PROCEEDINGS OF UNIVERSITY SEMINAR ON POLLUTION AND WATER RESOURCES

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NEW JERSEY GEOLOGICAL SURVEY

PROCEEDINGS OF

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Volume XII 1978-1979

by

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This volume of the Proceedings is dedicated to
the memory of Hugh Brockwill Ritman, former Director of Administration,
International Bank for Research and Development, Washington, D.C.,
and cofounder of the University Seminar Movement 1967 to 1980.

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INTRODUCTION

In the twelfth academic year, the Seminar was oriented toward national and regional water quality improvement programs including better use of the available water. Furthermore, tidal zone mapping and related topics were discussed and analyzed together with nation-wide problems caused by inefficient land records and surveys.

The Annual Meeting in Washington, D.C. was again held in the Cosmos Club, Washington, D.C. with the U. S. Geological Survey as host. Improving national water-quality monitoring data was the basic theme.

The most important activities of the Seminar, besides its regular meetings, can be summarized as follows:

(1) On March 2, 1979 in Reston, Virginia, U. S. Geological Survey celebrated its 100 year anniversary and the Seminar was invited to participate in the celebration.

(2) Department of Agriculture and Water Resources Planning of the Mexican Federal Government invited the Seminar representatives to participate in the III World Congress on Water Resources on April 23-27, 1979 in Mexico City. Seven members of the Seminar accepted the invitation and delivered papers on various water resource problems. The Secretary and Undersecretary of the Mexican Department of Agriculture and Water Resources expressed their interest in the water related problems of the Northeastern United States and agreed to exchange ideas in water resources planning in our Seminar during their planned visit in the academic year 1979-1980.

(3) The lectures of the Seminar also preserved their international character in the past academic year. The speakers who presented papers, besides members of the Seminar from the United States, were from Asia (1), Europe (2) and South America (1).

Finally, the Editor of the Proceedings together with the Steering Committee of the Seminar wish to express their appreciation to all members contributing articles and giving lectures. Only their unselfish effort is reflected in this volume. The publication was made possible by the generous assistance and cooperation of the U. S. Department of the Interior--U.S. Geological Survey and the State of New Jersey--Department of Environmental Protection, Bureau of Geology and Topography.

George J. Halasi-Kun
Chairman of the
University Seminar on
Pollution and Water Resources
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ENVIRONMENTAL HEALTH AND TECHNICAL COOPERATION AMONG DEVELOPING COUNTRIES[1]

by

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[1]From a paper presented at the XVI Congress of the Inter-American Association of Sanitary Engineering (AIDIS) held at Santo Domingo, Dominican Republic, on 19-24 February 1978. Also appearing in Spanish in the Boletin de la Oficina Sanitara Panamericana, 1978.

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The subject of technical cooperation between developing countries has attracted growing attention in recent years. The account presented here summarizes PAHO's efforts to promote such cooperation in the field of environmental health.

Introduction

The concept of technical cooperation among developing countries is adding a new dimension to international cooperation for economic growth and development. This concept, sometimes referred to as "TCDC," has been defined as "collective self-reliance and mutual support among developing countries" (1). Stated more fully, this definition becomes "the sharing of capacities and skills among developing countries--embracing programs, projects, and activities in which such inputs as know-how and expertise, consultant and subcontracting services, training facilities, equipment and supplies, and... information are provided by developing countries one to another."

The concept takes on added significance if we consider that during the next few decades billions of dollars will be invested in social, industrial, and resource development projects. If the experiences and, I might add, the mistakes of the highly industrialized nations are any indication, the rapidly developing nations will have to take steps to protect their societies from the preventable unwanted side-effects that technology and industrialization can bring. To accomplish this, it will be necessary to further develop national technical capabilities and resources of a multidisciplinary nature.

The developing countries' potential for sharing their development capabilities has grown steadily in recent years. In fact, there are already potentials and capabilities which have not yet been recognized, utilized, and harnessed to the development process. TCDC is thus a mechanism which might make it possible for countries to attain economic independence and self-reliance through mutual endeavor and equal partnership. All nations of the international community--developing and developed countries alike--share this goal, along with the agencies of the United Nations system.

International Organization Policies

In 1972 the United Nations General Assembly invited the United Nations Development Program (UNDP) to establish a working group on TCDC. This was followed by a series of regional intergovernmental meetings around the world which culminated in a resolution passed by the General Assembly in December 1976. This resolution designated a preparatory committee to organize a world conference on TCDC--a conference that will be held from 30 August to 12 September 1978 in Buenos Aires, Argentina.

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The Governing Bodies of WHO (the World Health Assembly and the WHO Executive Board) and PAHO's Directing Council (the Regional Committee of WHO for the Americas) have followed up these actions by approving a resolution (EB57.50) inviting the Member Governments to give priority attention to TCDC in the health sector. This resolution includes a recommendation for expanded support to developing countries designed to help them achieve self-reliance--as part of a new international economic order and in keeping with the United Nations Program of Action.

PAHO has adopted this new concept of technical cooperation. Accordingly, it is reorienting its operations to include those activities that the Director-General of WHO has defined as

> having a high degree of social relevant for Member States--in the sense that they are directed towards defining national health goals and ... will contribute directly and significantly to the improvement of the health status of their populations--through methods they can apply now and at a cost they can afford now.

The Current Outlook

One of the technical cooperation activities in the environmental health field that is being given priority attention is development of appropriate technology.

This is a complex matter, because despite the importance of technology for industrialization and economic development, only about one per cent of the world's original technology is being produced in the developing countries. Instead, the developing countries are relying almost exclusively on a transfer of technology from industrialized countries which is now costing them three to five billion dollars per year. If this trend continues, the cost may well reach 20 to 35 times this amount by the year 2000 (2). To reverse this trend, a concerted effort should be made to develop appropriate technology within the developing countries, as a complement to imported technology.

In addition, since the transfer of technology from advanced countries will continue, it will remain important to adapt this existing technology to the social, cultural, and economic conditions in the particular developing countries involved. However, even adaptation of existing technology may require commitment of considerable resources. In the case of water treatment and waste treatment systems, for example, under certain circumstances radical design and construction changes in these systems may be required. The transfer of known technology is also likely to require more than mere translation of books and manuals prepared in developed countries. The more advanced countries have to deal with a relatively narrow range of conditions, while developing countries have to deal with everything from complex urban environments to poorly developed rural societies and--in some cases--primitive tribal conditions. Under these circumstances, transfer of technology means continual adaptation and readaptation, even within different regions of the same country.

In seeking to develop appropriate technology, it should be remembered that man is not necessarily a technical animal. People must understand technology before they can reap the benefits which accrue from it. There are nu-

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merous cases where people--in many parts of the world--have been unable to make use of such facilities as water treatment plants, for example, because the technology was too complicated and could not be incorporated into the individual community's life-style. Technology should therefore be people-oriented, and, in activities relevant to health, every effort should be made to link health with economic productivity and community participation.

Application of the TCDC concept will assume considerable importance as preparations proceed for the Drinking Water and Sanitation Decade (1981-1990) proposed at the United Nations Conference on Water held in Mar del Plata, Argentina, in March 1977. That Conference reaffirmed the recommendations of the UN Conference on Habitat that urged countries to provide water and sanitation services to as many people as possible by 1990.

This effort to provide adequate and safe water supplies and waste disposal systems will require substantial input from industrialized countries and international agencies. Those concerned must thus be encouraged to concentrate on using appropriate technology, as described above. In addition, consultants from industrialized countries should employ qualified experts and consulting firms available in the developing countries and should utilize locally produced materials and equipment wherever possible.

Another key factor in the success of this worldwide effort to extend water supply and sanitation services, and for that matter all environmental health programs, is manpower development. I refer both to short-term training of professionals and subprofessionals and to formal degree-level academic programs.

In this connection, the massive capital investment needed to provide water and sanitation services, among others, must be accompanied by a correspondingly massive effort to develop systems for delivery of ongoing training that will serve the expanding community sanitation services. Insofar as possible, such training systems should be located in the developing countries involved, so that the programs will be geared to local conditions. This approach will also make it possible to start building up local training institutions that might someday gain regional recognition and that could serve as training resources for other developing countries.

With regard to formal academic training, PAHO and the Inter-American Association of Sanitary Engineering (AIDIS) hope to initiate a review and possible updating of curricula for training in environmental engineering and related professions. This has not been done in the Region since 1962, and sufficient developments have occurred in the environmental health field since then to warrant such action.

In the course of this review, we hope it will be possible to identify institutions in the Region that have the potential to develop into centers of excellence for specialized academic training. Hopefully, as these institutions evolve, the number of people going to industrialized countries for training may decline. Such local training is desirable in many cases, because it offers a way to avoid the kind of overly sophisticated training that results in dissatisfaction when the trained individual returns home, and that usually ends up producing one more "brain drain" statistic instead of technological advancement.

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PAHO Activities

At this point I would like to mention some specific environmental health activities of PAHO's Technical Cooperation Program that are directed at furthering the TCDC concept.

PAHO is seeking funds for support of a project to identify and strengthen various existing institutions in selected Hemisphere countries, in an effort to establish a network of specialized collaborating institutions. These focal institutions would work closely with two PAHO centers[2] in carrying out some or all of the following activities: (1) investigations to solve specific national or subregional problems; (2) training programs; (3) development of a regional network of information exchange centers; and (4) provision of technical assistance to the home countries involved and to other developing countries.

In seeking to identify potential collaborating institutions, PAHO will be utilizing the information assembled by the UNDP in its Directory of Services for Technical Cooperation Among Developing Countries, a document published in June 1977. This was the UNDP's first attempt to collect information on a global scale about capabilities and services available for bilateral or multilateral technical cooperation programs and projects between developing countries. It is expected that an updated version of this work will be published in late 1978.

PAHO has also prepared a project proposal for the Caribbean area--with assistance from the Canadian International Development Agency (CIDA)--that is entitled "Caribbean Basin Water Management." This proposal, if funded, will place major emphasis on the following:

1) Organization of a self-sustaining Eastern Caribbean Waterworks Training Delivery System that makes optimum use of appropriate existing institutions and technical expertise;

2) Education of technically trained individuals in the communications skills and instructional techniques they need to pass on their knowledge and experience; and

3) On-site development of appropriate performance-oriented training/job manuals and other instructional materials for the Eastern Caribbean territories.

The United Nations Environmental Program and the Government of Spain are jointly funding an International Center for Training and Education in Environmental Science for Spanish-speaking countries (CIFCA), which has been established in Madrid. Although initial training activities took place in Spain,

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[2]The Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS) and the Center for Human Ecology and Health (ECO).

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it is expected that greater emphasis will be given to the Americas in 1978. Besides providing short courses, CIFCA is prepared to help selected universities develop graduate programs--both in environmental sciences and engineering and in human ecology and health. PAHO's task here is to help identify those institutions that have potential for development. Hopefully, this is another activity which can be undertaken jointly with AIDIS.

It is expected that a CEPIS[3] technical and scientific information system will become operational in 1978. A grant from the Canadian International Development Research Center (IDRC) for design and implementation of a Regional environmental information network is supporting this work. A principal function of the system will be to prepare and distribute a series of guides and manuals on water supply, pollution control, laboratory analysis, and techniques for collection, processing, and dissemination of information. The Center also plans to assist countries in establishing their own information facilities as part of a Regional network of collaborating centers for information exchange.

In addition, investigators at CEPIS are examining lower-cost wastewater treatment methods and simplified ways of sampling, analyzing, and measuring contaminants in the environment. These projects are being undertaken in close collaboration with institutions in various countries.

Another project will soon be initiated at CEPIS for the Technical Development of Water Supply and Sewerage Institutions. This work is being supported by the Government of Peru and the Inter-American Development Bank (IDB). Its aim is to develop training courses and materials, an information system, and a research program all focusing upon operation and maintenance of water supply and wastewater treatment facilities. The project is to run for three years. It is expected that the experience gained in Peru will be disseminated and applied in other countries of the Region.

The new Pan American Center for Human Ecology and Health (ECO) has begun operating from its headquarters in Mexico City. ECO will be cooperating with member countries in determining the environmental impact that large-scale development projects will have on human health. The Center is not expected to undertake an in-house research or training program in the foreseeable future. Instead, ECO will serve as a catalyst promoting research and training in the countries of the Region. Its resources will be used to develop the countries' national assessment capabilities and to help institutions incorporate ecology into the curricula for students of medicine and other related disciplines concerned with environmental health.

Concluding Remarks

I should like to conclude with a few comments about the forementioned TCDC Conference soon to be held in Buenos Aires. The results of this gathering should be awaited with great anticipation. I say this because even though

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[3]The Pan American Center for Sanitary Engineering and Environmental Services.

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most WHO member countries have supported the TCDC concept, as have the international agencies, some ingrained attitudes may still have to be overcome if the concept is to be fully developed. That is, it will require new attitudes on the part of governments and international agencies to overcome a variety of administrative, technical, political, and psychological barriers, of which the following are some examples:

1) Are countries prepared to accept less than optimum technical assistance to solve a particular problem?

2) Would a potential trainee be willing to accept a degree from a local institution instead of one from a prestigious university in an industrialized country?

3) How many countries would accept the development of a center of excellence in an neighboring country and then seek to utilize this resource instead of developing their own?

4) How many countries are prepared to accept materials, equipment, and contractor services from a developing country which may not be "the best source available?"

5) Are international organizations prepared to orient their activities away from technical assistance and toward technical cooperation in order to develop self-reliance and the administrative framework needed to make TCDC a functional undertaking?

The Buenos Aires Conference should provide important guidelines for dealing with these barriers, and should help in assessing the extent to which such barriers can indeed be overcome.

SUMMARY

The concept of technical cooperation among developing countries is adding a new dimension to international cooperation. This concept, sometimes referred to by specialists as "TCDC," has been defined as "collective self-reliance and mutual support among developing countries."

In December 1976 the United Nations General Assembly called for a world conference on TCDC, a conference that will be held from 30 August to 12 September 1978 in Buenos Aires, Argentina. The concept has also been endorsed by PAHO and WHO, which have invited their Member Governments to give priority attention to TCDC in the health sector.

Within this evolving framework, PAHO's Technical Cooperation Program is preparing various specific actions in the field of environmental health that will be directed at furthering TCDC. These include the following:

- A project to establish a network of specialized collaborating institutions in developing Hemisphere countries.

- A project for training water management personnel in the Caribbean.

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o Establishment (by PAHO's Pan American Center for Sanitary Engineering and Environmental Sciences--CEPIS) of a technical and scientific information system.

o A CEPIS project to promote technical development of water supply and sewerage institutions.

o Continuing CEPIS research on low-cost wastewater treatment methods and simplified ways of sampling, analyzing, and measuring environmental contaminants.

o Determination of the environmental impact of large-scale development projects. This work is to be carried out in collaboration with the Member Governments by ECO, PAHO's new Pan American Center for Human Ecology and Health. ECO, which recently began operating from its headquarters in Mexico City, is expected to serve as a regional catalyst that will promote research and training activities.

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REFERENCES

(1) World Health Organization. "Technical Cooperation Among Developing Countries: Report by the Director-General." WHO Document EB60-77, Geneva, 16 May 1977.

(2) Ivanov, Ivan. Your own R and D is the key. Development Forum, April 1977.

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IMPROVING WATER-QUALITY MONITORING DATA

by

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*This publication is a product of the Task Force, not the agencies of the authors until final review by the agencies of Task Force findings. For identification purposes the author's home agencies are Council of Environmental Quality, U.S. Geological Survey, National Bureau of Standards, Environmental Protection Agency, and National Oceanic and Atmospheric Administration.

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INTRODUCTION

On May 23, 1977, the President forwarded his 1977 Environmental Program to the Congress. This message included the following directive: "I am also directing the Council on Environmental Quality to establish an interagency task force to review present environmental monitoring and data programs, and to recommend improvements that would make these programs more effective." This directive was based, in part, on the following concerns about the Nation's environmental monitoring programs:

> "More than a hundred federal programs from nearly every major agency presently generate data, statistics, and analytical information about environmental conditions, trends, and their causes. We depend heavily on the information from these programs, many of which are well conducted ...yet, there are major deficiencies. Large gaps, wasteful duplications, questionable validity, and lack of coordination characterize many of the nation's environmental monitoring and data programs. Lack of uniformity often prevents the comparison of one agency's data with another's. Inadequate quality assurance often reduces the scientific credibility of data and therefore its usefulness to decison makers. Important data are often collected but not well disseminated or made available to analysts efficiently ..." (White House, 1977).

On September 8, 1977 the Chairman of the Council on Environmental Quality established the Interagency Task Force on Environmental Data and Monitoring. Five major working groups were established for air, water, land use and natural resources, ecology and living resources, and socioeconomic problems. The Working Groups met for the first time on November 22, 1977 to begin its efforts. Initial work included compiling an inventory of water data and monitoring activities, and providing informal comments to the President's Reorganization Project.

In early 1978, the group moved forward to consider the problems and issues in water data and monitoring. By mid year the group had developed a long list of potential actions, approaches, and studies to address the issues.

INVENTORY OF WATER MONITORING ACTIVITIES

During late 1977 and early 1978 the Water Working Group compiled an inventory of federal water monitoring activities, which showed that programs to monitor water quality and quantity total about $278,400,000 in Federal funds. In addition, the Geological Survey spends $36,300,000 from State and local organizations.

The largest programs are in the National Oceanic and Atmospheric Administration (NOAA), the Geological Survey (GS), the Environmental Protection Agency (EPA), and the Bureau of Land Management (BLM). There are more than 100 different programs in water monitoring in about 20 different agencies.

Most monitoring by Federal agencies can be divided into two classes: (1) broad based information for multiple uses, such as in the programs of NOAA,

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GS, and Bureau of Census, and (2) support data collected to aid in implementation of specific programs, such as in programs of EPA, the Army, Bureau of Reclamation, and Forest Service. In addition, regulatory functions of some agencies require collection of water data by the private sector; that activity is not included in the inventory.

Water monitoring programs operated by State and local government and by the private sector also are of considerable size. State and local programs are estimated to be about one third the size of the total of Federal programs, and monitoring by private and municipal dischargers many total $50,000,000 or more per year. Non-federal monitoring of water quality by the States is supported by approximately $12 million annually for EPA.

Table 1 shows a summary of Federal activities in water data and monitoring that were funded for $1,000,000 or more in FY-78.

ANALYSIS OF PROBLEM AREAS AND CAUSES

The next major task of the water working group was to perform an intensive review of the entire group of water monitoring programs to identify problem areas. In addition, the group reviewed comments and criticisms raised by a number of different groups who had concerns about water monitoring. This included 11 different reports written during 1974-1978, Congressional testimony by 19 different witnesses, and oral and written input from 18 different Federal agencies. Through this process the group identified 128 separate citations of some 60 different problems with water data and monitoring activities. The 60 problems tended to cluster into 7 separate problems:

a. Insufficient coverage -- There are gaps in the coverage of current monitoring programs. Many of these occur in areas where abatement, control, or water resource programs have not yet been developed, or where monitoring is not explicitly called for by such programs. These gaps suggest that monitoring is being viewed as primarily a support service to other programs, rather than as independent information and analysis program for top management.

b. Macro-level Data -- The needs of scientists and national policy-makers for macro-level data are not being adequately met. With a few exceptions, most data are collected for "micro-level" studies (e.g., basin study, state-wide trends) rather than "macro-level" (e.g., nationwide, all estuaries). Since there is no macro-design, aggregations of micro-data are often viewed as having poor quality. Futhermore, the techniques for macro-level analyses are not well developed.

c. Inadequate coordination -- There has been inadequate coordination and fragmentation of monitoring programs. Coordination to date has been passive (e.g., OWDC) rather than active (i.e., real-time, feedback-loop). Managers of monitoring programs do not know about or take account of other users when designing collection efforts. Federal monitoring resources are not necessarily allocated to highest priority needs.

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Table 1. Summary of Federal Activities in Water Data and Monitoring That are Funded for $1 Million or More in 1978 FY

	Funding (millions of dollars)
Environmental Protection Agency (EPA)	
Chesapeake Bay -- Eutrophication and toxics	2.1
Great Lakes monitoring	3.6
NPDES compliance	4.1
Toxics monitoring (related to TSCA)	2.0
R&D methods development	3.2
R&D quality assurance	1.9
R&D methods improvements	2.4
Needs survey	1.0
Effluent guidelines	16.0
State and interstate agency monitoring	12.0
Storet and Biostoret	2.4
Regional monitoring programs	3.8
Soil Conservation Service	
Data for project eval., environmental impacts, etc.	1.0
Data acquisition for hydrologic purposes	3.0
National Oceanic and Atmospheric Administration (NOAA)	
Public forecasting and warning, marine research	1.1
Environmental data -- ocean data	3.7
Marine technology, ocean laboratory	3.8
Marine technology, manned under sea S&T	1.0
Estuarine and lake investigations	2.2
Public forecast and warning, marine weather	3.0
Marine technology, data buoys	8.2
Marine ecosystems	3.7
Marine resource monitoring, assessment, and prediction	9.5
Effects of marine environmental alterations	2.0
Ocean dumpsite research	1.8
Basic environmental services	8.9
Environmental satellite service (SEASAT-A)	5.4
Structure and motion of the ocean	3.1
Great Lakes research	1.2
Survey technology development	1.0
Data analysis	7.5
Fisheries habitat investigations	3.8
Fishery oceanography	1.9
Public forecast and warning (NWS)	3.9

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Table 1. (Cont'd) Summary of Federal Activities in Water Data and Monitoring That are Funded for $1 Million or More in 1978 FY

	Funding (millions of dollars)	
Mapping, charting, and surveying services	3.9	
National Bureau of Standards (NBS)		
Water measurement standards	1.2	
From EPA		(0.5)
Army Corps of Engineers		
Water control management data network	3.7	
Geological Survey (GS)		
Survey, investigation, research on water resources		
Federal appropriation	46.2	
Federal money for matching state and local funds	35.2	
Repay from state and local agencies		(36.3)
From more than 20 Federal agencies		(30.7)
Bureau of Land Management (BLM)		
Energy mineral rehabilitation inventory	5.9	
Nonpoint source monitoring	1.0	
OCS environmental studies	44.5	
Bureau of Reclamation		
Data acquisition for investigation, construction, oper.	1.6	
Total , () items excluded	278.4	

Activities for which details of funding are not known, but which probably exceed $1 million:

Forest Service -- Water supply, Monitoring of impacts, and Water resources inventory
Bureau of Census -- Water use
NOAA -- Satellite sensors
GS -- Protecting from mining, Disposal reinjection, and Topographic mapping

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d. Lack of data interpretation -- There is too much emphasis on collection of data, and too little on analysis of data. Data are often collected by one group and analyzed by another. More attention must be given to education/standardization in analysis techniques.

e. Deficiencies in support monitoring -- There are some deficiencies in monitoring to support specific programs. While in general resources are adequate for "support" type monitoring, there are deficiencies in cases where new abatement/control programs plan for monitoring support.

f. Quality assurance -- Quality assurance programs, while improving, are still inadequate. Most attention to date has been on handbooks and laboratory methods. Areas needing more attention are: siting criteria, field methods, preservation, and holding times. Also, more attention is needed to develop cost-effective methods.

g. Data Systems -- Full capabilities of macro-data systems are not being exploited, and some deficiencies remain. While the major data systems are operational (e.g., NAWDEX), there are many programs which do not yet store their data. Also, while these systems can easily flag subsets of data useful for various macro-level analyses, this capability is not being used, and macro-level analysis capabilities are not so well developed as they should be.

COORDINATION AND QUALITY ASSURANCE

Several findings emerged from the process of developing issue papers.

- The issues tend to overlap considerably, both in terms of definition of the problems involved, and the underlying hypotheses which tend to explain the causes for the problems.
- Solutions to one problem tend to have direct or indirect effects on other problems as well.
- A number of actions and events have been initiated by participating agencies during the last one to two years which are having an impact on the problems identified.

Two problems emerged in all the working groups which appeared of paramount importance: quality assurance and coordination. In fact as the Task Force has looked to identify implementable solutions, it appears that in many respects, quality assurance also may be subsumed under coordination. Water measurements relate to the state of a system at a particular place and time. It is not possible to perform verifying measurements at some later date because the system has changed. If a sample is collected and subsequently analyzed, the nature of the sample is often changed in the process. Because of the impossibility of verifying past measurements, quality assurance can only rest on a documented application of proven methodology by qualified personnel following accepted guidelines on sampling design. This statement should not be particularly startling. As obvious as this is, however, all of the studies on monitoring have identified flaws in the quality assurance aspects of environmental monitoring programs. The Task Force study teams

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dealing with quality assurance have identified two possible causes for the failure of quality assurance programs in face of the clear need for such programs and the acceptance of the ingredients which such programs must have: 1) confusion over the purpose of quality assurance as it applies to environmental monitoring, and 2) a lack of commitment to quality assurance at the administrative level where environmental programs are planned.

The objective of a quality assurance program is to provide every environmental datum with an accompanying estimate of its uncertainty. Put more strongly, "no number is significant, and subsequently worthy of being recorded, without an estimate of its uncertainty" (Brown, 1976). This statement was made recently at a symposium not by a scientist of somewhat extreme views, but by Representative George Brown, as chairman of of the Subcommittee on the Environment and the Atmosphere, U.S. House of Representatives. It is a succinct statement of the purpose of Quality Assurance.

Too often quality assurance is associated only with the minimization of uncertainty rather than the evaluation and reporting of uncertainty and this is unfortunate. Valuable resources can be wasted on squeezing the ultimate accuracy out of a measurement when such accuracy is not called for in the use of the data.

The second cause of ineffective implementation of quality assurance programs is a lack of commitment at appropriate administrative levels. We suspect that this lack of commitment may be due to a lack of attention rather than a conscious effort to downgrade quality assurance aspects of monitoring programs in favor of, say, increasing the number of monitoring stations or the number of reported parameters. This suspicion is borne out by the following example.

Volume IV of the final report of the NAS study on the acquisition and use of scientific information by the EPA is devoted to Environmental Monitoring. Quality assurance aspects of environmental monitoring are mentioned throughout this volume (including a valuable appendix on how to incorporate uncertainty into environmental guidelines). And yet, when the report recommends that EPA base its proposals and designs for ambient monitoring networks on prototype studies, quality assurance is not among the factors listed (NAS, 1977).

In a later chapter (following a chapter devoted almost exclusively to quality assurance) the report recommends "that a National Committee on Environmental Monitoring be established to coordinate Federal environmental monitoring efforts," and outlines the responsibilities of such a committee and again neglects to include quality assurance issues explicitly (NAS, 1977). We do not wish to point out that even those sensitve to the issue of quality assurance take it for granted when discussing "the big picture." But this is just the problem: in the deliberations leading to the design of monitoring programs, planners loose sight of quality assurance in consideration of program objectives and design criteria.

The major problem, however, can be said to focus on coordination because many of the quality assurance problems appear to be solvable if we establish a framework for coordination. Significant difficulty has been experienced making energy, natural resources, and environmental policy decisions, and in

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assessing the impact of these policies, because of inadequate and uncertain data concerning natural resources, environmental quality trends, pollution, human health characteristics, and their interrelationships.

While there are many diverse environmental monitoring activities being carried out in the United States by private, local, state, and federal entities and each of these activities typically has a valid objective, the activities tend to be narrowly conceived and largely uncoordinated with similar activities in other organizations. Their managers often appear to be unaware of related programs and all too often the data being gathered are poorly documented, and therefore of unknown validity and of limited use except to the original collectors.

There are numerous environmental data banks and systems operated by Federal and state agencies. It is becoming increasingly clear as the types, volumes and user needs for environmental data and information increase that federal and state programs, and others required or funded by the federal government, are in need of guidelines for data management in support of coordination of monitoring, survey, design, quality assurance, and related activities. Users of environmental data, or user-analysts supporting policy and decision-makers, are regularly forced to combine multidisciplinary data from different sources, in diverse formats and inadequately documented. Program directors have developed independent criteria for data merging and presentation -- inconsistencies which impair effectiveness and timeliness of analysis and add immeasurably to costs. It is difficult for the public to access these data resources, as they are widely dispersed and uncoordinated, without a central directory, or cross-media capability.

There currently are more than 20 federal agencies concerned with the collection and use of water data. Their needs for processing, storing, and interpreting these data are not met by the several dozen data systems available. These systems range from small, manual, dispersed filing systems to huge, automated centralized systems.

Full capabilities of major data systems are not being exploited, and some deficiencies remain. While the major data systems are operational and efficient (e.g., STORET) there are many programs which do not yet store their data. Also while these systems can easily flag subsets of data useful for various macro-level analyses, this capability is not being used, and macro-level analysis capabilities are not as well developed as they should be.

The CEQ/Interagency Task Force on Environmental Data and Monitoring has completed the study phase of its efforts. As a result of its activities several categories of initiatives have been identified to help address the problem identified.

1. Reorganization. The President's Reorganization Project (PRP) has proposed reorganizing the Department of the Interior into a new Department of Natural Resources (DNR). The fate of this recommendation is not yet known. The Task Force believes that reorganization alone will not solve all the problems with monitoring. Nevertheless, the proposed Department of Natural Resources provides an opportunity to integrate the functions of several of the largest data-collecting agencies: USGS, NOAA, the Forest Service and other

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groups within Interior. Provided the monitoring function receives a relatively high priority within the proposed DNR, this integration could be beneficial, particularly in the data management area. The Task Force has worked directly with the PRP staff to provide them technical backup on data and monitoring issues. Some of the Task Force recommendations are "reorganization sensitive" and their implementation awaits resolution of reorganization issues. The Task Force is recommending coordination of environmental monitoring, including quality assurance aspects, at the Department level with DNR. While this concept may not appear revolutionary, its occurrence would be unlikely without the Task Force recommendations.

2. Strengthening Interagency Coordination. The Task Force devoted its primary efforts to exploring better means for the 25+ Federal monitoring and user agencies to coordinate their efforts since coordination appears to be at the root of most other identified problems. Most of these agencies will not be affected by the proposed reorganization. Principal recommendations in this area are:

- Strengthen A-67 process (Office of Management and Budget Circular A-67 on water data coordination) including mandatory participation and more programmatic involvement. Meetings between Task Force participants and the Office of Management and Budget (OMB) have already taken place.

- Build upon the five-agency interagency agreement for land and natural resources.

- Establish a National Ecology Program to coordinate ecological monitoring and perform related activities. This may be accomplished in the reorganization context.

The Task Force has also identified coordination opportunities in the area of atmospheric deposition. An "umbrella" coordination proposal is also under development.

3. Improve Budgetary Procedures. The Task Force believes that the present Federal budget process tends to discourage multi-agency, multipurpose monitoring projects, since success depends on simultaneous funding by two or more agencies/programs over the life of the project. The Task Force recommends establishing objective procedures to identify such projects which have a potential for improving monitoring efficiency, and inform OMB as part of the budget process.

4. Integrate Data Management and Dissemination Systems. The Task Force recommends against an across-the-board integration of monitoring programs. However, in the case of data management and dissemination, the Task Force believes that a limited degree of integration has a potentially high return. It will be important to get state and local government involved in this process.

5. Long Term Management. Our ability to identify long term human influences in the environment is hampered by our lack of a long term measurement program. For this reason such a program is recommended. The Task Force has recommended a program of long term ecological measurement. The

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proposed National Science Foundation program will satisfy this recommendation.

CONCLUSION

Environmental monitoring is a large complex affair. It involves many different agencies, many millions of dollars, and a mix of competing objectives. For these reasons no quick fix will ever be possible to correct all the perceived problems. Periodic review and implementation of improvements will be necessary to achieve and maintain a high quality of data useful for environmental decision-making. The Environmental Data and Monitoring Task Force is now completing such a periodic assessment.

ACKNOWLEDGEMENT

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REFERENCES

Brown Jr., E.G. 1976. Methods and Standards for Environmental Measurements, Proc. 8th Materials Research Symp., Gaithersburg, Md., Sept. 2024. W.H. Kirchoff, Ed., NBS Special Publication 464, p. XVI.

National Academy of Sciences. 1977. Analytical Studies for the U.S. Environmental Protection Agency, Vol. IV Environmental Monitoring, A Report to the U.S. Environmental Protection Agency from the Study Group on Environmental Monitoring, p. 33-34.

White House. 1977. President's Environmental Program, Fact Sheet. Government Printing Office.

POTENTIAL ENVIRONMENTAL IMPACTS OF OCEAN THERMAL ENERGY CONVERSION

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I. Introduction

The Department of Energy is bound by the National Environmental Policy Act of 1969 to prepare an Environmental Impact Statement (EIS) on all of its actions which "significantly affect the quality of the human environment." The novel aspects of the OTEC Program, the size of an OTEC (Ocean Thermal Energy Conversion) unit, the federal and private investment involved, the commitment of support and manufacturing facilities, the quantities of water displaced for heating and cooling the working fluid, are all aspects of OTEC which may significantly affect the quality of the human environment. The OTEC program will require carefully examined analysis of its environmental impacts at several different stages in its development. Each EIS will include information on the following categories:

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.

It is likely that in the early stages of the OTEC program when design parameters are being conceptualized only and have not been manifested as hardware that a Programatic EIS will be written to summarize all known potential impacts which could result from an OTEC facility. The benefit that such a document could serve would be to alert the designers concerning impacts which could be prevented through proper design. When other stages of OTEC materialize, additional impact statements will be justified. For instance, when design features are well underway for the EOTP's*, impact statements should be written for both the 1 MWe and the 5 MWe versions. Also, the Demonstration Plant will require an impact statement.

A philosophy relevant to environmental impacts of OTEC should be established now which, historically speaking, is early in the developmental stages of the OTEC program. The point which cannot be emphasized enough is that negative impacts from OTEC are inevitable but they should not be blown out of proportion in relation to the overall program. In no way should these surfaced environmental impacts be presented to the public in such a distorted manner that they could result in public pressure stopping the program before its full contributions can be realized. OTEC is very much of an experiment now and emphasis is on developing an operational facility at sea. We really

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*Early Ocean Test Platform

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don't know if technical problems such as constructing 100 foot diameter pipe 1500 feet into the open ocean, controlling biofouling in the heat exchange tubes and manufacturing an efficient aluminum or titanium heat exchanger can be overcome. It is after OTEC has become an operational concept, after the EOTP and the Demonstration Plant have been tested, that we will know if the OTEC concept is worthy of commercialization. The overriding purpose for identifying environmental impacts of OTEC now is so that during design and operational activities efforts will be made to mitigate potentially adverse impacts when this is possible.

The attached figure displays the impacts which will be considered in this paper.

A programmatic environmental impact statement for OTEC will include "near-field" and "far-field" environmental impacts which are caused by OTEC on the environment and by the environment on OTEC. Potentially impacted are the socioeconomic environment, the biological environment, and physical environment.

II. Effects of OTEC on the Environment

This part of the environmental study will be concerned with the effects of OTEC on the surrounding environment. It will include consideration of how OTEC will stimulate the economy by providing a need for goods and services. Attraction of marine life to an OTEC facility will likewise be considered as will be the impacts of discharges.

II.A Effects on the Socioeconomic Environment

The socioeconomic environment includes those segments of the biosphere which encompass man and man's well being.

II.A.1 Near-Field Effects (Socioeconomic Environment)

Near-field effects of OTEC on the socioeconomic environment will be incurred mostly in providing employment opportunities on OTEC facilities. Several men will be needed to run and control the operations of the plant. A 100 MWe plant will need about 40 men to provide the necessary personnel for all contemplated shifts. Thus the number of people required on board will have a minimal effect on the economy of the area. However, if a considerable number of plants of 500 MWe capacity were to be built in a given area, then the movement of people to the area with their dependents could provide sizeable effects which should be analyzed completely.

II.A.2 Far-Field Effects (Socioeconomic Environment)

The far-field effects of the plant or plants on the socioeconomic environment are likely to be more important. In this category, one can list the alteration of shipping lanes, the stimulation of a helicopter industry, and other land-based support services, the provision for additional electricity needed to power tools and the encouragement of new industries in far-field areas such as aluminum and titanium production and shipbuilding. A great deal of importance should be given to the possiblity of siting OTEC

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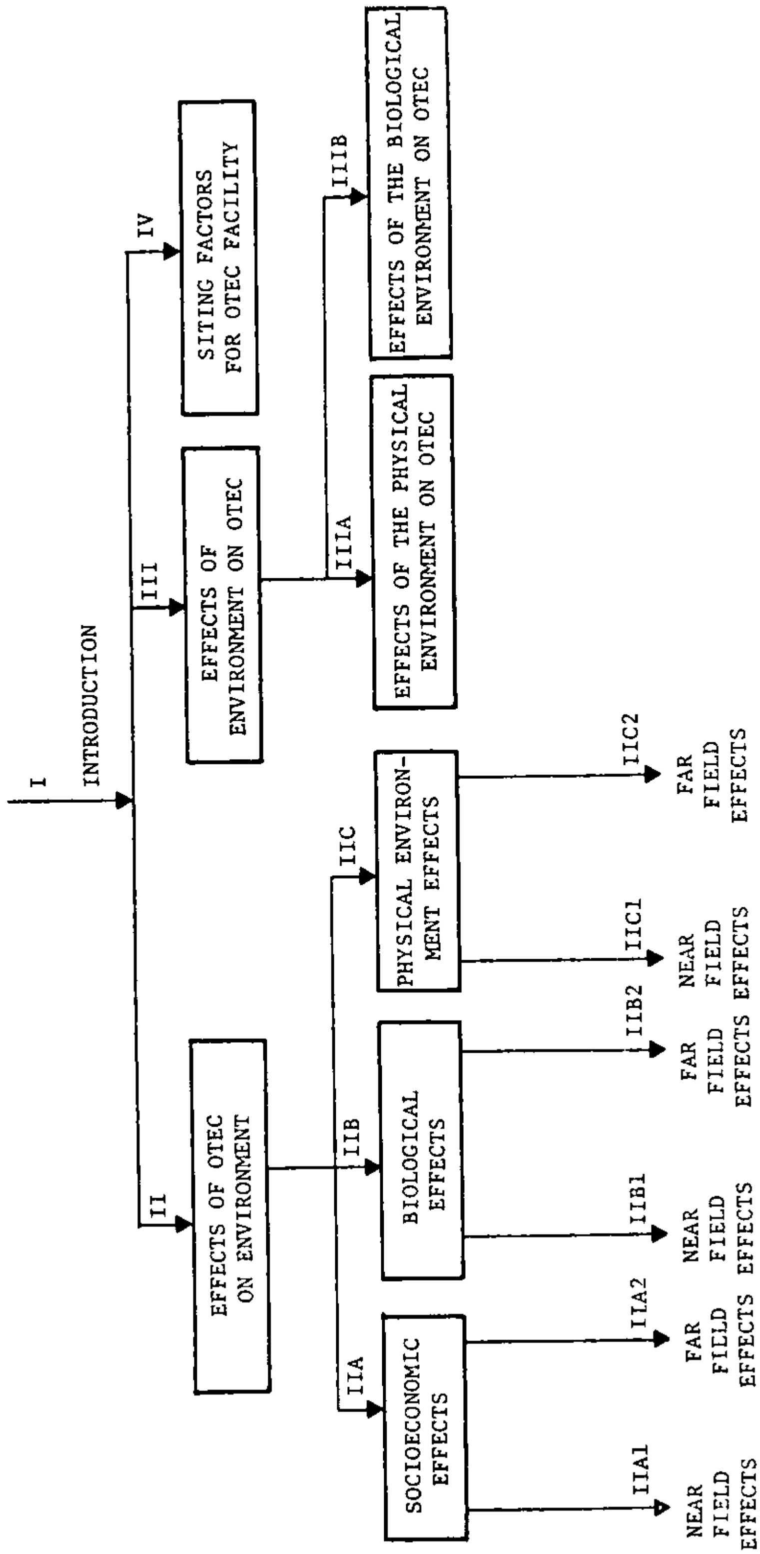

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plants on busy international shipping lanes. These lanes must be identified completely and the number of ships passing through the area must be determined. Alteration of these lanes must be provided for and the OTEC area must be clearly identified with markers visible night and day. Statistical studies should be initiated to determine the probability of collision of a ship with an OTEC plant. The results of these studies should be used to minimize the occurrences of such accidents.

The emplacement of OTEC plants in a given area could stimulate the helicopter business. If for every 500 MWe plant 50-60 people are employed to man the plant, there will always be a group of people at home on temporary leave while three other groups man the plant for a 24-hour period. In other words, there will always be a group ready to be transported to or from the facility. Likewise, there will be things to move from a land-based facility to the OTEC plant such as new pieces of equipment, rebuilt pieces, soldered pieces, etc. All have to be shipped to the plant on schedule. The movement of people and equipment by helicopter will provide a stimulus for this industry which might create new employment opportunities. The human environment will also be affected by the creation of new jobs in the utility market. A great deal of power will be produced by 500 MWe plants which could be interconnected to several utility grids. The added power will require additional lines for distribution which could benefit many auxiliary businesses. Also, because the OTEC concept and the applications resulting from it are new, there is a strong possiblity that new industries will develop in the areas under consideration and new job opportunities will appear.

II.B Effects on the Biological Environment

II.B.1 Near-Field Effects (Biological Environment)

Installation of an OTEC facility may impact the ocean environment by creating a reef which develops because the facility serves as a site for attachment or shelter of marine organisms. Formation of such an artificial reef on an OTEC facility is significant because: 1) the accumulation of great quantities of attached organisms will lower the facility's buoyancy and 2) the presence of large numbers of attached organisms, their floating planktonic larvae and larger animals which are attracted to the area to feed on them increases the likelihood that impingement and entrainment of these organisms would interfere with operation of the evaporator systems. Some information on artificial reef formation in the ocean environment can be extrapolated to OTEC.

It is a well known fact that stationary objects at sea attract communities of organism. This has been demonstrated in the artifical reefs which have developed from 5000 discarded tires off Northeast Florida, on offshore drilling towers, on discarded worn-out streetcars, junked automobiles, quarry rocks and concrete fish apartments off California and car bodies in Chesapeake Bay.

"Subsea plant life begins to grow immediately on the foreign objects and the little organisms that require protection or a solid surface on which to attach themselves quickly colonize the spot. They are followed by larger creatures that feed upon the existing life. Finally, the predatory pelagic fishes come around to prey upon the smaller animals. (Hauser, 1974)"

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The chronological appearance of fouling organisms on objects in the ocean is as follows (Dexter, 1974):

1) Motile organisms such as diatoms and protozoa

2) Motile bacteria

3) Sessile aquatic micro-organisms

4) Macro organisms (barnacles, hydroids, algae, and sedentary organisms) and free swimming larvae stages such as the nauplus larvae of barnacles and the ciliated larvae (planula) of some jellyfish (e.g. Gonionemus) or the free living asexual bud of some jellyfish (Vellella)

5) Larger consumers

On OTEC, mini-reef formation can be expected to occur, particularly on the upper portion of the hull and the cold water pipe. The grandiose size of both the hull, which has been described as a "supertanker on end," displacing approximately 200,000 tons, and the cold water pipe which in the Lockheed design would be approximately 1500 feet long and 105 to 129 feet in diameter, leaves no doubt that an OTEC will serve as suitable nucleus for formation of a reef. In one conceptual design, the cold water pipe leaves the hull at the 500 foot level where in the tropical open-ocean the seasonal low temperature, 95 percent of the time, approximates 55°F and the seasonal high temperature is 65°F (Tumble et. al., 1975 in Drugger, 1975). Because corals flourish only in water above about 68°F, it is unlikely that coral will foul the exterior of the cold water pipe. Other fouling organisms are also not likely to be abundant on the cold water pipe due to its depth. Evidence to support this can be drawn from an oil drilling rig in the Santa Barbara Channel where most life was in the 30 to 110 foot depth after 15 years (Hansen, 1975).

Dynamic fouling of the OTEC hull poses the most serious consideration since design engineers must be able to predict the maximum weight of attached organisms so that adequate buoyancy compensation, for this factor, can be made. Research is needed to produce information on the long term formation and control of fouling on stationary objects at OTEC sites.

The discharges of toxic wastes and their influence on living organisms must be investigated. Provisions to minimize the environmental impact of these discharges during normal operations and during emergencies should be considered during plant design stages. Limitations on these discharges must conform with regulations set by state, federal, and/or intra-governmental agencies. However, for design purposes, applicable EPA effuent guidelines should be considered acceptable in most cases. When chemicals or a combination of chemicals are used to control biofouling, the dose of the chemicals administered must be kept as small as possible without reducing the effectiveness of the procedure. When the OTEC concept has been proven for commercial purposes and enough operating data has been collected, new source performance standards for effluents will be established. Chlorine is one of the agents used for biofouling control. Current EPA regulations stipulate that 0.01 mg/l of chlorine is the maximum level that can be discharged in marine waters.

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Leaks of the working fluid, whether it be ammonia, propane or water are not expected to pose a serious potential impact on the environment. If ammonia should leak into the evaporator water due to a leak in the heat exchange tube, the ammonia, being an organic molecule and a component of amino acids, will readily be assimilated by biological systems. Current EPA regulations state that 0.4 mg/l of ammonia is the maximum level safe for aquatic life in the marine environment.

Because domestic wastes will probably be incinerated aboard the facility they will not impact the environment.

Discharge of toxic substances such as copper or other leachable materials from antifouling paints on the OTEC facility may, because of the toxic properties for which they were chosen, effect other marine life in the area. However, to assess the magnitude of the problem would require some studies once the compounds have been identified. The magnitude of the problem would be no greater than that which exists on ships at sea which are coated with antifouling paints.

OTEC platforms will attract, in all likelihood, birds and sea mammals. If rich biota develops near an OTEC plant, land birds will be attracted to it. If so, they would be expected to land on the plant as they would on buoys. If experience with oil platforms is any indication, breeding will not occur. Hazards to helicopters will not be significant because of the low speeds at which these aircraft operate on landing and take off. Conversely, hazards to marine birds from collision with helicopters will be slight. Two groups of mammals will be attracted by fish colonies developing around the station. These are cetaceans (whales, dolphins, and porpoises) and pinnipeds (walruses and seals). However, these mammals would seldom haul out on the structure and would never establish rookeries there.

Finally, the impact of the plant on the near-field biological environment can also be expressed in terms of nutrient enrichment created by local plant upwelling.

In areas of the oceans where upwellings bring nutrients, i.e., phosphates, nitrates, iron, manganese from deep depths to the surface, species diversity and abundance far exceeds that of less nutrient rich areas. Areas in the world where upwellings occur include the North California coast, West Africa, Bay of Fundy, Puget Sound, Greenland and South America. Off of the Monterey Peninsula of California it is the Aleutian Subartic Current (California Current) which accounts for the upwelling. Sea life along the Monterey coast is much more abundant than that occurring elsewhere on the California coast. Many of the nutrients which surface at upwelling have been regenerated in deep waters from sinking bodies or organisms produced in upper layers.

Mini-upwellings may develop around OTEC facilities when cold nutrient rich water is pumped from 1000 foot plus depths and is discharged into shallow waters. The resulting nutrient enrichment around the facility may increase the density of aquatic life because 1) nutrients in the cold deep water will be inoculated into the shallow water where existing organisms will be stimulated to grow and propagate, and 2) sparse populations living under conditions which are biologically unfavorable (deep, cold, aphotic waters)

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will be inoculated into a more favorable environment (shallow, warm, photic) where they can grow and propagate.

II.C Effects of the Physical Environment

II.C.1 Near-Field Effects (Physical Environment)

Warm surface water is pumped through the evaporator, where it drops in temperature before being discharged. If large volumes are used, circulation patterns could develop leading to a short circuiting on the warm water side. If that happens, the differential temperature on which the power cycle depends will decrease and the cycle efficiency with it. Similar problems are less likely to occur in the cold-water system. This phenomenon must be studied carefully with scaled flow models to supplement theoretical work on the subject. In both experimental and theoretical procedures, appropriate boundary values must be used to duplicate actual conditions.

Models have been developed by Fry (1976) to study the near-field impact of recirculation in a 200 MW OTEC facility. The results of this work indicate that the recirculation of the condensing water is not expected to be as serious in terms of shutting off the facility as is recirculation of condenser (cold) water into the evaporator. Calculations made indicate that if 40 percent of the evaporator flow from a 200 MW plant were recirculated, the power reduction would be less than 10 percent. The power reduction would be considerably larger if the condenser discharge were recirculated through the evaporator. Based on this work, the following recommendations were made:

1) Discharge OTEC evaporator and condenser water separately and below the mixed layer of the natural ocean;

2) Release the discharge of water from the evaporator at a depth where the water density mismatch is initially neutral or, perhaps more suitably, the discharge water would be negatively buoyant and thus sink; and

3) Use large diameter components to produce more desirable ocean flow patterns.

Another important impact of the plant on the immediate physical environment could result from plant discharges. Discharge of antifoulants and construction materials and other plant discharges into the ocean could lead to enhanced fouling and interference with plant operation. Potential effects of discharges on the biological environment have been discussed previously in subsection II.B.1.

Besides the biological effect of surfacing nutrients in the cold deep water pumped to the condensers, the corrosive effect of calcium precipitating from the same water may impact on OTEC facility for a least two reasons:

1) Precipitation of the calcium in the condensers will interfere with the efficiency of the heat exchanger.

2) High calcium levels in the water may stimulate the propagation and

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development of marine organisms which could accelerate the rate of fouling on subsurface components of OTEC.

According to Averdrup et. al (1942), the high concentration of soluble calcium in deep water is due to several factors including the following:

1) Skeletons of dead organisms have decomposed to release Ca and CO_2.

2) $CaCO_3$ cannot readily be precipitated by animals under low temperature conditions.

3) Increased pressure and low temperature favors the solubility of Ca.

When the deep water is pumped to the surface, Ca becomes less soluble and more utilizable by organisms which may be present.

A method proposed for avoiding or mitigating the potential problem is to discharge the cooling water at the depth where the water temperature is similar to the discharge temperature, well below the main hull and evaporator intake structure. To assay the extent of this potential problem, pilot studies should be performed to observe the effect of discharging deep cold water into the surface layers at potential OTEC sites. The EOTP's and various demonstration plants will be excellent vehicles from which to perform such studies. In selecting OTEC sites, the nutrients at various levels of the water column should be known so that the severity of this potential problem can be predicted. Possible nutrient levels in the water column could serve as a basis for selecting OTEC sites.

II.C.2 Far-Field Effects (Physical Environment)

One OTEC plant sited in the Gulf of Mexico, the Atlantic, or off the Florida coast is not going to create much of an impact on the large-scale water circulation, or on the climate, or on hurricane formation. However, if a large number of plants are placed in these areas, it is quite likely that changes in the temperature gradient may producce some meaningful changes in the water circulation. Water vapor and air temperature distributions may change and affect the climate causing modifications in hurricane formation. While there is little doubt that a multitude of OTEC plants may produce major atmospheric anomalies, the quantitative evaluation of these will probably proceed in conjunction with current oceanographic and climate research efforts sponsored by the National Science Foundation and the Office of Naval Research.

Exchange of water between plants is equally an important consideration. Piacsek, Martin and Roberts (1976) have calculated the area of ocean that would be required for 100 MW OTEC plants in different locations in order to assure no net effect on surface water temperature. The calculation was for the conservative conditions in which ocean current turbulences and other factors could result in almost complete recirculation of discharged cooling water from one plant to the warm water inlet of another plant. Mean temperature reduction of the warm water was calculated to be $4^{o}F$. If no more than a $0.1^{o}C$ surface water temperature change is allowed in the Puerto Rico area of the Atlantic, a typical 100 MW OTEC plant would require 2500 Km^2 with a radius of 28 Km; or in the Hawaiian area of the Pacific, an area of 6000 Km^2, and a radius of 44 Km.

