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International Programmes Group
National Water Research Institute
Burlington, Ontario L7R 4A6

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MANAGEMENT PERSPECTIVE

The following paper was presented to the Environmental Workshop held in Cairo, Egypt on October 7, 1992 as a part of the CIDA mission on the development of an environmental information system for the Arab Republic of Egypt. The purpose of the mission was a feasibility study to establish technical details on environmental databases currently in place in Egypt and prepare recommendations for the development of an environmental information system. Emphasis was placed on the water sector as this is the most pressing environmental issue in Egypt. In addition to the water quality and quantity aspects, discussions were also held on Land and Air issues. This paper presented to the Egyptian experts the first view of what such a system should consist of and some of the most important information channels that must be addressed. Development and transfer of information technology to the developing world is an area in which the insight, expertise, and experience that Environment Canada has developed in recent years can be brought to bear.

ABSTRACT

The development of an environmental information system necessitates a phased implementation approach. Phase I includes the elements that are traditionally viewed as comprising monitoring and assessment activities. Analysis tools for interpretive work are identified including statistics, modelling, and GIS. Phase II follows the information flow beyond project reporting to examine the process of decision making. The inclusion of other forms of knowledge beyond the strictly scientific is necessary where the development of multi-sectoral decisions must be made. Phase III extends the decision making process to the policy development and implementation field. This is accomplished by the inclusion of expert systems as advanced decision support systems which enable the manager to test various hypotheses and policy options prior to commitment. In addressing water resource issues, the importance of setting achievable and enforceable sectoral criteria and standards for industrial, agricultural, and drinking water supplies is discussed with reference to both usage and effluent criteria. Quality assurance and control is an area which must be critically addressed in any water resource project. The implementation of quality control programs must extend from the field sampling procedures and laboratory standard methods to both inter- and intra-laboratory tests and the development and maintenance of databases.

INTRODUCTION

An environmental information system (EIS) may be defined in many ways according to the perspective of individual requirements and uses. The essential purpose of such a system is to facilitate and streamline the flow of environmental information from data sources to decision makers and to provide the necessary analyses that are required to give decision makers adequate information. Such systems are traditionally viewed as comprising hardware and software components and are addressed in terms of computerization. There are many systems and approaches to environmental information processing. Geographical information systems (GIS) are widely used for spatial analysis in many areas and may be viewed as a spatially oriented EIS (Riddell, 1992). Most environmental water quality assessments whether they be undertaken in riverine or lacustrine systems principally derive numeric data gathered at a point in time and space. The problems associated with the analysis and interpretation of such data will always have temporal and spatial numerical variances to accommodate. The choice of available systems that can act as environmental information systems is quite limited as the requirements for flexibility encompassing data handling, analysis, synthesis, modelling, and graphics are demanding. Some systems are available that are designed for this type of environment (Swayne and Fraser, 1986; Swayne, *et al*, 1992). In many cases however, proposed configurations must be designed and built as specialized systems.

While there are normally three major sectors (water, air, and land) to be included in an EIS, it is not possible here to elaborate upon all of the details that are necessary for evaluation and assessment of these separate but related areas of investigation. This paper shows the major pathways required in the successful implementation of an EIS. With modifications related to specific sectoral characteristics, the structure of an EIS will provide the necessary framework for development.

The overall view of the components of an EIS is quite broad. The system begins with the requirements for data gathering and monitoring, moves through analysis and interpretation and leads on to decision support systems. Due to the complexity of implementing such a system it is clear that a phased approach is the most suitable strategy to follow. Beginning with a small implementation that is application driven and identifying significant milestones in development.

ENVIRONMENTAL INFORMATION SYSTEM -- PHASE I

Phase I of an EIS is concerned with primary activities of scientific sectoral agencies whether they be water, air, or land related. Monitoring programmes are designed to provide data on specific issues of concern. The structure and development of these monitoring programmes will be specific to the requirements of the issues under study and their design should be primarily the responsibility of the appropriate sectoral agency. In designing sectoral application projects, consideration must be given to the future flow of data within an EIS. Data produced must meet the requirements of an EIS structure in each phase (Figure 1).

