must therefore be studied as a single system.

In addition to the direct requirements for Gulf simulations, AES has a fundamental interest in using the Gulf Year as a model for similar studies in other parts of Canada. More and more, AES is being asked to assess the climatic implications of large ecological environmental modifications. Although global effects are being examined in many countries (for a recent survey, see the 1971 SMIC report, "Inadvertant Climate Modification"), and although there is a voluminous literature on microscale effects (shelter belts, irrigation of a field, dusting of a plot of snow), there is no information on the regional scale. In the SMIC report, particular concern was expressed about man-made modification of the Arctic, which might have profound effects on the climate of the whole Northern Hemisphere. One of the recommendations was that international agreement be sought to prevent large-scale (directly affecting over 1 million square kilometres) experiments in climate modification until the scientific community had reached a consensus on the effects. Nevertheless, modifications on the medium scale (about the size of the Gulf or of Hudson Bay) should be investigated as a profitable means of developing and verifying theoretical models that could ultimately be applied to the larger scales.

This same recommendation for more studies of climatic modification is expressed in the Science Council of Canada Reports on Marine Sciences and on the Environment. It must be emphasized, however, that very little is known at present in Canada (or elsewhere) about the regional scale, partly because there has been little dialogue over the years between meteorologists and oceanographers. The regrouping of AES and MSB into the same department is a promising sign, and the timing is right for a major attempt to simulate the atmosphere-Gulf system.

Another related justification for this program is in connection with GARP. One of the major inputs of heat into the atmospheric general circulation is through cold air advection over warmer waters, occurring mainly over the east coasts of Asia and North America. The Gulf is a convenient size for studying air-mass modifications, and there are upper air rawinsonde stations upwind at Seven Islands, Quebec, and downwind at Stephenville, Newfoundland.

7.2 Program

The experimental data to be collected for other reasons will be suitable for the climate modification program. However, AES will require certain additional resources (see section below on costs and budget).

ICE DRIFT STUDIES - GULF OF ST. LAWRENCE

This program, planned and carried out by McGill University, has been continuing for several years with cooperation from numerous Government agencies including the Atlantic Oceanographic Laboratory, Bedford Institute. During the past three winters the procedure followed (or planned but not actually executed in 1971) was to freeze a small vessel into an ice floe and observe its drift and the parameters of wind and current affecting the drift. In an attempt to study ice stress, that is the integrated effect on a floe of its collisions with other floes, radar reflectors were placed on several nearby floes and their relative locations with respect to the ship observed regularly. Because of the radar horizon of about 6 to 7 nautical miles, with the antenna height available on board ship, the area surveyed was really too small to obtain much quantitative information about ice stress.

For this reason a different method of operation is planned for the future. It is proposed to place in the Gulf five drifting buoys initially in the form of a square approximately 50 nautical miles to the side (with the fifth buoy at the centre of this square). Each buoy will be equipped with an anemometer, a pressure sensor, and a current meter as instrumentation. In addition, it will carry a transceiver which will receive Decca signals and rebroadcast them on VHF. This transceiver will also transmit several telemetry channels with the instrument output data. It is planned to put a receiver on board an ice reconnaissance aircraft which would decode the data received from each buoy transmitter. The information will then be separated into instrument and positioning data. The instrumentation data will be tape recorded, and positioning data will be supplied to a Decca receiver which will print out the buoy positions automatically.

The above paragraph summarizes the plans. It was proposed to put this plan into operation in March 1972, but there has been unexpected delay in the signing of the contract to be given to the Canadian Marconi Company for the development and construction of the transceivers, and it will now be impossible to do the work before March 1973. It is planned, however, to make field tests of the equipment in the open season of 1972, using ships of opportunity.

The Strait of Belle Isle Study Group of the Faculty of Engineering and Applied Science, Memorial University, Newfoundland, has started a special study of the Strait of Belle Isle region with respect to the possible building of a causeway across the Strait. Good liaison is maintained between this group and the Gulf of St. Lawrence Project. An important part of this study concerns the movements of ice, which are of great interest to the purpose of the Gulf Project. The use of radar in the study of the movements of sea ice is being investigated, along the lines already developed principally in Japan. This technique might be particularly applicable to the Strait of Belle Isle, where the small distances involved would help to keep the cost of it within reasonable bounds.

