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A METHOD FOR THE DETERMINATION OF
REGIONAL VALUES ASSOCIATED WITH THE
ASSESSMENT OF ENVIRONMENTAL IMPACTS

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Dedicated to my wife, Kathy

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CHAPTER I

INTRODUCTION

In recent years the American people have shown an increased perception of the environment as a complex, interacting system of balanced biological and physical elements. Concern for the effects of the activities of man on this dynamic system has resulted in federal legislation designed to insure that the environmental consequences of future governmental projects are incorporated into the planning and design process. The National Environmental Policy Act of 1969[1] requires the preparation of a detailed report assessing anticipated environmental impacts of any major federal action significantly affecting the quality of the human environment. Preparation of an environmental impact statement, therefore, is a Congressional requirement initiated to insure that environmental impacts of future federal actions are evaluated and reported. The Act also created the Council on Environmental Quality and assigned it the duty of preparing guidelines for the preparation of environmental impact statements. The required content of the impact statement has since been established, and methodologies have been introduced that are designed to assess environmental impact. However, no methodology for environmental impact assessment proposed to date has met with universal acceptance.

In the future, the issue of value judgments will become more critical for the environmental analyst. Parameters, designed to describe the environment, have been established and analytical tools have been developed to measure changes in these parameters. However, when the analyst attempts to assess the impact that a change in a particular parameter will have upon the environment, he must inherently rely upon value judgments. All environmental impact assessment methodologies must allow for decision-making based upon opinion as well as absolute evidence.

Two value judgment based decisions are currently necessary in order to evaluate environmental impacts. These two judgments may be referred to as the weighting and scaling of environmental parameters. The weighting of parameters refers to the determination of the emphasis or degree of consideration each parameter should be given relative to all other parameters in the assessment. The scaling of parameters refers to the determination of the effect on the environment that will result from a change in a given parameter. Both of these are opinion based estimates.

Existing environmental impact assessment methodologies are generally deficient in the method of value determination. When treating value determination, authors of environmental methodologies have either failed to recommend procedures or introduced their own values into the assessment method. Neither of these options is considered satisfactory.

Purpose of the Study

The purpose of this study was to apply a new decision-making method to the resolution of value determinations associated with environmental impact assessment. The Delphi[2] method of estimating is a technique which has recently found widespread application to various decision-making situations. It is a method which arrives at a group response without the negative features of direct group discussion. In this study, the Delphi technique was tested to determine the potential for application toward the regional establishment of weighting and scaling values which are vital to environmental impact evaluation.

In our technological society it is the accepted belief that experts are best equipped to make value determinations pertaining to their area of expertise. This is because the expert is assumed to possess more factual information upon which to base his opinion. It is also generally accepted that a value estimate may be given more weight if it represents the consensus of a number of individuals in the form of a group response.

Since environmental impact assessment is founded upon value judgment, it is logical that a committee of environmental experts be employed to make these decisions. This has been the case with existing methodologies. However, people in different regions of the country may be expected to have widely varying environmental values. To accept universal values and impose them upon all regions of the country is not justified. Similarily, the group responsible for the preparation of the environmental statement is generally the same group that has responsibility for the implementation of the project. In this situation, vested interests may distort value determination. It becomes evident that much more work is needed if existing methodologies for environmental impact assessment are to function as valid tools for the environmental analyst.

It has been the case, in the short history of environmental impact assessment, that nationally applied values are often not commensurate with regional interests. This situation has led to controversy over many federal projects. The Delphi adaptation to the determination of weighting and scaling values inherent in impact assessment, allows for these value judgments to be made by experts in the affected region of the country and for the particular project in question. The introduction of a relevant method for the elicitation of regional environmental values is an advancement in the state-of-the-art of environmental impact assessment.

Scope of the Study

The Delphi adaptation is believed to be applicable to any assessment methodology in which value judgments are employed. An existing assessment methodology, a current federal project, and a regional group of experts were selected to test the applicability of the Delphi method.

The assessment methodology selected for use in this study was the Environmental Evaluation System, developed by the Battelle-Columbus Laboratories.[3] The Battelle approach was chosen for the following reasons:

1) The Battelle methodology was designed explicitly for the assessment of water resource planning projects. These types of projects are of prime concern to people of the southwest United States; the area in which the study reported herein was undertaken.

2) The Battelle methodology has generally met with acceptance and has been recommended for use by governmental agencies for the assessment of federal water resource development projects.

3) In their report, the Battelle research team had stated:[3]

> The weights and value functions given in this report were developed by an interdisciplinary research team at Battelle-Columbus. Therefore, the weights and value functions reflect the combined judgments and personal opinions of the research team. In the long run, the weights should be refined to better reflect the views of society.
>
> Value functions represent in some cases a good correlation between parameter measurements and environmental quality. However, in others it is only a judgment of the researchers involved in the development of the

EES. These value functions should be inspected by experts in the appropriate fields to aid in their refinement.

Therefore, the objectives of this study are commensurate with the needed continued development of the Environmental Evaluation System. A further benefit of this study, secondary to the determination of the applicability of the Delphi method, will be the establishment of regional value judgments inherent in environmental impact assessment.

The Aubrey Reservoir Project, proposed by the U.S. Army, Corps of Engineers, Fort Worth District,[4] has been selected as a testcase for this study. This project has been selected for the following reasons:

1) The Aubrey Reservoir project is a current federal action.
2) It is typical of water resource development projects within the southwest United States.
3) A Battelle EES has been prepared and data necessary for a regional adaptation of the EES is available.
4) Within the Aubrey Reservoir project assessment, it has been recommended that a project be initiated to develop a version of the EES which is based upon regional value judgments.
5) It has also been recommended for the Aubrey project, that some means of entering regional public opinion and concern for the environment be established and entered into the Battelle EES.

The groups of experts employed in this study were selected from the scientific environmental advice community of the central Oklahoma area. Fourteen water pollution parameters were evaluated. The responses of these experts were believed to be representative of the community of Oklahoman experts, as the experts were chosen from: state water quality and pollution control agencies; the University of Oklahoma; and professional environmentalists of the central Oklahoma area. The method of selection of Delphi groups has been discussed in chapter four of this text.

There is considerable exchange of information between central Oklahoman and northern Texas environmental experts. As a result, values, with respect to water pollution parameters, are believed to be closely aligned. This assumption may not be valid for social value judgments, such as esthetics. However, for scientific parameters, such as those employed in this study, the correlation between central Oklahoma and north Texas values is believed to be high.

The regional values obtained via the Delphi method were compared to national Battelle values and variances were noted based upon the resulting EES assessments. The degree of variance between EES assessment results was indicative of the differences in value judgments between regional experts and the Battelle research team.

In summary, the objectives of this study were:

1) To propose a method for the elicitation of regional en-

vironmental value judgments using the Delphi method of estimating;

2) To apply this method to fourteen water pollution parameters for the Aubrey Reservoir project;

3) To compare, via separate Environmental Evaluation System assessments, regional value judgments to value judgments made by the Battelle research team;

4) To determine the applicability of the Delphi method for the fourteen water pollution parameters involved in this study;

5) To perform two individual analyses using the Delphi method in order to test the reliability of the method; and

6) To make recommendations and conclusions regarding the applicability of this new decision-making technique for the environmental analyst.

CHAPTER II

DEVELOPMENT OF THE ENVIRONMENTAL IMPACT STATEMENT PROCESS

The National Environmental Policy Act of 1969

During the late 1960's, Congress became increasingly aware of the profound impact of man's activity on the interrelations of all components of the natural environment. Through this Congressional awareness, a major action-forcing mechanism has been created guaranteeing that in the future the federal government will take into consideration the environmental consequences of its proposed actions.

The National Environmental Policy Act (NEPA) of 1969[1] has become the basic policy-setting federal law relating to protection of the environment. As the Employment Act of 1946[5] served as a watershed in the government's relationship to national economic problems, sponsers of NEPA strived to create similar legislation to be applied toward the government's relationship to environmental problems. This has been accomplished by declaring a federal responsibility for action and by providing for a council and an annual report.

The principal objectives of NEPA are: to declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damages to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the nation; and to establish a Council on Environmental Quality. In essence, this policy, instituted on January 1, 1970, directs all federal agencies to insure that environmental amenities and values are given equal consideration with technological and economic factors in government decision-making.

For the first time, national goals designed for environmental protection have been established by Congress. These national environmental goals, expressed by NEPA, declare:[1]

> ...it is the continuing responsibility of the Federal Government to use all practical means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs and resources to the end that the Nation may --
>
> 1) Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
>
> 2) Assure for all Americans safe, healthful, productive and esthetically and culturally pleasing surroundings;
>
> 3) Attain the widest range of beneficial use of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;
>
> 4) Preserve important historic, cultural, and natural aspects of our national heritage and maintain, wherever possible, an environment which supports diversity and variety of individual choice;
>
> 5) Achieve a balance between population and resource use which will permit high standards of living and a wide

sharing of life's amenities; and

6) Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

One of the major responsibilities required by NEPA of all federal agencies for matters under their jurisdiction is the preparation of environmental impact statements. The Act requires federal agencies to prepare statements assessing the environmental impact of their major actions which significantly affect the quality of the human environment. Thus, the environmental impact statement process is designed to insure that federal agency decisions are responsive to environmental concerns.

Title I, Declaration of National Environmental Policy, of NEPA[1] requires all agencies of the federal government to:

> include in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on --
>
> 1) The environmental impact of the proposed action;
>
> 2) Any adverse environmental effects which cannot be avoided should the proposal be implemented;
>
> 3) Alternatives to the proposed action;
>
> 4) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and
>
> 5) Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Within these five points of a broadly worded statute, Congress set the basic considerations to be included in environmental impact analysis. As a result of this Act, the federal government, instead of being an inadvertent contributor to environmental degradation, has been made a central participant in environmental conservation.

The action-forcing provision of environmental impact report preparation has no direct legislative model, although foundations are present in a number of earlier legislative and judicial developments relating to environmental protection. The importance of the impact statement requirement of NEPA is that it brought these separate stands together and confirmed them in a statute applicable across the entire federal government.

Initially the Act did not meet with universal acceptance. The general consensus of federal bureaucrats of that time seemed to be that Congress had succeeded in placing more red tape in the way before authorized projects could be set in motion or before administrative decisions previously taken for granted could be made. Due to the initial attitude of government agencies toward NEPA, the full promise and effect of the Act were not realized until the resulting avalanche of litigation was ruled upon by the courts and interpreted by affected agencies. As this line of action defined the intent of the Act, the environmental impact statement process began to resemble the analytical tool that had been originally conceived by its authors.

Attempts at further definition of the impact statement process have given rise to a large number of documents setting forth many different requirements. However, it should be noted that in the case of an inconsistency between the words of the Act and guidelines or regulations issued by an agency, the words of the Act prevail.

The primary purpose of Congress in enacting NEPA has been to establish a federal policy in favor of protecting and restoring the environment. The broad terms in which that policy is declared clearly make all aspects of man's surroundings the subject of federal concern.

The true test of NEPA's effectiveness lies in whether the results of the environmental analysis are reflected in agency decisions to minimize adverse environmental impacts. Because impact statements must be prepared and environmental factors given appropriate weight in decisions, many of the most environmentally undesirable projects and alternatives have been screened out of agency consideration.

At the 1973 Council on Environmental Quality annual review of NEPA compliance, agencies reported several instances of NEPA's influence on programs and projects. For example, the Corps of Engineers reported that 24 projects have been dropped, 44 other Corps projects have been temporarily or indefinitely delayed, and 197 projects have been significantly modified because of adverse environmental impacts identified through the environmental impact analysis process.[6] It would, therefore, appear that NEPA requirements are being built into agency procedures and NEPA's values are being integrated into agency programs.

The Council on Environmental Quality Guidelines

Shortly after the passage of NEPA, Executive Order 11514[7] was issued requiring agencies to implement the Act and directing the newly established Council on Environmental Quality (CEQ) to issue guidelines to federal agencies for the preparation of impact statements. As a result of this Executive Order, an initial and an updated set of guidelines have been issued by the Council. These guidelines are next in importance to the words of the Act.

The purpose of the CEQ guidelines is to define uniform procedures and approaches to be employed in the preparation of impact statements. The first set of guidelines issued on April 23, 1971, set up the impact statement process and, in particular, the concept of draft and final statements. This concept was developed in order to facilitate the consultation among federal agencies that the statute requires. The necessary content of the environmental impact statement was initially defined within seven points of the 1971 CEQ guidelines.[8] These seven points required the following:

Point 1: A detailed description of the proposed action, a description of the environmental interrelationship in the direct project area and the total affected area, and information and technical data adequate to permit a careful assessment of the environmental impact by commenting agencies;

Point 2: A description of any probable impact on the environment including ecological systems whether or not the impact is deemed beneficial or detrimental, and both primary and secondary significant consequences for the environment;

Point 3: A discussion of any adverse effects which cannot be avoided;

Point 4: A description of appropriate alternatives to recommended courses of action, and alternatives reported in such a manner that reviewers can independently judge if the environmental impact is derived from trying to gain maximum economic return or is inherent to the whole project;

Point 5: An assessment of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term environmental productivity, and an evaluation of the project or action in terms of uses of renewable and non-renewable resources;

Point 6: A description of any irreversible and irretrievable commitment of resources;

Point 7: A discussion of problems and objections raised by local entities in the review process and the disposition of the issues involved.

CEQ issued a list of the federal agencies to whom impact statements should normally be sent for comment. Draft statements were also required to be made available to interested state and local agencies. In addition, public hearings were directed to be held in order to give the public an opportunity to offer its views.

The agency's writing of the final impact statement follows the writing of the draft statement, circulation of the draft for comment, and preparation of responses to the comments received. CEQ, therefore, dictated that the draft must be revised to reflect the agency's consideration of the points raised by commenting groups.

The 1971 guidelines set up a comprehensive procedural structure for the impact statement process. The first place to go in order to assertain how the process should work, after consulting the statute, should be these CEQ guidelines.

On May 2, 1973, CEQ published in the Federal Register,[9] for public comment, a proposed revision of its guidelines for the preparation of environmental impact statements. In reaction to the proposed revised guidelines, the Council received numerous comments from environmental groups, federal, state and local agencies, industry, and private individuals. Two general themes were present in the majority of the comments: many reviewers expressed the desire that the Council increase the opportunity for public involvement in the impact statement process; and the Council received many comments requesting more detailed guidance on the responsibilities of federal agencies in the light of court decisions interpreting the Act.[10]

As a result of the response to the proposed revised guidelines, on August 1, 1973, CEQ issued a second set of guidelines for preparation of environmental impact statements. This second set of guidelines is supplementary to the first set, and it is in the form of recommendations to agencies rather than formal regulations. The 1973 guidelines, therefore, supersede the initial set issued by CEQ in 1971.

A number of questions on procedure and on the content of an impact statement that arose in the two years' experience under the first set of guidelines are dealt with in the revised guidelines. The updated required content of the environmental impact statement is covered within eight points of the 1973 CEQ guidelines.[10] The revised content of the impact statement requires:

Point 1: A description of the proposed action, a statement of the purposes of the proposed action, and a description of the environment affected adequate to permit an assessment of potential environmental impact by commenting agencies and the public;

Point 2: The relationship of the proposed action to land use plans, policies, and controls for the affected area;

Point 3: The probable impact of the proposed action on the environment, an assessment of the positive and negative effects of the proposed action as it affects both the national and international environment, and an analysis of secondary or indirect, as well as primary or direct, consequences for the environment;

Point 4: A discussion of alternatives to the proposed action;

Point 5: A discussion of any probable adverse environmental effects which cannot be avoided;

Point 6: An assessment of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity;

Point 7: A description of any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented;

Point 8: An indication of what other interests and considerations of federal policy are thought to affect the adverse environmental effects of the proposed action.

The revised guidelines emphasize that environmental considerations be taken into account from the beginning of the decision-making process. For example, initial environmental studies are directed to be undertaken concurrently with initial technical and economic studies. The guidelines encourage the use of program or generic impact statements to cover a number of related individual actions when comprehensive analysis is more useful and efficient than separate analysis of several related projects. The 1973 guidelines direct agencies to discuss the secondary environmental impacts of their actions. Energy conservation is specifically identified as a factor for agencies to consider in determining the potential environmental significance of their actions. The especial importance in evaluating energy use is pointed out. Possibilities for energy conservation in comparing alternatives to a proposed action are recommended.

The status of public participation in the impact statement process is significantly augmented in the revised guidelines. Agencies are required to publish revisions of their NEPA procedures in the Federal Register and to invite public comment. The revised guidelines further recommend an 'early warning' system to be devised by federal agencies in order to inform the public of a decision to prepare a draft environmental impact statement. It is hoped that this early warning will encourage the public to provide information and views for use in preparing statements. Agencies are also encouraged to experiment with innovative methods of public participation beyond the standard format of public hearings.

Due to the tendency of some agencies to rely exclusively on the services of the National Technical Information Service of the Department of Commerce to meet public requests for copies of environmental impact statements, CEQ, on May 15, 1973, issued a memorandum.[11] In this memorandum CEQ suggested that agencies initially print enough copies of statements to meet anticipated demand from the public.

Parties and their Roles in the Impact Statement Process

Before one can understand the full workings of the environmental impact statement process, the parties and their roles in the process should be reviewed.

The first party, and also the central federal force behind the impact statement process, is the Council on Environmental Quality. The Council, established by NEPA to formulate and recommend national policies to promote the improvement of the quality of the environment, consists of three members appointed by the President with the advice and consent of the Senate. CEQ is located within the Executive Office of the President. The Office of Environmental Quality, which provides staff for the Council, was subsequently established by Title II of the Environmental Quality Improvement Act of 1970.[12] CEQ's staff consists of a small group of about 60 staff members, of which only 15 to 20 are primarily involved in the impact statement process.

There are three basic activities in which the Council is engaged. The first duty is to write guidelines which lay down the basic rules for federal agencies to follow in the writing of statements. Secondly, CEQ reviews agency NEPA procedures, frequently suggesting changes, and generally monitoring how adequately each agency is implementing the Act. The third responsibility is to troubleshoot problem projects. CEQ mediates disputes in this capacity. On occasion they may even act as an advocate in the dispute. Through its annual report, CEQ informs Congress and the public of major environmental matters. The Council also makes public various special reports dealing with environmental quality and expedites public notice of environmental impact statement filings by publishing, in the Saturday Federal Register, weekly lists of statements received.

All impact statements must be filed with CEQ, but the Council is very selective in determining those in which it will intervene. It is important to point out that CEQ has no authority or staff resources to read even more than a small fraction of the statements it receives. It does not approve or disapprove projects. CEQ's main role is to act as internal advisor to the Executive Branch and to the President as contemplated by NEPA. In short, as long as the impact statement is submitted to CEQ, the Council will be able to fulfill its basic role in the impact statement process.

The Environmental Protection Agency (EPA) is the second party in the impact process. EPA, like other federal agencies, must prepare environmental impact statements for its proposed actions, however, it is unique in that it is the only federal agency required by law to review and comment in writing on virtually all impact statements issued by other federal agencies.

Section 309 of the Clean Air Acts Amendments of 1970[13] requires EPA's administrator to review and comment in writing on all those actions subject to the impact statement requirements of NEPA that relate to EPA's areas of responsibility. Section 309 also requires that EPA make its written review public. If the administrator determines the action to be unsatisfactory with respect to environmental quality he must make this determination public and refer the action to CEQ. The policies and procedures EPA follows in reviewing federal agency actions and fulfilling its responsibilities in the impact process are found in EPA Order 1640.1.[14]

After CEQ and EPA in the impact statement process come the parties to whom NEPA is primarily directed; the federal agencies of the government. It should be noted that NEPA creates no obligations or responsibilities on state or local agencies, public citizens, or private industry groups.

NEPA directs federal agencies to do two things. The first is mandatory and is the heart of the impact statement process. Before federal agencies reach a decision on a proposed action which may significantly affect the quality of the environment, the Act requires the preparation of a detailed analysis of the likely environmental consequences of the action. If the agency decides that an impact statement is required, a draft statement must be prepared. If no impact statement is required, the federal agency must file a negative declaration. The agency must throughly document the basis for its determination if the decision is made not to prepare a statement. Whether the decision is made to prepare a draft statement or to file a negative declaration, the analysis must be made available to the public.

The second responsibility created by NEPA is for each federal agency to make itself available to other agencies' proposed actions. This responsibility is highly discretionary.

The role of federal agencies in the impact process, as defined by NEPA, can then be summarized by stating that each federal agency must be involved in the writing of its own impact statements and also must be available for consulting or commenting on statements prepared by other federal agencies.

In addition to the requirements of the statute, CEQ's guidelines require each agency to establish, in consultation with the Council, its own formal procedure to implement the objectives of NEPA. Each agency's guidelines should:[15]

1) Identify those agency actions requiring an environmental impact statement.

2) Designate the appropriate time prior to decision to seek comments of other agencies.

3) Describe the mechanism through which statements are to be made available to the public.

4) Specify the general methods for obtaining information required in preparation of the statement.

5) Designate officials responsible for the statements.

6) Establish patterns for consulting with and taking into account comments of other agencies.

7) Provide timely public announcement of plans and programs with environmental impact.

Although federal agencies are not required, under the terms of NEPA, to consult with non-federal groups, state and local agencies, public citizens, and private industry are given an opportunity, under the CEQ guidelines, to comment on and criticize the environmental analysis prepared by a federal agency. In this manner, non-federal groups are involved in the impact statement process. All of the comments on an impact statement follow the statement through the agenoy review process and are made available to the public, the President, and CEQ. If the comments show that the environmental analysis is clearly faulty or that the project is unjustified, the project can be halted. In addition, although the federal agency is responsible for the environmental analysis, it often requires non-federal applicants to do the initial assessment toward the preparation of the impact statement.

Many federal agencies have developed, within their procedures for the preparation of environmental impact statements, the requirement of similar analysis and statements from both local governments and the private sector as a requirement for the award of a federal permit or grant. Thus, often before a federal agency will consider the action requested of it, an environmental analysis is required of non-federal applicants as part of the documentation to be submitted before the federal agency will take action. One should not underestimate the role of state and local agencies and public citizens and private industry groups in the environmental impact process.

A review of the parties and their roles in the impact statement process is not complete without a discussion of the role of the courts. NEPA has been called, by leading judges and legal scholars, one of the most opaque statutes ever written. As a result the courts have shaped the impact statement process in a manner almost unparalleled in the history of the development of federal programs.

Ordinarily questions are directed to the courts at the time a bill is drafted and enacted by Congress. However, this was not the case with the National Environmental Policy Act. It simply is not possible to find in the statute or its legislative history the answers to a number of questions surrounding the impact statement process. The courts have, thus, taken on the role of interpreter in the development of answers to major policy questions.

There are three general areas in which the courts have influenced the impact statement process. First, the courts have issued pronouncements on the abstract interpretation of the Act. The second, judicial influence involves the validity of the agency's regulations implementing NEPA. Third, the courts have pronounced whether an agency, in taking a specific action, has complied with the Act.

Examples of occasions when NEPA and CEQ guidelines did not cover all problem areas and court interpretations were required to include questions involving: the conditions under which an environmental impact statement must be prepared; the point in time at which the statement must be prepared; the agency which must prepare the statement; the required contents of the statement; and from whom comments should be sought and included in the statement.

With respect to the point in time, an environmental impact statement must be prepared; a court ruling has held that the draft statement must be prepared prior to the holding of public hearings on a project.[16] This is so that the public can be informed of the environmental consequences of a proposed action prior to its review. The courts have not ruled specifically as to the point in time the final statement must be prepared, but it is obvious that it must be complete before the ultimate administrative action on a project has been completed. One court, however, has ruled that it is not necessary to prepare an environmental impact statement until after the project has reached 'sufficient definiteness.'[17]

In the instance where more than one agency is responsible for different segments of a particular project, a conflict may arise in determining which agency is responsible for preparing the impact statement. The courts resolved this dilemma in a 1971 ruling that defined the responsibility to the 'lead agency.'[17] Guidelines for determining the lead agency have not been established, but the courts have specified that the responsibility of the lead agency will not permit that agency to sub-let portions of its statement to others.[18]

As previously stated, the National Environmental Policy Act of 1969 is clear in stating five areas which must be considered in a valid environmental impact statement. However, in this area the courts have further defined the intent of NEPA. Court ruling have pronounced that an impact statement must include: a full range of responsible opinions;[19] all known possible environmental consequences;[20] all alternatives, even beyond the agency's scope of authority, including consideration of alternatives that are not complete solutions, unless they are too 'remote from reality';[21] and the costs and benefits of each project so that the person making the final decision can weigh and balance all effects.[18]

The law requires that all federal agencies with jurisdiction or expertise, as well as state and local agencies dealing with enforcement of environmental standards, should be invited to comment on the environmental impact statement. A 1972 court decision indicated that litigants in law suits concerning the statement and interested citizens' groups should also be invited to comment.[22] It would appear that the trend favors the widest appeal possible for comments on the impact statement.[23]

Two areas of the impact process in which the courts have had, perhaps, the greatest impact concern the questions of under what conditions must a statement be prepared and that of retroactivity.

As stated in Section 102 of NEPA,[1] an environmental impact statement must be prepared and included with "every recommendation or reports on proposals for legislation and other major federal actions significantly affecting the quality of the human environment ..." Two areas have been interpreted by the courts which clarify and extend this section of the Act. Court cases have laid down the basic parameters for determining a 'major federal action' to include cost, size, duration of construction, duration of useful life, and the effect on the environment.[21,24-36] The trend is to generally declare any federal action costing more than $50,000 a major one.[23]

The second clarification, that of defining an action "significantly affecting the quality of the human environment," was provided by the Court of Appeals for the Fifth Circuit. The precedent was set that if any existing environmental factors would be significantly degraded by the project, an environmental impact statement must be prepared.[37] Some actions that have been considered major or environmentally significant include:

1) Actions whose impact is significant and highly controversial on environmental grounds;

2) Actions which are precedents for much larger actions which may have considerable environmental impact;

3) Actions which are decisions in principle about a major future course of action;

4) Actions which are major because of the involvement of several federal agencies, even though a particular agency's individual action is not major;

5) Actions whose impact includes environmentally beneficial as well as environmentally detrimental effects.

The CEQ guidelines require that, for all projects started prior to January 1, 1970, but to be completed at some later date, an impact statement must be prepared to the "maximum extent practicable."[8] Early court cases held that NEPA is not to be applied retroactively.[38] However, later cases all seem to deal with each situation as it is presented, ruling on specific cases rather than blanket statements.[23] One court has ruled that, even though a project was started prior to 1970, if a major action was needed for completion, an impact statement must be filed.[39] The court held:

> that an agency must file an impact statement whenever the agency intends to take steps that will result in a significant environmental impact, whether or not these steps were planned before January 1, 1970, and whether or not the proposed steps represent simply the last phase of an integrated operation most of which was completed before that date.

The court further ruled that "as long as appropriations are necessary for the continued construction of a project, impact statements should be filed."

Based on the above discussion it should be obvious that, whether it can be attributed to the aroused interest in environmental protection by the American public or simply the ambiguity of NEPA, the courts have played and will continue to play a major role in shaping the environmental impact statement process.

Major Stages in the Impact Statement Process

It may be helpful at this point to briefly summarize the major stages in the impact process. It is frequently useful to think of the process as involving four major stages. 1) The federal agency must decide if a statement is required for a proposed action. 2) If a statement is required, the agency must prepare a draft statement. If it is decided that a statement is not required the agency must issue a negative declaration accompanied by thorough documentation in support of the declaration. 3) The federal agency must circulate its draft statement for comment. The draft must be made available to all groups directly interested in the proposed action. Circulation must include other federal agencies, state and local agencies, CEQ and interested private groups and concerned citizens. The agency, after allowing a reasonable time for comment on the draft (usually 45 days), must then prepare the final statement by revising the draft to reflect the agency's response to all the major comments received. 4) In light of the analysis set forth in the final impact statement and other factors relevant to the decision-making process, the agency proceeds to reach a decision on the proposed action.

Applications of Environmental Impact Statements

The environmental impact statement can be seen to offer two general applications. NEPA dictates the Congressional application by which the impact statement provides an environmental disclosure study. The study enables federal agencies to evaluate the effect of their actions on the human environment and, where possible, balance the competing considerations to accomplish results which take into account environmental considerations.

In addition to the Congressional application, there has resulted a practical application derived from the impact statement process. The effect of agency delay and court rulings have enabled the environmental impact statement to serve as more than a disclosure device for balancing environmental problems. Perhaps the greatest practical impact of the statement process is the focusing of public attention on proposed projects. This focusing of public attention may result in further environmental consideration of alternatives. Public pressure has taken the form of boycotting certain private project promoters, political pressure on elected officials responsible for projects, or court actions based on legal grounds to stop projects. The statement process has, in some cases, resulted in agency delay rendering obsolete the purpose of the project. Also, judicial review may result in orders finding that the impact statement has not met either requirements of NEPA or standards applied by courts. Non-compliance with NEPA or court pronouncements can halt federal action until a proper impact statement is filed.

The Assessment of Environmental Impacts

At the core of the environmental impact statement process is the actual evaluation or assessment of environmental impacts. Although many methodologies have been developed which set procedural guidelines for quantifying environmental impacts, there are no universally applicable procedures for conducting an adequate analysis. Existing methodologies will be discussed in the following chapter of this text; however, it is appropriate at this point to briefly review some factors that should be taken into consideration when evaluating environmental impact.

The environment is a complex system of physical, biological, and chemical resources. The purpose of assessment methods is to insure that all factors of the environment are considered in the overall evaluation of the impact of a proposed action. The assessment method should evaluate alternatives, point up data needs, and minimize potential impact through feedback. Also, the public should have an input into the process.

There is a fine distinction between environmental assessment and the writing of an environmental impact statement. It is generally the case that most environmental impact statements are actually prepared by the government review agency. In many cases, the client or applicant is required to submit an environmental assessment study prior to the development of the impact statement. This assessment study contains the backup scientific material which is generally drawn upon to produce the impact statement.

The assessment process may be seen as a means of assuring that all possible adverse economic, social, and environmental effects relating to a proposed project have been fully considered and evaluated in the impact statement. This will allow that the final decisions on the project are made in the best overall interest.

As an integral part of planning, effect assessment is an iterative process which consists of identifying anticipated project caused or related effects, evaluating those effects, and considering measures to be taken to lessen or ameliorate these effects. The Corps of Engineers has recommended a sequence of steps to be followed in effect assessment:[40]

1) Assemble a profile of existing relevant economic, social, and environmental characteristics of the project area. Identify the causative factors.

2) Extend the profile to portray future conditions without the project.

3) Make a similar profile for 'with project' conditions identifying causative factors associated with each alternative. The objective of this profile is to examine all significant interactive and interrelated aspects regardless of the category in which any given effect is placed.

4) Identify all effects which will most likely have a material bearing on the decision-making process. This

should be done at the earliest possible stage in the assessment process and reconsidered at each stage in the light of public input and reaction.

5) Describe and display all significant effects in quantitative terms as objectively as possible, designating each as either beneficial or adverse.

6) Evaluate all beneficial and adverse effects by assigning values in monetary terms, where possible, and qualitatively in any event. This is largely subjective in nature, and explicit judgments should be made to permit open discussion in the event that conflicting viewpoints occur.

7) Consider project modifications where adverse effects are significant. A 'no-action' alternative must always be considered.

8) Seek assessment feedback from other sources. Informal exchange with federal, state and private groups is urged and should be sought at the beginning of any investigation and continued throughout as necessary. At this stage of the study, a public meeting is almost mandatory to obtain the views of local citizens and interested groups.

9) Use effect assessment results in making recommendations. The burden of judgment and defense rests with the originator.

10) Prepare a statement of findings. This is a summary which documents the assessment process, the investigations made, alternatives considered, and conclusions reached. It is a separate document, distinct from the environmental impact statement and accompanies final impact statements to CEQ.

11) Lastly, use effect assessments in the environmental impact statement preparation. The effect assessment should be used as input to the environmental impact statement.

Project effects that should be considered may be classified as social effects, economic effects, and environmental effects. Under social effects, parameters such as displacement of people, noise, and esthetic values should be included. National economic development, local government finance, land use, local/regional activity, real income distribution, employment/labor force, business and industrial activity, agricultural activity, and national defense should be among economic considerations. Typical environmental effects would be man-made and natural resources, pollution aspects, land and soils, animals and plants, ecosystems, and physical and hydrologic aspects. It should be noted that the above list consists of examples of various factors that should be considered in the assessment process and is in no way to be considered complete or limiting.

Early attempts at writing impact statements limited the consideration of environmental impact to the immediate physical environment. Local effects are important for the local population, but today the likelihood of a vast number of people being affected by an environmental alteration is great. There must always be considered the potential for environmental deterioration in effect to be multiplied and extended over large areas of the biosphere. Spatial extension of the effects of a development must, therefore, be a prime consideration when dealing with the assessment of environmental impact. The evaluation of an impact must be in the larger setting and must be undertaken as a part of the planning process rather than just an assessment of a single local proposal.

The natural environment is made up of a system of integrated components. The impact of an activity on a component of the environment must not be evaluated in terms of an isolated effect but on the basis of effects on the total dynamic system. Disturbance of such a complex system is often detected at a point in time much later than at the time of initial impact.

Environmental impact of a proposed action may be viewed as occurring on three basic levels. For the purpose of discussion, these levels may be classified as primary, secondary and tertiary impacts. Primary impacts can be identified as those occurring directly because of and in the immediate vicinity of the proposed activity.

The second set of CEQ guidelines defines significant impacts to also include those resulting from secondary effects. Secondary impacts can be viewed as those directly originating at the point of or in the area of a proposed activity and extending to or otherwise affecting the environment outside of that area.

Tertiary impacts may be seen as those caused indirectly by an action with the effects occurring at distant points from the location of the action. Little or no direct physical connection is necessary. Tertiary impacts are often more difficult to quantify but may affect a larger area and greater population. Adverse changes in policy or the establishment of undesirable precedents rather than actual physical damage are often attributed as teritiary effects.

CEQ has treated the significance of secondary and tertiary impacts in a combined sense in ruling that:[10]

> Secondary, as well as primary consequences for the environment should be included in the analysis. Many major federal actions, and particularly those that involve the construction or licensing of infrastructure investments (e.g., highways, airports, sewer systems, water resources projects, etc.) stimulate or induce secondary effects through impacts on existing community facilities and activities may often be even more substantial than the primary effects of the original action itself. For example, the effects of the proposed action on population growth may be among the more significant secondary effects. Such population and growth impacts should be estimated if expected to be significant ... and an assessment made of the affect of any possible change in population pattern or growth upon the resource base, including land use, water and the the public services of the area in question.

To date, impact statements, with few exceptions, have failed to include substantial analysis of tertiary impacts.

CHAPTER III

ENVIRONMENTAL IMPACT ASSESSMENT

Steps in the Assessment Process

An assessment of the environmental impact of a proposed action requires that methods and procedures be identified and developed which will insure that unquantified environmental amenities and values may be given appropriate consideration in decision-making. The assessment methodology should utilize a systematic, interdisciplinary approach. The systematic nature denotes that the method be well-ordered, uniform, all-inclusive and reproducible. An interdisciplinary characteristic guarantees inputs from many disciplines. The systematic, interdisciplinary approach should insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision-making which may have an impact on man's environment.

The following steps have been suggested by L. W. Canter[41] as a rational framework for conducting an environmental assessment. These five steps have been found common to several approaches in current use. It is believed that adherence to this framework will yield a systematic and interdisciplinary approach.

Step 1: Select and group into comparable categories a list of items to be used to describe the environment.

Step 2: Objectively quantify as many of the items as possible. Subjectively quantify the remaining items. Do without the project and for each alternative.

Step 3: Objectively scale each of the quantified items.

Step 4: Subjectively assign a significance value to the quantified and scaled items.

Step 5: Aggregate the information and display the results.

Assessment Methodologies

While CEQ guidelines define uniform procedures and approaches for the preparation of federal impact statements, technical approaches to meeting these specifications are not always available. The general lack of adequate methodological tools presents an obstacle to the meaningful review of environmental impacts of proposed major federal actions. With this lack of assessment methodologies, agencies have, in the past, shown far greater attention to procedural rather than content aspects of environmental impact statements. As recent attention has begun to shift to the quality of impact statements, methodological tools, useful in environmental impact assessment, are being developed.

The basic purpose of the impact assessment methodology is to insure a uniform procedure for the complete and unbiased assessment of the impact of human activity on the environment. Based on the method of identification of impacts, existing environmental impact assessment methodologies can be grouped into five principal types and assigned the headings: ad hoc; overlay; checklist; matrix; and network.[42]

Ad hoc refers to a methodology for environmental assessment in which the level of guidance is minimal. This method does not define specific parameters which should be examined, rather the assessment is limited to the investigation of broad areas of possible impact. Therefore, the ad hoc method provides minimal direction for impact assessment beyond the suggestion of general areas and types of impacts to examine. Examples of broad areas of impacts suggested in ad hoc methodologies include impacts on flora, impacts on fauna, and impacts on lakes.

A set of transparent maps of environmental characteristics is the basis for the overlay methodology. Through the overlaying of transparent maps a composite characterization of the regional environment is obtained. Impacts of the proposed action are identified by noting the impacted environmental characteristics lying within the project boundaries.