Although commonality of project structure is a worthy goal, it is not always practical in multi-disciplinary studies. Compatibility of data however, and the ability to exchange data and bring it into an EIS are absolute requirements for a successful project. To achieve this participants must be informed of the input requirements for data within an EIS. In the early stages of implementation representatives from participating groups must work together to build the initial EIS system. This will necessitate coordinated support and funding.

Quality assurance and quality control in all aspects of sampling, analysis and storage of the data, must also be addressed. Quality assurance starts with training in field sampling procedures. Laboratories must be using acceptable standard methods of

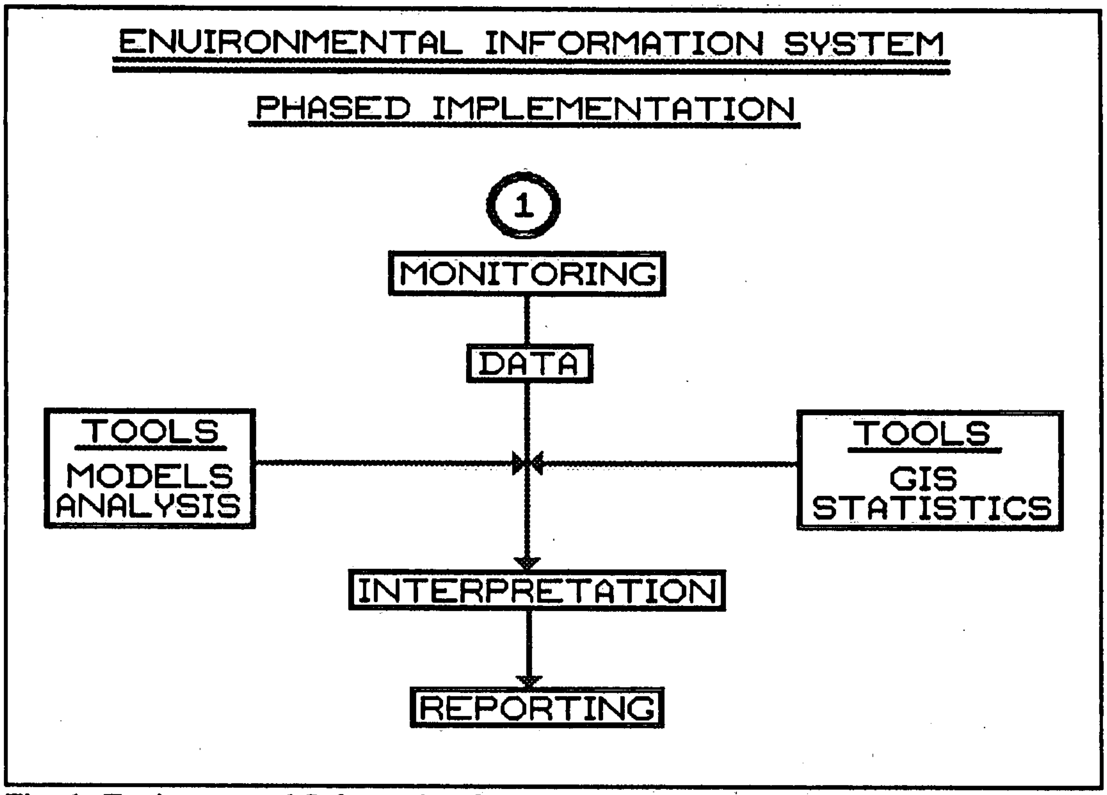

Fig. 1: Environmental Information System Structure, Phase 1

analysis and be actively involved in both intralab and interlab quality assurance testing. This topic will be explored in more detail later.

Once data has been obtained, many tools may be applied to assist in interpretation. The tools used may consist of a wide variety of systems ranging from simple statistical procedures, database and spreadsheet manipulations, and GIS tools, to sophisticated simulation and forecasting models. Such tools may form a component of an EIS and their attributes and requirements must be carefully considered. It is the responsibility of an analyst to use the best tools available to a study. With the selection and application of suitable tools, data interpretation proceeds and reports and/or scientific papers produced and published. Figure 1 depicts this component of an EIS. Many assessment projects and studies end at this point. Within an EIS however, activities have just begun.