SOCIO-ECONOMIC PROGRAM

In its initial stages the socio-economic program of the Gulf Project will be restricted to the provision of background studies designed (1) to describe current economic activity and the social significance and consequence of such activity, (2) to make a preliminary estimate of the effects of change, and (3) to make preliminary recommendations for development of the area. It is proposed that the socio-economic input into the project be divided into two distinct stages utilizing the product of ongoing programs and only the professional staff presently on strength in the Government department(s).

Stage	Time	Manpower Requirement	Function
1	1972-1974	3	Descriptive, present activity
2	1975-1976	3-4	Consideration of multi-disciplinary results and determination of socio-economic consequences

It should be noted that the socio-economic program designed to describe the Gulf system should not require additional funding since it can be argued that the resources necessary are available through a redefinition of priorities for those currently engaged in social science research. The timing and manpower for the program, particularly for Stage 1, as noted in the table above, do not necessarily refer to full time activity since much of the information which must be obtained and analyzed is available from ongoing activities.

Stage 1

This stage commencing in mid-1972 will involve the staff of the Bedford Institute Socio-Economic Unit. The primary tasks will be to describe the current economic activity based around, or influenced directly by, the Gulf of St. Lawrence. The work will involve the general description of the areas of development, economic activity and jurisdictional and political arrangements. Detailed examination of the factors indicated in the attachment to this note would follow. It is estimated that this aspect of the task would involve a total of 24 man-months effort using the services of three individuals during the 1972-1974 period. Many of the data necessary for the descriptive stage are currently available or will be obtainable from ongoing activities when the program commences. These data are obtainable from the continuing activities of Statistics Canada, DREE, National Health and Welfare, various services in the Department of the Environment, the Ministry of Transport, etc.

The description of the present socio-economic pattern will be done in terms of the dynamic interrelations between subregions in the Gulf area, between subpopulations and between industries, and with reference also to the outside influence upon the socio-economic system and to the influence of the economy of the Gulf of St. Lawrence on other parts of Canada. This will produce a working model which will make it possible to predict what the effects of any given change or 'stress' are likely to be; such, for example, as the intensification of the development of a given resource, or the gradual disappearance of a resource, or a gradual change in climate or in local productivity.

Stage 2

Stage 2 will start toward the end of the formal Gulf Year field project. During this stage it is estimated that the services of three (perhaps four) professionals will be required to consider the socio-economic aspects of scientific studies which had been undertaken during the previous two years, and to determine the socio-economic consequences of change which might be brought about if practical application of scientific findings were possible or if new resource management techniques were deemed desirable.

SOCIO-ECONOMIC PROGRAM

GULF OF ST. LAWRENCE PROJECT, STAGE 1

1.0 General Description of study areas development

2.0 Population and Sociological Characteristics

- 2.1 Numbers and Distribution
- 2.2 Age Structure
- 2.3 Education
- 2.4 Rural/Urban Trends
- 2.5 Occupational Distribution and Earnings
- 2.6 Mobility

3.0 Resource Utilization (for each sector--fisheries, water recreation, minerals, transportation)

- 3.1 Types
- 3.2 Source, Area, Extent
- 3.3 Methodology
- 3.4 Costs, Marketability, Profitability
- 3.5 Future Development
- 3.6 Notable Environmental Effects

4.0 Industrial Output

- 4.1 Location and Type
- 4.2 Capitalization
- 4.3 Ownership
- 4.4 Notable Environmental Effects

5.0 Responsibility

- 5.1 Federal
- 5.2 Provincial
- 5.3 Municipal
- 5.4 Private Sector

6.0 Effects and Consequence of Change (First Approximation)

- 6.1 On Environmental Quality
  - 6.1.1 Land and Land Use
  - 6.1.2 Marine
  - 6.1.3 Fresh Water Resources
  - 6.1.4 Atmosphere
- 6.2 On the Population
- 6.3 Requirements for Capital

7.0 Management Proposals (First Approximation)

7.1 For Improved Resource Utilization
7.2 For Increased Economic Development
7. 3 For Environmental Maintenance and Enhancement

BACKGROUND LITERATURE

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Paris, 18 November 1971

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INTERNATIONAL COORDINATING COUNCIL

OF THE

PROGRAMME ON MAN AND THE BIOSPHERE

First Session

Unesco House, 9 - 19 November 1971

DRAFT FINAL REPORT

V. SCIENTIFIC CONTENT OF THE PROGRAMME

Project No. 5 - The ecological effects of human activities in urban, industrial and rural areas on the value of lakes, marshes, rivers, deltas, estuaries and coastal zones, as resources for food production and for amenity, recreation and wildlife conservation

The problem and expected results

Deltas, estuaries and the coastal zone (including intertidal marshes, the seaweed zone and the waters of the continental shelves) are naturally productive areas which supply a significant proportion of the world's food protein and are important recreational areas. Human settlements tend to be concentrated on major lakes, rivers, estuaries, deltas and coastlines, and human activity is threatening the productivity of these zones.

