INFORMATION DISSEMINATION IN THE WATER RESOURCES FIELD

by

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ABSTRACT

The transfer and dissemination of information is a crucial element in the provision of adequate water resources. This is recognized by the United States Department of the Interior Office of Water Research and Technology. Through this agency the Water Resources Scientific Infromation Center (WRSIC) has been maintained as a national system for the storage and retrieval of abstracts of publications related to water resources research. Since its establishment in 1968 until 1976 WRSIC has compiled approximately 90,000 abstracts of publications dealing with water resources. Individuals and organizations which utilize this data base find it a very substantial help in their work. Users ranging from the most applied practitioner of water distribution to individuals doing exotic research on the fundamental properties of water can benefit from utilization of the WRSIC information base.

This study examines the total picture of information distribution in the water resources field from the viewpoint of persons seeking information. Although the study examines computerized searches from the WRSIC system, it views information dissemination as a whole and is not an evaluation of the WRSIC system *per se*. The present status of information dissemination in the water resources field is evaluated. In addition, recommendations are made for improvements in this area.

1. Overall Information Dissemination Process

Research on all aspects of water is performed for the purpose of improving the quality and quantity of available water resources. Thus it involves a large number of specific disciplines and types of endeavors. Included among these are engineering, physical sciences, life sciences, agriculture, law, and sociology.

The well being of the United States during coming decades is absolutely dependent upon the quality and availability of water. This is especially true considering the two imperatives required for the maintenance of the United States as a major economic power. These are high food productivity and domestic energy self sufficiency. For example, crop production in many Western states depends upon pumping of large quantities of irrigation water from aquifers whose levels are steadily decreasing. The energy shortage has added a massive new dimension to the water problem. Enormous quantities of water are required for the production of energy from new sources such as synthetic natural gas or shale oil. To compound the problem, some of the best sources of this energy are located in regions where water is already in very short supply. Utilization of coal, the United States' most abundant resource, creates severe water pollution problems. These include acid mine water production, mobilization of toxic elements, and disturbance of underground aquifers. At the present time imported petroleum is largely paid for by exportation of foodstuffs. Production of this food requires large quantities of irrigation water. Through this indirect path the energy shortage places an additional burden upon limited water resources.

Thus, it is easy to make a case for a high level of research on water resources. The making of wise, hard decisions regarding the use and allocation of water depends upon detailed knowledge of all facets of water and water resources. Fortunately, appreciable research has been carried out in these areas. Considering the magnitude of the problem, it is by no means certain that this research effort is sufficient in scope and funding. Nevertheless, researchers and the agencies which support them have done a good

job of compiling a large, useful base of knowledge in the field of water resources.

Information transfer is the facet of research most frequently performed inadequately. Generally the researcher tends to think of information transfer in terms of publication in professional journals. This mechanism is adequate for communication among researchers at the same level in the same profession. However, water resources is a large, mission-oriented area involving many specific kinds and levels of endeavor. Therefore, an adequate information dissemination program must include many vehicles besides professional journals. The importance of water resources information dissemination has been recognized by the United States Department of the Interior Office of Water Research and Technology (OWRT) and its predecessor organizations, and emphasis has been placed in this area. There is a continuing need to study and upgrade information transfer processes. Therefore, the purpose of this study is to evaluate existing means of information dissemination and to make recommendations for their improvement.

Discussion of water resources information dissemination is facilitated by a relatively detailed - and by necessity complex - picture of the overall information dissemination process. Such a picture is shown in Figure 1. In the interest of simplicity, the actual channels through which information is transferred - professional journals, libraries, computerized data retrieval systems, newspapers - are not shown in the diagram. Each aspect of this total picture will be discussed.

2. Information Consumers and Producers

Researchers in various disciplines are both consumers and producers of information. They may consist of individual academic research groups, non-profit research institutes, industrial research laboratories, and other entities. Individual researchers are normally categorized in various disciplines. This is especially true of academic research where the lines between divisions often are particularly sharp. Ideally researchers work at the frontiers of knowledge, building upon an existing knowledge base

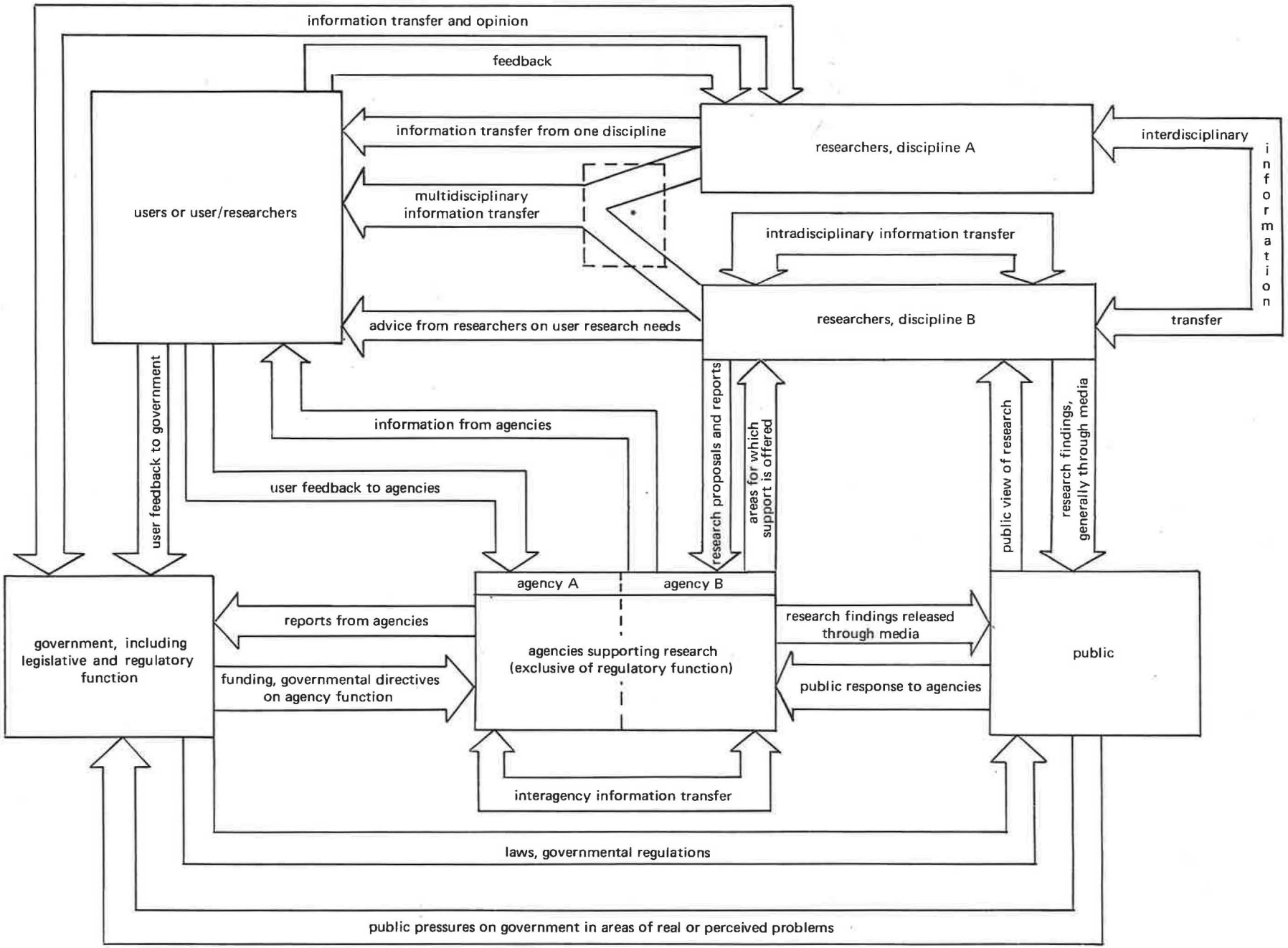


Figure 1. Information transfer among sectors concerned with water resources research.

*information synthesis

to produce new knowledge. Often this new knowledge does not have immediately obvious applications. In the case of mission-oriented research, however, knowledge of a specific kind is sought.

Although new knowledge is generally the objective of a research endeavor, the consolidation and interrelation of older knowledge is a vital - and often neglected - facet of research. This requires *synthesizers* who can analyze specific bodies of information, interpret it, and synthesize a more coherent whole from existing knowledge. Synthesizers can be especially valuable in pointing out areas where additional knowledge is needed.

Users of information constitute an extremely diverse group. Examples from water resources are industries, consulting concerns, water treatment plants, regulatory officials, and planners. Frequently there is not a sharp distinction between users and researhers. To a greater or lesser extent, users must do some research to acquire exactly the information needed for their mission. In such cases the research tends to be highly applied and objective-oriented. In the case of users in industry, such research results are often classified as proprietary information and do not get into the general information domain.

For the purposes of this discussion the term, *government*, is defined rather broadly. It applies to legislative and executive entities which make decisions, appropriate funds, and regulate. A separate term, *agency*, will be used to designate groups charged with research funding and administration. Federal, state, and local governments are all considered. Government plays a key role through its funding powers in determining what kinds of information will be obtained. Most scientific information which enters the public sector and becomes generally available is secured from projects funded by government sources. Basic decisions affecting research are made by executive and legislative bodies of government and have enormous influence upon the directions and priorities of research.

Government decision makers must rely upon information obtained from users, researchers, agencies, and the public in making crucial decisions affecting research. The quantity, accuracy, and

comprehensibility of this information is therefore essential to effective decision making by government. In addition to funding research, government has an important regulatory function. The success of government regulation is likewise dependent upon adequate high quality information to make sure that regulations are sound, that the right things are regulated, to avoid overregulation, and to make proper decisions.

