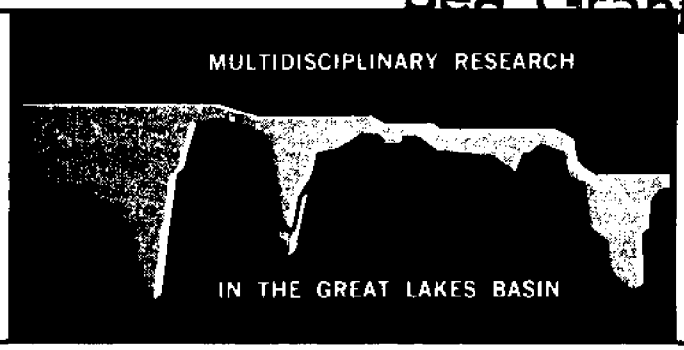

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THE DELPHI METHOD: A SYSTEMS APPROACH TO THE UTILIZATION OF EXPERTS IN TECHNOLOGICAL AND ENVIRONMENTAL FORECASTING

by
John D. Ludlow, Research Associate
The University of Michigan

A COOPERATIVE RESEARCH PROGRAM SPONSORED BY THE UNIVERSITY OF MICHIGAN AND
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University of Michigan

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SEA GRANT DELPHI EXERCISES: TECHNIQUES FOR UTILIZING INFORMED JUDGMENTS OF A MULTIDISCIPLINARY TEAM OF RESEARCHERS

by

John D. Ludlow, Research Associate
Bureau of Business Research, University of Michigan

BACKGROUND OF THIS PAPER

This paper is based on research done at the Bureau of Business Research, Graduate School of Business Administration, University of Michigan, in support of the Regional Economics and Water Resource Management project of the Sea Grant Program at the University of Michigan.

As of 2/24/71 revisions were made on several of the figures in the Appendix.

CONTENTS

FIGURES

APPENDIXES

EXHIBITS AND TABLES IN APPENDIXES

Exhibits

Tables

I

Introduction

Forecasting is an integral part of planning. A forecast should:

- Anticipate what occurrences are possible and assess their probabilities.
- Assess the interactions (cross-impacts) among these occurrences.
- Identify the occurrences that can be controlled and the extent of such control.
- Evaluate alternative future possibilities, considering varying degrees of intervention that are within our power to control.
- Convert these outcomes into displays that provide us with an assessment of the impact of the possible future.[1/]

The objective of this paper is to present a plan for using modified Delphi techniques--essentially a method for securing informed judgments of a group of experts--to secure the use of the competences of a multi-disciplinary team of researchers in forecasts related to planning for a representative region in the Great Lakes area. These forecasts will emphasize the consequences of regional planning on marine resources

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1/ Selwyn Enzer, "A Case Study Using Forecasting as a Decision-making Aid," IFF Working Paper, WP-2, Middletown, Conn., Institute for the Future, Dec., 1969.

and an effort will be made to blend an exploratory approach, based on feasibility, with a normative approach oriented to needs and desires.

The proposed program of Delphi exercises will provide data inputs to several other Sea Grant projects--especially those concerned with assessing the impact of technological developments on the Grand Traverse Bay area. It will also provide a rationale for utilizing the informed judgments of talented people as input to models for anticipating and shaping the future. Some secondary objectives, important in their own right, are:

1. The early identification of regional problems and opportunities as well as deficiencies in information so that scientific and technical expertise can be focused on the areas with the highest potential
2. The furthering of the Sea Grant goals of involving university personnel and establishing communication between them and communities that have an interest in marine resources
3. The involvement of regional planners and decision makers, not only to capitalize on their knowledge of the area in an exchange of information, but in order that political and institutional considerations may be taken into account and findings communicated in such a manner as to encourage the acceptance and implementation of policies and actions on which there appears to be a reasonable consensus

4. The improvement of communications among a multi-disciplinary team of researchers, many of whom are accustomed to operating independently or within the boundaries of individual disciplines

Experiments have shown that feedback and reassessment quite often result in convergence of opinions, as common elements of judgment are reinforced, ambiguities resolved, extreme positions clarified, and the impact of related events assessed. The refinement and strengthening of a consensus are especially important in regional planning, which is essentially a political process. But feedback and reassessment of informed judgments can be tremendously valuable even if it does not lead to convergence.

II

Background of the Sea Grant Delphi Exercises

The Sea Grant Program

The Congressional mandate in the Sea Grant Act calls for both the development of marine resources for economic and social benefits to the nation and for the education and training of personnel to carry out such development. Integral to the program is the communication of useful information to the various marine communities with an interest in marine resources.

The Sea Grant Program of the University of Michigan is designed to (1) establish standards of expertise and a center of knowledge for

Great Lakes research, and (2) provide useful information as a service to regional planners and decision makers. Predictive models are to be used as a focusing device to bring together experts who are competent in diverse fields and organize their knowledge to provide analytical assistance in the design of a comprehensive planning system for dealing with marine resource problems and opportunities.

The program strategy is to concentrate initially on a discrete subregion within the Great Lakes area, not only to avoid widely diffused research but to provide experience in coupling field research with systems analysis and model development. A feedback process is to be developed so that field research stimulates modeling, and the model in turn defines priorities for acquisition of additional field data. The Grand Traverse Bay Area[2/] was selected because it is a reasonable physical analogue to Lake Michigan, the next subsystem of concern, and representative of many areas in the Great Lakes region where the economic development and quality of life are closely related to water resources.

Although a considerable amount of empirical data is being developed in the Regional Economics program and other Sea Grant projects, judgments form the best source of insight into the future. The development of a method to obtain and refine informed judgments of knowledgeable people

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2/ For this research the Grand Traverse Bay Region is considered to be the following ten counties which make up the Region 10 of the State of Michigan's planning and development regions. These counties are Emmet, Charlevoix, Antrim, Kalkaska, Grand Traverse, Benzie, Manistee, Wexford, and Missaukee.

is one of the most challenging problems in the task of improving decision making and planning. The need is particularly crucial in the Sea Grant Program, where the decision maker must consider the opinions of a multidisciplinary team of advisers--some of them experts in extremely specialized areas, while the competence and experience of others span a wide range of technical, economic, social, legal, and political matters--and where precise quantification and models for combining judgments are lacking.

In spite of the importance of intuition and judgment there are inherent dangers in relying on the judgments of a single expert who will tend to view a problem in terms of the boundaries of his own expertise, even though his is only one of several disciplines bearing on the issue. The performance of the expert should improve when he can interact with other experts in the same or related fields. However, the use of a committee to effect the interaction introduces some serious administrative, logistical, sociological, and psychological barriers. The output is likely to be a compromise weighted toward the opinions of those in the group who are most articulate, most prominent, or better placed administratively.