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Fry (1976) predicts that if a 1°F degree drop in surface temperature is allowed, where ocean currents are strong, such as in the Caribbean, about 5 x 10^5 Mw_e can be produced from 2,300 plants drawing at a power density of 0.9 MW per square mile. Studies are needed to determine the far field impacts of changing ocean temperatures in a field of OTEC units. However, the deployment of more than one OTEC unit in any area should be done in such a manner that no change in ocean temperatures occur beyond the immediate site for each unit.

III. Effect of the Environment on OTEC

This part of the environmental study will be concerned with the effects of the environment on the plant. It will include studies related to ocean currents and the manner in which these affect the drag and lift applied on the cold-water pipe. Attention will also be given to spatial distribution and temporal variation of temperature, salinity, absorbed gases, nutrients, trace materials and fish distributions. The manner in which these ingredients are distributed affects not only the performance of some components, but it also impacts the design, construction and operation of the plant.

III.A Effects of the Physical Environemt on OTEC

To a large extent, surface wind and wave conditions determine the exterior shape of the plant. The design of the plant's exterior shape must take into account the forces acting on it and should be made such that the total force acting on the plant is minimal. Not only would this minimal force condition lead to less stress on the structure, but it would also produce cost savings in mooring the plant.

Concerning the effects of currents and the resulting hydrodynamic loads they produce, it is sufficient to state here that the flow past the cold water pipe at a Reynolds number in the 10^6 and 10^8 range requires detailed analysis to properly evaluate the drag and the lift exerted on the pipe and consequently on the plant.

III.B Effects of the Biological Environment on OTEC

Perhaps the most detrimental effects the environment exerts on the plant are those caused by the quality of water. If the concentration of organisms and micro-organisms in the water is large, biofouling results.

Scientists have found that by adding a monomolecular layer of fluorocarbon to the metal, the interfacial tension between the metal and the water is decreased and the interfacial tension between the metal and the slime is increased. Because these forces act against each other, the resultant force becomes smaller or possibly negative and the slime deposit is loosened from the metal surface.

It is necessary to remove the slime layer in order to increase the heat transfer coefficient. Heat is transferred to the ammonia through a layer of dirt on the ammonia side. Heat flowing through each of these layers is lost in direct proportion to the thickness of the layer. The elimination of

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fouling on both sides of the tube will thereby enhance the overall heat transfer coefficient. This tendency of a metal surface to foul is influenced by two factors:

1) The concentration of organisms in contact with the surface; and

2) The ability of the surface to promote attachment and growth of these organisms.

To combat the first factor requires finding sites where the concentration of organisms is very small. Little can be done if areas representing suitable temperature differentials are rich in organisms. The second factor is more amenable to manipulation. Fouling can be visualized by stating that the layer of slime which appears on the surface of the metal separates the metal from the water. Physically, there are three types of interfacial tensions: 1) between the metal and the water; 2) between the metal and the slime; and 3) between the slime and the water.

The intensity of fouling is not uniform over the various components of an OTEC plant. Most fouling occurs at the evaporator because it is supplied with surface waters where organisms and debris are most abundant.

Fouling becomes much less intense in deeper water and is least at the ocean bottom where non-living sediments become evident. As divers have known for some time, open ocean bottoms are veritable subsea deserts devoid of fish. Acoustical sensors placed for several years at depths exceeding 1,500 feet in the Atlantic near St. Croix showed fouling only near the bottom where sediments settled on wires and equipment.

Most of the available information on fouling has been gathered in near-shore waters. It is widely believed that plants located near shores would be greatly subjected to fouling, particularly the evaporator, the hull, and the upper parts of the cold-water pipe. Conversely, plants situated away from shore in mid-ocean would have to cope with a great deal less fouling.

Regardless of site, one primary environmental consideration for OTEC would be to keep warm and cold water inlets free from major obstructions.

Data available on coastal generating plants indicate the clogging of intake screens is caused by detritus, algae, crabs, jellyfish, and fish. It is easy to postulate that the greater water suction of OTEC plants would draw in not only these species but also large schools of pelagic fish off the intake screens. Other organisms such as jellyfish may be a problem at the warm-water intake, while squid and shrimp might be impinged at the cold-water intake.

To prevent the clogging of the intakes, trash racks and screens should be properly placed. Trash racks should precede the screens, particularly for the warm-water side. Larger organisms such as sharks and sea turtles could cause damage to the screens if allowed to reach that point. Marine biologists recommend Johnson screens because they are self-cleaning and reduce the intake velocity by providing increased surface area. Testing of the Johnson screens to determine the biofouling and the corrosion effects of various metals is in progress.

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IV. Siting Factors for OTEC Facilities

The final environmental consideration is that of sites for OTEC facilities.

Siting of OTEC stations will require consideration of many potentially interrelated factors. Site-related constraints on OTEC construction and operation are of concern, as well as potential effects of the stations on local and regional environmental and socioeconomic conditions. Baseline information needed for siting a facility includes natural conditions at potential ocean sites, shore-related conditions, and jurisdictions and resource uses at and near the sites.

Successful construction and operation of a station could be limited primarily by physical conditions at a particular site. Climatological conditions, especially those which affect wave height, currents, water temperature, and the local heat exchange budget of the ocean, are significant both seasonally and diurnally. Such factors would include storm frequencies, winds, and precipitation. Temperature and current must be known as they vary with area, depth, and time. Ocean depth and currents determine method and cost of maintaining the station's position (anchored or moving) and of product transmission. Sea bottom characteristics, such as slope and material, influence the types of anchoring and transmission that are feasible. Water turbidity could affect visual submarine checking of the station, as well as any biological productivity that might be locally induced by the station.

Chemical and biological baseline information would be required both to determine effects of increased biological productivity on the station, and potential impacts of the station on biological conditions. The physical presence of a station, and the tranfer of deep, nutrient-rich waters to the photic zone of the ocean, could increase biological productivity of an area. Effects of this on biofouling, on changes in the local and regional biota, and on changes in resources such as fisheries of rare and endangered species should be investigated for each site. In addition, fluid leaks and use of biocides would potentially affect biological productivity. Sensitivity of local organisms to biocides and other foreign materials, and likelihood of colonization by biofouling organisms should be determined.

Socioeconomic conditions onshore, especially those related to construction, and materials and labor supply, would have to be determined. Important factors would include: 1) prices and resources of raw materials for equipment; 2) location and suitability of sites for construction facilities; 3) local labor pool charecteristics, including source and numbers of trained construction and operating personnel; and 4) market available for OTEC products including alternative energy sources for this market. Distance of the station from shore would partially affect the cost of transporting OTEC products to shore.

Depending on local oceanographic conditions and distance of the facility from shore, operating conditions could be influenced by shore-related phenomena. These include runoff, freshwater percolation, and ocean waste disposal.

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Potential conflicts of resource use would have to be identified in the siting process. Conflicting uses, potential or existing, include: military, industrial (desalination), mining, drilling for oil and gas, commercial and recreational fishing, and navigation. Federal and international laws, regulations, and agreements governing ocean resource uses should also be investigated. Included may be Federal licenses and permits, U.S. Coast Guard regulations, and local water quality standards. These may vary or overlap depending on which geopolitical entities have jurisdiction in the area of concern.

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LIST OF REFERENCES

1. Averdrup, H. U., M. W. Johnson and R. H. Fleming. The Oceans, Prentice-Hall, Inc., Englewood Cliffs, New Jersey 1942. pp. 1087

2. Dexter, Stephen C. 1974. Microbiological Fouling and its Control in Coastal Water and the Deep Ocean. Woods Hole Oceanographic Institute Technical Report Prepared for the National Data Buoy Center under contracts H-83609-A, Amendment No. 3 and H-801B

3. Drugger, Gorden L. (Ed.) 1975. Proceedings, Third Workshop on Ocean Thermal Energy Conversion (OTEC). Houston, Texas. May 8-10

4. Fry, David J. "Effects of Oceanic Flow Patterns on the Thermal Efficiency of Ocean Thermal Energy Conversion (OTEC)," Technical Report of April 1976 to ERDA from Department of Civil Engineering, Carnegie - Mellon University, Pittsburgh, Pennsylvania, Grant Number E (11-1) 2895 initiated January 1, 1976.

5. Hauser, Hillary. 1974. Hilda's Hidden Haven. Exxon USA. Fourth Quarter. p. 16-21

6. Piacsek, S. A., P. J. Martin, and G. O. Roberts, 1976. Recirculation and Thermocline Perturbations from Ocean Thermal Power Plants Report No. NRL-GFD/OTEC 2-76 to ERDA under contract E(49-26)1005.

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ON SOME CONCEPTS FOR SOLVING MULTIOBJECTIVE PROGRAMMING PROBLEMS

by

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In the past few years, increasing attention has been given to the development of methods and applications of multicriteria decision making ([12], [13],[14], [15], [16], [17]). In this paper basic concepts of multiobjective programming problems are briefly reviewed, their mathematical properties are discussed and a new method for solving multiobjective programming problems is presented. The first concept to be discussed is noncooperative games, then cooperative games, compromise programming, goal programming models are described. Finally, a new method for solving multiobjective dynamic programming problems is introduced.

1. Noncooperative games

A mathematical game is a set $\Gamma = (n; X_1, X_2, \ldots, X_n; \phi_1, \phi_2, \ldots, \phi_n)$, where n is a positive integer, $X_1, X_2, \ldots, X_n$ are arbitrary sets and the functions $\phi_k (1 \leq K \leq n)$ are such that $\mathcal{D}(\phi_k) = X_1 \times X_2 \times \ldots \times X_n$, $\mathcal{R}(\phi_k) \subset R^1$. Here n is called the number of players, the sets X_k are the strategy sets and the functions ϕ_k are the pay-off functions. Assuming that the ℓth player chooses the strategy $x_\ell \in X_\ell$, the value $\phi_k(x_1, x_2, \ldots, x_n)$ is considered to be the income of player k ($k = 1,2,\ldots,n$). In the special case $\sum_{i=1}^{n} \phi_i = 0$, the game is called a zero sum n-person game.

The solution of a game is a vector $x^* = (x_1^*, \ldots, x_n^*)$ such that for $k = 1,2,\ldots,n$,

a) $x_k^* \in X_k$; (1)

b) $\phi_k(x_1^*, \ldots, x_{k-1}^*, x_k, x_{k+1}^* \ldots, x_n^*) \leq \phi_k(x_1^*, \ldots, x_n^*) \quad (\forall x_k \in X_k)$. (2)

Observe that inequality (2) implies that the equilibrium strategies are maximal to each player assuming that all the other players choose their corresponding equilibrium strategies.

The computation of the equilibrium point is the basic problem of game theory. The existence of equilibrium points is not true in general. But it can be proven if

a) the sets X_k are convex, closed, bounded subsets of finite dimensional Euclidean spaces;
b) the functions ϕ_k are continuous and for fixed values of x_i $(i \neq k)$ are concave with respect to x_k,

then the game has at least one equilibrium point.

This theorem gives no efficient numerical algorithm for finding the equilibrium points since the proof is based on the Brouwer fixed-point theorem which is not a constructive result. But in special cases, very efficient algorithms can be introduced for determining equilibrium point of n-person games.

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Consider next the case of the oligopoly game ([7]). Let

$$X_k = [0,L_k] \quad (L_k > 0,\ k = 1,2,\ldots,n) \tag{3}$$

and

$$\phi_k(x_1,\ldots,x_n) = x_k f\left(\sum_{i=1}^{n} x_i\right) - K_k(x_k), \tag{4}$$

in which the functions f and K_k have the following properties:

$$D(f) = [0,L], \text{ where } L = \sum_{i=1}^{n} L_i;\ D(K_k) = [0,L_k];$$

$$R(f) \subset R^1 \text{ and } R(K_k) \subset R^1.$$

The game defined by the sets of strategies (3) and pay-off functions (4) is called the <u>classical oligopoly game</u>.

Before discussing the equilibrium problem of this game we show how the game appears in several applications ([7]).

<u>Application 1</u>. Assume that n factories manufacture the same product and sell it on the same market. Let f be the unit price of the product, defined as a function of the total production level, let K_k be the cost function of the manufacturer k, and L_k be the upper bound of production of manufacturer k; thus, $\phi_k(x_1,\ldots,x_n)$ is the net income of firm k, in which x_i is the production level of manufacturer i, i = 1,2,...,n.

<u>Application 2</u>. Assume that a multipurpose water supply system is to be designed. Let the water users denoted by k (k = 1,2,...,n) and let the water quantity allocated to user k be denoted by x_k. If the maximal requirements of users are denoted by L_k, then $x_k \in [0,L_k]$ for k = 1,2,...,n. Let I be an investment cost given as a function of $\sum_{k=1}^{n} x_k$, let $u_k(x_k)$, $v_k(x_k)$ and $w_k(x_k)$ be, respectively, the production cost, income and water shortage loss of user k. Let us assume that the total investment cost is divided between users in proportion of water quantity utilized. Then the total income of user k can be determined by the function

$$-\frac{x_k}{\sum_{i=1}^{n} x_i}\, I\left(\sum_{i=1}^{n} x_i\right) - u_k(x_k) + v_k(x_k) - w_k(x_k). \tag{5}$$

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By introducing the notation

$$f\left(\sum_{i=1}^{n} x_i\right) = -\frac{1}{\sum_{i=1}^{n} x_i} I\left(\sum_{i=1}^{n} x_i\right)$$

$$K_k(x_k) = u_k(x_k) - v_k(x_k) + w_k(x_k)$$

function (5) is reduced to Equation (4).

Application 3. Let us now assume that n factories are located along a river and discharge waste into the river. It is also assumed that the total penalty paid by the factories is a function of the total waste discharged into the river and is divided among the factories proportionally to the total quantity of waste discharge. Let factory k discharge a quantity $x_k \leq L_k$. Then the total "income" of factory k can be given by the formula

$$-\frac{x_k}{\sum_{i=1}^{n} x_i} P\left(\sum_{i=1}^{n} x_i\right) - C_k(L_k - x_k), \tag{6}$$

in which $P(\cdot)$ is the penalty function and $C_k(\cdot)$ is the cleaning cost of factory k. Let

$$f\left(\sum_{i=1}^{n} x_i\right) = -\frac{1}{\sum_{i=1}^{n} x_i} P\left(\sum_{i=1}^{n} x_i\right), \quad K_k(x_k) = C_k(L_k - x_k),$$

then function (6) is reduced to the form of Equation (4).

Solution methodology: First it is shown that the equilibrium problem of the classical oligopoly game is equivalent to a fixed point problem in a one dimensional point-to-set mapping, and therefore the numerical solution of a scalar equation is sufficient to solve the problem.
Let

$$\psi_k(s,x_k,t_k) = t_k\, f(s - x_k + t_k) - K_k(t_k)$$

for $k = 1,2,\ldots,n$, $s \in [0,L]$, $x_k \in [0,L_k]$ and $t_k \in [0,\gamma_k]$, where $\gamma_k = \min\{L_k, L - s + x_k\}$. Since $\gamma_k \geq 0$, the interval for t_k cannot be empty. For $k = 1,2,\ldots,n$; $s \in [0,L]$; $x_k \in [0,L_k]$ let

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$$T_k(s,x_k) = \{t_k | t_k \in [0,\gamma_k], \psi_k(s,x_k,t_k) = \max_{0 \leq u_k \leq \gamma_k} \psi_k(s,x_k,u_k)\}$$

and for $k = 1,2,\ldots,n$; $s \in [0,L]$ let

$$X_k(s) = \{x_k | x_k \in [0,L_k], x_k \in T_k(s,x_k)\} .$$

Lemma. A vector $\underline{x}^* = (x_1^*,\ldots,x_n^*)$ is an equilibrium point of the classical oligopoly game if and only if $x_k^* \in X_k(s^*)$ $(k = 1,2,\ldots,n)$, where

$$s^* = \sum_{k=1}^{n} x_k^* .$$

Proof. The definition of the equilibrium point implies that a strategy vector $\underline{x}^* = (x_1^*,\ldots,x_n^*)$ is an equilibrium point of and only if

$$x_k^* f(s^* - x_k^* + x_k^*) - K_k(x_k^*) \geq t_k f(s^* - x_k^* + t_k) - K_k(t_k) \tag{7}$$

for $k = 1,2,\ldots,n$ and $t_k \in [0,L_k]$. One may observe that for $s^* = \sum_{i=1}^{n} x_i^*$ one has $\gamma_k = L_k$.

Inequality (7) is equivalent to setting $x_k^* \in T_k(s^*,x_k^*)$, that is, $x_k^* \in X_k(s^*)$.

Finally, let us introduce the following one dimensional point-to-set mapping:

$$X(s) = \{u | u = \sum_{i=1}^{n} x_i, x_i \in X_i(s)\} \quad (s \in [0,L]). \tag{8}$$

The lemma and definition (8) imply the following result.

Theorem 1. ([7]) A vector $\underline{x}^* = (x_1^*,\ldots,x_n^*)$ is an equilibrium point of the classical oligopoly game if and only if for $s^* = \sum_{i=1}^{n} x_i^*$, $s^* \in X(s^*)$ and for $k = 1,2,\ldots,n$, $x_k^* \in X_k(s^*)$.

Remark. The solution of the game is found in two steps:

Step 1: the solution of the one dimensional fixed point problem $s^* \in X(s^*)$ is found.

Step 2: the sets $X_k(s^*)$ are determined and vectors $\underline{x}^* = (x_1^*,\ldots,x_n^*)$ are computed such that

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$$x_k^* \in X_k(s^*) \quad (k = 1,2,\ldots,n) \text{ and } s^* = \sum_{k=1}^{n} x_k^*.$$

2. Cooperative games

Let us now consider the set of multiobjective programming problems having the form

$$\phi_i(x) \xrightarrow{x \in L} \max \qquad (i = 1,2,\ldots,n). \tag{9}$$

Let

$$L^* = \{\underline{y} \mid \underline{y} = (\phi_1(x),\ldots,\phi_n(x)),\ x \in L\}$$

be the set of feasible pay-off vectors, and let us assume that set L^* is closed, bounded and convex. It is also assumed that there exists a vector $\underline{\phi}^* \in L$ which is called the "status quo" point of the problem. A cooperative solution $\underline{\psi}(L, \underline{\phi}^*)$ is defined by the following axioms:

(i) $D(\underline{\psi}) = \{(L^*,\phi^*) \mid L^* \subset R^n$ closed, bounded, convex;

$\underline{\phi}^* \in R^n$ and there exists $\underline{\phi} \in L^*$ such that $\underline{\phi} > \underline{\phi}^*\}$

$R(\underline{\psi}) \subset R^n$;

(ii) $\underline{\psi}(L^*,\underline{\phi}^*) \in L^*$;

(iii) $\underline{\psi}(L^*,\underline{\phi}^*) \geqq \underline{\phi}^*$;

(iv) if $\underline{\phi} \in L^*$ and $\underline{\phi} \geqq \underline{\psi}(L^*,\underline{\phi}^*)$, then $\underline{\phi} = \underline{\psi}(L^*,\underline{\phi}^*)$;

(v) if $L_1 \subset L^*$ and $\underline{\psi}(L^*,\underline{\phi}^*) \in L_1^*$, then $\underline{\psi}(L^*,\underline{\phi}^*) = \underline{\psi}(L_1^*,\underline{\phi}^*)$;

(vi) if $\psi(L^*,\underline{\phi}^*) = (\psi_1,\ldots,\psi_n)$ and for the constants

$\alpha_k > 0$ and arbitrary $\beta_k, \underline{\phi}^{*\prime} = (\alpha_1\phi_1^* + \beta_1,\ldots,\alpha_n\phi_n^* + \beta_n)$

(where $\underline{\phi}^* = (\phi_1^*,\ldots,\phi_n^*)$),

$L^{*\prime} = \{(\alpha_1\phi_1 + \beta_1,\ldots,\alpha_n\phi_n + \beta_n) \mid (\phi_1,\ldots,\phi_n) \in L^*\}$,

then $\underline{\psi}(L^{*\prime},\underline{\phi}^{*\prime}) = (\alpha_1\psi_1 + \beta_1,\ldots,\alpha_n\psi_n + \beta_n)$;

(vii) if there exists $i \neq j$ such that $\underline{\phi} = (\phi_1,\ldots,\phi_n) \in L^*$

if and only if $\tilde{\underline{\phi}} = (\tilde{\phi}_1,\ldots,\tilde{\phi}_n) \in L^*$ $(\phi_k = \tilde{\phi}_k,\ k \neq i,\ k \neq j,$

$\phi_i = \tilde{\phi}_j,\ \phi_j = \tilde{\phi}_i)$, and the vector $\underline{\phi}^* = (\phi_1^*,\ldots,\phi_n^*)$

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satisfies the condition $\phi_i^* = \phi_j^*$, then $\psi_i = \psi_j$, where

$\underline{\psi}(L^*, \underline{\phi}^*) = (\psi_1, \ldots, \psi_n)$.

The basic theorem of the cooperative game approach is given next.

Theorem 2. ([7], [8]) There is a unique cooperative solution function satisfying axioms (i) - (vii) and this solution can be computed as the optimal solution of the following nonlinear programming problem:

$$\underline{y} \geqq \underline{\phi}^*$$

$$\underline{y} \in L^*$$

$$\prod_{i=1}^{n} |y_i - \phi_i^*| \to \max, \qquad (10)$$

where $\underline{y} - (y_i)$, $\underline{\phi}^* = (\phi_i^*)$.

Problem (10) can be described in the following manner. The decision-maker will choose a feasible pay-off vector which is greater than the "status quo" point for each of the n objectives and which is at a maximal distance (in a geometric sense) from the "status quo" point. This concept leads to the solution of a nonlinear programming problem.

3. General goal-programming methods

The usual form of a multiobjective programming problem is:

$$x \in L$$

$$\phi_i(x) \to \max \ (i = 1,2,\ldots,n) \qquad (11)$$

in which L is the set of feasible points and ϕ_i is the i^{th} objective.

Let us assume that the decision maker has two n tuples, $\underline{\phi}_* = (\phi_{i*})$, and $\underline{\phi}^* = (\phi_i^*)$. The numbers ϕ_{i*} give lower bounds for the goals $\phi_i(x)$ such that the decision maker does not accept any solution with lower values of $\phi_i(x)$ then the given lower bound ϕ_{i*}. It is also assumed that the real objective of the decision maker is to minimize a 2n variate function $g(\underline{\phi}(x), \underline{\phi}^*)$, which could be, for example, the distance between vector $\underline{\phi}(x) = (\phi_i(x))$ and a subjective goal vector $\underline{\phi}^*$. This principle can be summarized in the following programming problem:

$$x \in L$$

$$\phi_i(x) \geq \phi_{i*} \quad (i = 1,2,\ldots,n) \qquad (12)$$

$$g(\underline{\phi}(x), \underline{\phi}^*) \to \min.$$

In practice the function g has been chosen as a weighted ℓ_p-distance of

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n-dimensional vectors, defined by the equations

$$g(\underline{a},\underline{b}) = \rho_p(\underline{a},\underline{b}) = \{ \sum_{k=1}^{n} \alpha_k |a_k - b_k|^p \}^{\frac{1}{p}} \quad (1 \leq P < \infty)$$

and

$$g(\underline{a},\underline{b}) = \rho_\infty(\underline{a},\underline{b}) = \max\{ \alpha_k |a_k - b_k| \}$$

for all $\underline{a} = (a_i)$, $\underline{b} = (b_i) \in R^n$.

In the special case of $g = \rho_p$ (with some p) and with a special choice of vector $\underline{\phi}^*$ taken as $-\infty$, the goal programming concept is obtained ([4],[5]). In a further specialization, let $\underline{\phi}^*$ be the ideal point, with components

$$\phi_i^* - \max_{x \in L} \{\phi_i(x)\}$$

then the compromise programming method is obtained ([1], [3]). If we choose $\underline{\phi}^* = \underline{\phi}_*$ and

$$g(\underline{a},\underline{b}) = -\rho_g(\underline{a},\underline{b}) = - |a_1 - b_1| \cdot \ldots \cdot |a_n - b_n|$$

then the principle of cooperative games is derived.

Now we can show that in some special cases, problem (12) can be solved by special, commonly used algorithms. Let us assume that

$$L = \{\underline{x} | \underline{\underline{A}}\underline{x} \leq \underline{b}\}, \; \phi_i(\underline{x}) = \underline{c}_i^T \underline{x} \quad (i=1,2,\ldots,n).$$

First we consider the special case when $g = \rho_\infty$. Then it is easy to verify that problem (12) is equivalent to a linear programming problem having the form

$$\begin{aligned} &\underline{\underline{A}}\underline{x} \leq \underline{b} \\ &\left.\begin{aligned} &\underline{c}_k^T \underline{x} \geq \phi_{k*} \\ &\alpha_k \underline{c}_k^T \underline{x} - y \leq \phi_k^* \alpha_k \\ &\alpha_k \underline{c}_k^T \underline{x} + y \geq \phi_k^* \alpha_k \end{aligned}\right\} \quad (k = 1,2,\ldots,n) \\ &y \to \min \end{aligned}$$

In the special case of $g = \rho_1$, the problem (12) is equivalent to the linear programming problem

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$$\underline{\underline{A}}\underline{x} \leq \underline{b}$$

$$\left.\begin{aligned} \underline{c}_k^T\underline{x} &\geq \phi_k^* \\ \underline{c}_k^T\underline{x} + r_k &\geq \phi_k^* \\ \underline{c}_k^T\underline{x} - r_k &\leq \phi_k^* \end{aligned}\right\} \quad (k = 1,2,\ldots,n)$$

$$\sum_{k=1}^{n} \alpha_k r_k \rightarrow \min$$

Thus the simplex method can be used in the above two special cases. If $g = \rho_2$, then problem (12) can be reduced to a quadratic programming problem

$$\underline{\underline{A}}\underline{x} \leq \underline{b}$$

$$\underline{c}_k^T\underline{x} \geq \phi_k^* \qquad (k = 1,2,\ldots,n)$$

$$\sum_{k=1}^{n} \alpha_k (\underline{c}_k^T\underline{x} - \phi_k^*)^2 \rightarrow \min,$$

and by introducing the notations

$$\underline{\underline{C}} = \begin{bmatrix} \underline{c}_1^T \\ \underline{c}_2^T \\ \cdots \\ \underline{c}_n^T \end{bmatrix}, \qquad \underline{\underline{\Lambda}} = \begin{pmatrix} \alpha_1 & & & \\ & \alpha_2 & & \\ & & \ddots & \\ & & & \alpha_n \end{pmatrix}$$

the problem can be rewritten as

$$\underline{\underline{A}}\underline{x} \leq \underline{b}$$

$$\underline{\underline{C}}\underline{x} \geq \underline{\phi}^*$$

$$\underline{x}^T\underline{\underline{C}}^T\underline{\underline{\Lambda}}\underline{\underline{C}}\underline{x} - 2\underline{\phi}^{*T}\underline{\underline{\Lambda}}\underline{\underline{C}}\underline{x} \rightarrow \min$$

Observe that in the case of $\alpha_k \geq 0$ for $k = 1,2,\ldots,m$, matrix $\underline{\underline{C}}^T\underline{\underline{\Lambda}}\underline{\underline{C}}$ is positive semidefinite, since for arbitrary vector $\underline{u}$,

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$$\underline{u}^T\underline{\underline{C}}^T\underline{\underline{\Lambda}}\underline{\underline{C}}\underline{u} = \underline{u}^T\underline{\underline{C}}^T\underline{\underline{\Lambda}}^{\frac{1}{2}}\underline{\underline{\Lambda}}^{\frac{1}{2}}\underline{\underline{C}}\underline{u} = ||\underline{\underline{\Lambda}}^{\frac{1}{2}}\underline{\underline{C}}\underline{u}||_2^2 \geqq 0$$

Thus the quadratic programming problem is convex and it can be solved by usual methods ([10]).

In the following discussion we will assume that function g has the general form

$$g(\underline{a},\underline{b}) = u(\sum_{k=1}^{n} v_k\ (a_k-b_k)), \tag{13}$$

where function u is strictly monotone (increasing or decreasing), the functions v_i are arbitrary. We can easily show that the functions ρ_p $(1 \leqq p < \infty)$ and ρ_g all are special cases of the general form (13).

In the case of the weighted ℓ_p norms we can choose

$$u(t) = t^{\frac{1}{p}} \text{ and } v_k\ (t) = \alpha_k|t|^p \quad (k = 1,2,\ldots,n),$$

and if $g = -\rho_g$ then

$$u(t) = -\exp(t) \text{ and } v_k(t) = \log\ |t| \quad (k = 1,2,\ldots,n).$$

Let us next consider a discrete multiobjective dynamic programming problem ([11]) having the general form

$$s_m = f_m\ (s_{m-1},x_m) \quad (s_o \text{ is given})$$

$$\sum_{m=1}^{M} g_{mi}(s_m,x_m) \to \max\ (i = 1,2,\ldots,n)$$

where s_m are the state variables, and x_m are the decision variables. Remember that no restrictions are made about the decision and state spaces. By transforming our dynamic programming problem into the generalized goal programming problem (12) we have

$$\begin{gathered} s_m = f_m(s_{m-1},x_m) \quad (s_o \text{ is given}) \\ \sum_{m=1}^{M} g_{mi}(s_m,x_m) \geqq \phi_{i*} \quad (i = 1,2,\ldots,n) \\ u\ \{\sum_{i=1}^{n} v_i(\phi_i^* - \sum_{m=1}^{n} g_{mi}(s_m,x_m))\} \to \min \end{gathered} \tag{14}$$

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Since function u is strictly monotone increasing or decreasing so that this problem is equivalent to finding an optimal (maximal or minimal) point of the function

$$z = \sum_{i=1}^{n} v_i \left(\phi_i^* - \sum_{m=1}^{M} g_{mi} (s_m, x_m)\right)$$

subject to the same constraints. By introducing the new variables

$$\phi_i^* = \sum_{m=1}^{M} \phi_{mi}^* \qquad (\forall i)$$

$$d_{mi} = \phi_{mi}^* - g_{mi}(s_m, x_m) \qquad (\forall i, \forall n)$$

$$D_{mi} = \sum_{\ell=1}^{m} d_{\ell i}, \quad D_{oi} = 0, \quad (\forall i, \forall m)$$

function z can be rewritten as

$$z = \sum_{i=1}^{n} v_i(D_{Mi}) = \sum_{i=1}^{n} \sum_{m=1}^{M} [v_i(D_{mi}) - v_i(D_{m-1,i})] + \sum_{i=1}^{n} v_i(0) =$$

$$= \sum_{m=1}^{M} \sum_{i=1}^{n} [v_i(D_{mi}) - v_i(D_{mi} - \phi_{mi}^* + g_{mi}(s_m, x_m))] + \sum_{i=1}^{n} v_i(0)$$

Thus the optimization problem of function z is equivalent to optimizing the function

$$\sum_{m=1}^{M} \left\{ \sum_{i=1}^{n} [v_i(D_{mi}) - v_i(D_{mi} - \phi_{mi}^* + g_{mi}(s_m, x_m))] \right\}.$$

Let us define functions G_m by the following equation

$$G_m(s_m, D_{m1}, \ldots, D_{mn}, x_m) = \sum_{i=1}^{n} [v_i(D_{mi}) - v_i(D_{mi} - \phi_{mi}^* + g_m(s_m, x_m))]$$

then our problem has the form

$$s_m = f_m(s_{m-1}, x_m) \qquad (s_0 \text{ is given})$$

$$D_{mi} = D_{m-1,i} + \phi_{mi}^* - g_{mi}(f_m(s_{m-1}, x_m), x_m), \qquad D_{oi} = 0 \ (\forall i)$$

$$D_{Mi} \leq \phi_i^* - \phi_{i*} \qquad (\forall i)$$

$$\sum_{m=1}^{M} G_m(s_m, D_{m1}, \ldots, D_{mn}, x_m) \rightarrow \text{opt},$$

which is a regular dynamic programming problem with decision variable x_m and state variables s_m, $D_{m1}, \ldots, D_{mn}$ at stage m.

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Let us consider a multiobjective continuous control problem defined in the following way

$$\dot{s}(t) = f(t, s(t), x(t)), \; s(t_o) = s_o$$
$$\int_{t_o}^{t_1} g_i(t,s(t),x(t))\,dt \to \max \quad (i = 1,2,\ldots,n). \tag{15}$$

By applying the general principle for this specified problem we get

$$\int_{t_o}^{t_1} g_i(t,s(t), x(t))dt \geqq \phi_{i*} \quad (\forall i)$$
$$\dot{s}(t) = f(t,s(t),x(t)), \; s(t_0) = s_0$$
$$u\{\sum_{i=1}^{n} v_i(\phi_i^* - \int_{t_o}^{t_1} g_i(t,s(t),x(t))dt)\} \to \min \tag{16}$$

Let us introduce the following notations

$$\phi_i^* = \int_{t_0}^{t_1} \phi_i^*(t)dt,$$

$$D_i(t) = \int_{t_o}^{t} (\phi_i^*(\tau) - g_i(\tau,s(\tau), x(\tau)))d\tau.$$

Since function u is strictly monotone increasing or decreasing, the optimization problem of the objective function of problem (16) is equivalent to optimize the function

$$z = \sum_{i=1}^{n} v_i(D_i(t_1) = \sum_{i=1}^{n} \int_{t_o}^{t_1} v_i'(D_i(t))(\phi_i^*(t) - g_i(t,s(t),x(t)))dt =$$

$$= \int_{t_o}^{t_1} \sum_{i-1}^{n} v_i'(D_i(t))(\phi_i^*(t) - g_i(t,s(t),x(t))dt$$

Here we assumed that functions v_i are differentiable, and all the functions included in the problem are sufficiently smooth. Observe that for $i = 1,2,\dots,n$,

$$\dot{D}_i(t) = \phi_i^*(t) - g_i(t,s(t),x(t)),\ D_i(t_o) = 0,$$

and the second set of constraints of problem (16) is equivalent to the inequalities

$$D_i(t_1) \leqq \phi_i^* - \phi_{i*} \qquad (\forall_i).$$

Let the function G be defined by the equation

$$G(t,s(t),D_1(t),\dots,D_n(t),x(t)) = \sum_{i=1}^{n} v_i'(D_i(t))(\phi_i^*(t) - g_i(t,s(t),x(t)),$$

then our results can be summarized as

$$\dot{s}(t) = f(t,s(t),\ x(t)),\ s(t_0) = s_0.$$

$$\dot{D}_i(t) = \phi_i^*(t) - g_i(t,s(t),x(t)),\ D_i(t_o) = 0\ (\forall i)$$

$$D_i(t_1) \leqq \phi_i^* - \phi_{i*}\ (\forall i)$$

$$\int_{t_o}^{t_1} G(t,s(t),D_1(t),\dots,D_n(t),\ x(t))\,dt \rightarrow \text{opt},$$

which is a regular control problem with decision function $x(t)$ and state functions $s(t)$, $D_1(t),\dots,D_n(t)$.

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REFERENCES

[1] Zeleny, M. Compromise Programming. In the book "Multiple Criteria Decision Making" (Ed. M. Zeleny and J. L. Cochrane), University of South Carolina Press, 1973.

[2] Dinkelbach, W., W. Dürr. Effizienzaussagen bei Ersatzprogrammen zu Vektormaximumproblem. In R. Henn (ed.) Operations Research Verfahren, Vol. XII (Meisenheim: Hain), 1972.

[3] Duckstein, L., S. Opricovic. Multiobjective Optimization in River Basin Development. Working paper 77-41, SIE. University of Arizona, Tucson, AZ, 1978.

[4] Charnes, A., Cooper, W.W., Niehaus, R.J. Goal Programming Model for Manpower Planning. "Management Science in Planning and Control," T.A.P.O.J. Publ. No. 5, 1969.

[5] Charnes, A. et al. A Goal Programming Model for Media Planning. Management Science, 14.8 (April), 1968.

[6] Lane, M. N. Goal Programming and Satisfying Models in Economic Analysis. Ph.D. Thesis, Univ. of Texas at Austin, 1970.

[7] Szidarovszky, F. Game Theory (in Hungarian), Textbook of Eötvös Loránd University Budapest, 1977.

[8] Szidarovszky, F., Bogardi, I., L. Duckstein. Use of Cooperative Games in a Multiobjective Analysis of Mining and Environment. Second International Conference on Applied Numerical Modelling, Madrid, Sept. 1978.

[9] Szidarovszky, F., S. Yakowitz. Principles and Procedures in Numerical Analysis. Plenum Press, New York, 1978.

[10] Hadley, G. Nonlinear and Dynamic Programming. Addison-Wesley Publ. Comp. Inc., Reading, Mass., 1964.

[11] Bellman, R., S. Dreyfus. Applied Dynamic Programming. Princeton, N.J., Princeton University Press, 1962.

[12] Roy, B. Problems and Methods with Multiple Objective Functions. Mathematical Programming I, pp. 239-266, 1971.

[13] Monarchi, D., C. Kisiel and L. Duckstein. Interactive Multi-objective Programming in Water Resources: A Case Study. Water Resources Research, Vol. 9, No. 4, pp. 837-850, 1973.

NEW JERSEY GEOLOGICAL SURVEY

[14] Starr, M. K. and M. Zeleny. MCDM - State and Future of the Arts, in Multiple Criteria Decision Making, edited by M. K. Starr and M. Zeleny, North-Holland Publishing Co., Amsterdam-New York, pp. 5-29, 1977.

[15] Duckstein, L. Imbedding Uncertainties into Multiobjective Decision Models in Water Resources. Keynote paper, Session T1, Reliab. Analy., Int'l. Symp. on Risk & Reliab. in Water Res., June 1978, Waterloo, Ontario, Canada.

[16] Cohon, J. and D. Marks. A Review and Evaluation of Multiobjective Programming Techniques. Water Resources Research, Vol. 11, No. 2, pp. 208-220, April 1975.

[17] Haimes, Y. Y., W. A. Hall and H. T. Freedman. Multiobjective Optimization in Water Resources Systems: The Surrogate Worth Trade-off Method. Elsevier Scientific Publishing Company, The Netherlands, 1975.

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REGIONAL WATER SUPPLY PLANNING--GROUND WATER ESTIMATE BASED ON HYDROLOGIC SURVEY IN NEW JERSEY

by

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SYNOPSIS--Ground water in New Jersey occurs in the hard, consolidated sedimentary rocks and crystalline igneous and metamorphic rocks of the Applachian Highland and Piedmont Provinces of the geologic formations; and in the unconsolidated deposits in the Coastal Plain. To a lesser extent, water can be found also in unconsolidated sand and gravel of glacial origin in North Jersey. The ground water storage capacity is estimated from 100,000 well records and by hydrologic computation based on permeability of the various geologic formations.

INTRODUCTION

In rural areas where water supply or sewage treatment systems are locally or regionally not available, water quality planning is essential to meet the demand on water. Surface water is easier accessible in general than ground water, but its quantity is limited, not evenly distributed, depending on climatic conditions and its quality is also difficult to control taking into account flood, drought and pollution from the environment. It is estimated that 97.54% of all fresh water on the earth is ground water and half of this amount is available at a depth of less than 800m under the surface in accordance with DOXIADES (1967).

Shortage of water in areas of excessive demand emphasize the importance of correct estimate, proper development, regulation, and protection of supplies in order to insure the continued availability of this key natural resource. Regional water supply planning is based primarily on ground water availability. Ground water usage has been increased at an accelerating rate in recent years, and the trend will continue. In New Jersey in 1965, U. S. Geological Survey registered 2.27 million m^3/day ground water which has been only a 10% increase for the past decade and 24% of the total fresh water use. On the other hand, the 1970 U. S. Geological Survey already recorded 3.37 million m^3/day ground water, a 69% increase in five years and 35% of the total fresh water use (Sinnott, et al, 1978). Furthermore, 55% of the total population relied on ground water as their supply.

The ground water can be classified as:

(1) Ground water to a depth of 20m (contaminated subsurface water) has an unsteady water table depending on precipitation and evapotranspiration. It is very sensitive to pollution caused by man's activity on the surface, therefore, this water is generally not suitable for drinking purposes.

(2) Ground water in depth of 20 to 180m under the surface (potable ground water) is the most reliable source in the Appalachian Highland and Piedmont geologic provinces in New Jersey.

(3) Ground water in depth over 180m under the surface (geothermal and artesian water) is available in the Coastal Plains sediments and in the Kittatinny limestone formation in the Appalachian Highland. Leakage of the various aquifers and overburden of the water-bearing deeper situated layers produce artesian phenomena and geothermal effects, especially in Ocean County and along the Atlantic Coast. These regions have a very good potential for steady water supply of high quality and abundant quantity.

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GROUND WATER DATA COLLECTION FROM WELL RECORDS

To have a regional water supply estimate from ground water, statistical data of domestic and industrial well records throughout the region are essential. In New Jersey (area of 20,295km^2) for a period of 1941 to 1978 over 100,000 household and industrial wells were recorded. The well location is identified by a seven digit number equivalent to 14 hectare unit (see Figure 1). The first two digits identify the State Atlas Sheet (topographic map), the next two digits specify the Block (area of six minutes of latitude and six minutes of longitude), the last three digits narrows down the area to a 14 hectare unit. The well records are available from the Land Oriented Reference Data System of New Jersey (data bank).

Detailed analyses of well records indicate that (1) there is no correlation between well depth and yield (it depending on the porosity and thickness of the aquifer); (2) the availability of ground water decreases in wells over 180m depth except the Coastal Plains sediments and Kittatinny formations; (3) each formation has its own characteristic yields; and (4) there are varying limits to the amount of water which can be safely drawn from a unit area depending on climatic, surface coverage, or other local conditions. Successful wells can be located near minor geologic structures in accordance with WIDMER (1965).

Based on these well records, the ground water availability in the rock formations from Precambrian sediments through Triassic in age and in consolidated sediments from the Cretaceous to the present, can be estimated. Comparison of large statistical samples of well records in rock formations to a depth of as much as 500m has provided a means of estimating the ground water potential of area underlain by specific rock types. Several of these estimates of ground water availability have been tested against the experience in areas of suburban development during times of drought which occurred from 1961 to 1966. There is sufficient consistency in the results so that underlying rock and sediment types may be determined from well data where they are otherwise concealed by soil and overburden.

GROUND WATER AVAILABILITY BASED ON HYDROGEOLOGIC ESTIMATE

The areal distribution of ground water in New Jersey may be described in accordance with the physiographic provinces of the Garden State (see also Fig. 2):

(1) The Appalachian Highland and Valley Province in the North is the poorest region for ground water supply. The Paleozoic igneous rocks yield about 63 mm/year, and even in cases where these rocks are extremely weathered, they do not give more than 150 mm/year. In the valleys in the area of Kittatinny Limestone, the yield varies from 87 to 225 mm/year according to local conditions (calcium and magnesium content of the limestones, stratified drift, etc.). The Paleozoic Shales' capacity is below 47 mm/year.

(2) The Piedmont Province, comprising the central part of the State, is distinguished by the higher yielding Mesozoic Triassic Brunswick Formation (175 mm/year) and by the lower yielding Basalt and Diabase including the

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Triassic Stockton Formations in Hunterdon County and the silty Brunswick Sandstones in Bergen, Essex and Union Counties (87-125 mm/year). An extremely low yield of less than 47 mm/year is characteristic for the Lockatong and argillaceous Brunswick Formations in Hunterdon, Mercer and Middlesex Counties. Many drilled wells of moderate depth are supplied from joints in the crystalline rocks and in fault zones. Many shallow dug wells are supplied from surface deposits or from the upper decomposed part of the bedrock. Some wells in Triassic Sandstones yield rather large supplies. Special attention should given to the geological "Lake Passaic" in the Upper Passaic Valley where large diluvial deposits of gravel 30-60m deep topped by heavy clayey layers (9-12m) are potential ground water storage areas.

(3) In the Atlantic Coastal Plain Province the water is derived in rather large quantities from Mesozoic Cretaceous (Magothy-Raritan) Formations, Tertiary Neogene Sands and Quaternary deposits, chiefly sand and gravel interbedded with clay. Large supplies are obtained from Tertiary Cohansey Sands near the Atlantic Coast. The aquifers yield 250-425 mm/year. The large area of the Pine Barrens, including the Wharton Tract, yields 305 mm/year also for a longer period.

This general description of the three physiographic provinces has no bearing on exceptional high capacity wells and the characteristic yields are given for the periods of drought. Further significance of these well records is that they include the unsuccessful wells attempting to get amounts of water in excess of 47 mm/year. Approximately 15% of the total recorded number of wells -- especially in Northern New Jersey -- fell in this category and give valuable information about the ground water conditions of the different geological formations. Many of these wells in Northern New Jersey have been completed in the thick Pleistocene outwash deposits and most of the rock wells also have relatively thick covers of Pleistocene sands, gravels, and tills. The Pleistocene wells that have been unsuccessful (107 wells) have been drilled in thick tills, or silt-clogged outwash. Rock wells were unsuccessful (112 wells) because of a thick till cover over the underlying rock (WIDMER 1966).

Finally, the general location of the watershed has a decisive influence on the ground water availability. In the head water area the ground water quantity has a tendency to decrease due to the adjacent lower lying regions. In the lower courses area the ground water capacity may be increased by the additional ground water flowing from the abutting higher water table area.

The gathered statistical data on ground water availability in New Jersey is based also on pumping tests and records of the wells, and their figures can be accepted on the assumption of an average yearly rainfall of 1125 mm -- which value can drop for two consecutive years of drought even to a yearly 850 mm. The ground water in the northern half (rock country) of the area studied is available only to a depth of 180 m below the surface. Boring tests proved that below that level there is a very marked decrease in fractures and fissures from which water can be obtained. There is also evidence, of course, that certain fracture zones may give abundant water at great depth, but these fractures are those such as the Triassic border fault or others that have been mapped for years. In the coastal half (coastal plains) of this examined region, the limit according to the aquifer layers (water containing layers) is from 190 to 1000m (from West to East) below sea level (BARKSDALE 1958).

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It must be stressed that along fracture zones and faults, there is always a possibility of more ground water due to a greater permeability in the formations, even for longer distances. The same principle applies for border lines delineating the different geologic formations since the contact of these formations is never uniform and in most cases has a greater percentage of voids than the adjacent area. Consequently, this permits easier mining or outcrop of ground water. Generally, these zones include the regions of springs and wells of greater capacity. Therefore, the boundary lines are also the zones of greater ground water potential, especially in water poor regions. Similar attention should be given to the limestone areas with numerous secondary openings and caverns, as is the case along the Kittatinny formations in Northwestern New Jersey.

The evapotranspiration and interception average 450-560mm yearly, and average runoff is up to 550mm from the annual precipitation. The ground water availability indicator has a value from 0 to 450mm yearly, depending on the permeability and storage capacity of the geological formations (HALASI-KUN 1971).

Despite the fact that the estimate of the regional availability is complicated by factors such as recharge or transmissability from adjacent areas, there is clear evidence of correlation of permeability of geological formations with surface peak runoff and ground water availability. The comparison can be based only on average values of permeability because they are measured under difficult conditions and in various geological formations which are commensurate to formations used in establishing of runoff formula coefficients and ground water availability indicators (Table 1). It must be pointed out that the various formations are also, in general, already mixed or interwoven even in smaller drainage areas. The uneven surface weathering, artificial impervious surface due to urbanization, the disintegrated underlying rock formations at various depths and the possible present faults add to the difficulty of establishing a practical average value of permeability, ground water availability or surface runoff even for a smaller watershed.

The minimum ground water availability in mm/year given in Table 1 is based on records of lengthy periods of drought such as the 1961-1966 drought of New Jersey. For years with average rainfall, these values may be increased by 50%. On the other hand, the available quantity of ground water for practical planning purposes can be augmented further by an additional 50%, to a total of 200%, assuming that the ground water will be "mined" (taking out more than the natural supply) and the droughts which have a six years recurrence will be of shorter duration. This type of planning can lead to the danger of exhausting the stored ground water quantity, lowering the ground water table, and causing additional problems.

WATER POLLUTION PREVENTION BY MINIMUM LOT SIZE IN RURAL AND SEMI URBAN AREA

Studies indicate that regional planning after World War II has been focused on residential development in rural area. These settlements have been growing far from existing population centers and without any central water

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Table 1

Ground water availability in various hydrogeologic regions of New Jersey, USA and their average permeability

Hydrogeo-logic Regions:	Formations	Ground Water Availability in mm/year	Average permeability in millidarcys:*
(1)	Kaolinite, Clay including argillaceous Triassic or Tertiary Paleocene Flysch	Less than 17	1
(2)	Paleozoic Shales, Shist Mesozoic Marl	Less than 47	3.6
(3)	Igneous Rocks (except Basalt, Diabase), Sand-stones Mesozoic Triassic Stockton Form	63	6.25
(4)	Dolomite, Basalt, Tertiary Marl	87	16
(5)	Weathered Igneous rocks, Limestone, Tuff	150	16-36
(6)	Mesozoic Triassic Brunswick Formations	175	36
(7)	Mesozoic Cretaceous Clayey Sands Tertiary Eocene Clayey Sands	250	36-100
(8)	Tertiary Miocene Sands and Quaternary Moraines	300	100-200
(9)	Tertiary Neocene Sands, Mesozoic Cretaceous Magothy-Raritan Formations Quaternary River Drift	350	100-200
(10)	Tertiary Cohansey Sands with Quaternary Beach Sands (Cape May formations)	360	100-330

* 1 millimeinzer = 18.2 millidarcys

Values are based on over 100,000 well record files of domestic and industrial wells of the State of New Jersey from the period of 1941-1978. Further information, especially for regions (2), (3), (6), (7) and (9), is in references already mentioned: articles and books of Miller, J.; Widmer, K.; Rhodehammel, E.C.; Barksdale, H. C.; Kasabach, H. (See also: Davis, St. N., DeWiest, R. J. M. Hydrogeology, New York-Sydney: J. Wiley & Sons, 1966 and Linsey, R. K. Jr., Kohler, M. A., Paulhus, J. L. H., Hydrology for Engineers, New York-Toronto-London: McGraw-Hill, 1958)

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supply and sewage systems. The builders relied on septic systems and domestic wells, therefore, their attention turned to the ground water availability.

The ground water availability is computed from the hydrologic budget, or from the safe dependable yield of water, which can be mined without the risk of wells, ponds, brooks, or rivers running dry. This safe dependable yield is determined from a whole series of study of the interrelationships of measured rainfall, evaporation, well records, and geologic formations. Based on these studies in New Jersey, it has been determined the water absorbing, and conversely the water yielding capacity per square km of a given geologic formation (computed also in mm/year value). This safe dependable yield will remain a constant, whether water is withdrawn by way of thousand individual wells, or by a few master wells on the particular square km. The daily water consumption of a family by housing type is a known quantity. Thus, the safe dependable yield per square km of geologic formations--when divided by the liters needed for a family--results in the permissible number of lots per square km--or the recommended minimum lot area by geologic formation computed from the pollution effect of septic system effluent including elimination of ill effect on the ground water quality. Recommended minimum lot size by geologic formations is indicated in Table 2.