Agencies are defined here as groups which support research. Through their determination of funding priorities, agencies are strongly involved in establishing the type of research which is performed. In some cases - notably the Environmental Protection Agency - an agency which funds research also has a regulatory function. In other cases, such as the United States Department of the Interior Office of Water Research and Technology (OWRT), the agency has no regulatory function. Agencies generally receive their funding from government sources, although there is appreciable research support from private foundations.

Agencies which fund and administer research receive information from many quarters, including researchers, users, government, and the public. Their mission is strongly dependent upon government directives and funding. Government funding and directives are, in turn, strongly dependent upon the type, quality, and effectiveness of information transferred from the agencies to the decision-making segment of government. Those agencies which have regulatory functions receive particularly intense flows of information (and pressure) from the public (including special interests groups).

The *public* receives information from researchers, agencies, and other sources through the media (newspapers, television, radio). Information transferred through the media tends to be of a largely "popular", sometimes "sensational," nature. Public opinion, generated in part upon the basis of information received through the media, is brought to bear upon decision making segments of government. Groups with special interests are especially active in making their opinions known to government.

3. Information Transfer Involving Researchers

The most sophisticated modes of information transfer exist among researchers, particularly those in the same discipline. This occurs largely through professional journals. The volume of professional journal publication is enormous. Approximately 10,000 specialized journals are published in the United States, alone. Furthermore, professional meetings and symposia and the published proceedings from these provide additional channels for information transfer.

There are, however, deficiencies in information transfer even within the same discipline. The large volume of published work within any of the relatively large disciplines makes it quite difficult to keep current with the literature in the discipline. The proliferation of journals, many of dubious quality and limited circulation, tends to fragment the channels of information transfer. In some disciplines, or specialties therein, information transfer is largely confined to one or two select journals. In such cases it is not unknown for editorial and reviewing "establishments" to stifle new information if it goes contrary to the prevailing conventional wisdom. Thus, the history of science contains examples of new ideas which initially were suppressed, but later turned out to be landmarks in their field. (There are, of course, far more examples of crackpot ideas and theories which proved to be false, sometimes after the expenditure of large amounts of effort and money.)

Journals suffer from other deficiencies. They are expensive to subscribers, libraries, and research grants (in the form of page charges). The brevity of research papers often prevents the publication of details, such as experimental procedures, which might be crucial to the needs of the reader. Although incomplete and preliminary findings can be very useful in a rapidly moving research area, the publication of partial results is discouraged by journals. Similarly, the publication of negative results is discouraged, although knowing what does not work can be very useful information and can save another researcher a great deal of time. The rewards system among personnel involved in research normally encourages the production of large numbers of papers at the expense

of those which might be particularly innovative or complete.

Information transfer among disciplines is considerably less facile than that within a discipline. There are fewer interdisciplinary journals, and their quality is in general lower than those within a discipline. In part, this has resulted because publication in an interdisciplinary journal is looked upon, from the viewpoint of a discipline, with relatively less favor than publication in a discipline-oriented journal. In addition, the specialized jargon of disciplines tends to be a handicap to communication. However, most of the water resources problems of greatest research need are those which cut across disciplinary lines, making interdisciplinary communication a very important activity.

One of the weakest - yet most important - links in the whole information transfer scheme is that from researchers to users. It is unfortunately true that many research findings of potentially high utility are unused because of a lack of information transfer to potential users. There are several reasons for this sad state of affairs. A user frequently does not have expertise in a discipline from which information is needed and does not have ready access to the journals in which such information is published. Good channels do not exist by which researchers can publish for the consumption of non-specialized users. Such publication generally would not receive favorable peer recognition. As will be discussed later, adequate information transfer from a specialized research discipline to non-specialized users is the single greatest area of need in the field of water resources information dissemination.

Communication from researchers to the public generally occurs through relatively unsystematic channels. Frequently this happens when a research finding can be popularized to make a story for the media. The accuracy of these stories is not always high. Researchers misquoted or otherwise "burnt" by the press are often very reticent about communicating with the media. The need to have a topic which "sells" results in some areas being highly publicized, whereas others get little or no attention. This, too, is an area where inprovement is needed.

There is a relatively systematic and strong flow of information from researchers to agencies. Reporting requirements normally dictate that this be the case. In many agencies peer review is one of the primary mechanisms by which proposals are selected for funding and by which - as an inevitable consequence - research priorities are set. Peer review is strongly favored in the research community and has been responsible for the high quality of much research which has been performed. On the negative side, it has sometimes resulted in the funding of research with little practical importance - and in some cases not a great deal of fundamental significance. Research "establishments," often populated by second or third generation researchers tend to build up around specialized areas popularized by especially persuasive individuals or groups. On the other hand, areas of real need and importance have not received support because of the lack of articulate proponents in the research community.

Communication between researchers and legislative bodies and executive groups in government normally goes through indirect channels. Frequently funding agencies serve as intermediaries in this transfer. The media may be involved in publicizing research findings which in turn influence governmental decisions. Examples are highly publicized findings of chlorinated hydrocarbons in some water supplies or the alleged threat to the ozone layer by aerosol can Freon. In rare cases the publicity surrounding a particular research finding may be sufficient to result in congressional committee hearings.

4. Information Transfer Involving Users

The importance of information transfer from researchers to users has been discussed previously in this report. Users of research results need to have effective means to communicate their needs to researchers. Two-way communication is essential because in some cases users do not really understand what they need. In some cases the research requested is not feasible or worth the effort and expense required to obtain it.

User input to agencies can be valuable in setting meaningful research priorities. Such information often is not sought, partic-

ularly in any sort of systematic fashion. An example of this channel of communication is the bringing in of state and municipal officials to express their preferences in the funding of OWRT Allotment proposals which would be beneficial to regulation, water resource allocation, and other activities.

The flow of information from users to regulatory agencies can be quite intense, particularly when the users are being regulated. Users affected by regulations and government decisions generally communicate their opinions effectively to governmental bodies.

5. Information Transfer Involving Agencies

Agencies normally administer research funds appropriated by governmental bodies. Accurate communication of the desires of the body appropriating funds to the agency charged with the expenditure of the funds is of course essential to carrying out the mission for which the funds were appropriated. The success and even survival of an agency may depend upon how effectively it communicates with appropriating and decision-making branches of government.

Information transfer between agencies is a frequently overlooked, but vitally important communications link. "The right hand does not know what the left hand is doing" is all too frequently an accurate assessment of the interaction among funding agencies. As an example of the kind of communication which could be very helpful, assume that an agency concerned with water quality finds that there are unsoved problems regarding acid mine water production and that, specifically, an understanding is needed of the ways in which bacteria bring about the transformation of pyrite to sulfuric acid. The research required is more fundamental and expensive than that which the water quality agency is prepared to fund. In such a case the research need could be communicated to an agency with a capability for funding large scale projects in microbiology. Thus, the latter agency could solicit research proposals from microbiologists capable of studying the bacteria responsible for acid mine water formation.

The history of research funding has been marked by periods of intense activity in response to national needs of real or perceived acuity. Examples are the environmental concern of the late 1960's or the more recent energy crisis. One result is the establishment of agencies or new branches of existing agencies accompanied by very rapid funding increases. Sometimes the buildup is so rapid that hasty decisions must be made regarding research funding. As a result the funds often are not spent so effectively as might be hoped. In such cases communication from established agencies regarding research needs can be very helpful. As an example, it is obvious that the need for energy self-sufficiency in the United States is going to result in a massive expenditure of funds for energy-related research during the next two decades. There is every reason that this should be done. A solution to the energy problem is crucial to solving most of the other major problems (inflation, food production, environmental degradation) facing the United States. The magnitude of the problem is so great and the stakes so high, that expenditures for energy research and development will far exceed those for previous endeavors in nuclear science, space and health. The energy problem in the United States is largely a problem of water supply and quality. Coal mining, for example, produces acid mine water and may result in disruption of aquifers. Coal conversion facilities require large quantities of water. A great deal of research will be required to ensure adequate water quality and quantity for energy development. It is vital, therefore, that agencies with long-standing expertise in water research communicate effectively to energy research agencies the needs and priorities for further research on water related to energy development.

The flow of information between agencies and researchers is intense. Most of this information flow regards the acquisition and funding of research grants. Generally agency instructions in regard to applying for and reporting upon research grants are detailed and explicit. Research proposals from researchers to agencies are a form of information transfer. One area in which there is a need for better communication has to do with an objective evaluation of the capability of a particular researcher to

accomplish stated research objectives. In some cases investigators are more skillful at writing convincing research proposals than they are at accomplishing the proposed research. The reverse may also be true. Means are needed for effective, objective evaluation by third parties. For established investigators and research organizations, computerized evaluations of research citations and their significance hold some potential for predicting research potential.

Users of research can communicate their perceptions of research needs to agencies, although here the channels are not generally well developed. Agencies may serve to transfer useful information to consumers of research results. The degree to which this is done varies widely with the type and function of the agency. It is an endeavor of considerable potential for agency activities.

6. Information Transfer Involving the Public Sector

Information is transferred to the public sector primarily through the media (newspapers, television, radio). The importance of accuracy in this information transfer cannot be overrated. Both the sources of information (*e.g.*, researchers) and the media have a special responsibility for the dissemination of accurate, balanced information to the public sector. This responsibility is often not met. One reason is that the news which "sells" tends to be "bad news" or sensational news.