The Delphi method

The Delphi techniques, developed by researchers of the RAND Corporation, provide an initial step toward a systematic use of expert opinion and they appear to have a flexibility that would allow for a much

wider use than the published applications indicate.[3/] The basic features of the method include anonymous responses, iteration, numerical estimates, statistical group summaries, controlled feedback, and reassessment. The means which they provide for obtaining informed judgments preserves the desirable characteristics of face-to-face group deliberations while overcoming some of the associated psychological and administrative barriers. The method yields a cumulative assessment of the group's anticipations without requiring elaborate investigations and support of each issue under consideration.

The objective of the method is to obtain from a group of experts the most reliable consensus of opinion through anonymous responses to a carefully designed program of sequential interrogations. The techniques can be modified to exploit the talents of a well-informed multidisciplinary team of experts by securing judgments that are weighted to reflect specialized competence and, using the combined insight of the group, to interpret those judgments for regional planners and decision makers.

The information exchange is accomplished through a series of

3/ Initially the studies were under the guidance of Dr. Norman Dalkey and Dr. Olaf Helmer. For background information on the Delphi techniques, modifications, and applications see: John D. Ludlow, "The Delphi Method: A Systems Approach to the Utilization of Experts in Technological and Environmental Forecasting," Working Paper No. 3, Bureau of Business Research, Graduate School of Business Administration, University of Michigan, Ann Arbor, Michigan, March 24, 1970.

information packages referred to as rounds. The opening rounds are controlled brainstorming sessions in which a respondent is encouraged to present developments in his area of expertise which he feels will be important for a specific issue or topic. The feedback of responses from other informed people serves to stimulate him to consider developments in his own or related areas that he may have inadvertently neglected. To facilitate the initial exchange of information and to focus on common measures of values in developing and presenting a viewpoint that may be difficult to articulate, respondents attach numerical estimates to a list of important events developed by the group. Self-appraisal indexes are provided to permit the respondent to indicate his relative competence in specific issues and his familiarity with the region. Desirability and feasibility indexes can be designed to account for the value judgments of the estimators and the relative influence of technical, social, economic, and political factors. These serve to help the expert in making his judgment and the rest of the panel in interpreting them.

III

Research Needs

Although the initial focus of the Sea Grant Program is on a discrete subregion, its main concern is to develop techniques that will be useful in designing a comprehensive planning system for the management of the marine resources of the whole Great Lakes Basin.

The Delphi method will be employed in several roles that represent essentially new applications. At a recent conference recognized experts

in forecasting and planning[4/] were in agreement that the hierarchy of planning levels is best expressed by the basic three-level concept of policy planning, strategic planning, and tactical planning. Thus far the Delphi method has been employed primarily to obtain and refine the long-range forecasts associated with strategic planning. Sea Grant experts see their task not only as providing the basis for forecasting alternative futures for a region but as also assisting in "creating the future," and their combined judgments should be brought to bear also at the normative (policy formulation) level and at the operational level of planning. This will be attempted in the Sea Grant Delphi exercises.

The panels will be asked to make value judgments. Dalkey indicates that in making value judgments the validity of Delphi procedures--in the sense of the willingness of respondents to furnish lists of objectives or goals, to allocate weights, to accept a statistical aggregation of weights supplied by a group, and to reassess their judgments based upon feedback of information supplied by the group--is much more obscure than in factual judgments.[5/]

Several techniques for improving the estimating process will also be tested. A concern in securing personal probability assessments is

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4/ Erich Jantsch, Perspectives of Planning (Paris: Organization for Economic Cooperation and Development, 1969).

5/ Norman C. Dalkey, The Delphi Method: An Experimental Study of Group Opinion, Memorandum RM-5888-PR (Santa Monica, Calif.: RAND Corp., June, 1969).

that they correspond with the assessor's judgment (i.e., that he doesn't violate the postulates of coherence). The communication problem is compounded when individual distributions are combined into a single distribution representing a consensus of judgments and presented to a decision maker who must interpret it. To gain insight into the nature of the problem, numerical probabilities will be compared with associated verbal phrases. The Delphi techniques of numerical estimates, feedback of group responses, and reassessment will be employed to develop an ordered scale of verbal phrases, generally comparable to commonly used numerical probabilities. The verbal phrases may be more appropriate in estimating social developments where the use of numerical estimates tends to give an exaggerated, and consequently a somewhat less credible impression of precision.

Another vexing problem associated with personal probability estimates is the assumptions the estimator makes about the future environment. There is a proposed remedy which is procedural: the attention of the panel is first focused on the technical environment and the political, social, institutional and other environmental factors are assumed to develop along present trends. Subsequently, a broader perspective is taken and the influences of the other environmental factors and the value judgments of the estimator are taken into account by using such measures as desirability, feasibility, and importance indexes, developed for various time periods and from a personal as well as a societal orientation. These indexes assist the estimator in

making his judgments and the other panel members in interpreting and weighting them. Techniques for exploiting the use of conditional probability estimates will be examined by the program administrator.

The administrative procedures are flexible enough to incorporate further refinements as the exercises progress.