A specific list of environmental parameters to be investigated for possible impacts is the basis for the checklist approach. This methodology does not require the establishment of direct cause-effect links to project activities, however, guidelines on how parameter data are to be measured and interpreted should be presented.

The matrix methodology incorporates a list of project activities in addition to a checklist of potentially impacted environmental characteristics. A matrix, relating these two lists, is employed to identify cause-effect relationships between specific activities and impacts. Some matrix methodologies specify which actions impact which environmental characteristics, while others simply list the range of possible actions and characteristics in an open matrix.[42]

The network methodology works from a list of project activities to establish cause-condition-effect networks. This is an attempt to realize that a series of impacts may be set-off by a project action. A set of possible networks are defined, thus allowing the user to identify impacts by selecting and tracing out the appropriate project actions.

Evaluation of Methodologies

A recent report submitted to the U.S. Environmental Protection Agency[42] has set down specific criteria for evaluating the adequacy of an impact assessment methodology. The report suggests the evaluation of methodologies in terms of impact identification, impact measurement, impact interpretation, impact communication, resource requirements, replicability, and flexibility.

To insure that the content of the environmental assessment methodology meets the purposes of NEPA, it must effectively deal with the four key problem areas of impact identification, impact measurement, impact interpretation, and impact communication.

The identification of impacts should be comprehensive to address a full range of impacts. A methodology should identify specific parameters to be examined and require and suggest methods for identifying project impacts as distinct from future environmental changes produced by other causes. Methods for identifying the timing and the duration of impacts along with the sources of data used to identify impacts should be required as part of impact identification.

Impact measurement should include explicit measurable indicators to be used in the quantification of impacts on parameters. Measurement of impact magnitude as distinct from impact significance and the emphasis of objective rather than subjective impact measurements should be provided for in the methodology.

An approach, in order to deal with the problem of impact interpretation, should require explicit assessment of the significance of measured impacts on a local, regional, and national scale. Assumptions made to determine impact significance and an assessment of the uncertainty in impact projections should be stated. A methodology should require identification of any impacts of low probability but high potential damage or loss, a specific method for the comparison of alternatives, and a mechanism for public involvement.

Toward the effective communication of impact, a methodology should suggest a mechanism for linking impacts to the specific affected parties. A description of the project setting should be presented. An approach should also provide a format for presenting the results of the analysis and for highlighting key issues and impacts identified in the analysis. Finally, the methodology should provide guidelines for summarizing results in terms of the specific point required by NEPA and CEQ guidelines.

Resource requirements are reflected in terms of: the availability of data; specific manpower skills required; time needed to learn to use and apply the methodology; cost of the methodology compared to costs using other tools; and specific technologies required for use. The relative degree of ambiguity and the degree to which different impact analysts tend to produce widely different results should determine the replicability of the methodology. Flexibility of the methodology should be evaluated in terms of: the applicability to projects of widely different scale; the useful range of project or impact types; and the ease of modification to fit project situations other than those for which it was designed.

Review of Pertinent Methodologies

Nine pertinent methodologies for the assessment of environmental impact are presented. The review includes a discussion of the format, procedures, strengths, and weaknesses of each methodology. Methodologies selected are representative of the five categories of impact assessment previously mentioned. The first four approaches identify impacts via a checklist, the fifth method employs a matrix, the sixth and seventh methods are based on the overlay technique, the eighth method identifies impacts via a network, and the ninth method is ad hoc.

Notable methodologies based on the checklist approach to environmental impact assessment have been developed by the Battelle Memorial Institute, the Institute of Ecology at the University of Georgia, the U.S. Bureau of Reclamation, and the Tulsa District, U.S. Army Corps of Engineers.

The Battelle Approach[3]

"Environmental Evaluation System For Water Resources Planning," prepared by Battelle Memorial Institute, is a checklist procedure emphasizing quantitative impact assessment. A hierarchial arrangement of environmental quality indicators is used to classify the major areas of environmental concern into four major categories: ecology, environmental pollution, esthetics, and human interest. These four categories are further broken down into 18 components and, finally, into 78 parameters. The list of 78 environmental parameters is the key level of environmental impact within the system. Each environmental parameter represents a unit or an aspect of environmental significance worthy of separate consideration.

In an attempt to deal with the trade-off problem between beneficial and adverse impacts on the environment, a technique is employed whereby all environmental parameters are transferred into commensurate units. This technique consists of three steps. First, through the use of specified graphs or value functions, each set of parameter measurements is transformed into a corresponding environmental quality unit ranging from zero to one; zero denotes extremely bad quality and one represents very good quality. Second, all parameters are assigned weights which reflect the relative importance of the parameters as indicators of the degree to which projects may enhance or disturb the natural and social environment. Third, each set of environmental quality estimates is multiplied by the parameter's relative weight to obtain the common unit. The commensurate units for environmental impact analysis, called environmental impact units, are, therefore, equal to the parameter importance multiplied by the environmental quality.

Environmental impact units are used to trade-off beneficial environmental impacts with adverse environmental impacts for the expected future environment without the project and then with the project. A difference in environmental impact units between these two conditions constitutes either an adverse or a beneficial impact.

An important concept expressed in this approach is the use of a 'red flag' warning system. Red flag is a means of identifying parameters that, for a certain project, could be crucial in determining the magnitude and significance of the overall environmental impact. After a red flag is identified, the potential problem area must be investigated to determine whether a problem exists. Another use of the red flag is to signal parameters for which there are either no data or only qualitative data.

The Battelle Environmental Evaluation System is designed for major water resource projects but should adapt, with limited alteration of parameters, to other types of projects. Explicit procedures for impact measurement and evaluation are emphasized. This should produce highly replicable results. Spatial and temporal aspects of impacts are noted and weighted in the assessment.

Economic impacts are not dealt with in this assessment methodology and social impacts are only partially covered. The resource requirements are rather high which probably restricts the use to major projects. Also, no consideration is shown public participation, uncertainty, and risk concepts.

The Optimum Pathway Matrix Analysis[43]

The objective of the "Optimum Pathway Matrix Analysis Approach to the Environmental Decision Making Process" is to choose a highway route that contributes the least to the degradation of the human environment. The method is essentially a linear combination of component values multiplied by a weighting factor, giving the relative importance of the particular component values. Values are then scaled so that a mean impact index can be calculated for each route. The method is designed for projects in which alternatives have already been proposed and the problem is to select the most attractive alternative, based on environmental impact. In order to accomplish this, the differentiating routes are focused upon relative to one another.

A checklist of 56 environmental components are incorporated into this checklist methodology with measurable indicators specified for each component. Since there is no easy way to convert components, such as the cost of a road and the number of lives saved by building a road, into the same units, it was necessary to establish a means of scaling many different measurements in comparable units. This was accomplished by giving the most expensive road a value of one, and then to scale the remaining routes relative to this standard, or similarly, to give the safest route a value of one and to scale the remaining routes accordingly. This process makes the component value for each route a dimensionless number which can be used as an index of the relative merit of each route.

Weighting values are subjectively determined and also scaled and normalized to keep results within reasonable and understandable bounds. This procedure involved dividing each weight by the total sum of all weights. Both present and long-term weights are used, with the importance of long-term effects ten times greater than present effects.

Imprecision of the scaled environmental factors is included in the calculations of indices by assuming that the value of any environmental factor can vary randomly by 50 per cent. Standard statistical techniques are used to find the best route, given that there is some inexactitude in the values which go into the index. A computer program is employed to calculate indices for each route.

A wide range of impact types are analyzed including land use, social, aesthetics, and economic impacts. However, the methodology is used to evaluate highway project alternatives and the components listed are not suitable for other types of projects.

The use of subjectively determined weighting factors, tending to lend to lower replicability of the analysis, is compensated for by conducting several passes at the analysis and incorporating randomly generated error variation in both actual measurements and weights. As a result, a basis is provided for testing the significance of differences in total impact scores between alternatives.

The Bureau of Reclamation Approach[44]

"Guidelines for Implementing Principles and Standards for Multiobjective Planning of Water Resources," a checklist approach developed by a multiagency task force under the leadership of the Bureau of Reclamation, is an attempt to coordinate features of the Water Resources Council's "Proposed Principles and Standards for Planning Water and Related Land Resources"[45] and "Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources"[46] with requirements of NEPA. The approach is a response to a need to articulate procedures to meet changing public values and priorities in the field of water and related land resources. The essence of multiple objective planning is the formulation of alternative plans which reflect varying degrees of emphasis on the three objectives of national economic development, environmental quality, and regional development.

The approach recommends plan formulation involving a series of steps starting with the identification of needs and culminating in alternative plans and, where practicable, a recommended plan of action. It is an orderly and systematic process allowing reviewers insight into the basic assumptions employed, the data and information analyzed, the reasons and rationales used, and the range of implications of each alternative plan of action. It is essential that the steps are described in sufficient detail so that they may be understood by reviewers.

The plan formulation process, described in the methodology, consists of the following major steps:

1) Identify existing and projected problems and needs, and specify components of the multiobjectives relevant to the planning setting;

2) Evaluate resource capabilities, assuming conditions without projects or programs which are within the discretion of the planning entity or entities;

3) Formulate alternative plans to achieve varying levels of contributions to the specified components of the multiobjectives;

4) Analyze the differences among alternative plans to show trade-offs among the specified components of the multiobjectives;

5) Review and reconsider, if necessary, the specified components for the planning setting and reformulate additional alternative plans as appropriate; and

6) Where practicable select a recommended plan from among the alternatives based upon an evaluation of the beneficial and adverse effects and the trade-offs among the various objectives.

Four classes of beneficial environmental effects are identified. These result from: 1) the protections, enhancement, or creation of open and green spaces, wild and scenic rivers, lakes, beaches, shores, mountain and wilderness areas, esturaries, or other areas of natural beauty; 2) the preservation or enhancement of especially valuable archeological, historical, biological, and geological resources and selected ecological systems; 3) the enhancement of selected quality aspects of water, land, and air by control of pollution; 4) the preservation of freedom of choice to future resource users by actions that minimize or avoid irreversible or irretrievable effects, or, conversely, the adverse effects of failing to take such actions. A detailed outline further subdivides these four classes into general aspects of the environment affected. Detrimental effects are considered the converse of beneficial effects.

Environmental impacts, described in terms of quantitative measures, a descriptive-qualitative interpretation, and possible improvements, are identified by selecting from the outline those environmental aspects possibly affected by the proposed action. No specific procedures for predicting or measuring impacts is included and guidelines for the interpretation of impacts are not provided. Also, no comparison or weighting among impacts is considered.

The explicit identification of the without project environment as distinct from present conditions, and the use of a uniqueness rating system for evaluating quality and human influence are important ideas presented.

The methodology is unique in that it does not label impacts as environmental benefits or costs but only as impacts to be valued by others. The approach also argues against the aggregation of impacts.[42]

The four key features of the approach can, therefore, be summarized: 1) the identification of impacts by considering a broadly defined outline of environmental components; 2) the absence of a standard scheme for measurement of impacts on common terms; 3) the lack of guidance affected for the interpretation of impacts; and 4) the textual listing of conclusions implied as a communication procedure.

The Tulsa Approach[47]

Despite the title, the "Matrix Analysis of Alternatives for Water Resource Development," developed by the Tulsa District, U.S. Army Corps of Engineers, is considered a checklist approach. A display matrix is used to summarize and compare impacts of project alternatives. However, impacts are not linked to specific project actions as required by definition of the matrix type methodology.

The method is applicable for evaluating the relative impact of reasonable and comparable alternatives on man's total environment. Analysis of single plans or incomparable alternatives may be accomplished if value functions are established for the parameters considered. In this manner, absolute rather than relative impacts can be assigned.

The first step in the Tulsa District method is the assemblage of an interdisciplinary team to include individuals with basic knowledge of ecology, economics, engineering, geology, history/archeology, and social/cultural disciplines. Following a general discussion of the needs and possible methods of solution based on preliminary surveys, inventories, and environmental considerations, the team formulates a set of possible alternatives. Once a set of alternatives are formulated to the extent that data needed for project implementation are known, a reasonable number of parameters are to be established.

Parameters, indicative of the overall potential impact of alternatives, are identified within the three broad objectives of environmental quality, human life quality, and economics. Parameters should be broad and encompassing rather than detailed and specific, since a large number of detailed interactions are to be considered in the evaluation of each parameter. For each series of interactions described, measurable indicators should be identified.

A weight is subjectively assigned to each parameter to reflect its relative importance and to express its significance in relation to other parameters in evaluating impacts. A total weight of 100 points is assigned to each planning objective and is proportioned among parameters by using weighting factors. These weighting factors are decimal fractions representing the relative worth of planning considerations at comparable levels of the hierarchy. The proportional number of points which each parameter receives, called equivalency factors, are multiplied by raw scores, reflecting the relative magnitude of alternative impacts, to obtain a weighted score for each parameter for each alternative.

Raw scores for a parameter are assigned to each alternative on a relative basis. The magnitude of impact is estimated by the difference between projections of the with and without project conditions. A projection of the no action alternative established the without project condition and serves as a baseline for estimating the magnitude of impacts.

The methodology recommends grouping all parameters representing a major planning objective and to evaluate each objective independently. It is felt that this procedure allows significant trade-offs between planning objectives to be easily identified after the values for each category have been summarized into a single net impact value for each alternative.

Similar to the Optimum Pathway Matrix Approach, the Tulsa methodology tests for the significance of differences between alternatives by introducing error factors and conducting repeated computer runs. Statistical manipulations are dissimilar, however, and considered by the Corps' writers to be more valid.

Significant ideas incorporated into the approach include the use of a matrix to display trade-offs among major planning objectives, the reliance on relative rather than absolute impact measurements, statistical tests of significance with error introduction, and specific use of the no-project condition as a base line for impact evaluation.

The Leopold Approach[48]

"A Procedure for Evaluating Environmental Impact," is an open-celled matrix approach toward effective environmental assessment. The Leopold approach, as it is known, consists of three basic elements: 1) a listing of the effects on the environment which would be caused by the proposed development, and an estimate of the magnitude of each; 2) an evaluation of the importance of each of these effects; and 3) the combining of magnitude and importance estimates in terms of a summary evaluation. The analysis embodied in the approach is made through the use of an interaction matrix. On one axis of the matrix the actions which cause environmental impact are located, and on the other axis, existing environmental conditions that might be affected are found. Thus, a format is provided for comprehensive review, making clear to the investigator the multitude of interactions that may potentially be involved.

The sample matrix presented lists 100 actions horizontally and 88 environmental characteristics vertically, giving a total of 8,800 possible interactions. Not all possible interactions would apply to every project proposed, therefore, only a few of the interactions would be likely to involve impacts of such magnitude and importance that they deserve comprehensive treatment. Also, it is conceded that even this large matrix may not contain all elements necessary to make a full analysis of every project proposal encountered.

The efficient use of the matrix involves checking each action which is likely to be involved significantly. Each of the actions thus checked is evaluated in terms of magnitude of effect on environmental characteristics, and a slash is placed diagonally across each block which represents significant interaction. After all the boxes which represent possible impact have been marked, the most important ones are evaluated individually. A number from one to ten is placed in each marked box to indicate relative magnitude of impact and similarly, a value from one to ten is assigned each box to represent the relative importance of the impact. A score of ten represents the greatest magnitude or importance and a score of one shows the least.

Following the initial marking and evaluation of the marked interactions, it is recommended that a simplified or reduced matrix consisting of only those marked interactions, be constructed. The next step is to evaluate the numbers which have been placed in the marked boxes. The text of the environmental impact assessment is then primarily a discussion of the reasoning behind the assignment of numerical values for individual boxes marked, reflecting the relative importance and magnitude of each interaction.

The evaluations determined in this approach are subjectively arrived at by the analyst. Ecological and physical/chemical impacts are treated comprehensively. Social and indirect impacts are inadequately handled, and economic and secondary impacts are not addressed. As a result, the approach finds its value as a means of identifying project impacts and as a display format for communicating results of analysis.

The McHarg Method[49]

"A Comprehensive Highway Route-Selection Method," developed by Ian McHarg, is an approach employing transparencies of environmental characteristics overlaid on a regional base map. This involves categorizing environmental characteristics such as land capabilities and uses, social values, human values, etc., into three classes and using transparent overlay maps whose density varies with the class. The approach is specific for revealing the highway alignment possessing the maximum compatibility with the existing environment. As in other multipurpose planning, the objective is to maximize all potential complementary social benefits at the least social cost.

The McHarg method consists of identifying the area of concern as consisting of certain processes which represent values within the environment. These processes are considered as occurring throughout the area of interest in land, water, and air. The project area is then segmented depending on the ranking of each process; the most valuable land and the least, the most valuable water resources and the least, the most and least productive agricultural land, the richest wildlife habitats and those of no value, the areas of great and little scenic beauty, and so on for varying segments of the project area. With the understanding that if a highway transects the area it will destroy certain values, the approach attempts to define that alignment which will reduce the values the least.

Critical factors affecting the physical construction of a highway are identified and ranked from least to greatest cost. Transparent maps are constructed for each of the physiographic factors so that the darker of the three tone classes reflects the greatest cost and the lighter tone represents the least cost. Similarily, social values are marked so that the darker the tone, the higher the value. When these transparent maps are superimposed, the least social cost areas are revealed by the lightest tone.

In every case there should be little doubt as to the ranking within a category, however, there is no method presented for the relative or weighted ranking of the categories among themselves. All that can be done is to identify natural and social processes and to superimpose these maps. Through this process only the maximum concurrence of either high or low social costs are identified and a corridor is sought which transects the areas of least social cost for all categories considered together. It is obvious that this may tend to present a problem when assuming equal weight for each category but when it is conceded that the magnitude of parameters are not co-equal, the problem is compounded.

In addition to the absence of implicit weighting of characteristics mapped, there is an inability of the McHarg method to quantify as well as identify possible impacts. The maps represent three levels of the characteristics based upon compatibility with the highway, however, it is not indicated how this compatibility is determined. Since information is not directly quantified, only categorized into three levels, resource requirements are dependent upon the particular analyst.

The basic value of the McHarg approach lies in the screening of alternative project sites or routes. It is doubtful whether the method is sensitive enough to decide among alternatives already designated and studies in terms of engineering feasibility. The approach then seems most useful as an initial method for identifying and sifting out alternative project sites preliminary to a detailed environmental impact assessment.

The Krauskopf Approach[50]

"Evaluation of Environmental Impact through a Computer Modelling Process" is an overlay technique designed for highway route selection employing computer graphics. The process is designed in four phases consisting of: data bank development; determinant establishment; alternative representation; and alternative analysis and selection.

Use of a computer storage system requires the relating of areas of uniform size and shape, allowing data to be stored on a cellular basis. Data objectively collected on a large number of environmental characteristics are stored on a grid system of one kilometer square cells. The list of data chosen must be specific to the region under study. The environmental characteristics used are comprehensive particularly as regards land use and physiographic characteristics.

The second phase consists of construction of sets of factors which should influence the location of the facility under examination. A list of determinants is objectively constructed by interdisciplinary inputs and providing multidisciplinary data. Each determinant is represented by a weighted linear model determined subjectively by the team of specialists. The weighting values are designed to determine the relative influence of variables within the systems under consideration. A normalization process was performed at each level to bring derived values to a uniform base. In this manner subsystems of the modelling process may be interrelated. This determinant modelling process results in the creation of a spatial value surface for each determinant which is stored by the computer and may be displayed in the form of a symbolic map of the study area.

Since the determinants reflect only specific location factors, it is necessary in the third stage of the process that they be combined to form alternative surfaces upon which an optimum location may be found. The importance of each determinant to the final location of a facility is a subjective decision. The importance given each determinant will differ among analysts and represents a policy decision. Each cell value on the alternative surface represents the effective cost of the project on that cell with the total effective cost being the sum of the costs for each of the individual cells affected. An automated system is employed to utilize the actual cellular cost values rather than the symbols on a map which represent ranges of value. In this way the automated system considers all possible alternative sites to find the project location of minimum environmental cost.

In the final stage of the process any alternative solution may be placed on any alternative or determinant surface and its effective cost found for that surface. How much an alternative solution deviates from the minimum possible solution under a given set of criteria can then be obtained.

Although the approach was developed and applied to a highway setting, it is adaptable to other project types. The sensitive factor when using this methodology is that impacts must be geographically well defined and concentrated. The approach requires considerable amounts of data and is therefore, at present, not practical for the analysis of programs of broad geographical scope.

The methodology represents a significant advance in the development of overlay methodologies. It allows a demonstration of which weighted characteristics are central to a particular alternative solution; it easily handles several subjective weighting systems; the incremental costs of considering or generating additional alternatives is low; and it fits well with developing regional and statewide data bank systems.[42]

The Sorensen Approach[51]

"A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone," by Jens C. Sorensen, is a guide to identification of impacts rather than a full assessment methodology. The network approach is centered on the conclusion that in order to achieve or maintain desired levels of multiple use of a resources system it is essential to understand the impact of any proposed use on the total resources system. Network construction depends on breaking down the problems into relatable units. This breakdown is made by a cause-condition-effect analysis. It is the cause and effect relationships within the system that determine the nature and degree of impact. To delineate these relationships the format of a cause-condition-effect matrix is presented. The network is thus formed by the linkages of causes, conditions, and effects.

Listings of known examples and types of coastal resource degradation are treated as impacts generated by resource use. This is accomplished by tracing each impact back through effect-condition-cause factoring to a resource use and by projecting uses through cause-condition-effect to all the impact listings. A stepped matrix attached to a network is the format used to organize and portray these tracings. Through the use of a stepped matrix a continuous portrayal of the use to cause to condition relationship is obtained.

The approach is not a full methodology but rather a guide to the identification of impacts. The major strength of the approach is its ability to identify the pathways by which both primary and secondary environmental impacts are produced.

The preparation of the required detailed networks is a major undertaking, therefore, the approach is presently limited to some commercial, residential, and transportation uses for which networks have been prepared. An agency wishing to use the approach in other circumstances might develop the appropriate networks for reference in subsequent environmental impact assessments.

The Western Systems Approach[52]

"Environmental Guidelines," proposed by the Western Systems Coordinating Council, viewed as an impact assessment methodology, is an ad hoc procedure. The Western Systems approach, intended primarily as a planning tool for siting power generation and transmission facilities, addresses many of the concerns of environmental impact analysis and has been used in the preparation of impact statements.

An outline of considerations important to the selection of sites for each of several types of facilities is the format of the approach. Types of facilities considered include thermal generating plants, transmission lines, hydroelectric and pumped storage, and substations. The application is limited to the siting of electric power facilities and finds little application to other types of projects.

Pollution, ecological, economic, and social impacts are considered but secondary impacts such as induced growth, or energy use patterns are not addressed. Suggestions for a public information program are offered. Since the approach does not suggest specific means of measuring or evaluating impacts no particular types of data or resources are required.[42]

CHAPTER IV

EXPERIMENTAL PROCEDURES

Introduction

Within the southwest United States the need for water has been considered critical and has been called Oklahoma's number one problem.[53] Federal water resource development projects, therefore, have been a prime concern in this area of the country.

The Aubrey Reservoir project, proposed by the Fort Worth District, U.S. Army Corps of Engineers,[4] is a multipurpose water resource development project. It has been selected for use in this study because:

1) It is typical of federal water resource development projects in the southwest;

2) Sufficient data is available so that the background data needed to perform an environmental assessment is satisfied;

3) A Battelle, Environmental Evaluation System, assessment has been prepared and the results are available for comparison.

A general description of the Aubrey Reservoir project has been included as Appendix A of this report. A brief description of the procedures employed when using the Battelle approach for environmental impact assessment have been included as Appendix B.

In its report describing the Environmental Evaluation System (EES), Battelle suggested, if the system is to be used effectively, it is important to modify certain value judgment based procedures as more knowledge of public preferences becomes available. The assessment of the environmental impact resulting from the Aubrey Reservoir project did not employ a modification of these value determinations. Instead, the environmental impact assessment relied upon the judgments of the Battelle research team.

As a result of the study reported herein, the utilization of a regional group of experts for the assessment of impact resulting from the Aubrey Reservoir project has established certain regional value judgments. Also, the introduction of a new method for elicitation of group opinion has offered a refinement of the method for the determination of value dependent elements inherent to environmental impact assessment.

Three major stages were employed in this study:

1) A group of experts were selected.

2) Certain value determinations were established by the group via the Delphi method of estimating. These value judgments concerned the development of weights and scale functions for each parameter.

3) Information gathered in step two was aggregated and the results analyzed and compared to the results obtained via the Battelle value judgments.

In this chapter the selection of a group of experts and procedures for the application of the Delphi method to estimate value judgments inherent in environmental impact assessment are discussed. In the following chapter the aggregation and analysis of the results are presented.

Value Judgments and the Delphi

Environmental impact assessment is a decision-making process based upon information for which there is some basis for belief but for which there is little supporting evidence. This type of information is commonly referred to as opinion information which is the basis for value judgments. The two principal decisions which are dealt with in an impact assessment methodology concern the manner in which environmental parameters are: 1) quantified or weighted; and 2) scaled. Since no conclusive information exists describing the procedure in which environmental parameters are to be weighted and scaled, the environmental analyst must rely upon value judgments.

When dealing with value judgments, methodologies have relied upon the judgment, insight, experience, or wisdom of the analyst employing the methodology. Often the decisions based upon individual wisdom are open to debate. Since value judgments are at the core of the assessment process, any discrepency at this point may cast serious doubts on the validity of the assessment.

Methodologies proposed to date have established elaborate procedural formats to be followed in the assessment of environmental impact; however, no methodology has satisfactorily dealt with the analysis of opinion information. This is surprising since there exists a kind of technology developed especially for the resolution of problems for which only opinion information is available. This technology is referred to as a pooling of minds. It is based on the adage that "two heads are better than one" or more generally, "n heads are better than one." Committees, councils, panels, commissions, juries, boards, the voting public, and legislatures illustrate the extent to which the device of pooling of many minds has permeated society. Statistical justification for this technique is found throughout the literature.[2]

The traditional way of pooling individual opinions is by face-to-face discussion. However, numerous studies by psychologists in the past two decades have demonstrated some serious difficulties with face-to-face interaction.[55] Among the most serious are: 1) influence of dominant individuals; 2) noise; and 3) group pressure for conformity.

Studies have shown that the group opinion is likely to be highly influenced, if not determined, by the views of the member of the group who does the most talking. Unfortunately there is no significant correlation between success in influencing the group and competence in the problem being discussed. Noise refers to irrevelant or redundant material that obscures the directly relevant material offered by participants. Much of the communication in a discussion group has to do with individual and group interests, not with problem solving. This kind of communication, although it may appear problem oriented, is often irrelevant or biasing. Group pressure often puts a premium on compromise.

The Delphi[2,56-62] method is a technique designed to eliminate some of the problems associated with arriving at a group decision. The Delphi method is used for the elicitation of opinions with the object of obtaining a group response of a panel of experts. Direct confrontation and debate are replaced by a carefully planned, orderly program of sequential interrogations usually conducted by questionnaires. The series of questionnaires is interspersed with feedback derived from the respondents. Respondents give reasons for their opinions and these reasons are subjected to a critique by fellow respondents. The technique puts the emphasis on informed judgment. It attempts to improve the panel or committee approach by subjecting the views of individual experts to each other's criticism in ways that avoid face-to-face confrontation.

The Delphi procedures have, therefore, been designed to reduce the effects of the undesirable aspects of group interaction. The three distinctive features of the procedure are: 1) anonymity; 2) controlled feedback; and 3) statistical group response.

Anonymity is maintained by eliciting separate and private answers to prepared questions. It is a device to reduce the effect of the socially dominant individual. The procedure is carried out by a written questionnaire and all other interactions between respondents are through formal communication channels controlled by the experimenters.

Controlled feedback is a device to reduce noise. Several iterations are made where the results of the previous iteration are fed back to the respondents, normally in summarized form. As face-to-face confrontation is avoided the problem of noise is reduced.

Group opinion is represented through a statistical index. Where the group task is to estimate a numerical quantity, the median of individual estimates is the most useful index. Thus, there is no particular attempt to arrive at unanimity among the respondents. A spread of opinions on the final round is the normal outcome. This is a further device to reduce group pressure toward conformity.

Brown[61] points out that the Delphi technique eliminates committee activity altogether, thus further reducing the influence of certain psychological factors, such as specious persuasion, the unwillingness to abandon publicly expressed opinions, and the bandwagon effect of majority opinion. This technique replaces direct debate by a carefully designed program of sequential individual interrogations interspersed with information and opinion feedback derived by computed consensus from the earlier parts of the program. Some of the questions directed to the respondents may, for instance, inquire into the reasons for previously expressed opinions and a collection of such reasons may then be presented to each respondent in the group, together with an invitation to reconsider and possibly revise his earlier estimates. Both the inquiry into the reasons and subsequent feedback of the reasons adduced by others may serve to stimulate the experts into taking into due account considerations they might, through inadvertence, have neglected, and to give due weight to factors they were inclined to dismiss as unimportant on first thought.

The Delphi process is representative of an important class of techniques that need to be developed for further applications to decision-making situations. The remainder of this chapter is devoted to the application of the Delphi technique to the decision-making situations involved in the assessment of environmental impact.

Selection of a Delphi Panel

The first step in the application of the Delphi method is the selection of a group of experts. The selection of experts is an intricate problem even when the category of expertise needed is well defined. A man's expertness might be judged by any of the following criteria: status among peers; years of professional experience; self-appraisal of relative competence in different areas of inquiry; amount of relevant information to which he has access; or some combination of objective indices and prior judgment factors. The assessment of environmental impact should utilize an interdisciplinary approach, thus requiring inputs from many disciplines; for example: engineers, biologists, sociologists, planners, historians, archeologists, and economists.

Within the federal government is a large group of environmental experts who may be used to purvey information, predictions, and analyses to aid the formation of policy and making decisions. The environmental advice community is a highly miscellaneous assortment of in-house advisors, and external consultants from academia, industries, nonprofit corporations, and any other walk of life that appears relevant to the problem of environmental impact assessment.

The question of how to select a group of experts will be left to the discretion of the individual responsible for the assessment. However, it is strongly recommended that the panel of experts come from outside of the agency responsible for preparing the assessment. If a group of experts is scientifically selected from beyond the influence of the preparing agency, it is believed that the public will be less likely to suspect agency bias in the assessment. This point particularily applies to areas around which there is considerable controversy.

The group of experts should be qualified in the particular area that they are to be involved with in the assessment. For example, a limnologist would probably not be asked to estimate the effect of a project on national economic development. It will, therefore, be necessary to select different panels of experts for the different areas in the assessment to be investigated. Generally, three major areas are evident. These three areas deal with the appraisal of economic, social, and environmental impacts. These three major categories may be further subdivided into components. An example of subdivisions of the three categories follows.

Economic Parameters:
1) National Economic Development
2) Local Government Finance
3) Land Use
4) Local/Regional Activity
5) Real Income Distribution
6) Employment/Labor Force
7) Business and Industrial Activity
8) Agricultural Activity
9) National Defense

Social Parameters:
1) Esthetic Values
2) Displacement of People
3) Noise
4) Life Patterns
5) Mood/Atmosphere
6) Cultures
7) Historical Values
8) Educational/Scientific Values

Environmental Parameters:
1) Man-Made and Natural Resources
2) Water Pollution
3) Air Pollution
4) Land Pollution
5) Species and Populations
6) Habitats and Communities
7) Ecosystems
8) Physical and Hydrologic Aspects

The above list is an example of environmental categories subdivided into environmental components. It is not meant to be either complete or limiting. These general areas may be further subdivided as the individual project demands. Measurable environmental parameters are then grouped within each environmental component.

The next concern would be the number of experts to be included on the Delphi panel.

Studies[2] have shown that, when employing a group to arrive at a decision, the average group error decreases with an increase in the number of individuals within the group. Figure 1 shows the dependence on group size of the mean accuracy of a group response for a large set of experimentally derived answers to factual questions. The curve was derived by computing the average error of groups of various sizes where the individual answers were drawn from the experimental distribution. It is clear from figure 1 that with this population of answers, the gains in increasing group size are quite large.

Another important consideration, in respect to the number of experts to be selected, has to do with reliability. The most uncomfortable aspect of opinion for the decision-maker is that experts with apparently equivalent credentials are likely to give quite different answers to the same question. One of the major advantages of using a group response is that this diversity is replaced by a single representative opinion. In general, one would expect that in the area of opinion, group responses would be more reliable than individual opinions. This similarity can be measured by the correlation between the answers of the two groups over a set of questions.

For the analyst using expert opinion within a study, reliability can be considered to play somewhat the same role

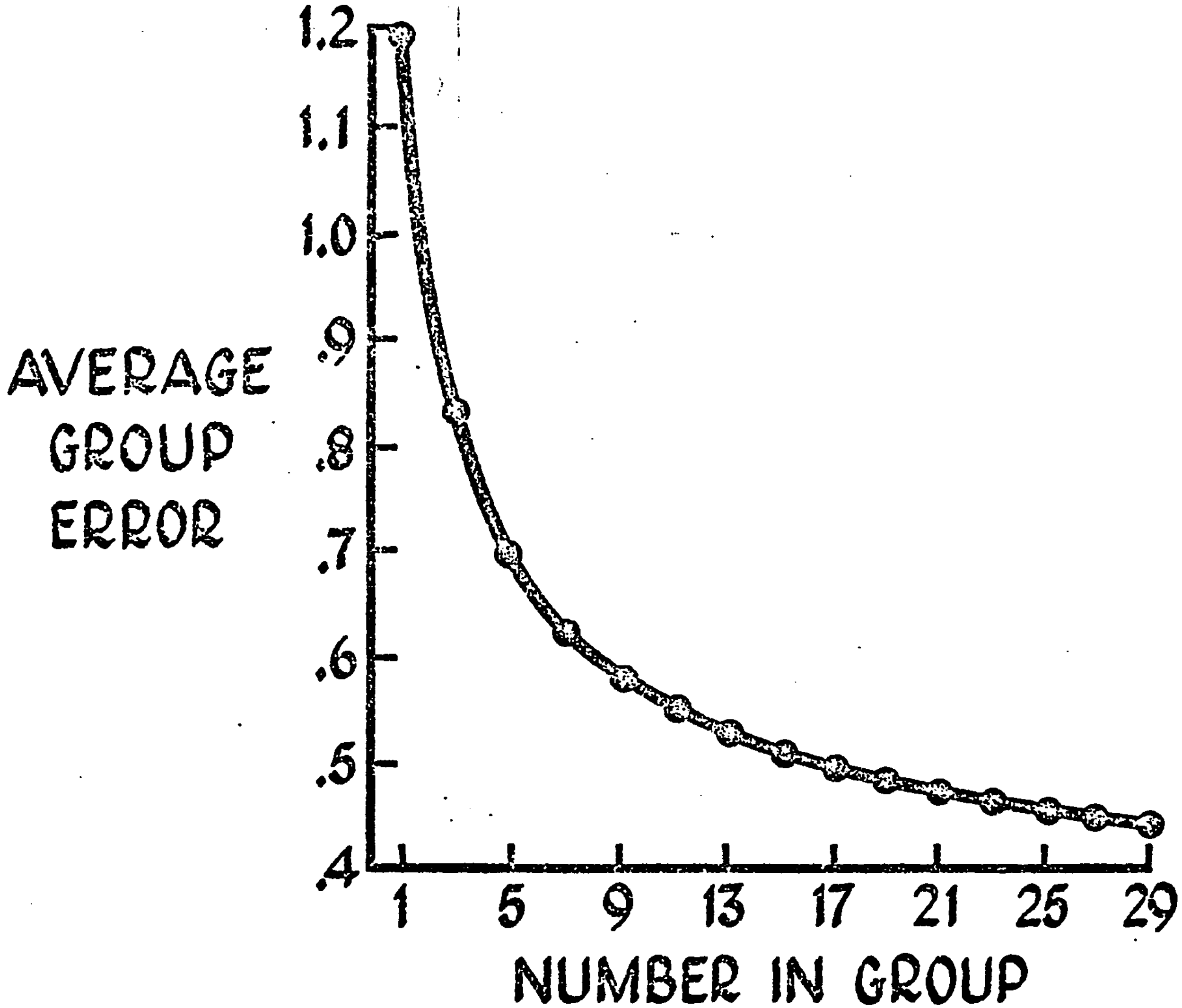


Figure 1. Effect of Group Size

as reproducibility in experimental investigations. It is clearly desirable that a study performed by another analyst, using the same approach, arrive at similar results.

Figure 2 shows the relationship between reliability and group size. It was constructed by selecting, at random, pairs of groups of respondents of various sizes and correlating the median responses of the pairs. The ordinate is the average of these correlations. It is clear that there is a definite and monotonic increase in the reliability of the group responses with increasing group size.[2]

It is noted that the use of the pooling of minds technique appears to be justified by considerations of both improved average accuracy and reliability. Techniques, such as the Delphi, which allow more direct pooling of information on the part of the group, are formulated to improve upon these quasi-statistical properties of group opinion. Therefore, average accuracy and reliability are expected to increase when the Delphi technique is employed.

The minimal recommended number of panel members for a Delphi appraisal is five, with no limit on the maximum.[2] Delphi procedures have been reported to improve group response when employing as few as three in the group.[56] It is critical that the qualifications of each expert and the number of experts enlisted to perform the environmental assessment be stipulated in the report.