ENVIRONMENTAL INFORMATION SYSTEM -- PHASE II

It is through the interpretive phase that data are converted to information and the process of evaluation and decision making really begins. The bringing together of information at the project level may be isolated to the specific purposes of a study. Very often however, evaluations must proceed at the multi-disciplinary and multi-sectoral level in order to enable managerial decisions to be made for a wider scope of environmental issues (Figure 2).

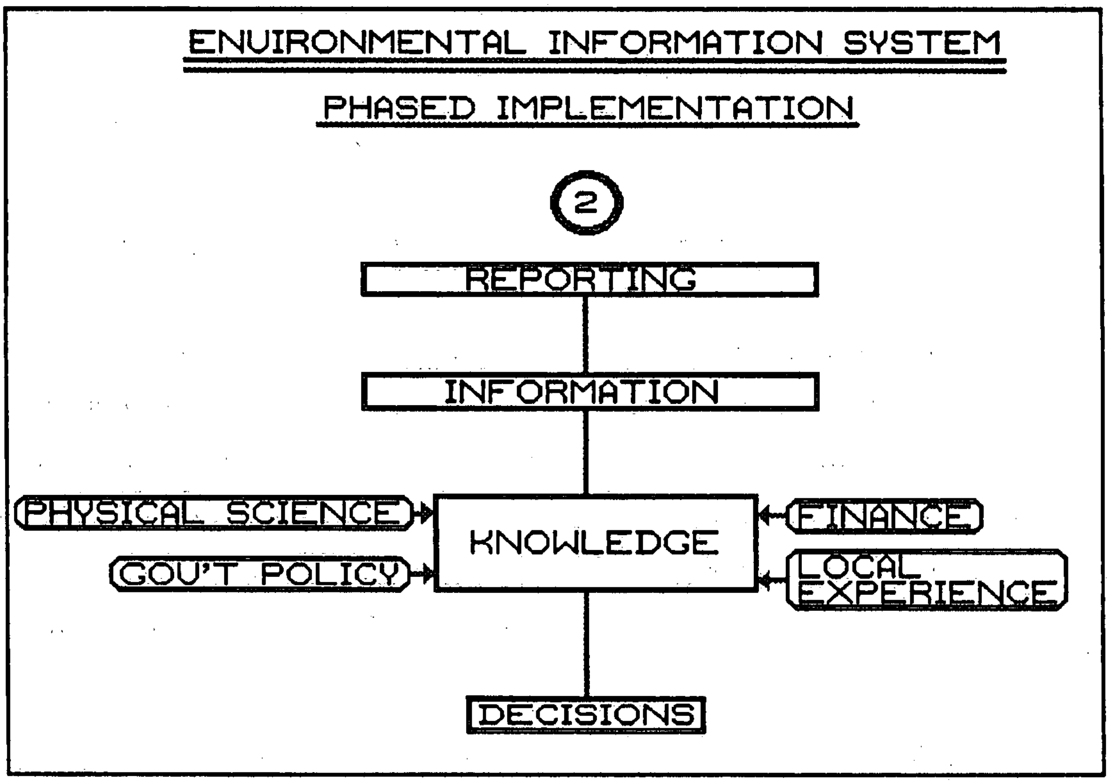

Fig. 2: Environmental Information System Structure, Phase 2

Many fundamental considerations must be taken into account in order to develop decisions based upon provided information. In environmental studies, obviously knowledge of the physical, chemical and biological sciences are required. Other knowledge factors such as government policy, financial constraints, and special factors related to local knowledge should also be brought together. It is this body of knowledge that enables the decision making process to proceed.

Although it may be argued that decisions are made at many points along the way, an environmental information system channelises the flow of information and knowledge in a structured manner. Decisions that are made may also include modifying factors to the EIS procedures themselves.