More recently, it has been recognized that septic tank effluents might be a source of nutrient contamination in ground water; the two nutrients of major concern being nitrogen and phosphorus. The concentration and distribution of nitrogen and phosphorus in septic effluent are primarily controlled by the chemical and biochemical reactions which they undergo in soil. The absorptive capacity of soils is controlled mainly by soil type, underlying geologic formation, the presence or lack of oxygen, and chemical form of the nutrient. For correct functioning of a septic tank, a properly operating leaching field is needed where the size of the field is commensurate to the absorption capacity of the subsurface formation. Overloaded septic system, undersize leaching field, and high water table in the adjacent area causing lack of oxygen are the main contributing factors for any malfunction of a septic system. It is imperative to establish minimum lot sizes by zoning ordinances, building codes, and construction permits in order to prevent the contamination of adjacent lots.

WIDMER (1965), KASABACH (1966) and MILLER (1974) discussed lot sizes as related to wells in considerable detail. Their reports, together with other studies, can be summarized in the minimum lot sizes specified by geologic formations as given in Table 2. These lot size recommendations are based on average, median yields, specific capacities of wells in various geologic formations and on practical experience. The lot sizes are somewhat higher than the yield and specific capacity data might indicate. However, these sizes consider only the ground water availability in an undeveloped area and were computed by estimating the average water availability, the probable percolation rate for each formation, the overlying soils, and the cumulative effect of development. On the other hand, it does not take into account either the polluting effect of septic systems, the amount of recharge area lost because of buildings and pavement or the effect of malfunctioning improperly maintained septic systems.

It should be noted that HORDON and NIESWAND (1978) approached the minimum lot size strictly from the viewpoint of securing ground water quality

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Table 2

Recommended minimum lot size in New Jersey based on dry year ground water storage

Hydrogeologic Regions:	Formations:		Minimum Lot Size in Hectares:
Appalachian Highland and Valley Province:			
(1)	Data not available		
(2)	Paleozoic Ordovician:	Martinsburg Shale	1.50 - 2.25
	Silurian:	Green Pond Congl.	1.50 - 2.00 *
		Shawangunk Congl.	1.50 - 2.00 *
	Devonian:	Esopus Grit	1.50 - 2.25
	Mesozoic Triassic	Lockatong formation	1.00 - 1.25
(3)	Proterozoic Precambrian:	Crystallines	1.50 - 2.00 *
		Gneiss	1.50 - 2.00 *
	Paleozoic Cambro-Devonian:	Hardyston	0.75 - 1.50
		High Falls Form.	0.75 - 1.00
(4)	Proterozoic Precambrian:	Frankline limestone	0.75 - 1.50
	Paleozoic Cambrian:	Kittatinny limestones	0.75 - 1.50
	Silurian:	Decker limestone, Bossardville, Manlius, Roundout, Poxono Form.	1.50 - 2.25
	Devonian:	Marcellus Shale, New Scottland, Stormville Formations	1.50 - 2.25
Piedmont Province:			
(4)	Mesozoic Triassic Igneous Rocks:	Diabase,	1.25 - 1.50
		Basalt flow,	1.00 - 1.25
	Mesozoic Triassic:	Stockton Form.	0.75
(5)	Paleozoic Ordovician-Devonian:	Oriskany, Becraft limestone Coeymans Form.	1.50 - 2.25
		Jacksonburg limestone	0.75 - 1.50
(6)	Mesozoic Triassic:	Brunswick Form.	0.50 - 0.75
(9)	Cenozoic Quaternary	Stratified Drift	0.50 - 0.75
Coastal Plain Province: (7) to (10) minimum lot size not applicable			

* In certain areas of non-fractured rocks, even 2 hectares may be too small a minimum lot size

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based on nutrient dilution: Nitrates and phosphates released from the septic tank effluent into the underlying aquifer without contravening potable water quality standards. In their assumption the dry year yield of the particular geologic formations were used as an estimate of the infiltration to ground water recharge. As a result, they came to the conclusion that the recommended lot sizes, as suggested previously, should be increased by 100% to meet the minimum quality requirements. This approach in calculation disregards the fact that the various geologic formations have ground water reserves from the previous years which can be depleted only by mining huge quantities for a longer period or by having several dry years in sequence similar to the 1961-1966 drought. Furthermore, the dry year yield is only the overflow from the ground water storage of the geologic formations and does not change the quantity of already stored ground water.

Finally, it must be stressed that the minimum lot size recommendation applies only in the geologic regions of the Appalachian Highland and Piedmont Provinces of New Jersey.

GROUND WATER STUDIES AND NEEDS FOR ADDITIONAL INFORMATION

There has been a general upward growth trend in New Jersey, not only in population but in economic activity, manifested by industrial development, increasing urbanization, and increasing water requirements. More information will be needed regarding the occurrence and availability of additional ground water supplies in the region, especially in the Coastal Plain area, and the hydrologic effects of their developments, to facilitate efficient management of the total water resources.

By 1970 in New Jersey, 3,778,000 people had their domestic water supply from ground water comparing to 3,030,000 who drew their supply from surface water resources. In accordance with the nationwide report of 1.1.1979, 10% of the hazardous and other wastes of the whole United States are produced in New Jersey which circumstance stresses even more the importance of efficient water quality management. Further research is needed to shape a more safe and accurate computation method in estimating (1) the ground water storage capacity of various geologic formations; (2) the effect of the six to nine year recurrence of the dry years on the accumulated ground water; and (3) the dilution from septic system effluent in the Appalachian Highland and Piedmont provinces including improvement of its management and control.

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REFERENCES

BARKSDALE, H.C., GREENMAN, D.W., LAND, S.M., MILTON, G.S., OUTLAW, D.E., Groundwater Resources in the Tri-State Region Adjacent to the Lower Delaware River, Special Report No. 13, Trenton: State of New Jersey, 1958.

DOXIADIS, C.A., "Water and Environment," Water for Peace, Vol. I, Washington, D.C.: International Conference on Water for Peace - May 23-31, 1967, pp. 33-60.

HALASI-KUN, G.J., "Aspects hydrologiques de la pollution et des ressources en eau, dans les domaines urbains et industriels", Actes du Congres: Sciences et Techniques An 2000, Paris: SCIF, 1971.

HALASI-KUN, G.J., "Data Collecting on Water Resources and Computations of Maximum Flood for Smaller Watershed", Simposio Internacional Sobre La Planificacion De Recursos Hidraulicos - Ponencias, Vol. I, Mexico, 1972.

HALASI-KUN, G.J., "Ground Water Computations in New Jersey, USA", Nordic Hydrology 5, 1974, pp. 108-118.

HALASI-KUN, G.J., "Land Oriented Water Resources Data System in New Jersey", Environmental Management: Land and Water Resources Policy. New Brunswick, N. J.: Rutgers University, 1978.

HORDON, R.M. AND NIESWANT, G.H., "Application of the Douglas Nutrient Dilution Model to the Non-Sewered Areas of Central New Jersey," 14th American Water Resources Conference, Orlando, Fla., Nov. 6-10, 1978.

KASABACH, H., Geology and Ground Water Resources of Hunterdon Co., Special Report No. 24, Trenton: State of New Jersey, 1966.

MILLER, J., Geology and Ground Water Resources of Sussex Co., Geol. Bulletin No. 73, Trenton: State of New Jersey, 1973.

RHODEHAMMEL, E.C., A Hydrologic Analysis of the New Jersey Pine Barrens Region, Water Resources Circular No. 22, Trenton: State of New Jersey and U.S.G.S., 1970.

SINNOTT, A. AND CUSHING, E.M., Summary Appraisals of the Nation's Ground-Water Resources-Mid-Atlantic Region, Washington, D.C.: Geological Survey Professional Paper 813-I, 1978.

WIDMER, K., Geology and Ground Water Resources of Mercer County, Geol. Report No. 7, Trenton: State of New Jersey, 1965.

WIDMER, K., "Study of Groundwater Recharge in Santa Clara Valley, Calif. and Its Application to New Jersey", Journal American Water Works Association, Vol. 58, No. 7 (1966). pp. 893-904.

WIDMER, K. AND HALASI-KUN, G.J., Land Oriented Reference Data System, Trenton: New Jersey Geological Survey, Bulletin No. 74, 1974.

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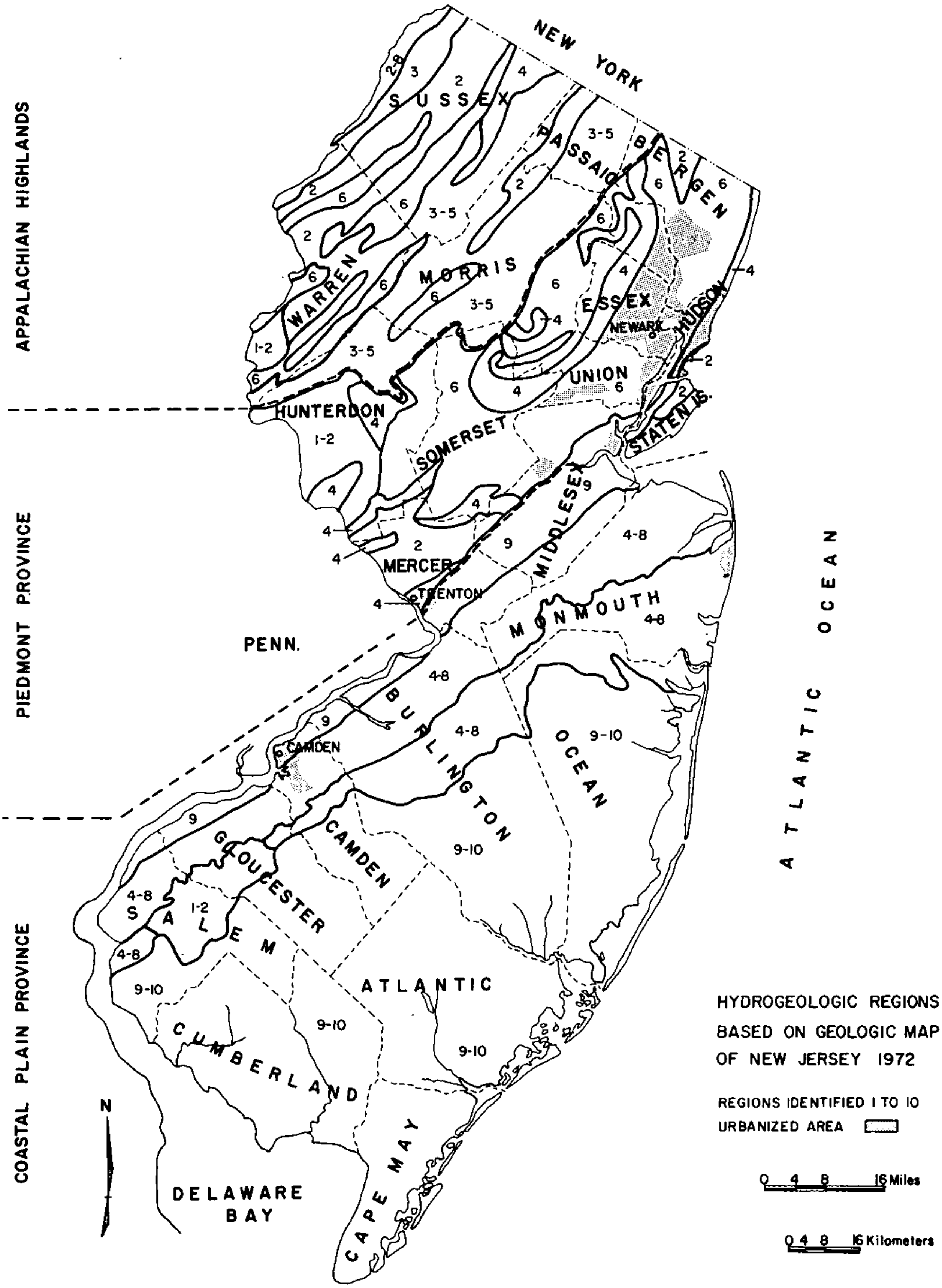

Figure 2

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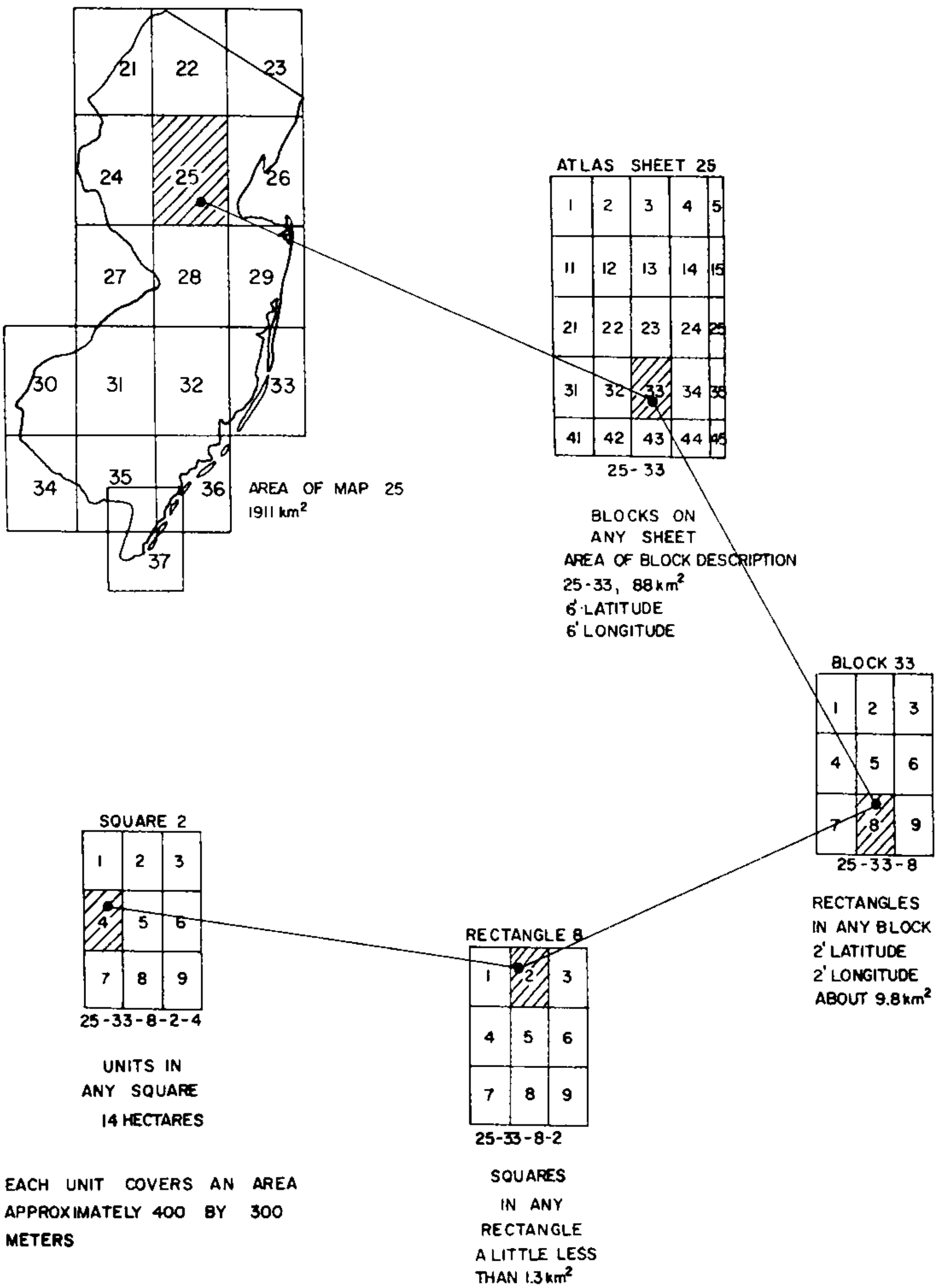

DIAGRAM Showing Use of New Jersey Rectangular Coordinate System
To Locate A Facility At 25-33-8-24
Figure 1. Schematic Diagram Locating Information

ALTERNATIVE APPROACHES TO GROUND-WATER MANAGEMENT

by

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ABSTRACT

Main objective of ground-water management is to ensure that ground-water resources will be available in appropriate time and in appropriate quantity and quality to meet the most important demands of our society. Traditional, and obvious, uses of ground water are the extraction for water supplies (domestic, municipal, agricultural and industrial) and natural discharge feeding lakes and maintaining base flow of streams. Not so obvious are the uses of ground-water reservoirs, the very framework within which ground water occurs and moves, and in which other fluids can be stored. In the last two decades, ground-water reservoirs have been intensively considered for many other purposes than water supplies. Diversified and very often conflicting uses need to be evaluated and dealt with in the most efficient way in order to determine the importance of each possible use, and to assign priorities of these uses. With rising competition for the use of ground-water reservoirs, we will also need to increase the potential for effective planning of ground-water development and protection. Man's development and use of ground water necessarily modifies the natural conditions and the total natural system must be successfully blended with the unnatural stresses placed upon it. This can be accomplished by developing alternative strategies for ground-water management. Among others, resource suitability analysis and ground-water zoning seem to be especially promising tools in comprehensive ground-water management. Also, new methods have to be introduced for dealing with existing or potential ground-water pollution problems such as preventive programs and pollution-potential analysis.

INTRODUCTION

Ground water represents the world's largest freshwater storage, but it is one of the most misunderstood and misused resources. It is also very vulnerable to irreparable damage. It needs adequate protection and management because pressures on its utilization are growing. The role of ground-water supply in total use of water has been increasing rapidly and will probably continue to do so with the rising standard of living and economic growth all over the world. Also, its importance as a source of fresh water is well established. NACE (1960) estimated that globally, about one million cubic miles (4 mill. km^3) of ground water are stored in the Earth's crust to a depth of one-half mile (800 m). These aquifers contain 33 times the amount of water in lakes and streams.

In the past decades ground-water reservoirs have been considered more and more for purposes other than water supply, such as use of deep wells for disposal of foreign fluids, use of aquifer as a heat sink, or use of aquifer as a storage space. Besides that, other legitimate activities within the ground-water reservoir tend to adversely affect the utilization and quality of ground-water: agricultural practices (including irrigation), recreation or urban development, drainage, mining, and waste disposal.

The objective of the ground-water management is to ensure that ground-water resource will be available in appropriate time and in appropriate quantity and quality to meet the most important demands of the society. Above all, ground-water resources should be reserved for drinking-water supply, then

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for the satisfaction of other water users, and finally, for purposes other than water supply (disposal place or storage space). The use of ground-water reservoirs for these special purposes should be allowed only after satisfying all the water requirements, and after proving that these uses would not have adverse effects on water supplies.

In order to accomodate all the conflicting uses of and activities within a ground-water reservoir, new methods for evaluating the capacity of a reservoir must be developed and introduced into comprehensive planning program.

USES OF GROUND-WATER RESERVOIRS

To conduct a successful ground-water management program, each ground-water or ground-water reservoir user may be faced with the need to give up one or more of totally independent actions in order to achieve a common benefit. It is difficult for a single user to be concerned with the long-term advantages of conservation and management of ground water when he does not feel that his own actions are jeopardized. This traditional attitude, however, may adversely affect the interests or actions of other users. These effects are progressive. Before all the users are affected or concerned, it may be too late to apply remedial measures. And, ground-water resources are especially vulnerable to damage which, in many cases, may be essentially irreversible. Or, it may be very difficult and expensive to restore the original quality of water.

As the development of ground-water reservoirs progresses, competition for their uses will intensify. The uses of ground-water reservoirs are diverse, and are likely to become more diverse in the future. Broadly speaking, the reservoir can be used, or abused, in four basic ways: (1) in its natural state, (2) for the extraction of ground water or other natural resources, (3) as a host for specific uses conducted on land overlying the reservoir, (4) as a host of specific uses inside the reservoir. Possible uses are summarized in Figure 1.

Traditional, and obvious, uses of ground water are for water supply (domestic, municipal, agricultural and industrial), and for base-flow contribution to surface waters.

(1) In natural conditions, all ground water eventually discharges into a surface water body, or at the ground surface in the form of a spring. The most important natural function of ground water is augmenting surface water and maintaining base flow in the streams. The interrelation of the two bodies of water -- surface and ground -- is most significant and has to be considered always.

(2) Unfortunately, ground water in its natural state satisfies man's quest for water in only a few areas where large springs discharge at the surface. In most cases, ground water for human consumption must be extracted. This use may be characterized as a primary use of a ground-water reservoir. Besides for water supplies, ground water is also used for health care in the form of mineral water for drinking cures and for baths as well as tasteful table waters.

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Sometimes, ground water has to be extracted for purposes other than water supply. Removal of water is common in most mines where water is pumped out and is not subsequently used for beneficial purposes. Such a removal is justified since ground water in this case is a hazard and can often limit or prohibit mining. In order to avoid wasting of a limited resource, management plans should include provisions for beneficial use of removed water.

Ground-water reservoirs can also be adversely affected by extraction of other natural resources. For example, aquifers used as a source of sand and gravel may be completely destroyed or altered. Less common is the use of ground water as a source of raw materials. Highly saline waters, brines, may contain enough valuable minerals to justify economic exploitation. However, this problem would be rarely met by ground-water manager.

Not so obvious are the secondary uses of ground-water reservoirs, which may be sometimes unusual or even exotic (KAZMAN, 1971), and their relation to ground water may be somewhat obscured. For discussion purposes, these uses can be grouped into two broad categories: land surface uses and subsurface uses.

(3) A ground-water reservoir can generally be affected by overlying land use in three ways: by modification of the infiltration rate, by modification of the flow, and by introduction of undesirable substances into the ground.

To the first group -- uses modifying the infiltration rate -- belong all activities which waterproof the land surface, thereby diminishing the opportunity for natural recharge (these include housing construction, surfacing of parking lots, roads and airfields); or activities which change runoff/infiltration balance, such as agricultural practices, changes in vegetative cover, and irrigation. Irrigation return water also affects water quality by slowly concentrating mineral content as the result of cumulative effect of evapotranspiration. Indirectly, the infiltration rate may also be modified by changes in vegetative cover which in turn leads to changes in evapotranspiration at the land surface.

The second group of land uses -- modifying the ground-water flow system -- includes drainage, development of streams, and excavation and surface mines dewatering. These may change the hydraulic gradient, thus producing a change in the direction of flow. The changed direction of ground-water flow can also induce an inflow of water of inferior quality. Drainage can alter ground-water flow patterns permanently, whereas excavation-dewatering and mining operations, being relatively short-lived, generally alter the flow system only temporarily. Surface-water development also belongs to this group. Wherever ground water discharges into or is recharged by a stream, a change of the character of the stream is likely to modify the ground-water regime.

The third group of land uses introduces undesirable substances into the ground and may cause impairment of ground-water quality. Potential pollutants may be introduced by either wastewater irrigation, or by percolation of leachates produced by water infiltrating through the refuse disposed in landfills or through soluble solids stored on the land surface (such as highway de-icing salt piles or mine waste piles). A related problem may be

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generated by agricultural application of pesticides, herbicides and fertilizers.

Additional ground-water quality problems, mostly of local scale, may be created by seepage from cesspools, septic tanks, animal feed lots and waste retention ponds and lagoons, or eventually, from polluted streams and lakes. A wide variety of harmful substances may be introduced into the ground by leaking or broken sanitary and storm sewers; by leaks in oil and other pipelines or in storage tanks containing hazardous liquids; and by percolation of liquids spilled accidently or deliberately at the land surface.

(4) In the last two decades, ground-water reservoirs have been considered more and more as a subsurface disposal facility or storage space.

The use of a ground-water reservoir for deep-well disposal is becoming increasingly common in the United States (RIMA, CHASE AND MEYERS, 1971). Underground disposal has been encouraged by the success oil companies have had over the last 40 years with injection wells for disposal of oil-field brines. This method of disposal is used largely by the chemical, petrochemical, steel and paper industries for wastes that are difficult and very expensive to treat, such as chlorinated hydrocarbons, steel pickling liquors and mercaptans.

Special problems of unique character are brought by the disposal of radioactive wastes, liquid or solid, which, if not controlled and monitored, may cause a very severe contamination of ground water for centuries.

Closely related to the problems of underground disposal of foreign liquids is the problem of using an aquifer as a storage container. The underground storage of natural gas far outshadows other uses made of ground-water reservoirs for storing liquids.

Among storage activities, one may include artificial recharge, which is nothing more than using an aquifer as an underground water reservoir. Some of the advantages of underground reservoir storage are quite obvious -- evaporation losses are minimized, and sedimentation, an everlasting disadvantage of surface reservoirs, is eliminated. But this use is still a multi-faceted problem and the available techniques are still inadequate to allow efficient transfer of large volumes of surface water into an aquifer (BROWN AND SIGNOR, 1974).

Highly mineralized saline aquifers can be used for the storage of fresh-water supplies (BROWN AND SILVEY, 1973). This idea was suggested as early as in 1947, but the major interest has developed in the last ten years.

Successful - but only slowly gaining recognition - is a special use of ground-water reservoirs utilizing the unique thermal properties of ground water. An aquifer can be used either as a heat sink (storage of heat on a cyclic basis) or, in conjunction with a heat pump, as an energy source. Large quantities of heat may be stored underground in special water wells, with more than three-fourths of the heat being recoverable after 90 days (MEYER AND TODD, 1973). A ground-water heat pump has the ability to extract heat energy from the water when heating is required, and expel heat to the water when air conditioning is required (GASS AND LEHR, 1977). The idea is not new and the basic technique is thirty years old, but for a number of factors, it has not

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gained recognition. Only recent developments of more efficient equipment, concern about diminishing sources of energy, and especially, efforts of the National Water Well Association to promote ground-water energy, resulted in a significant increase in interest in using ground water as an alternative energy source.

Another special use of a ground-water reservoir can be illustrated by flood and pollution control in the greater Chicago area. A system of more than 100 miles of tunnels though bedrock aquifers has been proposed to intercept overflow from existing combined and sanitary-storm sewer system and convey it to temporary underground storage chambers (PAPADOPULOS, LARSEN AND NEIL, 1969). Water will be pumped gradually from these storage chambers to surface reservoirs and then passed through a waste treatment plant, thereby reducing pollution of the water ways. A relatively simple system is proposed for the protection of ground water from pollution. It consists of maintaining higher ground-water pressure outside the tunnels and chambers than the pressure inside the structures. Any seepage will be inward rather than outward. If the hydraulic head is reduced due to ground-water pumpage, artificial recharge can be applied to maintain a higher ground-water pressure over the tunnel area. Three pilot tunnels of the first phase of the project are completed and the entire project is expected to be completed by 1983, depending upon the availability of federal funds.

The last two examples indicate a great range of diverse uses of ground-water reservoirs which can be expected in the future. One can anticipate the evolution of a variety of new and still unknown uses as the pressure for development and utilization of ground-water resources grow. This will subsequently generate a pressure on ground-water reservoir capacity to accomodate all these different, and often competing, uses and will certainly create problems which can only be dealt with in a comprehensive ground-water management program.

ALTERNATIVE METHODS FOR GROUND-WATER MANAGEMENT

As the development of ground-water reservoirs progresses, competition for their use will intensify. Diversified and very often conflicting uses need to be evaluated and dealt with in the most efficient way in order to determine the importance of each possible use, and to assign priorities of these uses. This can be accomplished by introducing new methods of the evaluation of ground-water resources. Among others, resource evaluation system and ground-water zoning seem to be especially promising tools in achieving the ultimate goal of ground-water management -- ground-water protection.

Resource Evaluation System

A prerequisite to the full development of ground-water reserves is adequate technical information, including the basic data necessary for application of proven hydrologic principles. The required data can be secured by a thorough resource inventory which reveals the needs for further research and investigation. Inventory is essential for any analysis or planning process. The ultimate purpose of the inventory is to collect data which are usually widely spread in files of various agencies, to compile and summarize

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them, and to present them in a form which can be used for further analysis and assessment of the resource.

There have been several attempts to develop a system for presenting an ever growing mass of natural resource information in a readily understandable form. The first land evaluation system was developed for the interpretation of the suitability of soils for suburban development in the Chicago area by Quay in 1960's. The interpretation of other geologic data on the same basis was later perfected by the Illinois Geological Survey.

Resource suitability studies can be carried on for various purposes and at a wide range of scales, from those of detailed investigations at specific sites to those of regional and statewide studies. Resource suitability analysis results in a series of maps which are actually graphical interpretations of the characteristics of specific areas with respect to particular uses. They help to resolve conflicts between limitations imposed by the natural environment and the requirements of proposed uses, warning against problem areas and guiding development to propitious ones.

One of the means to interpret and present the earth-science data in a form needed by planners is a resource interpretation system which consists of four levels of maps: basic resource maps, single-factor maps, limiting-factor maps, and a final land suitability map (ZAPOROZEC AND HOLE, 1976). The example given in Figure 2 refers to the evalution of land for solid waste disposal. Similarly, factors important for evaluation of any other use listed in Figure 1 can be selected and used in the system. The first category is based on primary resource information collected by federal, state and local agencies. The second category represents a series of maps showing specific kinds of information derived from the basic resource maps of the first category. The third category of maps is derived from the second-category maps and inlcudes those expressing degrees of limitations for a given purpose. The final land suitability map is constructed by superimposing various combinations of limiting-factor maps and by identifying the degree of suitability for specific use.

However, a land suitability map is at best a time-saving basic guide. The map does not replace the need for on-site investigation, but it reduces the number of sites to be studied in detail. Similar interpretation systems can be used for the evaluation of the biological environment (plant associations, wildlife), limitations set by existing land use (zoning, sanitary and water-related facilities, utility lines, highways), and social and cultural factors (population, economy, unique scenic and historic sites).

Ground-water Zoning

Another means of insuring the protection of ground-water quantity and quality is a regional zoning of ground-water resources. In essence, ground-water zoning, or better hydrogeologic regionalization, is regional subdivision of a particular geographical area into hydrogeologic units on the basis of similar hydrogeologic characteristics for the purpose of increasing the potential for effective planning of multiple use of aquifers. For wider acceptance and usability of ground-water zoning, it is necessary to establish a comparative classification system of hydrogeologic units (ZAPOROZEC, 1972).

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A hydrogeologic unit can be defined as an areal subdivision of rocks in the earth's crust distinguished and delineated on the basis of lithologic, geotectonic, geomorphic, hydrogeologic and hydraulic characteristics which form a framework for a reasonably distinct hydrologic system. Because hydrogeologic units can be of several different orders of magnitude, a further specification and classification of units is desirable.

The hydrogeologic district is the fundamental unit in the proposed classification. It may be divided into hydrogeologic zones, or even subzones when necessary. Single hydrogeologic districts may be grouped into a larger unit, the hydrogeologic province, and related provinces may be grouped to form the largest unit of all, the hydrogeologic realm.

The order of magnitude of hydrogeologic units can best be illustrated by the example of the United States, which can be subdivided into five hydrogeologic realms. These realms can be further subdivided into 21 hydrogeologic provinces (Figure 3).

In the process of hydrogeologic regionalization, the basic quantitative and qualitative characteristics of the units are determined and their possible uses evaluated. The smallest units, usually hydrogeologic zones, may be numbered and cataloged. Each unit is evaluated either as suitable for water supply or as suitable for other uses. This includes evaluation of the capability of a planning unit to accomodate all different, and very often conflicting, uses and activities, and identification of those activities which would tend to adversely affect the water resources; and evaluation of the need for protection of a unit against all potential hazards in terms of quantity and quality. After the regionalization is completed, the importance and primary use of each unit is determined, further research and monitoring of units is proposed, and the priorities of investigation and development are assigned. In such a way, hydrogeologic regionalization becomes a basic element of a framework plan.

PRINCIPLES OF GROUND-WATER PROTECTION

The quantity aspect of ground-water protection is to regulate ground-water withdrawals in such a way that the water-supply sources would not influence each other. This aspect is well documented in hydrologic literature and therefore, it will not be discussed in any detail.

There are two basic approaches in dealing with ground-water protection from the quality aspect. The first is handling existing cases of pollution, and the second is preventing new occurrences.

The most common approach toward existing problems is to start corrective action only after a specific incident of pollution has been discovered. This crisis-oriented approach is wrong. Locating and evaluating as many cases of ground-water pollution as possible should be a major concern to public agencies charged with the responsibility of protecting water quality. A major effort should be directed, at all levels of government, toward defining the areal extent and and severity of existing ground-water pollution problems.

Equally pressing as the need to develop methods and strategies for dealing with existing problems of ground-water pollution is the need to

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establish a program to prevent future problems. One part of the program would be an inventory of all possible sources of pollution and evaluation of their potential hazards. Ground-water protection can then be based on the same premise as surface water quality control: reduction of the pollution potential of a source, and eliminating some of those activities or uses of ground-water reservoirs that have the highest potential for introducing pollutants into the ground water.

Another part of the preventive program would be evaluating the potential of the environment for accepting pollution (defining the limits of the environment) and delineating the most critical areas where the physical environment has the least capacity to protect ground water from pollution, using a resource evaluation system described above.

There are many alternatives available for devising protective measures. For example: regulating patterns of ground-water uses; determining the protective zones for the intake areas of water wells; setting ground-water standards; enforcing land-use restrictions in critical areas; imposing restraints on individual uses of ground-water reservoirs that may lead to pollution; and delineating areas that have the highest pollution potential and areas where a certain degree of pollution is permissible (controlled pollution).

It is appropriate to mention at this time that monitoring is not included among protective devices even though it is often considered to be one. Monitoring is not a method of protecting ground-water quality at all. It is applied only when there is a need to determine the ground-water quality at a particular location and its changes with time, or when it is necessary to control if designed protective measures are working successfully.

The author has concentrated the discussion on the measures which here-to-fore have received only little attention: (1) delineating protective zones around the sources of water supplies, and (2) determining pollution potential.

(1) The concept of protective zones around the sources of water supplies applies primarily to densely populated regions. Therefore, it has been well established in Europe, where the population density is much higher than in other parts of the world. Protective zones are included in state regulations of many European countries.

The establishment of protective zones may have severe economic effects for a community. Ground water is not provided with sufficient protection if the limits are appointed too close. If the limits are too loose, other water users -- primarily industry -- are forced to go to unreasonable distances. Therefore, each zone should be delineated as reliably as possible on the basis of all available data or investigation, if necessary.

The boundaries of the zones may be set up considering the operational depressions of water level, continuity of withdrawal and duration of exploitation, or travel to the well for different materials (RICHTER, 1974). The protected area consists of several zones, usually two or three, according to the ground-water conditions. Zone I -- minimum zone of protection -- is confined to the immediate environment of the well (intake area) and includes

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protection against all kinds of influences. It is generally surrounded by fencing. Zone III is the maximum boundary of the protected area and includes protection against wide reaching effects such as waste disposal pollution. Certain uses of the area are allowed, such as low-capacity water supplies, light housing development, or small industrial development. Zone II -- intermediate zone of protection -- may be established within the limits of Zone III. All uses in this zone are regulated and limited to a permit.

Similarly, protective zones can be established for each land use affecting ground water, by giving a minimum distance from the point of water supply at which the use may be located.

(2) The principle of "controlled pollution" is to find, within the general area considered for a particular use, a site with the most favorable physical conditions, which can reduce the adverse effects of this use to minimum, or ideally, accomodate it without affecting the environment at all.

The prevention program can be concentrated on the delineation of areas where the environment is least likely to protect ground-water from pollution, i.e. the areas of limited use. The areas can be expressed graphically on a ground-water protection map. However, such maps are very generalized and therefore of little use for ground-water management.

A much better approach is to base a ground-water protection map on the evaluation of hydrogeologic systems and hydrogeologic regionalization. Then, based on hydrogeologic conditions of the area and the degree and pattern of water and other uses, a corresponding method of protection can be assigned. The primary objective is to protect the sources of water supplies. The protection, however, should not be limited only to the particular intake area, but should also include the protection of the entire hydrogeologic regime.

The map can delineate both the pollution potential and the degree of protection needed. Pollution potential can be expressed in several categories differentiated by color on the map. The categories of the degree of protection can be differentiated by hatching over the color.

CONCLUSION

Ground water, as our principal reserve of fresh water, is a valuable natural resource, and it deserves all the care which man can offer it. How long man will enjoy the benefits of ground water depends upon the degree to which he conserves and manages that vital resource. Ground water is the resource which presently offers the greatest opportunities for new management practices. So far much of our water utilization has been confined to haphazard local development. Rarely has there been integrated development of ground water and surface water, or of ground water and other resources. There is a need for more studies similar to the San Francisco Bay Region Environment and Resources Planning Study initiated in 1970 and carried out jointly by the U.S. Geological Survey and Department of Housing and Urban Development. Such studies will help society to live in harmony with the environment, taking advantage of countless benefits without threatening complex natural interrelationships.

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REFERENCES

BROWN, R.F., AND SIGNOR, D.C. (1974). Artificial Recharge - State of the Art: Ground Water, v. 12, no. 3, p. 152-160.

BROWN, R.F., AND SILVEY, W.D. (1973). Underground Storage and Retrieval of Fresh Water from a Brackish-Water Aquifer: Underground Waste Management and Artificial Recharge Preprints, v. 1, p. 379-419.

GASS, T.E., AND LEHR, J.H. (1977). Ground-Water Energy and the Ground-Water Source Heat Pump: Ground Water, v. 15, no. 3, p. 244-249.

KAZMAN, R.G. (1971). "Exotic Uses of Aquifers:" American Society of Civil Engineers, Proceedings, Journal of Irrigation and Drainage Division, v. 97, no. IR3, p. 515-522.

MEINZER, O.E. (1923). The Occurrence of Ground Water in the United States: U.S. Geological Survey, Water-Supply Paper 489 (reprinted in 1939 as Water-Supply Paper 494).

NACE, R. L. (1960), Water Management, Agriculture and Ground-Water Supplies: U.S. Geological Survey, Circular 415.

PAPADOPULOS, I.S., LARSEN, W.R., AND NEIL, F. C. (1969). Ground-Water Studies -- Chicagoland Deep Tunnel System. Ground Water, v. 7, no. 5, p. 3-15.

RICHTER, W. (1974). Aspects and Procedure in the Establishment of Groundwater Protection Areas: International Association of Hydrogeologists, Memoires v. X, Proceedings Congress Montpellier, France, p. 118-120.

RIMA, D. R., CHASE, E. B., AND MEYERS, B. M. (1971). Subsurface Waste Disposal by Means of Wells -- A Selective Annotated Bibliography; U.S. Geological Survey, Water-Supply Paper 2020.

VRANA, M. (1968). Map of Underground-Water Safeguarding in the Territory of Bohemia and Moravia, 1:500 000: International Association of Hydrogeologists, Proceedings General Assemby Prague, Czechoslovakia, p. 23-29.

ZAPOROZEC, A. (1972). Ground-Water Zoning in Water Resources Management: Water Resources Bulletin, v. 8, no. 6, p. 1137-1143.

ZAPOROZEC, A., AND HOLE, F. D. (1976). Resource Suitability Analysis in Regional Planning - with Special Reference to Wisconsin, U.S.A.: Geoforum, v. 7, no. 1, p. 13-22.

NATURAL USE		Ground-water springs	Base-flow contribution to surface waters			
EXTRACTION OF EXISTING RESOURCES		Extraction of water for water supply	Extraction of water for purposes other than water supply	Natural resources extraction		
LAND USES	MODIF. OF INF. RATE	General construction	Transportation: airfields, roads	Urban development	Agriculture practice	Irrigation
LAND USES	MODIF. OF FLOW SYST.	Surface water development	Surface mines dewatering	Excavation dewatering	Drainage	
LAND USES	INTRODUCTION OF UNDES. SUBSTANCES	Solid waste disposal	Salt or waste piling	Agricultural development	Recreational development	Incidental spillage of harmful liquids
LAND USES	INTRODUCTION OF UNDES. SUBSTANCES	Disposal of liquid waste by irrigation	Waste retention ponds & lagoons	Septic tanks, cesspools	Animal feedlots	Accidental breakage of sewers or pipelines
SUBSURFACE USES	DISPOSAL	Wastewater injection	Cooling or heating water disposal	Solid waste disposal	Radioactive waste disposal	
SUBSURFACE USES	STORAGE	Artificial recharge	Storage of fresh water in saline aquifers	Natural gas storage	Storage of storm runoff	

Figure 1. Classification of Possible Uses of Ground-Water Reservoirs.

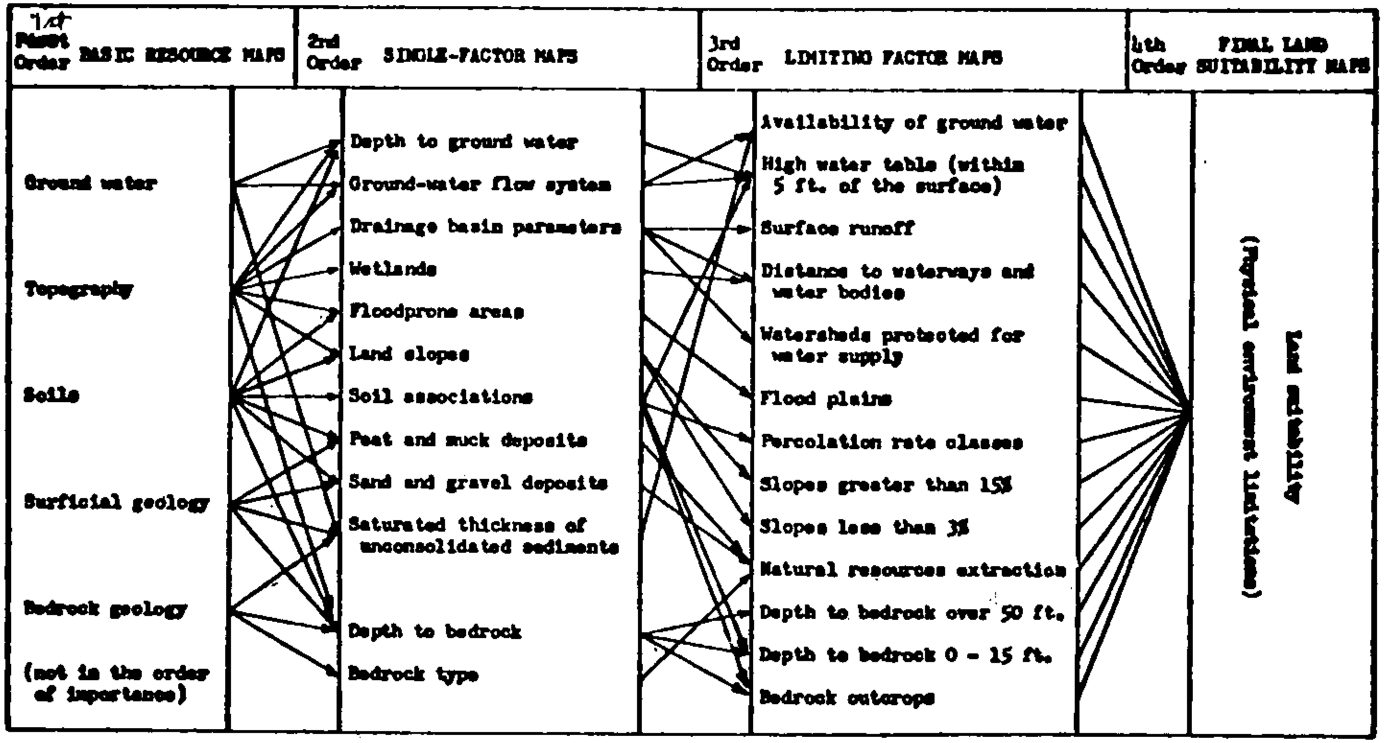

Figure 2. Resource Interpretation System.

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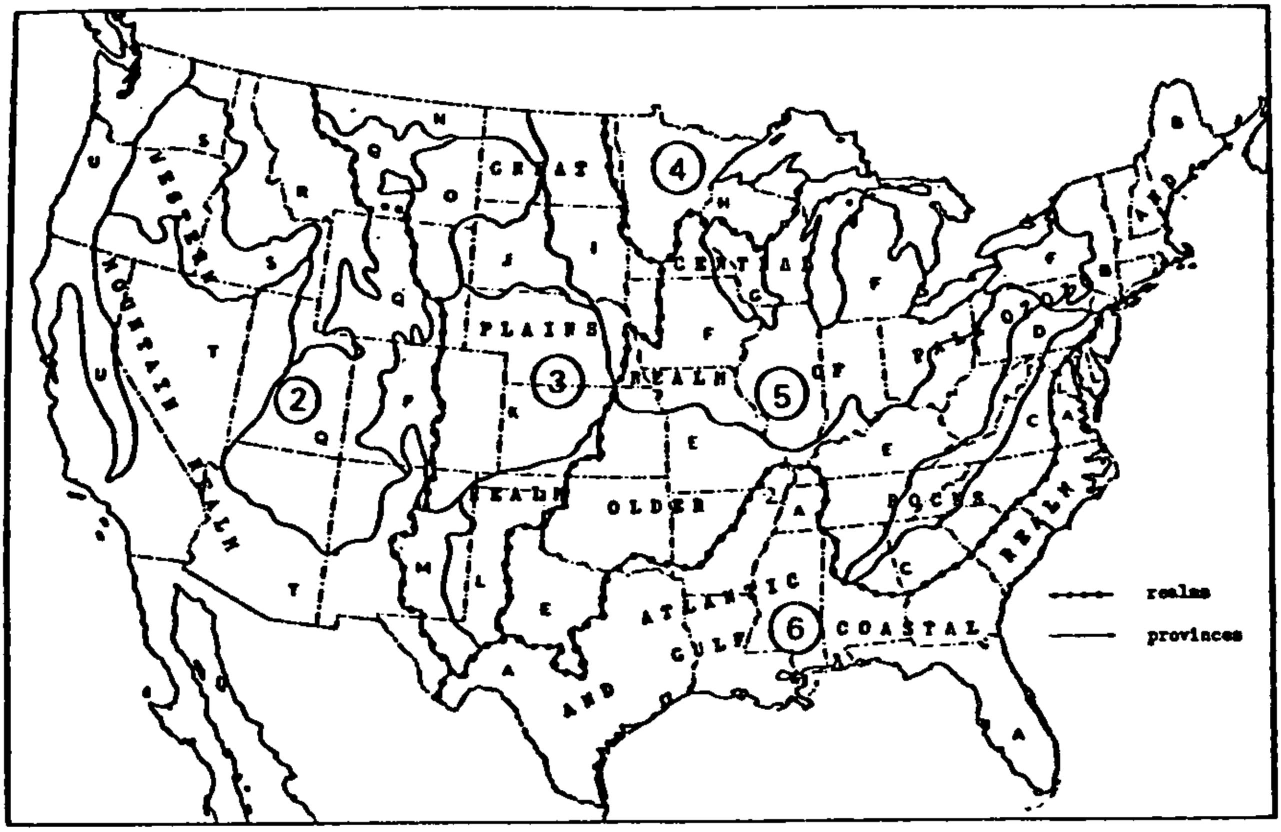

Figure 3. Hydrogeologic Provinces of the United States.

Hydrogeologic Realms (after Zaporozec, 1972):

1 Northern Permafrost realm (in Canada only)
2 Western Cordilleran realm (including intermontane plateaus)
3 Great Plains realm
4 Canadian Shield Drift-Crystalline realm
5 East-Central Paleozoic realm
6 Atlantic and Gulf Coastal Plain realm

Hydrogeologic Provinces (after Meinzer, 1923):

A Atlantic Coastal Plain province
B Northeastern Drift province
C Piedmont province
D Blue Ridge-Appalachian Valley province
E South-Central Paleozoic province
F North-Central Drift-Paleozoic province
G Wisconsin Paleozoic province
H Superior Drift-Crystalline province
I Dakota Drift-Cretaceous province
J Black Hills Cretaceous province
K Great Plains Pliocene-Cretaceous province
L Great Plains Pliocene-Paleozoic province
M Trans-Pecos Paleozoic province
N Northwestern Drift-Eocene-Cretaceous province
O Montana Eocene-Cretaceous province
P Southern Rocky Mountain province
Q Montana-Arizona Plateau province
R Northern Rocky Mountain province
S Columbia Plateau lava province
T Southwestern Bolson province
U Pacific Mountain province

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ECONOMIC REVIEW OF WATER AND NATURAL RESOURCES INVENTORY BASED ON LAND SURVEY (MULTIPURPOSE LAND RECORDS AND INFORMATION SYSTEMS, AN ASSESSMENT FROM AN ECONOMIC POINT OF VIEW)

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Economics is the very reason for cadastres. From William the Conquerer to Napoleon, needs for taxes based on fair assessment have caused the establishment of a land index. Who's got what, where, and how much of it? is the ancient question. The need to know has increased ever since.

Urbanization of a country requires more refined methods of assessment. Dwindling natural resources (including the land itself) force us to be more accurate in their determination. Spiralling cost for anything that man produces will prohibit us from wasting effort. Therefore, today it is being recognized that much additional data relating to the land can be effectively stored in and retrieved from such a land information system.

There is a catch, however. Richard Byler, program coordinator of RMLR in Pennsylvania, cautioned that "ability to do something technically does not mean that it will be done". Economics is the key to success. Will it pay to do something?

In 1978 the State of Wisconsin has conducted a study, entitled "Land Records: The Cost to the Citizen to Maintain the Present Land Information Base: A Case Study of Wisconsin". It found that residents paid $17 per person annually for information about the state's land: The same information that the government unintentionally collects again and again for the same areas of land. Since half of Wisconsin residents are taxpayers, the actual cost to each taxpayer was $34 in 1976. This does not include any private or commercial data collection and survey efforts. How did others respond?

NEW BRUNSWICK - NOVA SCOTIA - NEWFOUNDLAND

Recognition of these needs has spurred certain parts of North America into action. The unquestioned leaders in these efforts are the Maritime Provinces of Canada. Their Land Registration and Information Service (LRIS) was founded in 1973. It started with a densified geodetic control network and base maps. It includes parcel overlays, resource maps, a land registration system, and a land data bank.

One of its goals was to prepare maps on which properties are readily identified. The ultimate goal includes "indefeasible location and indefeasible title" of real estate, according to Jagoe.

The four basic project phases are:

Phase I	:	Geodetic Control Surveys
Phase II	:	Base Maps and Cadastral Maps
Phase III	:	Improved Land Tenure System
Phase IV	:	Land Data Bank (Multipurpose Mapping)

The following statistics pertain to the three provinces included in the system:

Population	:	1.6 million
Area	:	135,000 Km^2 or 52,120 sq.miles
Parcels	:	900,000

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In 1978 the system was operated and managed by 256 public employees.

Directorate	:	13
Systems & Planning Div.	:	32
Land Title Div.	:	132
Surveys & Mapping Div.	:	79

Combining these statistics gives a feel for the manpower requirements on a unit basis:

256 employees	for	1.6 million people	= 6250 residents	per	employee
"	"	135,000 Km^2	= 526 Km^2	"	"
"	"	52,000 sq.miles	= 203 sq.miles	"	"
"	"	900,000 parcels	= 3515 parcels	"	"

In 1977 the Council of Maritime Provinces conducted a benefit/cost study. The report is known as the Ross Study and was projected over a period of 25 years. Data following was obtained, directly or indirectly, from that analysis.

Project Cost:

The anticipated project cost for the next 15 years expressed in $ million is as follows:

Phase I	-	Geodetic Control	$20.7
Phase II	-	Mapping	
		Base Maps	26.5
		Property Lines	17.8
Phase III	-	Land Titles & Boundaries	39.0*
Phase IV	-	Data Banks	12.2
		Total.	$116.2 (million)

$116.2 million for 1.6 million population = $72 per person in 15 years. The annual expense is, therefore, $5 per resident.