Lake and river impoundments are changing the seasonal flow patterns of rivers, and use of water for irrigation is greatly reducing their total flow. The result is a reduction in the supply of silt and nutrients which are responsible for the great productivity of the deltas, and impairment of the estuarine mechanisms which control aquatic production. Salt marshes are being filled or modified, with a loss of their productive capacity which is important for the productivity of the whole coastal zone.

Change in the flow patterns of major rivers can also alter the bioclimate of the estuarine area, and produce unforeseen effects on the human population.

The flow of nitrates and phosphates into lakes and rivers from fertilized soils and from animal and human wastes is causing eutrophication, with consequent loss of amenity value and a shift to less desirable species of fish. Pollution by toxic substances is also a major problem.

A combination of the factors listed above is reducing the stocks of salmonid and other fishes which migrate up rivers to breed.

Deltas have a high natural instability, as well as a high productivity, and technical developments in deltas have almost always led to deterioration of the ecosystem.

Possible fields of action

It is proposed that studies be conducted on a number of lakes, marshes, rivers, deltas, estuarine and coastal systems of the world, to identify the mechanisms underlying the effects listed above, and to develop methods of avoiding or ameliorating them.

a) Studies on the relations between human activities, river flow patterns, sedimentation and estuarine mechanisms to establish the effects of human activity on the seasonal pattern of physical and chemical events in estuaries and deltas.

b) Studies of the relation between these physical and chemical events and biological production mechanisms in deltas, estuaries and adjacent coastal waters.

c) Studies of the special problems of coastal settlements, in areas where estuarine flushing methods are lacking, to establish effective methods of waste disposal which preserve the quality of the coastal environment.

d) Analysis of the effects on human populations, through changes in such factors as bioclimate, productivity, or recreational and cultural value of the lakes, marshes, rivers, deltas, estuaries and coastal zones.

PRESENT AND ANTICIPATED PARTICIPATING AGENCIES

At the time of the December 1970 meeting at the Bedford Institute, many agencies, Government and University, expressed lively interest in taking part in the Gulf Program. Since then others have done the same. The following list includes those so far involved or expected to be involved.

Department of the Environment

- Water Management Service
- Fisheries Service
- Atmospheric Environment Service
- Policy, Planning and Research Service
- Environmental Protection Service
- Lands, Forests and Wildlife Service

Department of National Health and Welfare

Department of Industry, Trade and Commerce

National Museum of Canada

McGill University, Marine Sciences Centre

GIROQ (Groupe Interuniversitaire des Recherches Océanographiques de Québec) -- Univ. of Laval, Univ. de Montréal, McGill University, Univ. de Québec (Rimouski).

CCIBP - Gulf of St. Lawrence Project

Dalhousie University

University of New Brunswick

University of Moncton, PIROP group

York University, Department of Physics

St. Mary's University

University of Guelph, College of Biological Sciences

University of Waterloo

Royal Ontario Museum

Memorial University, Newfoundland

University of P.E.I.

Governments of Quebec and the Atlantic Provinces

RESOURCE REQUIREMENTS

1. Manpower

The Gulf Study is planned to peak in 1974 with the major closely-coordinated portion commencing in late 1973, and running until approximately April 1975. However, in order that this effort may be most effectively applied, a number of feasibility and preliminary studies are required in 1972 and 1973. While the bulk of the resources proposed will come from the Department of the Environment, it is anticipated that a significant proportion of the manpower will be provided through universities and other agencies. In view of the goals of the Gulf study, the program proposed, and the timing, it is anticipated that the bulk of the university and other support to DOE will be provided through contracts with the Services involved. It should be noted, however, that the program of GIROQ in the St. Lawrence Estuary is judged to be a vital segment of the Gulf Study. At the present time, it is assumed that a major portion of the funding of this particular program will be provided by an NRC grant.

The first stage of the development of the Manpower Requirements followed from the identification of the major tasks to be undertaken. In the second stage, the existing resources that were considered as ongoing or could be focussed on the Gulf Study were identified. The proposed allocation of new resource requirements was assigned primarily to the Services that had the major responsibility and capability for a particular facet of the Study.