ENVIRONMENTAL INFORMATION SYSTEM -- PHASE III

The eventual goal of an environmental information system is to facilitate the development and implementation of sound environmental policy. Phase III involves the conversion of decisions regarding environmental information into policy (Figure 3). Developed policies may be made at the local, regional or national level. At this point in the phased implementation of an EIS the field of advanced decision support systems can be introduced.

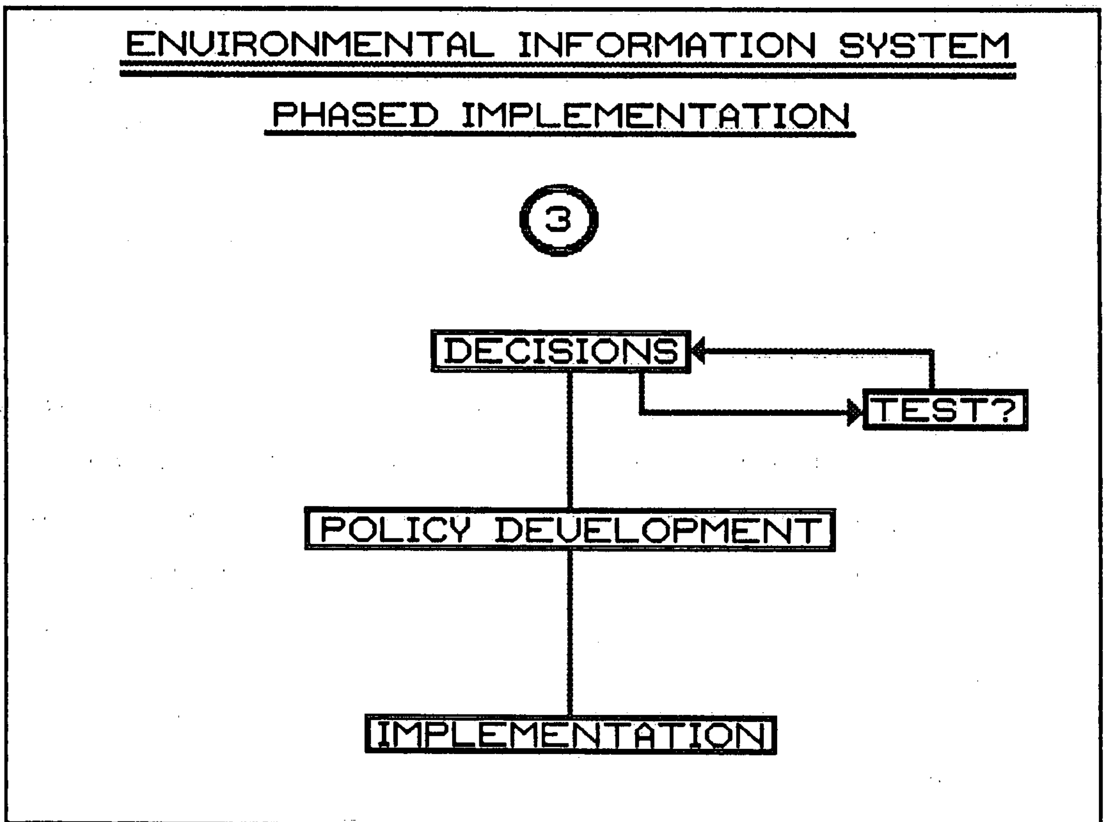

Fig. 3: Environmental Information System Structure, Phase 3

Computer systems using expert systems logic can be employed to allow for testing of hypothetical policy implementation. By testing decisions prior to setting policy the manager can test and adjust policies, including both financial and scientific factors before having to actually implement a policy. Optimization of alternatives can help in making decision and policy development more quantitative and reduce risk by providing confidence levels on judgements. This type and level of decision support system is quite advanced and is not envisioned to be part of an initial EIS installation. Such systems can be added in a modular form as familiarization and maturity in decision support technology develops.

Following implementation, it is essential that a continuous feedback of information be channelled to all participants in an EIS application. This will ensure that procedures currently employed may be upgraded as an EIS becomes better understood and that participants can see clearly the benefit of their participation.