Considerable public debate associated with opinion type information has been experienced with environmental im-

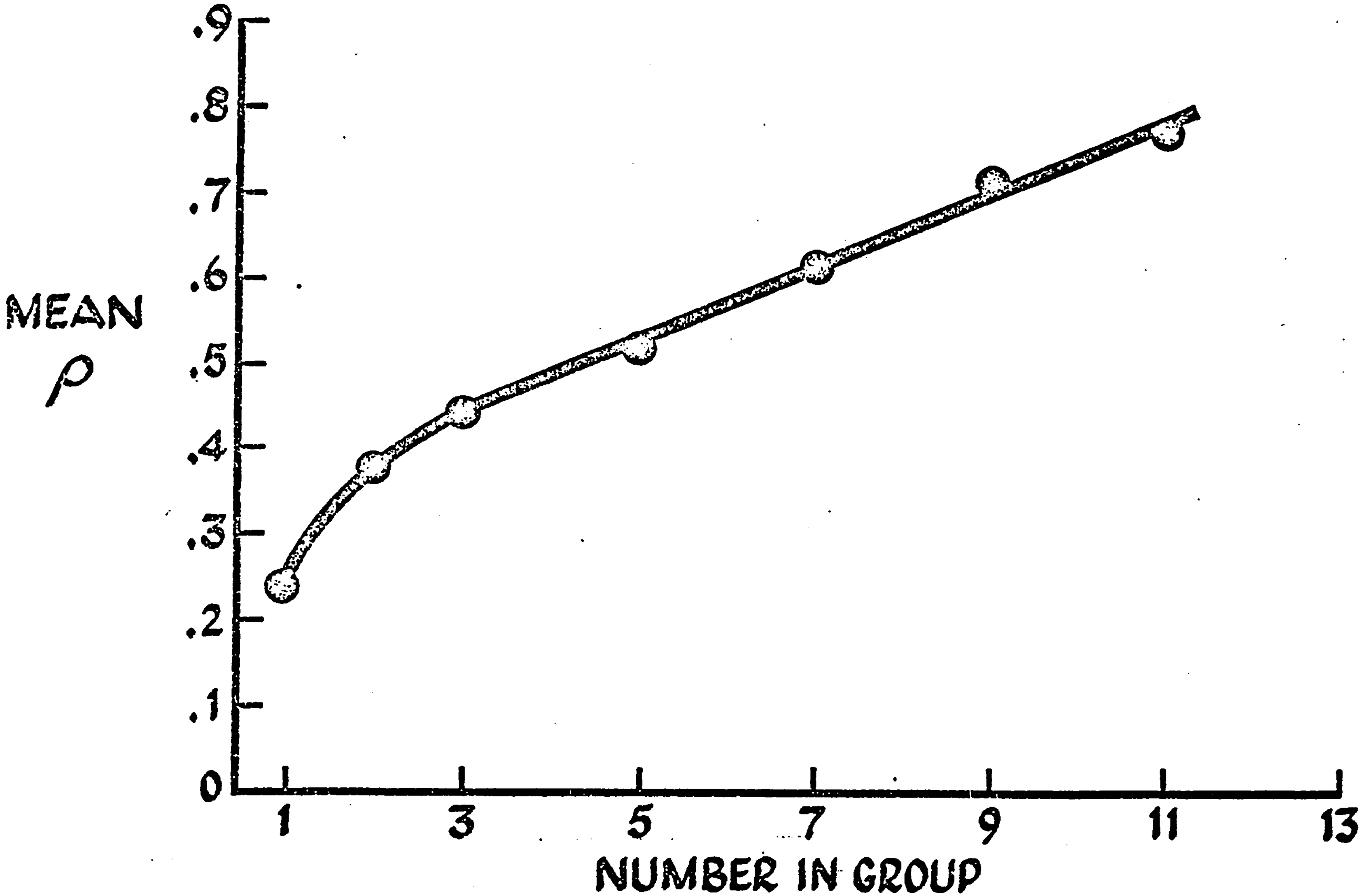


Figure 2. Reliability vs. Group Size

pact reports. If care is taken in the selection of a representative panel of experts, opinion induced debate will be reduced.

In order to compare the results of value judgments of the Battelle research team with value judgments of the regionally selected Delphi panel, it was necessary to limit the investigated environmental parameters to those employed within the Battelle EES. The EES water pollution parameters (see table 1) were selected for use in this study because:

1) The 14 water pollution parameters comprise 31.8 per cent of the total weight assigned to all of the 78 parameters within the EES;
2) Of the 78 parameters employed within the EES the 14 water pollution parameters rank first through twelfth, fifteenth, and sixteenth in terms of relative importance;
3) Of all the environmental components used in the EES, parameters for environmental water pollution are the most well developed because they have had the greatest past use;
4) The water pollution parameters are relatively easy to measure or estimate, and have a broad base of available information;
5) A broad base of scientists with expertise in water pollution exists in the central Oklahoma area;
6) By limiting the parameters to the 14 concerned with

Table 1. Fourteen EES Water Pollution Parameters

1. Basin Hydrologic Loss
2. Biochemical Oxygen Demand
3. Dissolved Oxygen
4. Fecal Coliforms
5. Total Inorganic Carbon
6. Total Inorganic Nitrogen
7. Inorganic Phosphate
8. Pesticides
9. Hydrogen Ion Concentration
10. Stream Flow Variation
11. Temperature
12. Total Dissolved Solids
13. Toxic Substances
14. Turbidity

water pollution we may rule out the possibility of gathering false information due to over extension of areas of expertise.

Two Delphi panels of nine members each were selected from the water pollution advice community of the central Oklahoma area. The size of each group was set at nine based upon the dependence of group size on the mean accuracy and the dependence of group size on reproducibility. When working with scientific parameters such as those that were dealt with in this study, a group of seven to ten individuals should be sufficient based upon Delphi requirements. However, when working with parameters involving social values it is felt that the group size will need to be expanded in order to include the full range of regional opinion.

The central Oklahoma advice community, with respect to water pollution parameters, was broken down into three general categories. These three categories encompassed experts from: 1) the academic community; 2) governmental enforcement agencies; and 3) the professional consulting or professional industrial community. Each of the two Delphi groups contained four members from the academic community, three members from governmental enforcement agencies, and two members from the professional division. The number of members representing each of the three general areas of thought was established based upon the relative involvement of that particular area in environmental impact assessment at the present time. Academic experts were drawn from the Environmental Science, Zoology, and Botany departments of the University of Oklahoma. Experts from the governmental enforcement area were selected from the State of Oklahoma Water Quality and Pollution Control agencies. Professional environmentalists were selected from private and industrial environmental consultants within Oklahoma City.

Each participant selected was matched with another participant based upon the area from which he represented (academic, enforcement, or professional), educational background and field, and years of professional experience. The resulting nine pairs of experts were then randomly assigned to one of two groups. One member of the matched pair was randomly assigned either to group one or group two and the other member was assigned to the remaining group. A summary of the experts selected and assigned to each of the two Delphi estimating groups is presented in table 2.

Two Delphi estimating groups were employed in order to obtain an idea of the reproducibility of the Delphi method when applied to environmental impact assessment. Responses of the two groups were tested in order to determine whether the members of the two groups were statistically from the same or different populations. The results of the statistical analysis are reported in the following chapter.

Nine members were also assigned to each group so that the median value could be employed as the best estimate of

Table 2. Composition of the Delphi Estimating Groups

General Area	Field	Educational Level (Degree)	Professional Experience (Years)
GROUP I:			
Academic	Env. Health Engineering	Ph.D.	16
Academic	Aquatic Ecology	Ph.D.	10
Academic	Botany	Ph.D.	7
Academic	Water Chemistry	Ph.D.	14
Enforcement	Civil Engineering	Ph.D.	5
Enforcement	Env. Science	M.S.	2
Enforcement	Sanitary Engineering	M.C.E.	20
Professional	Env. Science	Ph.D.	10
GROUP II:			
Academic	Env. Health Engineering	Ph.D.	10
Academic	Aquatic Microbiology	Ph.D.	11
Academic	Biology	Ph.D.	4
Academic	Civil Engineering	Ph.D.	14
Enforcement	Env. Science	M.S.	6
Enforcement	Env. Science	M.S.	5
Enforcement	Env. Health	Dr.P.H.	6
Professional	Env. Management	M.S.	5

the group opinion. After the Delphic procedures had begun to refine each groups' value estimates, one member of each group reported that he was unable to fully participate in the study and thus each group was reduced to eight members. Fortunately, the two respondents that were unable to fully participate were from the same matched pair representing experts from the professional advice community. The reduction of one member from each of the groups, therefore, did not effect the relationship between the two groups. Due to the reduction of group size to eight, the mean of the two central estimates was employed to replace the median as the best estimate of the group opinion.

Weighting of Parameters

Following the selection of the two panels of experts, work began toward the assessment of environmental impact. In order to insure that the value determinations involved in the assessment were responsive to the particular project, each member of the two Delphi estimating groups was supplied with a brief summary describing the nature of the project (see Appendix A). Basically, this information contained a review of the general project location and setting; purpose of the project; engineering considerations; and the without project measurement of selected parameters. Respondents were also directed to request additional information that they believed necessary in order to adequately assess water pollution effects of the particular project. Based upon this general information the Delphi groups were able to establish regional value judgments on a project-by-project basis. This project summary was the basis from which the panels arrived at weighting and scaling values for the parameters in which they were believed to have a high degree of expert value judgment. A summary of this nature should always be included in the draft environmental impact statement so that reviewers may see the basis from which certain parameter weights were established.

After reading the summary discussing the nature of the Aubrey Reservoir project, the duty of the Delphi panels was the weighting or quantification of parameters. For each parameter, the group members were individually directed, through a questionnaire, to assign a numerical value. This numerical value was to reflect what they believed was representative of the emphasis, or degree of consideration a given parameter should be awarded, relative to the other water pollution parameters for the Aubrey project. Parameter weighting values, therefore, reflected the relative importance of the parameters, as indicators of the degree to which the project may disturb or enhance the dynamic stability of man's relationship with the environment.

Respondents were directed to estimate numerical weighting values, representing the emphasis given each parameter, based on a scale ranging from 0.0 through 3.0, where:

0.0 — parameter of little or no importance;
1.0 — parameter of minor importance;
2.0 — parameter of moderate importance;
3.0 — parameter of major importance.

Parameter weighting estimates were expressed to one decimal place.

To allow for all value judgments employed in the Battelle EES, the Delphi panel members were required to estimate spatial and temporal weighting considerations.

Spatial weighting considerations involved weighting estimates for the upstream, at site, and downstream location for each parameter. Respondents were initially directed to estimate weighting values for the at site location for each parameter relative to the other thirteen water pollution parameters under consideration. After having done this, respondents were asked to make estimates, ranging from 0.0 to 3.0, for the upstream and downstream locations relative to the at site location value assigned for that particular parameter. Selection of the extent of the area to be included in each of these three spatial sectors was left to the discretion of the individual respondent. The respondents were informed that the extent of the three locations should include all areas that may be affected by the proposed project. These sectors are meant to be only a framework for including the spatial considerations in the EES.

In the evaluation of the with project environment, it is important to recognize the different impacts on the environment during each of the two time periods. Battelle recommended the use of construction (short-term) and operation (long-term) time frames in the use of the EES to evaluate the with project conditions. Commensurate with the EES, respondents were asked to estimate the ratio of anticipated operation:construction effects on the environment resulting from the Aubrey project for each of the 14 water pollution parameters. The respondents were given the information that the construction phase was estimated to last five years and that the operation or use phase was to be considered to extend as far into the future as they felt environmental effects could be projected.

In the first Delphi questionnaire, all respondents were asked to record estimates of the importance of each parameter with spatial and temporal considerations. The information from these groups of responses that furnished feedback data for the second interrogation were the limits of the interquartile ranges (i.e., the middle 50 per cent of each estimate).

In the second round, respondents were asked to reconsider their first round estimates in light of the additional information presented in the form of the interquartile range of the first round. Respondents were directed to make second round estimates that either fell within the first round interquartile limits or, if they believed that the value lay outside of the interquartile limits of the first round, to make an estimate that fell outside of those limits. However, if the respondent made a second round estimate that fell outside of the first round interquartile range, he was charged with the duty of giving reasons and stating in writing what factors were considered in defense of his deviationist opinion. The defense of the deviationist opinion was then presented to the other members of the estimating group in subsequent rounds and was the individuals' opportunity to influence the group toward his opinion.

In the third round questionnaire, the interquartile range of the previous round for the three spatial and two temporal conditions for every parameter was given along with a summary of reasons for deviationist opinions. Participants were directed to either comply with the interquartile range of the second round or to make a deviationist opinion. Again, if a deviationist opinion was offered, the respondent was required to defend it in writing. Also, respondents were directed that if they found serious fault with the rationale behind second round deviationist opinions, they could offer a written critique of the reasons offered by members of the group, to specify which arguments were found to be unconvincing, and why they believed them to be unconvincing. This critique was then provided to each member of the group as additional information in the next round.

In the fourth round, the interquartile range of the previous round was again used as numerical feedback. The counter-arguments against reasons for high and low estimates were summarized. Majority and minority opinions on the projections for each parameter were described and respondents were then asked to reconsider the pros and cons presented and give final, possibly revised, estimates of weighting values for each parameter.

The mean of the central two values of these final responses was then taken to represent the group response indicating the importance of each parameter toward the assessment of the environmental impact of the Aubrey Reservoir project.

Scaling of Parameters

Following the weighting process, the group of experts must arrive at scale values for the parameters under study. Scale values are used so that the properties of the environment, not commonly measured in commensurate units, may be transformed into common units for all parameters. This technique is based on the transformation of parameter measurements onto an environmental quality scale.

At the present time, analysis of water resources projects with respect to their impact on environmental quality is based almost entirely on standards for physical/chemical aspects of the environment. In many cases these standards are represented as the upper limits or maximum ranges as measured by selected parameters that will be acceptable to maintain the desired quality. The use of standards is important in administering and enforcing a desired policy but it is possible to improve on this approach for the planning and evaluation of environmental impact. Essentially, environmental quality is not confined to a bad or good scale, but includes a range of values between these two extremes.[3]

Within the EES a parameter measurement is transformed into environmental quality through the use of a value function. The value function relates the various levels of parameter measurement to the appropriate levels of environmental quality. The EES value functions for the water pollution parameters are shown in Appendix D.

Members of the Delphi panels were asked to establish ranges of parameter measure for each of four levels of environmental quality scale for each parameter under consideration. The four levels of environmental quality employed in this study were defined as excellent, good, fair, and poor environmental quality. The respondents were instructed to interpret the environmental quality levels where excellent denoted the range of extremely good environmental quality and poor denoted the range of extremely bad environmental quality. Good and fair levels of environmental quality were taken as intermediate levels between the two extremes. By defining environmental quality in this manner and establishing Battelle-like value functions for each parameter via Delphic procedures, it was possible to account for any change in a parameter that improved or degraded the environment.

An additional benefit of this approach was the resulting common base. Since all parameters were related to environmental quality, it was possible to compare different parameters on a common base. This transformation of parameters into a common range was necessary in order to be able to express environmental impacts in commensurate units.

The purpose of the scaling of parameters section of this study was to employ Delphic procedures to refine group estimates relating measureable units for each parameter into four environmental quality levels, and then to derive a value function graph for each parameter based upon the refined estimates.

In the first round of Delphi refinement the respondents were directed to establish upper and lower limits of parameter measurements for each of the four levels of environmental quality. The unit of parameter measurements that were employed were the same as those used in the EES. Respondents were advised that multiple ranges could exist for particular parameters. For example, as the unit of measure for a particular parameter increased from zero, the environmental quality may improve from poor to excellent at a certain level, but after a certain level, increasing the units may cause the environmental quality to degrade back down to poor. In this case ranges of poor, fair, and good environmental quality may exist on both the high and low limits of excellent environmental quality. In this instance the resulting value function may resemble something of a bell-shaped curve.

The same Delphi procedures were followed for refinement of scaling estimates as those outlined for estimating weighting values.

Each respondent was asked, via questionnaire, to estimate ranges of parameter units for each of four levels of environmental quality. In a follow-up questionnaire a summary of the distribution of responses, previously obtained, was fed back to the respondents by stating, as an indication of the spread of opinions, the interquartile range. Each respondent was then asked to reconsider his previous answer, possibly revise it, and, if his new response lay outside the interquartile range of the previous round, to state briefly why he thought the value should be much lower or that much higher than the majority opinion. The effect of placing the responsibility of justifying relatively extreme responses on the respondents had the effect of causing those without strong convictions to move their estimates closer to the middle, while those who felt they had a good argument for a deviationist opinion tended to retain and defend their original estimate.

In the third round, in addition to again summarizing the previous responses, which are now spread over a smaller interval, the respondents were given a concise summary of reasons presented in support of extreme positions. They were then asked to revise their second round responses, taking the proffered reasons into consideration and giving them whatever value they thought was justified. In this case, a respondent whose answer still remained outside the new interquartile range was required to state why he was unconvinced by opposing arguments.

In the fourth and final round, criticisms of the reasons previously offered were resubmitted to the respondents, and they were given one last chance to revise their estimates in view of counter-arguments. The mean of the middle two responses was taken to represent the nearest thing to a group consensus.

Following the Delphic refinement of group opinions for weighting and scaling estimates, information was aggregated and Battelle procedures were applied in order to analyze results of the procedures described herein. Results of this aggregation of information is discussed in the following chapter.

CHAPTER V

RESULTS AND DISCUSSION

Results of Statistical Analysis

The method by which the two estimating groups were selected was designed to insure that the individual group responses were representative of the same population. To confirm that this assumption was valid a statistical analysis was performed on the first and fourth rounds of group I and group II responses. The statistical test that was run on this data was the sign test.

The sign test is a nonparametric statistical method. Parametric hypotheses are those concerned with the population parameters. Nonparametric hypotheses do not involve the population but are concerned with the form of the population frequency distribution.[63] A hypothesis that the distributions for two populations are identical would be nonparametric.

Nonparametric statistical procedures apply not only to data that are difficult to quantify but also to situations where serious doubt exists about the assumptions underlying standard methodology. Nonparametric tests require no knowledge of, or assumptions about, the specific distribution being investigated. These tests are, therefore, also referred to as distribution-free tests. No knowledge of the form of the distribution, or of means, standard deviations, or other statistical measures associated with the variable being studied, is required. Nonparametric tests, therefore, are not dependent upon:

1) Normality;
2) Constancy of variance;
3) Independence.

Nonparametric procedures have been employed in this study to test the hypothesis that the distributions for two populations group I and group II are identical. Since measurements have been made on a 0.0 to 3.0 weighting scale, an open ratio scale, and varying units of parameter measurement, a lack of constancy of variance dictates that nonparametric methods be employed.

The sign test is useful whenever the experiment in question can be construed as a series of events with a binomial distribution. Each pair of responses is compared and y (the number of times A exceeds B) is used as the test statistic. This nonparametric test is known as the sign test because y is the number of positive (or negative) signs associated with the differences. A tie, or zero difference between A and B, is excluded from the analysis, thus effectively reducing the sample size.

The implied null hypothesis is that the two population distributions are identical and the resulting technique is completely independent of the form of the distribution of differences. Regardless of the distribution of differences, the probability that A exceeds B for a given pair will be p = 0.5 when the null hypothesis is true (the distribution for A and B are identical). Then y will possess a binomial probability distribution and a rejection region for y can be obtained using the binomial probability distribution.[63]

In this study the sign test was employed to test the distributions of the median values of group I and group II for the first and fourth rounds of estimates. The null hypothesis was that each difference between median values of group I and group II has a probability distribution with median 0. This null hypothesis will be true, for instance, if each difference is symmetrically distributed about a mean of zero. The null hypothesis would be rejected if the numbers of positive and negative signs differ significantly from equality. Critical regions for various levels of significance and percentiles for the sampling distribution were provided in tables developed by Dixon and Massey.[64] First and fourth round median values and sign differences between these values are included in tables 12 and 13 (Appendix C).

The sign test was run on the first and fourth rounds at 1, 5, 10 and 25 per cent levels of significance. The significance level refers to the probability of committing a type I error; rejection of a hypothesis that is actually true.

Results of the sign tests showed acceptance of the null hypothesis for both rounds at the 1, 5, 10, and 25 per cent levels of significance. The sign test, therefore, did not detect a difference in the two population distributions of group I and group II for the first and fourth round responses at the 25 per cent significance level.

Results of the sign tests together with the method by which the two groups were chosen lead to the conclusion that the two groups should not arrive at widely dissimilar final estimates. The degree of variation between final group assessment results may be interpreted as an indication of the reliability of the Delphi method for refinement of environmental value judgments.

Weighting Results

Two regional estimating groups were selected to establish weighting values for fourteen water pollution parameters. Each group was composed of eight experts in the field of water pollution. The method of group selection, the fourteen investigated parameters, and the Delphi method of refinement of group opinion have been discussed in the previous chapter of this report. In this section, results of the weighting process are presented.

Group I Weighting Results

In table 3 the group I interquartile ranges for the four rounds of weighting estimates are reported. It was noted

Table 3. Group I Interquartile Ranges and Final Delphi Weighting Estimates

SPATIAL WEIGHTING ESTIMATES

Parameter	First Round	Second Round	Third Round	Fourth Round	Delphi Group I Estimate
Basin Hydrologic Loss:					
Upstream	0.0-1.0	0.0-0.5	0.4-0.5	0.5-0.5	0.5
At Site	1.5-2.0	1.8-2.0	1.9-2.0	2.0-2.0	2.0
Downstream	1.0-2.0	1.0-2.0	1.5-2.0	1.5-2.0	1.7
Total					4.2
Biochemical Oxygen Demand:					
Upstream	1.0-3.0	1.0-2.5	1.0-2.3	1.3-2.3	1.8
At Site	2.0-2.5	2.0-2.5	2.3-2.5	2.5-2.5	2.5
Downstream	2.0-2.8	2.0-2.5	2.0-2.5	2.0-2.5	2.0
Total					6.3
Dissolved Oxygen:					
Upstream	2.0-2.5	2.0-2.5	2.0-2.5	2.0-2.5	2.5
At Site	2.5-3.0	2.8-3.0	2.8-3.0	2.9-3.0	3.0
Downstream	2.0-3.0	2.0-3.0	2.0-2.5	2.0-2.5	2.5
Total					8.0
Fecal Coliforms:					
Upstream	1.5-2.5	2.0-2.5	2.0-2.5	2.5-2.5	2.5
At Site	2.0-2.6	2.5-2.5	2.5-2.5	2.5-2.5	2.5
Downstream	1.5-2.0	1.5-2.0	1.5-2.0	2.0-2.0	2.0
Total					7.0
Total Inorganic Carbon:					
Upstream	1.0-1.5	1.0-1.5	1.0-1.3	1.0-1.3	1.0
At Site	1.0-2.0	1.5-2.0	1.5-2.0	2.0-2.0	2.0
Downstream	1.0-2.0	1.0-2.0	1.0-1.5	1.0-1.5	1.3
Total					4.3
Total Inorganic Nitrogen:					
Upstream	1.0-2.0	1.0-2.0	1.3-1.5	1.4-1.5	1.5
At Site	1.0-2.5	1.5-2.5	2.0-2.5	2.0-2.5	2.4
Downstream	1.0-2.0	1.0-2.0	1.5-2.0	1.8-2.0	2.0
Total					5.9
Inorganic Phosphate:					
Upstream	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.9
At Site	1.5-2.5	2.0-2.5	2.4-2.5	2.4-2.5	2.5
Downstream	1.0-2.0	1.5-2.0	1.5-2.0	2.0-2.0	2.0
Total					6.4

Table 3. (continued)

Parameter	First Round	Second Round	Third Round	Fourth Round	Delphi Group I Estimate
Pesticides:					
Upstream	1.5-3.0	1.5-2.5	2.3-2.5	2.5-2.5	2.5
At Site	1.5-2.8	1.5-2.8	2.5-2.8	2.8-2.8	2.8
Downstream	1.5-2.8	1.5-2.8	2.5-2.8	2.5-2.8	2.8
Total					8.1
Hydrogen Ion Concentration:					
Upstream	0.1-2.0	0.5-1.5	0.5-1.5	0.5-1.5	1.0
At Site	1.0-2.0	1.4-2.0	1.4-1.8	1.5-1.8	1.5
Downstream	1.0-2.0	1.0-1.5	1.0-1.5	1.0-1.5	1.3
Total					3.8
Stream Flow Variation:					
Upstream	1.0-2.0	1.0-2.0	1.5-2.0	2.0-2.0	2.0
At Site	1.0-2.0	1.0-2.0	1.5-2.0	1.5-2.0	2.0
Downstream	2.0-2.5	2.0-2.0	2.0-2.0	2.0-2.0	2.0
Total					6.0
Temperature:					
Upstream	0.5-2.0	0.5-2.0	1.0-1.5	1.5-1.5	1.5
At Site	1.0-2.0	1.5-2.0	1.5-2.0	2.0-2.0	2.0
Downstream	1.0-2.0	1.5-2.0	1.8-2.0	2.0-2.0	2.0
Total					5.5
Total Dissolved Solids:					
Upstream	1.5-2.0	1.5-2.0	1.5-2.0	1.5-2.0	1.6
At Site	1.5-2.0	1.5-2.0	1.8-2.0	1.8-2.0	1.8
Downstream	1.0-2.0	1.5-2.0	1.5-2.0	1.5-2.0	1.9
Total					5.3
Toxic Substances:					
Upstream	1.5-3.0	1.5-3.0	2.5-3.0	2.8-3.0	3.0
At Site	2.0-3.0	2.0-3.0	2.5-3.0	3.0-3.0	3.0
Downstream	1.5-3.0	1.5-3.0	2.5-3.0	2.8-3.0	2.9
Total					8.9
Turbidity:					
Upstream	2.0-2.0	2.0-2.0	2.0-2.0	2.0-2.0	2.0
At Site	1.5-2.5	1.5-2.5	2.3-2.5	2.5-2.5	2.5
Downstream	1.0-2.0	1.0-2.0	1.5-1.8	1.5-1.8	1.7
Total					6.2
TEMPORAL WEIGHTING ESTIMATES					
Basin Hydrologic Loss:	2:1-6:1	5:1-6:1	5:1-6:1	5:1-6:1	5:1

Table 3. (continued)

Parameter	First Round	Second Round	Third Round	Fourth Round	Delphi Group I Estimate
Biochemical Oxygen Demand:	3:1-10:1	3:1-10:1	3:1-5:1	3:1-5:1	3:1
Dissolved Oxygen:	2:1-8:1	2:1-5:1	2:1-3:1	3:1-3:1	3:1
Fecal Coliforms:	1:1-8:1	1:1-6:1	1:1-5:1	1:1-5:1	4:1
Total Inorganic Carbon:	2:1-5:1	3:1-5:1	3:1-5:1	3:1-5:1	4:1
Total Inorganic Nitrogen:	2:1-5:1	5:1-5:1	5:1-5:1	5:1-5:1	5:1
Inorganic Phosphate:	5:1-6:1	5:1-5:1	5:1-5:1	5:1-5:1	5:1
Pesticides:	1:1-8:1	1:1-5:1	1:1-4:1	1:1-4:1	2:1
Hydrogen Ion Concentration:	1:1-5:1	1:1-3:1	2:1-2:1	2:1-2:1	2:1
Stream Flow Variation:	1:1-5:1	1:1-5:1	2:1-5:1	3:1-5:1	5:1
Temperature:	2:1-5:1	2:1-4:1	3:1-4:1	3:1-4:1	3:1
Total Dissolved Solids:	1:1-5:1	1:1-3:1	1:1-2:1	1:1-2:1	2:1
Toxic Substances:	1:1-10:1	1:1-4:1	1:1-3:1	1:1-3:1	3:1
Turbidity:	3:1-5:1	3:1-5:1	4:1-5:1	5:1-5:1	5:1

that for every parameter, spatially and temporally weighted, the interquartile ranges either remained constant or decreased with successive interrogations. The systematic reduction in the limits of the interquartile ranges indicated that the Delphi method was successful in focusing group opinion. The differences between the upper and lower limits of the interquartile ranges served as an indication of the degree of agreement among members of the estimating group.

The median of the fourth round estimates was taken to represent the best estimate of the group opinion. The median value was employed as the best estimate of the group opinion because: 1) one-half of the group believed that the value should be the median value or less; and 2) one-half of the group believed that the value should be the median value or greater. The use of the final round median value as the best approximation of the group opinion was the Delphi method of compromise.

Group II Weighting Results

The Delphi method of arriving at a group opinion functioned smoothly for the resolution of group II weighting values. The interquartile ranges for weighting estimates, indicative of the dispersion of estimates or deviation of opinion, narrowed with each successive interrogation for all parameter estimates with one exception. There was a strong deviationist opinion supporting greater weight to be given to the at site location for the fecal coliform parameter due to the multipurpose use of the proposed lake. This resulted in a jump of the second round interquartile range from 1.0-2.0 to a 2.0-3.0 interquartile range in the third round. It was evident that deviationist opinions not only influenced the dispersion of estimates within the interquartile range, but also, for one parameter estimate, caused a profound alteration in the orientation of the interquartile range. The group II interquartile ranges for four rounds of weighting estimates are reported in table 4.

Table 4. Group II Interquartile Ranges and Final Delphi Weighting Estimates

Parameter	First Round	Second Round	Third Round	Fourth Round	Delphi Group II Estimate
Basin Hydrologic Loss:					
Upstream	0.0-0.5	0.0-0.5	0.1-0.5	0.3-0.5	0.5
At Site	1.5-2.5	1.5-2.0	1.7-2.0	1.7-2.0	1.9
Downstream	0.5-2.5	0.5-2.5	0.7-2.0	0.7-2.0	1.5
Total					3.9
Biochemical Oxygen Demand:					
Upstream	0.5-2.0	0.5-2.0	0.5-2.0	1.0-2.0	1.0
At Site	2.0-2.0	2.0-2.0	2.0-2.0	2.0-2.0	2.0
Downstream	2.0-2.0	2.0-2.0	2.0-2.0	2.0-2.0	2.0
Total					5.0
Dissolved Oxygen:					
Upstream	2.0-2.5	2.0-2.5	2.0-2.0	2.0-2.0	2.0
At Site	2.0-3.0	2.5-3.0	2.5-3.0	2.5-3.0	2.9
Downstream	2.5-3.0	2.7-3.0	2.7-3.0	2.7-3.0	2.8
Total					7.7
Fecal Coliforms:					
Upstream	0.5-2.0	0.5-2.0	1.0-2.0	1.0-2.0	1.7
At Site	1.0-2.0	1.0-2.0	2.0-3.0	2.0-2.5	2.3
Downstream	0.5-2.0	0.5-2.0	1.0-2.0	2.0-2.0	2.0
Total					6.0
Total Inorganic Carbon:					
Upstream	0.2-1.0	0.2-1.0	0.6-1.0	0.6-1.0	1.0
At Site	1.0-2.0	1.0-2.0	1.0-2.0	1.5-2.0	2.0
Downstream	0.8-1.5	1.0-1.5	1.0-1.5	1.0-1.2	1.0
Total					4.0
Total Inorganic Nitrogen:					
Upstream	0.2-2.0	0.2-2.0	0.5-1.0	0.6-1.0	1.9
At Site	1.5-2.0	1.5-2.0	1.5-2.0	1.5-2.0	1.8
Downstream	1.5-2.0	1.5-2.8	1.5-1.5	1.5-1.5	1.5
Total					5.2
Inorganic Phosphate:					
Upstream	0.2-2.0	0.2-2.0	1.0-1.5	1.0-1.5	1.1
At Site	2.0-2.0	2.0-2.0	2.0-2.0	2.0-2.0	2.0
Downstream	1.5-2.0	1.5-2.0	1.5-1.5	1.5-1.5	1.5
Total					4.6

Table 4. (continued)

Parameter	First Round	Second Round	Third Round	Fourth Round	Delphi Group II Estimate
Pesticides:					
Upstream	0.2-2.5	0.2-2.5	1.0-2.5	1.1-2.5	1.5
At Site	1.0-2.5	1.0-2.5	2.5-2.5	2.5-2.5	2.5
Downstream	1.0-2.0	1.0-2.0	1.5-2.0	1.5-2.0	1.9
Total					5.9
Hydrogen Ion Concentration:					
Upstream	0.2-2.0	0.2-2.0	0.5-1.0	0.5-1.0	0.8
At Site	0.5-1.0	0.5-1.0	0.5-1.0	0.8-1.0	1.0
Downstream	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0	1.9
Total					3.7
Stream Flow Variation:					
Upstream	1.0-1.0	1.0-1.0	1.0-1.0	1.0-1.0	1.0
At Site	0.3-1.0	0.3-1.0	0.5-1.0	0.5-1.0	0.8
Downstream	2.0-2.5	2.1-2.5	2.5-2.5	2.5-2.5	2.5
Total					4.3
Temperature:					
Upstream	0.0-1.0	0.2-1.0	0.2-1.0	1.0-1.0	1.0
At Site	0.5-2.0	0.6-2.0	0.9-2.0	2.0-2.0	2.0
Downstream	1.0-2.0	1.0-2.0	1.0-2.0	1.5-2.0	1.5
Total					4.5
Total Dissolved Solids:					
Upstream	0.4-2.0	0.4-2.0	0.5-1.0	0.8-1.0	1.9
At Site	1.5-2.0	1.5-2.0	1.5-1.8	1.5-1.7	1.5
Downstream	1.5-2.0	1.5-2.0	1.5-1.7	1.5-1.5	1.5
Total					4.9
Toxic Substances:					
Upstream	0.5-3.0	0.9-3.0	1.0-3.0	1.5-3.0	2.3
At Site	3.0-3.0	3.0-3.0	3.0-3.0	3.0-3.0	3.0
Downstream	2.0-3.0	2.0-3.0	2.0-3.0	2.0-2.5	2.3
Total					7.6
Turbidity:					
Upstream	1.0-1.0	1.0-1.0	1.0-1.0	1.0-1.0	1.0
At Site	1.0-1.8	1.0-1.5	1.3-1.5	1.4-1.5	1.5
Downstream	1.0-2.0	1.0-1.8	1.0-1.8	1.0-1.8	1.4
Total					3.9
TEMPORAL WEIGHTING ESTIMATES					
Basin Hydrologic Loss:					
	5:1-10:1	10:1-10:1	10:1-10:1	10:1-10:1	10:1

Table 4. (continued)

Parameter	First Round	Second Round	Third Round	Fourth Round	Delphi Group II Estimate
Biochemical Oxygen Demand:	4:1-10:1	4:1-10:1	5:1-10:1	7:1-10:1	10:1
Dissolved Oxygen:	4:1-10:1	4:1-10:1	5:1-10:1	8:1-10:1	10:1
Fecal Coliforms:	5:1-10:1	10:1-10:1	10:1-10:1	10:1-10:1	10:1
Total Inorganic Carbon:	3:1-10:1	3:1-10:1	5:1-10:1	5:1-10:1	6:1
Total Inorganic Nitrogen:	3:1-10:1	3:1-10:1	5:1-10:1	5:1-10:1	6:1
Inorganic Phosphate:	10:1-10:1	10:1-10:1	10:1-10:1	10:1-10:1	10:1
Pesticides:	2:1-10:1	2:1-10:1	6:1-10:1	10:1-10:1	10:1
Hydrogen Ion Concentration:	1:1-3:1	1:1-3:1	2:1-3:1	2:1-3:1	3:1
Stream Flow Variation:	1:5-4:1	1:5-4:1	1:4-2:1	1:1-2:1	2:1
Temperature:	3:1-5:1	4:1-5:1	4:1-5:1	4:1-5:1	5:1
Total Dissolved Solids:	2:1-5:1	2:1-5:1	3:1-5:1	4:1-5:1	5:1
Toxic Substances:	3:1-10:1	3:1-10:1	5:1-10:1	10:1-10:1	10:1
Turbidity:	1:5-4:1	1:5-2:1	1:5-2:1	1:1-2:1	2:1

Combined Groups Weighting Results

Responses of group I and group II have been shown to be representative of the same population. A measure of the applicability and reliability of the Delphi method for environmental assessment was made possible by the use of two estimating groups. The results of the two groups' weighting values were estimates of the opinions of the total population of experts from which the groups were chosen. Each of the groups' estimates was, therefore, a sample of the total population opinion.

In an attempt to further define the regional population values, the two groups were combined and a final round of Delphi refinement of group opinion was undertaken. By increasing the sample size a more accurate estimate of the population opinion was obtained.

In order to obtain combined groups estimates, all participants were supplied with the median values obtained in the group I and group II fourth round. The resulting medians of the combined round of estimation were taken as the best estimates of the combined groups opinions. These median values, therefore, were considered the best estimates of the population opinion. The combined groups interquartile ranges and final weighting estimates are included as table 5.