IV

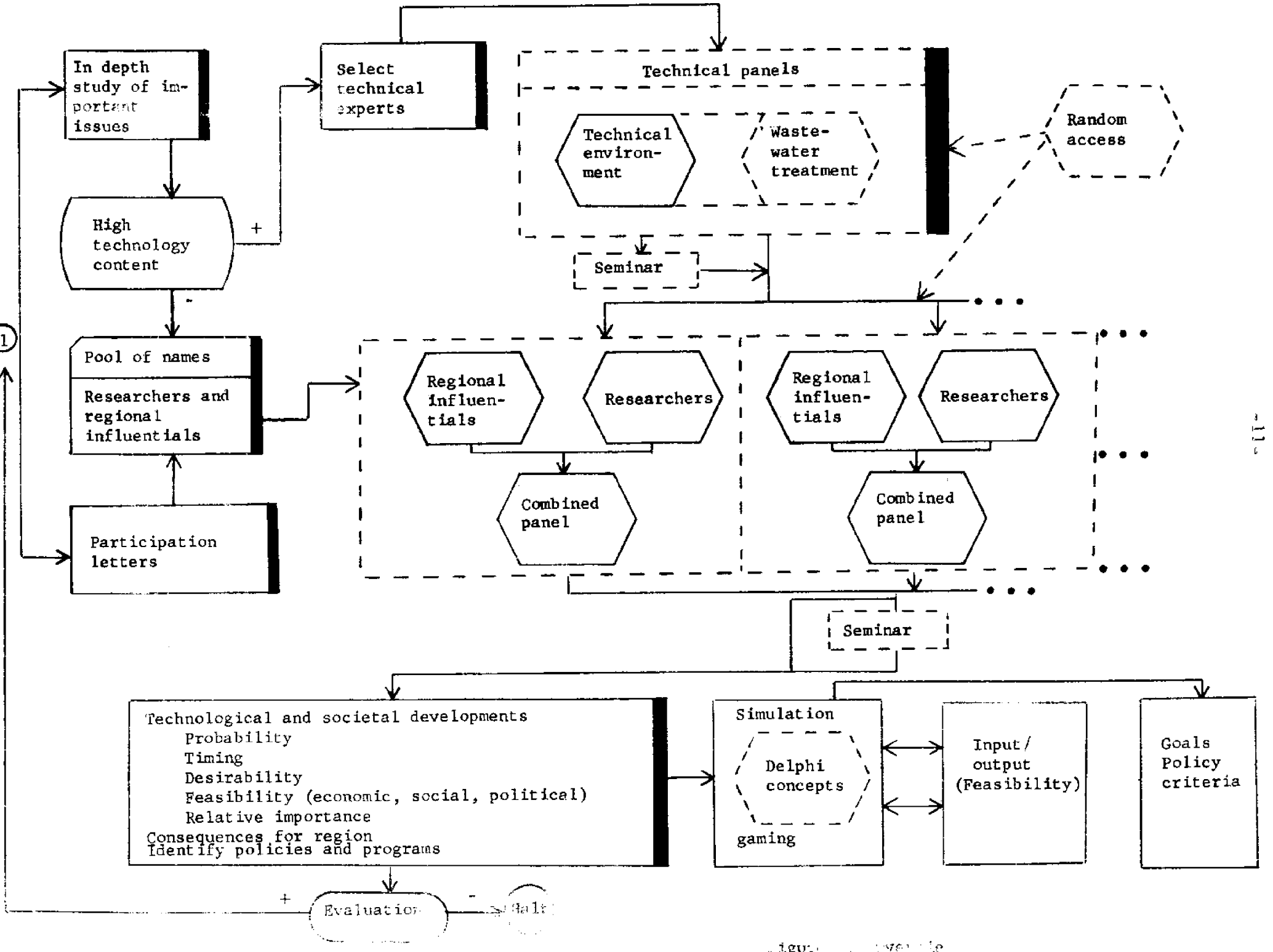
Methodology

Overall research design

The design of this exploratory research is depicted in Figure 1. In preparation for the Delphi exercises a study was made to determine which technical, social, economic, and political issues might have a significant impact on the region's marine resources.

A progressive type of Delphi method will be attempted in which a list of pertinent developments in the technical environment will be generated and assessed by a technical panel before the important societal developments are considered by broader multidisciplinary panels. The prior consideration by a technical panel simplifies the problems of making estimates based on assumptions about the total future environment, avoids bogging down the panel members with data and directs their attention to areas where their interest and expertise lie.

Many of the panel members selected should be experienced in the technology of waste water treatment and disposal and also familiar with the Grand Traverse Bay area. The self-appraisal and importance indexes


In depth study of important issues
Select technical experts
Technical panels
Technical environment
Waste-water treatment
Random access
High technology content
+
-
Seminar
Pool of names
Researchers and regional influentials
Regional influentials
Researchers
Regional influentials
Researchers
Combined panel
Combined panel
Participation letters
Seminar
Technological and societal developments
Probability
Timing
Desirability
Feasibility (economic, social, political)
Relative importance
Consequences for region
Identify policies and programs
Simulation
Delphi concepts
gaming
Input / output (Feasibility)
Goals Policy criteria
+
Evaluation
-

will provide a mechanism for developing a subgroup, competent and interested in waste water treatment and disposal, and thus provide an opportunity for gaining a level of specificity consistent with operational planning while considering related factors in the larger technical environment. Increased benefits from the exercises can be realized if a seminar is held to review the output of the technical panel.

The broader panels will consider the judgments of the technical panels as well as other technical and societal developments. Regional planners and decision makers will be invited to participate along with Sea Grant researchers. The panels will be balanced so far as is practicable in terms of experience, age, sex, and so on, and several panels will be conducted concurrently to check the methodology for consistency.

If the results justify it, a seminar will be held to review the output of the exercises.

The Delphi exercises together with forecasts based on methods and information from other Sea Grant projects will provide information for developing alternative scenarios for the Grand Traverse Bay region. These scenarios can be subjected to gaming and simulation during which the Delphi concepts of dynamic feedback and reassessment can be used to evaluate the impact of various forms of intervention and to develop strategies as well as to generate exogenous technological and societal developments. The alternative futures developed could be tested for feasibility in relation to the state or national environment.

Flexibility can be incorporated in the Delphi exercises so that the information exchange can be extended to other interested individuals

or groups on a random access basis. Evaluation and modification of the methodology to satisfy Sea Grant requirements will be conducted almost continuously.

Technical panels

There are expected to be about 25 experts participating in the technical panel with a subpanel knowledgeable in waste water treatment and disposal formed from the group on the basis of self-appraisal and importance indexes. Candidates for the technical panel will be contacted personally to insure that objectives and procedures are understood and that all relevant disciplines are very likely to be represented throughout the period of information exchange. This direct contact is also desirable since it is intended that the initial administrative procedures will be quite flexible.

The immediate objectives of the technical panel exercises are to use informed expert judgment to:

1. Establish consensus on the relative importance of pollution sources for Grand Traverse Bay and their potential for abatement
2. Obtain the insight of technical experts into the marine resource problems and opportunities of the Grand Traverse Bay area
3. Generate a list of technological developments that would be important for the area

4. Determine the probability, timing, desirability, and feasibility of these developments
5. Establish a subpanel of experts knowledgeable in the technology of waste water treatment and disposal and use their judgments to develop:
   a. Weighted alternative approaches to waste water treatment and disposal
   b. Research and informational references
   c. Research and informational needs

The essence of the Delphi method and modifications can best be illustrated by going through a series of sequential interrogations or rounds. Representative forms and responses are attached to this working paper (Figures 2-11).

Round 1

Each participant is sent a package of general background information and estimating forms for (1) sources of pollution and specific pollutants, and (2) important technical developments relating to water resources. (See Figures 2, 3, and 4).

It is desirable that the respondents volunteer most of the information that will be part of a combined list of events that will be fed back to them on subsequential rounds and narrowed on the basis of group judgments regarding importance and uncertainty. However, the administrator, with his technical consultants, should be prepared on subsequent rounds to interject some events for consideration by the

panel if an area of interest is not satisfactorily covered by unaided responses. The technical developments and sources of pollution are elicited on estimating forms designed to familiarize the panel with the estimating procedures and to minimize the inclusion of trivial events and those that cannot be subjected to the desired specific quantitative estimates. Definitions associated with the estimating factors for the early rounds are attached to the estimating forms (Figure 5).

The questionnaires are returned to an administrative assistant (in the Sea Grant Advisory Office) who records their arrival and insures that only a panel member's number is on the completed forms. He then turns them over to the chief investigator who, using technical consultants, will collate and edit them to eliminate duplications, combine similar events, and retain only discrete events and consistent technical references.

Round 2

Each participant receives the edited list of events and pollution sources and is asked to make his assessments, bearing in mind the interrelationships of other events that the panel felt were important (Figures 6 and 7). He may also add other developments that he wishes the panel to consider. The first two rounds are designed as brain-storming procedures with the panel indicating acceptance or rejection of an idea by the numerical estimates which they assign.

The responses are summarized to indicate the median estimate of the group--and selected subgroups--and the spread of opinions. The range of the consensus can be specifically designated but generally

the interquartile range--the interval containing the middle 50 per cent of the responses--is considered to represent the thrust of the current consensus.