Looking at the entire structure of a multi-sectoral information system need not be intimidating (Figure 4). The essential elements of data and information required already exist. What is required is a framework to build upon and the vision and drive to implement a fully integrated system. The provision of technology, although important, will not assure the success of an EIS. Infrastructure adjustments designed to provide coordinated activities are sometimes required.

DECISION SUPPORT SYSTEMS

Decision support systems may be viewed at many levels. The decision maker may simply look upon a table of data or a series of graphs as a decision support system. Factually, this is correct. What is envisioned for an EIS, however, is a systematic approach to providing appropriate synthesis of information gathered from many sources and sectors. The task of information integration is where a good decision support system can be of immense benefit.

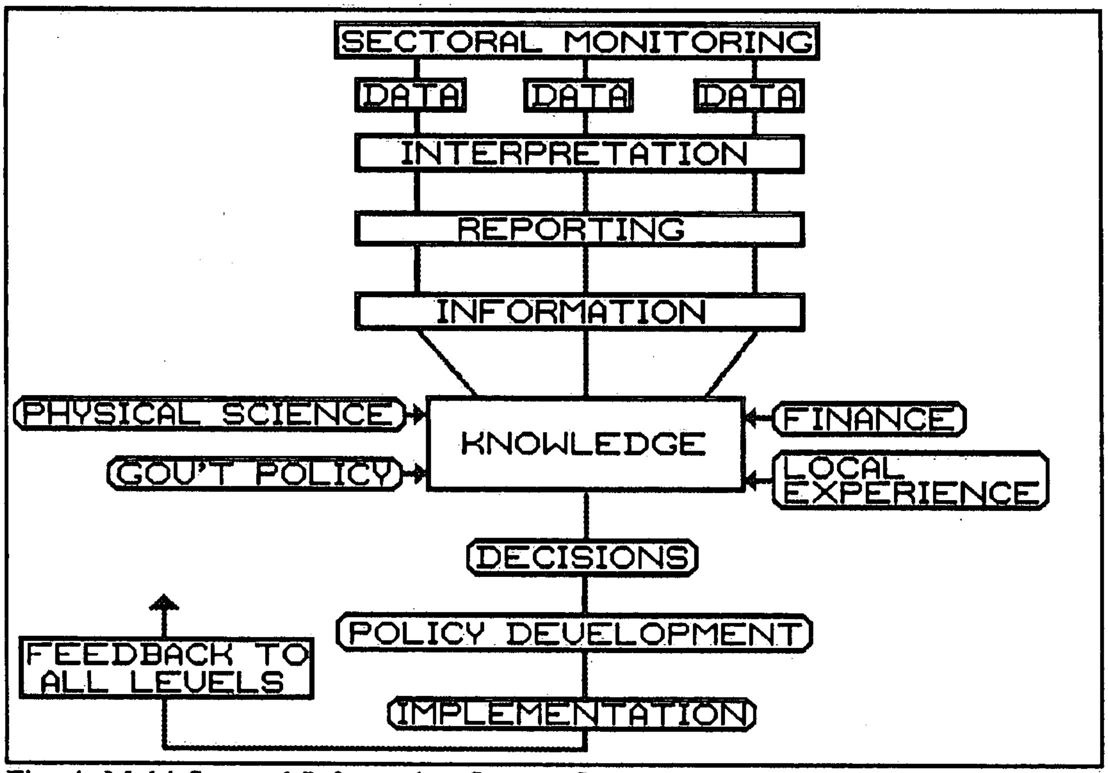

Fig. 4: Multi-Sectoral Information System Structure

Traditional interpretive tools such as spreadsheets, database manipulations, statistical analyses and GIS units continue to be important elements in the analysts tool box. It is possible that as an EIS develops over the years that sufficient scope may be obtained to allow even more sophisticated tools such as expert systems to be brought in. The use and application of expert systems to assist in decision making has been discussed by Davies (1986) and further advances in environmental applications of expert systems by Lam *et al* (1990). With such software systems it becomes possible to interrogate various decision and policy options through simulation. The inclusion of multi-factored analyses including cost/benefit and socio-economic information will significantly enhance decision support systems and allow for larger, more complex and perhaps difficult assessments to made effectively and efficiently. Figure 5 depicts the schematics of an advanced decision support system. Sectoral information produced in the interpretive phase of studies must be synthesized and integrated along with other inputs such as statistics, modelling and forecasting. The final product of an EIS decision support system is a firm basis including all necessary components for rational decision making.