Table 5. Combined Groups Interquartile Ranges and Final Weighting Estimates

SPATIAL WEIGHTING ESTIMATES

Parameter	Fifth Round	Delphi Combined Groups Estimate
Basin Hydrologic Loss:		
Upstream	0.5-0.5	0.5
At Site	1.9-2.0	2.0
Downstream	1.5-1.7	1.5
Total		4.0
Biochemical Oxygen Demand:		
Upstream	2.0-2.5	1.1
At Site	1.0-1.5	2.0
Downstream	2.0-2.0	2.0
Total		5.1
Dissolved Oxygen:		
Upstream	2.0-2.5	2.0
At Site	2.9-3.0	3.0
Downstream	2.5-2.8	2.5
Total		7.5
Fecal Coliforms:		
Upstream	1.7-2.1	1.7
At Site	2.3-2.5	2.5
Downstream	2.0-2.0	2.0
Total		6.2
Total Inorganic Carbon:		
Upstream	1.0-1.0	1.0
At Site	2.0-2.0	2.0
Downstream	1.0-1.1	1.0
Total		4.0
Total Inorganic Nitrogen:		
Upstream	1.5-1.9	1.5
At Site	1.8-2.0	2.0
Downstream	1.5-1.8	1.7
Total		5.2
Inorganic Phosphate:		
Upstream	1.1-1.9	1.5
At Site	2.0-2.5	2.4
Downstream	1.5-2.0	2.0
Total		5.9

Table 5. (continued)

Parameter	Fifth Round	Delphi Combined Groups Estimate
Pesticides:		
Upstream	1.5-2.5	2.3
At Site	2.5-2.8	2.8
Downstream	2.0-2.5	2.3
Total		7.4
Hydrogen Ion Concentration:		
Upstream	0.8-1.0	1.0
At Site	1.0-1.5	1.4
Downstream	1.4-1.6	1.5
Total		3.9
Stream Flow Variation:		
Upstream	1.0-2.0	1.0
At Site	2.0-2.0	2.0
Downstream	2.0-2.5	2.0
Total		5.0
Temperature:		
Upstream	1.0-1.5	1.0
At Site	2.0-2.0	2.0
Downstream	1.5-2.0	1.6
Total		4.6
Total Dissolved Solids:		
Upstream	1.6-1.9	1.6
At Site	1.5-1.8	1.7
Downstream	1.5-1.9	1.8
Total		5.1
Toxic Substances:		
Upstream	2.3-3.0	3.0
At Site	3.0-3.0	3.0
Downstream	2.5-2.9	2.8
Total		8.8
Turbidity:		
Upstream	1.2-2.0	1.5
At Site	1.9-2.5	2.3
Downstream	1.5-1.7	1.6
Total		5.4
TEMPORAL WEIGHTING ESTIMATES		
Basin Hydrologic Loss:	5:1-10:1	6:1

Table 5. (continued)

Parameter	Fifth Round	Delphi Combined Groups Estimate
Biochemical Oxygen Demand:	5:1-10:1	5:1
Dissolved Oxygen:	5:1-10:1	8:1
Fecal Coliforms:	5:1-10:1	5:1
Total Inorganic Carbon:	5:1-10:1	6:1
Total Inorganic Nitrogen:	5:1-6:1	5:1
Inorganic Phosphate:	5:1-7:1	5:1
Pesticides:	2:1-10:1	5:1
Hydrogen Ion Concentration:	2:1-3:1	3:1
Stream Flow Variation:	5:1-5:1	5:1
Temperature:	5:1-5:1	5:1
Total Dissolved Solids:	4:1-5:1	5:1
Toxic Substances:	5:1-10:1	8:1
Turbidity:	2:1-5:1	4:1

Comparison of Weighting Results

To establish weighting values that were comparable with the Battelle values and which could be employed in the EES approach, a relative weight was established for each parameter. The total weight for each parameter was then proportioned on a percentage basis among the upstream, at site and downstream locations. The median values, reported in tables 3, 4 and 5, for the three spatial locations were summed, thus producing a total parameter importance weight for each parameter. The parameter importance weight (expressed as total in tables 3, 4 and 5) was divided into each of the three spatial mean values. In this manner the percentage or relative importance of each of the three spatial locations was calculated.

Within the EES, 318 parameter importance units were distributed among the fourteen water pollution parameters. The distribution of the 318 parameter importance units was based upon value judgments of the Battelle research team. To establish a common base for comparison of regional group value judgments with Battelle value judgments, the Delphi derived parameter importance weights were expanded to include 318 parameter importance units. This was accomplished by the following process.

1) The fourteen Delphi derived parameter importance weighting values (expressed as total in tables 3, 4 and 5) were summed.

2) Each individual parameter importance weight was divided by the sum of the total parameter importance weights. This produced the relative percentage of the total Delphi weighting values for each parameter.
3) The percentage for each parameter was multiplied times 318 parameter importance units to arrive at a relative weight, expressed in parameter importance units, for each parameter.

As a result of this process a common base of 318 parameter importance units was established. This allowed for a direct comparison between results based upon group I, group II or combined groups value judgments and results based upon Battelle value judgments for the fourteen water pollution parameters.

Within the EES approach the temporal weight was sectioned into short-term (construction) and long-term (operation) phase considerations. Temporal considerations were expressed as a per cent construction and a per cent operation. These two per cent values, when summed, equalled 100 per cent of the temporal weight.

Each regional Delphi group was directed to express temporal weights as a ratio of operation:construction phases. The median of the fourth round ratio estimates was taken as the best estimate of the group opinion. This group value was transformed into a per cent operation and a per cent construction. By this procedure, the temporal weighting values of the Delphi groups were set on a common basis with the Battelle weighting values.

As a result of these procedures a common basis was established so that weighting value judgments of the Delphi groups could be compared with weighting value judgments of the Battelle research team. This basis was necessary in order to perform comparable EES assessments. Separate EES assessments were the tools in which comparisons of the effects of value judgments on final environmental impact were determined. Results of the group I, group II, combined groups and Battelle common basis weighting values are presented in table 6.

Table 6. Group I, Group II, Combined Groups and Battelle Weighting Values

Parameter	Group I Value	Group II Value	Combined Groups Value	Battelle Value
Basin Hydrologic Loss:				
Parameter Importance Units (PIU)	15	17	16	20
Upstream	0.12	0.13	0.12	0.20
At Site	0.48	0.49	0.50	0.60
Downstream	0.40	0.38	0.38	0.20
Operation	0.83	0.91	0.86	0.75
Construction	0.17	0.09	0.14	0.25
Biochemical Oxygen Demand:				
PIU	23	22	21	25
Upstream	0.28	0.20	0.22	0.20
At Site	0.40	0.40	0.39	0.60
Downstream	0.32	0.40	0.39	0.20
Operation	0.75	0.91	0.83	0 75
Construction	0.25	0.09	0.17	0.25
Dissolved Oxygen:				
PIU	30	34	31	31
Upstream	0.31	0.26	0.27	0.20
At Site	0.38	0.38	0.40	0.60
Downstream	0.31	0.36	0.33	0.20
Operation	0.75	0.91	0.89	0.75
Construction	0.25	0.09	0.11	0.25
Fecal Coliforms:				
PIU	26	27	25	18
Upstream	0.36	0.28	0.27	0.20
At Site	0.36	0.39	0.40	0.60
Downstream	0.28	0.33	0.33	0.20
Operation	0.80	0.91	0.83	0.75
Construction	0.20	0.09	0.17	0.25
Total Inorganic Carbon:				
PIU	16	18	16	22
Upstream	0.23	0.25	0.25	0.20
At Site	0.47	0.50	0.50	0.60
Downstream	0.30	0.25	0.25	0.20
Operation	0.80	0.91	0.86	0.75
Construction	0.20	0.09	0.14	0.25

Table 6. (continued)

Parameter	Group I Value	Group II Value	Combined Groups Value	Battelle Value
Total Inorganic Nitrogen:				
PIU	22	23	21	25
Upstream	0.25	0.36	0.29	0.20
At Site	0.41	0.35	0.38	0.60
Downstream	0.34	0.29	0.33	0.20
Operation	0.83	0.86	0.83	0.75
Construction	0.17	0.14	0.17	0.25
Inorganic Phosphate:				
PIU	24	21	24	28
Upstream	0.30	0.24	0.25	0.20
At Site	0.39	0.43	0.41	0.60
Downstream	0.31	0.33	0.34	0.20
Operation	0.83	0.91	0.83	0.75
Construction	0.17	0.09	0.17	0.25
Pesticides:				
PIU	30	26	30	16
Upstream	0.30	0.25	0.31	0.45
At Site	0.35	0.43	0.38	0.45
Downstream	0.35	0.32	0.31	0.10
Operation	0.67	0.91	0.83	0.50
Construction	0.33	0.09	0.17	0.50
Hydrogen Ion Concentration:				
PIU	14	17	16	18
Upstream	0.26	0.22	0.26	0.20
At Site	0.40	0.27	0.36	0.60
Downstream	0.34	0.51	0.38	0.20
Operation	0.67	0.75	0.75	0.75
Construction	0.33	0.25	0.25	0.25
Stream Flow Variation:				
PIU	22	19	20	28
Upstream	0.33	0.23	0.20	0.20
At Site	0.34	0.19	0.40	0.60
Downstream	0.33	0.58	0.40	0.20
Operation	0.83	0.67	0.83	0.75
Construction	0.17	0.33	0.17	0.25

Table 6. (continued)

Parameter	Group I Value	Group II Value	Combined Groups Value	Battelle Value
Temperature:				
PIU	20	20	19	28
Upstream	0.27	0.22	0.22	0.20
At Site	0.37	0.45	0.43	0.60
Downstream	0.36	0.33	0.35	0.20
Operation	0.75	0.83	0.83	0.75
Construction	0.25	0.17	0.17	0.25
Total Dissolved Solids:				
PIU	20	22	21	25
Upstream	0.30	0.38	0.31	0.75
At Site	0.34	0.31	0.34	0.25
Downstream	0.36	0.31	0.35	0.00
Operation	0.67	0.83	0.83	0.40
Construction	0.33	0.17	0.17	0.60
Toxic Substances:				
PIU	33	34	36	14
Upstream	0.34	0.26	0.34	0.20
At Site	0.34	0.38	0.34	0.60
Downstream	0.32	0.36	0.32	0.20
Operation	0.75	0.67	0.89	0.75
Construction	0.25	0.33	0.11	0.25
Turbidity:				
PIU	23	18	22	20
Upstream	0.32	0.26	0.27	0.45
At Site	0.40	0.38	0.43	0.45
Downstream	0.28	0.36	0.30	0.10
Operation	0.83	0.67	0.80	0.80
Construction	0.17	0.33	0.20	0.20

Scaling Results

The purpose of scaling parameters was to establish, for ranges of parameter measurements, an environmental quality level. Within this study, four major levels of environmental quality were employed. By using four levels of environmental quality the measure was not confined to a good or bad rating, but included a range of values between these two extremes. Parameter measurements were converted to a common environmental quality base via value function graphs. The benefit of this approach was the resulting common base. Since all parameters were related to environmental quality, it was possible to compare different parameters. As a result of this transformation of parameters into a common range it was possible to express environmental impacts in commensurate units.

Group I Scaling Results

Delphi respondents were directed to estimate upper and lower limits of parameter measure for four levels of environmental quality. The units in which each parameter was expressed were identical to those employed in the EES. Results of the Delphi refinement of group I scaling values are summarized in table 7.

The Delphi method worked efficiently for the group I estimating group. With each successive interrogation the interquartile ranges either remained constant or decreased. In no instance did an interquartile range increase with increased interrogations.

In order to establish value function graphs, comparative with the EES, the four levels of environmental quality were transformed into a 0.00 to 1.00 scale. Since there were four levels of environmental quality for which estimates were derived: 0.00 to 0.25 was set as the range of poor environmental quality; 0.25 to 0.50 was set as the range of fair environmental quality; 0.50 to 0.75 was set as the range of good environmental quality; and 0.75 to 1.00 was set as the range of excellent environmental quality.

Inspection of the group I estimates (table 7) revealed that the estimates were determined as continuous ranges of parameter measure for the various environmental quality levels. Respondants were not directed to consider the range of parameter measurements for levels of environmental quality to be either discrete or continuous. However, since the environmental quality scale was presented as a continuous function it was natural that the parameter measurement scale would also be assumed to be continuous. As a result, the lower parameter value for one environmental quality level was often the same as the upper parameter value for the next level.

In order to establish value function graphs the following process was employed:

1) The mean of the lower limit value for excellent environmental quality and the upper limit value for good environmental quality was taken as the transition

point from the excellent to the good range of environmental quality. This point was then plotted at the 0.75 level of the value function graph.

2) The mean of the lower limit value for good environmental quality and the upper limit value for fair environmental quality was plotted at the 0.50 level of the value function graph.

3) The mean of the lower limit value for fair environmental quality and the upper limit value for poor environmental quality was plotted at the 0.25 level of the value function graph.

4) The most environmentally excellent parameter measurement was awarded a 1.00 value on the value function graph.

5) The most environmentally poor parameter measurement was assigned a 0.00 value in the graph.

As a result of this procedure five points were established. A smooth curve was drawn through these five points. In this manner a value function graph was constructed for each parameter. The resulting value function graphs for the water pollution parameters were commensurate with those established by the Battelle group. In the instances where multiple environmental quality levels existed the same procedures resulted in the establishment of a value function graph based upon nine points; two points for each of poor, fair, and good environmental quality, and one point for the excellent environmental quality level. The parameter measurement that was the mean of the lower and upper limits of excellent environmental quality was awarded the 1.00 level on the multiple range graphs.

The resultant group I value function graphs were constructed for each parameter and reported in figure 5 (Appendix D). No attempt was made to establish regional scaling estimates for the toxic substances parameter. The Battelle graph for toxic substances was employed throughout because the parameter measurement was expressed on a undetectable-detectable basis. If a toxic substance was undetectable Battelle assigned an environmental quality of 1.00. If a toxic substance was detectable an environmental quality of 0.0 was assigned.

Table 7. Group I Interquartile Ranges and Final Scaling Values for Four Levels of Environmental Quality

Basin Hydrologic Loss: (Ratio = man made losses/annual natural discharge)

Excellent:	0.0 to 0.1-0.2	First Round
	0.0 to 0.1-0.2	Second Round
	0.0 to 0.1-0.2	Third Round
	0.0 to 0.1-0.2	Fourth Round
	0.0 to 0.1	Delphi Group I Value
Good:	0.1-0.2 to 0.2-0.4	First Round
	0.1-0.2 to 0.25-0.4	Second Round
	0.1-0.2 to 0.25-0.4	Third Round
	0.1-0.2 to 0.25-0.3	Fourth Round
	0.1 to 0.3	Delphi Group I Value
Fair:	0.2-0.4 to 0.4-0.6	First Round
	0.26-0.4 to 0.5-0.6	Second Round
	0.26-0.4 to 0.5-0.6	Third Round
	0.25-0.4 to 0.5-0.6	Fourth Round
	0.3 to 0.6	Delphi Group I Value
Poor:	0.5-0.6 to 1.0	First Round
	0.5-0.6 to 1.0	Second Round
	0.5-0.6 to 1.0	Third Round
	0.5-0.6 to 1.0	Fourth Round
	0.6 to 1.0	Delphi Group I Value

<u>Biochemical Oxygen Demand</u>: (mg/l BOD_5 Sluggish Stream)

Excellent:	0 to 3-5	First Round
	0 to 3-4	Second Round
	0 to 3-3	Third Round
	0 to 3-3	Fourth Round
	0 to 3	Delphi Group I Value
Good:	3-5 to 4-20	First Round
	3-5 to 4-15	Second Round
	3-4 to 5-10	Third Round
	3-3 to 5-9	Fourth Round
	3 to 7	Delphi Group I Value
Fair:	4-21 to 5-30	First Round
	4-16 to 5-30	Second Round
	5-10 to 10-20	Third Round
	5-9 to 10-19	Fourth Round
	7 to 13	Delphi Group I Value

Table 7. (continued)

Poor:	5-30 to Max	First Round
	5-30 to Max	Second Round
	10-20 to Max	Third Round
	10-20 to Max	Fourth Round
	13 to Max	Delphi Group I Value

Biochemical Oxygen Demand: (mg/l BOD_5 Swift Stream)

Excellent:	0 to 5-14	First Round
	0 to 6-14	Second Round
	0 to 6-10	Third Round
	0 to 6-6	Fourth Round
	0 to 6	Delphi Group I Value
Good:	5-15 to 8-24	First Round
	6-15 to 10-20	Second Round
	6-10 to 12-20	Third Round
	6-6 to 12-15	Fourth Round
	6 to 12	Delphi Group I Value
Fair:	8-25 to 12-40	First Round
	10-21 to 20-35	Second Round
	12-20 to 20-33	Third Round
	12-15 to 20-25	Fourth Round
	12 to 23	Delphi Group I Value
Poor:	12-40 to Max	First Round
	20-36 to Max	Second Round
	20-33 to Max	Third Round
	20-25 to Max	Fourth Round
	23 to Max	Delphi Group I Value

Dissolved Oxygen: (mg/l D.O.)

Excellent:	Max to 8.0-8.0	First Round
	Max to 8.0-8.0	Second Round
	Max to 8.0-8.0	Third Round
	Max to 8.0-8.0	Fourth Round
	Max to 8.0	Delphi Group I Value
Good:	8.0-7.7 to 7.0-6.0	First Round
	8.0-8.0 to 7.0-6.25	Second Round
	8.0-8.0 to 7.0-6.5	Third Round
	8.0-8.0 to 7.0-7.0	Fourth Round
	8.0 to 7.0	Delphi Group I Value
Fair:	7.0-6.0 to 6.0-4.0	First Round
	7.0-6.0 to 6.0-4.75	Second Round
	7.0-6.5 to 6.0-5.0	Third Round
	7.0-7.0 to 6.0-5.0	Fourth Round
	7.0 to 6.0	Delphi Group I Value

Table 7. (continued)

Poor:	6.0-4.0 to 0.0	First Round
	5.9-4.5 to 0.0	Second Round
	5.9-5.0 to 0.0	Third Round
	6.0-5.9 to 0.0	Fourth Round
	6.0 to 0.0	Delphi Group I Value
Total Inorganic Carbon:	(mg/l as C)	
Poor:	0 to 3-20	First Round
	0 to 5-10	Second Round
	0 to 5-8	Third Round
	0 to 5-6	Fourth Round
	0 to 6	Delphi Group I Value
Fair:	3-20 to 10-30	First Round
	5-10 to 14-20	Second Round
	7-8 to 15-17	Third Round
	5-6 to 15-15	Fourth Round
	6 to 15	Delphi Group I Value
Good:	10-30 to 19-40	First Round
	15-20 to 25-40	Second Round
	15-17 to 30-30	Third Round
	15-15 to 30-30	Fourth Round
	15 to 30	Delphi Group I Value
Excellent:	10-30 to 25-75	First Round
	20-30 to 40-70	Second Round
	30-30 to 50-50	Third Round
	30-30 to 50-50	Fourth Round
	30 to 50	Delphi Group I Value
Good:	25-75 to 50-80	First Round
	50-70 to 60-80	Second Round
	50-55 to 65-70	Third Round
	50-50 to 65-70	Fourth Round
	50 to 67	Delphi Group I Value
Fair:	50-100 to 70-200	First Round
	60-80 to 85-100	Second Round
	65-70 to 85-90	Third Round
	65-70 to 89-90	Fourth Round
	67 to 90	Delphi Group I Value
Poor:	71-200 to Max	First Round
	85-100 to Max	Second Round
	86-90 to Max	Third Round
	90-90 to Max	Fourth Round
	90 to Max	Delphi Group I Value

Table 7. (continued)

Fecal Coliforms: (MPN/100ml)			
Excellent:	0 to 100-1000	First Round	
	0 to 100-250	Second Round	
	0 to 100-100	Third Round	
	0 to 100-100	Fourth Round	
	0 to 100	Delphi Group I Value	
Good:	100-1000 to 1000-2400	First Round	
	100-250 to 1000-2000	Second Round	
	100-101 to 1000-1000	Third Round	
	100-100 to 1000-1000	Fourth Round	
	100 to 1000	Delphi Group I Value	
Fair:	1000-2400 to 3000-10000	First Round	
	1000-2000 to 3000-7000	Second Round	
	1000-1000 to 3000-3000	Third Round	
	1000-1000 to 3000-3000	Fourth Round	
	1000 to 3000	Delphi Group I Value	
Poor:	3000-10000 to Max	First Round	
	3001-7000 to Max	Second Round	
	3000-3001 to Max	Third Round	
	3000-3000 to Max	Fourth Round	
	3000 to Max	Delphi Group I Value	
Total Inorganic Nitrogen: (mg/l as N)			
Poor:	0.00 to 0.05-0.30	First Round	
	0.00 to 0.07-0.30	Second Round	
	0.00 to 0.10-0.20	Third Round	
	0.00 to 0.10-0.19	Fourth Round	
	0.00 to 0.15	Delphi Group I Value	
Fair:	0.05-0.30 to 0.10-0.50	First Round	
	0.07-0.30 to 0.10-0.50	Second Round	
	0.10-0.20 to 0.24-0.50	Third Round	
	0.10-0.20 to 0.30-0.50	Fourth Round	
	0.15 to 0.30	Delphi Group I Value	
Good:	0.10-0.50 to 0.15-1.00	First Round	
	0.11-0.50 to 0.20-1.00	Second Round	
	0.25-0.50 to 0.30-0.70	Third Round	
	0.30-0.50 to 0.40-0.70	Fourth Round	
	0.30 to 0.55	Delphi Group I Value	
Excellent:	0.10-1.00 to 0.50-2.00	First Round	
	0.20-1.00 to 1.00-2.00	Second Round	
	0.40-0.70 to 1.00-1.50	Third Round	
	0.40-0.70 to 1.00-1.20	Fourth Round	
	0.55 to 1.00	Delphi Group I Value	

Table 7. (continued)

Good:	0.50-2.00 to 1.00-4.00	First Round
	1.00-2.00 to 2.00-4.00	Second Round
	1.00-1.50 to 2.00-3.00	Third Round
	1.00-1.20 to 2.00-2.50	Fourth Round
	1.00 to 2.25	Delphi Group I Value
Fair:	1.00-4.00 to 3.00-7.00	First Round
	2.00-4.00 to 4.50-7.00	Second Round
	2.00-3.00 to 4.90-5.00	Third Round
	2.00-2.50 to 5.00-5.00	Fourth Round
	2.25 to 5.00	Delphi Group I Value
Poor:	3.00-7.00 to Max	First Round
	4.50-7.00 to Max	Second Round
	4.90-5.00 to Max	Third Round
	5.00-5.00 to Max	Fourth Round
	5.00 to Max	Delphi Group I Value

Inorganic Phosphate: (ug/l as P)

Poor:	0 to 3-50	First Round
	0 to 5-10	Second Round
	0 to 5-6	Third Round
	0 to 5-5	Fourth Round
	0 to 5	Delphi Group I Value
Fair:	3-50 to 6-60	First Round
	6-10 to 8-20	Second Round
	6-6 to 10-14	Third Round
	5-6 to 10-11	Fourth Round
	5 to 10	Delphi Group I Value
Good:	6-1000 to 9-1500	First Round
	8-20 to 10-50	Second Round
	10-14 to 20-30	Third Round
	10-11 to 20-20	Fourth Round
	10 to 20	Delphi Group I Value
Excellent:	9-100 to 100-2500	First Round
	10-100 to 100-200	Second Round
	20-30 to 100-100	Third Round
	20-20 to 100-100	Fourth Round
	20 to 100	Delphi Group I Value
Good:	100-2500 to 150-3000	First Round
	100-200 to 150-500	Second Round
	100-100 to 150-200	Third Round
	100-100 to 150-150	Fourth Round
	100 to 150	Delphi Group I Value

Table 7. (continued)

Fair:	150-3000 to 270-4000	First Round
	150-500 to 400-800	Second Round
	150-200 to 400-500	Third Round
	150-150 to 400-400	Fourth Round
	150 to 400	Delphi Group I Value
Poor:	270-4000 to Max	First Round
	400-800 to Max	Second Round
	400-500 to Max	Third Round
	400-400 to Max	Fourth Round
	400 to Max	Delphi Group I Value

Pesticides: (Conc. Ratio = concentration/max. permissible conc.)

Excellent:	0.00 to 0.10-0.20	First Round
	0.00 to 0.10-0.15	Second Round
	0.00 to 0.10-0.10	Third Round
	0.00 to 0.10-0.10	Fourth Round
	0.00 to 0.10	Delphi Group I Value
Good:	0.10-0.20 to 0.30-0.40	First Round
	0.10-0.15 to 0.35-0.40	Second Round
	0.10-0.10 to 0.35-0.35	Third Round
	0.10-0.10 to 0.35-0.35	Fourth Round
	0.10 to 0.35	Delphi Group I Value
Fair:	0.40-0.40 to 0.50-0.80	First Round
	0.35-0.40 to 0.50-0.60	Second Round
	0.35-0.35 to 0.50-0.50	Third Round
	0.35-0.35 to 0.50-0.50	Fourth Round
	0.35 to 0.50	Delphi Group I Value
Poor:	0.50-0.80 to Max	First Round
	0.50-0.60 to Max	Second Round
	0.50-0.50 to Max	Third Round
	0.50-0.50 to Max	Fourth Round
	0.50 to Max	Delphi Group I Value

Hydrogen Ion Concentration: (pH units)

Poor:	0.0 to 4.0-6.0	First Round
	0.0 to 5.0-6.0	Second Round
	0.0 to 5.0-5.8	Third Round
	0.0 to 5.0-5.8	Fourth Round
	0.0 to 5.6	Delphi Group I Value

Table 7. (continued)

Fair:	4.0-6.0 to 6.3-6.5	First Round
	5.0-6.0 to 6.4-6.5	Second Round
	5.0-5.8 to 6.5-6.5	Third Round
	5.0-5.8 to 6.5-6.5	Fourth Round
	5.7 to 6.5	Delphi Group I Value
Good:	6.0-7.0 to 6.5-7.4	First Round
	6.5-6.5 to 6.8-7.0	Second Round
	6.5-6.5 to 6.8-7.0	Third Round
	6.5-6.5 to 6.8-7.0	Fourth Round
	6.5 to 6.9	Delphi Group I Value
Excellent:	6.5-7.5 to 7.7-8.3	First Round
	6.5-7.0 to 8.0-8.0	Second Round
	6.8-7.0 to 8.0-8.0	Third Round
	6.8-7.0 to 8.0-8.0	Fourth Round
	6.9 to 8.0	Delphi Group I Value
Good:	8.0-8.1 to 8.3-9.0	First Round
	8.0-8.1 to 8.4-8.5	Second Round
	8.0-8.0 to 8.4-8.4	Third Round
	8.0-8.0 to 8.4-8.4	Fourth Round
	8.0 to 8.4	Delphi Group I Value
Fair:	8.4-9.3 to 8.7-10.0	First Round
	8.4-8.5 to 9.0-9.0	Second Round
	8.4-8.5 to 9.0-9.0	Third Round
	8.4-8.4 to 9.0-9.0	Fourth Round
	8.4 to 9.0	Delphi Group I Value
Poor:	8.8-10.0 to Max	First Round
	9.0-9.0 to Max	Second Round
	9.0-9.0 to Max	Third Round
	9.0-9.0 to Max	Fourth Round
	9.0 to Max	Delphi Group I Value
Turbidity: (Jackson Turbidity Units)		
Excellent:	0 to 5-25	First Round
	0 to 5-25	Second Round
	0 to 5-10	Third Round
	0 to 5-5	Fourth Round
	0 to 5	Delphi Group I Value
Good:	5-25 to 9-50	First Round
	5-25 to 10-30	Second Round
	5-10 to 11-20	Third Round
	5-5 to 11-15	Fourth Round
	5 to 15	Delphi Group I Value

Table 7. (continued)

Fair:	10-50 to 25-100	First Round
	11-30 to 25-100	Second Round
	11-20 to 25-50	Third Round
	12-15 to 25-30	Fourth Round
	15 to 28	Delphi Group I Value
Poor:	25-100 to Max	First Round
	25-100 to Max	Second Round
	26-50 to Max	Third Round
	25-30 to Max	Fourth Round
	28 to Max	Delphi Group I Value
<u>Stream Flow Variation</u>, ≤2:1: (Percent of days)		
Excellent:	100 to 95-75	First Round
	100 to 95-90	Second Round
	100 to 95-90	Third Round
	100 to 95-95	Fourth Round
	100 to 95	Delphi Group I Value
Good:	95-75 to 90-50	First Round
	95-90 to 90-75	Second Round
	95-90 to 87-75	Third Round
	95-94 to 85-75	Fourth Round
	95 to 83	Delphi Group I Value
Fair:	90-50 to 85-25	First Round
	89-70 to 85-40	Second Round
	85-75 to 68-50	Third Round
	85-75 to 65-50	Fourth Round
	83 to 58	Delphi Group I Value
Poor:	85-25 to Min	First Round
	84-40 to Min	Second Round
	68-50 to Min	Third Round
	65-60 to Min	Fourth Round
	58 to Min	Delphi Group I Value
<u>Stream Flow Variation</u>, 2:1-10:1: (Percent of days)		
Excellent:	0.0 to 0.5-3.5	First Round
	0.0 to 0.5-0.3	Second Round
	0.0 to 0.6-1.5	Third Round
	0.0 to 1.0-1.5	Fourth Round
	0.0 to 1.0	Delphi Group I Value
Good:	0.5-3.5 to 3.0-6.0	First Round
	0.6-3.0 to 3.0-5.0	Second Round
	0.6-1.5 to 3.5-4.0	Third Round
	1.0-1.5 to 3.5-4.0	Fourth Round
	1.0 to 3.6	Delphi Group I Value

Table 7. (continued)

Fair:	3.0-8.0 to 4.0-11.0	First Round
	3.1-5.0 to 5.0-8.0	Second Round
	3.5-4.0 to 5.0-6.5	Third Round
	3.5-4.0 to 5.0-5.6	Fourth Round
	3.6 to 5.0	Delphi Group I Value
Poor:	4.0-11.0 to Max	First Round
	5.0-8.0 to Max	Second Round
	5.1-6.5 to Max	Third Round
	5.0-5.6 to Max	Fourth Round
	5.0 to Max	Delphi Group I Value
Stream Flow Variation, 10:1-50:1:		(Percent of days)
Excellent:	0.0 to 0.9-1.5	First Round
	0.0 to 0.9-1.0	Second Round
	0.0 to 0.9-1.0	Third Round
	0.0 to 0.9-1.0	Fourth Round
	0.0 to 1.0	Delphi Group I Value
Good:	0.9-1.5 to 1.0-2.0	First Round
	1.0-1.0 to 1.5-1.9	Second Round
	1.0-1.0 to 1.5-1.5	Third Round
	1.0-1.0 to 1.5-1.5	Fourth Round
	1.0 to 1.5	Delphi Group I Value
Fair:	1.0-2.0 to 2.0-5.0	First Round
	1.5-2.0 to 2.0-4.0	Second Round
	1.5-1.6 to 2.5-3.0	Third Round
	1.5-1.5 to 2.5-3.0	Fourth Round
	1.5 to 2.5	Delphi Group I Value
Poor:	2.0-5.0 to Max	First Round
	2.0-4.0 to Max	Second Round
	2.6-3.0 to Max	Third Round
	2.5-3.0 to Max	Fourth Round
	2.6 to Max	Delphi Group I Value
Temperature:	(Degrees C departure from equilibrium)	
Poor:	-(Max) to -(5.0-4.0)	First Round
	-(Max) to -(5.0-4.0)	Second Round
	-(Max) to -(4.5-4.0)	Third Round
	-(Max) to -(4.0-4.0)	Fourth Round
	-(Max) to -4.0	Delphi Group I Value
Fair:	-(5.0-4.0) to -(4.0-2.0)	First Round
	-(5.0-4.0) to -(3.0-2.0)	Second Round
	-(4.5-4.0) to -(2.5-2.0)	Third Round
	-(4.0-4.0) to -(2.0-2.0)	Fourth Round
	-4.0 to -2.0	Delphi Group I Value

Table 7. (continued)

Good:	-(3.0-2.0) to -(2.0-1.0)	First Round
	-(3.0-2.0) to -(1.5-1.0)	Second Round
	-(2.5-2.0) to -(1.0-1.0)	Third Round
	-(2.0-2.0) to -(1.0-1.0)	Fourth Round
	-2.0 to -1.0	Delphi Group I Value
Excellent	-(2.0-1.0) to +(1.0-2.0)	First Round
	-(1.0-1.0) to +(1.0-1.0)	Second Round
	-(1.0-1.0) to +(1.0-1.0)	Third Round
	-(1.0-1.0) to +(1.0-1.0)	Fourth Round
	-1.0 to +1.0	Delphi Group I Value
Good:	+(1.0-2.0) to +(2.0-3.0)	First Round
	+(1.0-1.5) to +(2.0-2.5)	Second Round
	+(1.0-1.0) to +(2.0-2.0)	Third Round
	+(1.0-1.0) to +(2.0-2.0)	Fourth Round
	+1.0 to +2.0	Delphi Group I Value
Fair:	+(2.0-4.0) to +(4.0-5.0)	First Round
	+(2.0-2.5) to +(4.0-4.0)	Second Round
	+(2.0-2.3) to +(4.0-4.0)	Third Round
	+(2.0-2.0) to +(4.0-4.0)	Fourth Round
	+2.0 to +4.0	Delphi Group I Value
Poor:	+(4.0-5.0) to +(Max)	First Round
	+(4.0-4.1) to +(Max)	Second Round
	+(4.0-4.0) to +(Max)	Third Round
	+(4.0-4.0) to +(Max)	Fourth Round
	+4.0 to +Max	Delphi Group I Value
Total Dissolved Solids:	(mg/l T.D.S.)	
Poor:	0 to 10-33	First Round
	0 to 10-15	Second Round
	0 to 10-14	Third Round
	0 to 10-12	Fourth Round
	0 to 11	Delphi Group I Value
Fair:	10-33 to 15-66	First Round
	10-15 to 20-30	Second Round
	10-15 to 25-29	Third Round
	10-12 to 25-29	Fourth Round
	11 to 25	Delphi Group I Value
Good:	15-66 to 25-100	First Round
	20-30 to 30-50	Second Round
	25-30 to 40-50	Third Round
	25-29 to 40-49	Fourth Round
	25 to 43	Delphi Group I Value

Table 7. (continued)

Excellent:	0-50 to 100-300	First Round
	30-50 to 100-300	Second Round
	40-50 to 150-200	Third Round
	40-49 to 150-150	Fourth Round
	43 to 150	Delphi Group I Value
Good:	100-400 to 200-500	First Round
	100-300 to 300-500	Second Round
	150-201 to 300-400	Third Round
	150-150 to 300-300	Fourth Round
	150 to 300	Delphi Group I Value
Fair:	200-600 to 500-1000	First Round
	300-500 to 500-1000	Second Round
	300-401 to 600-750	Third Round
	300-300 to 600-650	Fourth Round
	300 to 600	Delphi Group I Value
Poor:	500-1000 to Max	First Round
	500-1000 to Max	Second Round
	601-750 to Max	Third Round
	600-650 to Max	Fourth Round
	600 to Max	Delphi Group I Value

Group II Scaling Results

The Delphi method of estimating functioned efficiently for the refinement of scaling estimates for the second regionally based estimating group. As with group I, the interquartile ranges of group II scaling responses decreased with increased interrogations. The median of the fourth round values was employed as the best estimate of the total group II opinion for each parameter. A summary of the results of the Delphi refinement of group II scaling values is reported in table 8.

Value functions were derived for group II values in a fashion identical to that described for group I. Group II scaling value functions are included in Appendix D as figure 6.