The water resources area has not been immune to difficulties with accurate information transfer in the media. The furor over detergent phosphates provides a good example. The average citizen probably received an impression of these phosphates as toxic, dangerous substances. Indeed, articles in some student newspapers regarding detergent phosphates were headlined with a figure of a skull and crossbones and "deadly phosphates" written across the figure. In truth, phosphates suffer from being essential nutrients so that under limited circumstances they cause excessive plant growth in water. This can cause a damaging condition known as eutrophication in bodies of water receiving phosphate pollution. As a result of public concern fueled by the publicity about this topic, many

localities hastily banned phosphate-containing detergents. Potentially dangerous substitutes were hastily introduced, and in some cases removed again at considerable expense.

Another more recent example involves chloroform in drinking water. It should be noted that until recently (and wisely) banned from that use, chloroform was used as an ingredient of some cough syrups at approximately 1 percent levels. Around 1974 it was found as a contaminant of some drinking water supplies, notably that of New Orleans. The unlikely possibility that chloroform at the part per trillion level would cause detrimental health effects has received much publicity in the media. By way of comparison, the tremendous, life saving improvement of municipal water quality during the last 50 years has scarcely been mentioned.

Researchers and others with access to accurate technical information have a special responsibility to transfer this information in an understandable form to the media. The media in turn are obligated to pass this information on to the public in an accurate and balanced fashion.

7. Computerized Information Retrieval Systems

Since 1968 the United States Department of the Interior has been involved in the development of a system for the acquisition, cataloging and dissemination of information in the water resources field. Through the Water Resources Scientific Information Center (WRSIC) a system has been developed for the storage and retrieval of selected water resources abstracts. Approximately 90,000 abstracts had been compiled by 1976. These abstracts are distributed through WATER RESOURCE ABSTRACTS, BIBLIOGRAPHIES. They are also accessible through a nation-wide computerized information retrieval network. This network has terminals at several locations in the United States. In 1976 terminals were available at the University of Arizona, Cornell University, North Carolina State University, the University of Wisconsin, and (Virginia only) Virginia Polytechnic Institute and State University.

Computerized systems can be used to retrieve abstracts in a specific area from a suitably cataloged large file of abstracts.

One of the first successful systems for accomplishing this was the General Information Processing System (GIPSY) developed at the University of Oklahoma. Another widely used system developed by the Atomic Energy Commission (now Energy Research and Development Administration is RECON (REmote CONsole). It is specifically designed to search indexes. These and similar systems are of course applicable to data bases other than those dealing with water resources data. It is not the purpose of this report to go into details on computerized literature search systems. However, it is necessary to have some understanding of the functions and operations of these systems.

Even with the advent of the computer, searching the literature is generally a manual process. The individual with access to a well stocked library goes through individual journals and technical reports. Aid is provided by special services, such as the highly sophisticated CHEMICAL ABSTRACTS service, with its well designed computer-printed index system. Review articles and personal communications (the "grapevine") are very helpful. However, even with the best of facilities, a manual search of the literature is a time-consuming, sometimes uncertain undertaking. It is little wonder, therefore, that the capabilities of the computer have been developed for searching the technical literature. Computerized literature search systems depend largely upon seeking out key words which identify desired citations, selecting those citations which apply to the search topic, and discarding those which do not. Thus the key consideration, and major challenge of computerized systems is to devise a basically mathematical mechanism to (ideally) take the place of human judgement - and misjudgement - in selecting the citations needed.

The basic operation of a computerized abstract retrieval system is the following: The operator must specify the data base to be searched. This is because there are many data bases besides WRSIC (including, for example, Toxic Materials Data Base, Energy Research and Development Projects File, *etc.*). A query is then formulated which hopefully will retrieve as many citations as possible containing desired information (along with, unavoidably, a

number of extraneous citations). This is a subset of information from the total data base. Statistical details (*e.g.*, number of citations) pertaining to this subset are displayed to assist the operator in evaluating the probable degree of adequacy of the subset. If the subset appears inadequate, instructions may be given to modify the subset. When statistics pertaining to the subset appear favorable in the operator's judgement, parts or all of the information may be displayed on a cathode ray tube or other device. If the information is judged satisfactory, it may be printed. If not, the query is formulated in a different manner and the search is repeated.

A user may obtain a WRSIC search from one of the WRSIC terminals by specifying desired authors, subject terms, or COWRR (Committee on Water Resources Research) categories. Subject terms in the form of *descriptors* are listed in *Water Resources Thesaurus,* 2nd edition, 1971. Descriptors are considered as "controlled" vocabulary, whereas other words are "free language." A paragraph describing the desired information may be submitted to a WRSIC center for processing by the staff. This is the mechanism preferred by some centers. The paragraph used to describe the information on chelation discussed in Section 9 is given below:

> "Information is desired on the sources, occurrence, levels, reactions, transport, effects, biological significance, degradation, analysis, and fates of chelating and complexing agents in natural waters and wastewaters. Included should be chelating agents and complexing agents from both pollutant and natural sources. Of particular significance is the role of chelating agents in the mobilization, colubilization, and transport of heavy metals and algal nutrient metals in water. Among the more significant specific chelating agents are NTA (nitrilotriacetic acid) EDTA (ethylenediaminetetraacetic acid), citrate, fulvic acid, and humic acid. In the case of the latter two materials try to exclude citations which do not deal specifically with their chelation properties. Please include all relevant citations."

Words which the requestor considers to be especially relevant to subject terms may be circled as a further aid in the search. In some cases only a few key citations are desired, and this may be specified. In this particular case a "broad spectrum"

search was desired. That was noted in the final paragraph of the request paragraph, "Please include all relevant citations."

The output from a computerized WRSIC search may be in several different forms. These are explained in a user's manual ("Searching Water Resource Literature by Computer," OWRT/WRSIC 75-001, Water Resources Scientific Information Center, Office of Water Research and Technology, U. S. Department of the Interior, Washington, D. C., March, 1975). Normally the output consists of an abstract describing the source (typically a journal article), the authors and their location, information about the source (such as journal volume number) and information regarding the mechanics of the search (*e.g.*, accession number). A typical abstract obtained from the search described above is the following:

set No.
↓
27/5/000001-000200// 48 ←*number of abstract in this printout*
acces- 74R09896 WRA-W7-19 05.A0
-sion No.→ (74-09896)DETERMINATION OF LABILE AND STRONGLY BOUND ←*title*
METALS IN LAKE WATER/
author→ CHAU,Y.K./LUM-SHUE-CHAN,K./
CANADA CENTRE FOR INLAND WATERS, BURLINGTON,(ONTARIO)./
WATER RESEARCH,VOL 8,NO 6,P 383-388,JUNE 1974.1 FIG,3 TAB,17 REF./
abstract→ DIFFERENTIAL PULSE ANODIC STRIPPING VOLTAMMETRY WAS APPLIED TO DIFFERENTIATE AND DETERMINE THE LABILE AND STRONGLY BOUND FORMS OF ZN,CD,PB AND CU IN LAKE WATER WITHOUT PRECONCENTRATION OF THE SAMPLE. THE SENSITIVITIES AS ESTABLISHED FOR AN OXIDATION PEAK CURRENT OF 0.020 MICROAMP ARE,0.2 PPB FOR ZN,0.4 PPB CD,0.7 PPB PB AND 0.5 PPB FOR CU.INTERFERENCES OF CATIONS AND ANIONS AND THE CHOICE OF A BUFFER SYSTEM ARE DISCUSSED.THE METHOD WAS APPLIED TO STUDY A NUMBER OF SMALL LAKES IN THE SUDBURY AREA, ONTARIO, CANDADA.(KNAPP-USGS)/
keywords→ POLAROGRAPHIC ANALYSIS/TRACE ELEMENTS/CHELATION/AQUEOUS SOLUTIONS/CHEMICAL ANALYSIS/WATER ANALYSIS/ELECTROCHEMISTRY/ ANALYTICAL TECHNIQUES/CADMIUM/LEAD/COPPER/

(Printing quality of the above is representative of actual printouts obtained.)

In addition to, or instead of the full abstracts, it is possible to list only titles and accession numbers. From this list the person requesting the search may select particularly interesting titles for a complete printout. This approach is often more desirable. There is a charge for additional or duplicated printouts.

8. Evaluation of Search Printouts

The two most important criteria for evaluating an information retrieval system are *recall* and *precision*. Recall is the percentage of relevant information in the data base which is retrieved. Suppose, for example, that a data base contains 200 abstracts actually relevant to the search and that a particular search retrieves 100 of these. The recall is 50 percent. It should be noted that relevancy is a subjective concept to a certain degree. This inevitably introduces some variability into the rate of recall.

Precision refers to the percentage of citations recalled which are actually relevant. Thus, if 100 citations are printed and 25 are relevant to the question addressed, the precision is 25 percent.

An ideal search would be one having 100 percent recall (all items in the data base relevant to the query are retrieved) and 100 percent precision (all irrelevant citations are rejected). In systems dealing with specific items of data (*e.g.*, annual levels of precipitation at official weather stations in the State of Missouri), this ideal is essentially achievable. It is difficult to achieve when the data base consists primarily of literature citations. Frequently it cannot be determined from the abstract alone whether a given citation is relevant to a query. The subject terms used to index the query may be inadequate to relate a citation to a particular query. The search specialist cannot be sufficiently expert in all areas to ensure complete recall and high precision. These parameters remain, however, useful indicators of the effectiveness of a particular search. Whereas, at least on a subjective basis, precision is relatively easy to evaluate, recall can be determined absolutely only through examination of each citation in the data base (a prohibitively time-consuming task when the base contains several thousand citations). A reasonably good idea of recall can be obtained by several searches of the data base, preferably by several different operators. These searches should be "broad spectrum" searches and will contain many irrelevant citations which must be rejected by the user.