*The Canadian study includes $174 million for land surveys to be paid by private land owners in order to include individual parcels in the system. This cost is, however, an ongoing cost that land owners now pay with or without the system when selling, buying, subdividing, or financing real estate. If included, the 15 year expense amounts to about $109 per person or an additional $7 per person annually.

Operating Cost:

The annual operating cost expressed in $ million, after 1983 is estimated to be:

Phase I	-	Geodetic Control	$0.8
Phase II	-	Mapping	2.0

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Phase III	-	Land Titles & Boundaries	6.7
Phase IV	-	Data Banks	2.0*

Total . . . . . .$11.5 (million)

$11.5 million per year for 1.6 million population = $7 per person
The annual operating cost is, therefore, estimated to be $7 per resident

*author's arbitrary estimate

Benefit/Cost Ratio of Quantifiable Items:

Benefit/cost ratios developed from the Ross Study below are based only on quantifiable benefits. It is safe to assume that the true ratio is far higher and in favor of the system, particularly as time goes on.

			B/C Ratio
Phase I	-	Geodetic Control	0.6
Phase II	-	Mapping	1.02
Phase III	-	Improved Deed Registry	0.6
		Title Guarantee	2.4
		Title & Property Line Guarantee	1.1*
Phase IV	-	Data Banks	Not yet developed

* Includes private ongoing costs mentioned above and should, therefore, be much higher.

Savings:

Surveyors, lawyers, and other experts have attempted to estimate the savings that will be derived from the LRIS. Most of them are expressed in percentages rather than dollars.

Phase I	-	Geodetic Control	- up to 30% savings in surveying & design
Phase II	-	Mapping	- over $100 million
Phase III	-	Land Titles & Boundaries	- 33% to 90% in title searches - 33% in legal fees for boundary disputes - 75%* in land surveys for boundary disputes
Phase IV	-	Data Banks	- Not estimated

*Author's conservative estimate

NORTH CAROLINA:

In 1977 the General Assembly of North Carolina ratified three bills pertaining to land records (c.589, c.932, c.1099). The law wisely mandates that the work "shall be shown to be a part of a larger undertaking for achieving ultimate long-term improvements in the land records".

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A government document, entitled "Keys to the Modernization of County Land Records" emphasizes "the long-term obligation to provide the public with a fully adequate record of all land transactions".

The people of North Carolina are to be commended for their foresight and effort. It is a noteworthy beginning in the establishment of a permanent land records and information system. Much of its success will depend on the cooperation and leadership of North Carolina land surveyors.

In terms of economics, it is a state-county matching funds program. In addition, the "Land Records Management Program" (c.932) is funded with $37,500 annually. At 5.5 million population, that annual expenditure amounts to less than 1 cent per person.

Compared to the Canadian LRIS, it skips Phase I - Geodetic Control - and starts off with Phase II - County Base Maps and Cadastral Maps. It provides for a Phase III limited to an improved deed recording system by assigning uniform parcel identifiers.

As has been shown in Canada, the mere improvement of deed recording and indexing produces the lowest benefit/cost ratio among the three possiblities of deed registry, title guarantees, or guarantee of title and boundary.

Since it is a new program, most of the effort is concentrated on Phase II. Model specifications for County Base Maps and for Cadastral Maps have been issued by the state. Certain weaknesses contained in these specifications will adversely affect the long-term benefit/cost ratio unless they are modified.

Model specifications for <u>County Base Maps</u> list detailed requirements for photography, photogrammetry, and cartography. They even want to know who the party chief was, but nowhere do they require a registered land surveyor. Geodetic requirements are listed for photogrammetric ground control. Specifications for permanent control are vague, open-ended, and left to the discretion of the contracting officer. Metric scales are not an option in this long-range program.

Model specifications for <u>Cadastral Maps</u> again require no land surveyor in spite of the fact that need for a "qualified surveyor" is mentioned in c.932 - Land Records Management Program. Accuracy requirements for plotting of property lines are not defined except in a general statement that they "are of utmost importance". No provision for upkeep is made in these specifications.

The absence of a systematic program to densify the geodetic control network first (Phase I) will make the implementation of c.589 - <u>Parcel Identifier Number Indexes</u> - difficult and costly. Sec.1-(d)-(6) requires that the identifier number "reflects the State plane coordinates of some point in the parcel".

If the people of North Carolina are to derive "long-term" benefits from this system, the land surveyor must show leadership. It is he who will be asked to identify the correct number for every parcel that he surveys. To be truly economical and cost-efficient, the North Carolina system will have to go beyond improved tax maps and beyond improved recording of deeds.

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PENNSYLVANIA:

The Regional Mapping and Land Records project (RMLR) involves five utility companies and five counties, including Philadelphia. It started in 1976. It is unique because it was initiated by "users" of land information - the utilities. Unlike others, RMLR was able to convince its participants that survey control was a prerequisite to the success of its program.

It started its pilot project with Phase I - Geodetic Control. Base mapping and cadastral mapping (Phase II) are underway. Besides improved tax maps, the program is aimed at utility and planning applications (Phase IV). Surface and underground utilities, soils, slopes, land use, geology and other environmental features will be shown on overlay maps as well as stored in data banks.

Phase III - Improved Deed Recording, has begun by the application of parcel identifiers in one county. Richard Byler, RMLR Coordinator, has suggested that title insurance companies, as direct beneficiaries of such a system, share the cost.

The pilot project area covers 50 square miles around Norristown, Pennsylvania. Mapping consultant, Joel Orr, estimates that $100,000 has been spent on private consultants plus each participant has spent no more than $15,000 in cash. A total of $250,000 spent on 50 square miles would amount to $5,000 per square mile mapped.

Both Byler and Orr agree that potential benefits to utility companies are enormous - avoidance of duplication of utility mapping and map maintenance, coordination of utility diggings and construction, to name a few.

OREGON:

The State of Oregon has started its cadastral mapping program as early as 1953. In 1976 the state's assessment and appraisal division converted to a computerized system called CAMS. The initials stand for Computer-Assisted Mapping System. CAMS is operated by cartographers and has been adopted by 31 of Oregon's 36 counties. The Department of Revenue provides mapping services to the counties on a matching-fund basis.

Here, too, Phase I - Geodetic Control - was skipped. The project started with Phase II - Cadastral Maps. As a result, many of the early maps are of poor quality and unreliable.

Lane County is the pioneer in this mapping effort. According to Robert A. Mead, Manager of the State's Urban-Rural Mapping Unit, "Lane County's map product . . . . . is entirely useless for most engineering work and some planning work". The assessors refuse to use it for cadastral purposes.

Nevertheless, the shortcomings of that first effort provided a valuable experience for other counties. A joint venture under the acronym of GLADS between the State, Marion County, and the City of Salem is in the development. GLADS stands for Geographic Land Data System and will rely on an accurate spatial relationship between each land parcel. It will be based on the State Plane Coordinate System.

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Mead considers Oregon's system "an economic success". Residual benefits are quite good. Map sales by assessors have been "lucrative". Title insurance companies rely exclusively on these state cadastral maps. Courts have almost "too much confidence" in the reliability of the maps, according to Mead.

Although no dollar values are available, benefits of the system seem to far outweigh its cost. Computerized mapping has led to a "cost avoidance" of three times the amount initially projected. Ten additional cartographers did not have to be hired.

Oregon's standard cadastral map is for the discovery, identification, inventory and appraisal of all real property in each county. By assigning a "standard parcel identifier" related to a "fly-sheet" (ownership page) it satisfies the minimum of Phase III - Improved Deed Recording.

It forms the basis for "soil-type maps" and thereby approaches the multi-purpose cadastre of Phase IV.

The Department of Revenue has prepared a comprehensive and detailed cadastral map manual that should ensure uniformity across the state. In 1977 the mapping unit employed 21 persons. At a population of 2.5 million, this amounts to 120,000 inhabitants being served by each cartographer. If one assumes a $20,000 annual salary plus another $20,000 for overhead and equipment, or a total expenditure of $40,000 by the state, this will be matched by the county, resulting in $80,000 for each state cartographer.

120,000 residents served by $80,000 = $0.67/resident

The annual project cost for Oregon's citizens would, therefore, be less than $1 per person. Compare that to Wisconsin's annual cost for single-purpose repetitive efforts of $17 per person.

NON-QUANTIFIABLE BENEFITS:

Most land records and information system investigators agree that it is nearly impossible to apply ordinary cost/benefit standards to this endeavour. They also agree that a selling job must be done if politicians are to be convinced of its benefits. As Orr put it: "Very few decision-makers will stick their own necks out . . . for fuzzy philanthropic ideas". "If governors, legislators, and administrators cannot be reached, it will be an exercise in futility" warned Mead. Byler asked: "Can we show sufficient direct tangible benefits and savings that someone will pay to install the system?"

Because benefit/cost analysis favors short-term results, Jagoe feels that it is one reason why it is so popular with politicians. "Politicians gladly vote millions to computerize our tax rolls becuase the payback is immediate", said Roberts.

Canada has shown the way to identify tangible benefits of its land record and information system. Costs are usually well-known and provide the scale for a benefit/cost analysis. It will be necessary, however, to seek out, to

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monitor, and to publicize the many and varied non-quantifiable benefits. Surveyors and conveyancers are uniquely qualified to procure the answers.

Most of these indirect benefits have been mentioned by others before. Zoning, land use planning, preliminary engineering design, location of utility right-of-way, certainty of location of title, inventory of natural resources, and protection of the environment are among them. How many millions are being spent in surveying and mapping of the 400 miles of railroad right-of-way in an ongoing crash program for the Northeast Corridor between Washington and Boston? And what about the siting of nuclear power plants or solar easements?

Direct cost, however, is not always the most important criteria. The Surface Mining Control and Reclamation Act of 1977, for instance, cannot be implemented without some form of a local land inventory system. A mini-multi-purpose cadastre will have to be established before strip mining can begin in a given area. What would the benefit/cost ratio be, if we had such a system in operation?

Would the enormous Indian claims ever have come up had Presidents Monroe and Adams followed that particular example of Napoleon? How can we avoid such problems in the future?

Following are a few examples of newspaper reports and others that can be directly related to the absence of a comprehensive reliable land record system. The reader may consider them food for thought and enter his own estimate of a benefit/cost ratio for each case.

<u>December 1978, Seneca, Illinois (Peabody Times, 1/11/79)</u>

Seven year old Wade Edwards drowned when an airshaft in an abandoned coal mine collapsed. Residents then realized that there is a network of 15 miles of abandoned tunnels somewhere beneath their village and demanded "to know more about it". Federal officials warned that the tunnels could collapse any time.

<u>March 1979, Louisville, Kentucky (Boston Globe, 3/3/79)</u>

A 17 acre site, also known as the "Valley of the Drums" contains 100,000 leaking drums of hazardous unidentifiable fluid. Wilson Creek runs through the field on its way to the Ohio River. The land owner is dead. Three other sites where liquid wastes with unknown potential for causing cancer, birth defects, and other ills are stored have recently been "discovered" in Kentucky. Estimates of the cost of cleaning up the four sites range to $10 million or more. Taxpayers may have to cover the cost.

<u>March 1979, Denver, Colorado (Boston Globe, 3/17/79)</u>

Thirty-two old radium dump sites have been "found" in Colorado last month. A federal official "in charge of a hunt" for these old dumps says the "search" should be expanded to Los Angeles and San Francisco. Both cities contained radium-product companies from 1910 to 1925. Considering that this is 1979, it is hard to believe that "search and hunt" are now the only available methods of solving such a serious health problem.

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March 1979, Washington, D.C. (Boston Globe, 3/3/79)

Barbara Blum, Deputy Administrator of the Environmental Protection Agency (EPA) said, "there may be" 1200 to 2000 dumps which could be leaking chemicals into soil and water across the country. She estimated that it would cost up to $50 billion to clean them up.

1974, Woburn & Burlington, Massachusetts (Boston Globe, 7/25/74)

Several families found themselves living in the "wrong" town because of an error in the town boundaries. The fact was discovered during town mapping. Back taxes, new sewer and water charges, transfer of children to another school, not to mention mental anguish, were among the "costs" to be paid.

1977, Lynn, Massachusetts

A large apartment building was built on the wrong lot and in the wrong town because of inaccurate boundary descriptions. It had to be moved.

January 1978, Chicago, Illinois (Boston Globe, 1/9/78)

Unplanned and haphazard growth in urban areas has limited housing choice and the opportunity of millions of Americans to move into better accommodations, reported the American Bar Association.

June 1978, Washington, D.C. (Bureau of National Affairs, Inc., 6/6/78)

President Carter in his water policy message to Congress, stated: "We have found that 25 separate Federal Agencies spend more than $10 billion per year on water resources projects and related programs. These projects often are planned without a uniform, standard basis for estimating benefits and costs". He directed Federal agency heads to provide cooperation and leadership "in the gathering and sharing of data" to ensure that all project assessments are "based on up-to-date conditions".

October 1978, Salt Lake City, Utah

The U.S. Forest Service is selling lumber rights to private firms. Due to the uncertainty of property lines, a 200 ft. buffer-zone is left around each parcel of government land. Private abutters then cut up to the edge of standing trees, including the 200 ft. buffer-zone of government trees, assuming that that is their property line. Government officials estimate an annual loss of $25 million.

1978/1979 U.S.A.

Several North Central states (Wisconsin, Michigan, Minnesota, and others) are facing a serious loss of basic monumentation of literally thousands of legal descriptions of land parcels. It appears that in the development of land during the 19th century, subdivisions used existing railroad right-of-way as reference lines and points-of-beginning in deed descriptions. The railroad track was the most common monument in the

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area. Tracks are being removed from abandoned railroad lines, thereby leaving a vast network of legal descriptions without its very backbone of reference. Properties are now floating, causing serious problems to owners, surveyors, and lawyers. This could not happen in a cadastre.

February 1979, Washington, D.C. (Detroit Free Press, 2/8/79)

The government is gearing up for the 1980 census and plans to hire 35,000 additional workers nationwide to help in collecting current addresses in rural areas. Estimated salaries for these temporary employees is $168 million.

CONCLUSION

In reviewing benefit/cost ratios of quantifiable items, a difference between the four basic project phases must be made. Phases I and II (Geodetic Control and Mapping) are the foundation of the entire system. They are means to an end. Phases III and IV (Improved Land Tenure System and Data Banks) are the goal of any comprehensive LRIS project. The Ross Study has found that in post-development years, the benefit/cost ratio will be nearly 3.0 for Phase I, while the B/C Ratio for Phase II will be better than 2.0. The report emphasized that "the initial development costs are necesary in order to achieve the long-term benefits".

It appears that the four-step development of the LRIS in Canada is a logical and long-range beneficial method. Of the three U.S. systems discussed here, only one, the RMLR in Pennsylvania, seems to have begun with Step I - Geodetic Control Surveys. This should pay off in the long run.

The other two - North Carolina and Oregon - have commenced their programs with Phase II - Mapping. Although deplorable, it is understandable. Short-range economic gains are more convincing to politicians everywhere. In the long run, however, this short-cut approach will prove less economical than the I - II - III - IV phase method of LRIS. Sooner or later a catching-up effort will have to begin. Perhaps this was the only way a program could get started at all. For a price, improvements can be made along the way.

Yes, there is more to life than dollars and cents. A multi-purpose cadastre, however, can be proven to be cost effective. If we look far enough, we will find many quantifiable reasons why such a system is necessary and why it is good for America. This should continue to be our responsibility.

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REFERENCES BY AREA AND PROGRAM

CANADA:

"Benefit Cost Study of the Land Registration and Information Service (LRIS) Program", conducted for The Council of Maritime Provinces by P.S. Ross & Partners, Halifax, Nova Scotia, April 1977.

"An Introduction and Economic Review of Maritime Land Registration Information Service of the Council of Maritime Provinces", by Ellis H.M. Jagoe, URISA '77 Conference, Kansas City, Missouri, August 1977.

"Cost Benefit Aspects in Establishing the Different Phases of a Land Information System", by Willis F. Roberts, Fredericton, New Brunswick, 1978.

"An Assessment From a Political Point of View" for a panel discussion on Land Records and Resource Information Systems, by Willis F. Roberts, Proceedings ACSM, Washington, D.C., March 1979.

NORTH CAROLINA:

"Key to the Modernization of County Land Records", by N.C. Department of Administration, October 1978.

"Model Specifications for County Base Maps", by N.C. Department of Administration, October 1978.

"Model Specifications for Cadastral Maps," by N.C. Department of Administration, October 1978.

"Rules and Regulations Governing State Grants for Improvement of Land Records", by N.C. Department of Administration, October 1978.

PENNSYLVANIA:

"RMLR: A Prototype for Automated Regional Land Data Systems", by Joel N. Orr, Danbury, Connecticut, 1978.

"Building a Constituency for Better Mapping and Land Records and Mastering the Technology - The RMLR Southeastern Pennsylvania Experience", by Richard P. Byler, Proceedings, MOLDS II, Washington, D.C., Oct. 1978.

OREGON:

"Developing A Computer-Assisted Mapping System", by Robert A. Mead, Proceedings, International Association of Assessing Officers Annual Convention, Portland, Oregon, September 1977.

"Cadastral Map Manual", Draft Chapters 1, 2, and 3, by Oregon Department of Revenue, Salem, Oregon, Jan. 1979.

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WATER-BORNE VECTORS OF DISEASE IN TROPICAL AND SUBTROPICAL AREAS; AND A NOVEL APPROACH TO MOSQUITO CONTROL USING ANNUAL FISH

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I. ABSTRACT

The three most prevalent tropical and subtropical diseases, malaria, filariasis and schistosomiasis are intimately related to the aquatic environment. The former two are transmitted by mosquitoes and the latter by snails. There must be concern when constructing new water projects and modifying existing areas that new breeding sites are not created. Although malaria had been eradicated and controlled in certain areas, it is currently increasing in frequency partially due to insect resistance and improper use and the negative environmental impact of pesticides. A trip to Turkey during the summer of 1976 on behalf of the World Health Organization indicated that improper irrigation techniques had the potential to create new mosquito breeding sites. In permanent bodies of water the mosquito fish, _Gambusia_, sp., has been used effectively for mosquito control. For those breeding sites which dry seasonally, the East African annual fish _Nothobranchius guentheri_ is now available for large-scale field testing. This fish, an effective larvivore, is able to maintain permanent populations in temporary bodies of water, in part due to the ability of the embryos to enter a developmental arrest, or diapause, similar to some species of insects.

II. INTRODUCTION

Many tropical and subtropical diseases are intimately involved with the aquatic environment (Hunter, 1976). These diseases, primarily involving viruses, protozoa and helminths (round and flatworms), affect millions of people. The three most prevalent diseases are malaria, filariasis and schistosomiasis. The plasmodium parasites of malaria are transmitted by the bite of female anophelene mosquitoes. After the blood meal, the mosquito lays its eggs in water where the eggs, larvae and pupae develop. Similarly, the nematode (roundworm) parasites of Bancroft's and Brug's filariasis are transmitted by the bite of a female mosquito, but of more diverse genera, including those of _Culex_, _Anopheles_, _Aedes_ and _Mansonia_. In onchocerciasis, or "river blindness," the nematode parasite is transmitted by the bite of black flies of the genus _Simulium_. These flies lay their eggs on various solid surfaces in water or at the water's edge, and the larvae usually prefer fast moving bodies of water. The parasitic trematodes (flatworms) of schistosomiasis must spend part of their life cycle in an aquatic snail and infection to man occurs in fresh water often after bathing. Therefore, the status of the aquatic environment is of critical importance if a country is to maintain adequate health standards as well as to achieve economic growth. Construction of new water projects as well as modification of existing ones must take into consideration the creation and destruction of breeding sites of vectors (carriers) of disease and of parasitic organisms. In addition, since medical intervention is often not feasible even if available in the developing countries, and since many of the diseases are related in one way or another to the aquatic environment, reduction of transmission by control of the water-borne vector is often a reasonable choice in a broad based plan of disease control.

III. BIOLOGY OF MALARIA

There are four known malaria parasites of man. They include _Plasmodium falciparum_, _P. vivax_, _P. malariae_ and _P. ovale_. The female mosquito transmits the plasmodium to man in the form of sporozoites during a blood meal. The

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sporozoites migrate directly to the liver and divide. After a period of time, the parasites, now called merozoites, migrate to the peripheral blood and take up residence in the red cells. There they divide again, ultimately lyse the red cells and enter new red cells to continue the parasitemia. However, a certain number of the merozoites do not enter new red cells but differentiate into male and female gametocytes, which when ingested by the mosquito complete the cycle. Fertilization of the male and female gametocytes occurs in the mosquito. Ultimately sporozoites enter the salivary glands of the mosquito and are ready to enter the human host at the next blood meal. The present global incidence of malaria is 150 million cases with 1.5 million deaths. Although these figures are much lower than several decades ago, when over a million people in India alone died of malaria, the incidence of malaria is increasing rapidly. The large increase is due to resistance of mosquitoes to various pesticides, increased drug resistance by the malaria parasites and lack of proper water management.

IV. BIOLOGY OF FILARIASIS

In Bancroft's and Brug's filariasis, the female mosquito transmits the nematode parasites, Wuchereria bancrofti and Brugia malayi respectively, to man in the form of its filiform (third stage) larvae during a blood meal. The larvae migrate to the lymphatic system and mature to adult forms. The adults liberate microfilariae which either remain in the lymphatics or migrate into the peripheral blood, where they are ingested by the mosquito during a blood meal. Within the mosquito the larvae undergo a series of changes and ultimately become the infective filiform larvae. The larvae then migrate to the mouthparts of the mosquito and are ready to enter the human host at the next blood meal. The classical clinical sign of Bancroft's and Brug's filariasis is elephantiasis which is due to obstruction of the lymphatic channels by scar tissue, especially in the vicinity of adult worms. Transmission of onchocerciasis, or "river blindness," is by black flies of the genus Simulium, but the pathological features of this disease are primarily due to the microfilarial larvae rather than the adult worm. The present global incidence of filariasis is over 300 million cases.

V. BIOLOGY OF SCHISTOSOMIASIS

When a human host enters waters contaminated with Schistosoma sp., the free-living cercarial form of the parasite penetrates the skin usually causing itching and a rash. The adults usually develop in blood vessels of the intestine and begin to lay eggs within 4-5 weeks. Due to the formation of abscesses, eggs are able to enter both the small and large intestine and thus allow for fecal contaminaton. If the contaminated feces reach fresh water, a free swimming larva (micracidium) develops. If a proper host snail is present, the larva penetrates the snail, passes through several generations and ultimately becomes a free-living cercaria ready to infect a human host which enters the water. The present global incidence of schistosomiasis is over 200 million cases.

VI. VECTOR CONTROL

One of the major approaches to disease control in the tropics is vector control. Since many of the diseases require an animal host intermediary, elimination or reduction of the intermediary can have a major impact on parasite

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populations. Although many of the control methods are relatively simple to implement in developed countries, this is not necessarily the case in the developing countries. While a discussion of vector control should include all known vectors of disease, this report will deal primarily with mosquito control.

A. Mechanical

The elimination of breeding sites is unquestionably the most effective means of mosquito control. This method consists of draining large areas of water such as swamps and marshes. In marsh drainage, for example, ditches are constructed so that every section of the marsh is exposed to tidal flow. This assures that no portion of the marsh has any standing water where mosquitoes can breed. Drainage and ditching as control measures are not being adequately implemented in the developing countries primarily due to the prohibitive costs of these programs. In addition, since these methods can drastically affect the ecology of an area, they invariably affect other organisms which are dependent on the aquatic environment.

B. Oiling

The use of oil to exterminate mosquito eggs, larvae, and pupae began at the end of the nineteenth century. L. O. Howards of the United States Bureau of Entomology, in 1892, suggested the application of kerosene to stagnant pools to destroy the aquatic stages of mosquitoes. Hardly any attention was paid to this idea until the discovery by Ross, Grassi, Celli, and others six years later that mosquitoes of the genus Anopheles are the vectors of malaria. Although oiling has been effectively employed in mosquito abatement, there are a number of objections and limitations to its use. First, oils can be toxic to other animals due to the excessive quantity of phenols. Second, it is offensive due to unpleasant odors. Third, it cannot be utilized in water being used for domestic purposes, such as wells. Fourth, oil eventually breaks up into globules which settle on the bottom so that reoiling of the same area several times is required for year-round control. Lastly, the expense in terms of manpower and materials make this method prohibitive for large scale operations.

C. Insecticides

One of the first successful insecticides was pyrethrum which is derived from the dried flowers of chrysanthemum. Since the 1920's hundreds of insecticides have come into use, some of the most effective being the chlorinated hydrocarbons, such as DDT. Zeidler synthesized DDT in 1874, but its effectiveness as an insecticide was not discovered until 1942 when it was found to be extremely lethal to lice, mosquitoes, and other insects. Worldwide use of DDT began shortly after the Second World War and resulted in a striking reduction of mosquito densities and significantly lower deaths due to malaria, dengue, yellow fever, and filariasis.

However, a few years after the implementation of the World Health Organization malaria eradication program in 1957, vector resistance to DDT was reported in Central America, Afghanistan, India, Indonesia, and many other countries. In Iran and Iraq DDT was replaced by another organochlorine chemical, dieldrin, but Anopheles stephensi overcame its toxicity three years

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after its introduction. A switch to malathion was made when malaria again reached epidemic proportions in the late 60's. Malathion, an organophosphorous insecticide increased the cost of the program fivefold. Recent reports indicate resistance of A. stephensi populations to this chemical (WHO, 1975).

Aside from the high cost of insecticides, one objection is that they are toxic to non-target animals. Trout, bluegills, and other cold-blooded animals are sensitive to minute concentrations of insecticides. Residues of organochlorine compounds have been correlated with the impairment of steroid metabolism, calcium deposition in the egg shell, and infertility in many bird populations (Peakall, 1970). DDT and its metabolites can now be detected throughout the biosphere. These chemicals accumulate in human milk (Stacey and Thomas, 1975) and in human tissues (Kraul and Karlog, 1976). Although exposure to massive dietary intake of DDT showed no observable effects in man (Laws, et al, 1967), numerous data on other vertebrates demonstrate that even low level exposure can disrupt learning abilities and reproduction (Anderson and Prins, 1970, Heath, et al., 1969). To date, insecticides are still the method of choice for vector control.

D. Biological

1. General

Various natural control agents have been tested under laboratory and field conditions to regulate mosquito populations (Arata, 1977). Among these are included bacteria that are known mosquito pathogens, such as Bacillus sphaericus (Kellen, 1965; Singer, 1973), Pseudomonas fluorescens (Mikhnovskaya and Povaznaya, 1975), nematodes, such as Romanomermis culicivorax (Levey and Miller, 1977), and viruses (Clark and Fukuda, 1971; Federici, 1973). Toxorhynchitin mosquitoes, which feed on mosquito larvae, have been introduced from West Africa to several Pacific islands. Their reproductive capacity, however, is too slow to adequately control mosquito larval density. Strains with chromosomal translocations and inversions leading to various degrees of sterility in males of Culex pipiens were generated and released into caged and wild populations (Laven, et al, 1972). The use of pheromones and other attractants of Aedes and Culex mosquitoes to artificial oviposition sites have been suggested as possible supplemental control measures (WHO, 1969).

2. Larvivorous Fish

At the turn of the century attention was concentrated on the effiacacy of larvivorous fish as a natural control agent of the aquatic stages of mosquitoes. Valuable studies on the influence of small minnows on mosquito density proved that fishes were effective for mosquito control (Seal, 1908, 1910; Hildebrand, 1919, 1921, 1925; Chidester, 1916).

There are several criteria which must be met before any fish can be employed in natural control programs:

1) The fish must be top-feeders, i.e., the predatory fish must seek their prey at the surface of the water.

2) The fish must be able to maintain permanent populations at adequate densities in the aquatic environment where mosquitoes propagate.

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3) The fish must have a large appetite for mosquito larvae.

4) The fish must be of small size since it would allow them to survive in very shallow waters and to penetrate into small breeding places. Small size also discourages people in the immediate area to exploit them as a food resource.

5) The fish must be highly prolific and the fry should be capable of fast growth to sexual maturity. The latter insures that only a short time is necessary to generate a large population after initial stocking.

6) The fish must be hardy enough to survive transportation to distant regions.

Gerberich and Laird (1968) published a list of 265 species of fishes that have been studied for use in anti-mosquito programs. Most of these fishes have characteristics which limit their effectiveness. However, one fish, *Gambusia affinis*, native to the Southern United States, has been shown to be an efficient larvivore and the only species of fish currently used in large scale anti-malaria programs. To fully appreciate the choice of *Gambusia* as a larvivore, it is essential to understand some of the biology of this top minnow.

a. *Gambusia affinis*

G. affinis is divided into two subspecies. *G. affinis affinis* is native to Georgia while *G. affinis holbrooki* inhabits the waters of the Mississippi delta region. They are found in all types of standing water as well as sluggish streams and are capable of surviving in both fresh and brackish water. *Gambusia* has a distinct preference for shallow waters and has been observed to live in waters too shallow to completely cover its body (Hildebrand, 1919). *G. affinis* is viviparous and at birth are already capable of consuming smaller mosquito larvae. The young fish grow to sexual maturity in 2 to 4 months, depending upon the environmetal conditions. A single female can have as many as 345 offspring in a single season and as many as 2,000 in its lifetime (Hildebrand, 1921). The females can eat 260 mosquito larvae in a single day while the male, owing to its smaller size, can consume only 60 larvae per day (Chacko, 1948). Although total control cannot be achieved, there are many examples of places where the introduction of mosquitofishes caused significant decline in the incidence of malaria. In Istria, following the introduction of *G. affinis*, the spleen rate from malaria was reduced from a high of 98% in 1924 to only 10% six years later (Hackett, 1931). Another example of the benefit of mosquitofish introduction was reported by Tabibzadeh (1970). In the Islamoo village in Gharabagh Dehistan of Shiraz, Iran in 1967, 20% of of the population showed positive cases of malaria parasites in the blood. This figure declined to 5% following the use of mosquitofishes as a control measure. No *Anopheles* larvae were found during the routine survey of the marshes surrounding the village in 1968.

b. Annual fish

In temporary bodies of water common to arid areas of alternating rainy and dry seasons, *Gambusia* must constantly be restocked. There are, however, a group of cyprinodontid fish known as annual fish, found in Africa and South

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America, which inhabit these temporary bodies of water. The biotopes take the form of sluggish streams, shallow ponds, pools, swamps, isolated water holes and puddles (Bailey, 1972; Myers, 1942). Occasionally populations are found in permanent bodies of water. As the waters dry, the entire juvenile and adult populations die, leaving the entire future generation in the form of thickly chorionated embryos encased in the muddy substratum. Although there are considerable fluctuations in the annual cycles of alternating rainy and dry seasons, annual fish continue to maintain permanent populations. Similar to many species of insects, embryos of annual fish are able to enter a diapause, or developmental arrest, at various stages of development and it is partially through this adaption that they are able to survive the variable durations of the rainy and dry season (Peters, 1963; Wourms, 1964, 1972; Markofsky and Matias, 1977; Matias and Markofsky, 1978). It has been demonstrated that diapausing embryos are relatively insensitive to thermal stresses compared to other stages of development (Matias and Markofsky, 1978).

The use of annual fish for mosquito control in temporary bodies of water has been proposed since 1941 (Vanderplank, 1941; Hildemann and Walford, 1963; WHO, 1973). Several limited studies have been undertaken to introduce these fish but they did not meet with any apparent success. The lack of successes has been due either to one or more of the following: 1) limited scope of the study, 2) inadequate knowledge of field conditions, 3) inadequate knowledge of the biology of the fish and 4) lack of adequate follow through of the initial project.

In the summer of 1976, one of the authors (J.M.) travelled to Southern Turkey on behalf of the World Health Organization to study the feasibility of introducing the East African annual fish, Nothobranchius guentheri, for mosquito control in temporary bodies of water. Gambusia had been successfully introduced into permanent bodies of water, primarily irrigation ponds (Figure 1). However, there were still problems controlling mosquito populations in temporary bodies of water. While malaria had been virtually eradicated in Turkey, its incidence was increasing rapidly. While temporary bodies of water are often natural phenomena due to seasonal rains, they may also be due to man's improper use of water resources. In the area of Turkey visited it was common to irrigate the fields by obstructing an irrigation canal and allowing indiscriminate flooding (Figs. 2 and 3). In addition, sewer water often was discharged downhill from dwellings and often merged with other water sources coming from the homes, resulting in a constant source of stagnant, polluted water (Figure 4). The areas studied were on the sides of roads, and often the design of the road did not provide for adequate drainage, thus contributing to the problem of mosquito control. We placed eggs of the annual fish, N. guentheri in the ground (Figure 5) but, unfortunately, there was no follow-up of the study. Currently more detailed and controlled studies are planned for Sri Lanka (Ceylon).

VII. SUMMARY

Until adequate vaccines are available, vector control is a reasonable choice for disease control in the tropics. Although insecticides are still the most effective means of control, insect resistance, high cost and negative environmental impact are making insecticides less desirable. Mechanical means are often costly and, therefore, impractical. As a result, there is great interest in developing biological or, in other words, a more natural means of

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control. While microbial agents are being considered and should contribute to vector control, the use of larvivorous fish in permanent bodies of water has traditionally been proved effective for mosquito control. However, in temporary breeding sites, common to areas of alternating rainy and dry seasons, the traditionally used larvivorous fish *G. affinis* must be restocked. However, there is now available for testing for mosquito control in temporary bodies of water a group of annual fish and, specifically, the annual fish *N. guentheri*. These fish survive the dry season in the form of embryos encased in the muddy substratum. At the onset of the rainy season the embryos hatch and grow rapidly on a diet of mosquito larvae and other aquatic organisms. Fertilized eggs are then redeposited in the substratum to await the next rainy season.

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Comments of the Editor:

<u>WATERBORNE DISEASE OUTBREAKS INCREASE IN LAST NINE YEARS</u>

There had been a steady decrease in the number of waterborne outbreaks during the late 1930's and 1940's when the number dropped from an average of 41 per year in the period 1936-'40 to 10 per year in the period 1951-'55. There has been no decline in outbreaks since then, and there has been a pronounced increase since 1970. Gunther F. Craun of the Health Effects Research Laboratory in Cincinnati reports in an article published in the <u>Journal of Environmental Health</u> (3-4/79) that the United States now experiences an average of 35 waterborne outbreaks per year. During the period 1971-'77, a total of 192 outbreaks occurred affecting 36,757 persons. Two deaths were associated with these events. To be considered an outbreak, at least two cases of disease must be reported before a common source can be investigated. Only events associated with water used or intended for drinking or domestic purposes are included. Of the outbreaks reported in the period 1971-'77, 12 percent involved chemical poisoning. The most commonly identified pathogen was <u>Giardia lamblia</u> which is responsible for giardiasis. The largest outbreak of giardiasis occurred in Rome, N.Y., in 1974-'75 and it affected some 5,300 persons.

The outbreaks in 1971-'77 were classified by type of water system, with more occurring in semipublic systems (58 percent) than in municipal systems (30 percent) or individual systems (12 percent). During previous years use of untreated ground water was responsible for most illness in municipal systems, however, in the recent period only six (10 percent) outbreaks occurred. In semipublic systems use of untreated ground water was responsible for most outbreaks during previous years and it was still important in 1971-'77 accounting for 43 percent of the outbreaks.

Almost half of the total outbreaks (49 percent) and illnesses (42 percent) were caused by either the use of untreated, contaminated ground water or problems in treatment of contaminated ground water, primarily inadequate or interrupted chlorination.

From The Ground Water Newsletter, Vol. 8, No. 9, May 15, 1979.

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REFERENCES

Anderson, J. and Prins, H.B. 1970. Effects of sublethal DDT on a simple reflex in brook trout. J. Fish. Res. Bd. Canada, 27, 331-334.

Arata, A. 1977. The developing role of microbial agents for vector control. Experentia 33, 125-130.

Bailey, R.G. 1972. Observations on the biology of Nothobranchius guentheri (Pfeffer) (Cyprinodontidae), an annual fish from the coastal region of East Africa. African J. Trop. Hydrobiol. and Fish., 2, 33-43.

Chacko, P.I. 1948. On the habits of the exotic mosquitofish Gambusia affinis (Baird Girard) in the waters of Madras. Curr. Science, 17, 93.

Chidester, F.E. 1916. Biological study of the more important of the fish enemies of the salt-marsh mosquitoes. New Jersey Agricultural Experiment. Stations Bull., 300.

Clark, T.B. and Fukuda, R. 1971. Field and laboratory observations of two viral diseases in Aedes sollicitans (Walker) in southwestern Louisiana. Mosq. News, 31, 193-199.

Frederici, B.A. 1973. Virus pathogens of mosquitoes and their potential use in mosquito control. In: International Seminar on Mosquito Control, Dubin, A., ed., Trois-Riviere, Canada.

Gerberich, J.B. and Laird, M. 1968. Bibliography of papers relating to the control of mosquitoes by the use of fish. (1961-1966), Rome, FAO Fisheries Techn. Paper No. 75.

Hackett, L.W. 1931. Recent developments in the control of malaria in Italy, J.S. Med. Assoc., 24, 426.

Heath, R.G., Spann, J.W., and Kreitzer, J.F. 1969. Marked DDT impairment of mallard reproduction in controlled studies. Nature, 224, 47-48.

Hildebrand, S.F. 1919. Fishes in relation to mosquito control in ponds. Appendix IX, Report U.S. Commissioner of Fishes for 1918.

---, 1921. Top minnows in relation to malaria control with notes on their habits and distribution. U.S. Public Health Service, Public Health Bulletin No. 114.

---, 1925. A study of the top minnow Gambusia holbrooki and its relation to mosquito control. U.S. Public Health Service, Public Health Bulletin No. 153.

Hildemann, W.H. and Walford, R. 1963. Annual fishes--promising species as biological control agents. WHO/VC/24, WHO/EBL/7 (Document).

Hunter, G.W., Schwartzwalder, J.C. and Clyde, D.T. 1976. Tropical Medicine. W.B. Saunders Co. Philadelphia.

NEW JERSEY GEOLOGICAL SURVEY

Kellen, W.R. 1965. Bacillus sphaericus Neide as a pathogen of mosquitoes. J. Invest. Pathol., 7, 442-448.

Kraul, J. and Karlog, D. 1976. Persistent organochlorine compounds in human organs collected in Denmark 1972-1973. Acta Pharmacol. et Toxicol., 38, 38-48.

Laven, H., Cousserans, J., and Guille, G. 1972. Eradicating mosquitoes using translocations: a first field experiment. Nature, 236, 456-457.

Laws, E.R., Curley, A., and Biros, E. 1967. Men with intensive occupational exposure to DDT. Arch. Env. Health, 15, 766-775.

Levy, R., Miller, T.W. 1977. Experimental release of Romanomermis culicivorax (Mermithidae: Nematoda) to control mosquitoes breeding in Southwest Florida. Mosq. News, 37, 483-486.

Markofsky, J. and Matias, J.R. 1977. The effects of temperature and season of collection on the onset and duration of diapause in embryos of the annual fish Nothobranchius guentheri. J. Exp. Zool., 202, 49-56.

Matias, J.R. and Markofsky, J. 1978. The survival of the embryos of the annual fish Nothobranchius guentheri exposed to temperature extremes and the subsequent effects on embryonic diapause. J. Exp. Zool., 204, 219-227.

Minknovskaya, P. and Povaznaya, R. 1975. Pseudomonas flourescens bacteria as pathogens of mosquito larvae. Med. Parazit. 44, 690-693.

Myers, G.S. 1942. Studies on South American freshwater fishes. Stanford Ichth. Bull., 2, 241-246.

Peakall, D.B. 1970. Pesticides and the reproduction of birds. Sci. Amer., 222, 73-78.

Peters, N. 1963. Embryonale anpassungen oviparer Zahnkarfen aus periodich austroknenden gewarsenn. Int. Revue ges. hydrobiol., 18, 257-313.

Seal, W.F. 1908. Fishes and the mosquito problem. Their serviceability as mosquito exterminators. Scientific Amer. Suppl., 65, 351-352.

---, 1910. Fishes in their relation to the mosquito problem. Bulletin U.S. Bureau of Fisheries, 28, 831-838.

Singer, S. 1973. Insecticidal activity of recent bacterial isolates and their toxins against mosquito larvae. Nature, 244, 110.

Stacey, C.L. and Thomas, B.W. 1975. Organochlorine pesticides in human milk, Western Australia. 1970-1971. Pestic. Monit. J., 9, 64-66.

Tabibzadeh, I., Behbehani, G., Nakhai, R. 1970. Use of Gambusia fish in the malaria eradication programme of Iran. WHO/MAL/70.716, WHO/VBC/70.198 (Document).

NEW JERSEY GEOLOGICAL SURVEY

Vanderplank, F.L. 1941. Nothobranchius and Barbus species, indigenous antimalarial fish in East Africa. E. Afr. Med. J., 17, 431-436.

WHO, 1969. Informal consultations on alternative methods of vector control. World Health Organization, Geneva.

---, 1973. World Health Org. Manual on Larval Control Operations in Malaria Programmes, Geneva.

---, 1975. Vector resistance to insecticides; a review of its operational significance in malaria eradication and control programme. WHO/MAL/76.883, WHO/VBC/76.634 (Document).

Wourms, J.P. 1964. Comparative studies on the early embryology of Nothobranchius taeniopygus and Aplocheilichthys pumilus with special reference to the naturally occurring embryonic diapause in teleost fishes. Ann. Rept. East African Freshwater Fisher. Inst., 1964, App. H., 68-73.

---, 1972. Developmental biology of annual fishes. II. Naturally occurring dispersion and reaggreagation of blastomeres during the development of annual fish eggs. J. Exp. Zool., 182, 169-200.

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Figure 1. Irrigation pond in Southern Turkey. After introduction of <u>Gambusia</u> into pond there was a marked decrease in the mosquito population.

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Figure 2. Indiscriminate flooding of field causing temporary breeding sites for mosquitoes.

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Figure 3. Flooded road caused by indiscriminate irrigation procedures.

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Figure 4. Sewer water exiting from concrete pipe merging with spring water. Fish were found in fresh water but not in polluted water.

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Figure 5. The placing of eggs of the annual fish, N. guentheri, into the ground for eventual hatching in the following year.

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LEAD--INDUSTRIAL MONITORING AND BIOLOGICAL TESTING

by

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INTRODUCTION

Industrial use of lead in the U.S. has reached an estimated 1.3 million tons annually. The consumption of such quantities of Pb has produced industrial exposures and resulted in environmental pollution hazards.

Historically, lead contamination of the environment can be traced to coal burning and the use of leaded anti-knock fuel additives. Today, both sources are still the major sources of lead pollutants.

To pinpoint potential sources of lead pollution, reliable determinations of trace lead concentrations on environmental and biological specimens are necessary to isolate potential pollutants.

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A. HISTORICAL

Heavy metals are hazardous concomitant of industrialization. Of the many metals used by the industry, lead poisoning has been recognized since its early use. In the past the danger of lead contamination was mainly confined to mining districts and immediate smelter refinery environment (157). Rapid technological developments and diversified use of lead derivatives have introduced lead, which was traditionally restricted to sparsely populated areas, to densely populated industrial sites. And because of the potential hazards to the environment and the public, lead monitoring has become of considerable concern to industry, governmental agencies and the public at large.

High incidence of lead poisoning with noticable clinical manifestations has been extensively studied in several professions; namely glass blowing, battery manufacturing, printing, and paint processing (94), chemical plants producing lead compounds and gasoline refineries (34). The main purpose of these studies was to deal with excessive exposures and to determine an upper limit, delineating acceptable from unacceptable lead absorption (110). Only limited interest was devoted to subclinical exposures. It is only in recent years that we can witness unprecedented endeavor by nontraditional heavy metal users in the direction of accumulating baseline information on workers exposures. This is due to renewed interest in accurate distribution and the biological effects of trace metals in human and animal tissues and body fluids (70,89,111,108,129,133-135).

B. INDUSTRIAL MONITORING

Nontraditional lead users are faced with intermittent handling of lead compounds, usually in combination with a wide variety of other heavy metals. The clinical significance of such multiple long-term exposures is still poorly understood due to lack of information.

We can presently observe two areas of continuous monitoring of industrial lead contamination:

1. Monitoring of the work environment.

Although monitoring practices vary from industry to industry, the following criteria for the identification of potentially hazardous areas have been recommended (110):

a/ Handling of lead in which it can become airborne and workers are potentially exposed.

b/ Length of time in the potentially contaminated area.

c/ Level of air contamination.

2. Diagnosis of lead absorption.

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C. DETERMINATION OF LEAD IN BIOLOGICAL SPECIMENS BY ATOMIC ABSORPTION SPECTROMETRY.

Direct diagnosis of lead absorption has made substantial progress in the past few years. It has been accomplished primarily by improvements in the determination of lead in the laboratory, where contamination and interferences during the quantitation of lead have been a major source of difficulties.

Significant improvements and reliable results can be traced to the introduction of atomic absorption spectrometry (AAS)(155), which despite of its uni-element determinations, still remains the choice technique for the determination of trace metals.

Interest in mass screening to establish baseline information of lead concentrations of workers prior to employment in working environments with potential exposures to lead, has led to the development of a wide variety of assays. Of special interest to blood lead analysts has been the introduction of a whole blood lead macroassay described by Hessel (58) and other authors (95,151). The precision of this assay is excellent and a coefficient of variation of 3-6% at concentrations of 10-40 mcg Pb/dl can be obtained in routine blood lead determinations.

As shown in Table I, numerous sources have been found to contribute to baseline lead concentrations found in humans and animals.

As the sensitivity of trace metal analytical techniques increased a careful reevaluation of old values was necessary. At the same time a strong demand to analyze large numbers of specimens was encountered. This has led to the development of several microtechniques namely the 'boat', the 'Delves' cup, and lately we can witness an explosion of thermoelectric vaporization techniques (see Table II). In these techniques the specimen volume needed for the analysis has been reduced and multiple analyses can be performed quickly. The organic solvent phase needed in flame AAS to increase the sensitivity, has in many instances been eliminated. To overcome interferences from volatile material during atomization, programmed pyrolysis and background correction have been introduced to simplify the overall procedure. While the need for tedious and time consuming digestion has been eliminated, matrix interferences are still a major source of difficulties and expertise in performing reliable determinations is required. In addition pretreatment techniques and matrix modifications are often needed (6,10,46,92,147). However, the sensitivity and convenience of electrothermal techniques highly favor their application in routine laboratory use.

In 'Zeeman modulation' high-precision background correction can be applied and the technique shows great promise in accurate trace metal analyses (19,60).

In the past few years, attempts have been made to develop Multielement Absorption Spectrometric (MAS) instrumentation (117,118). The advantages of such equipment is high throughout, small sample requirements, lower cost per test, and convenience of performing such determinations.

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TABLE I. Determination of Lead in Biological and Environmental Specimens.

Biological Specimens	
Blood (urine)	(3,13,15,21,23,24,30,36-38,40,43,47,55,58,59,61,66-68, 74,76,84,86,95,100,103,106,109,113,114,119,124,131,134, 135,140,141,151,154)
Urine	(4,5,77,83,87,101,120,122,123,155,160,161)
Semen	(108)
Tissues	(27,52,70,80,93,107,129,133,159)
Hair	(85,111,148)
Bones, Ivory	(89)
Feces	(112)
Environmental Specimens	
Drinking Water	(31,39)
Mineral Water	(65)
Sea Water	(42,90,115)
Wines, Beer	(28,56,153)
Milk	(53)
Sugar	(98)
Foodstuffs, Fish	(17,35,41,47,75,127,143,158)
Plastic Containers	(46)
Paper, Prints, Wax Crayons	(20,29,96,128)
Paints	(57)
Aerosols, Dusts, Soils	(41,91,105,130,152)
Coal, Coal Ashes	(16)
Gasoline	(32,137)

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TABLE II. Analytical Methods for the Determination of Lead in Biological and Environmental Specimens by Atomic Absorption Spectrometry

Method	References
Flame	(3,13,15,21,24,29,35,37,41,47,58,83,95,100, 101,106-108,120,122-124,130,131,137,151,155, 158,159,161)
'Boat'	(61,76,91)
'Delves' Microsampling Cup	(5,23,30,38,42,53,57,59,70,74,75,96,103,129, 148)
Electrothermal Atomization	(4,10,16,17,20,28,36,39,40,43,44,46,47,56, 65-68,86,87,89,90,92,93,98,109,112,114,128, 133-136,140,153)
Zeeman Modulation	(19,52,60,80-82)
Multielement Analysis	(117,118)
Hydride Generation	(146)

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D. OTHER LEAD ANALYTICAL TECHNIQUES.

Besides the AAS methods presented in chapter C, the most commonly used analytical procedures are: polarography (12, 54, 63, 71, 72, 79, 99, 102, 121, 126, 132, 139, 144, 150), X-ray fluorescence spectrometry (1, 2, 9, 45, 104, 138), spark source mass spectrometry (22, 51, 73), and optical emission spectrometry (142, 145, 149, 156).

Conventional neutron activation cannot be used for the determination of lead because of low reaction cross-sections. Partial success was achieved by using cyclic activation and measuring the short-lived isomer ^{207m}Pb produced on irradiation (33,116).

The polarographic techniques have excellent sensitivity and have been developed to such a degree, that they are now competing with AAS.

The advantages of X-ray fluorescence, mass spectrometry, and optical emission spectrometry are in their multielement determinations. These techniques, however, require substantial investment and highly experienced personnel.

E. DISTRIBUTION OF LEAD IN TISSUES AND BODY FLUIDS.

Prior to working in work places with potential exposures to lead, the worker is subject to lead intake from air, food and water. Any occupational exposures will therefore be in addition to such baseline lead concentrations. As shown in Figure 1, several pathways of lead intake, transport and excretion exist in the human body. With enhanced industrial hygiene awareness and continuous monitoring of the work environment, lead exposures of workers occur primarily through inhalation of airborne lead particulates or fumes containing volatile lead. Additional lead absorption may result from accidental exposures and from poor working habits exhibited during the course of handling lead materials.

Some of the inhaled larger particulates are transported from the lungs and bronchial passages by mucociliary action to the gastrointestinal system (27,14). Insoluble lead particulates will accumulate in the lungs up to age 40, while over 90 percent of the body burden is found in the bones. In adults the bone lead accumulation is a very slow process, while lead in the blood is readily taken up by the blood erythrocytes and plasma proteins (7,49,97). Experiments with animals have shown that the absorption of lead may be enhanced by diet deficient in minerals or diet rich in fat content (8). Conversely high mineral diets appear to reduce lead absorption. The excretion of lead and thus any reduction of the body burden is mainly via urine and feces. Some lead output is experienced during pregnancy and breast feeding periods (18,64).

Effect of Subclinical Exposures to Lead.

The exact definition of subclinical exposures to lead and subsequent blood lead concentrations are still under discussion, and appear to be lower as better understanding of low lead effect is being gathered. It is also

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apparent that a transient area of blood lead levels exists (49) in which harmful, though not irreversible, effects to "susceptible" workers may be produced. Blood lead values as low as 30 mcg Pb/dl have been pointed out.

Effects of subclinical exposures to lead may be summarized as follows:

a/ Hematopoietic effects (49,11)

b/ Potential damage to the nervous system (125)

c/ Potential reproductive damage (88,108)

d/ Potential effects on the fetus (64)

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DETERMINATION OF LEAD IN BLOOD AND URINE.