Table 8. Group II Interquartile Ranges and Final Scaling Values for Four Levels of Environmental Quality

Basin Hydrologic Loss: (Ratio = man made losses/annual natural discharge)

Excellent:	0.00 to 0.10-0.20	First Round
	0.00 to 0.10-0.18	Second Round
	0.00 to 0.10-0.10	Third Round
	0.00 to 0.10-0.10	Fourth Round
	0.00 to 0.10	Delphi Group II Value
Good:	0.10-0.20 to 0.25-0.40	First Round
	0.10-0.18 to 0.22-0.30	Second Round
	0.10-0.10 to 0.25-0.25	Third Round
	0.10-0.10 to 0.25-0.25	Fourth Round
	0.10 to 0.25	Delphi Group II Value
Fair:	0.22-0.40 to 0.50-0.60	First Round
	0.22-0.31 to 0.50-0.60	Second Round
	0.25-0.25 to 0.50-0.50	Third Round
	0.25-0.25 to 0.50-0.50	Fourth Round
	0.25 to 0.50	Delphi Group II Value
Poor:	0.50-0.60 to 1.00	First Round
	0.50-0.60 to 1.00	Second Round
	0.50-0.50 to 1.00	Third Round
	0.50-0.50 to 1.00	Fourth Round
	0.50 to 1.00	Delphi Group II Value

Biochemical Oxygen Demand: (mg/l BOD_5 Sluggish Stream)

Excellent:	0 to 3-10	First Round
	0 to 4-10	Second Round
	0 to 5-10	Third Round
	0 to 6-10	Fourth Round
	0 to 10	Delphi Group II Value
Good:	4-10 to 8-15	First Round
	4-10 to 8-15	Second Round
	5-10 to 10-20	Third Round
	6-10 to 15-20	Fourth Round
	10 to 19	Delphi Group II Value
Fair:	8-15 to 15-30	First Round
	9-15 to 20-30	Second Round
	10-20 to 20-30	Third Round
	15-20 to 25-30	Fourth Round
	19 to 30	Delphi Group II Value

Table 8. (continued)

Poor:	20-30 to Max	First Round
	20-30 to Max	Second Round
	20-30 to Max	Third Round
	25-30 to Max	Fourth Round
	30 to Max	Delphi Group II Value
Biochemical Oxygen Demand: (mg/l BOD_5 Swift Stream)		
Excellent:	0 to 5-10	First Round
	0 to 6-10	Second Round
	0 to 8-10	Third Round
	0 to 8-10	Fourth Round
	0 to 10	Delphi Group II Value
Good:	6-10 to 10-25	First Round
	6-10 to 11-25	Second Round
	8-10 to 20-25	Third Round
	9-10 to 20-25	Fourth Round
	10 to 24	Delphi Group II Value
Fair:	11-25 to 30-40	First Round
	11-25 to 30-40	Second Round
	20-25 to 30-40	Third Round
	21-25 to 30-40	Fourth Round
	24 to 35	Delphi Group II Value
Poor:	30-40 to Max	First Round
	30-40 to Max	Second Round
	30-40 to Max	Third Round
	31-40 to Max	Fourth Round
	35 to Max	Delphi Group II Value
Dissolved Oxygen: (mg/l D.O.)		
Excellent:	Max to 7.0-6.0	First Round
	Max to 7.0-7.0	Second Round
	Max to 7.0-7.0	Third Round
	Max to 7.0-7.0	Fourth Round
	Max to 7.0	Delphi Group II Value
Good:	7.0-6.0 to 5.0-5.0	First Round
	7.0-7.0 to 5.0-5.0	Second Round
	7.0-7.0 to 5.0-5.0	Third Round
	7.0-7.0 to 5.0-5.0	Fourth Round
	7.0 to 5.0	Delphi Group II Value
Fair:	5.0-5.0 to 4.0-4.0	First Round
	5.0-5.0 to 4.0-4.0	Second Round
	5.0-5.0 to 4.0-4.0	Third Round
	5.0-5.0 to 4.0-4.0	Fourth Round
	5.0 to 4.0	Delphi Group II Value

Table 8. (continued)

Poor:	4.0-4.0 to 0.0	First Round
	4.0-4.0 to 0.0	Second Round
	4.0-4.0 to 0.0	Third Round
	4.0-4.0 to 0.0	Fourth Round
	4.0 to 0.0	Delphi Group II Value
Total Inorganic Carbon: (mg/l T.I.C.)		
Poor:	0 to 3-5	First Round
	0 to 3-5	Second Round
	0 to 4-5	Third Round
	0 to 5-5	Fourth Round
	0 to 5	Delphi Group II Value
Fair:	3-5 to 6-15	First Round
	3-5 to 10-15	Second Round
	4-5 to 12-15	Third Round
	5-5 to 15-15	Fourth Round
	5 to 15	Delphi Group II Value
Good:	6-15 to 10-30	First Round
	10-15 to 20-25	Second Round
	12-15 to 20-25	Third Round
	15-15 to 20-25	Fourth Round
	15 to 25	Delphi Group II Value
Excellent:	10-30 to 30-60	First Round
	20-25 to 40-50	Second Round
	20-25 to 45-50	Third Round
	20-25 to 50-50	Fourth Round
	25 to 50	Delphi Group II Value
Good:	30-60 to 50-100	First Round
	40-50 to 65-100	Second Round
	45-50 to 70-85	Third Round
	50-50 to 70-80	Fourth Round
	50 to 75	Delphi Group II Value
Fair:	50-100 to 100-200	First Round
	65-100 to 100-200	Second Round
	70-85 to 100-150	Third Round
	70-80 to 100-150	Fourth Round
	75 to 133	Delphi Group II Value
Poor:	100-200 to Max	First Round
	100-200 to Max	Second Round
	100-150 to Max	Third Round
	100-150 to Max	Fourth Round
	133 to Max	Delphi Group II Value

Table 8. (continued)

<u>Fecal Coliforms</u>: (MPN/100ml)

Excellent:	0 to 100-200	First Round
	0 to 100-200	Second Round
	0 to 100-150	Third Round
	0 to 100-100	Fourth Round
	0 to 100	Delphi Group II Value
Good:	100-200 to 200-1000	First Round
	100-200 to 200-1000	Second Round
	100-150 to 500-1000	Third Round
	100-100 to 500-1000	Fourth Round
	100 to 625	Delphi Group II Value
Fair:	200-1000 to 1000-5000	First Round
	200-1000 to 1000-5000	Second Round
	500-1000 to 2000-5000	Third Round
	500-1000 to 2000-5000	Fourth Round
	625 to 4500	Delphi Group II Value
Poor:	1000-5000 to Max	First Round
	1000-5000 to Max	Second Round
	1000-5000 to Max	Third Round
	2000-5000 to Max	Fourth Round
	4500 to Max	Delphi Group II Value

<u>Total Inorganic Nitrogen</u>: (mg/l as N)

Poor:	0.00 to 0.03-0.10	First Round
	0.00 to 0.08-0.10	Second Round
	0.00 to 0.10-0.10	Third Round
	0.00 to 0.10-0.10	Fourth Round
	0.00 to 0.10	Delphi Group II Value
Fair:	0.03-0.10 to 0.06-0.30	First Round
	0.08-0.10 to 0.10-0.30	Second Round
	0.10-0.10 to 0.20-0.30	Third Round
	0.10-0.10 to 0.25-0.30	Fourth Round
	0.10 to 0.28	Delphi Group II Value
Good:	0.06-0.30 to 0.10-0.50	First Round
	0.10-0.30 to 0.10-0.40	Second Round
	0.20-0.30 to 0.40-0.40	Third Round
	0.25-0.30 to 0.40-0.40	Fourth Round
	0.28 to 0.40	Delphi Group II Value
Excellent:	0.10-0.50 to 0.50-1.50	First Round
	0.10-0.40 to 0.50-1.50	Second Round
	0.40-0.40 to 0.50-1.50	Third Round
	0.40-0.40 to 1.00-1.00	Fourth Round
	0.40 to 1.00	Delphi Group II Value

Table 8. (continued)

Good:	0.50-1.50 to 2.00-5.00	First Round
	0.50-1.50 to 2.00-5.00	Second Round
	0.50-1.50 to 2.00-3.00	Third Round
	1.00-1.00 to 2.00-3.00	Fourth Round
	1.00 to 2.50	Delphi Group II Value
Fair:	2.00-5.00 to 3.00-10.00	First Round
	2.00-5.00 to 3.00-10.00	Second Round
	2.00-3.00 to 4.00-10.00	Third Round
	2.00-3.00 to 4.00-6.00	Fourth Round
	2.50 to 5.50	Delphi Group II Value
Poor:	3.00-10.00 to Max	First Round
	3.00-10.00 to Max	Second Round
	4.00-10.00 to Max	Third Round
	4.00-6.00 to Max	Fourth Round
	5.50 to Max	Delphi Group II Value
Inorganic Phosphate: (ug/l as P)		
Poor:	0 to 3-10	First Round
	0 to 3-10	Second Round
	0 to 3-10	Third Round
	0 to 5-10	Fourth Round
	0 to 8	Delphi Group II Value
Fair:	3-10 to 6-50	First Round
	3-10 to 10-30	Second Round
	3-10 to 10-30	Third Round
	5-10 to 20-30	Fourth Round
	8 to 20	Delphi Group II Value
Good:	6-50 to 10-100	First Round
	10-30 to 10-50	Second Round
	10-30 to 40-50	Third Round
	20-30 to 40-50	Fourth Round
	20 to 43	Delphi Group II Value
Excellent:	50-100 to 100-200	First Round
	50-50 to 100-100	Second Round
	40-50 to 100-100	Third Round
	40-50 to 100-100	Fourth Round
	43 to 100	Delphi Group II Value
Good:	100-200 to 300-500	First Round
	100-100 to 300-300	Second Round
	100-100 to 300-300	Third Round
	100-100 to 300-300	Fourth Round
	100 to 300	Delphi Group II Value

Table 8. (continued)

Fair:	300-500 to 500-2000	First Round
	300-300 to 500-1500	Second Round
	300-300 to 500-1000	Third Round
	300-300 to 500-1000	Fourth Round
	300 to 850	Delphi Group II Value
Poor:	600-2000 to Max	First Round
	600-1500 to Max	Second Round
	500-1000 to Max	Third Round
	500-1000 to Max	Fourth Round
	850 to Max	Delphi Group II Value
Pesticides: (Conc. Ratio = concentration/max. permissible conc.)		
Excellent:	0.00 to 0.10-0.20	First Round
	0.00 to 0.10-0.10	Second Round
	0.00 to 0.10-0.10	Third Round
	0.00 to 0.10-0.10	Fourth Round
	0.00 to 0.10	Delphi Group II Value
Good:	0.10-0.30 to 0.25-0.50	First Round
	0.10-0.10 to 0.25-0.40	Second Round
	0.10-0.10 to 0.25-0.30	Third Round
	0.10-0.10 to 0.25-0.25	Fourth Round
	0.10 to 0.25	Delphi Group II Value
Fair:	0.10-0.50 to 0.50-0.80	First Round
	0.25-0.40 to 0.50-0.70	Second Round
	0.25-0.30 to 0.50-0.65	Third Round
	0.25-0.25 to 0.50-0.50	Fourth Round
	0.25 to 0.50	Delphi Group II Value
Poor:	0.50-0.80 to Max	First Round
	0.50-0.70 to Max	Second Round
	0.50-0.65 to Max	Third Round
	0.50-0.50 to Max	Fourth Round
	0.50 to Max	Delphi Group II Value
Hydrogen Ion Concentration: (pH units)		
Poor:	0.0 to 5.5-6.0	First Round
	0.0 to 5.5-5.5	Second Round
	0.0 to 5.5-5.5	Third Round
	0.0 to 5.5-5.5	Fourth Round
	0.0 to 5.5	Delphi Group II Value

Table 8. (continued)

Fair:	5.5-6.0 to 6.0-6.5	First Round
	5.5-5.5 to 6.1-6.5	Second Round
	5.5-5.5 to 6.2-6.5	Third Round
	5.5-5.5 to 6.3-6.5	Fourth Round
	5.5 to 6.5	Delphi Group II Value
Good:	6.0-6.5 to 6.5-7.0	First Round
	6.1-6.5 to 6.6-7.0	Second Round
	6.2-6.5 to 6.8-7.0	Third Round
	6.3-6.5 to 7.0-7.0	Fourth Round
	6.5 to 7.0	Delphi Group II Value
Excellent:	6.5-7.0 to 8.0-8.5	First Round
	6.6-7.0 to 8.0-8.5	Second Round
	6.8-7.0 to 8.3-8.5	Third Round
	7.0-7.0 to 8.3-8.5	Fourth Round
	7.0 to 8.5	Delphi Group II Value
Good:	8.0-8.5 to 8.5-9.0	First Round
	8.0-8.5 to 8.5-9.0	Second Round
	8.3-8.5 to 8.5-9.0	Third Round
	8.3-8.5 to 8.9-9.0	Fourth Round
	8.5 to 9.0	Delphi Group II Value
Fair:	8.5-9.0 to 9.0-9.5	First Round
	8.5-9.0 to 9.4-9.5	Second Round
	8.5-9.0 to 9.5-9.5	Third Round
	8.9-9.0 to 9.5-9.5	Fourth Round
	9.0 to 9.5	Delphi Group II Value
Poor:	9.0-9.5 to Max	First Round
	9.4-9.5 to Max	Second Round
	9.5-9.5 to Max	Third Round
	9.5-9.5 to Max	Fourth Round
	9.5 to Max	Delphi Group II Value

Turbidity: (Jackson Turbidity Units)

Excellent:	0 to 15-25	First Round
	0 to 15-25	Second Round
	0 to 15-25	Third Round
	0 to 20-25	Fourth Round
	0 to 25	Delphi Group II Value
Good:	15-25 to 50-100	First Round
	15-25 to 50-100	Second Round
	15-25 to 100-100	Third Round
	20-25 to 100-100	Fourth Round
	25 to 100	Delphi Group II Value

Table 8. (continued)

Fair:	50-100 to 120-200	First Round
	50-100 to 120-200	Second Round
	100-100 to 200-200	Third Round
	100-100 to 200-200	Fourth Round
	100 to 200	Delphi Group II Value
Poor:	120-200 to Max	First Round
	120-200 to Max	Second Round
	200-200 to Max	Third Round
	200-200 to Max	Fourth Round
	200 to Max	Delphi Group II Value
<u>Stream Flow Variation</u>, ≤2:1: (Percent of days)		
Excellent:	100 to 95-95	First Round
	100 to 95-95	Second Round
	100 to 95-95	Third Round
	100 to 95-95	Fourth Round
	100 to 95	Delphi Group II Value
Good:	95-95 to 90-80	First Round
	95-95 to 90-90	Second Round
	95-95 to 90-90	Third Round
	95-95 to 90-90	Fourth Round
	95 to 90	Delphi Group II Value
Fair:	90-80 to 80-50	First Round
	90-90 to 80-80	Second Round
	90-90 to 80-80	Third Round
	90-90 to 80-80	Fourth Round
	90 to 80	Delphi Group II Value
Poor:	80-50 to Min	First Round
	80-80 to Min	Second Round
	80-80 to Min	Third Round
	80-80 to Min	Fourth Round
	80 to Min	Delphi Group II Value
<u>Stream Flow Variation</u>, 2:1-10:1: (Percent of days)		
Excellent:	0.0 to 2.2-5.0	First Round
	0.0 to 3.0-3.0	Second Round
	0.0 to 3.0-3.0	Third Round
	0.0 to 3.0-3.0	Fourth Round
	0.0 to 3.0	Delphi Group II Value
Good:	3.0-5.0 to 5.0-10.0	First Round
	3.0-3.0 to 5.0-6.0	Second Round
	3.0-3.0 to 6.0-6.0	Third Round
	3.0-3.0 to 6.0-6.0	Fourth Round
	3.0 to 6.0	Delphi Group II Value

Table 8. (continued)

Fair:	6.0-10.0 to 8.0-20.0	First Round
	6.0-6.0 to 9.0-15.0	Second Round
	6.0-6.0 to 12.0-15.0	Third Round
	6.0-6.0 to 12.0-12.0	Fourth Round
	6.0 to 12.0	Delphi Group II Value
Poor:	9.0-20.0 to Max	First Round
	9.0-15.0 to Max	Second Round
	12.0-15.0 to Max	Third Round
	12.0-12.0 to Max	Fourth Round
	12.0 to Max	Delphi Group II Value
<u>Stream Flow Variation</u>, 10:1-50:1:	(Percent of days)	
Excellent:	0.0 to 0.0-1.0	First Round
	0.0 to 0.5-1.0	Second Round
	0.0 to 0.6-1.0	Third Round
	0.0 to 0.6-1.0	Fourth Round
	0.0 to 0.7	Delphi Group II Value
Good:	0.0-1.0 to 1.0-2.0	First Round
	0.6-1.0 to 2.0-2.0	Second Round
	0.6-1.0 to 2.0-2.0	Third Round
	0.6-1.0 to 2.0-2.0	Fourth Round
	0.7 to 2.0	Delphi Group II Value
Fair:	1.0-2.0 to 2.0-5.0	First Round
	2.0-2.0 to 4.0-5.0	Second Round
	2.0-2.0 to 4.0-5.0	Third Round
	2.0-2.0 to 4.0-4.0	Fourth Round
	2.0 to 4.0	Delphi Group II Value
Poor:	2.0-5.0 to Max	First Round
	4.0-5.0 to Max	Second Round
	4.0-5.0 to Max	Third Round
	4.0-4.0 to Max	Fourth Round
	4.0 to Max	Delphi Group II Value
<u>Temperature</u>:	(Degrees C departure from equilibrium)	
Poor:	-(Max) to -(8.0-5.0)	First Round
	-(Max) to -(8.0-6.0)	Second Round
	-(Max) to -(8.0-6.0)	Third Round
	-(Max) to -(8.0-6.0)	Fourth Round
	-(Max) to -6.0	Delphi Group II Value
Fair:	-(8.0-5.0) to -(5.0-3.0)	First Round
	-(8.0-6.0) to -(5.0-4.0)	Second Round
	-(8.0-6.0) to -(5.0-4.0)	Third Round
	-(8.0-6.0) to -(5.0-4.0)	Fourth Round
	-6.0 to -4.0	Delphi Group II Value

Table 8. (continued)

Good:	-(5.0-3.0) to -(3.0-1.0)	First Round
	-(5.0-4.0) to -(3.0-2.0)	Second Round
	-(5.0-4.0) to -(3.0-2.0)	Third Round
	-(5.0-4.0) to -(3.0-2.0)	Fourth Round
	-4.0 to -2.0	Delphi Group II Value
Excellent	-(3.0-1.0) to +(1.0-3.0)	First Round
	-(3.0-1.0) to +(1.0-2.0)	Second Round
	-(3.0-2.0) to +(2.0-2.0)	Third Round
	-(3.0-2.0) to +(2.0-2.0)	Fourth Round
	-2.0 to +2.0	Delphi Group II Value
Good:	+(1.0-3.0) to +(3.0-5.0)	First Round
	+(2.0-2.0) to +(3.0-4.0)	Second Round
	+(2.0-2.0) to +(3.5-4.0)	Third Round
	+(2.0-2.0) to +(4.0-4.0)	Fourth Round
	+2.0 to +4.0	Delphi Group II Value
Fair:	+(3.0-5.0) to +(5.0-8.0)	First Round
	+(3.0-4.0) to +(6.0-8.0)	Second Round
	+(3.5-4.0) to +(6.0-7.0)	Third Round
	+(4.0-4.0) to +(6.0-6.0)	Fourth Round
	+4.0 to +6.0	Delphi Group II Value
Poor:	+(5.0-8.0) to +(Max)	First Round
	+(6.0-8.0) to +(Max)	Second Round
	+(6.0-7.0) to +(Max)	Third Round
	+(6.0-6.0) to +(Max)	Fourth Round
	+6.0 to +Max	Delphi Group II Value

Total Dissolved Solids: (mg/l T.D.S.)

Poor:	0 to 50-50	First Round
	0 to 50-50	Second Round
	0 to 50-50	Third Round
	0 to 50-50	Fourth Round
	0 to 50	Delphi Group II Value
Fair:	50-50 to 74-75	First Round
	50-50 to 75-75	Second Round
	50-50 to 75-75	Third Round
	50-50 to 75-75	Fourth Round
	50 to 75	Delphi Group II Value
Good:	75-75 to 99-100	First Round
	75-75 to 100-100	Second Round
	75-75 to 100-100	Third Round
	75-75 to 100-100	Fourth Round
	75 to 100	Delphi Group II Value

Table 8. (continued)

Excellent:	20-100 to 100-400	First Round
	100-100 to 150-300	Second Round
	100-100 to 200-300	Third Round
	100-100 to 200-300	Fourth Round
	100 to 300	Delphi Group II Value
Good:	100-400 to 500-750	First Round
	150-300 to 500-500	Second Round
	200-300 to 500-500	Third Round
	200-300 to 500-500	Fourth Round
	300 to 500	Delphi Group II Value
Fair:	500-750 to 750-1500	First Round
	500-500 to 750-1200	Second Round
	500-500 to 750-1000	Third Round
	500-500 to 750-1000	Fourth Round
	500 to 750	Delphi Group II Value
Poor:	750-1500 to Max	First Round
	800-1200 to Max	Second Round
	750-1000 to Max	Third Round
	750-1000 to Max	Fourth Round
	750 to Max	Delphi Group II Value

Combined Groups Scaling Results

Ranges of parameter measurement were established for the water pollution parameters by group I and group II for four environmental quality levels. This was accomplished through four rounds of Delphi questionnaires. For the fifth round questionnaire members of both groups were combined and total group opinions were derived. The group I and group II median values of the fourth round were the information supplied in the fifth round questionnaire. Results of the combined groups scaling estimates are reported in table 9.

The combined groups value function graphs were established for each parameter. These graphs were also designed on a basis common with the graphs established by the Battelle group. Four levels of environmental quality were transformed onto a 0.00 to 1.00 scale. Parameter measurements were plotted and value function graphs were established for each parameter. The combined groups value function graphs are included in Appendix D as figure 7.

Table 9. Combined Groups Interquartile Ranges and Final Scaling Values

Basin Hydrologic Loss: (Ratio = man made losses/annual natural discharge)

Excellent:	0.00 to 0.10-0.10	Fifth Round
	0.00 to 0.10	Delphi Groups Value
Good:	0.10-0.10 to 0.25-0.25	Fifth Round
	0.10 to 0.25	Delphi Groups Value
Fair:	0.25-0.26 to 0.50-0.50	Fifth Round
	0.25 to 0.50	Delphi Groups Value
Poor:	0.50-0.50 to 1.00	Fifth Round
	0.50 to 1.00	Delphi Groups Value

Biochemical Oxygen Demand: (mg/l BOD_5 Sluggish Stream)

Excellent:	0 to 3-5	Fifth Round
	0 to 5	Delphi Groups Value
Good:	3-5 to 10-15	Fifth Round
	5 to 10	Delphi Groups Value
Fair:	10-15 to 15-20	Fifth Round
	10 to 20	Delphi Groups Value
Poor:	15-20 to Max	Fifth Round
	20 to Max	Delphi Groups Value

Biochemical Oxygen Demand: (mg/l BOD_5 Swift Stream)

Excellent:	0 to 6-9	Fifth Round
	0 to 7	Delphi Groups Value
Good:	6-10 to 15-20	Fifth Round
	7 to 15	Delphi Groups Value
Fair:	15-20 to 25-30	Fifth Round
	15 to 30	Delphi Groups Value
Poor:	25-30 to Max	Fifth Round
	30 to Max	Delphi Groups Value

Dissolved Oxygen: (mg/l D.O.)

Excellent:	Max to 7.0-8.0	Fifth Round
	Max to 8.0	Delphi Groups Value

Table 9. (continued)

Good:	7.0-8.0 to 5.0-7.0 8.0 to 6.0	Fifth Round Delphi Groups Value
Fair:	5.0-7.0 to 4.0-5.0 6.0 to 4.5	Fifth Round Delphi Groups Value
Poor:	4.0-5.0 to 0.0 4.5 to 0.0	Fifth Round Delphi Groups Value
Total Inorganic Carbon: (mg/l as C)		
Poor:	0 to 5-5 0 to 5	Fifth Round Delphi Groups Value
Fair:	5-6 to 15-15 5 to 15	Fifth Round Delphi Groups Value
Good:	15-15 to 25-30 15 to 25	Fifth Round Delphi Groups Value
Excellent:	25-30 to 50-50 25 to 50	Fifth Round Delphi Groups Value
Good:	50-50 to 70-75 50 to 75	Fifth Round Delphi Groups Value
Fair:	70-75 to 100-100 75 to 100	Fifth Round Delphi Groups Value
Poor:	100-100 to Max 100 to Max	Fifth Round Delphi Groups Value
Fecal Coliforms: (MPN/100ml)		
Excellent:	0 to 100-100 0 to 100	Fifth Round Delphi Groups Value
Good:	100-100 to 700-1000 100 to 750	Fifth Round Delphi Groups Value
Fair:	700-1000 to 3000-4000 750 to 3000	Fifth Round Delphi Groups Value
Poor:	3000-4000 to Max 3000 to Max	Fifth Round Delphi Groups Value
Total Inorganic Nitrogen: (mg/l as N)		
Poor:	0.00 to 0.10-0.15 0.00 to 0.10	Fifth Round Delphi Groups Value

Table 9. (continued)

Fair:	0.10-0.15 to 0.30-0.30 0.10 to 0.30	Fifth Round Delphi Groups Value
Good:	0.30-0.30 to 0.45-0.50 0.30 to 0.50	Fifth Round Delphi Groups Value
Excellent:	0.45-0.50 to 1.00-1.00 0.50 to 1.00	Fifth Round Delphi Groups Value
Good:	1.00-1.00 to 2.31-2.50 1.00 to 2.50	Fifth Round Delphi Groups Value
Fair:	2.31-2.50 to 5.00-5.00 2.50 to 5.00	Fifth Round Delphi Groups Value
Poor:	5.00-5.00 to Max 5.00 to Max	Fifth Round Delphi Groups Value
Inorganic Phosphate: (ug/l as P)		
Poor:	0 to 5-5 0 to 5	Fifth Round Delphi Groups Value
Fair:	5-5 to 10-14 5 to 10	Fifth Round Delphi Groups Value
Good:	10-15 to 20-30 10 to 25	Fifth Round Delphi Groups Value
Excellent:	20-30 to 100-100 25 to 100	Fifth Round Delphi Groups Value
Good:	100-100 to 150-200 100 to 190	Fifth Round Delphi Groups Value
Fair:	150-200 to 400-600 190 to 500	Fifth Round Delphi Groups Value
Poor:	400-600 to Max 500 to Max	Fifth Round Delphi Groups Value
Pesticides: (Conc. Ratio = concentration/max. permissible conc.)		
Excellent:	0.00 to 0.10-0.10 0.00 to 0.10	Fifth Round Delphi Groups Value
Good:	0.10-0.10 to 0.25-0.30 0.10 to 0.25	Fifth Round Delphi Groups Value

Table 9. (continued)

Fair:	0.25-0.30 to 0.50-0.50 0.25 to 0.50	Fifth Round Delphi Groups Value
Poor:	0.50-0.50 to Max 0.50 to Max	Fifth Round Delphi Groups Value
Hydrogen Ion Concentration: (pH units)		
Poor:	0.0 to 5.5-5.0 0.0 to 5.5	Fifth Round Delphi Groups Value
Fair:	5.5-5.5 to 6.5-6.5 5.5 to 6.5	Fifth Round Delphi Groups Value
Good:	6.5-6.5 to 7.0-7.0 6.5 to 7.0	Fifth Round Delphi Groups Value
Excellent:	7.0-7.0 to 8.0-8.3 7.0 to 8.0	Fifth Round Delphi Groups Value
Good:	8.0-8.3 to 9.0-9.0 8.0 to 9.0	Fifth Round Delphi Groups Value
Fair:	9.0-9.0 to 9.4-9.5 9.0 to 9.5	Fifth Round Delphi Groups Value
Poor:	9.4-9.5 to Max 9.5 to Max	Fifth Round Delphi Groups Value
Turbidity: (Jackson Turbidity Units)		
Excellent:	0 to 5-20 0 to 13	Fifth Round Delphi Groups Value
Good:	5-20 to 20-100 13 to 50	Fifth Round Delphi Groups Value
Fair:	20-100 to 100-200 50 to 100	Fifth Round Delphi Groups Value
Poor:	100-200 to Max 100 to Max	Fifth Round Delphi Groups Value
Stream Flow Variation, ≤2:1: (Percent of days)		
Excellent:	100 to 95-95 100 to 95	Fifth Round Delphi Groups Value
Good:	95-95 to 85-90 95 to 88	Fifth Round Delphi Groups Value

Table 9. (continued)

Fair:	85-90 to 70-80 88 to 78	Fifth Round Delphi Groups Value
Poor:	70-80 to Min 78 to Min	Fifth Round Delphi Groups Value
<u>Stream Flow Variation</u>, 2:1-10:1: (Percent of days)		
Excellent:	0.0 to 1.0-2.0 0.0 to 2.0	Fifth Round Delphi Groups Value
Good:	1.0-2.0 to 4.0-5.0 2.0 to 4.0	Fifth Round Delphi Groups Value
Fair:	4.0-5.0 to 6.0-8.0 4.0 to 8.0	Fifth Round Delphi Groups Value
Poor:	6.0-8.0 to Max 8.0 to Max	Fifth Round Delphi Groups Value
<u>Stream Flow Variation</u>, 10:1-50:1: (Percent of days)		
Excellent:	0.0 to 0.7-0.8 0.0 to 0.7	Fifth Round Delphi Groups Value
Good:	0.7-0.8 to 1.5-2.0 0.7 to 1.5	Fifth Round Delphi Groups Value
Fair:	1.5-2.0 to 3.0-3.5 1.5 to 3.0	Fifth Round Delphi Groups Value
Poor:	3.0-3.5 to Max 3.0 to Max	Fifth Round Delphi Groups Value
<u>Temperature</u>: (Degrees C departure from equilibrium)		
Poor:	-(Max) to -(6.0-4.0) -(Max) to -5.5	Fifth Round Delphi Groups Value
Fair:	-(6.0-4.0) to -(4.0-3.0) -5.5 to -3.0	Fifth Round Delphi Groups Value
Good:	-(4.0-3.0) to -(2.0-1.0) -3.0 to -1.8	Fifth Round Delphi Groups Value
Excellent	-(2.0-1.0) to +(1.0-2.0) -1.8 to +1.3	Fifth Round Delphi Groups Value
Good:	+(1.0-2.0) to +(3.0-4.0) +1.3 to +3.0	Fifth Round Delphi Groups Value

Table 9. (continued)

Fair:	+(3.0-4.0) to +(4.0-6.0) +3.0 to +5.0	Fifth Round Delphi Groups Value
Poor:	+(4.0-6.0) to Max +5.0 to Max	Fifth Round Delphi Groups Value
Total Dissolved Solids: (mg/l T.D.S.)		
Poor:	0 to 15-35 0 to 25	Fifth Round Delphi Groups Value
Fair:	15-35 to 30-50 25 to 50	Fifth Round Delphi Groups Value
Good:	30-50 to 50-100 50 to 100	Fifth Round Delphi Groups Value
Excellent:	50-100 to 150-200 100 to 190	Fifth Round Delphi Groups Value
Good:	150-200 to 300-500 190 to 400	Fifth Round Delphi Groups Value
Fair:	300-500 to 600-750 400 to 700	Fifth Round Delphi Groups Value
Poor:	600-750 to Max 700 to Max	Fifth Round Delphi Groups Value

Results of EES Assessments

Four separate EES assessments were performed in which the environmental impact of the Aubrey Reservoir project on fourteen water pollution parameters was considered. Each assessment assumed different judgment based weighting and scaling values. The four value judgments employed were those of: 1) the Battelle research team; 2) the regional Delphi group I; 3) the regional Delphi group II; and 4) the combined regional Delphi groups.

The EES approach employed to perform the assessments is outlined in Appendix B. Parameter data, necessary for the EES assessment of water pollution parameters, is included in Appendix E.

In the EES, environmental impacts are measured in Environmental Impact Units (EIU). Benefits to the environment are indicated by positive EIU values and degradations of the environment are indicated by negative EIU values. The further the EIU value is from zero, the greater is the magnitude of impact.

An EES assessment has been performed for the proposed Aubrey Reservoir project by the Institute for Environmental Studies, North Texas State University.[65] In this study, Battelle value judgments were employed. Battelle values are reported in table 6 and figure 4.

The method for the elicitation of value judgments for the two regional groups has been discussed. Value judgments (weighting and scaling values) necessary to perform an EES assessment have been determined for group I, group II, and the groups combined. These values are reported in tables 3, 4 and 5 and figures 5, 6 and 7.

Comparison of the results of the four EES assessments revealed differences in the degree of predicted environmental impact between the Battelle group and the regional groups for water pollution parameters of the Aubrey Reservoir project. The results of the four assessments are included in table 10.

In their assessment of the Aubrey Reservoir project the Institute for Environmental Studies, committed a procedural error in determining the environmental impact resulting from alteration of the BOD parameter. A measurement of 26 mg/l BOD was employed in the assessment for the without project condition. The correct weighted parameter measurement, without the project, was 10.8 mg/l BOD. A corrected environmental impact on biochemical oxygen demand has been calculated and included in table 10.

Analysis of table 10 revealed a marked difference between the regionally based environmental assessments and the environment assessment of the Battelle research team. The impact on water pollution parameters for the Aubrey project was -1.55 EIU employing Battelle judgment based values. The impact based upon regional value judgments were: -9.12 EIU

Table 10. Results of EES Assessments Employing Group I, Group II, Combined Groups, and Battelle Values

Environmental Parameter	Battelle[A] Net Change (EIU)	Group I Net Change (EIU)	Group II Net Change (EIU)	Combined Net Change (EIU)
Basin Hydrologic Loss:	0.00	-0.15	-0.17	-0.16
BOD:	+7.50 (-1.25)[B]	-4.37	-0.88	-2.52
Dissolved Oxygen:	-1.55	-2.10	-1.70	-3.72
Fecal Coliforms:	0.00	0.00	0.00	0.00
Inorganic Carbon:	0.00	-3.04	-2.88	-2.72
Inorganic Nitrogen:	+4.25	+5.94	+3.45	+4.62
Inorganic Phosphate:	0.00	+6.00	+3.15	+6.00
Pesticides:	-1.60	-3.00	-1.82	-2.10
pH:	0.00	0.00	0.00	0.00
Stream Flow Variation:	0.00	0.00	0.00	0.00
Temperature:	-1.40	-8.40	-5.00	-6.84
Total Dissolved Solids:	0.00	0.00	0.00	0.00
Toxic Substances:	0.00	0.00	0.00	0.00
Turbidity:	+1.00	0.00	-1.08	0.00
Total:	+8.20 (-1.55)[B]	-9.12	-6.93	-7.44

[A] As determined by The Institute for Environmental Studies, North Texas State University

[B] Corrected estimate

for group I; -6.93 EIU for group II; and -7.44 EIU for the two regional groups combined.

For every impacted parameter, with the exception of group II BOD and inorganic nitrogen, the impacts of the regional groups were of greater magnitude than those assessed via the Battelle values.

The total net change for all 78 parameters assessed via Battelle weighting and scaling values for the Aubrey Reservoir project was +1.74 EIU. Based upon the results reported in table 10, it was concluded that regional weighting and scaling value judgments were at variance with the Battelle weighting and scaling value judgments. The discrepancy of -5.89 EIU for only the fourteen water pollution parameters between an assessment employing regional values and the assessment employing Battelle values was, in this context, considered significant.

Regional values established in this study were more sensitive to alterations of the environment. For fourteen water pollution parameters, the regional Delphi groups were more protective of the without project environment. This was evident in the magnitude of detrimental impact established for each assessment.

Discussion of Results

Applicability of the Delphi Method

The applicability of the Delphi method to value judgments inherent in environmental impact assessment has been established for fourteen water pollution parameters. The use of two independent estimating groups has supported the conclusion that the Delphi is a viable method for the environmental analyst. With respect to weighting and scaling value judgments, the Delphi method of statistical refinement of group values resulted in a convergence of group opinion for both groups. This was seen as decreases in the ranges of dispersion of opinions; the interquartile ranges.

The Delphi method was found to be successful in eliminating the negative features of group interaction. An orderly program of sequential interrogations conducted by questionnaire eliminated direct confrontation and debate. The Delphi technique was successful in the elimination of the influence of dominant individuals, noise, and group pressure for conformity.

It is believed that the Delphi method is applicable to the regional assessment of water pollution parameters for any environmental impact assessment methodology involving weighting and scaling value judgments. Further studies are necessary to determine the applicability of the Delphi technique to the full range of parameters associated with environmental impact assessment.

Reliability of the Delphi Method

A benefit derived from the use of two groups in this study was that a measure of the reliability of the Delphi method for environmental impact assessment was obtained. The two groups were selected as representative of the same general population of experts. Based upon the method of selection and statistical analysis of responses, these groups were believed to be essentially the same with respect to the value judgments required for the study.

The reliability of the Delphi method was measured by calculating the correlation coefficient for the nine impacted water pollution parameters (see table 10). The EIU values for the nine group I and group II impacted parameters were first plotted on a scatter diagram. Examination of this scatterplot confirmed the existance of linear regression and homoscedasticity. A correlation coefficient of +0.87 was calculated for the two groups employed in this study. Therefore, high correlation was observed between groups.

Inspection of figure 2 revealed that the calculated correlation coefficient of 0.60 for an open group of eight would be expected. It has been concluded that within this study, the Delphi method has demonstrated an improvement upon the reliability of group response. It is noted that many more analyses of this nature are needed to statistically determine the effect of the Delphi on reliability with respect to value judgments inherent to environmental impact assessment. However, the results obtained in this study are encouraging.

The total impact value obtained via the two regional groups of -9.12 EIU and -6.93 EIU were much closer to each other than either was to the Battelle value of -1.55 EIU.

The major variances between group I and group II involved the biochemical oxygen demand and temperature parameters. Here the differences in environmental impact were -3.49 and -3.40 respectively. In both cases, if these values were brought closer together, the total environmental impact values of the two groups would converge. It is also important to note that a reduction of either group I or group II total impact value by these amounts would still result in regional values of impact that were more than twice the value obtained via the Battelle value judgments.

Reliability of the Delphi method for environmental impact assessment is clearly dependent upon the selection of the estimating groups. Reliability can generally be expected to be high if large groups are selected at random from a population of all potential experts. However, as previously discussed, the selection of members of advisory bodies is rarely if ever at random out of the total pool of experts. Therefore, when employing the Delphi method, it is critical that care be taken in arriving at the composition of the estimating group.

Evaluation of the Delphi Method for Environmental Assessment

The Delphi technique has been shown to be a viable method for the elicitation of group value judgments for fourteen water pollution parameters. Application of this methodology resulted in significant differences between regional group values and values established by the Battelle research group. Since no true value exists by which to test the results, it was not possible to prove one method, or set of values, more accurate than the other. To evaluate the significance of the Delphi method for impact assessment the attributes and detriments must be considered.