In some cases it is desirable to deliberately choose a low

recall in order to obtain just a few references relevant to the query. Some information services suggest this approach. However, there are pitfalls involved because of the wide variation in abstracts obtained. For example, suppose that one wanted to have some basis for deciding on the safety of the detergent phosphate substitute, NTA. One abstract on this topic states that, "The substitution of NTA for phosphates in detergents may pose problems greater than the eutrophication associated with the use of the phosphates. NTA potentially may cause kidney damage, may chelate metal ions and thereby damage many types of equipment, or may degrade into secondary amines and become carcinogenic." Reading this abstract and basing a decision on it would certainly lead to a conclusion different from one based on another abstract from the same search which states that, "A review of the available experimental and field information on nitrilotriacetic acid (NTA) indicates a very low probability of environmental or human hazard at the maximally proposed levels for use in detergents." Although the latter abstract goes on to point out the need for continued research and surveillance if NTA is used as a detergent phosphate substitute, its general tone is favorable toward such use. There are many other abstracts on this topic ranging from those which are very favorable to the use of NTA to those which are highly unfavorable. A wise decision on this topic could be made only after examining as many of these abstracts as possible and making a judgement considering them all. This points out the desirability of having review papers written by impartial experts on controversial topics where choices need to be made by the public and by decision-making bodies. Unfortunately, the computer cannot perform that function.

Discussion with "first time" users have revealed that in general a search does not provide exhaustive coverage of the topic. Many of these users are aware of references not cited by the search. They generally agree, however, that a search provides a good overall view and picks up citations which may be used in a conventional (manual) literature search. Most first time users questioned asked for a "broad spectrum" search. In some cases these

turned out to be too broad. With experience, however, a user learns to "zero in" on a topic.

Computerized systems are particularly well adapted to the storage and retrieval of hard data. The United States Geological Survey in particular makes use of computerized data bases and retrieval systems. Included are data bases on rock characteristics, mineral reserves, coal resources, mineral characteristics, lead isotope ratios, oil and gas wells, geothermal resources, oil shale resources and other information.

Typical of the Geological Survey data bases is the Computerized Resources Information Bank (CRIB), a system which makes use of the GIPSY program for information processing and retrieval. CRIB provides a very rapid mechanism for the organization, summarization, and display of information on mineral resources. The information, which may apply to a mineral deposit or several related deposits, includes name, location, commodity information, geology, production, reserves, potential resources, and references. The GIPSY and RECON programs enable searches of the file for words, parts of words, phrases, numeric data, and other parameters. The Geological Survey system is of course different in type and purpose from the WRSIC system. However, it is an example of a system even more adapted to computerized information retrieval than is a conventional citation search.

9. Literature Search on Chelation in Natural Waters

As part of a comparative study of computerized literature search systems, a search was initiated on the topic of chelating and complexing agents in natural waters and waste waters. Identical search requests were sent simultaneously to the Washington, D. C., WRSIC office, University of Arizona Water Resources Research Center, Cornell University Northeast Water Resources Information Terminal, North Carolina State University Southern Water Resources Southern Water Resources Scientific Information Center, and University of Wisconsin Water Resources Information Program. Printouts were received from each of these within approximately 10 days of the time the request was made. These printouts were compared. The purpose of this comparative study was not to evaluate the

effectiveness of any individual terminal, but to get some idea of the consistency of the operation as a whole.

Each center was sent a one-paragraph description of the search desired, as follows:

> "Information is desired on the sources, occurrence, levels, reactions, transport, effects, biological significance, degradation, analysis, and fates of chelating and complexing agents in natural waters and wastewaters. Included should be chelating agents and complexing agents from both pollutant and natural sources. Of particular significances is the role of chelating agents in the mobilization, solubilization, and transport of heavy metals and algal nutrient metals in water. Among the more significant specific chelating agents are NTA (nitrilotriacetic acid), EDTA (ethylenediaminetetraacetic acid), citrate, fulvic acid, and humic acid. In the case of the latter two materials, try to exclude citations which do not deal specifically with their chelation properties. Please include all relevant citations.

There was no telephone contact with search specialists at the information centers.

The printout from WRSIC headquarters in Washington was quite extensive, with a total of 544 citations. This was excellent for purposes of comparison, because only 10 citations were given from other centers, combined, which were not cited in the Washington printout. A total of 254 citations were obtained from Wisconsin, 261 from North Carolina, and 181 from New York. A total of 47 complete citations were obtained from Arizona, along with 219 title-only citations.

The citations were evaluated for relevance - the degree to which the citation applied to the search topic. The ratings used are the following:

high: exactly the kind of information desired - a very important citation

adequate: a useful citation

marginal: a citation only peripherally related to the subject request

none: no relevance to the request

In evaluating precision, those citations in the high and adequate category were considered to be relevant and useful.

The quality of the abstracts was rated in all categories except the "none" category. Abstracts were rated on usefulness, information content, and clarity as follows:

good: a useful, informative, well-written abstract

adequate: a useful abstract, but not written in the best, most concise style

poor: A poorly written abstract lacking in useful content

No attempt was made to evaluate recall quantitatively. However, the area covered by the search is one in which the investigator has been involved for several years, and several of his graduate students have been actively engaged in research on the topic. As a result of this familiarity with the topic and the literature pertaining to it, it was the investigator's opinion that the Washington printout contained citations to essentially all significant works on this topic in the time period covered. Detailed perusal of some of the journals most frequently cited did not reveal any relevant papers not cited by the search from Washington. Therefore, it was concluded that the Washington search approached 100 percent recall. This was useful in evaluating the other searches and the system as a whole.

Abstracts were checked for errors, though not in great detail. Approximately 20 percent of the citations were found to contain minor errors, *e.g.*, number of illustrations in the paper cited. Most of the errors found were minor typographical mistakes. It is considered unlikely that more than 50 percent of all errors were actually found.

Table 1 shows the relevance of the data from the five search centers. Examination of Table 1 does not reveal any significant differences in precision among the five terminals. The approximately 50 percent precsion level from each center is quite high considering that these were broad-spectrum searches performed by personnel not experienced in the area searched.

Retrieval of a maximum number of citations in the "high" relevance category is especially important. This aspect was compared for the Wisconsin, North Carolina, and New York searches. All of these had comparable numbers of citations consisting of

Table 1. Relevance of Citations from Chelation Search.

	percent in relevance category				percent
	none	marginal	adequate	high	precision
Washington	33.8	14.0	26.7	25.6	52.3
Wisconsin	39.4	13.4	22.0	25.2	47.2
Arizona	38.7	13.9	19.2	28.2	47.4
North Carolina	38.7	13.8	21.8	25.7	47.5
New York	30.4	13.8	27.6	28.2	55.8

* Includes citations from only the "adequate" and "high" categories.

complete abstracts (many of the Arizona citations included titles, only). These are shown in Figure 2 on page 23.

From the data presented in Figure 2 it is seen that 56.6 percent of the citations rated high were cited by all three centers, 26.3 percent by two terminals, and 17.1 percent by only one terminal. The inherent inability of a computerized citation search to retrieve all highly relevant citations in the data base should be noted with caution by those relying on such a search to retrieve all important information.

The quality of abstracts is a crucial measure of the usefulness of a literature compilation. This factor has not received much attention in previous evaluations of retrieval systems because most searches are performed for academic research personnel with access to adequate libraries. Thus, even an inadequate abstract will provide sufficient information to enable the user to make a judgement regarding whether the original work should be obtained. However, those having the greatest need for computerized literature surveys (although they are not as of yet the largest users) are personnel who do not have convenient access to large university libraries, and generally do not have the time to make additional studies. For these users, a poorly written abstract lacking in useful content is of little use. Ideally, all abstracts should be informative and useful entities in their own right.

Examination of the adequacy of the abstracts from the chelat-

Figure 2

Distribution of High Relevance Ratings
Among Wisconsin, North Carolina, and
New York Citations on Chelation Search

	W	NC	NY
W75-01331	+	+	+
W75-00446	+	+	+
W74-08722	+	+	+
W74-07624	+	+	+
W74-07228	+	+	+
W74-06048	+	+	+
W74-06036	+	+	+
W74-03578	+	+	+
W74-01398	+	+	+
W73-14783	+	+	+
W73-13645	+	+	+
W73-11070	+	+	+
W73-16408	+	+	+
W73-10062	+	+	+
W73-07171	+	+	+
W73-02112	+	+	+
W73-01668	+	+	+
W72-14694	+	+	+
W72-11238	+	+	+
W72-10707	+	+	+
W72-07512	+	+	+
W72-05907	+	+	+
W72-04463	+	+	+
W72-04052	+	+	+
W72-01986	+	+	+
W72-01097	+	+	+
W71-12094	+	+	+
W71-11246	+	+	+
W71-11241	+	+	+
W71-11028	+	+	+
W71-09674	+	+	+
W71-09190	+	+	+
W71-05639	+	+	+
W71-04072	+	+	+
W71-03495	+	+	+
W71-03027	+	+	+
W70-03508	+	+	+
W70-02502	+	+	+
W69-08275	+	+	+
W69-07817	+	+	+
W69-07428	+	+	+
W69-04971	+	+	+
W69-00259	+	+	+
W74-11262	+	+	
W74-09886	+	+	
W74-06998	+	+	
W74-02658	+	+	
W74-01326	+	+	
W73-15244	+	+	
W73-15187	+	+	
W73-14949	+	+	
W73-14287	+	+	
W73-02783	+	+	
W72-01201	+	+	
W82-09251	+	+	
W72-07675	+	+	
W72-04901	+	+	
W71-13405	+	+	
W71-11392	+	+	
W71-11247	+	+	
W71-09805	+	+	
W71-09190	+	+	
W72-12710	+	+	
W73-14982	+		
W74-06173		+	
W73-07726		+	
W71-00132		+	
W75-00196			+
W74-09432			+
W73-09193			+
W73-08253			+
W73-01079			+
W72-03552			+
W71-07901			+
W71-07726			+
W70-02248			+