A. CHOICE AND COLLECTION OF SPECIMENS

Bones are known to contain the highest concentration of lead (50). The bone lead level is a measure of past and chronic exposures. Since there is a steady state between the bone lead and blood lead, individuals with high chronic exposures may be most susceptible to early clinical toxicity resulting from additional lead intake (49). It would therefore appear that workers with high past exposures to lead (having high levels of lead in the bones), would be well advised of their situation and thus spared of additional industrial lead exposures.

Blood and urine, being sensitive to the immediate input of lead, are to be looked at as indicators of current absorption of lead (110).

Since the choice of specimen for continuous monitoring of lead exposures is determined by the availability of suitable specimens, it is not surprising that blood and urine have been studied most.

For subclinical exposures blood lead in conjunction with biochemical and clinical testing have proved to be the most useful indicators for early diagnosis of exposures resulting in blood lead levels greater than 30 mcg Pb/dl.

Blood Lead Analysis.

Many critical objections have been raised about the reliability of routine blood lead determinations (25,78). Analysis of the variation of results obtained on survey specimens points to systematic experimental errors. One source of errors can be traced to the popular practice of "spiking" blood specimens with inorganic lead and relying upon recovery of such additions. The pitfall of such additions has been excellently documented by the use of ^{203}Pb (84). It was pointed out, that "... because of differences in in vivo and in vitro lead binding, recovery of added inorganic lead may not accurately reflect the fate of endogenous lead in some analytical procedures."

Unfortunately, despite of the many objections raised against "spiking", there is no easy substitute, and many workers continue to include recovery of added lead as the best approximation for the evaluation of lead analytical techniques. Due to this methodological ambiguity, participation in state and national surveys is therefore of invaluable help in establishing the accuracy of blood lead assays.

Blood Lead Reference Intervals.

Depending on the method used and the living environment of individuals tested, various blood lead concentration means have been observed (see Table III). These results reflect lead uptake from natural sources and undoubtedly from ambient air contamination.

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Since only subclinical exposures to lead were anticipated in this study, careful attention was given to the selection of individual workers used for the determination of lead in blood of adults without known occupational exposure to lead. For the purpose of this study workers without known exposures to lead and residing in the same area as those workers which were then monitored for lead exposures, were selected to participate in the reference group. The group consisted of IBM employees participating in the IBM Voluntary Health Screening Program (26). Employees of the IBM East Fishkill plant, living in rural Dutchess County, New York, were asked to participate. Only those individuals living away from close proximity of major highways or unusually heavy traffic, not participating in range shooting, and not performing household activities which could contribute to elevated blood lead levels, were selected.

Whole blood samples were collected by venipuncture in lead free Becton-Dickinson Vacutainers containing 143 USP units of Sodium Heparin. The blood specimens were refrigerated at 4°C within 1 hour and shipped to the laboratory where the specimens were analyzed within 48 hours.

Lead Concentrations in Blood of Workers Monitored for Potential Exposures to Lead.

Workers handling inorganic lead (particulate PbO_2 powder) used at the East Fishkill IBM plant, were tested for blood lead concentrations. Whole blood specimens were collected and handled in the same manner as the unexposed reference group.

Urine Lead Analysis.

Varied opinions exist as to the usefulness of urine lead assays. The difficulties associated with the analysis of lead in urine are heightened further by ambiguities encountered in the final interpretation of urine lead results. In spite of these difficulties, it has been shown, that urinary lead may serve as a useful index of current lead absorption (77,154).

Although the blood can be looked at as the preferred specimen for the diagnosis of current lead exposure, strong reluctance of the workers against frequent blood drawing has been experienced. This has led to substituting blood specimens with screen testing of urine lead excretion. The 24-hours urine collection was found impractical to implement in the plant working environment and therefore only early morning specimens were used.

The workers were instructed to void first morning specimens at home or on occasion at the IBM medical location. Urines were collected in acid washed polyethylene containers with the following instructions given to each participant:

1/ Keep cup on bottle until A. M. just prior to using.

2/ Wash hands carefully before voiding.

3/ Void at least 50 ml.

4/ Urine used as specimen must be the first specimen in the A. M.

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TABLE III. Concentrations of Lead in Blood of Adults Without Known Occupational Exposures to Lead.

Date	Location	No. of Subjects	Blood Lead mcg/dl	Ref.
1961	New Orleans	130	22 ± 19	62
	Chicago	97	20 ± 8	
	New York City	112	20 ± 8	
1967	New York City	105	17 ± 18	48
1961	Cincinatti	137	20 ± 18	62
	Denver	131	19 ± 7	
1967	California Cities	27	19 ± 4	48
1971	Hartford, Conn.	19	19 ± 4	100
1967	Ohio Cities	20	18 ± 10	48
1961	Dallas	128	18 ± 7	62
1974	Ann Arbor, Mich.	89	15 ± 13	55
1961	Rural Ohio	102	14 ± 6	62
1977	Farmington, Conn.	21	13 ± 4	108
1967	Rural Ohio	102	12 ± 6	48
1965	Suburban Philadelphia	81	13 ± 6*	105
1978	East Fishkill, N. Y.	59	11 ± 3	**

* Reported in mcg/Pb/100 gm blood
** This study

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The specimens were refrigerated at 4°C and then shipped to the laboratory where the lead content was determined within 48 hrs.

Urine lead was determined by acid digestion (120,123). The resulting inorganic lead was chelated with Ammonium Pyrrolidine Dithiocarbamate (APDC) and the lead complex was extracted with Methyl Isobutyl Ketone (MIBK). The concentration of lead was measured by flame Atomic Absorption Spectrometry (AAS) at 283.3 nm.

In addition to lead determination by acid digestion, it was investigated whether urine lead could also be determined without the use of tedious and somewhat susceptible to extraneous contamination acid digestion. Since this study is primarily dealing with workers exposed to inorganic lead, it was thought, that the use of such procedure would substantially shorten the time needed to perform the analysis and would also provide sufficient information on undesirable exposures.

B. INSTRUMENTATION

An atomic absorption spectrophotometer (Model 303, Perkin Elmer Corp., Norwalk, Conn.) in combination with a "Boling" three-slot acetylene burner was used. The instrument settings were as follows: Slit 4, Noise 2, Scale 3. Optimal settings were tested by aspirating a water solution containing 1 mcg Pb/ml. Prior to aspirating MIBK extracts, several blank extracts were aspirated to eliminate any traces of lead remaining in the AAS burner.

C. REAGENTS

Reagents were selected to obtain the lowest blank values. Ultrapure reagents did not require any further purification and were used whenever possible.

- Sulfuric Acid, Ultrapure, E. Merck Co.
- Nitric Acid, Ultrapure, E. Merck Co.
- Acetic Acid, Ultrapure, E. Merck Co.
- Ammonia Solution, 25%, Ultrapure, E. Merck Co.
- Hydrogen Peroxide, 30% solution, Fisher Scientific
- Ammonium Pyrrolidine Dithiocarbamate, K&K Labs
- Triton X-100, Sigma Co.
- Lead standard solution, 1000 mcg Pb/ml, Fisher Certified, Fisher Scientific Co.
- Blood lead controls: Lyophilized elevated blood lead control, TOX-EL (A. R. Smith Laboratories)
- Urine lead controls: 5 ml aliquots of urine containing approximately 250 mcg Pb/L, obtained from a cow which was dosed with lead acetate (courtesy of New York State, Dept. of Health, Albany, N. Y.). Aliquots were kept frozen in polystyrene screw cup tubes.
- Distilled-deionized water was used routinely. All glassware was acid washed in 10% nitric acid.

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D. ANALYTICAL PROCEDURES

Determination of Lead Content in Whole Blood.

Duplicate 2ml aliquots of well mixed heparinized blood are pipeted into 10 ml test tubes. Similarly blank, and 5, 10, 20, 40, and 80 mcg Pb/dl standards, and controls are prepared. One ml of mixed solution of 1% Triton X-100 and 1% solution APDC /1:1/ is added to all tubes, which are then mixed on a Vortex mixer and allowed to stand for 5 min. Two ml of MIBK saturated with water are added and the tubes are shaken for 5 min. The tubes are then centrifuged for 10 min at 3000 rpm and clear MIBK extracts are transferred with Pasteur pipets into 6 ml screw cap tubes. The extracts are then aspirated into the burner of flame AAS using MIBK as a baseline.

Determination of Lead in Urine

A. By acid digestion.

There are numerous ashing or acid digestion procedures for the determination of lead in urine / see Table I /. Complete digestion is needed for quantitative measurement of trace concentrations of lead in urine.

In this study the technique producing low lead blank was used.

Twenty ml of urine in duplicate are transferred into acid washed Phillips beakers in which several blank runs were made. Add 0.9 ml of concentrated sulfuric acid, two glass beads and heat on hot plate / temperature inside the tube to be at least 185^{o}C /. When the volume of urines being evaporated is reduced to about 2 ml, blank, controls, and 5, 10, 20, 40, and 80 mcg Pb/L standards are also put on the digestion plate and the preparations are digested with intermittent swirling for about 30 min. To all flasks 1 ml of concentrated nitric acid is added and the digestion is continued for 15 to 20 min. After that 1 ml of 30% hydrogen peroxide is added and the digestion is continued for 15 to 20 min. If necessary, more nitric acid or peroxide is added to all flasks until clear solutions are obtained, At the end of digestion about 3 to 5 ml of water is added and the flasks are heated again for another 5 min.

All lead is now in inorganic form and can be chelated with APDC. The pH is adjusted to pH 3.5 by addition of ammonia solution and the digests are transferred into 10 ml extraction tubes. One ml of 1% APDC is added, mixed, and let stand for 5 min. The extraction with MIBK and the measurement of lead by AAS is continued as described in the whole blood lead analysis.

B. Without acid digestion.

Twenty ml of urine in duplicate are transferred into 35 ml screw cap tubes. The acidity of urine specimens is adjusted to pH 3.5 with Acetic Acid. Similarly blank, 5, 10, 20, 40, and 80 mcg Pb/L standards, and urine controls are prepared. To all tubes 1 ml of 1% APDC solution is added, and allowed to stand for 5 min. Thereafter the analysis is continued as described in the whole blood lead analysis.

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E. ANALYTICAL RECOVERIES

Aliquots of 10 to 40 mcg Pb/dl were added to whole blood. The mean recovery of lead was 101%. As shown in Table IV, the coefficient of variation was 2.9 to 4.9%.

Precision.

The day-to-day variability of the method was measured by using TOX-EL (Pb) lyophilized whole blood control (A. R. Smith Laboratories, Los Angeles, California). The coefficient of variation of 36 measurements made over a two year period was 3.6%.

F. RESULTS

Reference Intervals for Lead in Whole Blood.

Blood lead concentrations of healthy men without occupational exposure to lead were measured by flame AAS. A frequency-distribution graph of lead concentrations in whole blood from 59 men (age 35 to 63 years) is shown in Figure 2. The mean concentration of blood lead was 11.4 mcg Pb/dl (S.D. $\pm$2.8; range= 6 to 19), (50th percentile= 11.3).

As shown in Table III, there is a high variation in reported blood lead mean concentrations. A decrease of lead from metropolises to suburbia can be observed, and should be taken into consideration if highly mobile workers are to be monitored for potential exposures to lead.

Correlation of Blood Lead Concentrations with The Age of Men Without Occupational Exposure to Lead.

The correlation of blood lead concentrations with the age of 59 adult men (age 35 to 63 years) without occupational exposure to lead is presented in Figure 3. Although a relatively poor correlation was obtained (correlation coefficient = .46), an increase in the level of blood lead with the age of men can be observed.

Correlation of Blood Lead Concentrations with Blood Hemoglobin Levels.

The correlation of blood lead concentrations with the blood hemoglobin levels of 56 men without ococupational exposure to lead is presented in Figure 4. (Blood lead mean $\bar{x}$ = 11.4 mcg Pb/dl, S.D. $\pm$ 2.8, range = 6 to 19; Hemoglobin mean $\bar{x}$ = 16.7 gm/dl, S.D. $\pm$ 1.3, range = 14.0 to 20.2).

Urine Lead Concentrations as Determined With and Without Acid Digestion.

1. Correlation of urine lead concentrations with the specific gravity of urine.

The correlation of urine lead concentrations, determined without digestion of urine samples from 58 males who had no occupational exposure to lead, is presented in Figure 5. (Urine lead (no digestion) mean $\bar{x}$ = 8.1 mcg Pb/L, S.D. $\pm$ 2.8, range = 3 to 16; Specific gravity mean (25°C) = 1.022, S.D. $\pm$ .006, range = 1.010 to 1.034).

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TABLE IV. Recovery of Lead Added to Whole Blood

No. specimens	Pb added mcg/dl	Pb recovered mcg/dl	C. V.
6	10	9.92	4.9
6	20	20.70	4.4
6	30	30.37	3.7
6	40	40.42	2.9

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As shown a parallel increase of lead concentrations with increased specific gravity can be observed.

Similar correlation was obtained with urine lead determined with acid digestion (Urine lead (by digestion) mean $\bar{x}$ = 13.4 mcg Pb/L, S.D. ± 4.7, range = 5 to 27; Specific gravity (25°C) mean $\bar{x}$ = 1.022, S.D. ± .007, range 1.010 to 1.034).

Therefore all urine lead results have been adjusted to a specific gravity of 1.024. Similar correction has been used by other workers (154).

2. Correlation of Urine Lead Concentrations Obtained With and Without Acid Digestion.

The correlation of urine lead concentrations determined with and without acid digestion of urine specimens from 32 males without occupational exposure to lead is shown in Figure 6. (Urine lead (no digestion) mean $\bar{x}$ = 8.6 mcg Pb/L, S.D. ± 3.1, range = 4 to 16; Urine lead (by digestion) $\bar{x}$ = 13.6, S.D. ± 4.8, range 7 to 27).

The correlation of urine lead concentrations determined with and without acid digestion of urine specimens from 29 workers handling inorganic lead /PbO_2/ is shown in Figure 7. Urine lead (no digestion) mean $\bar{x}$ = 11.1 mcg Pb/L, S.D. ± 6.4, range 2 to 26); Urine lead (by digestion) mean $\bar{x}$ = 17.7 mcg Pb/L, S.D. ± 9.5, range 6 to 45).

For ease of comparison the means of lead concentrations in urines of both groups are presented in Table V.

The correlation of combined urine lead concentrations determined with and without acid digestion of both groups is presented in Figure 8 (Urine lead (No digestion) mean $\bar{x}$ = 9.8 mcg Pb/L, S.D. ± 5.0, range 2 to 26; Urine lead (Digestion) mean $\bar{x}$ = 15.5 mcg Pb/L, S.D. ± 7.6, range 5 to 45).

Comparisons of Lead in Blood and Urines of Men With no Occupational Exposure to Lead and Workers Handling Inorganic Lead PbO_2/.

The comparisons of the means of blood and urine lead concentrations of men with no occupational exposure to lead and workers handling inorganic lead is presented in Table VI.

Urine lead concentrations are presented as follows:

- Urine Pb (No dig., No corr.) ... Pb without acid digestion of urine and no adjustment for specific gravity was made.

- Urine Pb (No dig., Corr.) ... Pb without digestion of urine and adjustment was made for specific gravity.

- Urine Pb (Dig., No corr.) ... Pb with acid digestion and no adjustment for specific gravity.

- Urine Pb (Dig., Corr.) ... Pb with acid digestion and adjustment for specific gravity.

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TABLE V. Comparisons of Mean Urine Lead Concentrations Obtained With and Without Acid Digestion.

	No digestion	Digestion	P Value*
Control group N = 32	8.6 mcg Pb/L S.D. ± 3.1	13. mcg Pb/L S.D. ± 4.7	P <.01
Workers N = 29	11.1 mcg Pb/L S.D. ± 6.4	17.7 mcg Pb/L S.D. ± 9.5	P <.01

* Paired t-test

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TABLE VI. Comparisons of Lead Concentrations in Blood and Urines of Men With no Occupational Exposure to Lead and Workers Handling Inorganic Lead /PbO_2/.

	Controls	Workers	P Value*
Blood Pb	11.4 mcg/dl S.D.± 2.8 N = 59	14.8 mcg/dl S.D.± 4.8 N = 45	P<.01
Urine Pb (No dig., No corr.)	8.1 mcg/L S.D.± 2.8 N = 56	11.1 mcg/L S.D.± 5.8 N = 45	P<.01
Urine Pb (No dig., Corr.)	9.3 mcg/L S.D.± 3.4 N = 56	11.8 mcg/L S.D.± 5.4 N = 43	P<.01
Urine Pb (Dig., No corr.)	13.4 mcg/L S.D.± 4.7 N = 33	16.9 mcg/L S.D.± 9.4 N = 27	P=.06
Urine Pb (Dig., Corr.)	15.8 mcg/L S.D.± 6.2 N = 33	17.3 mcg/L S.D.± 8.1 N = 27	P>.10

* t-test

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G. DISCUSSION

As shown in Figures 6-8, and in Table V, the concentrations of lead determined with acid digestion of urine specimens were higher than the lead concentrations determined without acid digestion. Our present finding is in agreement with similar observations reported by other authors (110,123,124, 155).

From results obtained in this study it appears, that the differences in the means of urine lead concentrarions, determined with and without acid digestion, remain constant, and amount to about 5-6 mcg Pb/L. This difference represents a substantial error from "true" total lead concentrations at urine lead level within or near the reference interval of men with no occupational exposure to lead.

Similarly low total lead concentrations would be obtained, if urine samples from workers with subclinical exposure to lead, were analyzed without the use of acid digestion. The error would be negligible if high exposure to lead is to be dealt with.

As indicated in Table VI, the mean lead concentrations in whole blood of workers handling inorganic lead were higher than those of men with no exposure to lead. Similarly the lead concentrations in urines of men handling inorganic lead were higher when compared to those of men with no exposure to lead. These differences, although statistically significant ($P < .01$), have no clinical significance, as both concentrations are far below the blood or urine lead concentration limits recommended recently (69).

Statistical analysis of the mean differences of urine lead concentrations presented in Table VI indicates that the most significant difference ($P < .01$) was obtained on lead concentrations determined without the use of acid digestion and with no correction for the specific gravity of urines (Urine Pb (No dig., No corr.)). The use of acid digestion and the introduction of a correction for the specific gravity of urine, while theoretically correct, seem to gradually affect the final data in such a way (expanded range and $P > .10$) as to contradict the usefulness of a tedious, time consuming, and very costly acid digestion.

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SUMMARY

The determination of lead concentrations in urine and in whole blood by atomic absorption spectrometry was used to monitor exposures of workers to subclinical levels of lead. Due to low concentration range, efforts were made to obtain the highest precision and accuracy.

The mean blood lead concentration of 59 adult men with no occupational exposure to lead was $\bar{x}$ = 11.4 mcg Pb/dl, S.D. = 2.8, range 6 to 19. The correlations between the lead concentration in whole blood and the age of men, and the hemoglobin level of the same group of men is presented.

The determination of lead concentrations in urine with and without acid digestion is described. It was found that the lead concentrations were in the average 5-6 mcg/L higher than the lead concentrations obtained without acid digestion.

It was also found, that the use of acid digestion for the determination of total lead in urine and the use of a correction for the specific gravity, although theoretically correct, seem to affect the final data in such a way as to contradict the usefulness of acid digestion.

The determination of lead in urine, without the use of acid digestion, is easy to perform; it is fast and sufficiently reliable data for screen purposes can be obtained easily.

NEW JERSEY GEOLOGICAL SURVEY

REFERENCES

1. Agarwal, M., Bennett, R. B., Stump, I. G., and J. M. D'Auria, Anal. Chem. 47,924(1975).

2. Alfrey, A. C., Nunnelly, L. L., Rudolph, H., and W. R. Smythe, Advances in X-ray Analysis, Vol. 19,497(1976).

3. Amare, F., Anal. Chem. 46,1597(1974).

4. Amos, M. D., Bennett, P. A., Brodie, K. G., Lung, P. W. Y., and J. P. Matousek, Anal. Chem. 43,211(1971).

5. Anderson, M. P. and B. B. Mesman, Am. Ind. Hyg. Ass. J. 34,310(1973).

6. Baily, P. and T. A. Kilroe, Anal. Chim. Acta 77,29(1975).

7. Baloh, R. W., Arch. Environ. Health 28,198(1974).

8. Barltrop, D. and H. E. Khoo, Proc. Univ. Mo's Ann. Conf. on Trace Subst. in Environ. Health, 9th Univ. of Mo, Columbia, Vol. 9,369(1975).

9. Barnes, B. K., Coleman, R. M., Kegel, G. H. R., Quinn, P. W., and N. J. Rencricca, Advances in X-ray Analysis, Vol. 18,343(1975).

10. Beaty, R. D. and M. M. Cooksey, At. Absorption Newslett. 17,53(1978).

11. Beliles, R. R. Metals. Toxicology. The Basic Science of Poisons. Casarett and Doull, Eds., Macmillan Publ. Co., New York, pp. 454(1975).

12. Ben-Bassat, A. H. I., Blindermann, J. M., and A. Salomon, Anal. Chem. 47,534(1975).

13. Berman, E., At. Absorption Newslett. 3,111(1964).

14. Berman, E., Clin. Pediatrics 5,287(1966).

15. Berman, E., Valavanis, V., and A. A. Dubin, Clin. Chem. 14,239(1968).

16. Block, C., Anal. Chim. Acta 80,369(1975).

17. Brady, D. V., Montalvo, J. G., Jung, J., and R. A. Curran, At. Absorption Newslett. 13,118(1974).

18. Bridbord, K., Preventive Medicine 7,311(1978).

19. Brown, S. D., Anal. Chem. 49,1269A(1977).

20. Castellani, F., Riccioni, R., Gusteri, M., Bartocci, V., and P. Cescon, At. Absorption Newslett. 16,57(1977).

21. Cernik, A. A., Brit. J. Industr. Med. 27,40(1970).

NEW JERSEY GEOLOGICAL SURVEY

22. de Leenheer, A. P., Roncucci, R. R., Eds. "Quantitative Mass Spectrometry in Life Sciences," Elsevier Publishing Co., Amsterdam, 1977.

23. Delves, H. T., Analyst 95,431(1970)

24. Donovan, P. P. and D. T. Feeley, Analyst 94,879(1969).

25. Donovan, D. T., Vought, V. M., and A. B. Rakow, Arch. Environ. Health 23,111(1971).

26. Duffy, J. C. and K. F. Moonan, Industr. Med. Surg. 39,35(1970).

27. Dulka, J. J. and T. H. Risby, Anal. Chem. 48,640A(1976).

28. Dyer, R. H., and A. F. Ansher, J. Food Sci. 42,534(1977).

29. Eaton, D. F., Fowles, G. W. A., Thomas, M. W., and G. B. Turnbull, Environ. Sci. Techn., 9,768(1975).

30. Ediger, R. and R. Coleman, At. Absorption Newslett. 11,33(1972).

31. Ediger, R. D., At. Absorption Newslett. 12,151(1973).

32. Edwards, H. W. and H. G. Wheat, Environ. Sci. Techn. 12,687(1978).

33. Egan, A. and N. M. Spyrou, Anal. Chem. 48,1959(1976).

34. Elkins, H. B. The Chemistry of Industrial Toxicology, New York, John Wiley & Sons, pp. 49-57(1959).

35. Evans, W. H., Read, J. I., and B. E. Lucas, Analyst 103,580(1978).

36. Evenson, M. A. and D. D. Pendergast, Clin. Chem. 20,163(1974).

37. Farrelly, R. O. and J. Pybus, Clin. Chem. 15,566(1969).

38. Fernandez, F. J. and H. L. Kahn, At. Absorption Newslett. 10,1(1971).

39. Fernandez, F. J. and D. C. Manning, At. Absorption Newslett. 10,65(1971).

40. Fernandez, F. J., Clin. Chem. 21,558(1975).

41. Friend, M. T., Smith, C. A., and D. Wishart, At. Absorption Newslett. 16,46(1977).

42. Gabrielli, Favretto, L., Marletta, Pertoldo, G., and L. Favretto, At. Absorption Newslett. 16,4(1977).

43. Garnys, V. P. and J. P. Matousek, Clin. Chem. 21,891(1975).

44. Geladi, P. and F. Adams, Anal. Chim. Acta 96,229 (1978).

NEW JERSEY GEOLOGICAL SURVEY

45. Giauque, R. D., Garrett, R. B., and L. Y. Goda, Anal. Chem. 49,1012(1977).

46. Girgis-Takla, P. and I. Chroncos, Analyst 103,122(1978).

47. Goldsmith, C. D., Scanlon, P. F., and W. R. Pirie, Bull. Environ. Cont. Toxicology 16,66(1976).

48. Goldwater, L. J. and A. W. Hoover, Arch. Environ. Health 15,64(1967).

49. Goyer, R. A. and P. Mushak, "Toxicology of Trace Elements" by Goyer & Mehlman, Hemisphere, Advances in Modern Toxicology, Vol. 2,41-77(1977).

50. Goyer, R. A. and B. C. Rhyne, Int. Rev. Exp. Pathol. 12,1(1973).

51. Guidoboni, R., Anal. Chem. 45,1275(1973).

52. Hadeishi, T. and R. D. Laughlin, Anal. Chem. 48,1009(1976).

53. Haelen, P., Cooper, G., and C. Pampel, At. Absorption Newslett. 13,1(1974).

54. Haerdi, W. and D. Monnier, Mitt. Gebiete Lebensm. Hyg. 50,243(1959).

55. Hecker, H., Allen, H. E., Dinnan, B. D., and J. V. Neel, Arch. Environ. Health 29,181(1974).

56. Helin, T. R. and J. C. Slaughter, J. Inst. Brew. 83,15(1977).

57. Henn, E. L., At. Absorption Newslett. 12,109(1973).

58. Hessel, D. W., At. Absorption Newslett. 7,55(1968).

59. Hicks, J. M., Gutierrez, A. N., and B. E. Worthy, Clin. Chem. 19,322(1973).

60. Hiefte, G. M. and T. R. Copeland, Anal. Chem. 50,300R(1978).

61. Hilderbrand, S., Koirtohann, S. R., and E. E. Pickett, Biochem. Med. 3,437(1970).

62. Hofreuter, D. H., Calcott, E. J., Keenan, R. G., and C. Xintaras, Arch. Environ. Health 3,568(1961).

63. Horiguchi, S., Teramoto, K., Shingawa, K., and G. Endo, J. Osaka City Med. Center 22,No. 10-12,299(1973).

64. Hricko, A., Preventive Med. 7,394(1978).

65. Hudnik, V., Gomiscek, S., and B. Gorenc, Anal. Chim. Acta 98,39(1978).

66. Human, H. G. and E. Norval, Anal. Chim. Acta 73,73(1974).

NEW JERSEY GEOLOGICAL SURVEY

67. Hwang, J. Y., Ullucci, P. A., Smith, S. B., and A. L. Malenfant, Anal. Chem. 43,1319(1971).

68. Hwang, J. Y., Ullucci, P. A., and C. J. Mokeler, Anal. Chem. 45,795(1973).

69. Inorganic Lead. Final Environmental Impact Statement. PB-284 746. U.S. Department of Commerce NTIS, 1978.

70. Jackson, K. W., Marczak, E., and D. G. Mitchell, Anal. Chim. Acta 97,37(1978).

71. Jagner, D., Anal. Chem. 50,1924(1978).

72. Jensovsky, L. and Z. Roth, Naturwissenschaften 48,382(1961).

73. Jaworski, J. F., and G. H. Morrison, Anal. Chem. 46,2080(1974).

74. Joselow, M. M. and J. D. Bogden, At. Absorption Newslett. 11,99(1972).

75. Julsham, K. and O. R. Brackhan, At. Absorption Newslett. 14,49(1975).

76. Kahn, H. L. and J. S. Sebestyen, At. Absorption Newslett. 9,33(1970).

77. Kehoe, R., Arch. Environ. Health 8,348(1964).

78. Keppler, J. F., Maxfield, M. E., Moss, W. D., Tietjen, G., and A. L. Linch, Am. Ind. Hyg. Assoc. J. 31,412(1970).

79. Kisser, W., Mikrochimica Acta 3,545(1974).

80. Koizumi, H. and Kazno Yasuda, Anal. Chem. 48,1178(1976).

81. Koizumi, H., Yasuda, K., and M. Katayama, Anal. Chem. 49,1106(1977).

82. Koizumi, H., Anal. Chem. 50,1101(1978).

83. Kopito, L. and H. Schwachman, J. Lab. Clin. Med. 70,326(1967).

84. Kopito, L. E., Davis, M. A., and H. Schwachman, Clin. Chem. 20,205(1974).

85. Kopito L. E. and H. Schwachman, J. Invest. Dermatology 64,342(1975).

86. Kubasik, N. P., Volosin, M. T., and M. H. Murray, Clin. Chem. 18,410(1972).

87. Kubasik, N. P. and M. T. Volosin, Clin. Chem. 19,954(1973).

88. Lancranjan, I., Popescu, H., Gavanescu, O., Klepsch, I., and C. Serbanescu, Arch. Environ. Health 30,396(1975).

89. Langmyhr, F. J. and I. Kjuus, Anal. Chim. Acta 100,139(1978).

NEW JERSEY GEOLOGICAL SURVEY

90. Lars-Göran Danielsson, Anal. Chim. Acta 98,47(1978).

91. Luecke, W. and R. Emmermann, At. Absorption Newslett. 10,45(1971).

92. Manning, D. C. and W. Slavin, At. Absorption Newslett. 17,43(1978).

93. Matousek, J. P. and B. J. Stevens, Clin. Chem. 17,363(1971).

94. Mayers, M. R. Occupational Health. Hazards of the Work Environment. Baltimore, Williams&Wilkins Co., pp. 69,70.

95. Mitchell, P. G., Ryan, F. J., and K. M. Aldous, At. Absorption Newslett. 11,120(1972).

96. Mitchell, D. G., Aldous, K. M., and A. F. Ward, At. Absorption Newslett. 13,121(1974)

97. Morgan, G. B. and E. W. Bretthauer, Anal. Chem. 49,1210A(1977).

98. Morris, N. M., Clarke, M. A., Tripp, V. W., and F. G. Carpenter, J. Agric. Food Chem. 24,45(1976).

99. Morrell, G. and G. Giridhar, Clin. Chem. 22,221(1976).

100. Murphy, T. F., Shozo, Nomoto, and F. W. Sunderman, Jr., Annals Clin. Lab. Sc. 1,57(1971).

101. Nelson, K. W., Am. Ind. Hyg. Assoc. J. 26,442(1965).

102. Nürnberg, H. W., Electrochimica 22,935(1977).

103. Olsen, E. D. and P. J. Jatlow, Clin. Chem. 18,1312(1972).

104. Ophus, E. M., Fagerland, G., and B. M. Gullvag, Acta Zoologica 56,177(1975).

105. PHS Publication No. 999-Ap-12(1965).

106. Pierce, J. O. and J. Cholak, Arch. Environ. Health 13,208(1966).

107. Piper, K. G. and G. Higgins, Proc. Ass. Clin. Biochem. 4,190(1967).

108. Plechaty, M. M., Noll, B., and F. William Sunderman, Jr., Annals Clin. Lab. Sci. 7,515(1977).

109. Posma, F. D., Balke, J., Herber, R. F., and E. J. Stuik, Anal. Chem. 47,834(1975).

110. Public Health Service, HSMHA, NIOSH HSM 73-11-010(1972).

111. Reeves, R. D., Jolley, K. W., and P. D. Buckley, Bull. Envir. Contam. Toxicol. 14,579(1975).

NEW JERSEY GEOLOGICAL SURVEY

112. Riner, J. C., Wright, F. C., and C. A. McBeth, At. Absorption Newslett. 6,129(1974).

113. Robinson, J. W., Wolcott, D. K., and L. Rhodes, Anal. Chim. Acta 78,285(1975).

114. Rosen, J. F., J. Lab. Med. 80,567(1972).

115. Roth, I. and H. Hornung, Environ. Sci. Techn. 11,265(1977).

116. Ryan, D. E., Stuart, D. C., and A. Chattopadhyay, Anal. Chim. Acta 100,87(1978).

117. Salin, E. D. and J. D. Ingle, Anal. Chem. 50,1737(1978).

118. Salin, E. D. and J. D. Ingle, Jr., Anal. Chem. 50,1745(1978).

119. Schlebusch, H. and B. Niehoff, Z. Klin. Biochem. 12,218(1974).

120. Searle, B., Chan, W., Jensen, C., and B. Davidow, At. Absorption Newslett. 8,126(1969).

121. Sedivec, V. and J. Flek, Pracovni Lekar 18,74(1966).

122. Segal, R. L., Clin. Chem. 15,1224(1969).

123. Selander, K. and K. Cramer, Brit. J. Industr. Med. 25,139(1968).

124. Selander, K. and K. Cramer, Brit. J. Industr. Med. 25,209(1968).

125. Seppalainen, A. M., Tola, S., Hernberg, S., and B. Kock, Arch. Environ. Health 30,180(1975).

126. Shalgosky, H. I. and J. Watling, Anal. Chim. Acta 26,66(1962).

127. Siccama, T. G. and W. H. Smith, Environ. Sci. Techn., 12,593(1978).

128. Simon, P., Giessen, B. C., and T. R. Copeland, Anal. Chem. 49,2285(1977).

129. Singh, N. P., Thind, I. S., Vitale, L. F., and M. Pavlov, J. Lab. Clin. Med. 87,273(1976).

130. Solomon, R. L. and J. W. Hartford, Environ. Sci. Techn. 10,773(1976).

131. Sprague, S. and W. Slavin, At. Absorption Newslett. 5,9(1966).

132. Srbova, J., Pracovni Lekar 18,72(1966).

133. Stegvik, K., Mikalsen, G., and E. A. Mylius, Bull. Envir. Contam. Toxicology 15,734(1976).

134. Stoeppler, M., Kampel, M., and B. Welz, Z. Analyt. Chem. 282,369(1976).

NEW JERSEY GEOLOGICAL SURVEY

135. Stoeppler, M. and K. Brandt, Analyst 103,714(1978).

136. Sturgeon, R. E., Anal. Chem. 49,1255A(1977).

137. Supp, G. R., Gibbs, J., and M. Juszli, At. Absorption Newslett. 12,66(1973).

138. Takemoto, S., Kitamura, H., Hideki, K., Kuge, Y., Nakaguwa, S., and K. Murata, Bunseki Kagaku 25,40(1976).

139. Teisinger, J. Hygiena Sanit., 8,28(1954).

140. Therell, B. L., Drosche, J. M., and T. W. Dziuk, Clin. Chem. 24,1182(1978).

141. Thompson, K. C. and R. G. Godden, Analyst 101,174(1976).

142. Török, T., Mike, J., and E. Gegus, "Spectrochemical Analysis", Adam Hilger, Bristol, 1977.

143. Ure, A. M., Hernandez-Artiga, M. P., and M. C. Mitchell, Anal. Chim. Acta 96,37(1978).

144. Valenta, P., Rutzel, H., Nürnberg, H. W., and M. Stoeppler, Z. Anal. Chem. 285,25(1977).

145. Valkovic, V. "Trace Element Analysis". Taylor and Francis, London, Halsted-Wiley, New York, 1975.

146. Vijan, P. N. and G. R. Wood, Analyst 101,966(1976).

147. Volosin, M. T., Kubasik, N. P., and H. E. Sine, Clin. Chem. 21,1986(1975).

148. Von Graef, V., J. Clin. Chem. Clin. Biochem. 14,181(1976).

149. Von Lehmden, D., Jungers, R., and R. Lee, Jr., Anal. Chem. 46,245(1974).

150. Vydra, F., Julakova, E., and K. Stulik, "Electrochemical Stripping Analysis", Ellis Horwood Ltd, Chichester, 1976.

151. Wasterlund Helmerson, W., At. Absorption Newslett. 9,133(1970).

152. Wedding, R. B., Bazzaz, F. A., and J. J. Stukel, Environ. Sci. Techn. 10,1139(1976).

153. Weiner, J., J. Inst. Brew. 83,82(1977).

154. Williams, M. K., King, E., and J. Walford, Brit. J. Industr. Med. 26,202(1969).

155. Willis, J. B., Anal. Chem. 34,614(1962).

NEW JERSEY GEOLOGICAL SURVEY

156. Winefordner, J. D., Ed., "Chemical Analysis Series, Vol. 46. Trace Analysis: Spectroscopic Methods for Elements", Wiley-Interscience, New York, 1976.

157. Wixon, B. G. and J. C. Jennett, Environ. Sci. Techn. 9,1128(1975).

158. Wong, M. H. and F. Y. Tam, J. Environ. Health A13,13(1978).

159. Yeager, D. W., Cholak, J., and E. W. Henderson, Envir. Sc. Techn. 5,1020(1971).

160. Zielhuis, R. L., Arch. Environ. Health 23,299(1971).

161. Zurlo, N., Griffini, A. M., and G. Colombo, Anal. Chim. Acta 47,203(1969).

NEW JERSEY GEOLOGICAL SURVEY

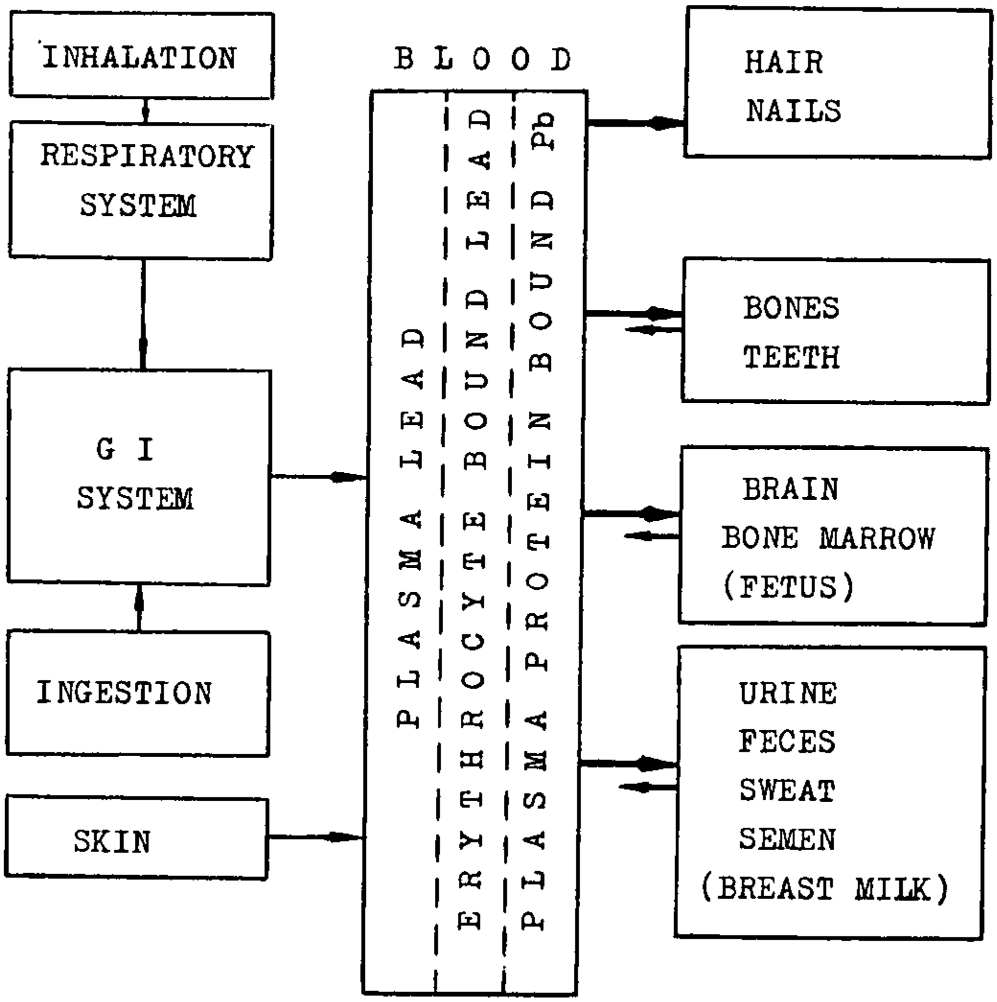

Figure 1. Physiological pathways of lead absorption and excretion.

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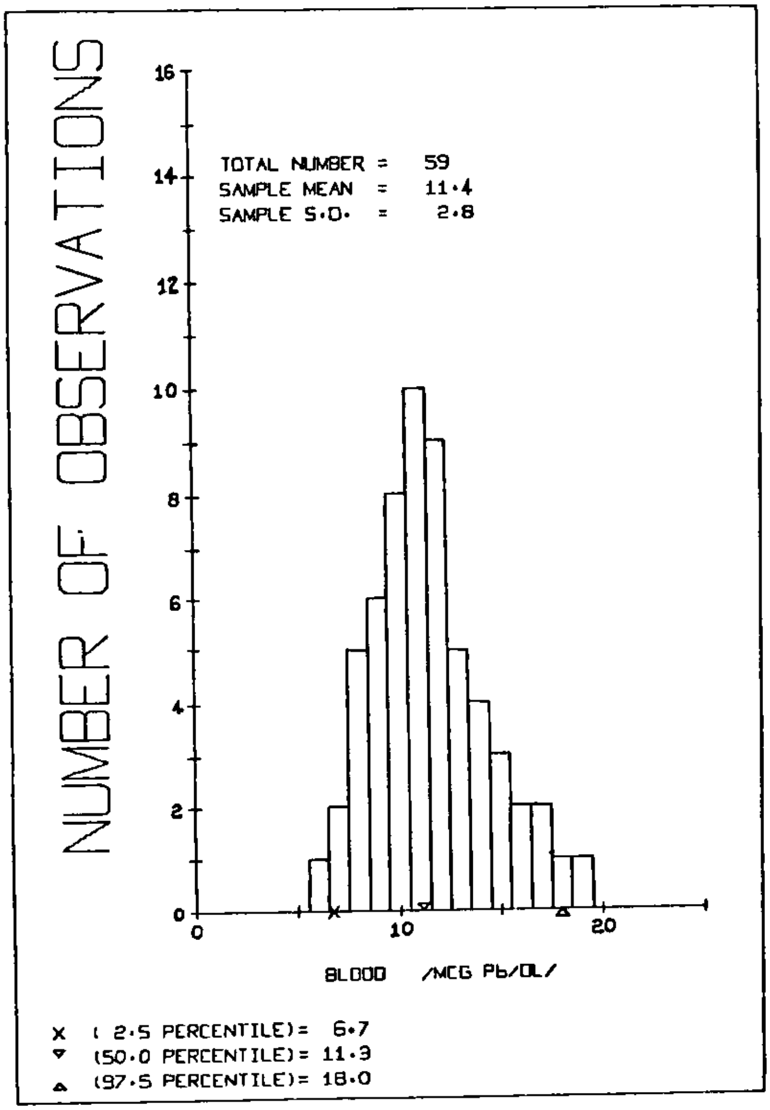

Figure 2. Frequency distribution of lead concentrations in blood of men with no occupational exposure to lead.

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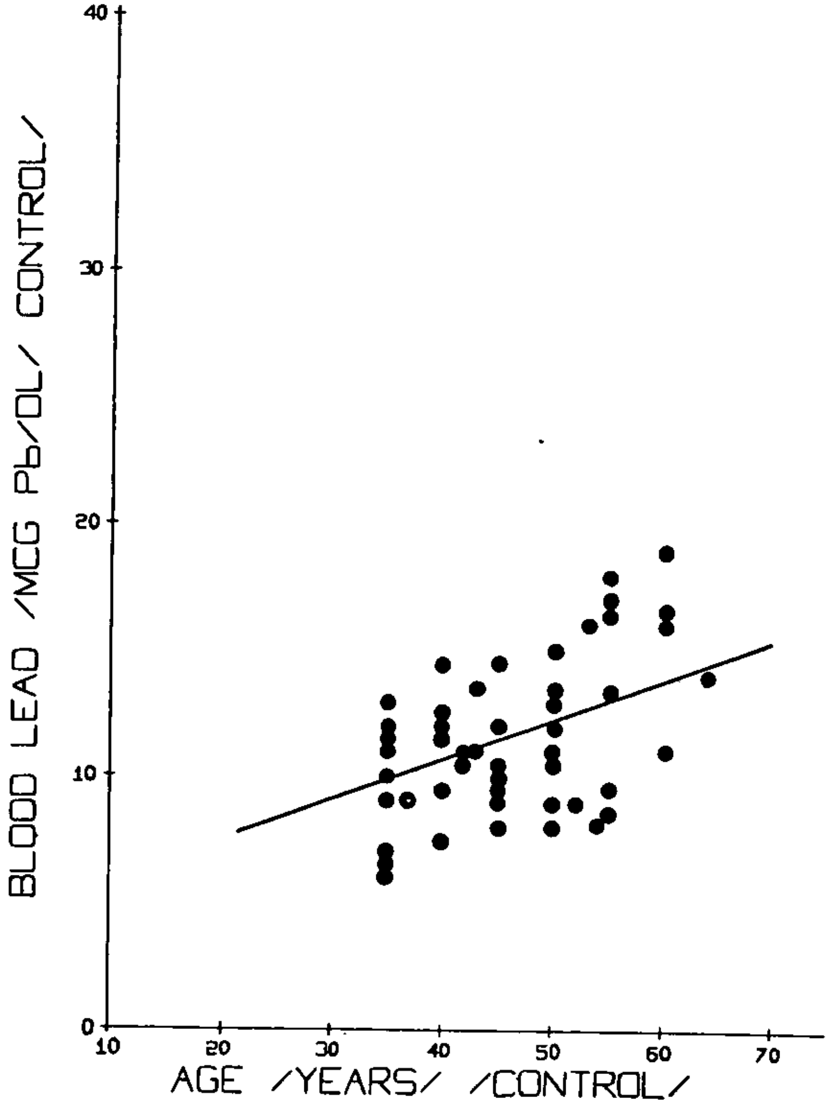

Figure 3. Correlation of blood lead with the age of men without occupational exposure to lead.

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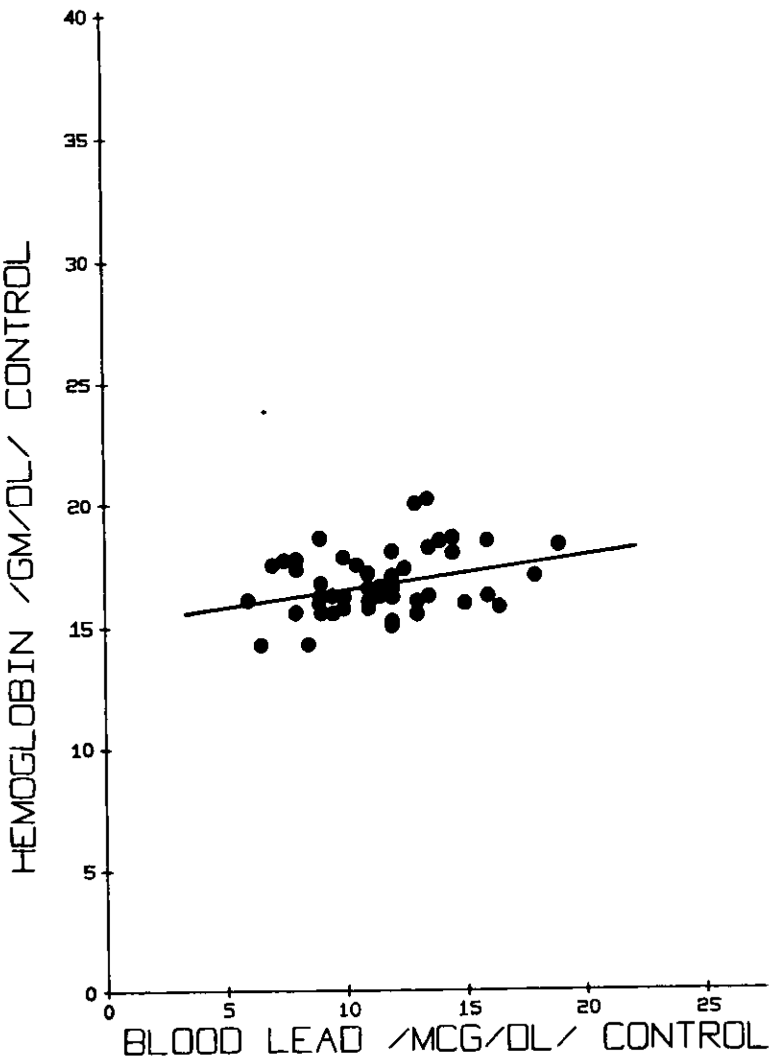

Figure 4. Correlation of blood lead with blood hemoglobin.

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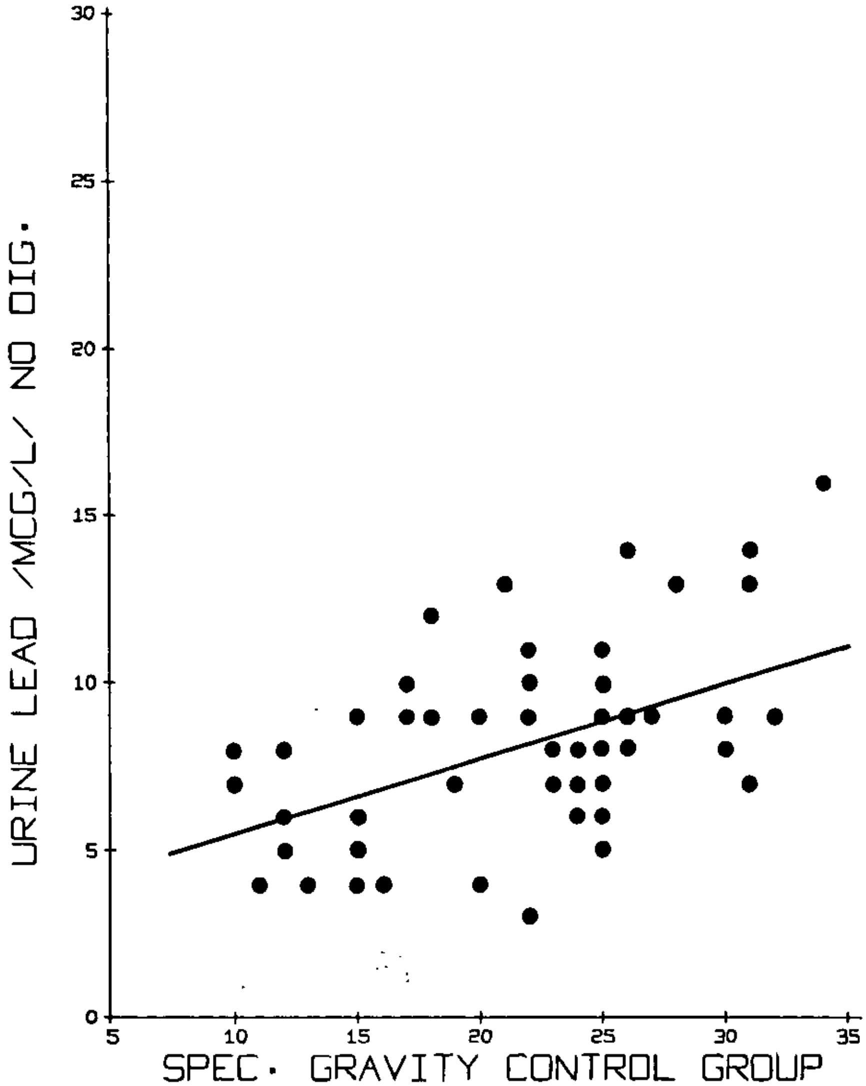

Figure 5. Correlation of urine lead with specific gravity.