Round 3

Starting with this round and on subsequent rounds, the statistical summary of the previous round is presented to the panel members (Figures 8 and 9). Each respondent is asked to reassess his position on those events that the panel has decided are important and on which there exists a wide range of opinions, considering carefully the statistical summaries, prerequisite technological improvements, and the internal consistency of interrelated events. If his revised estimate falls outside the ranges indicated as the consensus for the previous round, he is asked to provide brief supporting arguments for this extreme position. These minority opinions together with specific questions directed to specific panel members--based on an analysis of their previous responses--are included in the summaries of subsequent rounds. Respondents may be asked to revise their judgments on specific events as the result of the administrator's indicating a delay in prerequisite technology or proposing a specific type of intervention, such as pollution control regulations. (See Figure 10.)

Those panel members who have indicated a competence and an interest in waste water treatment and disposal will be asked to indicate an order of preference for waste water and disposal systems for a region similar to the Grand Traverse Bay Region, to provide pertinent research

and literature references, and to list information needs and research priorities. All respondents will be asked to indicate what problems and opportunities they foresee for the region (Figure 11).

Fourth and subsequent rounds

The information provided by the group is fed back to the respondents who are asked to reassess their position on important events on which there is still no satisfactory consensus and to provide a weighting of preferred approaches to waste water treatment and disposal and problems and opportunities of the region.

If the results warrant, a seminar which could include regional planners and other interested people will be convened to discuss the results of the Delphi exercises.

Broad multidisciplinary panels

Panels of approximately 25 members will be selected from a pool of names drawn up from the responses to a participation letter sent to all researchers in the Sea Grant program and to planners and decision makers in the Grand Traverse Bay Region. Biographical information provided by the participation questionnaire will be the basis for balancing the panels.

The information exchange will be directed so that for the first two rounds participants from the region will constitute separate panels from the Sea Grant researchers. On subsequent rounds they will join together to comprise three combined panels. The output of the separate

and combined panels will be compared to check the consistency of the methodology.

The immediate objectives of the broader panels are to utilize informed expert judgments to:

1. Identify important technological and societal developments--in addition to those identified by the technical panel--that could influence regional planning in the next 20 years
2. Determine the probability, timing, desirability, feasibility, relative importance, and trends of these developments
3. Anticipate the probable impact of these technological and societal developments on the region
4. Identify the problems and opportunities for the region in the next ten years

The iterative feedback and reassessment techniques for the broader panels are similar to those employed by the technical panels. Some of the estimating procedures will be modified, however, to deal realistically with conceptual differences in anticipating future societal changes and forecasting technological progress.[6/]

6/ The comparison of expected technological and societal developments is based on information contained in: Raul de Brigard and Olaf Helmer, "Some Potential Societal Developments, 1970-2000," IFF Report R-7, Middletown, Conn., Institute for the Future, Apr., 1970.

In technological forecasting, technology is generally treated as an irresistible force which can be accelerated or decelerated by society, but cannot be stopped or reversed. The occurrence or nonoccurrence of societal developments, however, depends greatly on the nature of human intervention and both progress and regression are possible. In addition, the process of social change is far more complex and the vocabulary far less precise in the social sciences than in the hard sciences.

Some techniques will be explored to obtain and refine group judgments without giving an exaggerated impression of precision. One technique is to present graphically the historical trends of particular interest and ask the panel to extend the graphs through the forecasting period. Feasibility, desirability, and importance indexes, together with arguments advanced to support positions outside the median range, can be used to define a consensus which can be further refined through feedback and reassessment.

Another similar technique, which researchers at the Institute for the Future have used in a series of studies dealing with long-range forecasting of technological and societal events,[7/] is to elicit from the panel possible future societal developments which might occur in the forecasting period and which would represent changes from current patterns. Two nominative scales were used in those studies to indicate the importance

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7/ Ibid., p. 17.

and the strength of the trends. This technique will be modified in an attempt to avoid some of the ambiguities in scale and timing that were encountered.

The combined panels of planners and decision makers from the region and Sea Grant researchers will assess the impact on the Grand Traverse Bay region of the technological and societal developments which the technical panel or earlier rounds of the broader panel have described in terms of timing, desirability, feasibility (social, political, institutional, technical, economic), importance, and trend. And they will explore the feasibility of various forms of intervention to avoid undesirable consequences or to improve the likelihood of realizing opportunities.

In the Sea Grant exercises the Delphi techniques will be used in conjunction with other methods of obtaining group judgments including interviews and conferences or seminars to discuss the results of exercises and the effectiveness of methodological modifications.

V

Evaluation

Evaluating the effectiveness of the Delphi techniques in the Sea Grant exercises can be related conceptually to the test marketing of a new product--in this case the new product is a group of management techniques for obtaining a consensus of informed judgments.

Thus far, the Delphi method has received limited exposure which has been primarily among technically-oriented people. The Sea Grant

exercises will provide a unique opportunity for an evaluation of the method in an operational exercise with a much broader segment of talented people: noncaptive respondents and decision makers who have not had a key role in committing resources to the exercises or an active role in administering them. Even more important the participants will be particularly well qualified to criticize the techniques--they are not only concerned with the substantive results of the exercises but are dedicated to searching for improved methodologies and have a relatively keen awareness of the behavioral difficulties encountered in conventional approaches to group deliberations and assessments. Their recommendations could result in significant improvement and refinement of the method as well as wider applications.

FIGURES (2-11) AND APPENDIXES

These forms and figures are not necessarily those that will be used in the Sea Grant Delphi exercises but are given as examples of the type of information that will be contained in the early rounds.

Round 1 Panel T-1

Panel Member_____

This information package consists of:

1. Bureau of Business Research Working Paper No. 22 containing:

   a. A detailed description of the Sea Grant Delphi exercises including representative forms and explanations of estimating factors

   b. The initial memorandum to the technical panel (Appendix A)

   c. A summary of problems and opportunities in marine resources and alternatives in waste water collection, treatment, and disposal (Appendix B)

   d. A summary of socioeconomic development in the Grand Traverse Bay Region (Appendix C)

2. Forms to be accomplished:

   a. Important technical developments (Form A)

   b. Sources of pollution (Form B)

   c. Problems and opportunities (Form C)

   d. Biographical information

   e. Personal verbal phrase-numerical probability scale

Please submit your response as early as practical but no later than 5 March 1971.

TO: Delphi Administor
Sea Grant Advisory Office
Room 146G
Natural Resources Building

Figure 2. Information package for Round 1 of Delphi Technical Panel 1.

Round 1
Panel Member_____ ESTIMATING FORM A: IMPORTANT DEVELOPMENTS PANEL T-1

1. Self Evaluation (A). Check (✓) the one phrase that comes closest to expressing your familiarity with the Grand Traverse Bay Region. (You will have an opportunity to reassess this evaluation on each round.)