W: Wisconsin

NC: North Carolina

NY: New York

ion search gave the following:

percentage of *good* abstracts, defined as those which are useful, informative, and well written: 10.2%

percentage of *adequate* abstracts, defined as those which are useful, but not written in the best, most concise style: 60.3%

percentage of *poor* abstracts, defined as those poorly written and lacking in useful content: 29.5%

It is indeed unfortunate that only about 10 percent of the abstracts are classified as "good" and would have optimum value in their own right. It is precisely these kinds of abstracts which should be available to non-academic users not involved in research who would be using the WRSIC system as a rapid, efficient means to secure information needed to deal with an applied water resources problem. Approximately 60 percent of the abstracts were classified as adequate. These are certainly useful to the individual with access to the original works, but of marginal use to those relying on the abstract itself for information. Unfortunately, 29.5 percent of the abstracts are classified as poor. This means that except for providing the title and reference, the abstract is of virtually no use and just as well not be included in the search printout.

The value of an abstract is to a certain extent a subjective judgement, and some justification for judging this value should be given. This may be done through the example of a poor abstract compared to one rewritten from the same reference which does have the qualities desired in an abstract. As an example, consider the following abstract designated "poor."

27/5/000001-000200// 24
75R01644 WRA-W8-04 05.D0
(W75-01644) THE USE OF CHELATING ION EXCHANGE IN CONJUNCTION WITH RADIOISOTOPE X-RAY SPECTROMETRY FOR DETERMINATION OF TRACE AMOUNTS OF METALS IN WATER/
HOLYNSKA,B./
INSTITUTE OF NUCLEAR PHYSICS AND TECHNIQUES,KRAKOW (POLAND)./
RADIOCHEMISTRY AND RADIOANALYTICAL LETTERS,VOL 17 NO 5/6,P 313-324,JUNE 20, 1974.6 FIG,1 TAB,11 REF./
THE CHELATING ION-EXCHANGE RESIN CHELEX-100 WAS APPLIED FOR COLLECTION OF TRACE AMOUNTS OF SEVERAL METAL IONS FROM AQUEOUS SOLUTIONS.THE KINETICS OF THE EXCHANGE REACTION HAS BEEN MEASURED,AS WELL AS THE INFLUENCE OF PH OF THE SOLUTION AND CALCIUM OR SOIDUM IONS CONCENTRATIONS ON THE METAL COLLECTION.THE RADIOISOTOPE X-RAY FLUORESCENCE METHOD HAS BEEN APPLIED FOR DETERMINATION OF METAL IONS SORBED ON THE RESIN.(PRAGUE-FIRL)

There are many deficiencies in the above abstract. It does not tell specifically which metal ions were removed, nor does it give their concentrations. The rates of metal removal are not given. The levels of interfering ions are not stated. Precisions and sensitivities of measurements are not given. There are no experimental details on either the procedure or apparatus. Factors (particularly chemical binding of metals to organic species) which might prevent metal removal from solution, are not mentioned. Nothing is said about applying the method to real samples.

Reading of the original manuscript revealed that the abstract given in the citation was copied verbatim from that given in the original (frequently a very poor source). An expanded, improved abstract was written based upon the original paper. This abstract is presented on page 26. It may be noted that the new abstract does not have the deficiencies of the original. In addition it contains an abstractor's note on a point not covered in the original reference. This note pertains to an aspect which might be crucial to the user.

The availability of an original reference upon which a citation is based is sometimes difficult to determine and varies with the position and location of the user. Some journals, such as *The Journal of the Water Pollution Control Federation*, are commonplace around installations dealing with water resources. On the other hand, *The Journal of the Japan Wood Research Society* surely is not widely circulated in the United States. The citations given in chelation search were rated for availability, and were considered available for checking if the original work is likely to be kept in a reasonably well stocked technical library. Research project completion reports, papers presented at meetings, and publications from the National Technical Information Service were not classified as being readily available. Using these criteria, 55.5 percent of the chelation search were classified as being available. Many of the most useful citations come from readily available sources and should, of course, be cited. On the other hand, one of the more useful functions of an abstracting service is to make available to users information from sources which are not readily

Abstract written by S. E. Manahan as a substitute for the inadequate abstract in the chelation search.

27/5/000001-000200// 24
75R01644 WRA-W8-03 05.A0
(W75-01644) THE USE OF CHELATING ION EXCHANGE IN CONJUNCTION WITH RADIOISOTOPE X-RAY SPECTROMETRY FOR DETERMINATION OF TRACE AMOUNTS OF METALS IN WATER/
HOLYNSKA, B./
INSTITUTE OF NUCLEAR PHYSICS AND TECHNIQUES, KRAKOW (POLAND)./
RADIOCHEMISTRY AND RADIOANALYTICAL LETTERS, VOL 17, NO 5/6,P 313-324,JUNE 20,1974.6 Fig,1TAB,11 REF./
THE USE OF CHELEX-100 CHELATING ION EXCHANGE RESIN FOR THE COLLECTION OF ZINC, IRON, MERCURY, COPPER, AND LEAD IONS FROM WATER FOR X-RAY FLUORESCENCE ANALYSIS WAS STUDIED. THE RATES OF COLLECTION, INFLUENCE OF PH AND EFFECTS OF SODIUM AND CALCIUM IONS WERE DETERMINED. THE IONS AT CONCENTRATIONS OF 0.1 TO 10 PPB IN 100 TO 500 ML OF WATER WERE COLLECTED BY 0.1 G DRIED CHELEX-100 IN THE HYDROGEN FORM AND LESS THAN 60 MICRONS SIZE. THE TIMES REQUIRED FOR APPROXIMATELY COMPLETE EXCHANGE WERE FE(III), 40 MIN; ZN(II), 60 MIN; PB(II), 60 MIN; CU(II), 30 MIN; and HG(II), 120 MIN. COLLECTION OF MERCURY WAS SLOWER AND LESS EFFICIENT THAN THAT OF OTHER METALS. CALCIUM UP TO 250 PPM AND SODIUM UP TO 9000 PPM DO NOT PREVENT UPTAKE OF IRON, ZINC, LEAD, COPPER, AND MERCURY. LINEAR CALCULATION PLOTS WERE OBTAINED FOR IRON BETWEEN 0.1 and 100 PPM AND FOR LEAD BETWEEN 0.1 and 1.0 PPM. THE TOTAL ERROR OF LEAD MEASUREMENT (1 STANDARD DEVIATION) WAS 3 TO 15 PERCENT. LEAD DOES NOT INTERFERE WITH THE DETERMINATION OF IRON AND IRON DOES NOT INTERFERE WITH THE DETERMINATION OF LEAD. THE X-RAY SPECTRA WERE EXCITED WITH A CADMIUM-109 SOURCE (22.6 KEV X-RAY) OR A PLUTONIUM-238 SOURCE (13-21 KEV X-RAY) AND MEASURED WITH A SI/LI DETECTOR AND MULTICHANNEL ANALYZER OR WITH AN ARGON PROPORTIONAL COUNTER AFTER WAVELENGTH DISPERSION. TWO SEA WATER SAMPLES WERE ANALYZED AND FOUND TO CONTAIN SIGNIFICANT LEVELS OF POLLUTANT ZINC (1 AND 2 PPM). ABSTRACTORS NOTE: THE EFFECTS OF ORGANIC BINDING ON THE COLLECTION OF METALS WAS NOT CONSIDERED AND COULD PREVENT UPTAKE OF METALS PARTICULARLY FROM SEWAGE SAMPLES./

available. In the latter case, however, the abstracts should be of especially high quality and should contain sufficient information to be useful without access to the original work.

In searching a long list of citations, the legibility of abstracts makes a great deal of difference. Computerized systems as presently constituted have some deficiencies in this regard. In some cases the necessity for using all capital letters yields a printing style which is generally unfamiliar to the reader. Ambiguities in meaning may result, such as with the use of chemical symbols where, with normal printing, the first letter is always capitalized and the second letter (when present) is lower case. The greatest problem with legibility, however, occurs in reading the page-wide columns of printing consisting of 120 characters. A fast reader can scan a normal line of print at one time. This is one of the primary "tricks"of speed reading. With such a wide column, however, it is impossible to view a whole line. Thus, the reading rate is slowed. Furthermore, it is very easy to get lost in going from one line to the next, further slowing the reading rate. The abstract printed on page 28 clearly illustrates these problems. The abstract is also shown in a two-colum style, which is considerably more legible. It would seem possible to do this with present systems.