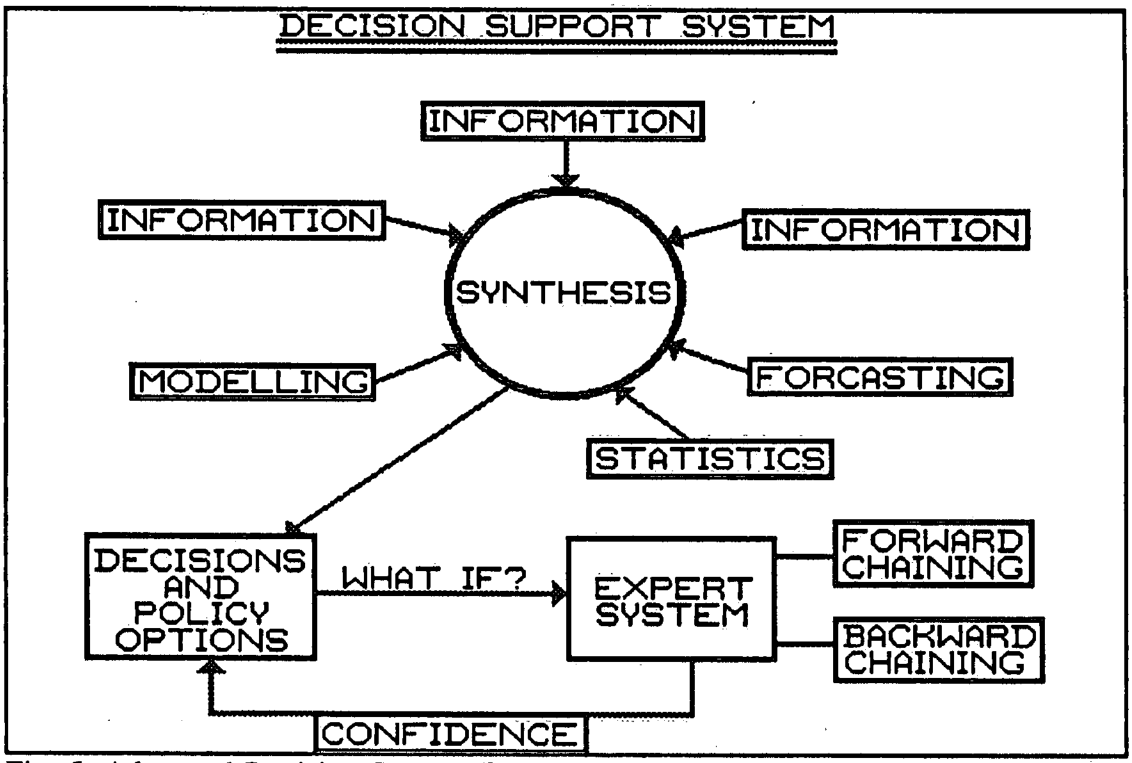

Fig. 5: Advanced Decision Support System Construct

In an advanced EIS version, expert systems technology can be applied in which decisions can be evaluated using both forward and backward chaining techniques. Simply put, forward chaining assesses decisions and conditions and makes a recommended conclusion. Backward chaining assesses a conclusion and identifies the pathways of decisions and conditions that would be required to achieve the conclusion.

WATER RESOURCES

All water sector assessments are concerned, essentially, with two categories - water quantity and water quality. Within these two broad areas there are primarily three sectors to be considered, industrial, agricultural, and municipal. Doubtless, there are other sectoral concerns but these three are the major areas of concern.