Tables 1 to 5 inclusive show the manpower requirements by discipline and support agency. While the magnitude of the existing resources that can be handled within WMS, FS and AES are fairly well known, the figures from other agencies are known in only a fragmentary way. In terms of additional requirements, it is proposed that part of these would be found through new positions within DOE and part through contract and grant arrangements both with universities and other outside agencies. The right-hand side of the Tables identify new requirements, for which it is proposed that funds would come from DOE. The man-years listed under 'University and other outside agencies' are shown separately since they constitute a substantial proportion of the total effort. The work to be done would be carried out mainly by contracting on a project basis. By way of further explanation of the Tables, it should be noted that the man-year requirements are identified by year without a 'carry-over' feature. For example in Table 1, under 'new requirements, DOE' if 41 new man-years are established in 1973-1974 no additional man-years are required in subsequent years.

Table 6 contains a summation of all manpower resources for the entire project as planned to date. It should be noted that the project as outlined herein is as yet not entirely complete since LF & WS and EPS within the department, and others within Health and Welfare, MOT, National Museums, etc., have yet to be identified.

2. Shore Facilities

At present, no new shore facilities are requested for the Gulf Study *per se* (apart from short term rental arrangements at selected sites). It is recognized, however, that the existing facilities will suffer considerable strain. Construction of a facility to house a tissue bank is recommended. This, however, is visualized as serving a national need of which material from the Gulf Study would constitute only one segment.

3. Support Vehicles

Carrying out the planned program will require major vessel support as well as use of aircraft. A significant proportion of the vessel requirements can be met by utilizing existing WMS and FS vessels, but charters will have to be employed as well if the project plan is to be realized. It is also recognized that the project can be handled most efficiently by having projects carried out on a single vessel rather than moving it from ship to ship. It is therefore proposed that one of the ships chartered for the Gulf project be used to offset the diversion of one of the Fisheries Service ships.

All of the ships employed require as a minimum, laboratory space, 110-volt ac power, and small winches and handling facilities for carrying out standard meteorological, physical, chemical and biological oceanographic observations. In addition, the physical oceanographic program employing current meters requires a ship with mooring capabilities; the fish inventory program requires a ship with fishing capability; the winter physical oceanographic program requires a ship with mooring capability and some icebreaking capability; the ice studies require use of an icebreaker for brief periods; the larval and immature fish studies require a vessel with suitable handling gear for sampling.

Vessel needs have been identified according to required capabilities in Tables 7, 8 and 9. All vessels require as a minimum, laboratory space, 110-volt ac power, and small winches and handling facilities for carrying out physical, chemical and biological oceanographic observations. In addition, a Type A vessel requires mooring capability, Type B requires fishing capability, Type C requires mooring capability plus considerable iceabreaking capacity, Type D needs to meet minimum requirements only, and Type E requires full icebreaking capability.

In Tables 10, 11 and 12 the proposed ship usage is identified. It is proposed that the *Dawson, Prince*, one chartered ship equivalent to *Dawson* but with fishing capability, and one smaller chartered vessel equivalent to *Prince*, fulfill the major requirements, with short period usage of the *Hudson, Cameron, Sackville* and an icebreaker. In order that the *Prince* can be made available for the Gulf Program, it is proposed that a third charter be arranged in 'trade for *Prince*'.

It is anticipated that the meteorological, chemical, physical and biological programs will require the use of aircraft but, until feasibility studies are carried out in 1972 and 1973, it is uncertain as to how much time will be needed. At present, it would appear that during the winter months, the program can be handled in cooperation with the existing ice reconnaissance flights, provided it can be extended somewhat to include open water areas. If feasibility studies planned for 1972 prove that certain biological properties can be mapped by aircraft, aerial coverage at fortnightly intervals is desirable. A similar schedule would be desirable for heat budget studies. In addition, special flights for gyre identification would prove valuable. It appears therefore that approximately 40 flights would be needed by an aircraft with at least DC-3 capability.

4. Financial Requirements

(a) Operating

Tables 13 to 17 show the proposed operating expenditures by discipline and agency. Similarly as in the Manpower Requirements, figures have been broken into two parts: those available through diversion of existing resources, and new requirements. Table 18 shows the total requirement, broken down on a service and agency basis. Additional resources under the heading of university and non-government agencies would be handled by contracts and/or grants through DOE. Ship and aircraft costs are shown in Table 19. Although the *Prince* is shown as one of the proposed ships to be used in Tables 10 to 12, no cost is shown in Table 19. Instead, the cost of one intermediate charter at $1000 per day is shown. It is proposed that WMS charter one large vessel and FS two of intermediate size. Aircraft charter requirements are shown as an AES responsibility.