(1) ☐ Totally unfamiliar with area

(2) ☐ Casually acquainted

(3) ☐ Well acquainted with a few aspects

(4) ☐ Generally familiar

(5) ☐ Actively studying the region's developmer

2. List in the evaluation matrix below potential developments in the next 20 years that you feel will be important to the marine resources of the area. List also prerequisite technical events associated with the developments. In specifying a development or event a point should be chosen at which they will have significant effects on other developments or events or on the system in general.

3. Indicate with a check mark (✓) those events and developments that are closely related to waste water treatment and disposal.

4. Evaluate several events or developments with respect to the factors on right of the matrix to familiarize yourself with the numerical estimates that will be requested on subsequent rounds.

No.	Technical Event or Development	Is the Development or Event Related to Waste Water Treatment? If Yes (✓)	Self Evaluation (B). How Familiar are You With Event or Development? 1 - 5	Probability of Occurrence in (1971-1980) 0% - 100%	Event or Development is Prerequisite to Event or Development No(s).	Timing: Year by which the probability is x that the event will have occurred x= 25%	Timing x= 50%	Timing x= 75%	Remarks--Administrator: Relative to Self Evaluation 1 = unfamiliar 2 = slightly familiar 3 = generally acquainted 4 = well acquainted 5 = expert or researcher in area	Remarks--Respondent

Figure 3. Round 1 form for estimating important developments.

Round 1
Panel Member_____

CONTINUATION OF
ESTIMATING FORM A: IMPORTANT DEVELOPMENTS

PANEL T-1

Indicate with a check mark (✓) those events and developments that are closely related to waste water treatment and disposal.

Evaluate several events or developments with respect to the factors on right of the matrix to familiarize yourself with the numerical estimates that will be requested on subsequent rounds.

No.	Technical Event or Development	Is the Development or Event Related to Waste Water Treatment? If Yes (✓)	Self Evaluation (R). How Familiar are You With Event or Development? 1 - 5	Probability of Occurrence in (1971-1980) 0% - 100%	Event or Development is Prerequisite to Event or Development No(s).	Timing: Year by which the probability is x that the event will have occurred x= 25%	x= 50%	x= 75%	Remarks--Administrator: Relative to Self Evaluation 1 = unfamiliar 2 = slightly familiar 3 = generally acquainted 4 = well acquainted 5 = expert or researcher in area	Remarks--Respondent

Figure 3. (con't)

Round 1
Panel Member

PANEL T-1

Estimating Form (B): Sources of Pollution

Listed below are some potential sources of pollution to a body of water comparable to Grand Traverse Bay and some specific pollutants. The purpose of this estimating form is to develop a list of pollution sources and pollutants that in subsequent rounds will be presented in a Matrix Form which will permit judgments to be made as to the relative importance of pollution sources, the social and economic activities affected, and the technical and economic feasibility of making the associated problems more tolerable. A tentative Matrix to be used in round 2 is on page 32 of Working Paper No. 22 in the information package.

Sources of Pollution

1. Effluent from Traverse City sewerage system
2. Septic tanks in the region
3. Storm water run off
4. Industrial wastes

You are requested to add others

Specific Pollutants

1. Phosphorus compounds
2. Nitrogen compounds
3. Oxygen consuming Organic matter
4. Bacteria viruses
5. Turbidity
6. Suspended solids

You are requested to add others

Figure 4. Preliminary form for establishing estimating matrix.

Definition of Estimating Factors and Indexes

Self-evaluation indexes -- scale 1 to 5

(a) Familiarity with the Grand Traverse Bay Region

Your estimate of your familiarity with the Grand Traverse Bay Region (the 10 county area shown in the information package)

1 = Totally unfamiliar with the region
2 = Casually acquainted with the region
3 = Well acquainted with a few aspects of the region
4 = Generally familiar with the region
5 = Actively studying the social and economic development of the region

(b) Familiarity with the item being considered

Your estimate of your knowledge and comprehension of the specific development being considered in comparison to other researchers who are participating in the Sea Grant Program at the University of Michigan

1 = Unfamiliar
2 = Slightly familiar
3 = Generally acquainted
4 = Well acquainted with most aspects
5 = Expert or researcher working in the area

Feasibility indexes -- scale 1 to 5

(a) Technical feasibility

Your estimate of the technical difficulty in accomplishing the event. Assume a political and social environment which might evolve normally from present circumstances

1 = Extremely difficult
2 = Very difficult
3 = Moderately difficult
4 = Slightly difficult
5 = Routine development

Figure 5. Definition of estimating factors and indexes--early rounds.

Definition of Estimating Factors -- continued

(b) Economic feasibility

Your estimate of the economic reasonableness of accomplishing the event. Assume a political and social environment which might evolve normally from present circumstances

1 = Extreme subsidy required
2 = Moderate subsidy required
3 = Economic aspects are of minor concern
4 = Slightly attractive economically
5 = Economically attractive

Although the main focus of this panel is on technical performance, some developments will be highly dependent on economic considerations. For some of these developments technically trained individuals can best make the economic feasibility assessment.

Timing

In an attempt to reconcile variations in personal probability estimating routines and to further refine the consensus of informed judgments, you are asked to:

(a) Estimate the probability that the event will happen in the 1971-1980 time period
(b) Estimate the dates by which the probability is .25, .50, and .75 that the event will have occurred
(c) Indicate--by remarks--any significant discontinuities in your probability estimates
(d) Indicate numerical probability estimates for each of a list of probability-related words and phases. This is a one time requirement and is an attempt to develop verbal labels to a probability scale which can be used in estimating societal developments where numerical estimates could give an exaggerated impression of precision

Importance Index -- scale 1 to 10

Starting with the second round the events will be rated according to their importance to the exercise as judged by the panel. In subsequent rounds only "important" issues on which there is no reasonable consensus

Figure 5 (con't).

Definitions of Estimating Factors--continued

will be considered by the panel. After examining all events on the estimating form make a judgment as to the most important and least important and assign a value of 10 and 1 respectively. Then assign each of the other events values from 2 to 9 as you estimate their values relative to the most important and least important events. You may assign the same value of any number of events.

Personal Probability Assessments

Personal probability assessments are an important feature of the Delphi techniques. However, in estimating probabilities associated with social and political developments numerical scales give an exaggerated impression of precision. Therefore an attempt will be made to establish for each Delphi panel an ordered list of verbal phrases that corresponds generally to commonly used numerical probabilities. You are requested to assign a numerical probability from .00 to 1.00 to each of the following verbal phrases that intuitively express the notion of the likelihood of an event, for example: Likely = .70.

1. Highly probable =	___	11. Slight odds against =	___
2. Very likely =	___	12. Uncertain =	___
3. Very probable =	___	13. Somewhat unlikely =	___
4. Quite likely =	___	14. Fairly unlikely =	___
5. Good chance =	___	15. Rather unlikely =	___
6. Likely =	___	16. Not much chance =	___
7. Rather likely =	___	17. Improbable =	___
8. Better than even =	___	18. Quite unlikely =	___
9. Slight odds in favor =	___	19. Very unlikely =	___
10. Tossup =	___	20. Highly improbable =	___

Figure 5 (con't)

Select from the above list--or add your own--verbal phrases that best describe the following numerical probabilities.