Within each sector there are standards and criteria for both usage requirements and effluent restrictions. It is crucial that these standards and criteria be clearly defined, understood and adhered to (Figure 6). Where necessary sufficient legislation and enforcement activities must be associated with these standards. The most stringent criteria for use is that of drinking water. This is true independently from the source of water, whether it be from a treated source in a city or from a hand worked pump with groundwater as source. In some instances general practices of the population may be an impediment to achieving good quality water. In such cases a broad based public educational program should be considered.

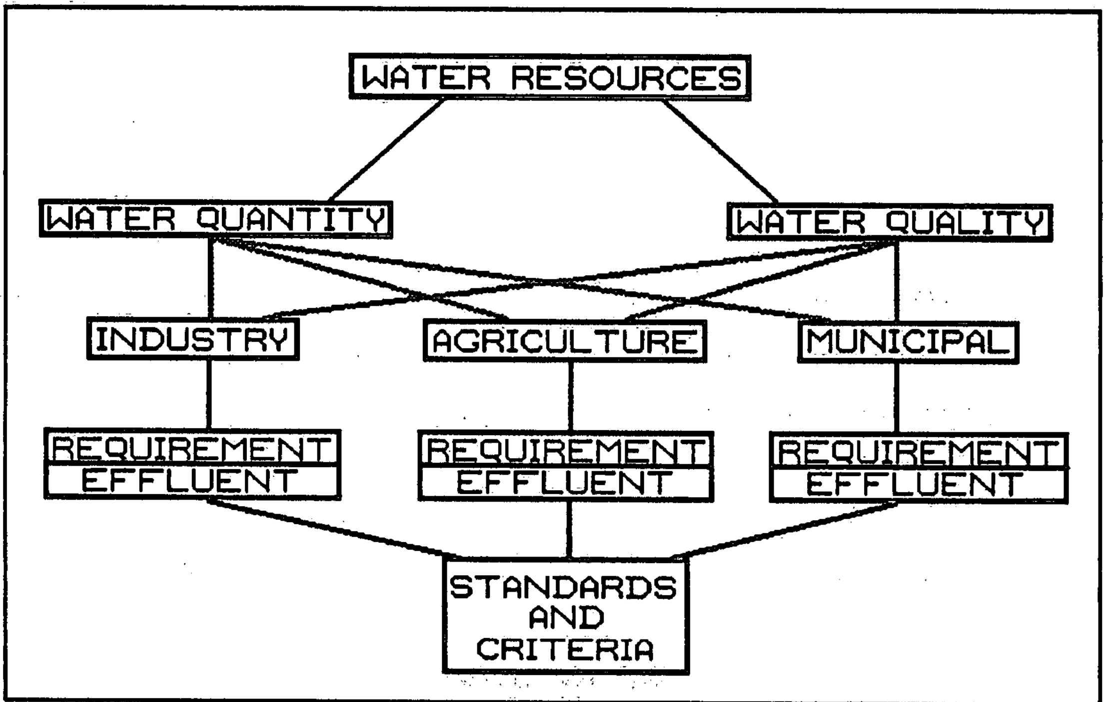

Fig. 6: Structure For Requirements and Restrictions Criteria

Agricultural requirements are normally less strict for usage criteria, but where water courses receive agricultural effluents followed down stream by intakes for potable water supplies, sufficient standards must be in place to allow for continued usage of the water.

Industrial requirements are typically the lowest for usage quality criteria, but effluent standards must be necessarily the most stringent. Significant dumping of industrial waste water to river receiving waters presents an ever increasing risk of significant water degradation.

Standards that are enforceable must be imposed and enforced. If such standards are difficult to impose due to socio-economic factors then standards should be imposed in a steadily incremental manner to allow for a reasonable time schedule for adherence. There is no point in imposing a final criteria which cannot be met and then not entering into enforcement activities because the criteria itself cannot be enforced. The final desired criteria should be stated clearly with a schedule of compliance set and agreed upon.