10. Setting Research Priorities from Computerized Searches

One of the potentially most useful applications of computerized literature searches is the determination of areas of research need or over-emphasis. This potential has not yet been utilized to its maximum capacity. The chelation search revealed some areas of both need and over-emphasis. The search was divided into the following topics and the number of citations found under each are given:

1. Types and sources of chelating agents and metal chelates in water: 8 citations
2. Occurrence of chelating agents in natural waters and waste waters: 3 citations
3. Effects of chelating agents in water: 66 citations
4. Degradation and removal of chelating agents: 23 citations
5. Analysis of chelating agents: 26 citations

27/5/000001-000200// 57
74R07624 WRA-W7-15 05.B0
(W74-07624)BIODEGRADATION OF NITRILOTRIACETATE (NTA) IN SOILS/
TIEDJE,J.M./MASON,B.B./
MICHIGAN STATE UNIV., EAST LANSING.DEPT. OF CROP AND SOIL SCIENCES./
SOIL SCIENCE SOCIETY OF AMERICA PROCEEDINGS, VOL 38,NO 2,P278-283,MARCH-APRIL 1974.3 FIG,5 TAB,17REF./

NITRILOTRIACETATE (NTA) WAS BIODEGRADED IN A VARIETY OF SOILS. THE PROCESS WAS MEASURED BY TOTAL CO2 AND CO2 PRODUCTION FROM C-14-CARBOXYL-NTA. PRODUCTION OF CO2 AND C-14 FOLLOWED SIMILAR PATTERNS AND SUGGESTED COMPLETE DEGRADATION OF NTA. C-14 PRODUCTION WAS USED ROUTINELY TO ASSAY NTA DISSIMILATION. AT 40 PPM OF NTA IN SOILS RECEIVING SEWAGE EFFLUENT AND IN MUCK SOILS, MAXIMUM RATES OF DEGRADATION WERE 8 TO 10 PPM/DAY WHILE IN MINERAL SURFACE SOILS, THEY RANGED FROM 0.5 to 6 PPM/DAY. THE RATES IN SUBSOILS WERE ALWAYS LESS THAN FOR THE SURFACE SOILS FROM THE SAME SITE. DEGRADATION RATES DID NOT CORRELATE WITH PH, DRAINAGE, TEXTURE, OR PLANT COVER. RATES OF DEGRADATION INCREASED FROM 2 TO 64 PPM/DAY AS NTA CONCENTRATION WAS INCREASED FROM 10 TO 600 PPM. C-14 PRODUCTION FROM NTA DID NOT OCCUR ANAEROBICALLY AND WAS SEVERELY LIMITED UNDER MACROAEROPHILIC CONDITIONS. NTA WAS DEGRADED AT 24 AND 12.5 C. IT WAS ALSO DEGRADED AT 2 C IF PREVIOUSLY ACCLIMATIZED AT 12.5 C. IMINODIACETATE WAS A POSSIBLE INTERMEDIATE IN NTA DEGRADATION WHILE N-METHYLIMINODIACETATE WAS NOT.

27/5/000001-000200// 57
74R07624 WRA-W7-15 05.B0
(W74-07624)BIODEGRADATION OF NITRILOTRIACETATE (NTA)IN SOILS
TIEDJE,J.M./MASON,B.B./
MICHIGAN STATE UNIV.,EAST LANSING.DEPT.OF CROP AND SOIL SCIENCES./
SOIL SCIENCE SOCIETY OF AMERICA PROCEEDINGS,VOL 38,NO 2,P278-283,MARCH-APRIL 1974.3 FIG,5 TAB,17 REF./

NITRILOTRIACETATE (NTA) WAS BIODEGRADED IN A VARIETY OF SOILS. THE PROCESS WAS MEASURED BY TOTAL CO2 AND CO2 PRODUCTION FROM C-14-CARBOXYL-NTA. PRODUCTION OF CO2 AND C-14 FOLLOWED SIMILAR PATTERNS AND SUGGESTED COMPLETE DEGRADATION OF NTA. C-14 PRODUCTION WAS USED ROUTINELY TO ASSAY NTA DISSIMILATION. AT 40 PPM OF NTA IN SOILS RECEIVING SEWAGE EFFLUENT AND IN MUCK SOILS, MAXIMUM RATES OF DEGRADATION WERE 8 TO 10 PPM/DAY WHILE IN MINERAL SURFACE SOILS, THEY RANGED FROM 0.5 TO 6 PPM/DAY. THE RATES IN SUBSOILS WERE ALWAYS LESS THAN FOR THE SURFACE SOILS FROM THE SAME SITE. DEGRADATION RATES DID NOT CORRELATE WITH PH, DRAINAGE, TEXTURE, OR PLANT COVER. RATES OF DEGRADATION INCREASED FROM 2 TO 64 PPM/DAY AS NTA CONCENTRATION WAS INCREASED FROM 10 TO 600 PPM. C-14 PRODUCTION FROM NTA DID NOT OCCUR ANAEROBICALLY AND IT WAS SEVERELY LIMITED UNDER MACROAEROPHILIC CONDITIONS. NTA WAS DEGRADED AT 24 AND 12.5 C. IT WAS ALSO DEGRADED AT 2 C IF PREVIOUSLY ACCLIMATIZED AT 12.5 C. IMINODIACETATE WAS A POSSIBLE INTERMEDIATE IN NTA DEGRADATION WHILE N-METHYLIMINODIACETATE WAS NOT. (KNAPP-USGS)/

From the numbers of citations in each category listed on page 27, it appears that relatively little work has been done on the types and sources of chelating agents and metal chelates in water. Of the eight citations listed on this topic, three deal with the use of chelating agents to treat boiler feedwater and the remainder deal with humic materials in water. Thus, only a narrow spectrum of possibilities is covered. This points out the need for a large-scale systematic study of the types and sources of chelating agents, particularly from pollutant sources, which are likely to get into natural waters and wastewaters.

Only three citations involve the actual occurrence of chelating agents in natural waters and wastewaters. This points out the single greatest area of research need in this area. Detailed investigations are needed to establish whether or not chelating agents are actually getting into natural waters and wastewaters.

A large amount of research has been performed on the effects of chelating agents. This may be considered to be adequate as a proportion of the total research effort. Much of this work has been done on NTA. If this detergent phosphate substitute is not in fact going to be used in the United States, some of this effort should be concentrated on other compounds, instead.

A total of 23 citations deal with the degradation and removal of chelating agents from water. However, 16 of these citations are on NTA. The need for emphasis upon other materials is again suggested.

The 26 citations on the analysis of chelating agents - most from recent work - indicate an encouraging emphasis on a research area of real need. One of the major reasons that the role of chelating agents in heavy metal mobilization and transport had received so little attention until approximately 1970 was due to the lack of methods of analysis for these substances. A total of 14 of the analysis methods cited pertain to NTA, which shows the emphasis placed upon this controversial material in recent years. Only two deal with naturally occurring humic compounds with chelating properties.

Examination of the citations dealing with chelating agent

analysis citations reveals the following specific needs for research on methods for the chemical analysis of chelating agents in natural waters and wastewaters.

1. There is a need for a detailed, broadly based comparative study of analytical methods for chelating agents applied to real samples in natural waters and wastewaters.
2. A multi-species method of analysis is needed in which a number of specific chelating compounds can be identified in the same sample.
3. A good method of analysis is needed for naturally occurring chelating agents (particularly humic substances) in natural waters and wastewaters.
4. A simple water testing kit is needed to show the presence or absence of significant levels of chelating agents in water.

The search on chelating agents in water revealed another interesting sidelight. Out of a total of 539 citations which referred to chelating agents in some respect, 123 citations dealt with the use of synthetic chelating agents for the analysis of metals. (In evaluating the search, most of these 123 citations were placed in the "none" relevance category because they did not deal with the information requested.) Prior to the development of modern, relatively inexpensive instrumental analysis techniques, the best methods of analysis for most significant heavy metals in water were based upon the formation of colored compounds formed by the chemical reactions of the metals with chelating agents synthesized to interact more or less specifically with the metals being analyzed. The development of atomic absorption analysis in the mid-1960's made most of these methods of analysis obsolete. However, for an approximately 40 year period beginning around 1930, tremendous amounts of research were rightly devoted to metal analysis using chelating compounds. Such research efforts have a momentum of their own. Although these methods are no longer the best for most metals, the research on this topic has continued at a high level. Therefore, except in very special cases where justification can be shown very clearly, additional research should not be funded for the complexometric analysis of metals. Many of the researchers working in this area should be encouraged to pursue other problems where need exists. One such area, which would require minimum

reorientation, is the analysis of chelating agents in natural waters and wastewaters.

From a critical examination of the chelation search, some specific research projects may be chosen which need to be performed. The following is a list of some of these judged to be of potential benefit in the water resources area:

1. A study of the production, uses, and disposal of the major chelating compounds used in industry, food processing, cleaning, and other applications. This should be primarily a paper study to determine types, amounts, and uses of chelating agents and the probability of their getting into wastewaters and natural water systems. Where deficiencies in chemical analysis methodologies are revealed, research on the development of new methods should be funded
2. A comparative study of available analytical methods for chelating agents in natural water and wastewater samples.
3. A systematic survey of selected natural waters and wastewaters to determine the occurrence of chelating agents.
4. An investigation of the possible production of organometallic compounds, (*e.g.*, the methyl mercury type) from the biodegradation of metal chelates.
5. Biodegradation of chelating humic substances.
6. Uses of chelating humic substances in practical applications, *e.g.*, water purification.

11. Literature Search on Trace-Level Pollutants Arising from the Mining and Utilization of Coal

A literature search was requested from Wisconsin and Washington on trace-level pollutants produced from increased mining and utilization of coal as a domestic energy source. This search was made because of the certainty that coal will be used to a very large extent to fill the energy gap in the United States during coming decades. The potential for increased water pollution from this development is relatively high. The major problem associated with coal mining, particularly in Missouri, Iowa, and the major coal producing states east of the Mississippi, is acid mine water production. This problem has been investigated very extensively and was not included in the study. Toxic heavy metals and other elements, as well as organic (humic) materials from coal are particularly important. The search description is the following:

I would like to initiate a search through SIE described as follows: The general area of the search is the origin, transport, and fates of trace-level pollutants arising from the mining and utilization of coal. This excludes acid mine water as such, and excludes the sulfuric acid and iron found in acid mine water. It may create some problems to program the search in such a way as to exlude the large number of projects dealing solely with acid mine water. The trace elements from coal of particular interest are titanium, vanadium, chromium, manganese, cobalt, nickel, copper, zinc, molybdenum, cadmium, mercury, and lead. The primary organic material of interest is coal humic acid. There is a very large amount of work being cone on humic acids originating from soil and originating in water. If possible, these should be excluded. The search should also include radioactive materials (uranium and radium) entering water from a coal source.