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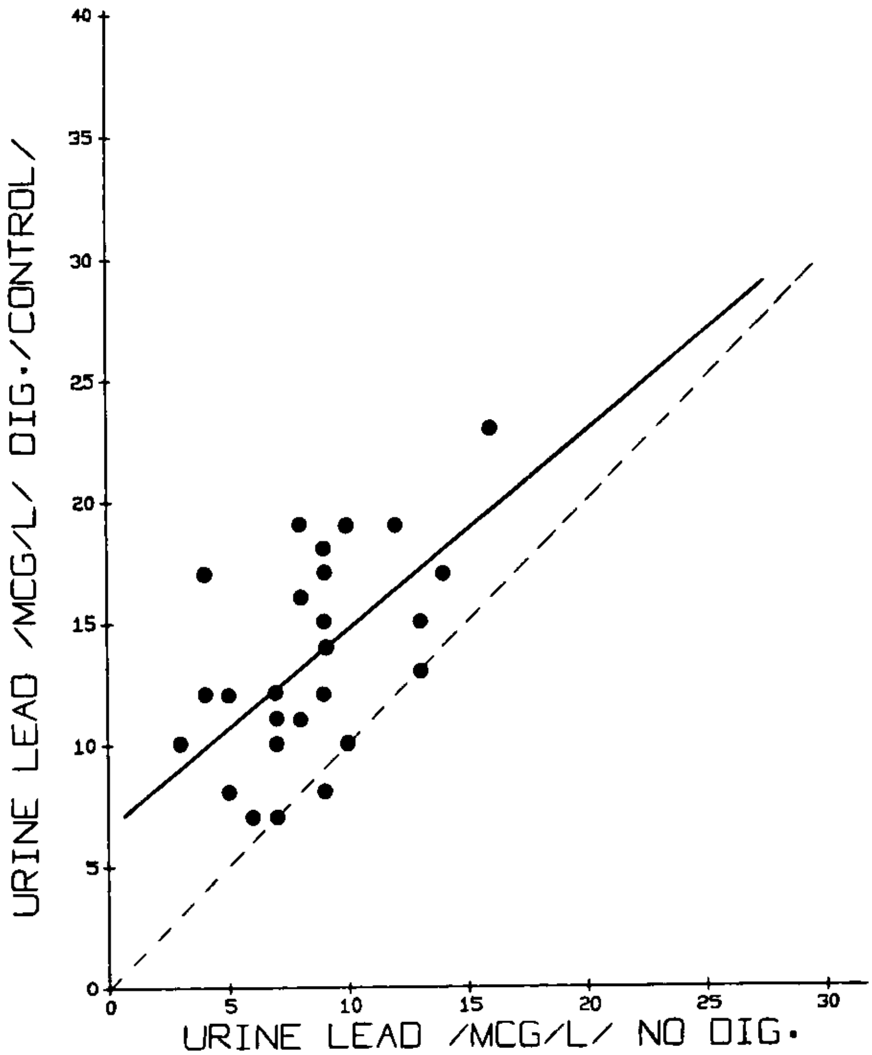

Figure 6. Correlation of urine lead concentrations determined with and without acid digestion.

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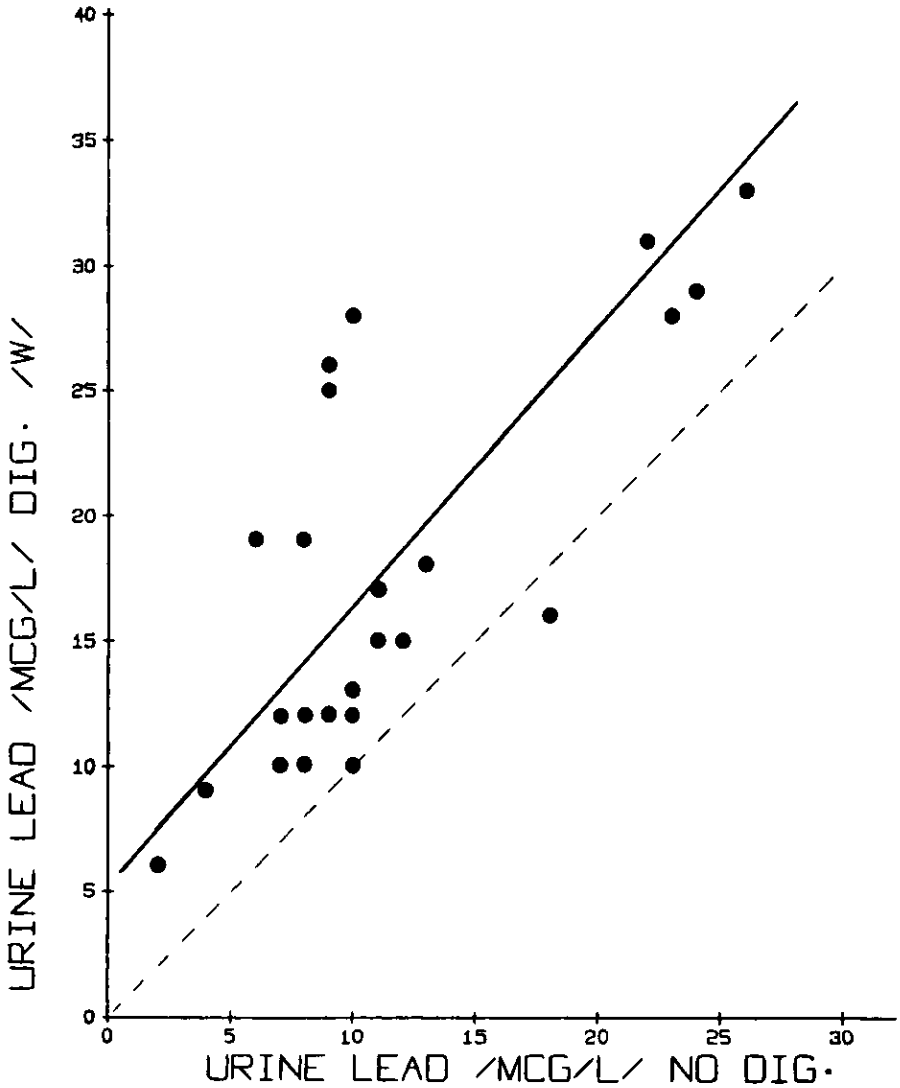

Figure 7. Correlation of urine lead of workers handling inorganic lead determined with and without acid digestion.

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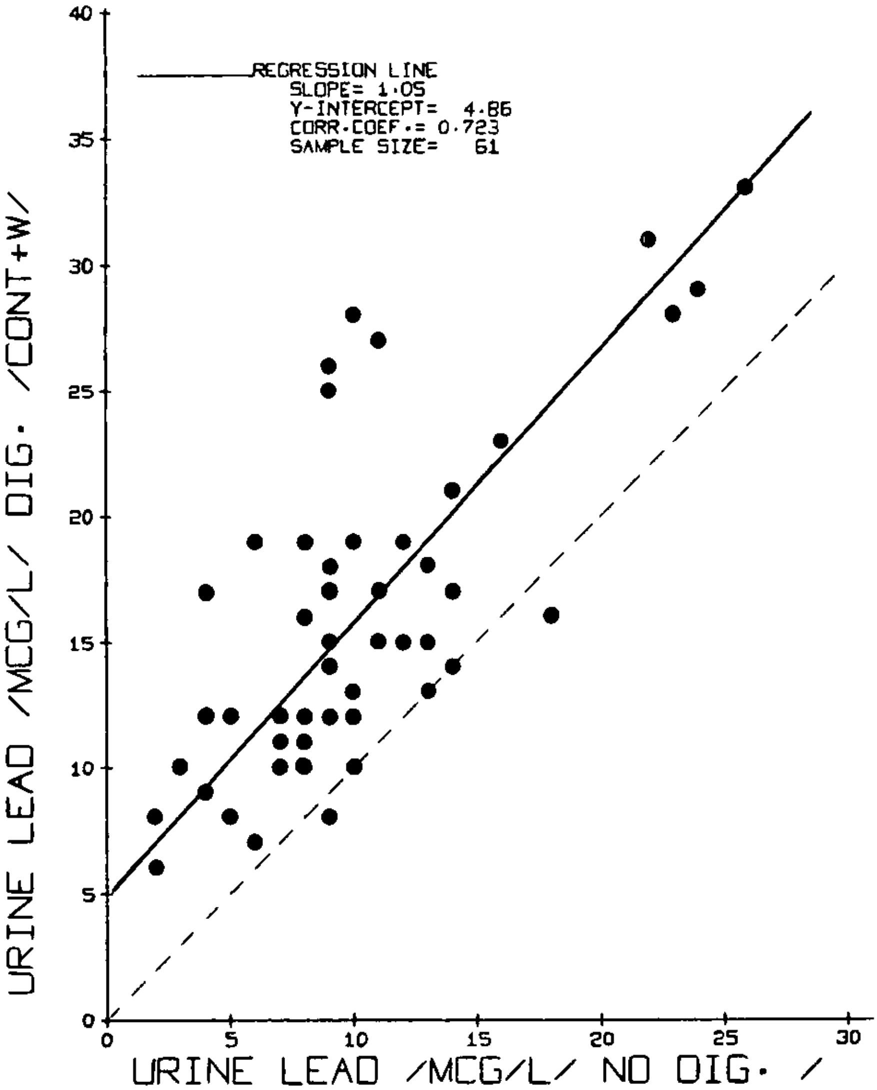

Figure 8. Correlation of combined urine lead concentrations determined with and without acid digestion.

NEW JERSEY GEOLOGICAL SURVEY

NEW JERSEY'S TIDE LANDS MAPPING PROGRAM

by

ROLAND YOUNGHANS, M.S.

The New Jersey Department of Environmental Protection

NEW JERSEY GEOLOGICAL SURVEY

New Jersey's meadowlands are defined as those lands now or formerly consisting chiefly of salt water swamps, meadows, or marshes. The legislature has directed the State's tidelands agency (NRC) to perform the following tasks with regard to meadowlands:

(a) To undertake studies and surveys;

(b) To determine and certify which lands are State-owned;

(c) To publish maps which clearly indicate as State-owned lands those parcels now or formerly flowed by mean high tide.

A program to accomplish these tasks has been developed by and is being implemented on behalf of the NRC by the Department of Environmental Protection's (DEP) Office of Environmental Analysis (OEA). This program draws upon the expertise residing within a wide variety of disciplines, including cartography, photogrammetry, remote sensing, biology, tides and their measurement, statistics, surveying, civil engineering, computer sciences, and the law. It consists of some fourteen (14) major work elements which are by their very nature technically complex. In addition, all work elements are interrelated, and most of them should be undertaken and completed simultaneously so as to maximize efficiency and minimize costs.

Some of the major work tasks associated with the program are described below. These tasks were chosen to demonstrate the costs, complexity, and element interrelationships of the State-wide mapping effort:

(a) Federal certification of the level of mean high tide is nearing completion. Data needed for the determination of mean high tide is being collected at locations extending from near the New York Border, around Cape May, up the Delaware, inland on tidal waterways (saline, semi-saline, and fresh), and terminating at Trenton.

(b) More than 6000 frames of natural color and color infrared aerial photography has been acquired at a cost of $240,000. This photography was collected only at certain times on cloudless days when the elevation of tidal waters were suitable for such purposes (below predicted high tide).

(c) The photography is used to prepare not less than 1500 base maps, each of which encompasses an area of 964 acres. Base maps are essential for delineating claims and for the ultimate mapping of those claims.

(d) Photographs also are used to analyze meadowlands vegetative species having tidal access.

(e) In conjunction with such photographic analyses, extensive field verification studies are performed by trained biologists, engineers, and surveyors to key vegetative photographic signatures relative to establish on-the-ground local mean high tide datums (elevations).

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(f) A substantial number of additional detailed field studies are conducted by trained OEA personnel and consultants to determine if: (1) justification exists for either the transfer or extrapolation of representative photographic keys to areas adjacent to locations where photographic keys have been validated; (2) an existing watercourse is tidal, and, if tidal, the location of the "head of tide."

(g) Historical information, including old maps, tax maps, photographs, charts, surveys, and other pertinent records must be gathered and analyzed in detail for both former and existing claims compilation use. The bulk of such materials reside in municipalities, counties, the various departments of State government, Federal agencies, mosquito commissions, historical societies and in the records of private engineering and land surveying companies.

(h) The final product is a clear plastic stable base overlay keyed to the appropriate base photomap. The overlay depicts graphically those meadowlands areas now or formerly below mean high tide and those areas not claimed by the State. Please note that all analytical and claims depiction work is conducted without the benefit or burden of individual parcel boundaries. This insures an impartial approach.

(i) When an individual parcel must be identified as either State or privately owned, a description becomes necessary. The State employs a computer digitization technique to perform this task. Resulting numerical representations are then used to formulate complicated metes and bounds descriptions and calculate acreages.

All of the above described tasks must be carried out on meadowlands scattered throughout 1.7 million acres of land (35% of the State) located within seventeen (17) of the State's twenty-one (21) counties. "Claimed land" acreage figures within this vast area are unknown. Estimates, however, indicate that tidelands claims can be anticipated on not less than 100,000 acres or on not more than 270,000 acres. The exact location of potential claims is, of course, unknown; exact acreage and location data can be made available only when the program now underway is completed.

One may ask when the work will be terminated. The answer is simple: completion times are dependent upon resources, but it can be completed in 7 years at a cost of about 12.8 million dollars. Funding in excess of optimal yearly needs would not materially hasten the time-table for completion.

Tidelands are dedicated assets of the State School Fund. It is difficult to accurately assess the potential money benefit which could be realized to the School Fund from riparian land transactions because of total acreage uncertainties, changes in fair market valuations, and other considerations. Estimates show, however, that the potential monetary value of State-owned meadowland is not less than 234 million dollars and could be substantially in excess of that amount. This potential return appreciably exceeds the costs associated with the State's mapping program.

In addition to monetary considerations, the State and its citizens can reap other benefits, among which are:

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(a) Enhancement of State land acquisition negotiations;

(b) Freeing of lands from cloud on title;

(c) Stimulate orderly development and reduce development costs;

(d) Strengthening of regulatory and enforcement efforts;

(e) Establish ownership certainty and eliminate title insurance uncertainties.

Maps and claims overlays prepared in accord with N.J.S.A. 13:1B-13.1 et seq. and O'Neill v. State Highway Department, 50 N.J. 307 (1967) have been challenged in City of Newark et al. v. Natural Resource Council in the Department of Environmental Protection, et als., Cal. No. 98-0067, Appellate Docket A-3311-73. The action was commenced in the Appellate Division and remanded to the Law Division of the Superior Court, Bergen County, to create an adequate administrative record and for proposed findings of fact and conclusions of law on the part of the trial judge. The core issue presented in this appeal is whether or not the NRC reasonably complied with the legislative mandate of the statute. Note that this action was not a quiet title suit. The conclusions of the trial court relevant to these proceedings follow:

(a) The State's maps reasonably complied with the requirements of N.J.S.A. 13:1B-13.3;
(b) Base photo maps with claims overlays are maps within the meaning of N.J.S.A. 13:1B-13.4 and O'Neill; and,
(c) There is sufficient credible evidence in the record of the administrative agency to support the selection and application of the particular methodology here employed in stating claims to meadowlands and in the claims themselves as evidenced by the maps here questioned.

SUMMARY

Coastal mapping programs are undertaken for a wide variety of purposes, including planning, land-use regulation, and parcel ownership requirements. Mapping detail, scale, and accuracy are functions of a coastal mapping program's purpose, legislative or regulatory directives, and the potential for litigation; hence, generally applicable technical and realistic time and costs guidelines for the structuring of all such programs cannot be formulated. If a mapping effort fulfills a legitimate purpose or need and reasonably meets all legal requirements and challenges, then the work is successful, and the time and money spent to achieve the purpose is justified.

NEW JERSEY GEOLOGICAL SURVEY

THE MEAN HIGH WATER LINE: INSIGHT TO LAW, SCIENCE AND TECHNOLOGY

by

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NEW JERSEY GEOLOGICAL SURVEY

I. INTRODUCTION TO A CREATIVE INSIGHT

To the lawyer it is a fiction! To the scientist it is a phenomena! To the technological human it is precision. To all it carries a label known as the mean high water line. To society it has varying impacts depending upon the context in which it surfaces and the interpreter's scope background. To us here this seminar will serve as an experience to a new insight. The insight raising us all, regardless of our profession or calling, to a new horizon in the realm of understanding the crossroads of the worlds of law, science and technology. Hopefully, this insight will stimulate continuing process of com- munication and education.

In this age of complex scientific and technological progress a maze of overburdening legal regulation has been born. Fortunately, many times communications stream between the worlds of law, science and technology is dry and without flow. Yet society demands on a daily basis specific determinations. The world of science and technology through its research and development gives birth to a nuclear generated plant at the Three Mile Island. It is responding to society's energy crisis. The law responds through its structure of the Nuclear Regulatory Commission and a network of other agencies and regulations. A threat of disaster demonstrates notable weakness in the link. A failure of effective communication and joint execution. After the experience the same process, on a new horizon commences. The decision makers in respective areas of challenge are called upon to reconcile dialectic interests, doctrines and opinions. Ultimately a new commitment must be made. So it is with the model of this seminar.

The broad solution lies in the methodology by which one chooses to discover the truth. To choose the theory of jurisprudence, scientific method or the analysis of technology to reach this point will result in same basic dialectic. For each is born and developed in a different world of academia, totally different set of experiences and distinct separate frames of reference. An interface which will jell mutual input of each is needed. A task of an extreme transcendental nature. A Jesuit theologian, Bernard J. R. Lonergan, S.J., provides a pivotal method for the task. He suggests a dynamic continuing process at point of inquiry to insight. The method which emanates from the pinnacle of man's understanding, i.e., self-appropriation. For essential stages for this consciousness must be developed. They are: experience, understanding, judging and deciding.[1] Within these four dimensions a creative insight can be obtained relative to relationship of law, science and technology with regard to the mean high water line.

II. THE INVISIBLE BOUNDARY

In the last two decades much attention has been placed upon controversial coastal areas of this country. Many segments of society have competed for their ownership and use. It is in this area that the environmental interests have warned of needed conservation. Here industry and commercial ventures have sought to utilize its harbors, waters and adjoining land surfaces. It is also here that a center for recreation and leisure has sought to expand its activity. In this atmosphere many professions have been presented with complex problems.

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First in the line of challenges is the issue of ownership. Who is it that shall be vested with the title to the various areas of water and land as they intersect and invade each other. The jurisprudence covering this issue is one rooted in centuries of doctrine. An invisible boundary known as the mean high water line is the crucial legal fiction. For it is this boundary that separates the sovereign interest and private property rights. The doctrine is clear: its application a tidy mess. It can be traced to early Roman origins, through its modifications under the English law and early treatment by the various state and federal courts in the United States. Historically the King, had, and now the various sovereign states maintain a title interest in tidal areas. This sovereign interest is held as a trustee for the public.[2] All lands that are touched by the ebb and flow of the tide lying below the mean high tide line the water course or coastal shore for centuries has been deemed to be vested in the sovereign. The legal doctrine emerged from the ancient concept that the King had the right of way, and incorporeal hereditament to all navigable streams and water ways. The theory underlying this doctrine was the protection of the public interest in fishery and navigation. The first famous case on this subject in the United States is that of Martin v. Waddell's Lessee.[3] This title interest exists regardless of the fact that record deed ownership approximately three centuries can be traced in most of the original colonies back to the initial King's grants.[4]

Some states have held that the navigability of the water course is material so long as the water course is ebbed and flowed by the tide.[5] In other states the doctrine has been abandoned. For many decades the Courts restricted the application of the doctrine to areas within the boundaries of the watercourses, such as oyster beds, waterfront areas.[6] However, in the past few decades, as the world of science demanded protection of the marshland areas the doctrine has been greatly broadened. It now applies to highly vegetated estuarine areas that are only periodically inundated by tides. In these areas of merging water and land beyond the shore and water course the invisible boundary has become a vexing problem to the world of law.[7]

The mean high water line as decreed by many courts is the intersection of the land with the water surface at the elevation of mean high water. In the case of O'Neill v. State Highway Department,[8] is a typical example of the clarity of the legal decree. The Court stated:

> "The State owns in fee simple all lands that are flowed by the tide up to the high-water line or mark. The high water line or mark is the line formed by the intersection of the tidal plane of mean high water of mean high tide with the shore."

Left with this apparently uncomplicated rule, the lawyer must enter into the proof problem. The simple task of establishing and demarcating that boundary is where he must seek the the aid of the scientific and technological expert. The first stage of this experience is disarming. For the scientist comes from a perspective of the phenomena of the tide as it is affected by the lunar cycle. Phenomena is known in terms of impacts upon plant, animal life and in terms of very special environmental atmosphere. The geologist reflects the unique nature of the soils and peat in the areas. The marine biologist discloses a unique life cycle of various habitats and vegetation. The world

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of technology brings yet another perspective. Here mean high water is found to be a tidal datum that is the arithmetic mean of the high water heights observed over a specific nineteen year metonic cycle (The National Tidal Datum Epoch). Only the higher high water of each pair of high waters of a tidal day is included in the mean. Tidal stations of various degrees of accuracy can measure the vertical aspect. The horizontal precision of the surveyor will combine this place the line in question underground or on a legal document.[9]

When combined three approaches can either be found on a collision course or a high level of interfacing.

Ultimately a decision-a committment-must be reached. However, before that the tortuous process of research leads to understanding and analysis leads to judging.

III. THE PROCESS OF UNDERSTANDING AND JUDGING

The combination of law, science, and technology in the stage of understanding and judging will provide some interesting insights. Due to the comparative success of utilizing remote sensing aerial photography in a botanical approach to wet land management stemmed some to a conclusion that the mean high water line could be established by the same methodology in the marsh. Although plant figure may be an important parameter of the ecological health of vegetation in the marsh, it takes a completely different challenge, legally, when attempted to be utilized to establish a title boundary. Recently, the New York Court of Appeals in 289 Dolphin Lane Associates v. The Township of South Hampton[10] refused to accept an alleged vegetation line even though the Court stated that this "New Technology" may be "intellectually fascinating." Basically the Court reviewed the approach as being scientifically contested. However, the adjoining state of New Jersey, representatives of the Department of Environmental Protection working in concert with a commercial scientific company developed a controversial claim of ownership to marsh lands by a biological approach. Infra-red photography was taken throughout the area of the state followed by a process of aerial interpretation of signature tones to establish various vegetation types. In the area in question, the Hackensack Meadowlands, prime species found was a plant known as Phragmites. Within the species, the state attempted to establish color tones and relate them to relative tidal inundation. It was then alleged through their process of research and understanding that a biological line could be established for purposes of title delineation. A botanical delineation was judged and committed to. It was documented in a report entitled "Hackensack Meadowlands Botanical Delineation Program, Final Report."[11] This approach has been the subject of extended litigation.[12]

On the other hand well established segments of the world of technology and many scientists alike came forth to refute this scientific contribution. The effort of all is geared to the truth. In the initial stages it appeared as if conventional surveying techniques, rooted in decades of application remain unaffected by the new scientific challenge.[13] However, as a general economic consideration the technique has begun to gain creditability. The question of accuracy between this new scientific method as compared to technological methodology still remain heavy controversy. Query: could the

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technique be a valid legal tool for purposes of broad application but yet rebuttable for more specific purposes? That is to say a broad general mapping purposes be upheld but when challenged on a specific piece of property by a mean high water line drawn by conventional surveying techniques disputed.

The utopia at this stage of understanding and judging should come from a jelling of the experiences of law, science, and technology. A serious communication gap must be faced. Yet the reality of the presence of science and technology in law is no better appreciated than in the contemporary court room, administrative proceeding or legislative corridor. In this context the research-understanding stage should resolve in a combined judging progression. It is important that this progression be done as a combination of fields in question.

IV. A COMBINED JUDGMENT

The location of the mean high water line on a particular piece of property should be the combined judgment of all disciplines involved, each coming from its proper perspective. The legal requirement ironically can be best served by a combination of the disciplines. Great experience and success of surveying and mapping is essential since it cuts to the core of the truth attempted, i.e. the demarcation of a specific legal boundary. The field of photogrammetry, hydrology, engineering, biology, botany, geology, computer modeling and statistics are all relevant. Remote sensing can make its contribution.[14] Hydrologic modeling of the particular water basin in question is helpful. Valuable aid can be obtained from the biological and environmental disclosures. Of course, the tidal datum of the National Ocean Survey is of the essence of the problem. Ultimately the statistical analysis of each approach separately and jointly can be performed. Here the statistician serve as a tremendous tool in verifying the accuracy obtained by the various approaches. Yet it must be realized that the process is not for the purpose of usurping the function of the Court, administrative agency or legislature but rather for the purpose of aiding that judgment which will ultimately result in a committment.

The bridge to committment must be a cautious combined effort. The ultimate insight and decision must be deep and well judged. It cannot be oblivious to the fallacies and weaknesses in the scientific theories and experimentation presented, nor can it ignore the tolerances of the gages and equipment of the technician. Yet, when each is utilized in conjunction with the other the ultimate insight should be as close to the truth as is capable by any group of humans.

Experience in the location of a mean high water line through the stages of understanding and judging reveals an essential point. There is no discipline involved that is without difficulty. Whether the matter involves the establishment of title boundaries or environmental mapping, the nature of the estuarine area is such that it demands the attention of many disciplines. Thus, the world of the lawyer, surveyor, botanist, ecologist, hydrologist, statistician, photogrammetrist and other fields are brought together at this crossroad. However when one commits this combined approach a new effort is still necessary. This new effort is toward furtherance of individual perfection combined with the bridge of communication.

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V. COMMITMENT TO INDIVIDUAL PERFECTION AND COMBINED COMMUNICATION

The whole process is demonstrated by the attempt to locate the mean high water line is an exciting experience for all who come in contact with it. After the ultimate decision is rendered the process must commence again. A new experience and new questions surface as a result of reaching the committment horizon. Better questions can now be asked and more extensive research com- menced leading to new understanding judgments. Ultimately the higher horizon of insight will be reached. And so the process must continue.

However, this process is demanding indeed upon the individuals, professions and groups involved. There is a deep responsibility to endeavor to strive for continual advancement of individual qualifications and refinement of the tools of the calling. The coastal mapper must recognize serious deficiency in the lack of density in the present geodetic net work.[15] Efforts must be made to improve and densify system. The state of the art must be refined to account for vertical as well as the horizontal aspects of delineating this boundary. Equipment upgrading must be maximized. Stress of specifications and accuracy standards of the Geodetic Control Survey must be incorporated.

Likewise, the scientist must strive to move its conclusions out of the area of speculation. The demands of scientific methodology must be met and advanced. The pitfalls of attempting to convert a scientific conclusion into technical or legal determination must be recognized.

The lawyer, scientist and technological contributor must each individually advance their level of qualification through further education and experience. The institutions of each discipline will then be prepared to take the challenge of effective communication with the others. This communication must first be rooted in that discipline's own academic atmosphere. The contemporary law school throughout the country must dedicate more and more courses and seminars dealing with scientific and technical topics. Today, unlike a decade ago law school catalogues will reflect such courses as "Computers and the Law, Law and Biology, Technology, Computer Highest Legal Research, Law and Medicine, Legal Process and Technological Change, Sociology of Law, Environmental Law*** it's really happening.[16] An evaluation process is now occurring: "From the legal perspective, the scientist contributions can be seen as primarily one of establishing facts: The ones necessary to generate public policy (legislative facts), and the ones necessary to implement policy (adjudicative facts)***. What is needed is an examination of all courses to determine whether they are helpful in preparing tomorrow's lawyer to marshall facts and grasp technological vocabulary in context. ***Only with exposure to the commonalities and differences of various disciplines can tomorrow's lawyers be prepared to meet the growing number of diverse problems which demand solution".[17]

Commitment by all disciplines to this end with a continuing process as described by Rev. Lonergan will result in a new interface for law, science and technology. The mean high water line, the model utilized, will come closer to being the truth.

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FOOTNOTES

1. Lonergan, Bernard, J.R., S.J., Method of Theology, Herder and Herder, New York (1972) and Insight a Study of Human Understanding, Philosophical Library, New York (1957), Liddy, Richard M. Lonergan's Method, American p. 68, Aug. 5, 1972.

2. Porro, Alfred A., Jr., Confluence of Science and Law: Estuarine Zone, University of Georgia, Georgia Marine Extension Center Workshop, April 12-14, 1977.

3. 16 Pet. 367, 41 U.S. 346, 10 L. Ed. 997 (1842); See extensive historical discussion in Arnold v. Mundy, 6 NJL Sup. Ct. (1821) and Gough v. Bell, 23 NJL 670 (1852).

4. Abbott, Some Legal Problems Involved in Saving Georgia's Marshes, Georgia State Bar Journal, at p. 28 (Aug. 1970); Leaming and Spicer, Grants and Concessions of New Jersey 1664-1703 (1881); Vol. I New Jersey Archives, Documents Relating to Colonial History of the State, 1631 1687, (1880); Vol. III Kents Commentaries, Supra., p. 607.

5. Shaltz v. Wilson, 44 N.J. Super. 591, 131 A.2d 415 (App. Div.), Cert. denied, 24 N.J. 546, 133 A.2d 395 (1957).

6. Shively v. Bowlby, 152 U.S. 1 (1894)

7. Porro, Invisible Boundary Private and Sovereign Marshland Interests, 3 Natural Res. Law. 512 (1970).

8. 50 N.J. 307, 235 A.2d 1 (1967)

9. Coastal Mapping Handbook, U.S. Department of the Interior, Geological Survey and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (1978).

10. Porro, Alfred A., Jr. and Weidener, James P., L.S., P.P. The Mean High Water Line: Biological vs. Conventional Methods The New Jersey Experience, 1978 ACSM-ASP Annual Spring Convention, February 26-March 4, 1978, Washington, D.C.

11. Prepared for State of New Jersey by Earth Satellite Corp. Sept. 1973.

12. City of Newark, et al. v. Natural Resource Council, et al. and New Jersey Sports and Exposition Authority v. Borough of East Rutherford.

13. New Jersey Sports and Exposition Authority v. Mario Greenberg Parker, Case 5 in Bergen County Court, Hackensack, N.J., 1974-1979.

14. Latin, Howard A., Tannehill, Gary W. and White, Robert E., Remote Sensing Evidence and Environmental Law, 64 Calif. L. Rev. 1359, 1364, 1368 and 1370 (1976); Osterhoudt, William L., Remote Identification by Forward-Looking Infrared: A New Scientific Challenge, Legal Notes and Viewpoints Practicing Law Institute, July 15, 1977.

NEW JERSEY GEOLOGICAL SURVEY

15. Halasi-Kun, G.J., The Geodetic Survey in New Jersey, ACSM Bulletin American Congress on Surveying and Mapping, Volume 52, Nov. 1977.

16. Issue Dedicated to Jurimetrics in Education, 16 Jurimetrics Journal, p. 71-73 (Winter 1975).

17. Field, Thomas G., Training Lawyers to Cope with Science, The Profession Can No longer Afford to Hide From What It Doesn't Know, Learning and the Law, Section of Legal Education and Admissions, American Bar Association p. 31 (Fall 1977).

NEW JERSEY GEOLOGICAL SURVEY

STATUS OF TIDAL SURVEYING AND MONUMENTS IN NEW JERSEY - 1979

by

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NEW JERSEY GEOLOGICAL SURVEY

INTRODUCTION

The Wetlands Mapping Program implemented provisions of the New Jersey Wetlands Act of 1970, the purpose of which is to protect wetlands by regulating the use of private property. The Act authorizes the Department of Environmental Protection to inventory and map certain tidal wetlands within the state and to adopt orders regulating activities which alter or pollute coastal wetlands. Wetlands are defined in the Act as "any bank, marsh, swamp, meadow, flat or lowland subject to tidal action along any inlet, estuary, or tributary waterway including those areas now or formerly connected to tidal waters whose surface is at or below an elevation of one foot above local extreme high water...".

The program of tidal land mapping is interdisciplinary. Mapping of saline wetlands were obtained by aerial photos on Kodak Aerochrom Infrared 2443 film at an altitude of 1800m fitted to existing triangulation of The New Jersey Geodetic Control Survey. The tidal wetland delineation is by mapping the plant species of the area demanding saline water. The survey is achieved by 7 species having high frequency in saline water. An additional 22 species were used which are typical for fresh-brackish wetlands. Each delineated area was defined as having an aerial extent of 2 or more hectares. Delineated categories representing associations were designated to species which covered 25% or more of the unit delineated. More than 6000 frames of natural color and color infrared aerial photography has been acquired at a cost of $240,000.

Besides the vegetation, topographic characteristics, soil conditions and tidal gauging stations (over one thousand) were also applied as indicators of the tidal area. Estimates, according to Yunghans, indicate that tidelands claims as state property can be anticipated on not less than 40,000 hectares or on not more than 110,000 hectares. The exact location of potential claims is unknown; it will be available only when the program now underway is completed.

Further, I will describe only the traditional surveying and its monuments available in the tidal land, because of the complexity of the program and because the tidal land delineation also requires the identification of the sea level (one foot above local extreme high water).

U. S. NATIONAL GEODETIC SURVEY TIDAL BENCH MARK DATA FOR NEW JERSEY

First-order control leveling was begun in 1878 to provide elevation control for trigonometric leveling. As additional level lines became available and connections to tidal stations increased in number, various adjustments of the level net were required.

The first level net adjustment occurred in 1899 and was followed by partial adjustment in 1903, 1907 and 1912. Mean sea level at the Sandy Hook, New Jersey tide station was the datum for bench mark elevations. References to the "Sandy Hook Datum" still persist, despite the fact that it was superseded by the readjustment of 1927 of the whole United States and by the 1929 General Adjustment combining the level nets of the United States and

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Canada. The 1929 General Adjustment was computed by holding sea level fixed as observed at twenty-one tide stations in the United States and five in Canada. The resulting datum from which all elevations in the adjustment are based is referred to as the Sea Level Datum of 1929 and since 1977 the National Geodetic Vertical Datum of 1929 in accordance with the Federal Register, Volume 41; No. 96 - page 20202 of 17 May 1977. This latest change in name became necessary because it did not reflect the local tidal elevation.

U. S. National Geodetic Survey, together with N. J. Geodetic Control Survey, installed and is maintaining 98 tidal bench marks along the Atlantic Ocean, Delaware, Raritan, Passaic and Hudson Rivers including tributaries from Alpine on the Hudson to Trenton on the Delaware. Elevations of these tidal bench marks are given by the difference of sea-level datum of the National Geodetic Vertical Datum of 1929 and "mean low water" for each location. All these stations are tied into the National Geodetic Network.

The "Sea Level Datum of 1929" is believed by many surveyors and the general public to be the exact surface elevation of a "quiet sea." This definition is not accurate when discussing precise elevations or differences in elevation over large areas of the earth. A more appropriate definition for an elevation or height above (or below) sea level would be "the vertical distance a unit mass moves from the reference equipotential surface to another equipotential surface." It is a known fact that the "vertical distance" between any two different equipotential surfaces varies as we move on the earth, due to the unequal distribution of the earth's mass.

For years the reference equipotential surface was the surface of a "quiet sea." Based on astronomical and geophysical phenomena, approximately 18.6 years of observations are required to obtain the surface of quiet sea (or mean sea-level or Sea Level Datum of 1929). Since 1929, most federal, state, county, and municipal agencies have published elevations based on this elevation datum and require to use them.

In recent years geodesists and oceanographers have studied the differences in the mean sea level determined by precise leveling and compared with local sea level gauge observations. The studies have indicated an observable difference between the sea level leveling datum and the oceanographer's sea level datum, which could not be accounted for as errors in observations. These studies led to change the "Sea Level Datum of 1929" to "National Geodetic Vertical Datum of 1929" in 1977.

To comply with the above observations of the geodesists and oceanographers, additional adjustment of the Sea Level Datum is planned by 1985 when not only new adjustment will be computed but also all the values will be given in metric system.

U. S. NATIONAL OCEAN SURVEY - LOCAL TIDAL BENCH MARKS IN NEW JERSEY BASED ON LOCAL TIDAL OBSERVATION

For accuracy of local sea-level datum and tidal water elevation, over one thousand local tidal bench marks have been installed along the coast of New Jersey in two hundred forty locations from 1975 to 1978. In all locations the bench marks were installed in groups consisting of 4 to 5 tidal gauge

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stations. The installation was authorized by NJSA Chapter 404, Laws of 1968, Title 13:1b-13.1 et seq. to undertake title studies and surveys of meadowlands to determine and certify those lands which are state owned. These studies and surveys are performed by the Office of Environmental Analysis of the N. J. Dept. of Environmental Protection for the Natural Resource Council and depend upon tide elevations derived from local tidal observations.

The installation and operation of tide gauges and local tidal bench marks were contracted to Coast Survey Ltd. (a geodetic survey company recruiting its personnel mainly from retired personnel of the National Ocean Survey and National Geodetic Survey). The installation of the stations conforms with the specification of National Ocean Survey (NOS). These observed data are determined and the relative local tidal elevations are certified by NOS. However, the contract did not call for establishing elevations of the tidal bench marks in conformity with the National Geodetic Network. Therefore, the relative elevation of the tidal water level to the tidal bench mark is given individually without any reference to the geodetic network. To remedy this deficiency, it is planned in the Program that the N. J. Geodetic Control Survey will tie-in these bench marks into the national network system at a later date.

The present installation reports identify each station by name and number with a description. The NOS tidal datum certifications are related to the bench marks. They also identify the months of tidal records and control tide stations used to compute the datum. These local tidal bench marks, when used, must be tied into the National Geodetic Survey's or N.J.G.C.S.'s network by a N. J. licensed surveyor in each location individually to obtain the customary elevation used by the U. S. National Geodetic Survey.

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REFERENCES

(1) Barker, H., Mapping digest for New Jersey, Bulletin 66, N. J. Bureau of Geology and Topography, Trenton, N. J., 1965.

(2) Brown, A., Wetlands Mapping in New Jersey and New York, Proceedings of the American Society of Photogrammetry, Washington, D.C., 1977.

(3) Federal Register (Volume 41; No. 96; page 20202) of 17 May 1977, National Vertical Control Net (1977).

(4) Halasi-Kun, G. J., "Land Oriented Water Resources Data System in New Jersey", Environmental Management: Land and Water Resources Policy, New Brunswick: Rutgers University, Cook College, Dept. of Environmental Resources, 1978.

(5) Halasi-Kun, G. J. et al, Proceedings of University Seminars on Pollution and Water Resources, Volume X 1975-1978 (Selected Papers on Geodetic Survey) - Bulletin 75D, N. J. Bureau of Geology and Topography, Trenton, N. J., 1979.

(6) Yunghans, R., New Jersey's Tide Lands Mapping Program, 1979 (Manuscript).

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MEDIUM-TERM FORECASTING OF HYDRO-ELECTRIC ENERGY INFLOWS

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NEW JERSEY GEOLOGICAL SURVEY

MEDIUM TERM FORECASTING OF HYDRO-ELECTRIC ENERGY INFLOWS

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1. THE PORTUGUESE ELECTRIC POWER GENERATING SYSTEM

Nowadays, the population of Portugal is about 9 million inhabitants and the annual production of electric energy in 1978 was equal to 13819 Gwh with a contribution of 10555 Gwh coming from hydro-electric plants (76%).

The configuration of this electric power system is presented in Table 1 and the location of the rivers with hydro-electric plants is given in Figure 1.

Therefore, the hydro-electric power sub-system is very important and the management of the electric utility implies a great effort of analysis to model and to control the stochastic hydro-electric energy inflows.

2. THE HYDRO-ELECTRIC ENERGY INFLOWS

The electric energy that can be produced by an hydro-electric plant using a given runoff inflow can be computed assuming a load duration curve and the usual operation rules. The obtained monthly energy inflows for a sample of 42 hydrologic years (1 Oct. - 30 Sept.) are presented in Tables 2 and 3 for the set of plants with reservoirs (system A) and for the set of run-of-river plants (system B). The estimates of monthly means & standard deviations and the annual estimates of monthly correlograms and skewness coefficients are presented in Table 4 and Figures 2 & 3. From these results several conclusions can be obtained:

- The inter-annual variability of energy inflows is large for both systems and particularly high for A:

  C_V= 1.25 and 0.41 for A and B, respectively.

- The distribution of the energy inflow over the 12 months is far from uniform (specially for system B):

	A	B
max m_τ	608.2	729.0
min m_τ	14.8	320.6

- The coefficient of variation for monthly inflows is also rather high (Figures 4 & 5), particularly for plants with reservoirs:

	A	B
max CV	1.25	0.41
min CV	0.65	0.26

- The monthly distribution of the annual inflow is also highly variable:

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τ		1	2	3	4	5	6	7	8	9	10	11	12
N.º of	A	1	3	9	9	9	11	0	0	0	0	0	0
max X_τ	B	0	3	7	7	3	13	5	4	1	0	0	0
N.º of	A	3	0	0	0	0	0	0	0	0	2	31	6
min X_τ	B	4	2	1	0	0	0	0	0	6	2	19	9

- The symmetry hypothesis is not rejected for B but A inflows are significantly skewed ($\sqrt{\beta_1} = 1.94$)
- Monthly inflows are strongly autocorrelated and as it could be expected the periodicity is dominated by the 12-month period component (Figures 2 & 3).

3. ON THE MANAGEMENT OF AN ELECTRIC POWER SYSTEM

The load factor is a time-varying parameter and it is expressed as a function of the corresponding duration of occurrence by the load duration curve (Figure 6) where the peak/intermediate and base loads have to be met by the hydro-electric plants and thermal power systems, respectively.

Therefore, the management of the electric power system implies:

a) A short-term dispatch of the generating units in order to satisfy the load curve (usually a weekly load cycle curve is used with this purpose) with minimum costs assuming that the demand and the usable inflows are known.

b) A medium-term analysis of future electric energy demand and available energy inflows with the objective of optimizing the transfers on time of stored inflows in order to use that stock when its value is maximized.

The first analysis is usually known as the "dispatching problem" and it is based on the most recent information available about the load and generators states as well as data or short-term predictions about the inflows. Several methods have been developed with this purpose and recent advances have been obtained with the development and implementation of optimization algorithms, (1) & (2).

Unfortunately similar progresses have not been taking place in the medium-term analysis because the uncertainty is now a much more important factor and the prediction methods have been just developed for short-term analyses.

However, this second problem is extremely important for electric power systems with an important sub-system of hydro-electric plants with reservoirs and highly seasonal variable inflows as it is the case of the Portuguese systems because great economies can be achieved by a better use of the available water.

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The main objective of the medium-term planning is defining a strategy for using or storing water in order to avoid spills, to guarantee minimal stocks at dry periods and to maximize the value produced by the available inflows. Guide rules have to be obtained from this analysis to be used as operational restrictions to solve the short-term dispatching problem, i.e., the amount of stored water that can be used at each period (usually with a duration not greater than 1 month and not smaller than 1 day) has to be determined as a function of the present level of stock and the future inflows and energy demand.

The decision of keeping or using an extra m^3 of stored water should be based on the famous economic principle of marginal analysis which implies the comparison of the value produced by that water, ΔU_t with the expected value associated to it if it is kept in storage, ΔV_t. ΔU_t can be easily estimated as the marginal cost of power production by the alternative generators at time t but ΔV_t implies the modelling of the future uncertainty factors as well as a set of operating rules and therefore it is a much more debatable estimate:

$$\Delta V_t = 0.p_1 + \int_{\tau=t+1}^{\infty} \{\alpha^{(\tau-t)} \int_{C_\tau=0}^{C_\tau=T_\tau} \int_{T_\tau=0}^{T_\tau=\max T_\tau} \Delta U_\tau [C_\tau, T_\tau] f(C_\tau, T_\tau) dC_\tau dT_\tau \} g(\tau) d\tau + L.p_2 \quad (1)$$

with $C_\tau = D_\tau - W_\tau$

where p_1 and p_2 are the probability of that m^3 of water being spilled over and being used to avoid a failure of the electric power system (with a present value of that loss equal to L), respectively. α is an appropriate discounting factor, D_τ is the demanded energy during the time unit when that water is used and W_τ is the energy already produced in τ by the stored water. Thus, C_τ is the required energy to satisfy the demand, T_τ is the maximum energy producible by the alternative generating system and $\Delta U_\tau[C_\tau, T_\tau]$ has the shape given in Figure 7. (3).

The time τ and W_τ are function of the stored energy at time t and of the future demand and inflows. T_τ is the available capacity from the generating units without reservoirs (thermal and nuclear power stations, etc.) if eq.(1) is applied to the set of hydro-electric plants with reservoirs and therefore includes thermal (and nuclear) power stations as well as run-of-river plants where the available capacity of the former sub-system has a narrow domain of variation when compared to the latter one which depends on the energy inflows. The demand D_τ has a much smaller coefficient of variation than the analysed inflows and thus the most of significant uncertainty comes from the inflows of the systems A & B.

The methodology developed to carry out this medium-term forecasting is presented in next sections of this paper.

4. FORECASTING METHODS

Many models have been proposed to carry out prediction analyses in Hydrology, (4), but major developments fall in these classes:

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a) ARIMA models

These models are based on the well known Box-Jenkins approach, (5), that can be applied to the hydrologic time-series $\{X_t\}$ or to the time-series obtained by removing $\{X_t\}$ seasonal components, $\{Y_t\}$.

Although the differencing process suggested by these authors to eliminate seasonality can produce results similar to those obtained by removing from $\{X_t\}$ the major deterministic harmonics, (6), it is now clear that that approach has the disadvantage of increasing the parameters estimation errors and thus the latter may be preferable, (7) & (8), for hydrologic purposes.

Several developments on the definition of the objective function for the model calibration (ML or Akaike function) and on the battery of tests for checking the estimated models have been recently obtained.

These models present also the advantage of being easily applied to prediction or simulation analyses through several packages that can be now found at most computer centres.

Their major shortcomings come from the assumed gaussian and stationary hypotheses as well as from the assumption that serial dependence can be expressed by a short-time memory markovian structure.

b) Kalman models

These models, (9), have also a short memory structure and are based on the well known Kalman filtering theory. This filter is also linear and gaussian but stationarity is not assumed any more as the system state and the transition matrices are functions of the time.

Two significant drawbacks can be pointed out:

The covariance matrices have to be known and several computational/convergence problems arise when the existing algorithms are used.

c) Long memory models

The study of the Hurst effect has been responsible for a lot of research on long run dependence in hydrologic sequences and the fractional Gaussian Noise model proposed by Mandelbrot & Wallis, (10), or the so-called Broken-Line models of Mejia, Dawdy & Nordin, (11), are the major contributions to develop models satisfying Hurst results.

Unfortunately, the gaussian and stationarity hypotheses are used and there are serious implementation problems to be solved.

It should be also pointed out that this family of models has grown up with the purpose of simulating the Hurst effect rather than decreasing the uncertainty associated to the medium or long-term future.

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5. A METHODOLOGY FOR MEDIUM-TERM FORECASTING

5.1. General Approach

From the previous sections it is rather obvious the need of a simulator of the energy monthly inflows using the information concerning the past inflows in order to decrease the uncertainty associated to the medium-term future. Unfortunately, the prediction models that have been developed and briefly described in 4. are not adequate to fulfill this aim and therefore the following approach is adopted:

A - Developing a simulation model for monthly inflows with the purpose of generating time-series samples similar to the historical samples.

B - Searching for methods by which the available information on past inflows occurred during the present hydrologic year can be incorporated into the simulation models previously developed in order to reduce the uncertainty of inflows of next months.

The models obtained by A & B will be designated by Dynamic Simulation Models.

Box-Jenkins methodology is used to cope with task A and the basic principles of Bayesian analysis are adopted to carry out the second stage of this research.

5.2. A Simulation Model To Generate Monthly Energy Inflows

5.2.1. Introduction

Box & Jenkins methodology is adopted to develop the simulation models for monthly inflows of systems A & B and it is applied to the historical time-series after being deseasonalized by removing the mean and the standard deviation deterministic harmonics.

The system B inflows are not significantly skewed and by this approach an adequate model is obtained as it is shown in Tables 5, 6 & 7. The parameters estimated from the historical record record are compared to those estimated from a generated sample $\{X_t^*\}$ using the estimated model. This sample is three times longer than the data.

This model is also not rejected by the usual tests applied to the residuals estimates.

However, modelling system A inflows is more difficult because they are positively skewed and therefore the gaussian hypothesis is no longer valid. The following procedure is usually recommended and adopted to solve this problem, (6):

a) Transforming the data by an appropriate analytical function to

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eliminate the estimated skewness. With this purpose, a non-linear function has to be used and a logarithmic expression is often adopted.

b) Identifying and estimating a gaussian model to the transformed data according to (5).

c) Testing the model through the residuals analysis (periodogram and correlation tests).

d) Generating time-series through the non-rejected model and transforming them back by the inverse of the function used in a).

The extremal properties of the generated synthetic data are particularly important in this study and the testing criteria referred in c) do not explicitly take into account these properties and the applied non-linear transformation can be responsible for the lack of similarity between real and generate extremes.

This approach is applied to model system A inflows and in the next section the extremal properties of the generated time-series are compared to those estimated using the data. The lack of similarity is quite obvious and an alternative approach is proposed and successfully used (section 5.2.4).

5.2.2. Rejection of Extremes Generated By A Model Non-rejected Through The Cumulative Periodogram And Box Autocorrelation Tests

The available data on hydro-electric monthly inflows $\{X_{t=\tau+12i}$ with $\tau=1,\ldots 12$ and $i=0,1,\ldots N-1\}$ for the Portuguese set of power stations with reservoirs was presented in Table 2. The estimated skewness coefficient ($\sqrt{\beta_1}$) is equal to 1.94 and therefore a logarithmic transformation is applied to $\{X_t\}$ according to (6):

$Y_t = \ln X_t$

as $X_t > 0$ for the analyzed data,

$\{Y_t\}$ has important seasonal components (table 8 and figure 8) and major deterministic harmonics are estimated through Fourier Analysis. The filtered time-series, $\{Z_t\}$, can be then modelled by an ARMA model and the following results are obtained:

a) Type of model: AR (2)

b) Estimated parameters:

$\hat{\phi}_1=0.597$ $\hat{\phi}_2=-0.007$ $\hat{\sigma}_a=0.80$

c) Autocorrelation test applied to the generated residuals time-series according to (12):

$$Q=n(n+2).\{\sum_{k=1}^{m} \hat{\rho}_k^2 /(n-k)\} \sim X^2_{m-p-q}$$

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if the residuals are uncorrelated where n,m,p, and q are the number of generated residuals, the maximum lag analysed, the order of AR and of MA, respectively.

With n=120 and m=60 one obtains:

$$Q=26.974 < \chi^2_{58}\ (0.95)=76.4$$

d) Normality χ^2 test:

Adopting 5 equiprobable classes, the usual χ^2 test gives

$$D=\sum_{i=1}^{5}\frac{(e_i - 0_i)^2}{e_i} = 2.08 \leq \chi^2_4\ (0.95)=9.49$$

where e_i is the expected number of residuals according to the normal assumption and 0_i is the corresponding number of generated residuals.

e) Cumulative periodogram check:

The white noise normalized cumulative periodogram, C(fj), with

$f_j = \frac{j}{n}$ and $j=0,1,\ldots,\frac{n}{2}$ (even), should satisfy

$$[c(f_j) - 2f_j] \leq K(\alpha)/\sqrt{\frac{n-2}{2}}$$

with probability α where K(0.95)=1.36 according to Box & Jenkins, 1970:

$$M=\max\ [c(f_j) - 2f_j] = 0.07 < 0.185$$

Therefore, according to the usual procedure $\{X_t\}$ values can be generated through this model making $X_t=e^{Y_t}$

The estimated extremal quantiles from the generated sample (3 x 42 years) are presented in Table 9.