DATA QUALITY

A very important aspect of an EIS is the element concerned with data quality and quality control. The primary concern here begins with the gathering of samples from the field. Regularized sampling procedures taking into account the type of parameter(s) to be analyzed for should be standardized. The adoption and implementation of laboratory standard methods that are agreed upon and accepted by participating laboratories in an EIS process must be developed. Intralab and interlab comparison studies should be established as a routine operative activity. Database development and maintenance is included as a part of the data quality requirement as this item is critical if the flow of data and information within an EIS is to function properly (Figure 7).

If the data being provided to an EIS is of questionable quality the results obtained by the most sophisticated computer system will also be questionable. Significant time, training and effort must be placed at the fundamental primary data sampling and analysis activities of the agencies and institutions providing data to an EIS. A very important part of this activity is the training, support and maintenance of skilled personnel. To enable and maintain sources of good quality data and to enter, edit, and maintain these data in a readily usable form, people who have abilities to provide these data must be developed and funded at a level that will encourage them to continue in their roles. This training and funding element should be considered as a requirement for the successful implementation of an Environmental Information System.

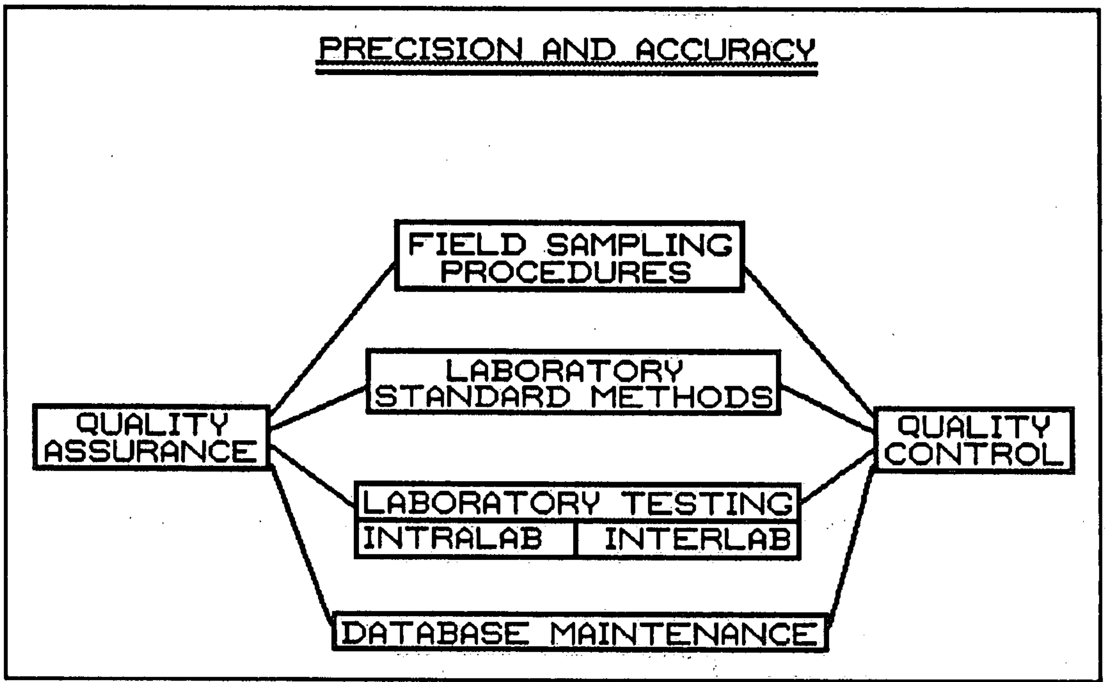

Fig. 7: QA/QC factors to be considered in EIS construction

CONCLUSION

The final stage in the implementation of an EIS and in fact the product of these activities, is the development of new policies designed to improve environmental conditions on a multi-sectoral, multi-disciplinary basis. By embarking on this project an agency is committed to streamlining the environmental activities in both the research and operational areas of environmental assessment. The task is a large one that requires dedicated funding and institutional support at many levels of government. The end product will provide managers and decision makers at all stages of the planning, implementation, and evaluation of multi-sectoral / multi-disciplinary environmental studies with a solution to handling the ever increasing and complex issues facing them.

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