(b) Capital Expenditures

Tables 20 to 23 show capital costs by discipline and agency, while Table 24 shows the total cost by agency.

(c) Total Resource Requirements

Table 25 shows the total costs of the project broken down on the basis of agency and year. Estimated total new funds required if the project as presently visualized is to be realized are just under $10 million. If the proposal for the construction of a tissue bank if supported and identified as part of the Gulf Project, an additional $1 million would be needed. Table 26 shows a breakdown of both manpower and costs of the Project on an agency and yearly basis. It should be noted that the costs for the additional work to be undertaken by universities and outside agencies are to be borne by DOE. Table 27 is a summary of the new resource requirements broken down into Operating and Capital and by Service within DOE. The cost of the contract work to be undertaken by universities and other outside agencies is incorporated in these figures.

TABLE 1 MANPOWER REQUIREMENTS (MAN YEARS PER YEAR) BIOLOGY

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	55		32			23*						
1973/4	154		56			27*		41			30	71
1974/5	152		56			25*		41			30	71
1975/6	95		36					41			18	59
TOTAL	456		180			75		123			78	201

N.B. The table shows total manpower requirements on a per year basis with no "carry-over" feature. For example under "New Requirements, DOE", if 41 MY are approved for 1973/4, no additional man years are required in subsequent years.

*These figures are from GIROQ program and include some non-biological studies.

TABLE 2 MANPOWER REQUIREMENTS (MAN YEARS PER YEAR) PHYSICAL OCEANOGRAPHY

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	13		3	8		2						
1973/4	59		4	26		2		1	18		8	27
1974/5	64		4	28		2		3	19		8	30
1975/6	64		4	28		2		3	19		8	30
TOTAL	200		15	90		8		7	56		24	87

TABLE 3 MANPOWER REQUIREMENTS (MAN YEARS PER YEAR) CHEM. & GEOL.

YEAR	TOTAL	*From Ongoing Projects*					*New Requirements*					
		DOE			OTHER FEDERAL AGENCIES	UNIV. & OTHER OUTSIDE AGENCIES	DOE			OTHER FEDERAL AGENCIES	UNIV. & OTHER OUTSIDE AGENCIES	TOTAL NEW
		AES	F.S.	WMS			AES	F.S.	WMS			
1972/3	13		1	12								
1973/4	33	1	2	18	3				4		5	9
1974/5	62	1	2	18	6			2	13		20	35
1975/6	49	1	2	14	4			1	13		14	28
TOTAL	157	3	7	62	13			3	30		39	72

TABLE 4 MANPOWER REQUIREMENTS (MAN YEARS PER YEAR) METEOROLOGY

YEAR	TOTAL	*From Ongoing Projects*					*New Requirements*					
		DOE			OTHER FEDERAL AGENCIES	UNIV.& OTHER OUTSIDE AGENCIES	DOE			OTHER FEDERAL AGENCIES	UNIV.& OTHER OUTSIDE AGENCIES	TOTAL NEW
		AES	F.S.	WMS			AES	F.S.	WMS			
1972/3	1	1										
1973/4	22	3					19					19
1974/5	24	3					21					21
1975/6	16	4					12					12
TOTAL	63	11					52					52

TABLE 5 MANPOWER REQUIREMENTS (MAN YEARS PER YEAR) SOCIO-ECONOMIC

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	3			3								
1973/4	3			3								
1974/5	4			4								
1975/6	3			3								
TOTAL	13			13								

TABLE 6 MANPOWER REQUIREMENTS (MAN YEARS PER YEAR) TOTAL

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV.& OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV.& OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	85	1	36	23		25						
1973/4	271	4	62	47	3	29	19	42	22		43	126
1974/5	306	4	62	50	6	27	21	46	32		58	157
1975/6	227	5	42	45	4	2	12	45	32		40	129
TOTAL	889	14	202	165	13	83	52	133	86		141	412

TABLE 7

VESSEL REQUIREMENTS

1973 MONTH

VESSEL TYPE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
A					X	X	X	X	X	X	X	X
B				X	X	X	X	X	X	X		
B					X	X	X	X	X	X	X	
D					X	X	X	X	X	X		
D						X	X	X	X	X	X	

N.B. All vessels require as a minimum, laboratory space, 110 V AC power, and small winches and handling facilities for carrying out standard physical, chemical and biological oceanographic obs.