Table 2.
Summary of Findings from Computer Search WRSIC on Trace-Level Pollutants Arising from the Mining and Utilization of Coal

Item	Washington	Wisconsin
Total number of citations	37	34
Total number of citations identical to those from the other search	23	23
Percentage of citations identical to those from the other search	$\frac{23}{37}\times 100 = 62\%$	$\frac{23}{34}\times 100 = 68\%$
Total number of citations relevant to the topic searched	19	13
A. Very important	3	1
B Important	12	8
C. Marginal	4	4
Percentage of total citations which are relevant	$\frac{19}{37}\times 100 = 51\%$	$\frac{13}{34}\times 100 = 38\%$
Percentage of relevant citations classified as very important	$\frac{3}{19}\times 100 = 16\%$	$\frac{1}{13}\times 100 = 8\%$
Percentage of relevant citations classified as important	$\frac{12}{19}\times 100 = 63\%$	$\frac{8}{13}\times 100 = 61\%$
Percentage of relevant citations classified as marginal	$\frac{4}{19}\times 100 = 21\%$	$\frac{4}{13}\times 100 = 31\%$
Number of relevant citations not revealed by the other search	7	1
Number of relevant citations exclusively on mercury	8	7
Percentage of relevant citations exclusively on mercury	$\frac{8}{19}\times 100 = 42\%$	$\frac{7}{13}\times 100 = 54\%$

A total of 37 citations were obtained from Washington and 34 from Wisconsin. Analysis of these citations is given in Table 2 on page 32. In this case the Washington printout contained an appreciably higher percentage of relevant citations. It will be used in discussing the results.

Considering the very small number of citations highly relevant to the request, it is apparent that insufficient work is being done on trace-level pollutants from coal. This deficiency may be due in part to preoccupation with the acid mine water problem. Furthermore, of the relevant citations, 42 percent deal exclusively with mercury. Admittedly, mercury is a serious pollution problem with the use of coal as a fuel. However, it is by no means the only problem, or necessarily the most important. From an analysis of this printout, the following conclusions may be drawn:

1. Acid mine water as a problem with increased coal utilization has been studied extensively, and these studies are probably at a sufficiently high level.

2. Mercury is receiving a great deal of study in relation to coal utilization, probably sufficient in its relationship to other pollutants.

3. The potential for water pollution by coal-originated trace elements other than mercury should be studied more.

4. Attention should be given to the specific chemical species entering water from coal sources (each element may of course occur as one of several different species in water).

5. Organic materials entering water from exposed coal seams and from aquifers disturbed by coal mining should be studied.

12. Role of State Water Resources Research Centers in Information Dissemination

The individual state Water Resources Research Centers are the most likely contacts for potential users of water resources research information. Therefore, they have a special role to play in dissemination water resources information. There are several ways in which state centers function in the dissemination of information. In most states, an annual meeting is held presenting the activ-

ities of OWRT research in the state. Many state OWRT directors make direct, vigorous efforts to get information directly to potential users.

Some idea of the importance of the state centers in this regard may be gained by examining data on computerized searches executed in states with information terminals as compared to those not having terminals. For example, Technical Report 73 from the Northeast Water Resources Information Terminal at Cornell University in New York (August, 1973) shows that during an 11-month period from April, 1972 to February, 1973, 65 percent of the searches in the 18-state area served by this terminal were requested from the state of New York. The Wisconsin terminal received 50 percent of its requests from Wisconsin out of the 21-state region served. Of the 15-state region served by North Carolina, 78 percent of the requests came from that state. These figures may well show that in those states having a terminal, contact between users and the Water Resources Research Director's office in the state is a major factor in getting information out to users in the state.

A visit to the director's office in the State of Colorado in August, 1975, showed that the state has had an exemplary system of Water Resources information dissemination. Using an extensive list of persons with interests in water resources in the state, the director (in 1974-75) provided information retrieval inquiry forms to personnel in educational institutions, state agencies, municipalities, planning boards, consulting firms and other areas. The first request for information was processed free of charge. This resulted in the filing of approximately 50 requests through the Colorado State Center. These requests were in turn transmitted to the University of Arizona Office of Arid Land Studies information retrieval office for execution of the search. Each search was returned to the Colorado OWRT office for examination and editing (where necessary), then forwarded to the user.

In addition to the approximately 50 requests handled directly through the director's office, a number of subsequent requests were sent directly to the Arizona center by users who had become familiar with the system. By handling the first inquiry through

the director's office, users were made aware of the capabilities of the office as a source of information. In many cases a request for information to the state office can be referred to an investigator in the state without the necessity of going through a computerized search.

Users submitting requests through the Colorado Center included faculty and students at Colorado State University and other educational institutions, state agencies, and private concerns. Of the latter, engineering consulting concerns found the service to be of particular use. The charge for an individual search is minor compared to other expenses involved on a major consulting project, and the average cost/benefit ratio is quite favorable.

Topics search through the Colorado Center included fishery biology, botany, geology, and many others. General satisfaction was expressed by users. According to the Colorado OWRT Director, the general concensus of first-time users was that, although the search did not necessarily provide exhaustive coverage of the topic, it did provide a good overall view. In addition, it picked up citations which may be missed in a conventional literature search. Most users asked for a "broad spectrum" search, which in many cases turned out to be too broad. There is probably a tendency not to "zero in" sufficiently on a topic when the system is used for the first time. As a result of vigorous promotion, the state of Colorado, without an information terminal, approaches Arizona in use of the Arizona system.

Although it is not the purpose of this study to evaluate the role of state centers in disseminating information, one is led to the conclusion that the degree of information dissemination to non-research users in a state is a direct function of how vigorously this information is "sold" from the state director's office. As will be discussed later, the centers have the potential to be the key components of a truly comprehensive nationwide system for information dissemination in water resoures.

13. Recommendations

These studies have shown the considerable potential of computerized information retrieval systems - much of it unrealized -

for the dissemination of water resources information. The service of the individual search centers is perhaps even better than should be expected considering their small size and meagerness of support. According to information available to the investigator in August, 1975, the staff of the Southern Water Resources Scientific Information Center at North Carolina State University consisted of one person with a master's degree in library science, doing the job as part of the duties of assistant document librarian at the D. H. Hill Library at North Carolina State University. Occasional assistance was provided by a library assistant with a knowledge of meteorology. The administrative functions of the center were handled by the project co-directors, the director of the Water Resources Research Institute, and the assistant director for references services in the library. As of February, 1975, the staff of the Northeast Water Resources Information Terminal at Cornell University in New York consisted of a terminal operator with a B.S. degree in biological sciences supervised by an individual with a master's degree in library science and a bachelor's degree in engineering. Although it is not clear from the NEWRIT report, apparently the latter person was spending approximately 15 percent time on the OWRT information terminal project. Overall supervision was provided by the engineering librarian and the director of the Water Resources and Marine Sciences Center.

Although the above descriptions of information center staff may not be exact in every detail, it is apparent that the staffs are small. They cannot contain among their members a number of individuals with a wide range of experience in the numberous disciplines involved in water resources. It is a genuine credit to the system as a whole that these systems perform as well as they do. Since useful results can be obtained from an organization with minimum staff, support, and facilities, what could be accomplished with a truly adequate system with substantial financial support, staff experienced in a number of disciplines, and state of the art facilities?

It is interesting to consider designing from the ground, up, an optimum system for computerized information retrieval and dissemination in the water resources field. What should be expected from such a system? What would be required to accomplish these expectations? Some of the major expectations are the following:

1. A large data base consisting of abstracts which are informative and of high quality (quality of abstracts is relatively more important than quantity)
2. Shortest possible time from the date of the request until delivery to the user
3. Maximum recall and precision
4. Availability of a review paper or papers on the subject to serve as a substitute for, or supplement to the citation printout
5. Direct personal contact with one or more persons who are expert in the desired area

Having outlined a rather idealized system for information retrieval and dissemination, it is now possible to consider the requirements for accomplishing such a system. The first requirement is a group of experts representing essentially all of the disciplines involved with the total water resources picture. These experts need not, and probably cannot, be located in only one location. Computerized systems cannot replace knowledgeable people. For example, when a question arises regarding the influence of the combined effects of irrigation, soil type, and fertilization upon increased water salinity, there is no substitute for an experienced person in providing an accurate answer.

The actual searches probably should be performed at one location, ideally the same as that of the data bank. This enables concentration in one location of a group of information retrieval experts having a number of interests and a diversity of backgrounds and experience. Economies should be affected by this means. Location of the terminal adjacent to the information bank would eliminate transmission problems mentioned as delays in some of the printouts obtained as part of this study. There is little difference in the time and reliability involved in sending printouts by first class mail if the distance is 200 miles compared to 2000 miles. Unless the terminal is close enough to enable a

personal distance, distance to the user is of minor importance.

The terminal should be located in a library stocked with a large number of review papers, OWRT completion reports, and similar documents. If one of these closely fits the needs of the request, a photocopy could be sent to the requestor in place of, or as a supplement to the computer printout.