In the previous chapter of this report the general advantages of the Delphi method were discussed. When applied to selected environmental parameters the Delphi method has eliminated negative features of open group response. These negative features included:

1) Influence of dominant individuals;
2) Noise;
3) Group pressure for conformity.

Additional attributes are realized when the Delphi method is applied to the assessment of environmental impact. These specific attributes include:

1) Regionally determined values;
2) Explanation and defense of established values;
3) Public input guaranteed in the methodology.

The Battelle EES is a significant advancement in the techniques for assessing environmental impacts. However, this method should be tailored to major geographic regions and only used for comparison among projects and alternatives within a single region. It is recommended that having several versions of the EES with regional applicability is more realistic than a single version.[65] It is believed that comparison among projects and their alternatives within a region is more meaningful than between different regions. The Delphi method allows for this latitude of regional version of consideration.

The Battelle EES includes parameters which are basically important only to the Bureau of Reclamations' projects in the western states.[65] Under the Delphi method, these parameters may be replaced by those relevant to the geographic region within which the impact will occur. By selecting regional Delphi groups those parameters which have importance in a particular region can be weighted and scaled according to their significance within that region.

The importance of the method for selection of Delphi group members cannot be overemphasized. If care is taken in the selection process, it is believed that public acceptance of the impact assessment will be high. By requiring Delphi respondants to offer reasons in support of their opinions and presenting these comments in the draft impact statement, reviewers will be able to better evaluate value based decisions inherent to the particular impact assessment.

In the final analysis the public will be the judge as to the best or most acceptable methodology for environmental impact assessment. The Delphi method is believed to be more responsive to public opinion because the estimating groups may be selected from the region in which the project will have the greatest effect. Also, the Delphi method can guarantee consideration of public opinion. Following the initial assessment of environmental impact, a draft statement must be made available for comment. Under the Delphi procedures, comments from reviewers may serve as deviationist opinions. As with in-group deviationist opinions, reviewer's opinions can be summarized and fed to the Delphi groups in additional rounds of refinement. In this manner the Delphi procedures guarantee that public opinion is built into the assessment methodology.

The Delphi method of estimating has been shown to be applicable to the resolution of value judgments inherent to environmental impact assessment. Results have indicated that the reliability of the Delphi method is better than that of open group response. Although additional research is necessary to confirm the value of the Delphi method for the environmental analyst, the attributes of the method support the hypothesis that the Delphi method is a significant advancement in the evolution of the environmental impact assessment process.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based upon analyses of the fourteen, Aubrey Reservoir, water pollution parameters investigated in this study, the following conclusions regarding the relevance of the Delphi method for the environmental analyst, have been drawn.

1) The Delphi method of estimating is a viable technique for the elicitation of regional expert opinion for value judgments associated with the assessment of environmental impact.
2) The Delphi method should adapt to either decision or information assessment methodologies. (A decision document is vital to determining the best course of action, an information document functions primarily to reveal the implications of a single, clearly best choice). The sole requirement for the Delphi adaptation is the employment of value judgments within the assessment methodology.
3) The Delphi method is applicable to the measurement of impact magnitude as distinct from impact significance. This has been demonstrated by the determination of weighting and scaling value judgments inherent in the assessment of

environmental impact.

4) Results of separate EES assessments have shown that regional values of experts are significantly different from values determined by the Battelle research team. If these results are indicative of the values of the southwest region of the country, the final Battelle assessment, reported by the Corps of Engineers, for the environmental impact of the Aubrey Reservoir project, is at variance with anticipated regional values.

5) The reliability of the Delphi method for the refinement of expert group response is greater than that which would be expected under open-group conditions.

6) The Battelle EES conforms well to the Delphi procedures for elicitation of regional expert value determinations.

7) Results obtained employing the Delphi refinement of weighting and scaling value judgments are only as valid as the method of expert group selection. Extreme emphasis and consideration must be paid to the method of regional expert selection when applying the Delphi method to the assessment of environmental impact.

8) By enabling a method for the elicitation of regional expert values, the Delphi technique is commensurate with the need for refinement of weighting and scaling values as stated by Battelle in their report of the EES methodology. Also, by allowing for regional value determination, the Delphi technique may be employed for the development of a regional version of the EES, thereby, satis-

fying the major criticism of the Aubrey assessment by the North Texas State University group which prepared the environmental assessment of the Aubrey Reservoir project.

Recommendations

Procedures for the assessment of environmental impact consist of a variety of techniques for evaluating tangible and intangible aspects of environmental quality. All of these techniques rely upon value judgments. As a result of this study, the Delphi method of estimating has been shown to be applicable to the elicitation of values associated with environmental impact assessment. Experience with the Delphi adaptation to environmental assessment has led to the following recommendations:

1) The applicability of the Delphi method has been established for fourteen water pollution parameters of a water resource development project. Further research should be undertaken in order to determine the applicability of the Delphi method to the full range of value judgments associated with environmental assessment.
2) The Delphi method has been shown to be applicable to the Battelle EES methodology. It is recommended that additional research establishes the applicability of the Delphi method to other environmental assessment methodologies.
3) Procedures need to be established for the selection of Delphi groups of experts for regional impact assessments. Also, the total number of independent Delphi groups, ne-

cessary to determine a complete assessment needs to be established.

4) Theoretically, the Delphi adaptation is expected to meet with better public acceptance than previously proposed methods for value determination because the values are regional in nature and public input is guaranteed by the method. This concept needs to be field tested.

5) The Delphi procedures are time consuming and require considerable resources for a complete assessment of impacts resulting from a major federal action. Research, such as computerization of input, is needed in order to make the Delphi adaptation a more realistic option for the environmental analyst. It is, perhaps, practical to establish Delphi obtained weighting and scaling values on a general region basis, such as the Trinity River basin, and to employ these general values for projects within the region.

6) A catalog should be maintained in which all regionally determined environmental value determinations are indexed. In this manner, with time, regional emphasis on certain parameters may be realized.

7) The development of the state-of-the-art of environmental impact assessment has been the introduction of various tools for the evaluation of tangible and intangible aspects of environmental quality. This study has introduced the Delphi method for elicitation of regional value judgments. It is hoped that future research will expand

and refine the applicability of this new decision-making technique for the environmental analyst.

REFERENCES

1. Public Law 91-190, "The National Environmental Policy Act of 1969," 42 U.S.C. 4321 et seq., December 31, 1969.

2. Dalkey, Norman C., The Delphi Method: An Experimental Study of Group Opinion, Prepared for United States Air Force Project Rand, Rand Corporation, Santa Monica, California, June 1969.

3. Dee, Norbert; Janet K. Baker; Neil L. Drobny; Kenneth M Duke; and David C. Fahringer, Environmental Evaluation System for Water Resource Planning, Report to Bureau of Reclamation, U.S. Department of the Interior, Battelle Columbus Laboratories, Columbus, Ohio, January 31, 1972.

4. U.S. Army Engineer District, Fort Worth, Texas, Final Environmental Impact Statement, Aubrey Lake, Elm Fork, Trinity River, Texas, January 31, 1974.

5. Public Law 304, "The Employment Act of 1946," Chapter 33, 60 Stat. 23, (February 20, 1946), as amended, 15 U.S.C. pp. 1021-1024.

6. Council on Environmental Quality, Environmental Quality - 1973, the fourth annual report of the Council on Environmental Quality, September 1973, pp. 235-248.

7. U.S. President, "Executive Order 11514, Protection and Enhancement of Environmental Quality," Federal Register, volume 35, number 46, March 5, 1970, pp. 4247-4248.

8. Council on Environmental Quality, "Statement on Proposed Federal Actions Affecting the Environment," Federal Register, volume 36, number 79, Washington, D.C., April 23, 1971, pp. 7724-7729.

9. Council on Environmental Quality, "Preparation of Environmental Impact Statements: Guidelines," Federal Register, volume 38, May 2, 1973, pp. 10856-10866.

10. Council on Environmental Quality, "Preparation of Environmental Impact Statements: Guidelines," Federal Register, August 1, 1973, pp. 20550-20562.

11. Council on Environmental Quality, "Memorandum to the Heads of all Federal Agencies Assuring Public Availability of Environmental Impact Statements under NEPA," May 15, 1973, reprinted in 3:5 102 Monitor, 1973.

12. 84 Stat. 114, 42 U.S.C. 4372

13. Public Law 91-604, "The Clean Air Acts Amendments of 1970," as codified in 42 U.S.C., 1857 et seq., 49 U.S.C. (December 31, 1970), pp. 1421-1430.

14. Environmental Protection Agency, EPA Order 1640.1, Washington, D.C., 1970.

15. Moore, Sheppard N., "The Environmental Impact Statement Process," Environmental Protection Agency, Region IV, Atlanta, from Proceedings, Workshop on Environmental Impact Statements, Florida Technological University, Orlando, June 12-13, 1973, pp. 7-20.

16. Daly vs. Volpe, 4 E.R.C. 1486, D C - W.D. Washington, D.C., August 1972.

17. Upper Pecos vs. Stans, 3 E.R.C. 1418, CA-10, December 1971.

18. Calvert Cliffs Coordinating Committee vs. Atomic Energy Commission, 2 E.R.C. 1779.

19. Committee for Nuclear Responsibility vs. Seaborg, 3 E.R.C. 1126.

20. Environmental Defense Fund vs. Corps of Engineers (Gilham), 325 F. Supp 749, D C _ E.D. Arkansas, 1971.

21. N.R.D.C. vs. Morton, 337 F., Supp 165.

22. Brooks vs. Volpe, 4 E.R.C. 1492, 1498, D C _ W.D. Washington, August 1972.

23. Gluckman, David, "NEPA - Recent Decisions and Trends," Proceedings, Workshop on Environmental Impact Statements, Florida Technological University, Orlando, June 12-13, 1973, p.35.

24. Complaint of N.R.D.C. to Civil Aeronautics Board, 2 E.R.C. 1808.

25. Committee for Nuclear Responsibility vs. Seaborg, 463 F. 2d, 783, Washington, D.C., 1971.

26. Citizens Airport Committee vs. Volpe, 4 E.R.C. 1738.

27. Lever Brothers vs. Federal Trade Commission, 325 F. Supp 371.

28. City of New York vs. United States, 337 F. Supp 150.

29. Scenic Hudson Preservation Society vs. Federal Power Commission, 453 F. 2d, 463, CA - 2.

30. Environmental Defense Fund vs. Hardin, 325 F. Supp 1401.

31. Environmental Defense Fund vs. Corps of Engineers, 324 F. Supp 878.

32. Arlington Coalition vs. Volpe, 485 F. 2d 1323, CA - 4.

33. Goose Hollows Foothills League vs. Romney, 334 F. Supp 877.

34. Hanly vs. Mitchell, 460 F. 2d 640, CA - 2.

35. Billings vs. Camp, 4 E.R.C. 1744, Washington, D.C.

36. N.R.D.C. vs. Tennessee Valley Authority, 5 E.R.C. 1316, D.C. - E. Tennessee 1973.

37. Save Our Ten Acres vs. Kreger, 4 E.R.C. 1941, January 16, 1973.

38. Pennsylvania Environmental Council vs. Bartlett, 454 F. 2d 613, CA - 3, 1971.

39. Environmental Defense Fund vs. Tennessee Valley Authority, Tellico Dam, 4 E.R.C. 1857, CA - 6, 1972.

40. Department of the Army, Guidelines for Assessment of Economic, Social, and Environmental Effects of Civil Works Projects, Office of the Chief of Engineers, Washington, D.C., September 28, 1972.

41. Canter, Larry W., "Steps in Environmental Impact Assessment," (unpublished report) School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, Oklahoma, 1974.

42. Warner, Maurice L. and Edward H. Preston, A Review of Environmental Impact Assessment Methodologies, Prepared for Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C., April 1974.

43. Institute of Ecology, University of Georgia, "Optimum Pathway Matrix Analysis Approach to the Environmental Decision Making Process: Test case: Relative Impact of Proposed Highway Alternatives," Athens, Georgia: University of Georgia, Institute of Ecology, 1971 (Mimeographed).

44. United States Department of the Interior, "Guidelines for Implementing Principles and Standards for Multiobjective Planning of Water Resources," Review Draft, Bureau of Reclamation, Washington, D.C., December 1972.

45. United States Water Resources Council, "Proposed Principles and Standards for Planning Water and Related Land Resources," Federal Register, December 21, 1971.

46. United States Senate, "Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources," Senate Document No. 97, 87th Congress, 2d Session, 1972.

47. Tulsa District, U.S. Army Corps of Engineers, Matrix Analysis of Alternatives for Water Resource Development, draft technical paper, July 31, 1972.

48. Leopold, Luna B., et al., A Procedure for Evaluating Environmental Impact, U.S. Geological Survey Circular 645, Washington, D.C., U.S. Government Printing Office, 1971.

49. McHarg, Ian, "A Comprehensive Highway Route-Selection Method," Highway Research Record, Number 246, pp. 1-15, 1968. or McHarg, Design With Nature, Garden City, New York, New York, Natural History Press, pp. 31-41, 1969.

50. Krauskopf, Thomas M., and Dennis C. Bunde, "Evaluation of Environmental Impact Through a Computer Modelling Process," Environmental Impact Analysis: Philosophy and Methods, (eds.) Robert Ditton and Thomas Goodale, Madison, Wisconsin, University of Wisconsin Sea Grant Program, pp. 107-125, 1972.

51. Sorensen, Jens C., A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone, The Department of Landscape Architecture, College of Environmental Design, University of California, Berkeley, California, August 1974.

52. Western Systems Coordinating Council, Environmental Committee, Environmental Guidelines, Southern California Electric Company, 1971.

53. Reid, George W., et al. "Water, Oklahomas No. 1 Problem," Bureau of Water Resources Research, University of Oklahoma, Norman, Oklahoma, 1963.

54. United States Environmental Protection Agency, Environmental Impact Statement Guidelines, Region X, Seattle, Washington, April 1973.

55. Dalkey, Norman C., "Delphi," paper prepared for presentation to the Second Symposium on Long-Range Forecasting and Planning, Almagordo, New Mexico, October 11-12, 1967.

56. Brown, B., S. Cochran and N. Dalkey, The Delphi Method II: Structure of Experiments, Prepared for United States Air Force under Project Rand, Rand Corporation, Santa Monica, California, June 1969.

57. Dalkey, N., B. Brown and S. Cochran, The Delphi Method III: Use of Self Ratings to Improve Group Estimates, Prepared for United States Air Force Project Rand, Rand Corporation, Santa Monica, California, November 1969.

58. Dalkey, N., B. Brown and S. Cochran, The Delphi Method IV: Effect of Percentile Feedback and Feed-In of Relevant Facts, Prepared for United States Air Force Project Rand, Rand Corporation, Santa Monica, California, March 1970.

59. Helmer, Olaf, "The Use of the Delphi Technique in Problems of Educational Innovations," The American Behavioral Scientist, paper reproduced by the Rand Corporation, Santa Monica, California, December 1966.

60. Helmer, Olaf, "Analysis of the Future: The Delphi Method," Rivista Italiana di Ammenistrazione Industriale, reproduced by the Rand Corporation, Santa Monica, California, March 1967.

61. Brown, Bernice B., "Delphi Process: A Methodology Used for the Elicitation of Opinions of Experts," ASTME Vectors, February 1968, reproduced by the Rand Corporation, Santa Monica, California, September 1968.

62. Rescher, Nicholas, "Delphi and Values," reproduced by the Rand Corporation, Santa Monica, California, September 1969.

63. Mendenhall, William, Introduction to Probability and Statistics, Third Edition, Duxbury Press, a Division of Wadsworth Publishing Company, Inc., Belmont, California, 1971.

64. Dixon, Wilfred J. and Frank J. Massey, Jr., Introduction to Statistical Analysis, Third Edition, McGraw-Hill Book Company, New York, 1969.

65. The Institute for Environmental Studies, North Texas State University, Denton, Texas, A Systems Evaluation of the Environmental Impact of the Aubrey Reservoir Project on Elm Fork of the Trinity River in North Texas, Final Report submitted to the U.S. Army Corps of Engineers, Fort Worth District, June 30, 1972.

APPENDIX A

PROPOSED AUBREY RESERVOIR PROJECT

AUBREY RESERVOIR

Project Description

Aubrey Lake is a proposed multipurpose (i.e., flood control, water supply, recreation, and fish and wildlife) reservoir project. The impoundment will be located in parts of Denton, Cooke, and Grayson Counties in north central Texas. The recommended Aubrey Lake damsite will be in Denton County at river mile 60.0 of the Elm Fork of the Trinity River, about 4 miles northwest of Aubrey, Texas. The drainage area or watershed covers 692 square miles extending into Montague County along Elm Fork, into southern Cooke County along numerous tributaries, into southwestern Grayson County along Buck Creek and Range Creek, and along Elm Fork and Isle du Bois, and their tributaries in Denton County (figure 3).

The project has been designed as an earthfill embankment consisting primarily of compacted medium to high plasticity clays. A 100-foot long uncontrolled spillway will be constructed in the left abutment, and a 13-foot diameter outlet works conduit is planned for the right flood plain. The dimensions, elevations, and capacities of the proposed Aubrey Reservoir are shown in table 11.

The lake will form a "V" shape as it backs water into

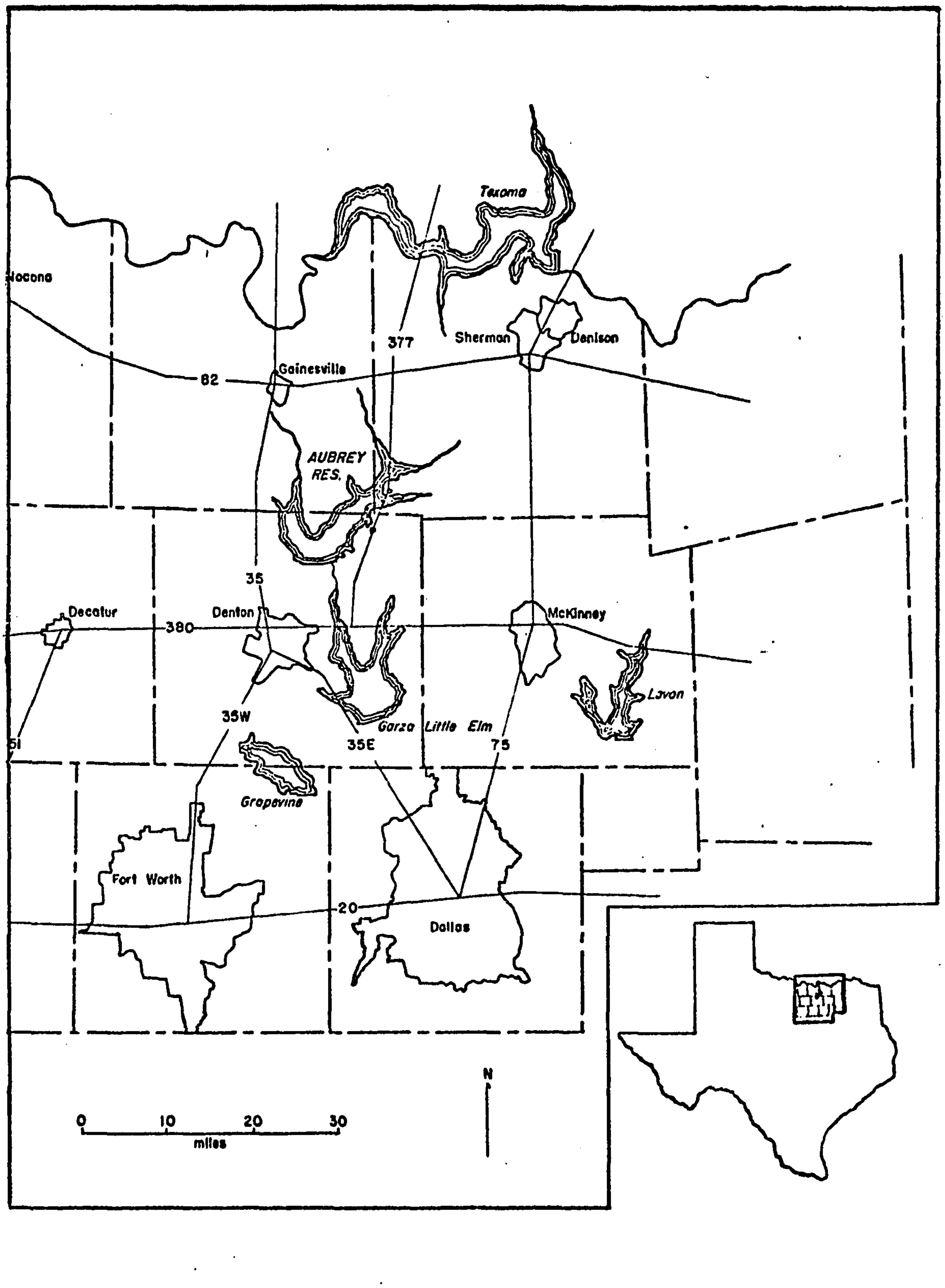


Figure 3. Aubrey Reservoir Project Location

Table 11. Dimensions, Elevations, and Capacities of the Proposed Aubrey Reservoir

Item	Units
Drainage Area	692 Square Miles
Top of Dam	657.0 Feet MSL
Top of Dam	136.0 Feet (above stream bed)
Dam Length	14,700 Feet
Dam Crest Width	42 Feet
Design W.S. (1000 Ft. Uncontrolled Broadcrest Spillway)	655.8 Feet MSL
Upper Guide Contour	641.0 Feet MSL
Top of Flood Control Pool	636.0 Feet MSL
Top of Conservation Pool	627.0 Feet MSL
Stream Bed	528.0 Feet MSL
Flood Storage	249,000 Acre-Feet
Flood Storage	6.7 In. of runoff
Conservation Storage	627,400 Acre-Feet
Sediment	54,600 Acre-Feet
Total Storage	931,000 Acre-Feet
Yield (initial)	134.0 CFS
Yield (initial)	86.6 MGD
Yield (ultimate)	117.0 CFS
Area at Upper Guide Contour	35,050 Acres
Area at Top of Conservation Pool	25,200 Acres
Area at Top of Flood Control Pool	32,600 Acres
Area at Maximum Design	55,300 Acres

the Elm Fork and Isle du Bois Creek valleys. At the conservation pool level, the lake will inundate about 20 miles of the Elm Fork channel and about 23 miles of Isle du Bois Creek channel, and will create a total shoreline of approximately 162 miles. A full flood control pool will inundate about 23 miles of the Elm Fork channel and about 25 miles of the Isle du Bois channel. At this water surface elevation the widest point of the lake will be about 6 miles across.

The construction of Aubrey Lake will involve approximately 43,560 acres in 1,187 tracts and 945 ownerships.

The primary project purposes are water supply, recreation, and fish and wildlife. Before the accumulation of sediment, the storage initially available in the conservation pool below elevation 627.0 feet msl will, under present conditions of watershed development, produce a dependable yield of 134.0 cubic feet per second. Of this water supply yield, 74 per cent is for the city of Dallas and 26 per cent is for the city of Denton. These amounts will supply a portion of the projected long range water needs of these two municipalities.

The project will provide for up to 6,240,000 recreation days annually. The principal recreation resources of Aubrey Lake will be the scenic beauty of the lake, the favorable climate, and the fish and wildlife resources of the project area. Approximately 11 public-use areas, including 2,800 acres above the conservation pool, will accomodate activities such as camping, picnicking, hiking, and water-based activities such as boating, fishing, swimming, and water skiing.

Aubrey Lake will constitute a major change in the aquatic environment. The project will result in the alteration from several warmwater stream fisheries to a large impoundment-type fishery. After the lake is filled, the productivity of fish should be high, but later this productivity is projected to decrease.

Water Pollution Parameters

Basin Hydrologic Loss

The basin hydrologic loss parameter is an attempt to relate crucial elements of the overall hydrologic budget to their impact on environmental quality. Basin hydrologic loss is expressed as a ratio between losses of water from a basin due to man-made developments and losses due to natural annual discharges. Man-made losses include those losses that result from evaporation of water from a reservoir. Natural loss is that amount of water lost at the mouth of a river or creek due to discharge. As defined by the ratio described above, basin hydrologic loss will range from 0.0 to 1.0. For the proposed project site, without the project:

$$\frac{\text{Man-made losses}}{\text{Natural losses}} = \frac{\text{611,000 acre feet (net depletion)}}{\text{4,181,400 acre feet (net inflow)}}$$

$$= 0.146$$

Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) is defined as an estimate of the quantity of oxygen required by an ecosystem to biologically oxidize the organic contents in an aquatic environment. Therefore, a 5-day BOD test provides a means for measuring the organic pollution load of an aquatic system.

BOD is important only insofar as it promotes the depletion of dissolved oxygen or the growth of undesirable benthic organisms. In a slow sluggish stream or reservoir lesser concentrations of BOD may be sufficient to produce undesirable conditions, whereas a swift mountain stream may easily handle much greater concentrations of BOD without sufficient deleterious effects. This is because swift moving streams have a greater capacity for reaeration and for preventing the accumulation of high BOD materials in bottom deposits than do sluggish streams or reservoirs.

In the area of the proposed site, the BOD_5 values, without the project, average 6-26 mg/l.

Dissolved Oxygen

Dissolved oxygen (DO) is that amount of oxygen which is found in solution in water. DO concentrations for the proposed project site, without the project, were found to average 7.5 mg/l (90-100% saturation) at ambient temperatures.

Fecal Coliforms

Fecal coliforms are the most widely used bacteriological indicator system to demonstrate the presence of fecal matter from warm-blooded animals. They are indicative of the degree of contamination contributed by fecal wastes. Fecal coliform densities are calculated from Most Probable Number (MPN) tables. An arithmetical mean of 3.0×10^3 fecal coliforms per 100 ml was derived for the proposed project area under without projects conditions.

Total Inorganic Carbon

Total inorganic carbon (TIC) of an aquatic system is the sum of carbon existing as carbon dioxide, bicarbonate, and carbonate. Inorganic carbon is a major carbon source for photosynthetic organisms and is necessary for the maintenance of the aquatic food web. Inorganic carbon is usually present in sufficient quantities to support algal growth. There is growing evidence that, in some instances of low concentrations, it may be a significant algal growth limiting factor. Analysis of samples indicated an average of 54 mg/l TIC in the project area under no project conditions.

Total Inorganic Nitrogen

Nitrogen is a micronutrient essential to all living organisms. It plays a fundamental part in governing community structure and function within the aquatic ecosystem. Inorganic nitrogen is often a growth determining factor in the aquatic environment. Total inorganic nitrogen (TIN) is the total of ammonia, nitrite, and nitrate-nitrogen. TIN samples show concentrations ranging from 0.3 to 2.7 mg/l with a mean concentration of 2.5 mg/l for the proposed site area prior to project implementation.

Inorganic Phosphate

Phosphorus occurs in various forms in water. It is found in both soluble and particulate phases. Phosphorus is often the growth determining nutrient which accelerates the rate of eutrophication. Upstream, without the project, analyses show that the inorganic phosphate level averages 0.5 mg/l. Phosphate averages at the site and further downstream are about 0.27 mg/l.

Pesticides

Pesticides include the broad category of insecticides, herbicides, and algicides. Because maximum permissible concentrations vary widely, a useful basis for expressing total pesticide is the ratio of existing (or expected) concentration of a given pesticide to its respective maximum permissible concentration. For the without project condition:

$$\text{Concentration Ratio} = \frac{\text{Concentration}}{\text{Max. Permissible Concentration}} = 0.5$$

Hydrogen Ion Concentration (pH)

The hydrogen ion concentration is defined as the negative log of the molar concentration of hydrogen ions present in an aqueous solution. Values for most natural waters vary between 6.5 and 8.5. The average pH is 7.9 for waters in the area of the proposed project.

Stream Flow Variation

Stream flow variation is expressed as the ratio between the maximum and minimum flow changes that occur in a stream with relation to time. This parameter is important ecologically because environments can be drastically altered if the magnitude and frequency of these variations occur rapidly and for prolonged periods of time.

The magnitude of the stream flow variation expressed as the ratio Daily Max/Daily Min, for three discrete values of flow is required:

Daily Max/Daily Min
≤ 2:1
2:1-10:1
10:1-50:1

The predominant period of time over which the flow changes from a maximum to a minimum value or visa versa is greater than 24 hours. The unit of parameter measurement is expressed as the number of days per year (expressed as a percentage of 365) over which the above flow ratios occur. Under no project conditions it was calculated that in 97% of the time, the flow is 2:1, 2% of the time the ratio is 2:1-10:1, and 1% of the time the ratio is 10:1-50:1 (all changes occurring in a 24 hour period).

Temperature

Temperature exerts significant influence on chemical equilibria in natural waters and dictates the solution rates for various minerals. The unique physical properties of water are to a large degree regulated by temperature. Aggregate temperature effects are best handled not in term of temperature per se, but in terms of the magnitude of departure from natural conditions expressed as + or - degrees C.

Total Dissolved Solids

Total dissolved solids (TDS) is a measure of all soluble materials in solution in a water supply. TDS was estimated from conductivity data using the relationship:

$$TDS = A \times \text{Specific Conductance}$$

The coefficient, A, for this study was estimated to be 0.6. TDS samples showed concentrations of 870 mg/l upstream and 688 mg/l at the site before project implementation.

Toxic Substances

Toxic compounds are those substances in water that cause harm or death to the organisms in the aquatic ecosystem by altering some metabolic activity. The effects of toxic substances in water range from odor production or orgnoleptic properties to toxicity and death of the affected organism. For the purpose of this study, criteria have been established where a detectable concentration of any toxic substance is considered poor environmental quality. Arsenic, a heavy metal, was detected upstream from the reservoir in concentrations of one part in 10,000.

Turbidity

Turbidity refers to any suspended matter in water, such as clay, silt, finely divided organic or inorganic matter, plankton, and any other microscopic organisms which impede the transmittance of light. Turbidity is an indicator of the amount of suspended matter, or solids, in water. Turbidity concentrations without the project measure, upstream from the site 120 Jackson Turbidity Units (JTU), at the site 115 JTU, and downstream from the site 85 JTU.

APPENDIX B

BATTELLE ENVIRONMENTAL EVALUATION SYSTEM

ENVIRONMENTAL EVALUATION SYSTEM

Description[65]

The Battelle, Environmental Evaluation System[3] was discussed in chapter three of this report. In this section the procedures employed to arrive at the environmental impact determined in chapter five are presented.

All environmental parameters were transformed into commensurate units. This transformation followed three basic steps:

1) Weight parameters according to their relative importance in PIU's.
2) Transform all parameter estimates into corresponding units of Environmental Quality (EQ), scaled on a 0-1 range (0 = extremely poor quality; 1 = extremely high quality and corresponds to the maximum PIU assigned to a parameter). This process provided a common base with which all parameters, regardless of their unit of measurement, were directly compared. As a result, impacts were expressed in commensurate units. The transformation of a parameter estimate or measurement into EQ was achieved through the use of a value function which related the various levels of parameter estimates

or measurements to appropriate EQ levels.

3) Obtain commensurate units or Environmental Impact Units (EIU), which were calculated as:

$$EIU = EQ \times PIU_{max}$$

Environmental impacts were measured in EIU's. For example, assume that a measurement of 5 parameter units, corresponding to an EQ of 0.5 (from a value function graph), represents the present status of the parameter without the project. The predicted parameter measurement of the parameter with the project is 3 (EQ = 0.3 from the same value function graph). Assume a maximum of 50 PIU's for the parameter. The impact of the project on the parameter in EIU's is calculated as:

$$\begin{aligned} \text{Project Impact} &= EIU_{(\text{with project})} - EIU_{(\text{without})} \\ &= (0.3 \times 50) - (0.5 \times 50) \\ &= (15) - (25) \\ &= -10 \text{ EIU} \end{aligned}$$

To capture the spatial and temporal aspects of the project's impact on the parameters, two time frames were employed. These time frames were referred to as the construction (short-term) and the operation (long-term) phases. Three spatial frames (upstream, at site and downstream) were also used for the with project EIU evaluation. The without project EIU's were evaluated using a single time frame and the three spatial frames. The temporal and spatial frames were expressed in terms of relative importance for each phase within each frame. The relative importance of each time frame were assigned on the basis of professional judgment of the evaluator.

Spatial and temporal considerations were transformed into EQ units for each parameter for the with and without project conditions. This was achieved in four basic steps:

1) Assign relative importance (RI) to each spatial and temporal frame according to professional judgment.
2) Multiply this RI factor by the actual parameter measurement for that condition.
3) Sum the products of RI and the actual parameter measurements for the with and without values. This resulted in an estimate of the parameter value which was weighted according to the RI of each spatial and temporal frame.

$$\text{Parameter Value (with or without)} = \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} X_{ij}$$

where: i = Spatial index

j = Temporal index

C_{ij} = Importance of condition ij

X_{ij} = Measurement of condition ij

n = Number of spatial areas considered

m = Number of time frames considered

4) Determine the EQ of the weighted parameter estimates for with and without the project from a value function graph.

The environmental impact on a parameter, in EIU, was calculated as:

$$EIU = (PIU \times EQ_{with}) - (PIU \times EQ_{without})$$

where EQ's were derived according to the preceding four steps. The following is an example using assumed data to calculate environmental impact on a parameter.

Example

Assume:

Maximum PIU = 50

Spatial RI = 0.25 upstream
0.50 at site
0.25 downstream

Temporal RI = 0.25 construction
0.75 operation

Parameter measurements and estimates:

Without Project = 10 upstream
10 at site
10 downstream

With Project (construction) = 8 upstream
8 at site
8 downstream

With Project (operation) = 4 upstream
4 at site
4 downstream

These values were then used to calculate the environmental impact as follows:

Weighted Parameter Measurement Without Project $= 1.0\,((0.25 \times 10) + (0.50 \times 10) + (0.25 \times 10)) = 10.0$

Weighted Parameter Estimate With Project - Construction Period $= 0.25\ ((0.25 \times 8) + (0.50 \times 8) + (0.25 \times 8)) = 2.0$

Weighted Parameter Estimate With Project - Operation Period $= 0.75\ ((0.25 \times 4) + (0.50 \times 4) + (0.25 \times 4)) = 3.0$

Total Weighted Parameter Estimate With Project $= 2.0 + 3.0 = 5.0$

For this example a value function graph was assumed where a parameter measurement of 10.0 equaled an EQ of 1.0 and a parameter measurement of 5.0 equaled an EQ of 0.5. Thus:

$$\text{"Without" EQ} = 1.0$$

$$\text{"With" EQ} = 0.5$$

Therefore, the environmental impact (EIU) on the parameter is:

$$\begin{aligned} EIU &= (PIU \times EQ_{with}) - (PIU \times EQ_{without}) \\ &= (50 \times 0.5) - (50 \times 1.0) \\ &= -25 \text{ EIU} \end{aligned}$$

To obtain the total numerical impact index for the entire project it is necessary to determine the EIU for each specific parameter and then sum over all 78 parameters employed in the EES. The Environmental Impact Index in EIU's is determined by using the following equation:

$$EIU = \sum_{i=1}^{78} Wi\ EQi_{(with)} - \sum_{i=1}^{78} Wi\ EQi_{(without)}$$

where: i = parameter index

Wi = relative importance of i^{th} parameter in PIU

EQi = environmental quality coefficient of i^{th}

parameter obtained from the parameter value function graph

A negative (-) change indicates an adverse environmental impact and a positive (+) change indicates a beneficial impact.

Weighting values, determined by Battelle, Delphi groups I and II, and the combined Delphi groups, have been reported in chapter 5. Value function graphs are presented in Appendix D. Aubrey Reservoir parameter measurements and estimates are included in Appendix E.