TYPE A - Requires mooring capability
TYPE B - Requires fishing capability
TYPE C - Requires mooring capability plus considerable ice breaking capacity
TYPE D - Minimum requirements only
TYPE E - Full Ice Breaker

TABLE 8

VESSEL REQUIREMENTS

1974 MONTH

VESSEL TYPE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
A	X			X	X	X	X	X	X	X	X	X
B				X	X	X	X	X	X	X		
B					X	X	X	X	X	X	X	
C		X	X									
D					X	X	X	X	X			
D						X	X	X	X	X	X	
E			X									

N.B. All vessels require as a minimum, laboratory space, 110 V AC power, and small winches and handling facilities for carrying out standard physical, chemical and biological oceanographic obs.

TYPE A - Requires mooring capability
TYPE B - Requires fishing capability
TYPE C - Requires mooring capability plus considerable ice breaking capacity
TYPE D - Minimum requirements only
TYPE E - Full Ice Breaker

TABLE 9

VESSEL REQUIREMENTS

1975

MONTH

VESSEL TYPE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
A	X			X								
C		X	X									
E			X									

N.B. All vessels require as a minimum, laboratory space, 110 V AC power, and small winches and handling facilities for carrying out standard physical, chemical and biological oceanographic obs.

TYPE A - Requires mooring capability
TYPE B - Requires fishing capability
TYPE C - Requires mooring capability plus considerable ice breaking capacity
TYPE D - Minimum requirements only
TYPE E - Full Ice Breaker

TABLE 10

PROPOSED SHIP USAGE

1973 VESSEL	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
DAWSON					X	X	X	X	X	X	X	X
PRINCE					X	X	X	X	X	X	X	
CAMERON				X	X	X						
SACKVILLE						X	X	X	X	X		
CHARTER #1					X	X	X	X	X	X	X	
CHARTER #2							X	X	X	X		

N.B. Charter #1 = Large vessel equivalent to DAWSON but with fishing capability.

Charter #2 = Intermediate vessel equivalent to PRINCE.

TABLE 11

PROPOSED SHIP USAGE

1974 VESSEL	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
DAWSON	X			X	X	X	X	X	X	X	X	X
HUDSON		X	X									
PRINCE					X	X	X	X	X	X	X	
CAMERON				X	X	X						
SACKVILLE						X	X	X	X	X		
CHARTER #1					X	X	X	X	X	X	X	
CHARTER #2							X	X	X	X		
ICE BREAKER			X									

N.B. Charter #1 = Large vessel equivalent to DAWSON but with fishing capability.

Charter #2 = Intermediate vessel equivalent to PRINCE.

TABLE 12

PROPOSED SHIP USAGE

1975

VESSEL	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
DAWSON	X			X								
HUDSON		X	X									
ICE BREAKER			X									

TABLE 13

OPERATING EXPENSES (EXCLUDING SHIPS)

BIOLOGY

(In thousands of $)

		From Ongoing Projects					*New Requirements*					
			DOE		OTHER	UNIV.& OTHER		DOE		OTHER	UNIV.& OTHER	
YEAR	TOTAL	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES*	TOTAL NEW
1972/3	775		512			263						
1973/4	2287		896			315		656			420	1076
1974/5	2278		896			306		656			420	1076
1975/6	1652		576					656			420	1076
TOTAL	6992		2880			884		1968			1260	3228

*Funds to be provided by DOE (FS)

TABLE 14

OPERATING EXPENSES (EXCLUDING SHIPS)

PHYSICAL OCEANOG.

		From Ongoing Projects					*New Requirements*					
			DOE		OTHER	UNIV.& OTHER		DOE		OTHER	UNIV.& OTHER	
YEAR	TOTAL	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES*	TOTAL NEW
1972/3	204		48	128		28						
1973/4	924		64	416		28		16	288		112	416
1974/5	1004		64	448		28		48	304		112	464
1975/6	1004		64	448		28		48	304		112	464
TOTAL	3136		240	1440		112		112	896		336	1344

*Funds to be provided by DOE (WMS)

TABLE 15

OPERATING EXPENSES (EXCLUDING SHIPS)

(In thousands of $)

CHEM & GEOL.