Taken as a whole, the OWRT/WRSIC system has the potential of being a large, comprehensive information system in its own right. Full realization of that potential could best be accomplished by a centralized information dissemination system having modern, state-of-the-art equipment and an extensive file of reports on specific topics. The staff at this location would have access by telephone to each of the 50 state directors. Included among these is a wide range of expertise in water resources. Each of these directors has access to approximately 10 senior investigators of past or current Allotment or Matching grants. The qualifications and specialties of each of these investigators could be listed with the central information dissemination facility, most logically by computer. This means that the central facility would have access to at least 500 persons representing practically every imaginable area of expertise in water resources. Telephone contact with an expert in a particular area would in many cases result in the transfer of much more accurate and concise information to the user. Very frequently the expert contacted could point out a particularly pertinent review paper which would be exactly what is needed by the user.

Above all, state center directors and their administrative assistants should be experts in information dissemination. This does not mean that they should be experts in the technical sense of having training in library science or computerized information retrieval systems. Rather, the director should know people in the water resources area - both users of information and researchers producing the information needed. The director should be the person in the state to whom users look for water resources information, and should be the person who can provide this information or tell the users where they may go to obtain it.

Information, like any other commodity, needs to be "marketed." This applies particularly to information most needed at the grass roots level. A rural water district planning a new water supply and distribution system needs a great deal of information to make the wisest, most objective decisions possible. Much of the information they need has in fact been researched and is available in the technical literature and other sources. Normally the persons involved, however, do not have the expertise required to go to highly technical sources for the needed information, and they may not be at all familiar with these sources. In such cases vigorous salesmanship on the part of WRSIC personnel, or OWRT investigators funded specifically for information dissemination, can perform an extremely useful service.

In order to get information to the grass roots level, careful consideration must be given to the format of the information. A technical paper or a group of technical papers may be of little use to persons grappling with applied water resources problems. This points to a largely unmet need for interpretive papers which digest highly technical information and convert it to a form which can be used by relatively non-expert persons. It should be noted that this is far different from writing articles for the popular media. It is a talent which requires special writing skill to present facts in a form comprehensible to the non-expert. The paper must indicate where the non-expert may go to obtain additional information.

The function of consulting should not be overlooked as a valuable aid to information transfer. If an agency, industry, planning board, *etc.*, needs specialized information services above and beyond those which can be provided by not more than one half hour's work spent in telephone conversations, writing letters, or finding and mailing appropriate technical reports, the services of a consultant may be appropriate. In many cases it is possible for investigators in the water resources area to serve as consultants, and this may be the least expensive way for users to get needed information. Furthermore, through reimbursement of the individual and/or his employer (university or

onable to imagine the development of printers which can print at the speed and cost per page comparable to a modern photocopy machine from material stored many miles distant. At the present time record player-type machines are becoming available in which whole television features can be played from one disc. With increased resolution these discs will be capable of storing printed material. This holds the possibility of storing the information now contained in a large library within one room. Properly cataloged and automated, this information could be displayed on television screens by simply dialing the proper code numbers. Printed material could be reproduced as desired. The billing system for this service could be set up so that royalties would automatically go to publishers of commercial books and journals. With such a system, anybody in the country could have access to all of the material in the Library of Congress, thus totally revolutionizing the information dissemination process. Such a system may become a reality sooner than is generally realized.

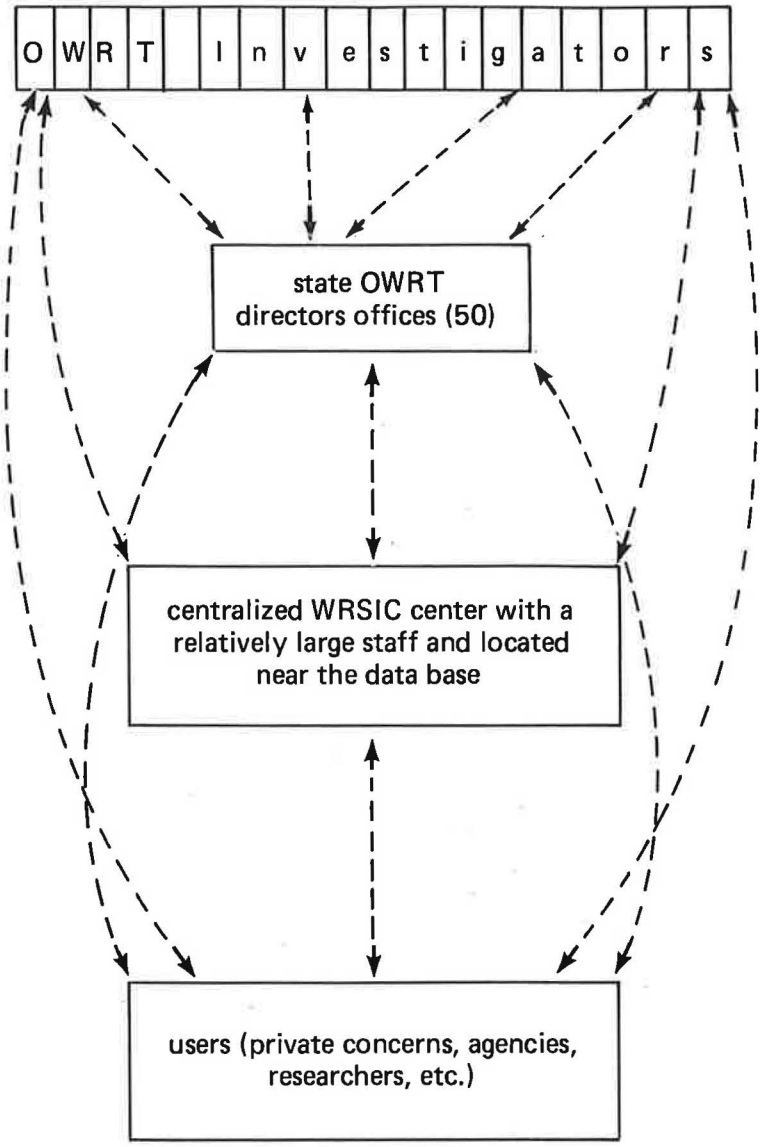
Figure 3 shows an idealized total system for information transfer in the water resources field. It integrates the WRSIC system with state centers. The central feature of this system is a well staffed, very well equipped WRSIC information center. This does not preclude the existence of other centers, particularly those having specialized interests and capabilities.) The center has formal channels to each of the state director's offices, which in turn have direct contact with individual investigators. There are several pathways for primary information transfer. Normally a non-research user would look to the state director's office as a primary information contact and would receive aid in formulating a request. This request would be forwarded to the WRSIC center for processing. The printout, along with review articles and other available information, would be forwarded directly to the user. If desired, the printout could go through the state director's office for further interpretation. As part of the search processing operation, the WRSIC center could contact other state directors' offices where there is known to be expertise in specific areas. Individual OWRT investigators might be contacted

research institute) a financial incentive is provided which will aid in prompt and effective service.

Interpretation and synthesis of the existing body of technical knowledge should receive its proper share of emphasis in the overall research scheme. Research is an increasingly expensive undertaking, and it is not possible for small agencies to fund projects of the magnitude really needed. Although many small "shoestring" research operations are beneficial, there is nevertheless a critical mass of endeavor which is normally required for a successful research project. In many cases talented individuals cannot be funded for good research projects because of a lack of funds. Some of these persons have good writing skills and access to good libraries. Consideration should be given to funding these individuals for "paper" projects in which the investigator reviews the literature and produces interpretive reviews on specific topics. These reviews could then be distributed to users as part of the overall information dissemination process.

Carefully written research proposals are also good sources of information and can be very helpful to individuals interested in the area covered by the proposal. An obvious pitfall is the justified reluctance of many researchers to publicize ideas in detail before the research is well underway. However, particularly informative proposals could, with the investigator's permission, be filed with the appropriate information dissemination group and be made available to parties with an interest in a particular subject. Alternatively, a large literature review section could be required for each proposal, and these sections could be made available to interested parties.

Ideally each state director's office should have a terminal connected to the centralized information bank. This would be rather expensive, but might well be the best investment for agency funds. Advances in electronics and computer science are occurring at such a rapid rate that present systems should be viewed as being very primitive compared to systems expected within several years. Even in the cost area, the picture is somewhat optimistic. The electronic calculator, an expensive luxury item several years ago, is now as commonplace as the slide rule. It is not unreas-



Idealized total system for information transfer in the water resources field.

influent, temperature, availability of sunlight, microbial species, and other environmental conditions. It is believed that the possibility of high-rate operation of a modified lagoon would make the capital and operating costs cheaper.

Two major functions which were expected to be accomplished by the addition of biogrowth sheets were increased biological growth support medium and physical microstraining. Several types of biological contact films have successfully been used in other biological treatment processes such as trickling filters, bio-disc process, and fixed activated sludge process. Physical removal of algae has been achieved with microstrainers. Fiberglass screens with openings as fine as 16 x 18 mesh were thus selected to serve as the fixed growth medium for biological contact stabilization and also serve as strainers for algae retention in the lagoon. The added biogrowth sheets maintained a relatively stable concentration of active microbial populations in the experimental lagoons and reduced the requirement for recirculation.

Temperature is known to be an important factor influencing the growth of phytoplankton and thermal microstratification frequently may occur in field lagoons. The added biogrowth sheets also provided a buffering effect to the modified lagoons and kept an uniform temperature throughout the depth of the lagoon. The application of this effect was tested in field-scale model lagoons with a greater depth and exposure to more variable temperatures from the influent and atmosphere.