Obviously, the generated extremes are not similar to those estimated from real data.

5.2.3. A Theoretical Explanation For The Detected Dissimilarity

If W is a lognormal variate defined for $W > \theta$ then $V=\ln(W-\theta)$ is a gaussian variate ($V \sim N(\mu_V; \sigma_V)$) and if θ is known the ML estimators of the parameters of f(W) or equivalently, the ML estimators of μ_V and σ_V can be obtained through the application of least squares to the transformed data, $\ln(W-\theta)$, (13). This may explain the popularity of the described approach based on the estimation of the model parameters for the transformed data.

However, if θ is not known or if it is a function of unknown parameters the problem is much more complex, because the referred $\hat{\mu}_V$ and $\hat{\sigma}_V$ are not ML estimators any more and several alternative estimation procedures have been proposed with debatable success, (14) & (15).

If the time-serial interdependence of $\{X_t\}$ using untransformed standardized data is adequately described by an AR(p) model as it uses to be the case in Hydrology ($p<3$) and assuming that the model residuals $\{a_{t=\tau+12i}\}$ follow a lognormal distribution with a skewness coefficient depending on $\tau(\sqrt{\beta}_1(\tau))$, then this model parameters $(\theta(\tau), \mu_V(\tau), \sigma_V(\tau), \phi_1, \ldots \phi_p)$ should be estimated through the maximization of the logarithm of the likelihood function:

$$\ln L=\ln\left\{\frac{1}{\left[\prod_{\tau=1}^{12}\sigma_V(\tau)\right]^{N}\cdot(\sqrt{2\Pi})^{12N}}\cdot\frac{e^{-\left\{\sum_{i=0}^{N-1}\sum_{\tau=1}^{12}\frac{[\ln(a_{\tau+12i}-\theta(\tau))-\mu_V(\tau)]^2}{2\sigma_V^2(\tau)}\right\}}}{\prod_{i=0}^{N-1}\prod_{\tau=1}^{12}(a_{\tau+12i}-\theta(\tau))}\right\}$$

where $\ln(V_{\tau=12i}=a_{\tau+12i}-\theta_\tau)\sim N(\mu_V(\tau);\sigma_V(\tau))$.

$\{a_{\tau+12i}\}$ are defined by:

$$a_{t=\tau+12i}=X_t-\sum_{k=1}^{p}\phi_k X_{t-k}$$

and so they are a function of the adopted values for $\phi_1,\ldots,\phi_k$. $\frac{\partial \ln L}{\partial\mu_V(\tau)}$ and $\frac{\partial \ln L}{\partial\sigma_V(\tau)}$ are equal to zero when

$$\mu_V(\tau)=\sum_{i=0}^{N-1}\ln(a_{\tau+12i}-\theta_\tau)\;/N \tag{2}$$

$$\sigma_V^2(\tau)=\sum_{i=0}^{N-1}\left[\ln(a_{\tau+12i}-\theta_\tau)-\mu_V(\tau)\right]^2/N \tag{3}$$

as it could be expected and

$$\theta(\tau)=-\exp\{\tfrac{1}{2}\sigma_V^2(\tau)+\mu_V(\tau)\} \tag{4}$$

because $E(a_{\tau+12i})=0$.

Thus, the estimation of $\mu_V(\tau)$, $\sigma_V^2(\tau)$ and $\theta(\tau)$ is easy providing that $\phi_1,\ldots,\phi_p$, have been obtained.

Therefore, the residuals $\{a_{\tau+12i}\}$ are computed for each set of values

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given to $\phi_1,\ldots,\phi_p$, and the following function

$$F= \sum_{i=0}^{N-1} \sum_{\tau=1}^{12} \ln\{[X_{t=\tau+12i} - \sum_{k=1}^{p} \phi_k \cdot X_{t-k}] - \theta(\tau)\}+$$

$$+ \sum_{i=0}^{N-1} \sum_{\tau=1}^{12} \{\ln[X_{t=\tau+12i} - \sum_{k=1}^{p} \phi_k \cdot X_{t-k} - \theta(\tau)] - \mu_V(\tau)\}^2 \cdot \frac{1}{2\sigma_V^2(\tau)}$$

is determined by using equations (2), (3) and (4).

Then, Powell algorithm is used to search for $(\phi_1,\ldots,\phi_p)$ values which minimize F.

This objective function (F) is rather distinct from that (G) minimized according to the usual approach:

$$G = \sum_{i=0}^{N-1} \sum_{\tau=1}^{12} \{\ln \left(\frac{X_t}{X_{t-1}^{\phi} \cdots X_{t-p}^{\phi p}} \right)^2\}$$

and the minimum of G can be rather far from that of F, namely because X_t values are raised to ϕ_k which may be responsible for introducing important distortions.

A further development can be introduced by considering also $\phi_1,\ldots,\phi_p$ as functions of τ.

Other non-linear transformations were adopted ($Y_t=X_t^{\lambda}$), but the similarity between real and generated extremes was not significantly improved and therefore an alternative approach avoiding non-linear transformations was adopted.

5.2.4. An Alternative Approach Without Data Transformation

The modelling approach described in 5.2.2. is now directly applied to the data and the model parameters are estimated by minimizing F, because the lognormal law is a better approximation to the distribution of the obtained residuals rather than the normal law.

The following results are obtained:

Model : AR(2) with $\hat{\phi}_1=0.550$ $\hat{\phi}_2=-0.014$ $\hat{\sigma}_a=0.84$

$Q=31.692 < \chi^2_{58}(0.95)=76.4$

M=0.07

Thus, this model is also not rejected by these tests.

The residuals quantiles are estimated and an interpolation procedure

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using the splines technique is adopted to generate the residuals time-series.

The estimated quantiles for a generated sample three times longer than the original data are presented in tables 10,11 & 12 and they are now very similar to those estimated from the data.

5.3. A Bayesian Approach For The Development Of Dynamic Simulation Models

The tool traditionally adopted to search and to identify serial interdependence is correlation analysis but this case illustrates how this approach can be unpowerful to treat this type of forecasting problems.

Let be considered as an example the case of being at the 1st day of month t_0, $(t_0 - 1)$ months after the starting of the hydrologic year. The correlation matrix between past and future inflows (system A) is presented in Table 13 and the hypothesis of independence is not rejected by these results. However, let be adopted the Bayesian attitude of searching the value of past information, I, to forecast the future event A, by comparing the probability (distribution) of the future inflows P(A) (or F(A)) without knowing I with that conditioned by I.

Defining the event B $(\alpha\ \beta)$ by the occurrence of $(I_\alpha < I \leq I_\beta)$ where

$$F_I(I_\beta) = \beta \text{ and } F_I(I_\alpha) = \alpha \text{ with } I = \sum_{\tau=1}^{t_0-1} X_\tau \text{ and } \beta > \alpha$$

then the conditional distribution of $A = \sum_{\tau=t_0}^{H} X_\tau$ with $H = t_0, \ldots, 17$

given B, $F(A/B(\alpha,\beta))$, can be easily estimated and its mean & quantiles are presented in Figures 9 & 10 as a function of H and with

$B(\alpha,\beta) = \{B(0,\ 0.33);\ B(0.67,\ 1.00)\}$:

The relevance of past information to forecast the future is clearly evidenced by these graphs.

Thus, at each instant of time the past total inflow can be used to up date the model to simulate future inflows and the following questions have now to be discussed:

- Which is the most convenient number of B events?
- Which are the most convenient α and β limits?

The answer to these two questions was obtained by experimental analysis using the maximization of the sensitivity of A parameters regarding B events as a selection criterion providing that the dimension of the available sub-samples is above a minimum limit (e.g., 8 hydrologic years).

The adopted solution is:

B(0;0.20)

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B(0.70; 1.00)
B(0;1.00)

where B(0;1.00) corresponds to the case of not using past information. As an example, the corresponding graphs for systems A and B with t_0=1 NOV & 1 FEB are presented in Figures 11 to 18 from which the following conclusions can be obtained:

- The past information is usually very relevant to decrease the uncertainty about the future, particularly for run-of-river plants inflows. It is surprising how this information is so useful even when just the month of October is known.

- The highest quantiles use to be a more sensitive function of the past inflows than the lowest ones.

- There are just a few crossings between the lines of estimated parameters of future inflows for the cases of a dry, wet or medium past with $H \leq 12$ but there are several crossings for $H > 12$ which confirms the weak interdependence (independence?) between successive hydrologic years.

Furthermore, for any specific time of hydrologic year, t, one can study the conditional distribution of the inflows for the future month t^* assuming that the event $B(\alpha, \beta)$ is known and to compare its features to those obtained if (α, β) is ignored.

As an example, the monthly and cumulative inflows are presented in Tables 15 to 18 with t=1 JAN by which the previous conclusions are confirmed:

- The estimated means and quantiles of future inflows are significantly and positively interrelated with the 1st trimestre inflows.

- The coefficient of variation of cumulative inflows is significantly decreased by the information on past inflows.

- The identified model does not depend on that information (AR(2)) with $([\phi_2] < 0.10)$ but ϕ_1 takes distinct positive values.

Several theoretical refinements can be introduced in this approach such as:

- Expressing the estimated parameters, $\hat{\theta}$, of X_t with $t>t_0$ as a

  a continuous function of $I_{t_0} = \Sigma_{\tau=1}^{t_0-1} X_\tau$, $\hat{\theta}/I_{t_0}$, by interpolation

  of the discrete values estimated for with B_i and $i=1,\ldots,k$,

  $(\hat{\theta}/B_i)$ and satisfying the required condition:

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$$\hat{\theta} = \int_{\Omega} (\hat{\theta} / I_{t_0}) \; f(I_{t_0}) \; dI_{t_0}$$

where $\hat{\theta}$ is the unconditional estimate of θ .

- Defining $I_{t_0} = \sum_{\tau=1}^{t_0 - 1} X_{\tau} \cdot e^{-\alpha (t_0 - \tau)}$

instead of the previous expression $I_{t_0} = \sum_{\tau=1}^{t_0 - 1} X_{\tau}$ where α has to be numerically optimized.

However, it should be pointed out that the presented results can be already used to obtain important reductions of the future uncertainty.

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6. CONCLUSIONS

- The contribution given by hydroelectric plants with reservoir and run-of-river plants to the energy produced by the Portuguese electric power system is rather important.

- The management of this electric power system implies a short-term and a medium-term analysis. The basic source of uncertainty for the latter is the extremely high variability of monthly energy inflows.

- Often, water is spilled over or reservoirs get dry and severe economic losses arise from these events by which the need of a medium-term forecasting methodology applicable to monthly energy inflows is emphasized.

- The developed prediction models are not adequate to this study because some of their main hypotheses are not validated of the historical data such as the gaussian and linear assumptions, the short-memory model structure and using the correlation analysis as the basic tool to study interdependence.

- A methodology is proposed and applied to the available data to solve this problem including this two-stage approach:

  a) Developing a simulation model for monthly inflows without assuming the gaussian hypothesis.

  b) Adopting Bayesian principles to incorporate information about the available data on inflows occurred during the present hydrologic year into the developed simulation models in order to decrease the uncertainty about the medium-term future.

- The relevance of past information to carry out medium-term forecasts is high as it is shown by the presented analyses and results although not being easily detectable by the correlation analysis.

- The obtained models (Dynamic Simulation Models) can be used to improve the medium-term management of this electric utility and to obtain important cost reductions as the new estimates of inflows parameters are rather distinct than those obtained without using past information.

- Further research can be carried out to improve the application of the Bayesian principles and to model a multisite configuration of the electric power generation system.

  The method proposed in (16) is being now used to solve this last problem.

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8. REFERENCES

1) Elgerd, O, 1971, "ELECTRIC ENERGY SYSTEMS THEORY", McGraw-Hill

2) Stevenson, W.D., 1962, "ELEMENTS OF POWER SYSTEM ANALYSIS", McGraw-Hill

3) Massé, P., 1968, "LE CHOIX DES INVESTISSEMENTS", Dunod

4) Lawrence, A.J. and N.T. Kottegoda, 1977, "STOCHASTIC MODELLING OF RIVER-FLOW TIME SERIES", Journal of Royal Statistical Society A, 140, Part 1, p. 1.

5) Box, G.E.P. and Jenkins, G., 1970, "TIME-SERIES ANALYSIS, FORECASTING AND CONTROL", Holden-Day

6) Rosesner, L.A. and Yevjevich, V.M. 1966, "MATHEMATICAL MODELS FOR TIME-SERIES OF MONTHLY PRECIPITATION AND MONTHLY RUNOFF", Hydrology Papers, 15, Colorado State University, Fort Collins, USA

7) Kavvas, M.L. and J.W. Delleur, 1975, "REMOVAL OF PERIODICITIES BY DIFFERENCING AND MONTHLY MEAN SUBTRACTION", Journal of Hydrology, 26, p. 335

8) Valadares Tavares, L. "SIMULATION OF NON-STATIONARY MONTHLY RUNOFF FOR RIVERS WITH HIGHLY VARIABLE DISCHARGES", in "Modelling, Identification and Control in Environmental Systems", Vansteenkiste, ed. IFIP, North Holland, 1978.

9) Kalman, R.E., 1961, "CANONICAL STRUCTURE OF LINEAR DYNAMIC SYSTEMS", Proc. Nat. Ac. Sci., USA, 48, p. 596

10) Mandelbrot, B.B. and Wallis, J.R., 1968, "COMPUTER EXPERIMENTS WITH FRACTIONAL GAUSSIAN NOISES", Water Resource Research, 5, p. 228

11) Mejia, J.M., Dawdy, D.R. and Nordin, C.F., 1974, "STREAMFLOW SIMULATION. 3. THE BROKEN LINE PROCESS AND OPERATIONAL HYDROLOGY", Water Resource Research, 10, p. 242

12) Ljung, G.M. & G.E.P. Box, 1978, "ON A MEASURE OF LACK OF FIT IN TIME-SERIES MODELS", Biometrika, 65, p. 297

13) Johnson, N.L. & S. Kotz, 1970, "CONTINUOUS UNIVARIATE DISTRIBUTIONS-1", Houghton

14) Cohen, A.C., 1951, "ESTIMATING PARAMETERS OF LOGARITHMIC-NORMAL DISTRIBUTIONS OF MAXIMUM LIKELIHOOD", J.A.S.A., 46, p. 206

15) Hill, B.M., 1963, "THE THREE-PARAMETER LOGNORMAL DISTRIBUTION AND BAYESIAN ANALYSIS OF A POINT-SOURCE EPIDEMIC", JASA, 58, p. 72

16) Valadares Tavares, L., 1977, "A RECONSIDERATION OF LAWRANCE AND FIERING TWO-STATION MODELS", Journal of Hydrology, 33, p. 185

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TABLE 1

Portuguese Electric Power Production System
(1978)

Sub-system		Name	Location (district or river)	Installed Capacity (MW)	Reservoir capacity ($10^6 m3$; Gwh)
Thermal		Tapada do Outeiro	Setúbal	3x50	-
		Carregado	Santarém	6x125	-
		Tunes	Faro	2x16	-
		Alto de Mira	Lisbon	6x24	-
		Barreiro	Setúbal	2x35	-
	Cávado-Rabagão	Alto Rabagão	Rabagão	2x36	550; 973.1
		Vila Nova (Paradela)	Cávado	1x54	159.4; 222.5
		Vila Nova (Venda Nova)	Rabagão	3x27	94.8; 128.0
		Salamonde	Cávado	2x21	56.8; 27.6
		Filarinho das Furnas	Homem	1x64	116.0; 138.0
		Caniçada	Cávado	2x30	144.4; 33.1
	Inter-national Douro	Miranda	Douro	3x58	- -
		Picote	Douro	3x60	- -
		Bemposta	Douro	3x70	- -
	National Douro	Tabuaco	Tavora	2x32	97.5; 100.6
		Régua	Douro	3x52	;
		Carrapatelo	Douro	3x60	- -
		Valeira	Douro	3x72	;

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TABLE 1 (Cont'd.)

Portuguese Electric Power Production System
(1978)

Sub-system		Name	Location (district or river)	Installed Capacity (MW)	Reservoir capacity ($10^6 m3$; Gwh)
	Zézere-Tejo	Cabril	Zézere	2x49	614.0; 339.3
		Bouça	Zézere	2x25	- -
		Castelo de Bode	Zêzere	3x46	900.5; 163.0
		Fratel	Tejo	3x43	- -
	Secondary Sub-system	with reservoirs	-	85	217.8; 135.2
		without reservoirs	-	100	- -

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TABLE 2

Monthly inflows for the set of hydro-electric plants with reservoir (system A)

$m = 265.4;\ s = 329.88;\ \sqrt{\beta_1} = 1.94$

	OUT	NOV	DEZ	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET
1933/34	128.9	115.1	216.5	281.1	91.8	519.5	485.0	153.1	48.1	15.0	14.3	19.5
1934/35	22.8	76.0	905.3	201.9	244.6	325.7	160.1	125.5	106.7	43.8	18.3	17.8
1935/36	27.7	332.5	936.3	1610.1	1498.0	1306.5	812.3	216.8	118.0	56.0	22.6	22.7
1936/37	60.6	141.0	112.6	819.2	756.4	1136.1	535.8	151.3	93.8	22.5	10.5	21.4
1937/38	78.9	525.3	763.1	371.4	131.0	106.3	71.0	103.7	34.8	13.5	5.4	21.5
1938/39	35.9	123.9	365.1	1192.5	300.3	162.0	396.0	153.1	125.7	41.1	19.1	61.8
1939/40	323.2	435.3	346.7	1100.1	1240.0	845.1	299.7	269.4	92.4	28.5	7.6	9.1
1940/41	63.1	511.4	151.7	1184.1	1214.6	897.0	529.7	522.5	242.5	64.5	17.0	11.3
1941/42	18.4	153.4	76.0	128.5	81.4	783.7	434.9	433.4	163.6	35.1	11.5	24.8
1942/43	127.8	314.9	716.2	1284.4	452.4	392.6	200.0	89.2	19.8	32.7	6.0	82.2
1943/44	355.6	176.3	275.8	123.3	66.8	141.3	337.8	85.3	38.9	41.1	19.5	23.8
1944/45	25.5	93.6	240.0	149.2	158.3	65.7	58.8	54.6	21.8	2.4	7.6	12.8
1945/46	75.0	211.4	959.8	273.6	194.7	408.4	317.1	720.0	306.4	34.0	20.1	35.5
1946/47	103.0	195.7	324.7	321.1	1441.7	1402.1	590.3	185.2	42.7	16.4	10.7	18.1
1947/48	41.6	40.6	305.4	1241.8	377.7	213.4	150.8	206.2	89.7	15.3	27.3	12.6
1948/49	27.3	93.8	432.5	261.6	97.4	61.5	46.7	32.4	18.0	1.7	0.0	65.6
1949/50	100.5	233.9	320.0	148.4	618.3	271.5	103.1	318.4	167.8	42.8	10.8	17.1
1950/51	31.6	285.5	230.0	446.4	968.4	1025.1	172.2	219.3	114.0	37.3	15.3	21.7
1951/52	51.5	700.9	228.6	181.4	145.6	381.4	403.6	363.7	96.7	35.2	15.3	27.3
1952/53	79.8	380.8	509.1	248.9	167.2	119.5	142.4	101.2	25.6	15.4	3.4	20.6
1953/54	159.7	179.8	483.0	110.9	309.1	595.1	179.4	190.7	91.5	21.8	17.7	12.0
1954/55	34.2	217.0	215.7	1155.5	785.4	407.0	137.8	94.8	87.9	19.6	6.8	9.8
1955/56	22.5	415.7	719.8	806.4	204.7	869.1	639.5	271.0	120.8	50.2	33.9	111.1
1956/57	98.3	57.3	110.4	117.8	667.0	436.0	178.0	135.0	60.6	20.3	17.2	13.8
1957/58	10.5	85.2	130.4	508.1	481.1	600.0	496.4	89.0	193.1	87.7	31.1	57.4
1958/59	109.0	32.5	813.4	562.7	219.4	717.7	465.3	219.6	71.8	22.4	12.4	36.5
1959/60	117.1	563.0	1337.4	692.1	1158.4	877.3	360.1	193.2	69.4	22.3	26.8	40.7
1960/61	617.6	1060.5	587.7	588.7	307.6	154.6	288.5	169.0	97.3	26.6	8.3	10.7
1961/62	127.1	469.7	955.2	904.9	132.8	899.0	388.1	109.0	41.9	11.7	3.1	14.9
1962/63	38.0	73.2	69.9	918.5	921.5	979.2	521.3	120.8	143.7	27.1	8.0	12.1
1963/64	32.2	1075.0	825.4	232.9	730.3	939.2	290.5	96.2	157.5	32.6	9.2	11.9
1964/65	72.3	25.8	45.0	315.0	257.7	665.8	125.2	60.6	13.6	3.8	3.3	64.8
1965/66	246.6	649.0	643.0	1342.2	1857.8	304.3	773.5	139.8	91.6	20.4	19.0	15.5
1966/67	365.1	282.0	179.2	274.4	450.2	362.9	133.7	256.0	62.2	3.7	0.5	11.5
1967/68	47.1	183.6	63.5	44.5	662.9	253.7	394.9	340.0	64.4	17.6	12.5	94.8
1968/69	93.0	416.9	691.0	854.4	716.7	1292.7	284.8	441.2	191.9	47.2	25.9	69.3
1969/70	79.0	226.0	138.4	1827.0	347.5	116.1	73.1	277.0	112.1	31.1	18.7	21.3
1970/71	19.7	159.8	90.6	565.7	196.9	217.9	346.7	367.1	321.5	139.0	61.5	23.3
1971/72	39.1	34.1	55.7	288.6	982.2	462.1	132.4	104.6	37.2	16.8	8.6	20.3
1972/73	112.6	234.2	433.7	728.6	177.8	103.6	82.2	454.4	100.4	45.0	13.8	25.8
1973/74	114.3	115.5	170.6	852.2	709.4	207.7	126.8	147.9	272.1	94.7	16.7	34.0
1974/75	12.2	230.7	92.5	283.6	306.1	519.3	121.9	77.6	35.5	15.7	3.6	20.8

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TABLE 3

Monthly inflows for the set of run-of-river hydro-electric plants (system B)

$m = 538.4; \quad s = 218.0; \quad \sqrt{\beta_1} = 0.36$

	OUT	NOV	DEZ	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET
1933/34	438.8	357.5	379.9	565.1	355.0	758.6	858.4	836.4	558.1	634.4	452.4	346.2
1934/35	290.1	299.4	773.4	687.6	568.5	798.4	548.6	607.1	636.4	387.6	357.1	331.3
1935/36	370.5	438.3	862.3	828.8	770.3	917.5	863.1	927.2	742.4	623.7	364.5	370.5
1936/37	458.8	563.6	409.3	769.9	829.7	929.0	917.8	745.2	487.2	420.9	385.4	438.5
1937/38	541.3	853.9	931.6	891.6	701.6	440.7	330.7	382.0	341.3	411.5	363.8	313.3
1938/39	306.8	443.3	645.0	865.4	749.6	633.0	848.2	561.0	445.3	452.5	399.2	453.1
1939/40	645.5	830.1	692.9	919.6	865.6	947.2	607.1	803.9	450.9	412.6	378.8	410.4
1940/41	501.4	753.9	615.8	900.9	831.8	934.7	899.7	944.3	822.8	534.9	443.2	455.2
1941/42	487.9	502.1	439.2	465.9	451.8	750.5	676.1	750.0	312.0	427.6	479.9	452.3
1942/43	537.6	605.1	751.8	845.1	748.1	713.9	680.0	559.0	315.9	447.7	433.0	404.7
1943/44	592.3	689.0	677.2	523.9	429.4	502.9	479.8	325.4	287.6	377.7	304.6	275.5
1944/45	300.4	431.6	545.6	477.3	508.8	349.7	272.7	241.8	192.4	178.7	135.3	197.7
1945/46	197.2	277.7	686.4	630.3	442.9	587.4	845.4	949.0	655.1	366.9	420.6	402.4
1946/47	382.2	398.5	558.6	602.2	819.9	882.4	904.4	804.6	436.7	419.6	385.1	431.8
1947/48	490.3	418.9	443.8	911.2	836.6	725.7	524.0	675.7	425.2	403.1	365.2	338.5
1948/49	328.7	300.8	419.7	481.1	273.4	179.5	196.8	194.4	179.4	185.8	165.2	164.8
1949/50	250.9	206.7	365.9	338.1	437.4	415.4	245.7	323.6	499.0	301.6	277.6	285.1
1950/51	280.8	257.3	384.5	576.2	781.9	891.2	743.6	614.5	502.8	366.0	375.4	421.1
1951/52	511.6	824.7	676.3	643.7	571.7	578.6	851.0	724.5	328.5	432.9	375.2	391.2
1952/53	427.3	512.2	754.4	670.7	571.0	570.5	602.7	391.9	267.4	313.3	297.3	295.2
1953/54	357.3	388.3	539.9	464.5	582.2	775.4	590.7	593.8	308.3	306.5	311.9	302.8
1954/55	332.6	337.9	399.6	757.9	859.3	857.2	606.2	369.8	278.4	330.1	332.6	368.9
1955/56	400.7	726.0	813.0	940.2	830.5	898.3	909.2	916.4	560.8	371.6	361.6	447.9
1956/57	496.4	508.8	404.7	322.6	478.0	493.7	328.1	276.2	192.4	179.6	202.9	259.4
1957/58	292.4	339.3	298.9	455.7	699.0	775.8	793.9	561.1	300.6	335.5	241.2	311.1
1958/59	399.1	374.8	742.0	855.4	599.8	799.6	742.4	708.4	443.0	303.7	300.2	419.2
1959/60	575.0	814.7	909.9	938.5	830.8	946.0	899.5	739.7	456.2	405.5	332.4	400.9
1960/61	721.4	895.5	952.0	947.5	838.9	795.1	557.4	472.8	388.8	419.6	368.6	453.6
1961/62	518.1	821.4	902.4	853.8	786.9	932.4	870.8	630.2	354.0	368.7	349.0	356.9
1962/63	400.8	361.7	330.7	929.9	840.2	951.3	902.3	614.8	481.6	343.3	321.1	400.9
1963/64	440.5	790.0	944.5	809.9	748.1	943.9	928.8	525.4	499.3	411.5	323.4	354.0
1964/65	392.2	382.0	276.3	347.4	438.1	786.8	514.5	277.5	179.4	180.2	182.6	253.9
1965/66	488.7	731.0	944.7	939.6	710.6	925.0	909.8	667.1	512.6	387.0	345.3	343.2
1966/67	538.7	862.5	702.3	622.4	639.4	783.4	453.8	617.0	357.8	318.0	324.1	344.5
1967/68	358.2	516.8	491.2	416.5	696.1	699.9	768.6	760.2	322.4	287.8	284.4	338.6
1968/69	392.0	540.0	596.5	780.2	749.4	917.2	862.6	826.0	675.8	442.9	327.5	461.4
1969/70	538.8	516.0	401.9	830.4	894.5	749.7	486.4	635.5	536.1	363.5	297.3	428.7
1970/71	392.8	411.7	339.5	378.7	447.9	382.2	496.6	929.7	846.5	606.9	465.4	574.5
1971/72	588.1	582.8	296.6	425.3	851.8	967.5	776.7	737.3	554.5	402.3	246.8	391.0
1972/73	582.0	725.4	860.6	913.0	707.7	643.1	489.1	789.4	573.2	504.1	330.3	170.3
1973/74	350.7	459.8	367.5	862.7	903.4	850.5	818.1	600.7	338.8	458.3	174.6	139.1
1974/75	345.0	557.8	469.9	493.3	491.5	605.1	527.6	438.2	419.8	305.9	149.9	247.5

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TABLE 4

Monthly Means (m_τ), Standard Deviations (S_τ) and Skewness Coefficient ($\sqrt{\beta_1}$)

τ	1	2	3	4	5	6	7	8	9	10	11	12	—	
m_τ	103.47	283.99	411.12	608.18	543.55	536.78	304.46	210.92	104.88	32.66	14.81	30.46	265.44	
S_τ	118.66	248.31	325.68	461.81	447.66	378.42	198.46	145.27	76.12	26.18	10.95	24.68	330.21	$\sqrt{\beta_1}=1.94$
CV_τ	1.148	0.847	0.792	0.759	0.823	0.705	0.651	0.689	0.726	0.801	0.739	0.810	1.244	
m_τ	429.33	533.34	594.32	680.83	663.05	728.97	662.36	613.52	434.38	377.22	320.58	349.31	532.3	
S_τ	118.49	196.74	211.82	108.01	176.20	201.63	215.78	209.54	165.72	113.24	93.66	100.24	220.3	$\sqrt{\beta_1}=0.35$
CV_τ	0.276	0.369	0.356	0.305	0.265	0.273	0.325	0.341	0.381	0.300	0.292	0.287	0.413	

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TABLE 5

Statistical Parameters of the Generated Inflows (system B)

	1	2	3	4	5	6	7	8	9	10	11	12
m (X_t)	429.3	533.3	594.3	680.8	663.1	729.0	662.4	613.5	434.4	377.2	320.6	349.3
m (X_t^*)	427.6	544.5	600.7	687.0	661.2	727.0	674.2	599.7	425.4	377.2	319.1	352.8
S (X_t)	118.5	196.7	211.8	208.0	176.2	201.6	215.8	209.5	165.7	113.2	93.7	100.2
S (X_t^*)	107.8	189.6	208.8	228.4	164.2	195.0	200.2	211.7	154.7	106.0	92.5	91.9

$m(x_t) = 532.3$; $s(x_t) = 220.3$; $\sqrt{\beta_1}(X_t) = 0.35$

$m(x_t^*) = 533.0$; $s(x_t^*) = 218.9$; $\sqrt{\beta_1}(X_t^*) = 0.45$

$R(x_t) = 14140$

$R(x_t^*) = 15240$; 9632 ; 7207

$MR(x_t^*) = 10690$

X_t = Historical sample

X_t^* = Generated sample

R(.) ~ Estimated adjusted range

TABLE 6

Runs Distribution (system B)

K	1	2	3	4	5	6	7	8	9	10
$N(X_t)$	101	64	32	19	14	6	1	0	0	0
$N(X_t^*)$	128	47	33	19	15	5	2	0	0	0

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TABLE 7

Estimated Quantiles (system B)

Monthly inflows (12 months)	F(Q)	0.002	0.010	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.99	0.998
	$Q(X_t)$	53.0	139.1	287.6	338.1	378.8	425.2	478.0	558.6	665.1	773.4	862.5	947.2	952.0
	$Q(X_t^*)$	61.0	124.8	272.9	341.9	391.5	446.3	503.8	570.1	643.4	730.0	837.9	1110.0	1204.0
	F(Q)	0.02	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	0.98
Monthly inflows (December)	$Q(X_t)$	276.3	296.6	330.7	379.9	404.7	469.9	557.7	645.0	702.3	773.4	902.4	944.5	944.70
	$Q(X_t^*)$	101.9	178.5	316.0	408.1	472.0	570.1	621.1	661.5	735.4	801.8	848.4	880.7	909.5
Monthly inflows (August)	$Q(X_t)$	53.0	135.3	165.2	241.2	297.3	321.1	330.3	349.0	365.2	378.8	420.6	452.4	465.4
	$Q(X_t^*)$	124.8	146.0	181.2	228.5	287.6	303.8	320.9	336.6	365.5	389.4	438.4	482.4	493.3
Annual maxima of monthly inflows	$Q(X_t)$	481.1	499.0	545.6	750.5	786.8	855.4	865.4	904.4	929.0	940.2	946.0	951.3	952.0
	$\gamma=832.2$ $\sigma=139.7$													
	$Q(X_t^*)$	498.8	537.2	602.7	707.5	779.6	823.2	848.7	877.7	917.9	977.1	1075.0	1131.9	1204.0
	$\gamma=849.3$ $\sigma=170.3$													
Annual minima of monthly inflows	$Q(X_t)$	53.0	135.3	149.9	179.6	246.8	284.4	302.8	315.9	328.5	343.2	364.5	382.2	385.4
	$\gamma=284.1$ $\sigma=82.7$													
	$Q(X_t^*)$	61.1	92.7	141.6	181.2	213.0	239.3	264.2	290.2	311.1	343.3	380.0	406.9	426.9
	$\gamma=262.9$ $\sigma=92.0$													

TABLE 8

Estimated mean (m_{τ}) and standard deviation (S_{τ}) for $\{Y_t = \ln X_t\}$ (system A)

	1	2	3	4	5	6	7	8	9	10	11	12
m_{τ}	4.19	5.28	5.66	6.08	5.94	5.98	5.48	5.14	4.39	3.17	2.40	3.17
S_{τ}	0.94	0.92	0.92	0.89	0.89	0.86	0.74	0.67	0.78	0.90	0.91	0.67

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TABLE 9

Estimated quantiles (Gwh) for given and generated monthly inflows

(model developed for logarithmic data) - (system A)

F(Q)	0.002	0.006	0.010	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	0.990	0.994	0.998
Given monthly $Q(X_t)$ inflows	0.50	1.70	3.10	15.50	26.60	54.60	92.40	127.10	191.90	288.50	435.30	730.30	1402.10	1498.00	1827.00
Generated monthly $Q(X^*_t)$ inflows	3.55	5.53	6.57	19.38	32.17	48.21	73.66	115.95	174.58	267.21	418.14	737.44	2690.40	3217.63	5902.35

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TABLE 10

Statistical Parameters of the Generated Inflows (system A)

τ	1	2	3	4	5	6	7	8	9	10	11	12
$m_\tau(X_t)$	103.5	284.0	411.1	608.2	543.6	536.8	304.5	210.9	104.9	32.7	14.8	30.5
$m_\tau(X_t^*)$	103.0	289.4	436.4	620.7	612.7	606.1	282.3	193.1	100.4	29.8	15.0	30.4
$S_\tau(X_t)$	118.7	248.3	325.7	461.8	447.7	378.4	198.5	145.3	76.1	26.2	11.0	24.7
$S_\tau(X_t^*)$	79.3	154.5	294.9	404.6	377.7	335.4	159.5	125.8	55.2	15.1	7.8	22.9

$m(X_t) = 265.4$; $S(X_t) = 330.2$; $\sqrt{\beta_1}(X_t) = 1.94$

$m(X_t^*) = 276.6$; $S(X_t^*) = 316.4$; $\sqrt{\beta_1}(X_t^*) = 1.56$

$R(X_t) = 10550$

$R(X_t^*) = 8405$; 10310 ; 11980

$MR(X_t^*) = 10230$

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TABLE 11

Runs Distribution (system A)

K	1	2	3	4	5	6	7	8	9	10
$N(X_t)$	101	64	32	19	14	6	1	0	0	0
$N(X_t^*)$	128	47	33	19	15	5	2	0	0	0

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TABLE 12

Estimated Quantiles (system A)

Monthly inflows (12 months)	F(Q)	0.002	0.010	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.99	0.998
	$Q(X_t^*)$	0.1	1.8	15.3	27.2	49.6	97.6	158.3	226.5	322.5	472.1	787.6	1243.6	1433.9
	F(Q)	0.02	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	0.98
Monthly inflows (December)	$Q(X_t)$	45.0	55.7	69.9	110.4	151.7	216.5	275.8	365.1	509.1	716.2	825.4	955.2	959.8
	$Q(X_t^*)$	23.1	46.1	104.9	184.8	236.0	293.7	363.3	426.5	498.0	714.8	844.0	1026.0	1166.2
Monthly inflows (August)	$Q(X_t)$	0.5	1.0	3.3	6.0	8.0	10.5	12.4	15.3	17.7	19.1	25.9	31.1	33.9
	$Q(X_t^*)$	1.4	3.0	5.3	8.1	9.9	11.6	14.1	16.3	18.2	21.3	27.5	29.9	30.3
Annual maxima of monthly inflows	$Q(X_t)$	240.0	355.6	450.2	565.7	662.9	728.6	852.2	979.2	1075.0	1214.6	1292.7	1610.1	1827.0
	γ=921.1 σ=380.2													
	$Q(X_t^*)$	239.2	377.4	490.3	685.2	803.8	871.8	926.4	981.1	1064.5	1165.4	1253.7	1358.3	1433.9
	γ=925.6 σ=293.9													
Annual minima of monthly inflows	$Q(X_t)$	0.5	1.0	3.1	5.4	8.0	10.5	11.3	12.6	15.3	17.8	19.7	22.5	22.6
	γ=12.0 σ=6.5													
	$Q(X_t^*)$	0.1	1.0	1.8	4.8	6.7	8.4	10.8	11.7	16.3	18.1	23.5	29.3	30.3
	γ=12.0 σ=8.1													

TABLE 13

Correlation matrix between past and future inflows (system A)

$$\hat{P}\left(\sum_{t=1}^{t_o-1} X_{ti} \sum_{t=t_o}^{H} X_t\right) \text{ with } t_o = 2,\ldots 12 \text{ and } H= t_o,\ldots,12$$

t_o \ H	2	3	4	5	6	7	8	9	10	11	12
2 (Nov)	0.42	0.27	0.18	0.15	0.07	0.06	0.05	0.04	0.04	0.04	0.03
3 (Dec)		0.37	0.26	0.27	0.22	0.22	0.22	0.22	0.22	0.21	0.21
4 (Jan)	-	-	0.13	0.15	0.17	0.18	0.18	0.18	0.17	0.17	0.17
5 (Feb)	-	-	-	0.34	0.31	0.33	0.33	0.33	0.33	0.33	0.33
6 (Mar)	-	-	-	-	0.37	0.43	0.41	0.40	0.40	0.40	0.39
7 (Apr)	-	-	-	-	-	0.53	0.44	0.40	0.39	0.38	0.37
8 (May)	-	-	-	-	-	-	0.08	0.10	0.11	0.11	0.10
9 (Jun)	-	-	-	-	-	-	-	0.18	0.17	0.17	0.19
10 (Jul)	-	-	-	-	-	-	-	-	0.14	0.16	0.10
11 (Aug)	-	-	-	-	-	-	-	-	-	0.20	0.03
12 (Sept)	-	-	-	-	-	-	-	-	-	-	0.05

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TABLE 14

Analysis of Future Inflows (T_O= 1 JAN) for System A

	τ	= 1	2	3	4	5	6	7	8	9	10	11	12
B(0 ; 1.00) $\hat{\phi}_1$=0.55	M(τ)	103	284	411	608	544	537	305	211	105	33	15	31
	S(τ)	119	248	326	462	448	378	198	145	76	26	11	25
	CV (τ)	1.155	0.873	0.793	0.760	0.823	0.704	0.591	0.687	0.724	0.788	0.733	0.806
	Q(0.80)	117.10	416.90	716.20	918.50	785.40	877.30	465.30	277.00	143.70	42.80	19.10	36.50
	Q(0.10)	19.70	40.60	69.90	123.30	97.40	106.30	73.10	77.60	21.80	11.70	3.40	11.30
B(0 ; 0.20) $\hat{\phi}_1$=0.23	M(τ)	43	97	80	361	531	550	329	207	125	43	19	39
	S(τ)	30	61	29	292	334	260	162	148	102	46	19	30
	CV(τ)	0.698	0.629	0.362	0.809	0.629	0.473	0.492	0.715	0.816	1.070	1.000	0.769
	Q(o.10)	10.50	25.80	45.00	44.50	81.40	217.90	125.60	60.60	13.60	3.80	3.30	12.10
	Q(o.80)	47.10	153.40	90.60	508.10	667.00	665.80	434.90	340.00	163.60	35.10	17.20	57.40
B(0.20 ; 0.70) $\hat{\phi}_1$=0.28	M(τ)	96	213	325	573	452	443	247	199	94	30	13	24
	S(τ)	94	156	209	482	381	378	181	126	65	22	7	15
	CV(τ)	0.979	0.732	0.643	0.841	0.843	0.853	0.733	0.633	0.691	0.733	0.538	0.625
	Q(o.10)	22.80	40.60	112.60	123.30	91.80	65.70	58.80	54.60	21.80	2.40	1.00	11.30
	Q(o.80)	112.60	234.20	432.50	852.20	709.40	595.10	403.60	256.00	112.10	41.10	17.70	25.80
B(0.70 ; 1.00) $\hat{\phi}_1$=0.36	M(τ)	157	539	790	838	719	699	394	235	112	31	16	37
	S(τ)	170	273	245	438	591	414	228	183	79	14	10	33
	CV(τ)	1.083	0.506	0.310	0.523	0.822	0.592	0.579	0.779	0.670	0.452	0.625	0.892
	Q(o.10)	22.50	211.40	346.70	232.90	131.00	106.30	71.00	89.20	19.80	11.70	3.10	9.10
	Q(o.80)	127.80	563.00	936.30	1100.10	1158.40	899.00	388.10	269.40	120.80	34.00	22.60	40.70

NEW JERSEY GEOLOGICAL SURVEY

TABLE 15

Analysis of Cumulative Future Inflows (T_O = 1 JAN) for System A

		τ = 1	2	3	4	5	6	7	8	9	10	11	12
B (0; 1.00)	MC	105.7	391.0	809.9	1426.0	1975.3	2512.5	2821.4	3035.6	3142.2	3175.3	3190.2	3220.9
	SC	119.2	320.8	536.7	754.8	1005.5	1204.0	1323.5	1343.7	1360.1	1364.2	1366.5	1365.4
	CVC=SC/MC	1.128	0.820	0.663	0.529	0.589	0.479	0.469	0.443	0.433	0.430	0.426	0.424
	QC(0.10)	22.5	98.1	226.1	417.5	833.4	1241.4	1506.8	1567.1	1601.1	1642.2	1661.7	1635.5
	QC(0.75)	114.3	531.9	1158.0	1964.4	2589.7	3288.3	3685.2	3774.2	3771.5	3898.1	3986.4	3917.1
B (0; 0.20)	MC	21.8	99.9	219.7	494.8	827.3	1165.9	1419.4	1566.5	1606.2	1628.8	1630.0	1669.5
	SC	5.7	16.9	61.7	158.8	201.4	216.4	329.9	415.5	433.3	439.7	444.3	448.7
	CVC=SC/MC	0.261	0.169	0.281	0.321	0.245	0.186	0.232	0.265	0.270	0.271	0.273	0.269
	QC(0.10)	10.5	77.2	128.9	338.7	457.7	732.3	791.1	845.7	867.5	869.9	877.5	890.3
	QC(0.75)	25.5	111.2	266.0	588.3	997.8	1256.3	1647.7	1799.8	1868.4	1890.7	1897.9	1911.7
B (0.20; 0.70)	MC	64.9	280.7	648.0	1223.0	1688.6	2145.5	2388.6	2619.1	2747.3	2787.3	2803.7	2831.7
	SC	26.2	97.0	225.3	310.4	357.8	499.9	555.1	533.3	531.4	527.7	526.3	532.8
	CVC=SC/MC	0.404	0.346	0.348	0.254	0.212	0.233	0.232	0.204	0.193	0.189	0.188	0.188
	QC(0.10)	32.2	155.6	359.1	815.2	1215.3	1505.3	1795.7	2061.9	2168.6	2199.0	2204.4	2225.9
	QC(0.75)	79.8	339.5	822.5	1517.6	1962.0	2454.7	2807.1	3084.1	3196.2	3227.3	3246.0	3267.3
B (0.70; 1.00)	MC	233.0	778.0	1486.6	2401.9	3243.5	4052.6	4513.5	4743.9	4857.2	4890.4	4906.6	4936.4
	SC	156.4	329.9	386.8	363.5	739.5	789.6	910.8	924.5	933.9	940.5	944.3	941.1
	CVC=SC/MC	0.671	0.424	0.260	0.151	0.228	0.195	0.202	0.195	0.192	0.192	0.192	0.191
	QC(0.10)	112.6	509.9	1105.2	1910.3	2407.8	3038.2	3561.7	3713.0	3806.8	3829.3	3839.8	3861.2
	QC(0.75)	323.2	758.5	1552.0	2709.6	3445.3	4290.1	4590.1	5074.1	5316.6	5381.1	5398.1	5409.4

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TABLE 16

Analysis of Cumulative Future Inflows (T_O = 1 JAN) for System A

	τ	= 1	2	3	4	5	6	7	8	9	10	11	12
B(0 ; 1.00) $\hat{\phi}_1$=0.73 $\hat{\phi}_2$=0	M(τ)	429	533	594	681	663	729	662	614	434	377	321	349
	S(τ)	118	197	212	208	176	202	216	210	166	113	94	100
	CV(τ)	0.275	0.370	0.357	0.305	0.265	0.277	0.326	0.342	0.382	0.300	0.293	0.286
	Q_1	280.80	299.40	330.70	378.70	429.40	382.20	328.10	277.50	192.40	180.20	165.20	170.30
	Q4	537.60	731.00	773.40	891.60	830.80	917.50	863.10	789.40	554.50	432.90	378.80	428.70
B(0 ; 0.20) $\hat{\phi}_1$=0.80 $\hat{\phi}_2$=0.04	M(τ)	321	325	375	518	569	622	539	469	387	304	268	317
	S(τ)	66	63	83	204	226	285	246	230	219	148	123	148
	CV(τ)	0.206	0.194	0.221	0.394	0.397	0.458	0.456	0.490	0.566	0.487	0.459	0.467
	Q1	219.20	206.70	276.30	338.10	273.40	179.50	196.80	194.40	179.40	89.00	0.459	0.467
	Q4	392.20	361.70	399.60	576.20	781.90	857.20	743.60	614.50	499.00	343.30	332.60	400.90
B(0.20 ; 0.70) $\hat{\phi}_1$=0.73 $\hat{\phi}_2$=0.02	M (τ)	404	469	544	658	666	747	698	667	465	391	323	357
	S (τ)	94	107	155	188	172	162	193	201	175	118	99	91
	CV(τ)	0.233	0.228	0.285	0.286	0.258	0.217	0.276	0.301	0.376	0.302	0.307	0.255
	Q1	290.10	299.40	367.40	416.50	442.90	493.70	328.10	276.20	192.40	179.60	149.90	197.70
	Q4	487.90	516.80	645.00	830.40	829.70	882.40	858.40	804.60	558.10	442.90	385.40	431.80
B(0.70 ; 1.00) $\hat{\phi}_1$=0.28 $\hat{\phi}_2$=0.04	M(τ)	546	782	828	830	724	773	690	627	417	405	353	359
	S(τ)	83	82	113	142	122	182	214	172	97	45	33	76
	CV(τ)	0.152	0.105	0.136	0.171	0.169	0.235	0.310	0.274	0.233	0.111	0.093	0.212
	Q1	400.70	605.10	676.30	523.90	429.40	440.70	330.70	325.40	287.60	318.00	304.60	170.30
	Q4	582.00	830.10	931.60	938.50	830.50	932.40	899.50	739.70	499.30	419.60	368.60	404.70

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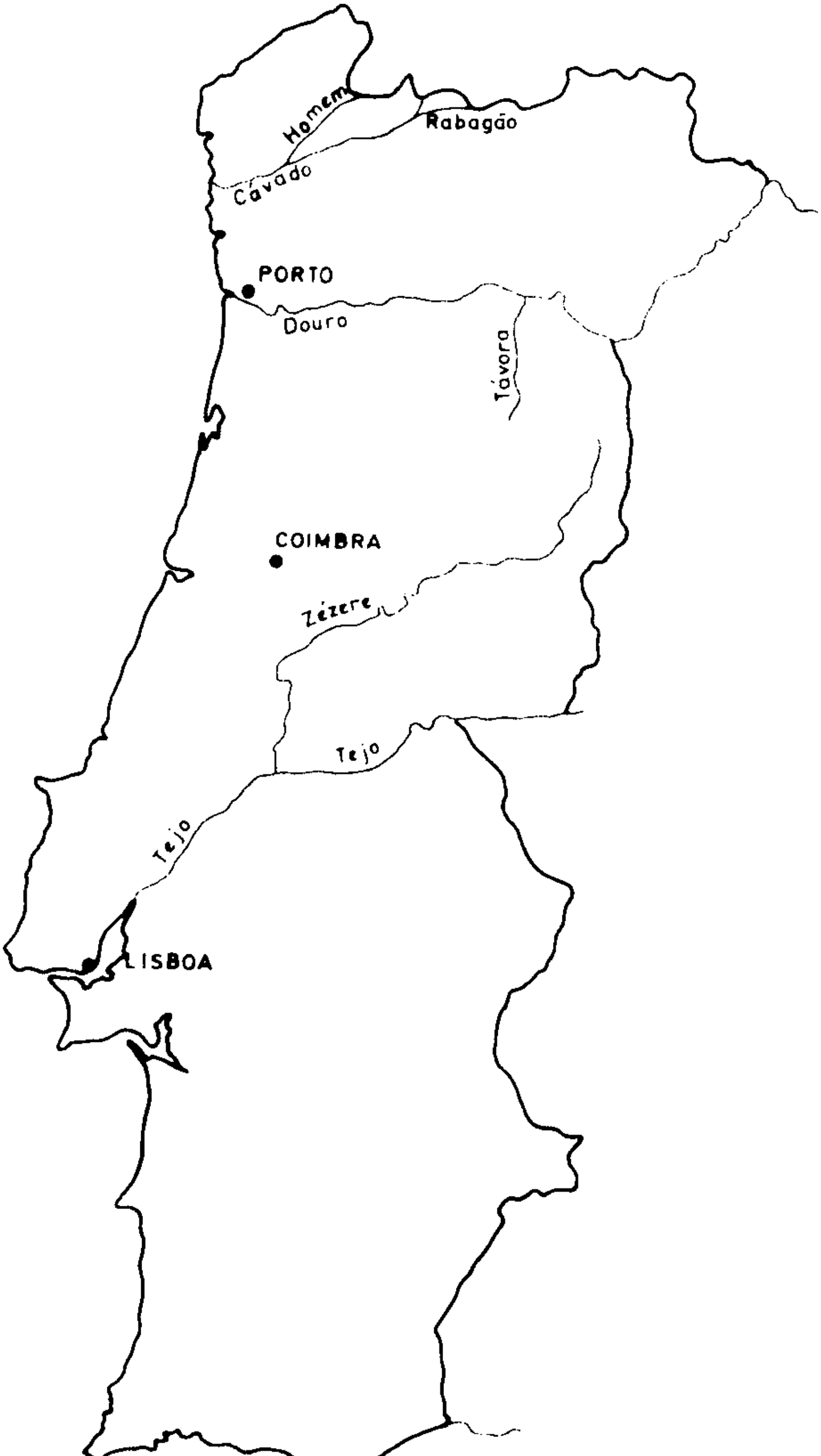