.10	_____	.75	_____
.25	_____	.90	_____
.50	_____		

Figure 5 (con't).

Round 2
Panel Member_____

ESTIMATING FORM (A): IMPORTANT DEVELOPMENTS

PANEL T-1

1. Self evaluation (A). Check (✓) the one phrase that comes closest to expressing your familiarity with the Grand Traverse Bay Region.

(1) ☐ Totally unfamiliar with the area

(2) ☐ Casually acquainted

(3) ☐ Well acquainted with a few aspects

(4) ☐ Generally familiar

(5) ☐ Actively studying the region's developmen

2. Listed in the evaluation matrix below are technical events and developments contributed by you and your Delphi panel as important to the marine resources of the area in the next 20 years. Add other events that you would like the panel to consider.

3. Evaluate all events and developments with respect to the factors on the right (economic feasibility only if pertinent). If you add events or developments, indicate (by number) if it is prerequisite to a listed event or development.

No.	Technical Event or Development	Self Evaluation (B). How Familiar Are You With the Event or Development? 1 - 5	How Important is the Development to the Region? (See Remarks) 0-3	Feasibility: Technical 1-5	Feasibility: Economic 1-5	Probability of Occurrence in (1971-1980)? 0%-100%	Event or Development is Prerequisite to Listed Event or Development? No(s).	Timing: Year by which the probability is x that the event will have occurred: X= 25%	X= 50%	X= 75%	Remarks--Respondent
				1=Extremely Difficult . . . 5=Routine							

Importance Index
0=no importance
1=minor
2=great
3=very great

Self Evaluation Index
1=unfamiliar
2=slightly familiar
3=generally acquaint
4=well acquainted
5 expert or researcher in area

Figure 6. Round 2 form for estimating important developments.

Round 2
Panel Member

Estimating Form B: Sources of Pollution

Listed below are some potential sources of pollution of Grand Traverse Bay and some specific pollutants.

1. Add others which you would like the panel to consider
2. Evaluate with respect to the factors on the right. Assume a social and political environment which is consistent with present trends

Description of Source	Self-Evaluation	Relative Importance 1971-1980	Relative Importance 1981-1990	Abatement Feasibility: Technical	Abatement Feasibility: Economic	Specific Pollutants: Phosphorus	Nitrogen	Bacteria viruses	BOD	Turbidity	Suspended solids	Add Others	Social and Economic Activities Affected
													1. Recreation 2. Commercial fishing 3. Indus. water quality 4. Aesthetics 5. Public water supply List Others 6. 7. 8.
	1-5	1-10	1-10	1-5	1-5	Source contributes what % of specific pollutant							List (by number) in order of importance
1. Effluent from Traverse City sewerage system (see definitions)													
2. Septic tanks in the region													
3. Storm water run off													
4. Industrial Wastes													
a. Food processing													
b. Other													
Estimates should sum to 100 →						100	100	100	100	100	100	100	100

Figure 7. Round 2 matrix for estimating pollution potentials.

SUMMARY OF GROUP RESPONSE

1. The following events will not be considered further by the panel because the panel has indicated that they are relatively unimportant

2. The following events will not be considered further by the panel because a reasonably strong group consensus has been indicated.

3. You are asked to reassess your estimates of the remaining events on the basis of information supplied by your Delphi panel. Consider the interrelationships among events as well as the judgments of the other panel members.

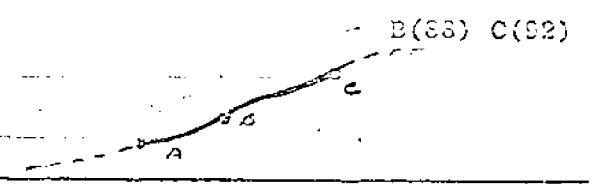
Figure 8. Events relegated to background information based on importance and consensus.

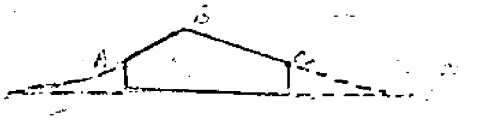
STATISTICAL SUMMARIES OF GROUP RESPONSE

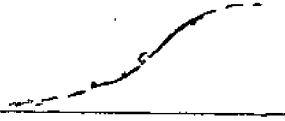
Event 1 OPERATIONAL PHYSICOCHEMICAL COAGULATION/ADSORPTION DIRECT TREATMENT PLANT

PANEL AND SUBPANELS	No. of Resps.	Range	Opportunity Lapse (yrs)	Familiarity Dev't	Familiarity R'n	Feasibility Tech	Feasibility Econ	Prob. 1971-1980 %	Prob. 50% Year	TIMING: GROUP MEDIANS A = 25%, B = 50%, C = 75%
**Previous estimate	-		2	3	6	5	1	30	(1990)	
Total panel	25	U	5	7	7	7	5	30	1978	
		M	4	4	6	6	4	72	1979	
		L	1	1	1	2	1	21	1983	
Those who rated competence 3 or more	8	U	3	7	6	7	5	90	1973	
		M	2	6	6	6	4	75	1980	
		L	2	5	5	4	2	25	1982	
Civil Engineers	5	U	3	7	6	7	6	90	1971	
		M	2	6	6	6	5	72	1979	
		L	1	5	5	5	5	47	1981	

1 9 7 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
Later(year)







Support for Extreme Positions:

Event 2 POLLUTANT FREE ENGINES IN OVER 50% OF NEW CARS SOLD

Previous estimate			2	3	6	3	5	.75	1977
Total Panel									

U = upper quartile M = median L = lower quartile. The interquartile range--the interval containing the middle 50 percent of the responses--is considered the current consensus

** If reassessed estimate is outside of the consensus range, for the total panel, the respondent is asked to submit brief arguments to support his position.

Figure 9. Example of a Statistical Summary

Round 3
Panel Member_____

ESTIMATING FORM (A): IMPORTANT DEVELOPMENTS

PANEL T-1

1. Self evaluation (A). Check (✓) the one phrase that comes closest to expressing your familiarity with the Grand Traverse Bay Region.

   (1) ☐ Totally unfamiliar with the area

   (2) ☐ Casually acquainted

   (3) ☐ Well acquainted with a few aspects

   (4) ☐ Generally familiar

   (5) ☐ Actively studying the region's development

2. Listed below are technical events and developments which you and your panel have judged important and on which a satisfactory consensus has not been obtained. You are asked to reassess your position, considering the attached statistical summaries and the internal consistency of interrelated events.

3. Evaluate all developments with respect to the factors on the right of the matrix. If any revised estimate falls outside of the consensus ranges, as indicated on the attached summary, submit brief supporting argument.