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES*	NEW
1972/3	208		16	192								
1973/4	528	16	32	288	48				64		80	144
1974/5	992	16	32	288	96			32	208		320	560
1975/6	784	16	32	224	64			16	208		224	448
TOTAL	2512	48	112	992	208			48	480		624	1152

*Funds to be provided by DOE (WMS)

TABLE 16

OPERATING EXPENSES (EXCLUDING SHIPS)

METEOROLOGY

		From Ongoing Projects					*New Requirements*					
			DOE		OTHER FEDERAL	UNIV.& OTHER OUTSIDE		DOE		OTHER FEDERAL	UNIV.& OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	16	16										
1973/4	417	48					304				65	369
1974/5	434	48					336				50	386
1975/6	276	64					192				20	212
TOTAL	1143	176					832				135	967

*Funds to be provided by DOE (AES)

TABLE 17

OPERATING EXPENSES (EXCLUDING SHIPS)

(In thousands of $)

SOCIO-ECONOMICS

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	48			48								
1973/4	48			48								
1974/5	64			64								
1975/6	48			48								
TOTAL	208			208								

TABLE 18

OPERATING EXPENSES (EXCLUDING SHIPS)

TOTAL

		From Ongoing Projects					*New Requirements*					
			DOE		OTHER FEDERAL	UNIV. & OTHER OUTSIDE		DOE		OTHER FEDERAL	UNIV & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES*	NEW
1972/3	1251	16	576	368		291						
1973/4	4204	64	992	752	48	343	304	672	352		677	2005
1974/5	4772	64	992	800	96	334	336	736	512		902	2486
1975/6	3764	80	672	720	64	28	192	720	512		776	2200
TOTAL	13991	224	3232	2640	208	996	832	2128	1376		2355	6691

*Funds to be provided by DOE

TABLE 19

OPERATING EXPENSES (SHIPS & AIRCRAFT)

(In thousands of $)

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	131					131						
1973/4	1871		135	500	225	131	80	400	400			880
1974/5	2381		135	955	260	131	100	400	400			900
1975/6	400			345	35		20					20
TOTAL	4783		270	1800	520	393	200	800	800			1800

Daily ship costs computed as follows: DAWSON - $1600; HUDSON - $3700; SACKVILLE - $1100; CAMERON - $1500; PRINCE - $1000; LARGE CHARTER - $2000; INTERMEDIATE CHARTER - $1000; ICE BREAKER - $5000.

TABLE 20

CAPITAL EXPENDITURES

BIOLOGY

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV.&OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV.&OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES	NEW
1972/3	150					150						
1973/4	227					27		200				200
1974/5	238		35			3		200				200
1975/6	60		40					20				20
TOTAL	675		75			180		420				420

TABLE 21

CAPITAL EXPENDITURES

PHYSICAL OCEANOGRAPHY

		From Ongoing Projects					*New Requirements*					
			DOE		OTHER	UNIV. & OTHER		DOE		OTHER	UNIV. & OTHER	
YEAR	TOTAL	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES*	TOTAL NEW
1972/3	35		5	30		?						
1973/4	480		5	40				20	400		15	435
1974/5	65		5	40				20				20
1975/6	15			15								
TOTAL	595		15	125				40	400		15	455

*Funds to be provided by DOE (WMS)

TABLE 22

CAPITAL EXPENDITURES

CHEM & GEOL.

		From Ongoing Projects					*New Requirements*					
			DOE		OTHER	UNIV. & OTHER		DOE		OTHER	UNIV. & OTHER	
YEAR	TOTAL	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES	AES	F.S.	WMS	FEDERAL AGENCIES	OUTSIDE AGENCIES*	TOTAL NEW
1972/3	75		5	70								
1973/4	215		5	40	5				85		80	165
1974/5	160		5	50	5				50		50	100
1975/6												
TOTAL	450		15	160	10				135		130	265

*Funds to be provided by DOE (WMS)

TABLE 23

CAPITAL EXPENDITURES

(In thousands of $)

METEOROLOGY

YEAR	TOTAL	*From Ongoing Projects*					*New Requirements*					
		DOE			OTHER FEDERAL AGENCIES	UNIV. & OTHER OUTSIDE AGENCIES	DOE			OTHER FEDERAL AGENCIES	UNIV. & OTHER OUTSIDE AGENCIES	TOTAL NEW
		AES	F.S.	WMS			AES	F.S.	WMS			
1972/3												
1973/4	346						346					346
1974/5	9						9					9
1975/6	6						6					6
TOTAL	361						361					361