APPENDIX C

STATISTICAL ANALYSES

Table 12. Median Values and Sign Differences for Group I and Group II First Round Estimates

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
SPATIAL WEIGHTING ESTIMATES			
Basin Hydrologic Loss:			
Upstream	0.1	0.4	-
At Site	2.0	2.0	
Downstream	2.0	1.8	+
Biochemical Oxygen Demand:			
Upstream	2.3	1.5	+
At Site	2.3	2.0	+
Downstream	2.0	2.0	
Dissolved Oxygen:			
Upstream	2.0	2.0	
At Site	3.0	2.8	+
Downstream	2.0	2.8	-
Fecal Coliforms:			
Upstream	2.3	0.8	+
At Site	2.3	1.5	+
Downstream	2.0	1.5	+
Total Inorganic Carbon:			
Upstream	1.0	0.6	+
At Site	2.0	1.5	+
Downstream	1.0	1.0	
Total Inorganic Nitrogen:			
Upstream	1.5	1.3	+
At Site	1.9	2.0	-
Downstream	1.5	1.8	-
Inorganic Phosphate:			
Upstream	1.5	1.5	
At Site	2.2	2.0	+
Downstream	1.8	2.0	-

Table 12. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Pesticides:			
Upstream	2.3	0.8	+
At Site	2.0	1.5	+
Downstream	2.0	1.5	+
Hydrogen Ion Concentration:			
Upstream	1.0	0.8	+
At Site	1.7	0.5	+
Downstream	1.2	0.7	+
Stream Flow Variation:			
Upstream	2.0	1.0	+
At Site	1.3	0.8	+
Downstream	2.0	2.3	-
Temperature:			
Upstream	1.0	0.4	+
At Site	1.8	0.8	+
Downstream	2.0	1.0	+
Total Dissolved Solids:			
Upstream	1.8	1.8	
At Site	1.9	1.8	+
Downstream	1.8	2.0	-
Toxic Substances:			
Upstream	2.5	1.9	+
At Site	3.0	3.0	
Downstream	2.3	2.5	-
Turbidity:			
Upstream	2.0	1.0	+
At Site	2.0	1.3	+
Downstream	1.3	1.0	+
TEMPORAL WEIGHTING ESTIMATES			
Basin Hydrologic Loss:	6:1	10:1	-

Table 12. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
BOD:	5:1	5:1	
Dissolved Oxygen:	3:1	5:1	-
Fecal Coliforms:	4:1	10:1	-
Total Inorganic Carbon:	3:1	8:1	-
Total Inorganic Nitrogen:	5:1	8:1	-
Inorganic Phosphate:	5:1	10:1	-
Pesticides:	2:1	3:1	-
Hydrogen Ion Concentration:	2:1	1:1	+
Stream Flow Variation:	4:1	1:1	+
Temperature:	3:1	4:1	-
Total Dissolved Solids:	2:1	4:1	-
Toxic Substances:	2:1	10:1	-
Turbidity:	4:1	1:1	+
SCALING ESTIMATES			
Basin Hydrologic Loss: (Ratio = man made losses/annual natural discharge)			
Excellent - Good	0.15	0.14	+
Good - Fair	0.35	0.28	+
Fair - Poor	0.50	0.50	
Biochemical Oxygen Demand: (mg/l BOD_5 Sluggish Stream)			
Excellent - Good	5	5	
Good - Fair	9	10	-
Fair - Poor	21	23	-
Biochemical Oxygen Demand: (mg/l BOD_5 Swift Stream)			
Excellent - Good	6	10	-
Good - Fair	13	23	-
Fair - Poor	27	35	-

Table 12. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Dissolved Oxygen: (mg/l D.O.)			
Excellent - Good	7.9	7.0	+
Good - Fair	6.0	5.0	+
Fair - Poor	4.0	4.0	
Total Inorganic Carbon: (mg/l as C)			
Poor - Fair	10	5	+
Fair - Good	17	10	+
Good - Excellent	25	25	
Excellent - Good	45	50	-
Good - Fair	60	95	-
Fair - Poor	88	140	-
Fecal Coliforms: (MPN/100ml)			
Excellent - Good	150	175	-
Good - Fair	1000	1000	
Fair - Poor	6250	3000	+
Total Inorganic Nitrogen: (mg/l as N)			
Poor - Fair	0.25	0.10	+
Fair - Good	0.50	0.18	+
Good - Excellent	0.80	0.30	+
Excellent - Good	1.15	0.75	+
Good - Fair	2.50	3.25	-
Fair - Poor	4.50	7.50	-
Inorganic Phosphate: (ug/l as P)			
Poor - Fair	8	10	-
Fair - Good	14	28	-
Good - Excellent	20	55	-
Excellent - Good	100	100	
Good - Fair	200	450	-
Fair - Poor	450	700	-
Pesticides: (Conc. Ratio = concentration/max. permissible conc.)			
Excellent - Good	0.10	0.10	
Good - Fair	0.40	0.35	+
Fair - Poor	0.55	0.72	-

Table 12. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Hydrogen Ion Concentration: (pH units)			
Poor - Fair	5.8	5.5	+
Fair - Good	6.4	6.0	+
Good - Excellent	6.8	6.8	
Excellent - Good	8.0	8.3	-
Good - Fair	8.8	8.9	-
Fair - Poor	9.5	9.4	+
Turbidity: (Jackson Turbidity Units)			
Excellent - Good	5	23	-
Good - Fair	15	90	-
Fair - Poor	38	145	-
Stream Flow Variation, ≤2:1: (Percent of days)			
Excellent - Good	95	96	-
Good - Fair	83	90	-
Fair - Poor	45	80	-
Stream Flow Variation, 2:1-10:1 (Percent of days)			
Excellent - Good	2.0	5.0	-
Good - Fair	4.0	10.0	-
Fair - Poor	8.0	15.0	-
Stream Flow Variation, 10:1-50:1 (Percent of days)			
Excellent - Good	1.0	0.5	+
Good - Fair	2.0	1.6	+
Fair - Poor	3.0	5.0	-
Temperature: (Degress C departure from equilibrium)			
Poor - Fair	-4.0	-6.5	-
Fair - Good	-3.0	-4.0	-
Good - Excellent	-2.0	-2.0	
Excellent - Good	1.0	2.0	-
Good - Fair	3.0	4.0	-
Fair - Poor	4.0	6.5	-

Table 12. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Total Dissolved Solids:	(mg/l T.D.S.)		
Poor - Fair	15	50	-
Fair - Good	30	75	-
Good - Excellent	50	100	-
Excellent - Good	200	225	-
Good - Fair	400	500	-
Fair - Poor	600	850	-

Table 13. Median Values and Sign Differences for Group I and Group II Fourth Round Estimates

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
SPATIAL WEIGHTING ESTIMATES			
Basin Hydrologic Loss:			
Upstream	0.5	0.5	
At Site	2.0	1.9	+
Downstream	1.7	1.5	+
Biochemical Oxygen Demand:			
Upstream	1.8	1.0	+
At Site	2.5	2.0	+
Downstream	2.0	2.0	
Dissolved Oxygen:			
Upstream	2.5	2.0	+
At Site	3.0	2.9	+
Downstream	2.5	2.8	-
Fecal Coliforms:			
Upstream	2.5	1.7	+
At Site	2.5	2.3	+
Downstream	2.0	2.0	
Total Inorganic Carbon:			
Upstream	1.0	1.0	
At Site	2.0	2.0	
Downstream	1.3	1.0	+
Total Inorganic Nitrogen:			
Upstream	1.5	1.9	-
At Site	2.4	1.8	+
Downstream	2.0	1.5	+
Inorganic Phosphate:			
Upstream	1.9	1.1	+
At Site	2.5	2.0	+
Downstream	2.0	1.5	+

Table 13. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Pesticides:			
Upstream	2.5	1.5	+
At Site	2.8	2.5	+
Downstream	2.8	1.9	+
Hydrogen Ion Concentration:			
Upstream	1.0	0.8	+
At Site	1.5	1.0	+
Downstream	1.3	1.9	-
Stream Flow Variation:			
Upstream	2.0	1.0	+
At Site	2.0	0.8	+
Downstream	2.0	2.5	-
Temperature:			
Upstream	1.5	1.0	+
At Site	2.0	2.0	
Downstream	2.0	1.5	+
Total Dissolved Solids:			
Upstream	1.6	1.9	-
At Site	1.8	1.5	+
Downstream	1.9	1.5	+
Toxic Substances:			
Upstream	3.0	2.3	+
At Site	3.0	3.0	
Downstream	2.9	2.3	+
Turbidity:			
Upstream	2.0	1.0	+
At Site	2.5	1.5	+
Downstream	1.7	1.4	+
TEMPORAL WEIGHTING ESTIMATES			
Basin Hydrologic Loss:	5:1	10:1	-

Table 13. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
BOD:	3:1	10:1	-
Dissolved Oxygen:	3:1	10:1	-
Fecal Coliforms:	4:1	10:1	-
Total Inorganic Carbon:	4:1	6:1	-
Total Inorganic Nitrogen:	5:1	6:1	-
Inorganic Phosphate:	5:1	10:1	-
Pesticides:	2:1	10:1	-
Hydrogen Ion Concentration:	2:1	3:1	-
Stream Flow Variation:	5:1	2:1	+
Temperature:	3:1	5:1	-
Total Dissolved Solids:	2:1	5:1	-
Toxic Substances:	3:1	10:1	-
Turbidity:	5:1	2:1	+
SCALING ESTIMATES			
Basin Hydrologic Loss: (Ratio = man made losses/annual natural discharge)			
Excellent - Good	0.10	0.10	
Good - Fair	0.30	0.25	+
Fair - Poor	0.60	0.50	+
Biochemical Oxygen Demand: (mg/l BOD_5 Sluggish Stream)			
Excellent - Good	3	10	-
Good - Fair	7	19	-
Fair - Poor	13	30	-
Biochemical Oxygen Demand: (mg/l BOD_5 Swift Stream)			
Excellent - Good	6	10	-
Good - Fair	12	24	-
Fair - Poor	23	35	-

Table 13. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Dissolved Oxygen: (mg/l D.O.)			
Excellent - Good	8.0	7.0	+
Good - Fair	7.0	5.0	+
Fair - Poor	6.0	4.0	+
Total Inorganic Carbon: (mg/l as C)			
Poor - Fair	6	5	+
Fair - Good	15	15	
Good - Excellent	30	25	+
Excellent - Good	50	50	
Good - Fair	67	75	-
Fair - Poor	90	133	-
Fecal Coliforms: (MPN/100ml)			
Excellent - Good	100	100	
Good - Fair	1000	625	+
Fair - Poor	3000	4500	-
Total Inorganic Nitrogen: (mg/l as N)			
Poor - Fair	0.15	0.10	+
Fair - Good	0.30	0.28	+
Good - Excellent	0.55	0.40	+
Excellent - Good	1.00	1.00	
Good - Fair	2.25	2.50	-
Fair - Poor	5.00	5.50	-
Inorganic Phosphate: (ug/l as P)			
Poor - Fair	5	8	-
Fair - Good	10	20	-
Good - Excellent	20	43	-
Excellent - Good	100	100	
Good - Fair	150	300	-
Fair - Poor	400	850	-
Pesticides: (Conc. Ratio = concentration/max. permissible conc.)			
Excellent - Good	0.10	0.10	
Good - Fair	0.35	0.25	+
Fair - Poor	0.50	0.50	

Table 13. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Hydrogen Ion Concentration: (pH units)			
Poor - Fair	5.6	5.5	+
Fair - Good	6.5	6.5	
Good - Excellent	6.9	7.0	-
Excellent - Good	8.0	8.5	-
Good - Fair	8.4	9.0	-
Fair - Poor	9.0	9.5	-
Turbidity: (Jackson Turbidity Units)			
Excellent - Good	5	25	-
Good - Fair	15	100	-
Fair - Poor	28	200	-
Stream Flow Variation, ≤2:1: (Percent of days)			
Excellent - Good	95	95	
Good - Fair	83	90	-
Fair - Poor	58	80	-
Stream Flow Variation, 2:1-10:1: (Percent of days)			
Excellent - Good	1.0	3.0	-
Good - Fair	3.6	6.0	-
Fair - Poor	5.0	12.0	-
Stream Flow Variation, 10:1-50:1: (Percent of days)			
Excellent - Good	1.0	0.7	+
Good - Fair	1.5	2.0	-
Fair - Poor	2.5	4.0	-
Temperature: (Degress C departure from equilibrium)			
Poor - Fair	-4.0	-6.0	-
Fair - Good	-2.0	-4.0	-
Good - Excellent	-1.0	-2.0	-
Excellent - Good	1.0	2.0	-
Good - Fair	2.0	4.0	-
Fair - Poor	4.0	6.0	-

Table 13. (continued)

Parameter	Group I Median (A)	Group II Median (B)	Sign (A-B)
Total Dissolved Solids:	(mg/l T.D.S.)		
Poor - Fair	11	50	-
Fair - Good	25	75	-
Good - Excellent	43	100	-
Excellent - Good	150	300	-
Good - Fair	300	500	-
Fair - Poor	600	750	-

APPENDIX D

VALUE FUNCTION GRAPHS

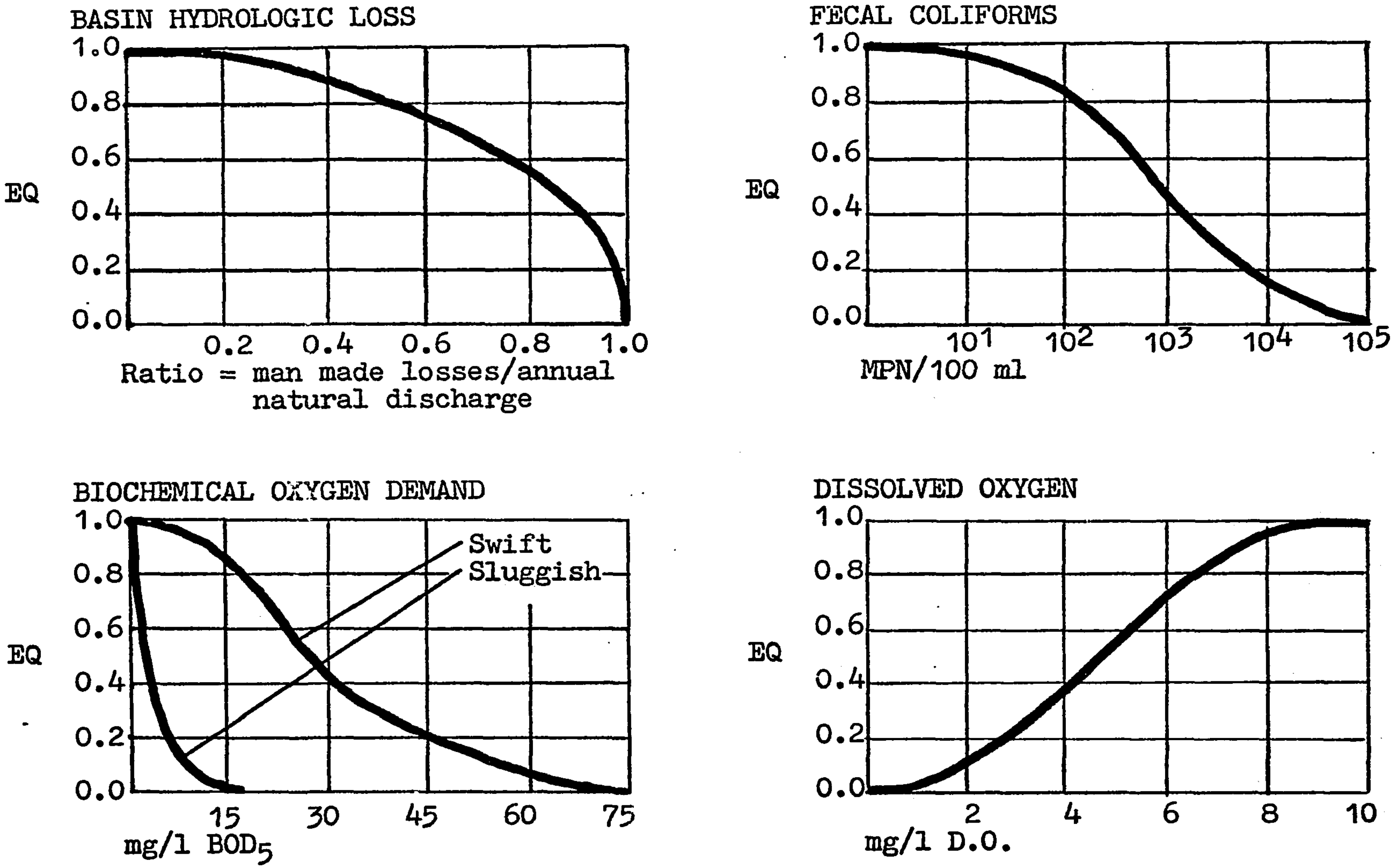


Figure 4. Battelle EES Value Function Graphs

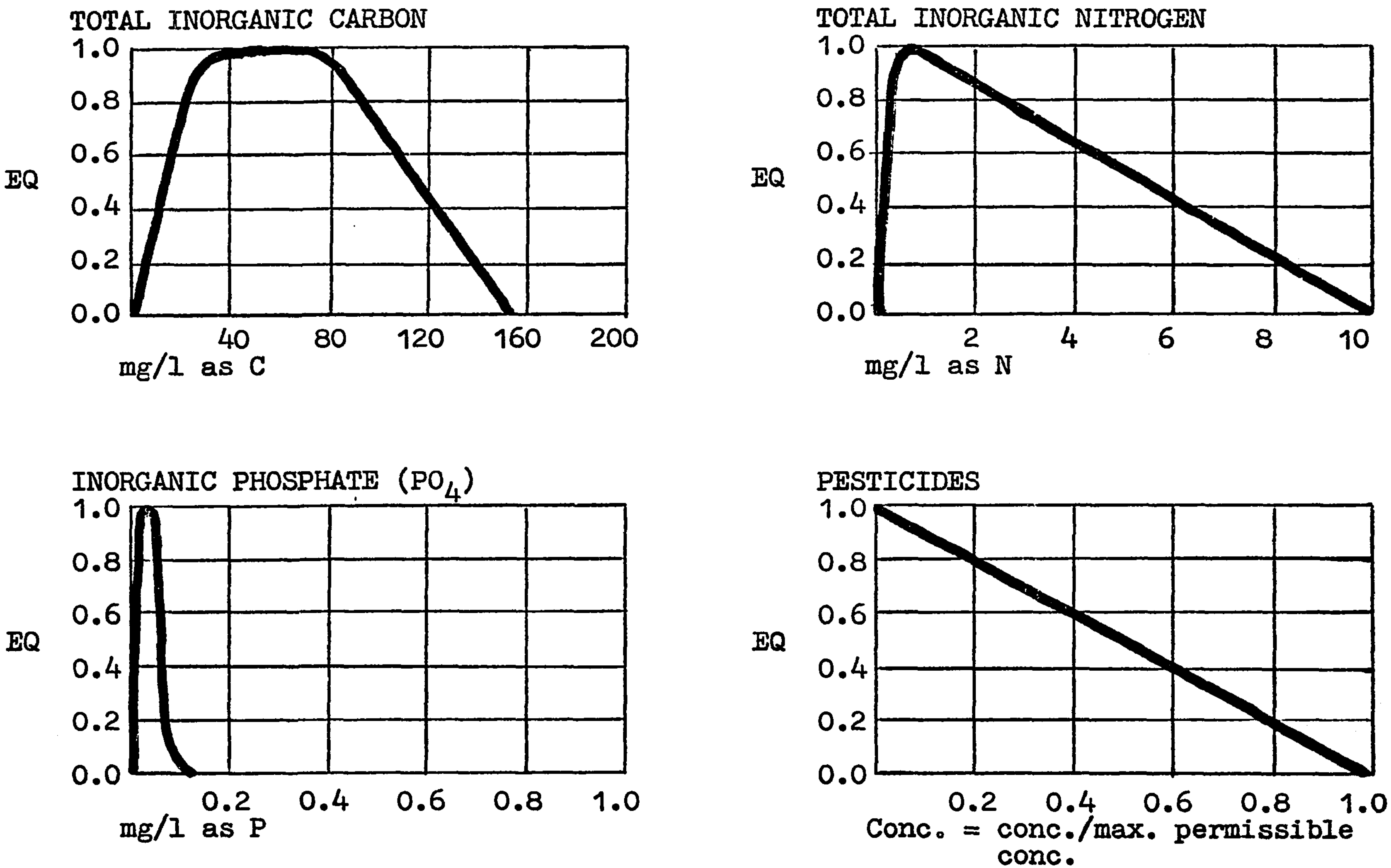
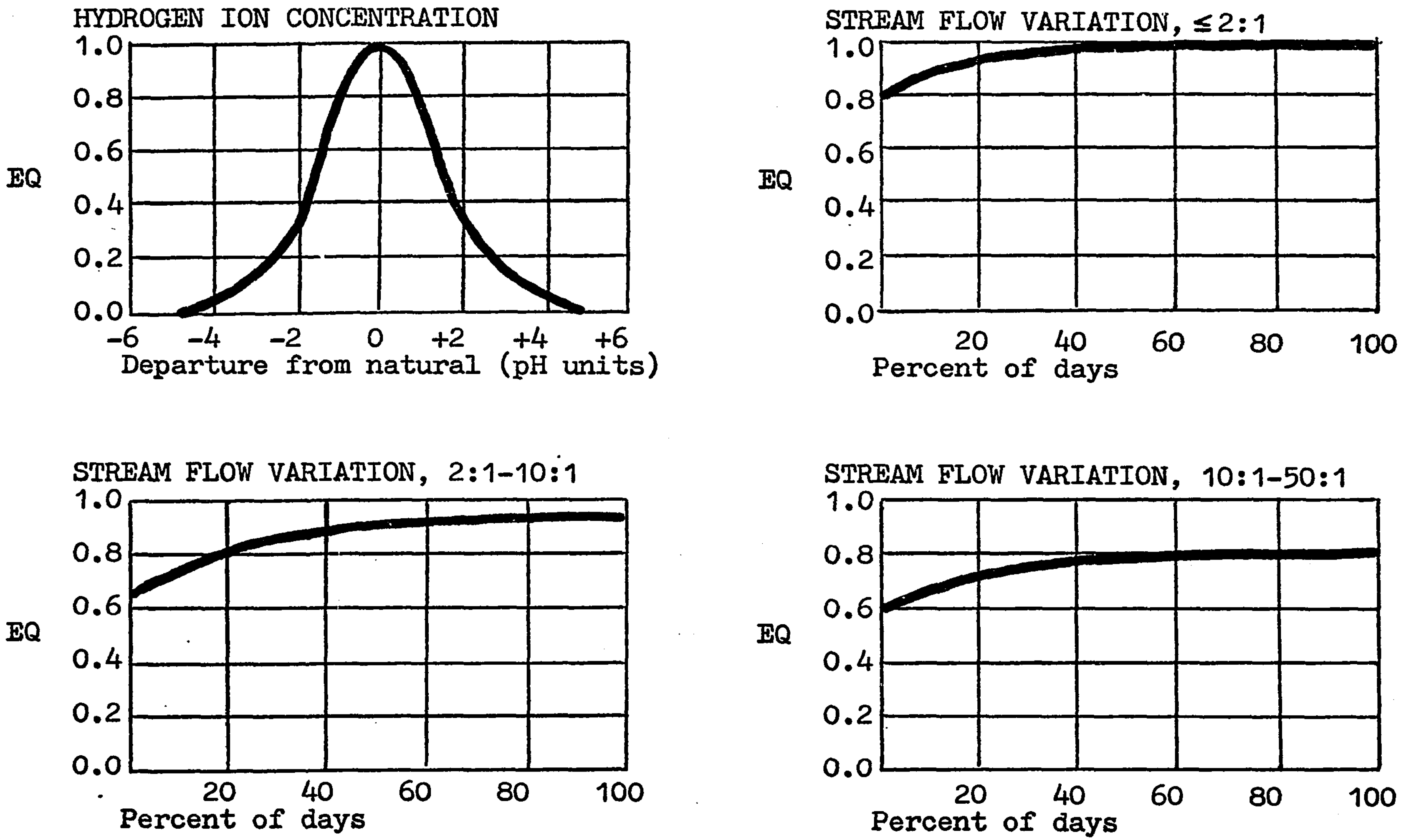


Figure 4. (continued)



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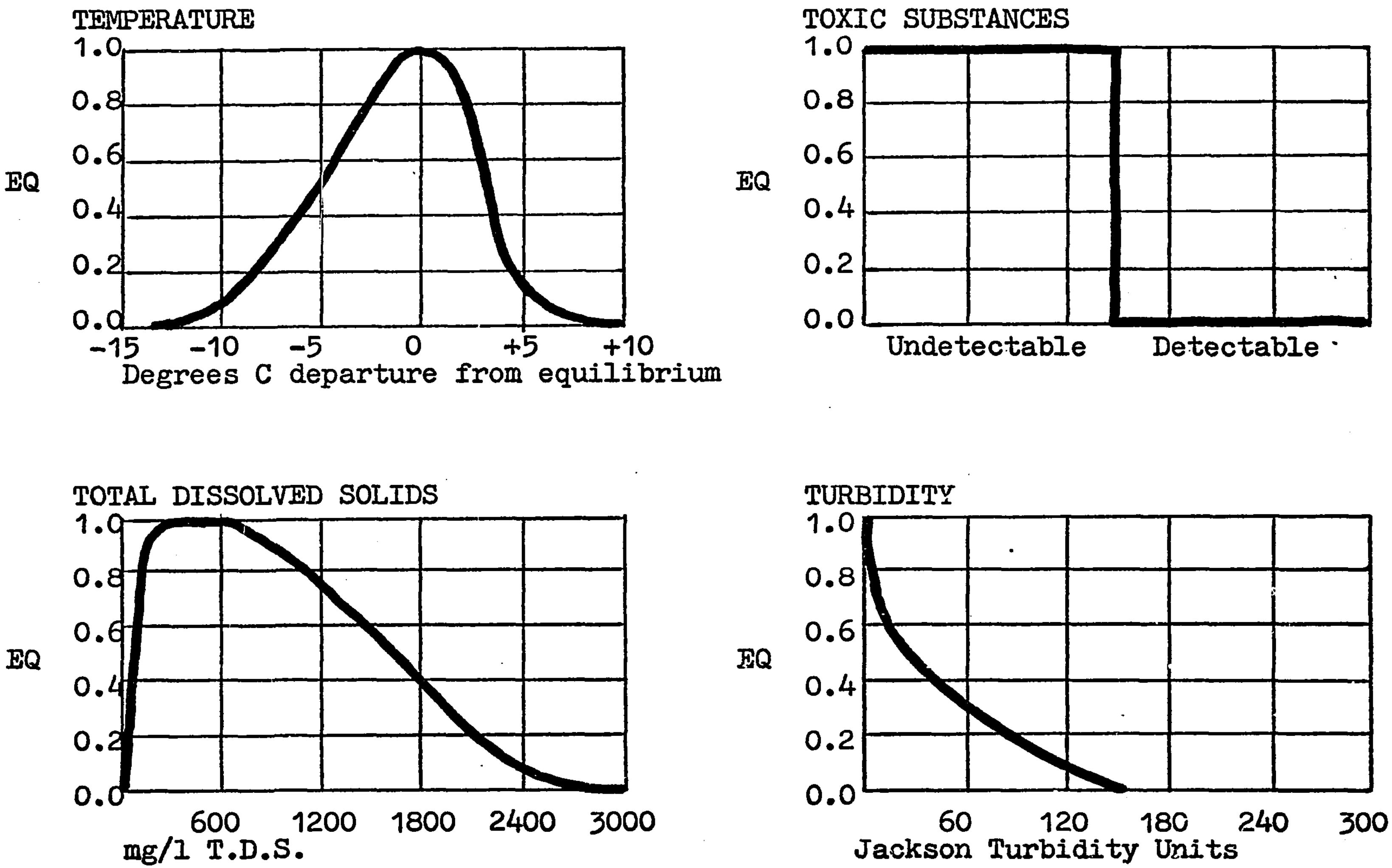


Figure 4. (continued)

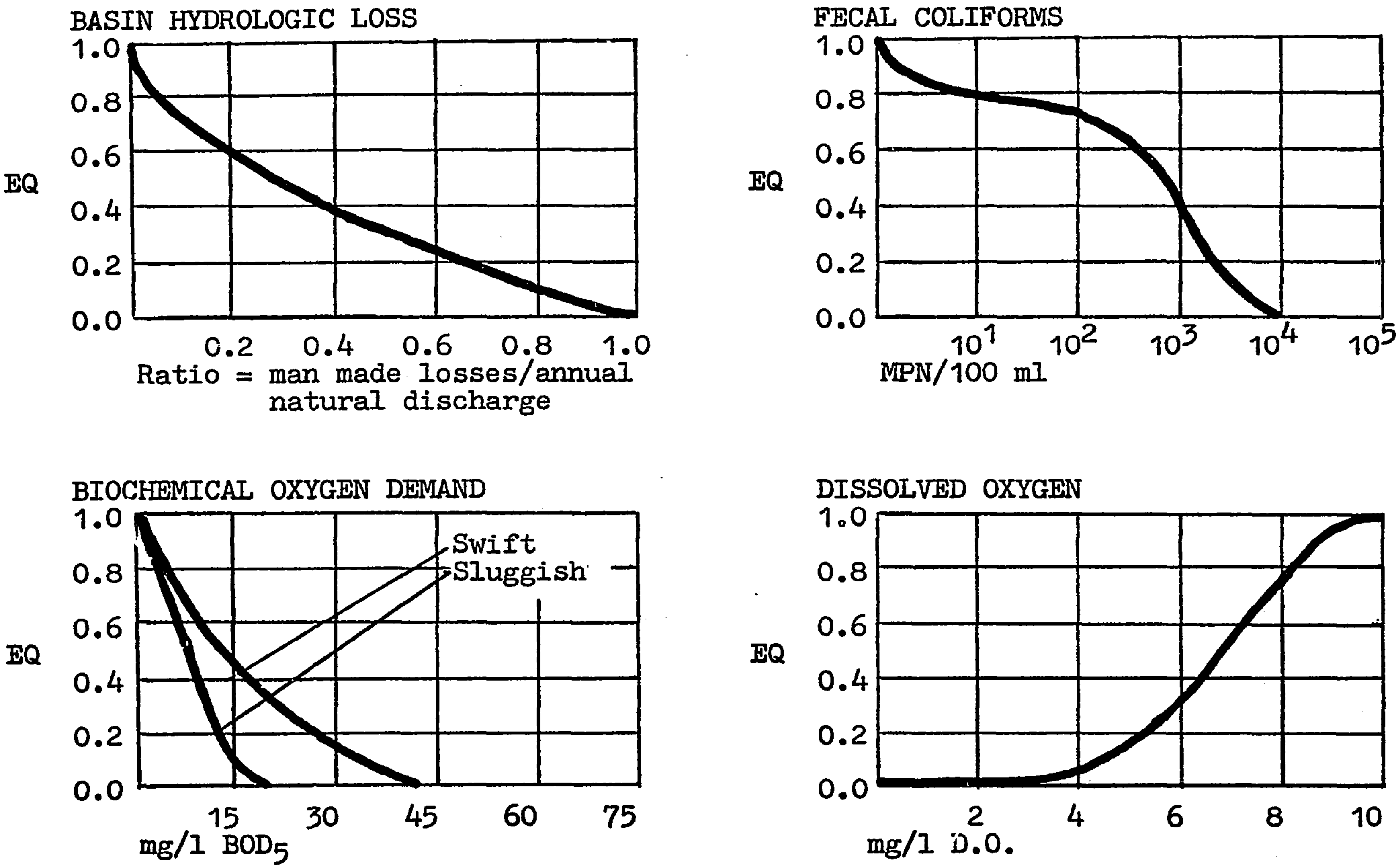
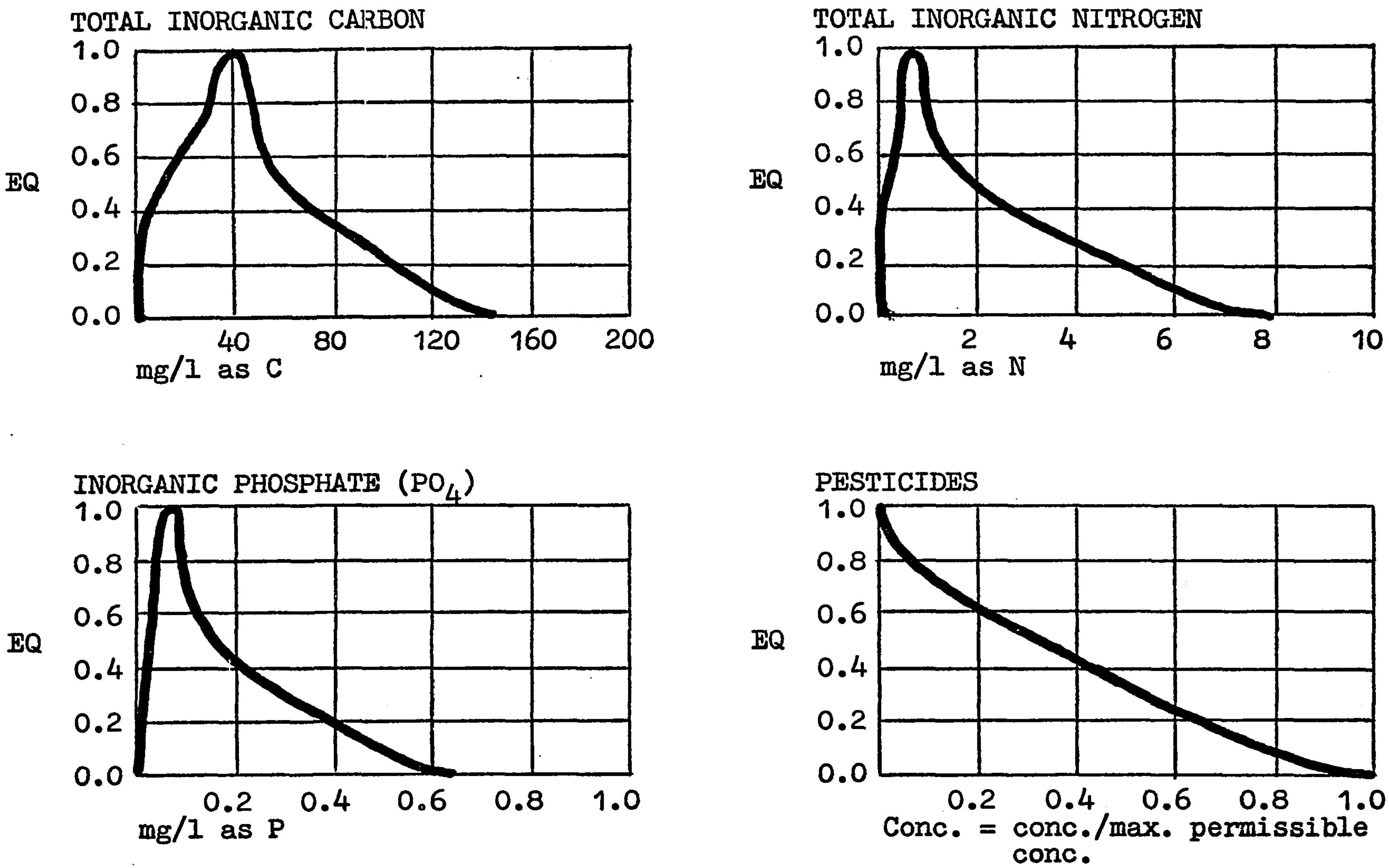


Figure 5. Delphi Group I Value Function Graphs



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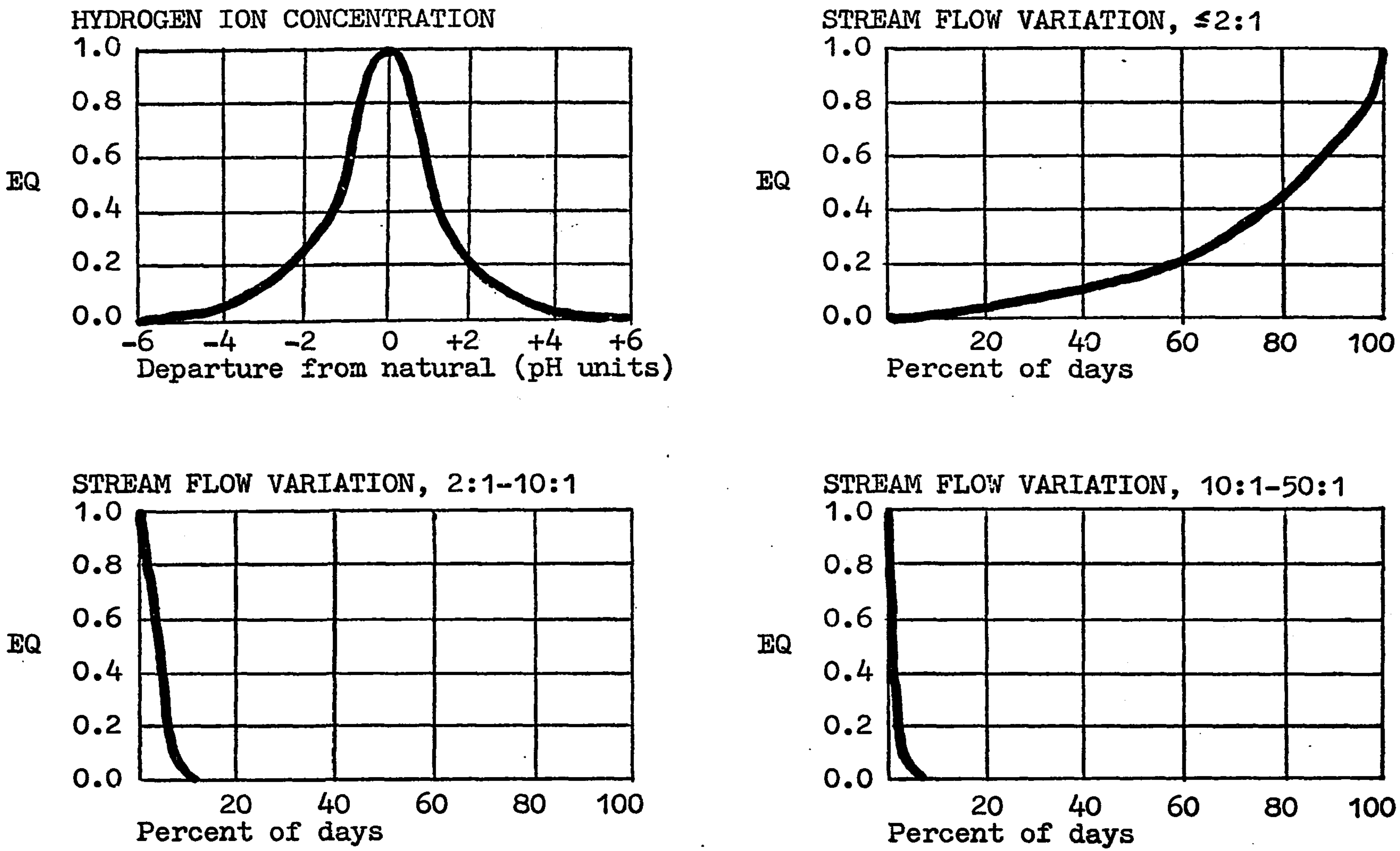