Figure 1 - Rivers with major hydro-electric plants

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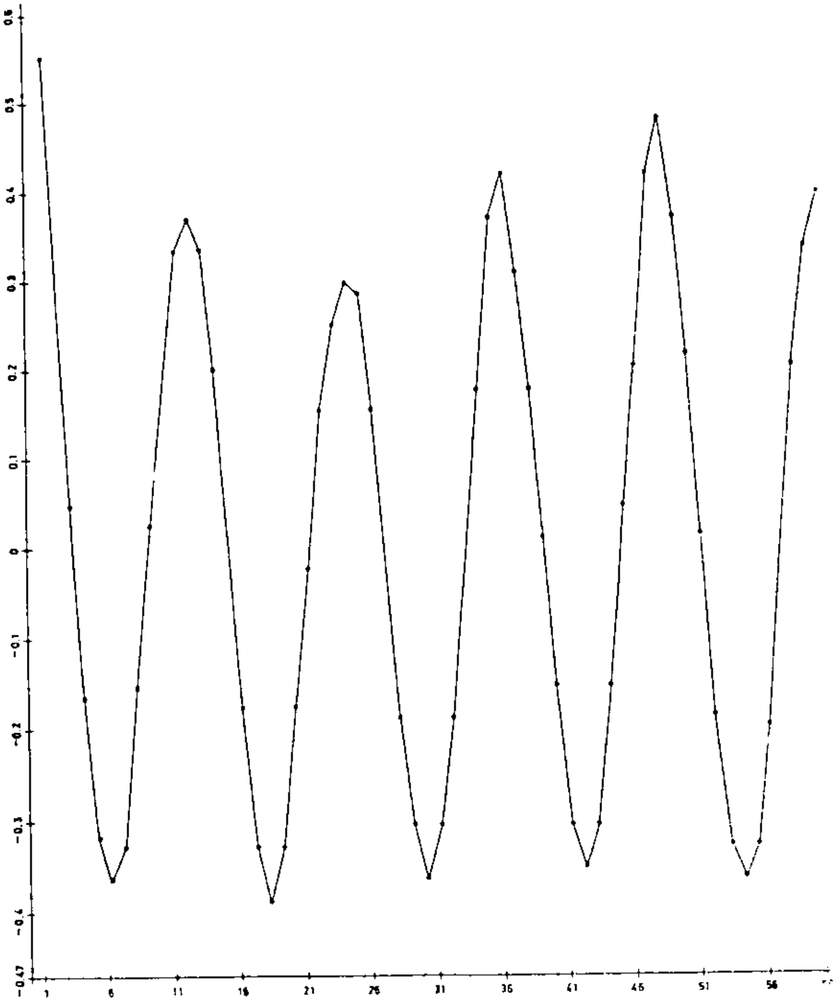

Figure 2 - Estimated autocorrelation for System A inflows

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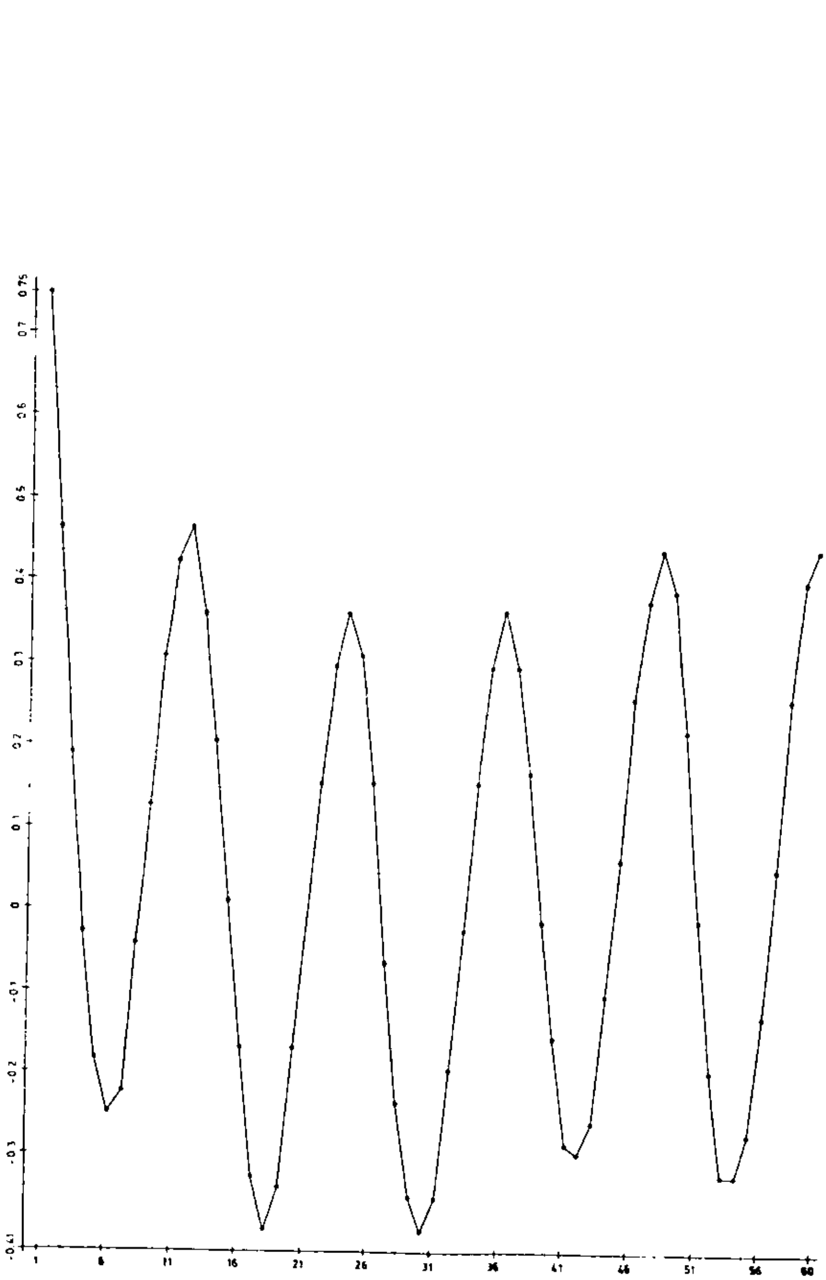

Figure 3 - Estimated autocorrelation for system B inflows

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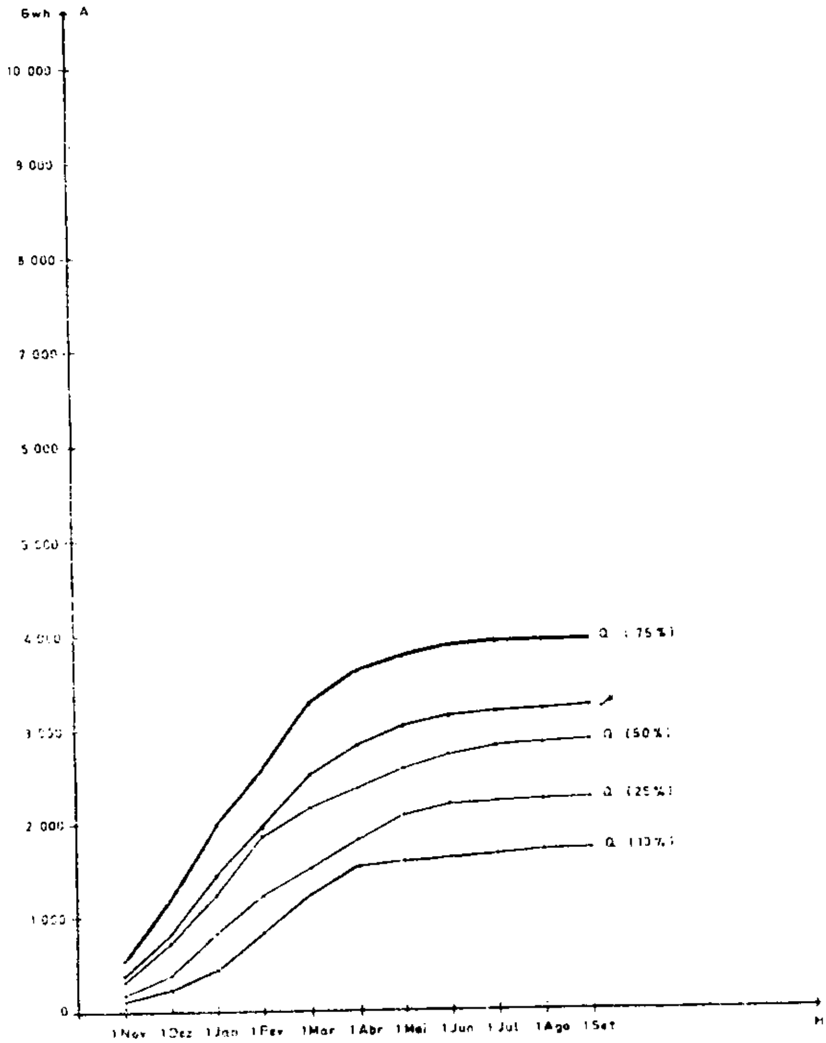

Figure 4 - Cumulative monthly inflows (system A)

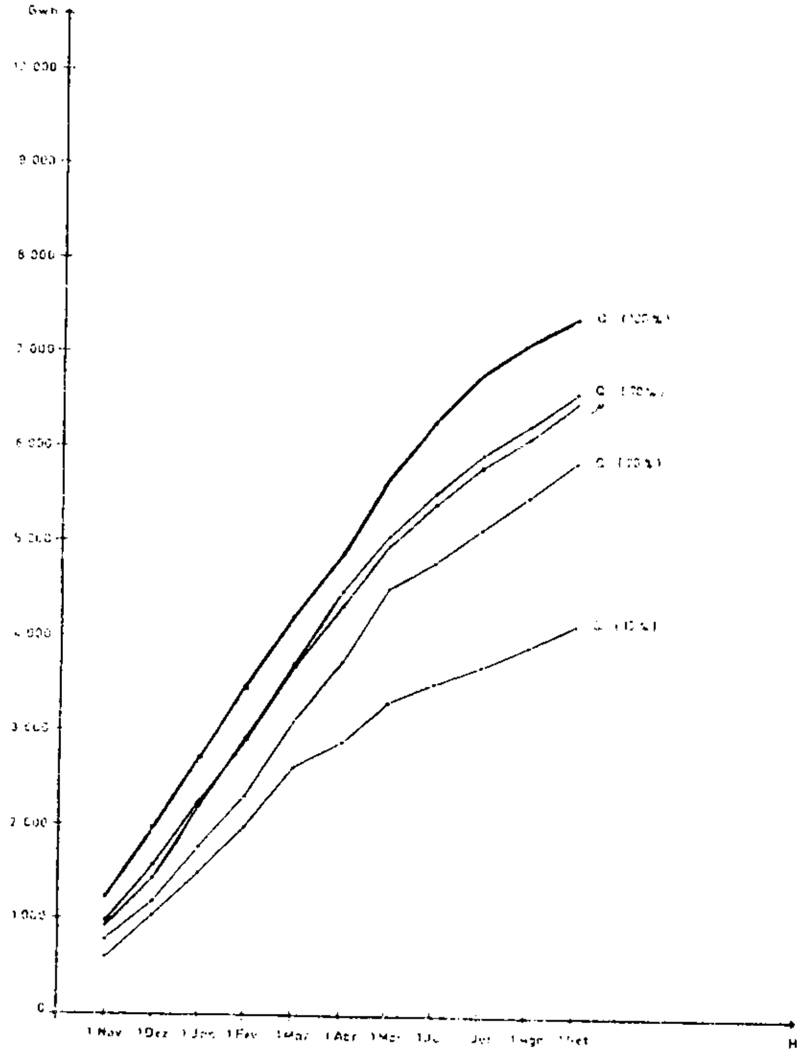

Figure 5 - Cumulative monthly inflows (system B)

NEW JERSEY GEOLOGICAL SURVEY

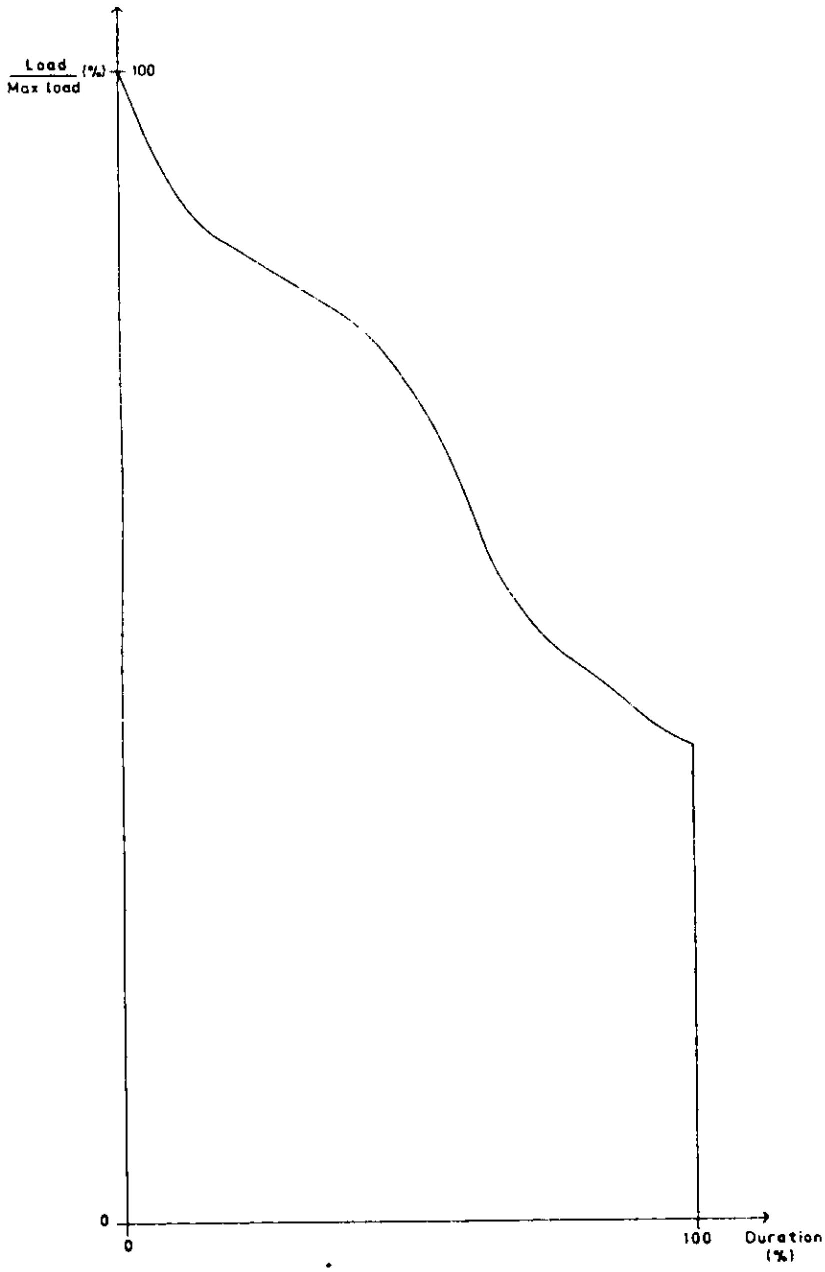

Figure 6 - A load duration curve

NEW JERSEY GEOLOGICAL SURVEY

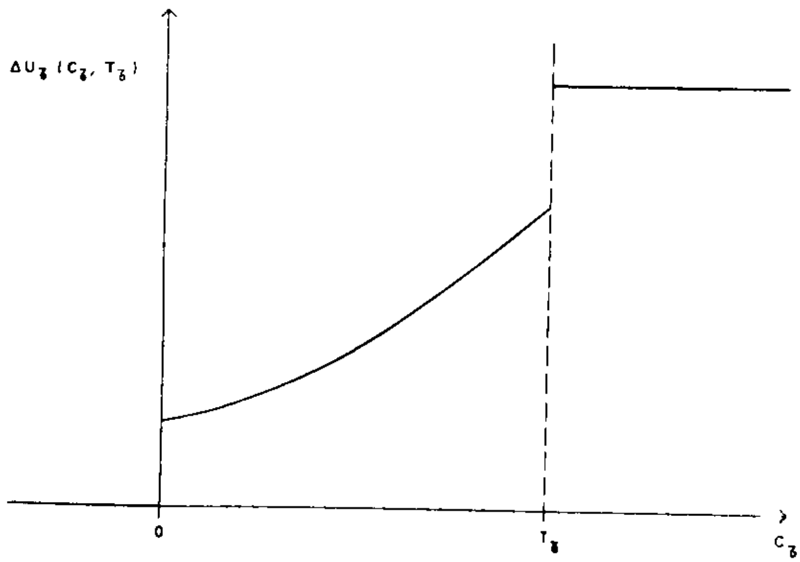

Figure 7 - ΔU_{z} as a function of C_{z} and T_{z}

NEW JERSEY GEOLOGICAL SURVEY

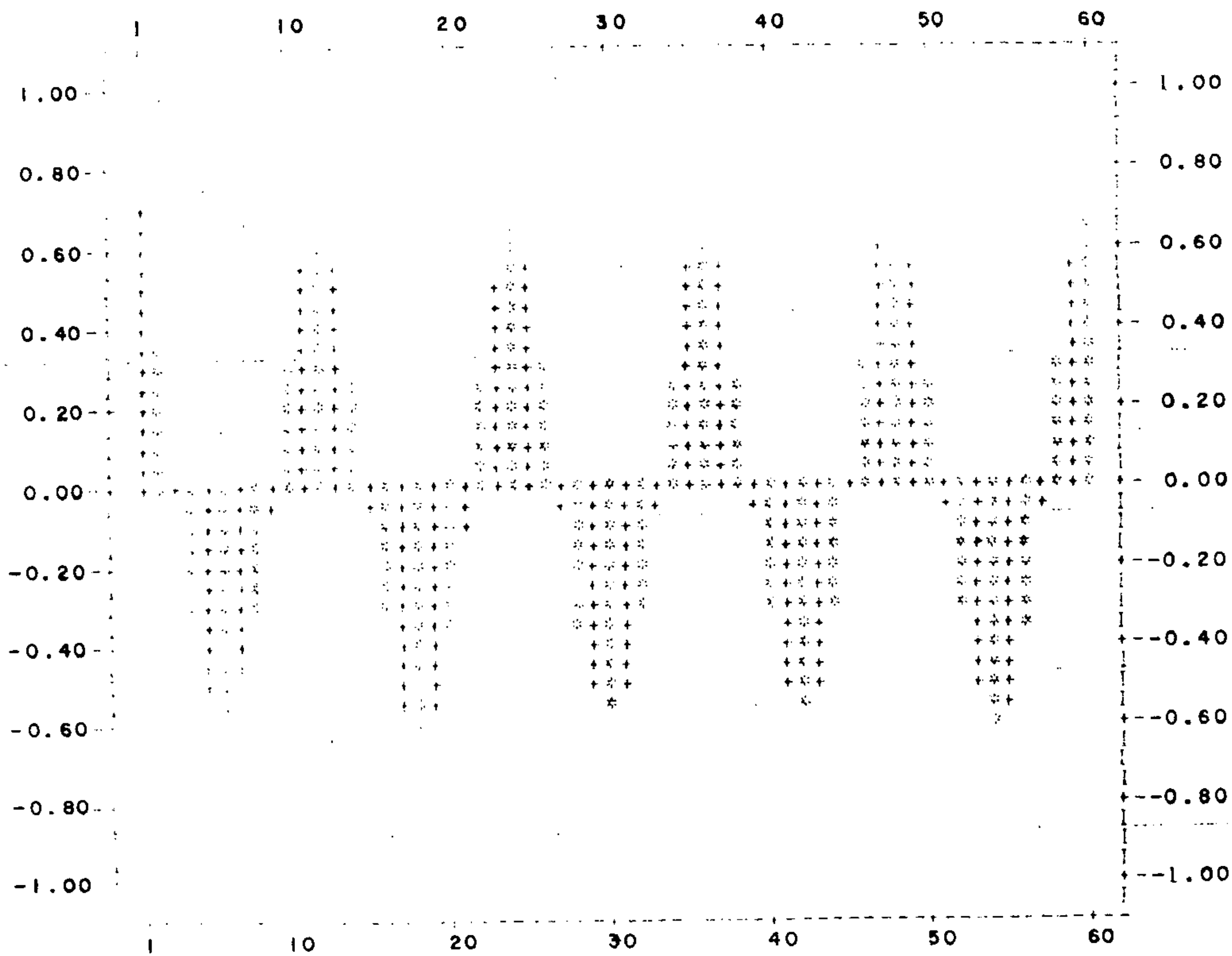

Figure 8 - Estimated autocorrelation for logarithmic inflows (system A)

NEW JERSEY GEOLOGICAL SURVEY

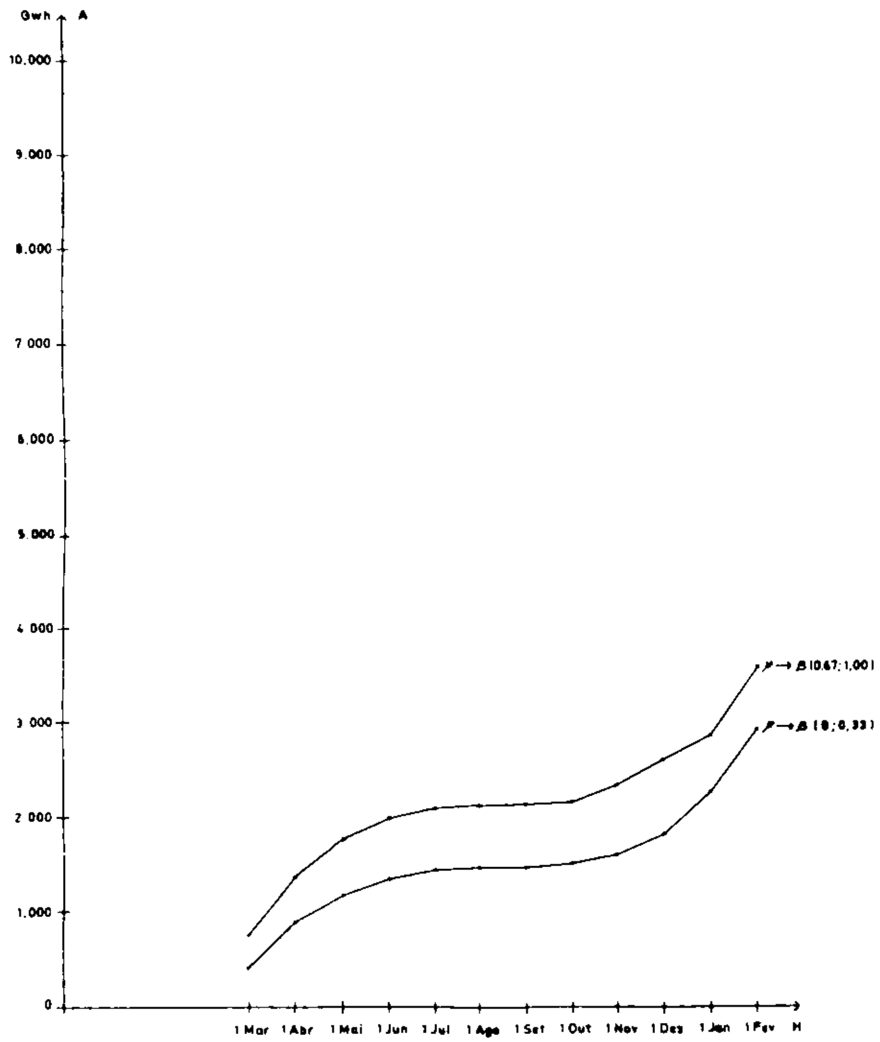

Figure 9 - Estimated means of A with t_o = 1 FEB (system A) using (0;0.33) and (0.67;1.00)

NEW JERSEY GEOLOGICAL SURVEY

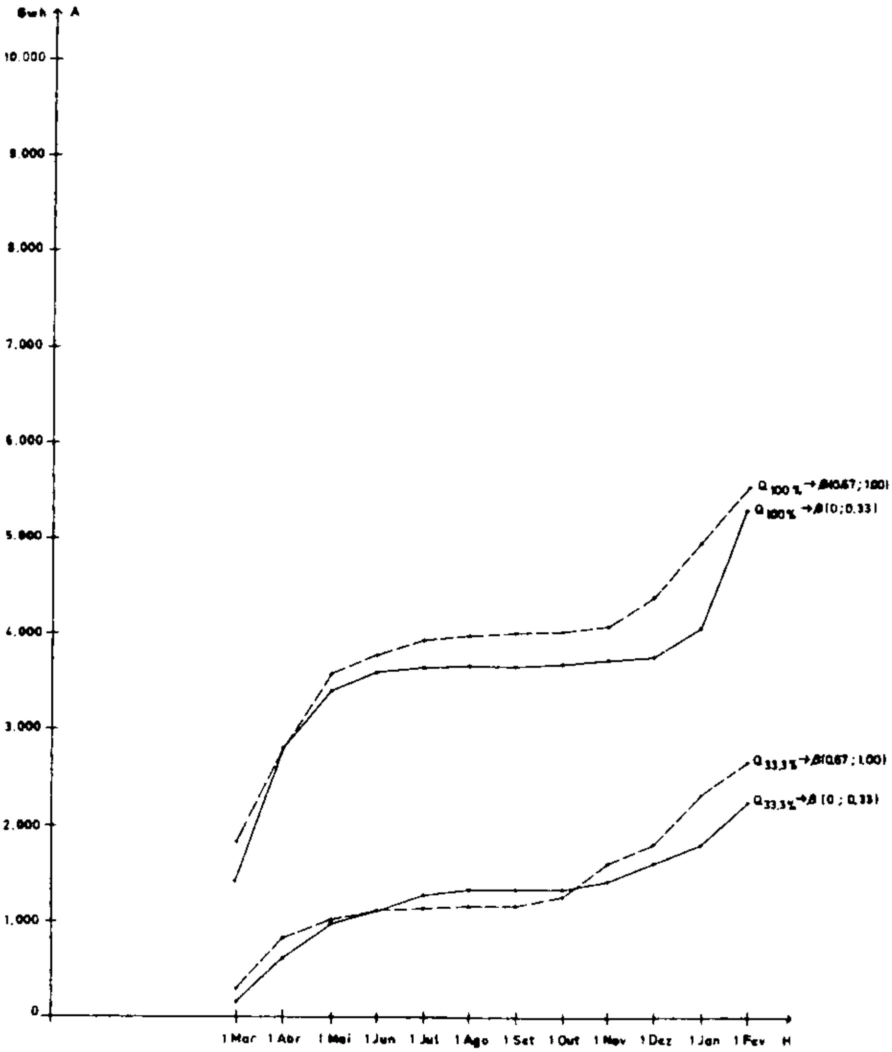

Figure 10 - Estimated quantiles of A with t_o = 1 FEB (system A) using B(0;0.33) and B (0.67;1.00)

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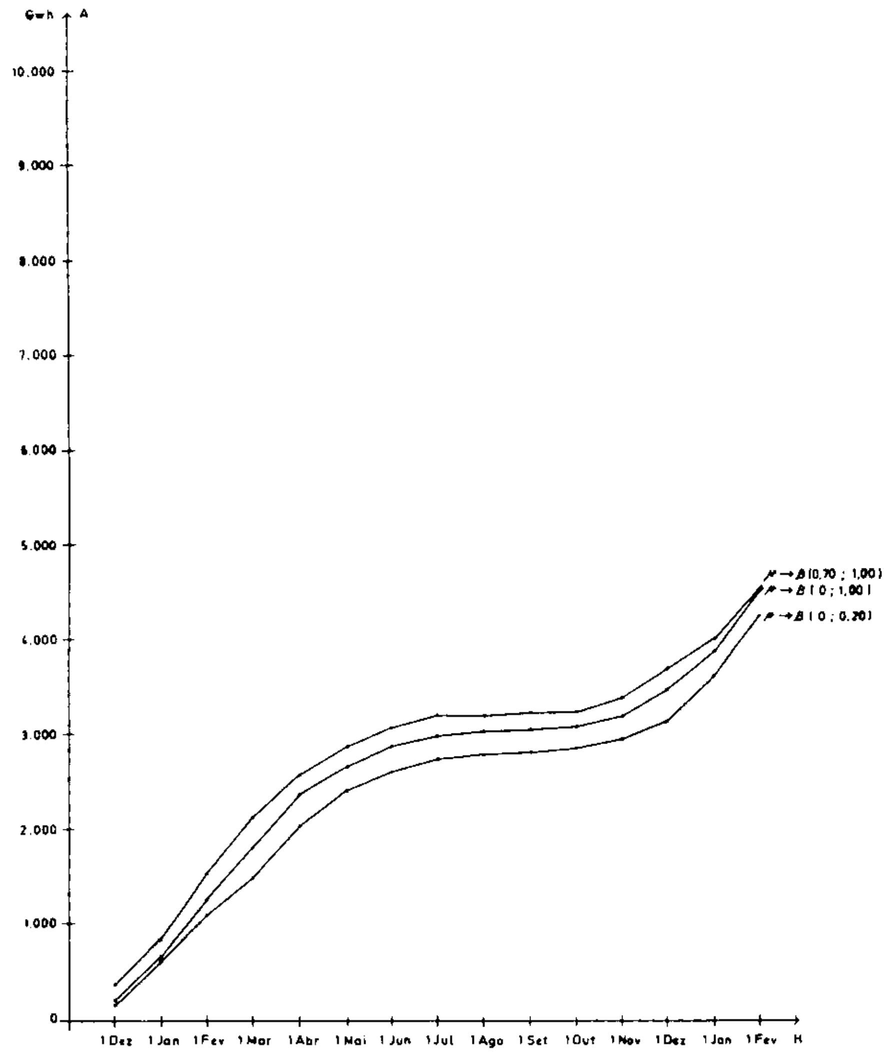

Figure 11 - Estimated means of A with t_O = 1 NOV (system A) using B (0;0.20); B(0.70;100) and B(0;1.00)

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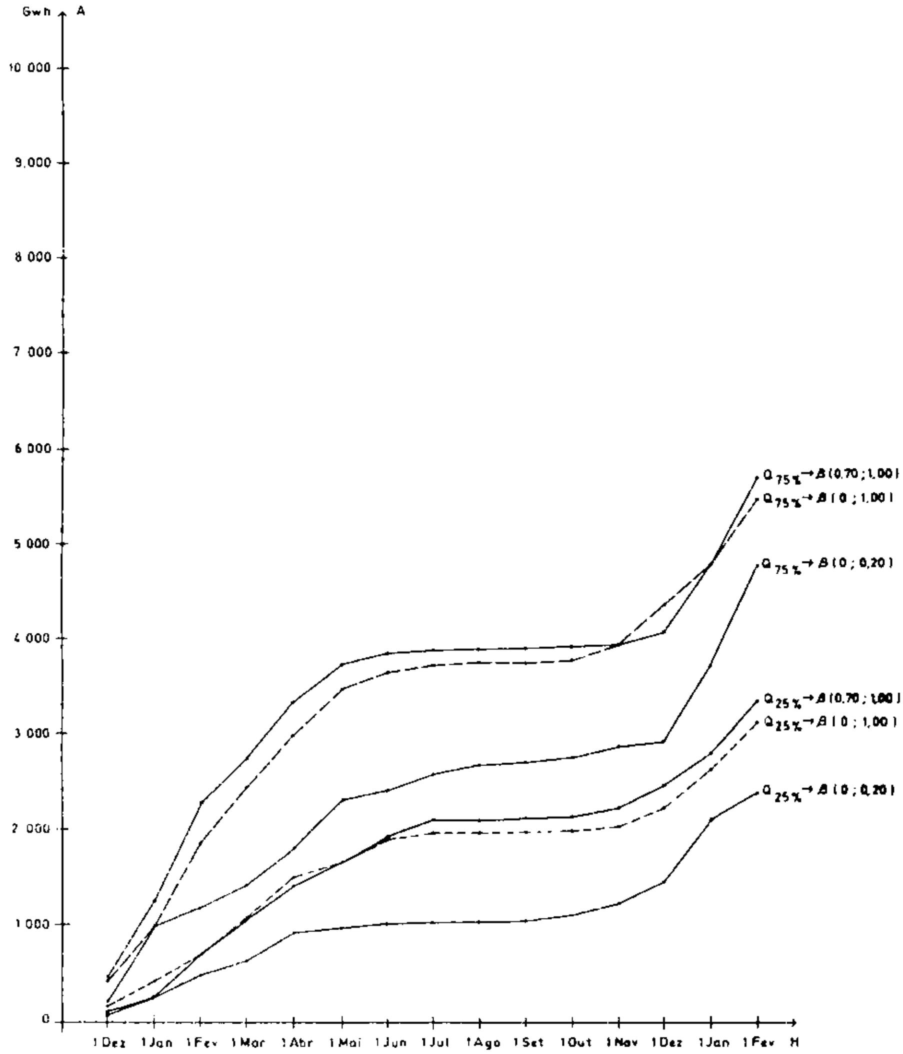

Figure 12 - Estimated quantiles of A with t_o = 1 NOV (system A) using B(0;20), B(0.70;1.00) and B(0;1.00)

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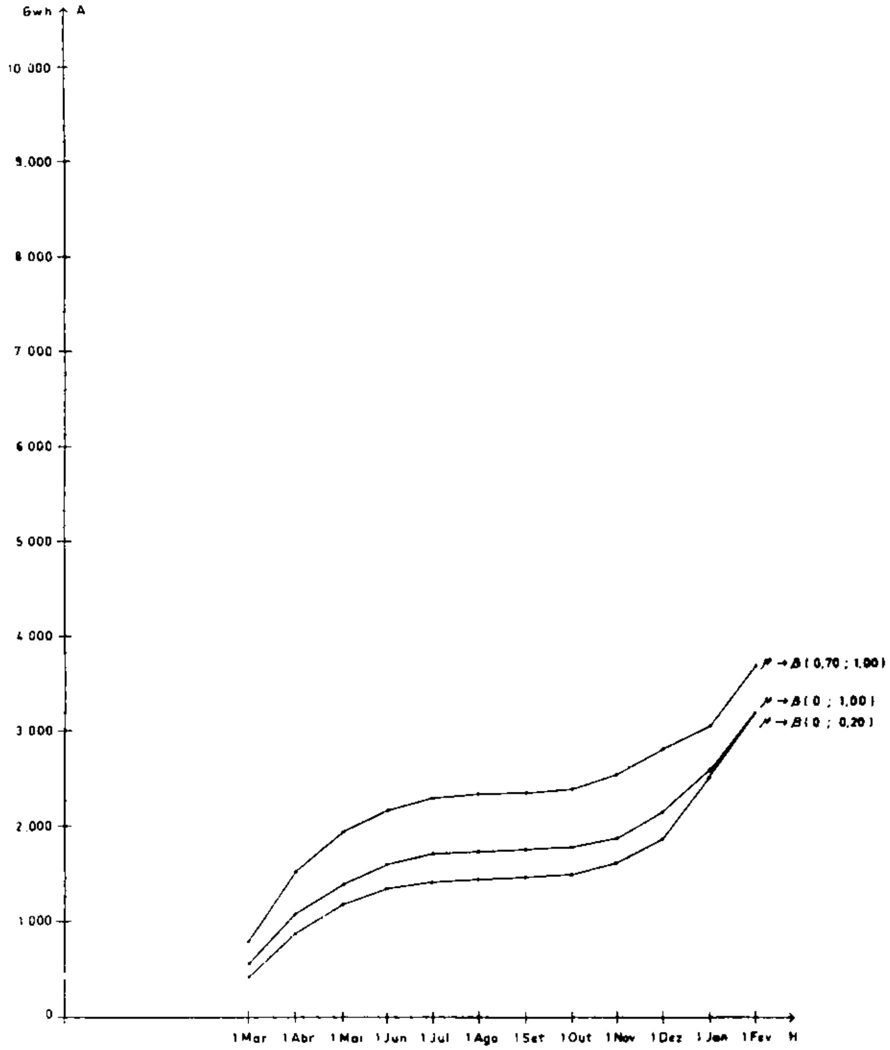

Figure 13 - Estimated means of A with t_o = 1 FEB (system A) using B(0;20), B(0.70;1.00) and B(0;1.00)

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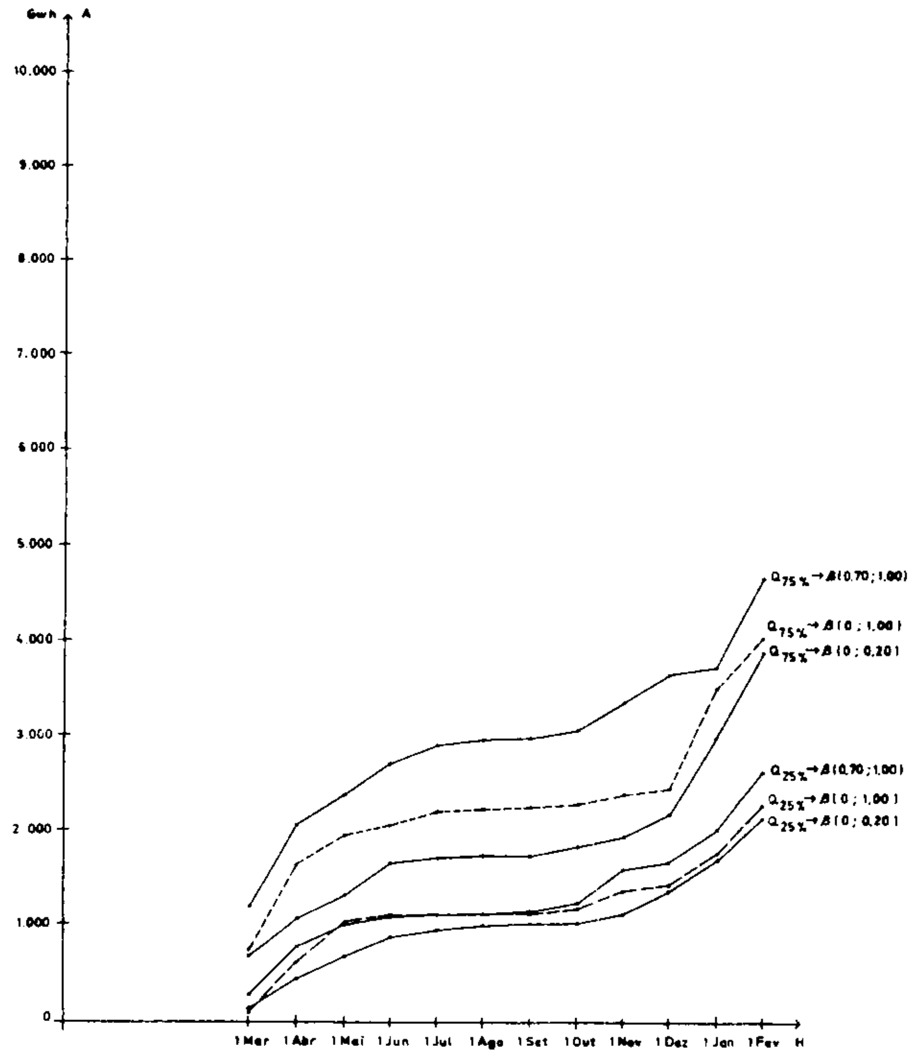

Figure 14 - Estimated quantiles of A with t_o = 1 FEB (system A) using B(0;0.20), B(0.70;1.00) and B(0;1.00)

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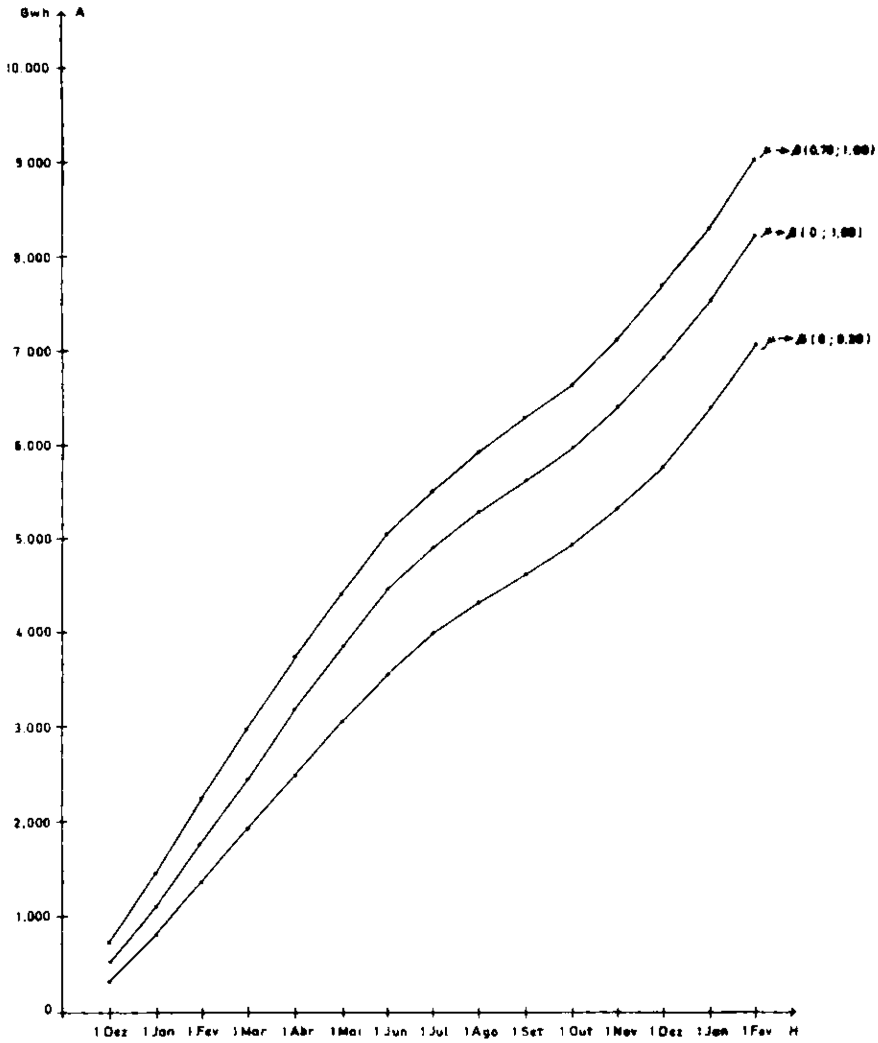

Figure 15 - Estimated means of A with t_o = 1 NOV (system B) using B(0;20), B(0.70;1.00) and B(0;1.00)

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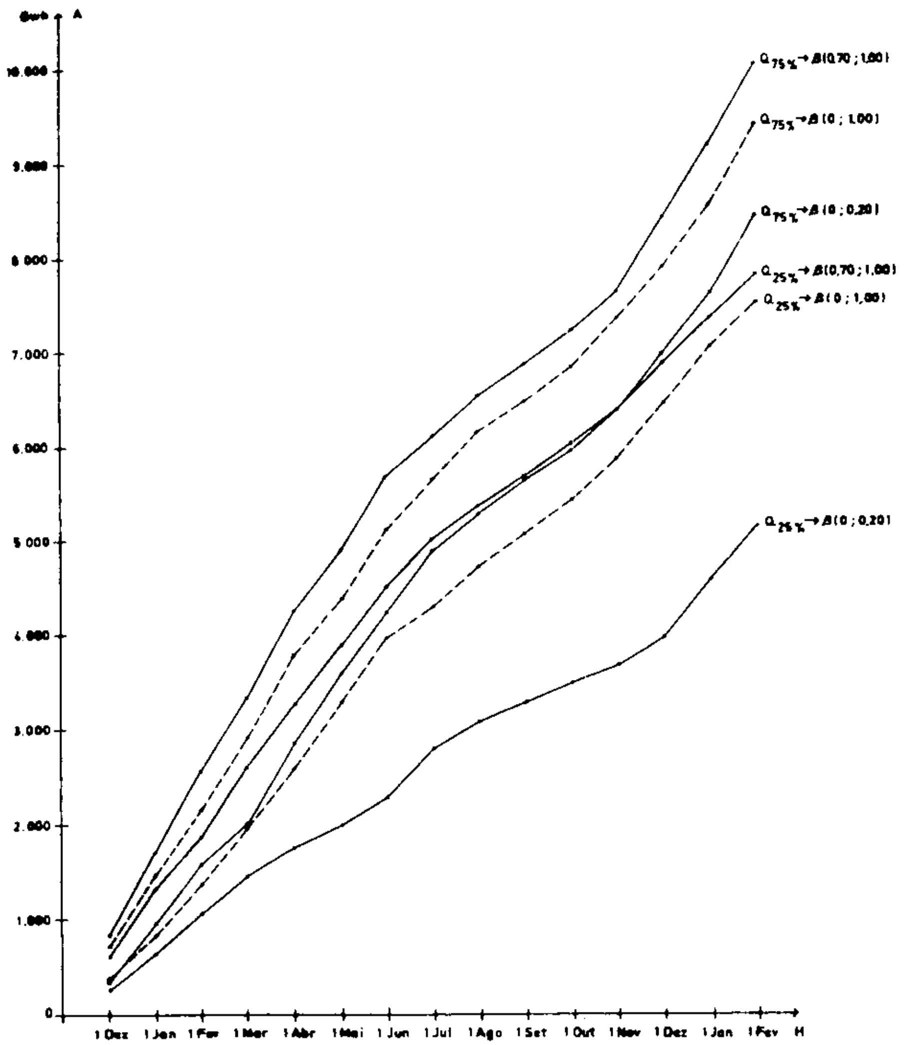

Figure 16 - Estimated quantiles of A with t_o = 1 NOV (system B) using B(0;0.20), B(0.70;1.00) and B(0;1.00)

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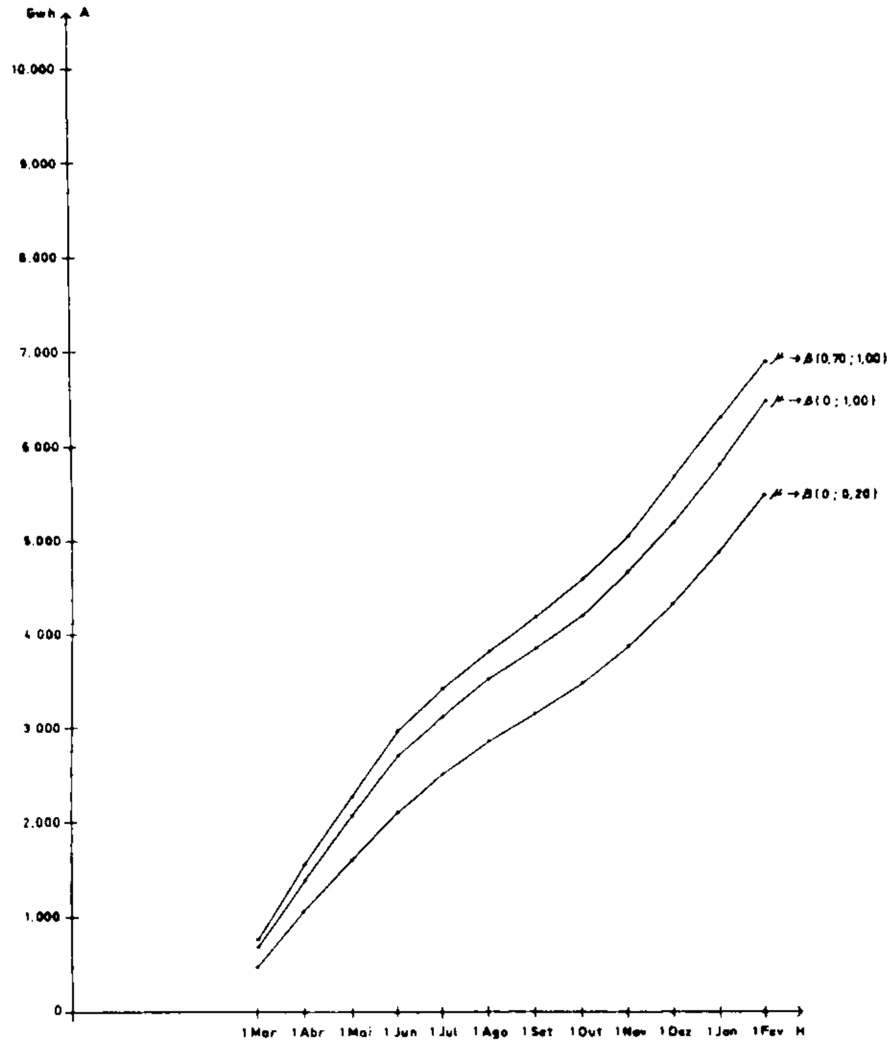

Figure 17 - Estimated means of A with t_o = 1 FEB (system B) using B(0;0.20), B(0.70;1.00) and B(0;1.00)

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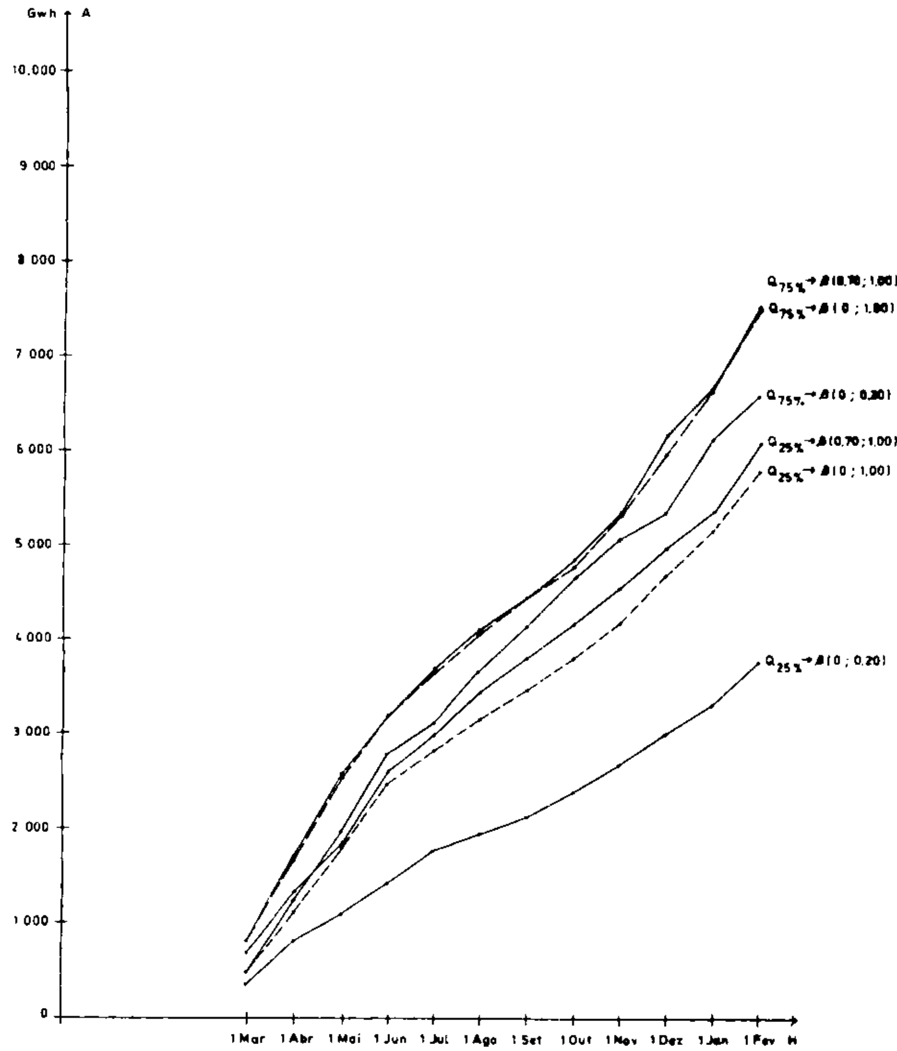

Figure 18 - Estimated quantiles of A with t_o = 1 FEB (system B) using B(0;0.20), B(0.70;1.00) and B(0;1.00)

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APPENDIX

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Columbia University

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Geological Survey, Reston, Va.

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*Died, June 1979.

Appendix 1

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Raphael Hurwitz
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H. William Menard
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U.S. Dept. of the Interior (1978-)
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Appendix 4

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