TABLE 24

CAPITAL EXPENDITURES

TOTAL

YEAR	TOTAL	*From Ongoing Projects*					*New Requirements*					
		DOE			OTHER FEDERAL AGENCIES	UNIV. & OTHER OUTSIDE AGENCIES	DOE			OTHER FEDERAL AGENCIES	UNIV. & OTHER OUTSIDE AGENCIES*	TOTAL NEW
		AES	F.S.	WMS			AES	F.S.	WMS			
1972/3	260		10	100		150						
1973/4	1268		10	80	5	27	346	220	485		95	1146
1974/5	472		45	90	5	3	9	220	50		50	329
1975/6	81		40	15			6	20				26
TOTAL	2081		105	285	10	180	361	460	535		145	1501

*Funds to be provided by DOE

TABLE 25

TOTAL FINANCIAL PICTURE

(In thousands of $)

(Summation of Tables 18, 19 and 24)

		From Ongoing Projects					*New Requirements*					
		DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	DOE			OTHER FEDERAL	UNIV. & OTHER OUTSIDE	TOTAL
YEAR	TOTAL	AES	F.S.	WMS	AGENCIES	AGENCIES	AES	F.S.	WMS	AGENCIES	AGENCIES*	NEW
1972/3	1642	16	586	468		572						
1973/4	7343	64	1137	1332	278	501	730	1292	1237		772	4031
1974/5	7625	64	1172	1845	361	468	445	1356	962		952	3715
1975/6	4245	80	712	1080	99	28	218	740	512		776	2246
TOTAL	20855	224	3607	4725	738	1569	1393	3388	2711		2500	9992

*Funds to be supplied by DOE

TABLE 26

SUMMARY OF RESOURCE REQUIREMENTS BY AGENCY AND YEAR

1972/73

AGENCY	*From Ongoing Projects* M.Y.	$(000)	*New Requirements* M.Y.	$(000)	*Total* M.Y.	$(000)
DOE	60	1070	-	-	60	1070
UNIV.	25	572	-	-	25	572
TOTAL	85	1642	-	-	85	1642

1973/74

AGENCY	*From Ongoing Projects* M.Y.	$(000)	*New Requirements* M.Y.	$(000)	*Total* M.Y.	$(000)
DOE	113	2533	83	3259	196	5792
EMR	3	53	-	-	3	53
DND	-	225	-	-	-	225
UNIV. & OUTSIDE	29	501	43	772*	72	1273
TOTAL	145	3312	126	4031	271	7343

1974/75

AGENCY	*From Ongoing Projects* M.Y.	$(000)	*New Requirements* M.Y.	$(000)	*Total* M.Y.	$(000)
DOE	116	3081	99	2763	215	5844
EMR	6	101	-	-	6	101
DND	-	225	-	-	-	225
MOT	-	35	-	-	-	35
UNIV. & OUTSIDE	27	468	58	952*	85	1420
TOTAL	149	3910	157	3715	306	7625

1975/76

AGENCY	*From Ongoing Projects* M.Y.	$(000)	*New Requirements* M.Y.	$(000)	*Total* M.Y.	$(000)
DOE	92	1872	89	1470	181	3342
EMR	4	64	-	-	4	64
MOT	-	35	-	-	-	35
UNIV. & OUTSIDE	2	28	40	776*	42	804
TOTAL	98	1999	129	2246	227	4245

*Funds to be provided by DOE

TABLE 27

SUMMARY OF NEW RESOURCE REQUIREMENTS BY SERVICE WITHIN DOE

(Man-Years/Year and $000/Year)

FISHERIES SERVICE

YEAR	M.Y.	$000 O&M	$000 CAP.	TOTAL $000
1973/74	42	1492	220	1712
1974/75	46	1556	220	1776
1975/76	45	1140	20	1160
TOTAL	133	4188	460	4648

WATER MANAGEMENT SERVICE

YEAR	M.Y.	$000 O&M	$000 CAP.	TOTAL $000
1973/74	22	944	580	1524
1974/75	32	1344	100	1484
1975/76	32	848		848
TOTAL	86	3200	680	3880

ATMOSPHERIC ENVIRONMENT SERVICE

YEAR	M.Y.	$000 O&M	$000 CAP.	TOTAL $000
1973/74	19	449	346	795
1974/75	21	486	9	495
1975/76	12	232	6	238
TOTAL	52	1167	361	1528

TOTAL OF FS, WMS, AES

YEAR	M.Y.	$000 O&M	$000 CAP.	TOTAL $000
1973/74	83	2885	1146	4031
1974/75	99	3386	329	3715
1975/76	89	2220	26	2246
TOTAL	271	8491	1501	9992