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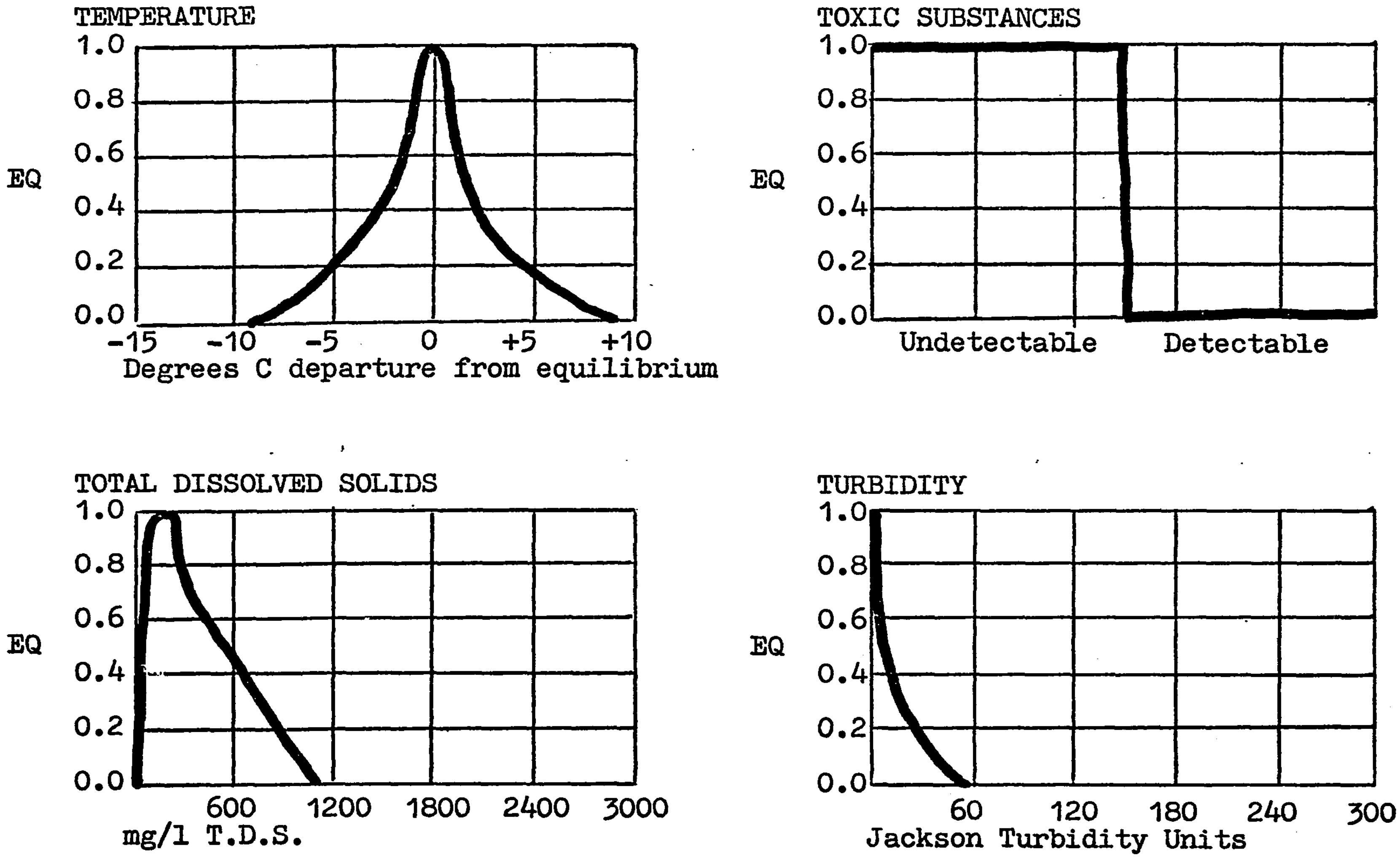

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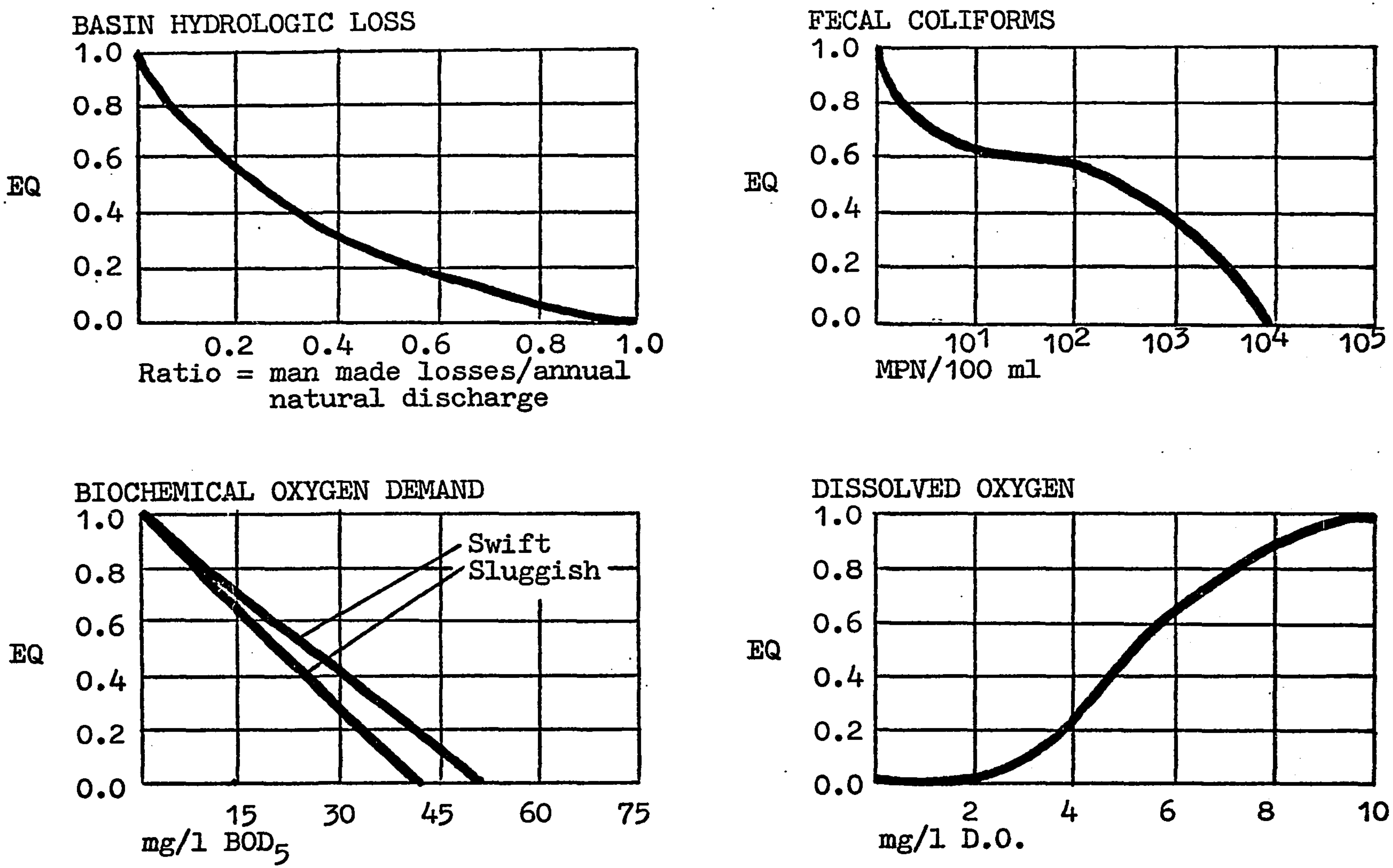


Figure 6. Delphi Group II Value Function Graphs

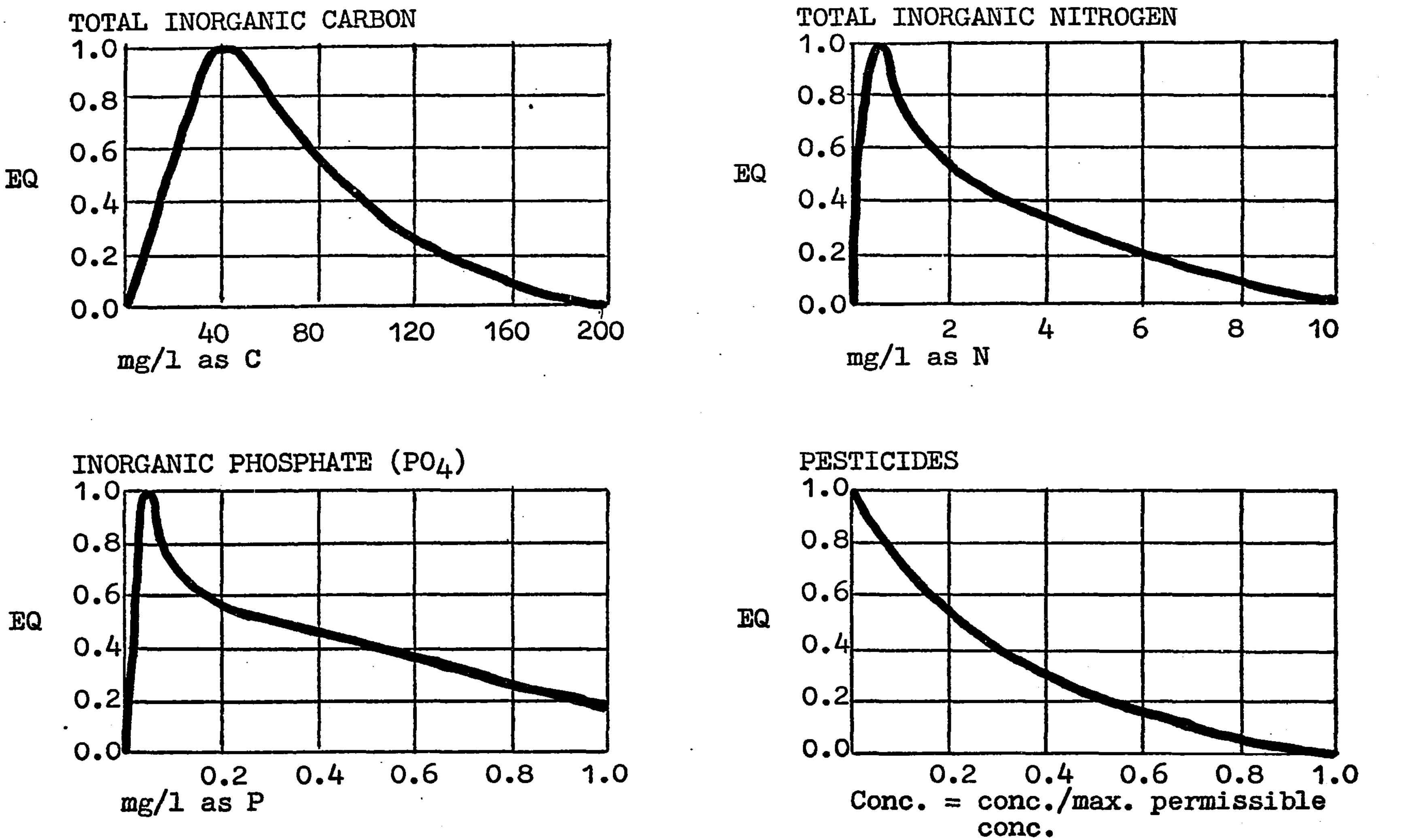
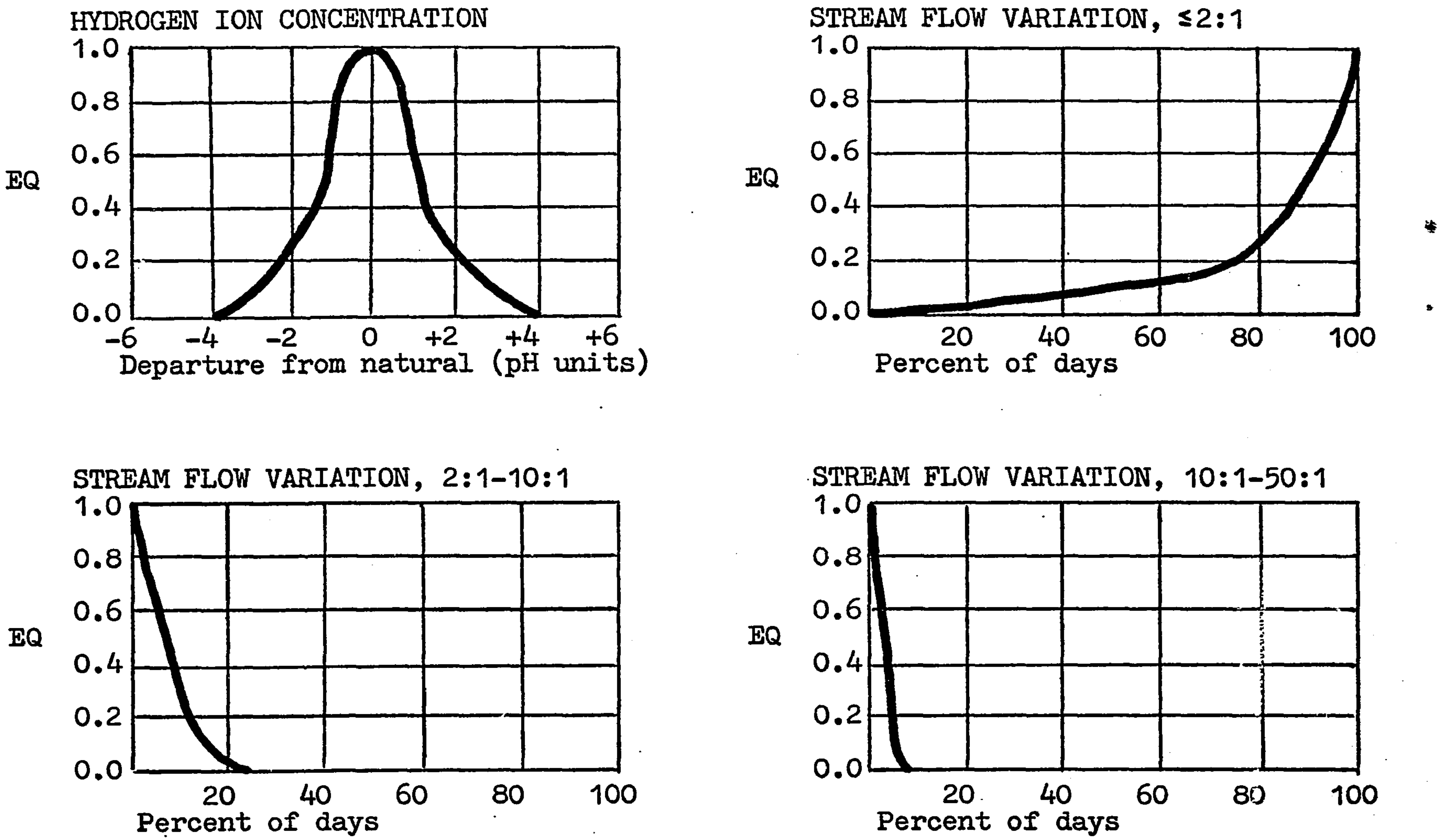


Figure 6. (continued)



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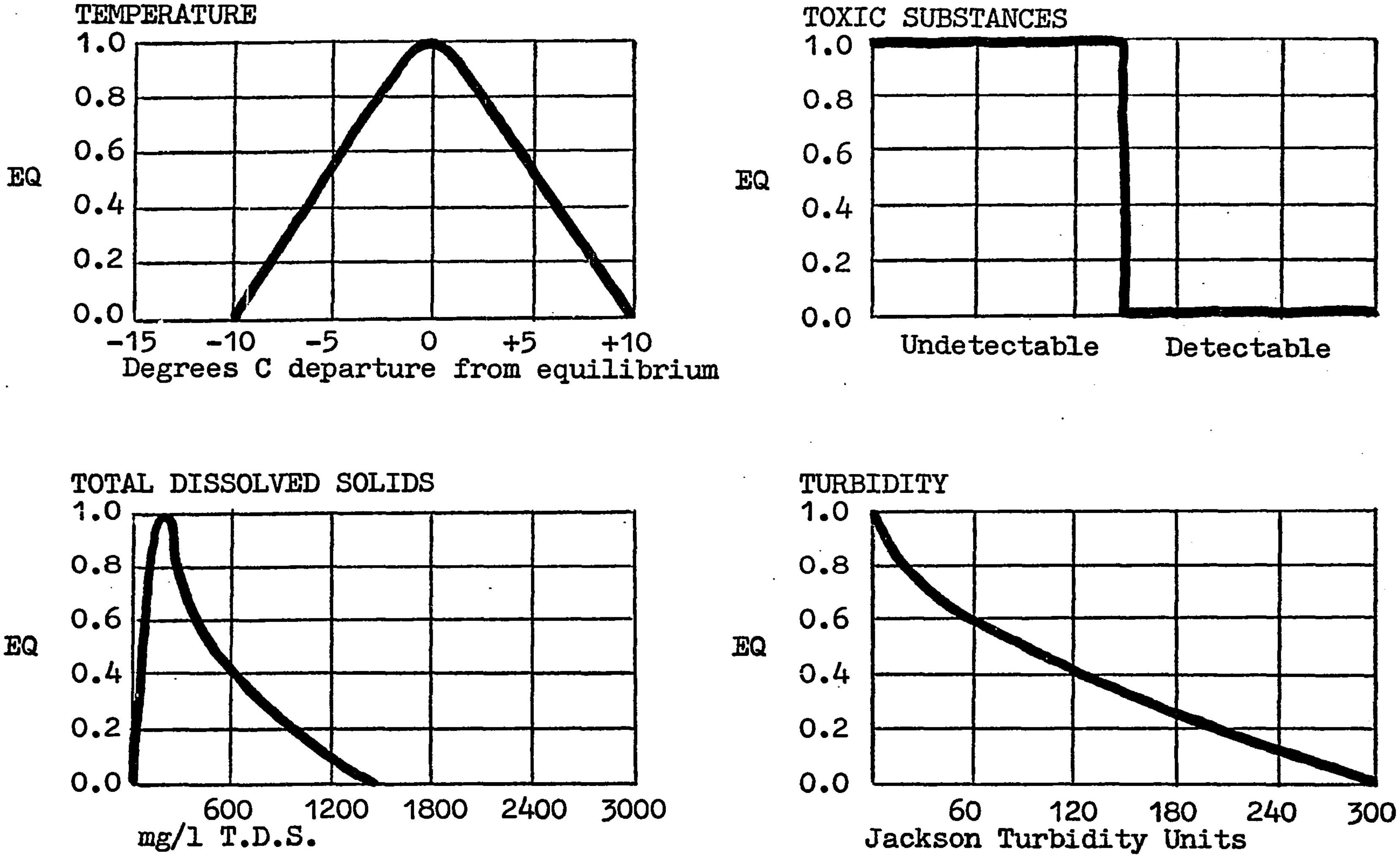

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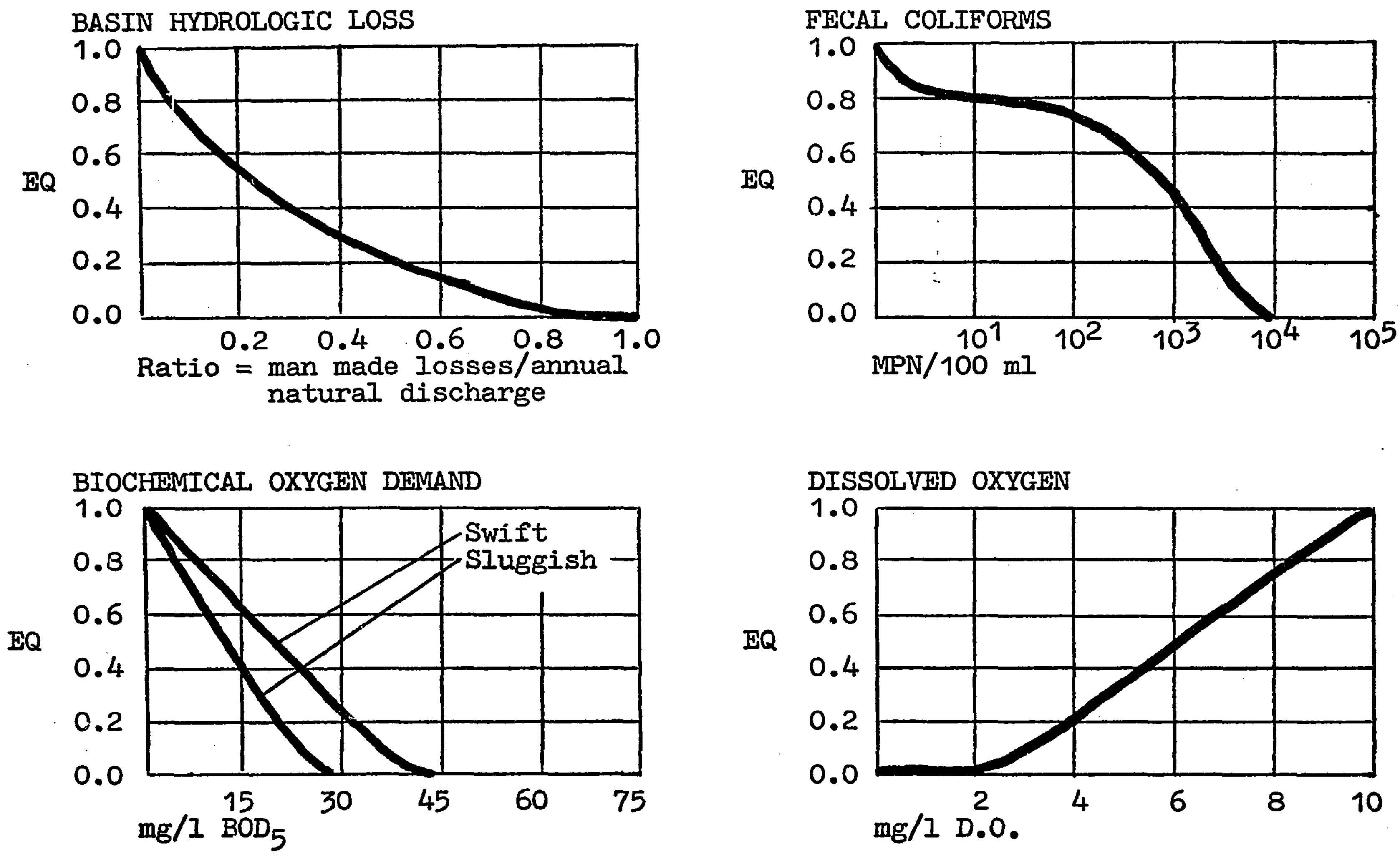


Figure 7. Delphi Combined Groups Value Function Graphs

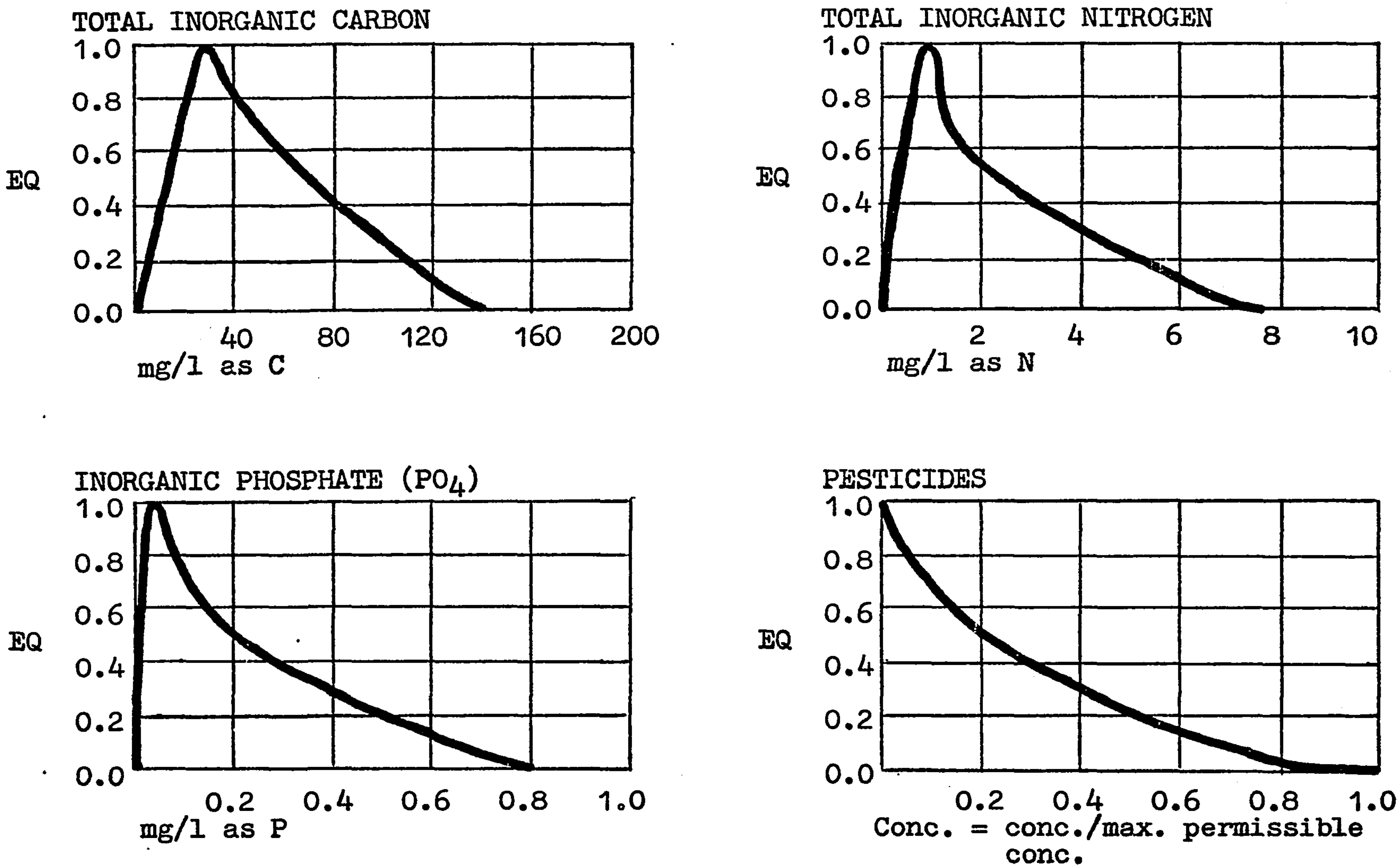
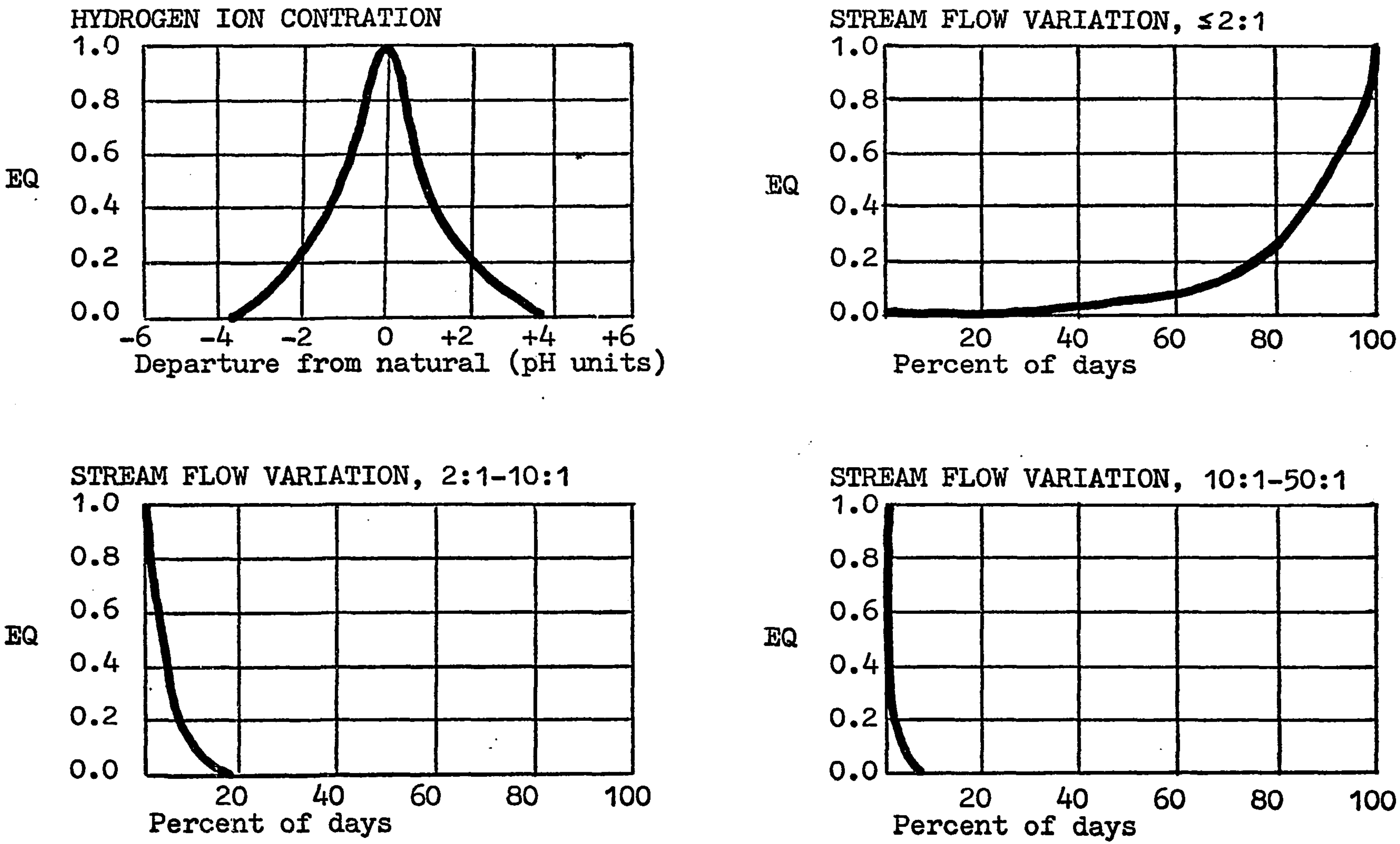


Figure 7. (continued)



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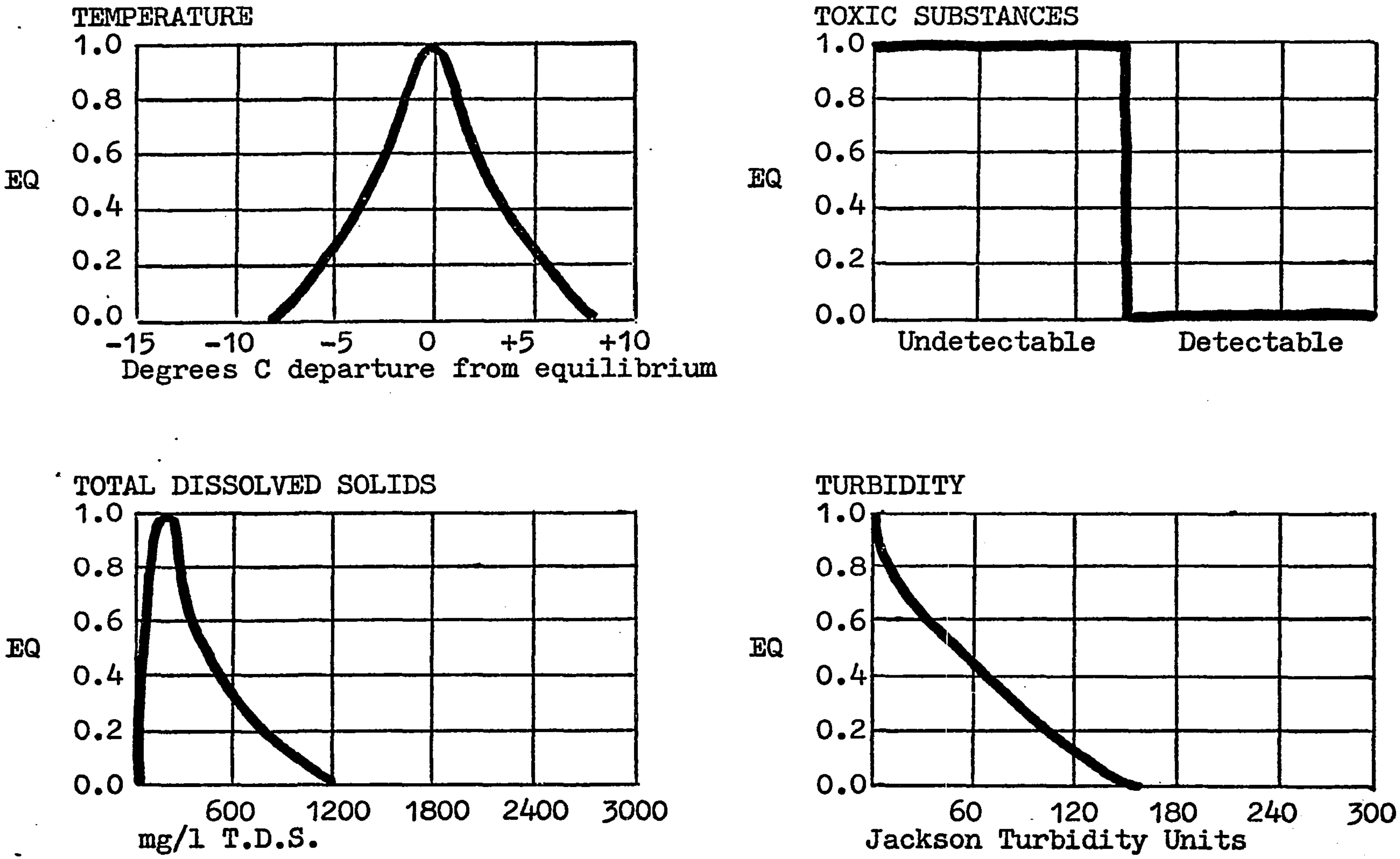

Figure 7. (continued)

APPENDIX E

AUBREY RESERVOIR PARAMETER MEASUREMENTS AND ESTIMATES

Table 14. Existing and Predicted Future Parameter Measurements for the Aubrey Reservoir Project

	Upstream	At Site	Downstream
Basin Hydrologic Loss: (Ratio = man made losses/annual natural discharge)			
With Project	--	0.146	--
With Project (construction)	--	0.161	--
With Project (operation)	--	0.146	--
Biochemical Oxygen Demand: (mg/l BOD_5)			
With Project	30	6	6
With Project (construction)	30	6	6
With Project (operation)	30	12	8
Dissolved Oxygen: (mg/l D.O.)			
With Project	7.5	7.5	7.5
With Project (construction)	7.5	7.1	7.1
With Project (operation)	7.5	7.1	7.1
Total Inorganic Carbon: (mg/l as C)			
With Project	54	54	54
With Project (construction)	54	40	40
With Project (operation)	54	80	80
Fecal Coliforms: (MPN/100ml)			
With Project	3000	3000	3000
With Project (construction)	3000	100	--
With Project (operation)	3000	1000	--
Total Inorganic Nitrogen: (mg/l as N)			
With Project	2.7	2.7	2.7
With Project (construction)	2.7	0.5	0.5
With Project (operation)	2.7	0.5	0.5
Inorganic Phosphate: (mg/l as P)			
With Project	0.5	0.27	0.27
With Project (construction)	0.5	0.06	0.06
With Project (operation)	0.5	0.03	0.03

Table 14. (continued)

	Upstream	At Site	Downstream
Pesticides: (Conc. Ratio = concentration/max. permissible conc.)			
With Project	0.5	0.5	0.5
With Project (construction)	0.6	0.6	0.6
With Project (operation)	0.6	0.6	0.6
Hydrogen Ion Concentration: (pH units)			
With Project	7.9	7.9	7.9
With Project (construction)	7.9	7.9	7.9
With Project (operation)	7.9	7.9	7.9
Turbidity: (Jackson Turbidity Units)			
With Project	120	115	85
With Project (construction)	120	250	250
With Project (operation)	120	60	65
Stream Flow Variation, Daily Max/Daily Min (Percent of days)			
	≤2:1	2:1-10:1	10:1-50:1
With Project	97	2	1
With Project (construction)	97	2	1
With Project (operation)	97	2	1
Temperature: (Degrees C departure from equilibrium)			
With Project	0	0	0
With Project (construction)	0	0	0
With Project (operation)	0	3	3
Total Dissolved Solids: (mg/l T.D.S.)			
With Project	870	688	--
With Project (construction)	870	688	--
With Project (operation)	870	688	--
Toxic Substances: (Detectable or Non-detectable)			
With Project	detec.	detec.	detec.
With Project (construction)	detec.	detec.	detec.
With Project (operation)	detec.	detec.	detec.