No.	Technical Event or Development	Self Evaluation (B). How Familiar Are You With the Event or Development?	Importance (See Remarks)	Feasibility		Probability of Occurrence in (1971-1980)?	Timing			Remarks-Administrator
				Technical	Economic		Year by which the probability is x that the event will have occurred			Importance Index 1=least important 10=most important 2-9=all others depending on the values relative to the most and least important. Same value may be assigned to several events.
				1=Extremely Difficult . . . 5=Routine			25%= 50%= 75%=			
		1-5	1-10	1-5	1-5	0%-100%	x=25%	x=50%	x=75%	Remarks-Indicate if Supporting Arguments Attached

Figure 10. Round 3 form for estimating important developments.

Estimating Form C: Problems and Opportunities

List what you feel are the most important problems and opportunities in the Grand Traverse Bay Watershed Area related to its water resources. Be as specific as practicable. A combined and edited list of problems and opportunities will be fed back to the panel on the next round and estimating proceedures will be employed to establish their relative importance and impact on the region.

Figure 11. Form for developing an ordered list of problems and opportunities.

APPENDIX A

INITIAL MEMORANDUM TO TECHNICAL PANEL

MEMORANDUM

TO:

FROM: John D. Ludlow
Regional Economics and Water
Resource Management
Sea Grant Program

SUBJECT: Delphi Technical Panel 1

Thank you for agreeing to serve on the "Delphi" panel to consider technological developments that will have important influence on the water resources and related social and economic development of a region with the general physical and economic characteristics of the Grand Traverse Bay watershed area. This panel is made up of approximately 25 technical experts from the University of Michigan whose reputation and experience indicate that they can make a valuable contribution toward a definition of future technical environments for water resource management.

This Delphi exercise is part of a program to develop regional forecasts which emphasize the interdependence of economic and social development and water management decisions. A summary of the panel's judgments will provide background information for broader based Delphi panels--including regional planners and decision makers--which will consider the social and political as well as the technical environment.

Although a considerable amount of empirical data is being developed in the regional economics program and other Sea Grant projects, the best source of insight into the future is the judgment of well informed people. In the Sea Grant program, which employs the concepts of systems analysis and a multidisciplinary team of researchers, one of the most challenging issues is that of securing the consensus of those judgments on important issues. The Delphi techniques developed by researchers of the RAND Corporation provide a systematic method for obtaining and refining opinion and appear to have the flexibility to be effective in relating forecasting to regional planning.

The basic features of the Delphi method--anonymous response, numerical estimates, statistical group summaries, controlled feedback and reassessment--provide a systematic method for obtaining informed judgments that preserves the desirable characteristics of conventional methods of obtaining group judgments while minimizing some of the associated behavioral and administrative difficulties.

The panel is a multidisciplinary group and it is expected that some members will be experts in specialized areas while the competences and experiences of others will span a wide range of disciplines. Self appraisal indexes will permit the respondent to indicate his relative competence on specific issues and his familiarity with the region.

Experiments have shown that feedback and reassessment often result in the convergence of opinions as common elements of judgment are reinforced, ambiguities resolved, extreme positions clarified, and judgments formulated and refined as the interrelationships of events and the weighted opinions of experts in other areas are considered. However, the feedback and reassessment of informed judgments should be tremendously valuable even if it does not lead to convergence.

The information package for the first of four rounds of questioning is enclosed with this letter. In each round after the second a panel member will receive a copy of his past response and a summary of the values assigned by the entire panel and by various subgroups within the panel. Special instructions will accompany each information package but you may want to retain this letter for future reference. To insure anonymity each respondent will be identified by a number--which will be linked to his name only for the purposes of mailing out information packages and checking in the responses. This will be done by an adminsitrative assistant in the Sea Grant office. Some biographical information will be requested to help develop statistical summaries for subgroups within the panel. The first information package is relatively large because it contains much background information. An important feature of the Delphi method is that it does not require elaborate development and support of positions taken on each issue. After the panel has established which items are to be considered first,these will be continuously narrowed until only those items are left judged important to the exercise and on which a satisfactory consensus has not been reached.

The immediate objectives of the technical panel exercises are to use informed expert judgment to:

1. Establish the consensus on the relative importance of pollution sources for Grand Traverse Bay and their potential for abatement

2. Obtain the insight of technical experts into the marine resource problems and opportunities of the Grand Traverse Bay area

3. Generate a list of technological developments that would be important for the area

4. Determine the probability, timing, desirability, and feasibility of these developments

5. Establish a subpanel of experts knowledgeable in the technology of waste water treatment and disposal,and use their judgments to develop:

    a. Weighted alternative approaches to waste water treatment and disposal

    b. Research and informational references

    c. Research and informational needs

Please feel free to request any additional information--either by telephone (764-1366) or with your questionnaire response. A final summary and a complete analysis of the exercises will be sent to each respondent upon completion of the final round of information packages, expected to be round four.

Pages 40 to 70, which are missing from this copy, contained Appendixes B and C. It is felt that these Appendixes would be of interest only to those participating in the exercise.

2/8/71

APPENDIX D

PARTICIPATION LETTER

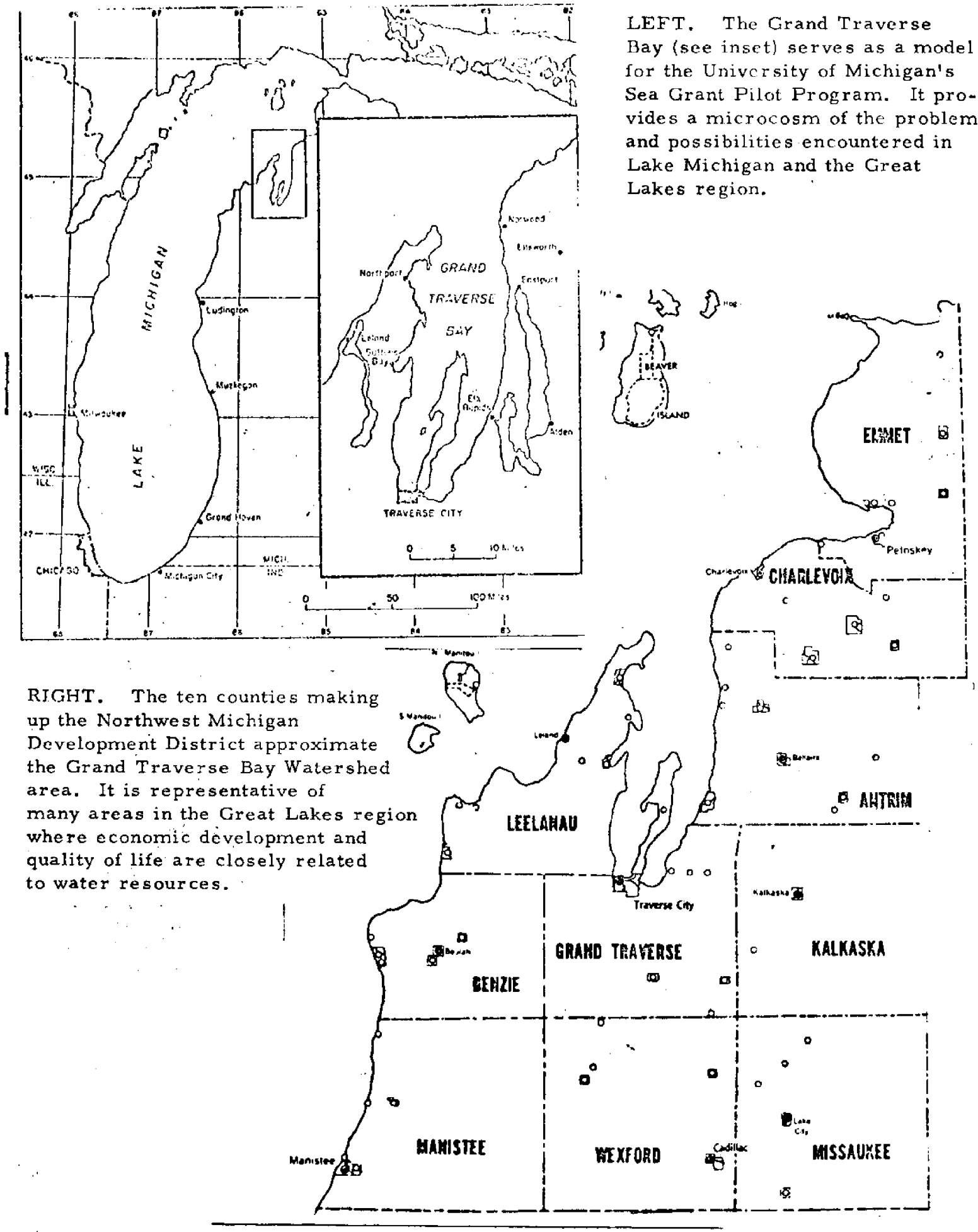
Dear (Regional Influential):

You are invited to participate in an exchange of information with the researchers in the Sea Grant Program of the University of Michigan. From this exchange, forecasts of the impact of technological and social changes on the Grand Traverse Bay area (see the attached Exhibit 5 for a more precise definition of the area) will be developed.

The aims of the Sea Grant Program of the University of Michigan are: (1) to establish standards of expertise and a center of knowledge for Great Lakes research, and (2) to provide useful information as a service to regional planners and decision makers. The Grand Traverse Bay area was selected because it is representative of many areas in the Great Lakes region where economic development and the quality of life are closely related to water resources.

Although a considerable amount of empirical and scientific data is being gathered and used as a basis for projections, the judgments of informed people form the best source of insight into the future. To obtain informed judgments systematically, the Sea Grant Program will use the Delphi techniques developed by the researchers of the Rand Corporation as part of their study of methods for improving decision making. The method is designed to obtain the most reliable consensus of opinion from anonymous responses by a group of experts to a carefully designed program of sequential interrogations.

The exchange of information is accomplished through a series of information packages referred to as rounds. The early rounds are controlled brainstorming sessions in which the respondent is encouraged to present what he feels will be important technical and social developments in the future. The responses are edited to eliminate duplication or ambiguous items, and are then combined and fed back to the group. In subsequent rounds the respondents will be asked to attach numerical estimates to each development indicating its probability, timing, importance and impact on the Grand Traverse Bay area. Self-appraisal indexes will permit the respondent to indicate his relative competence on specific issues and his familiarity with the region.



LEFT. The Grand Traverse Bay (see inset) serves as a model for the University of Michigan's Sea Grant Pilot Program. It provides a microcosm of the problem and possibilities encountered in Lake Michigan and the Great Lakes region.

RIGHT. The ten counties making up the Northwest Michigan Development District approximate the Grand Traverse Bay Watershed area. It is representative of many areas in the Great Lakes region where economic development and quality of life are closely related to water resources.

Exhibit 5. The Grand Traverse Bay Region

After the second round, each participant will receive a copy of his past response with a statistical summary of the values assigned by the entire panel and by various subgroups within the panel. Information obtained from research in the Sea Grant Program and from a Delphi panel of technical experts will also be provided as background information to assist the participants in the formulation of their individual judgments.

Experiments have shown that feedback and reassessment often result in the convergence of opinions as common elements of judgments are reinforced, ambiguities resolved, extreme positions clarified, and the judgments formulated and refined as the interrelationships of events and the weighted opinions of experts in other areas are considered. However, the feedback and reassessment of informed judgments should be tremendously valuable even if they do not lead to convergence.

An important feature of the Delphi method is that it does not require elaborate development and support of positions taken on each issue. After the panel has established which items are to be considered these will be continuously narrowed until only those items are left which have been judged important to the exercise and on which a satisfactory consensus has not been reached.

In assessing the likelihood of social developments, quantitative probability estimates give an exaggerated impression of precision. You are requested to complete the form on probability assessments so that an ordered list of verbal phases that intuitively express the notion of numerical probability can be developed for your panel.

To insure anonymity each respondent will be identified by a number—which will be linked to his name only for the purposes of mailing out information packages and checking in the responses.

Please feel free to request any additional information—either by telephone (313/764-1366) or with your response. A final summary and a complete analysis of the exercises will be sent to each respondent upon completion of the final round of information packages—expected to be round four. A seminar will be held at the University of Michigan to review the output of the Delphi exercises.

It is requested that you respond to this letter as soon as practical but not later than . The procedures are sufficiently flexible that you may miss a round and still be represented in the final results.

John D. Ludlow
Research Associate
Bureau of Business Research
Graduate School of Business
University of Michigan

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2	"A Scoring System to Aid in Evaluating a Large Number of Proposed Public Works Projects by a Federal Agency," by M. Lynn Spruill
3	"The Delphi Method: A Systems Approach to the Utilization of Experts in Technological and Environmental Forecasting," by John D. Ludlow
4	"What Consumers of Fashion Want to Know," by Claude R. Martin, Jr.--Out of print. To be published in a forthcoming issue of the Journal of Retailing.
5	"Performance Issues of the Automobile Industry," by Sidney C. Sufrin, H. Paul Root, Roger L. Wright, and Fred R. Kaen
6	"Management Experience with Applications of Multidimensional Scaling Methods," by James R. Taylor
7	"Profitability and Industry Concentration," by Daryl Winn
8	"Why Differences in Buying Time? A Multivariate Approach," by Joseph W. Newman and Richard Staelin--Out of print. To be published in a forthcoming issue of the Journal of Marketing Research.
9	"The Contribution of the Professional Buyer to the Success or Failure of a Store," by Claude R. Martin
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11	"A Marketing Rationale for the Distribution of Automobiles," by H. O. Helmers
12	"Global Capital Markets," by Merwin H. Waterman
13	"The Theory of Double Jeopardy and Its Contribution to Understanding Consumer Behavior," by Claude R. Martin
14	"A Study of the Sources and Uses of Information in the Development of Minority Enterprise--A Proposal for Research on Entrepreneurship," by Patricia L. Braden and Dr. H. Paul Root
15	"Program Auditing," by Andrew M. McCosh
16	"Time Series Forecasting Procedures for an Economic Simulation Model," by Kenneth O. Cogger
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