WATER MANAGEMENT IN PARK AND RECREATION AREAS

WATER
RESOURCES
FIELD
SUPPORT
LABORATORY

WRFSL REPORT No. 82-5

NATIONAL PARK SERVICE
Department of the Interior

WATER RESOURCES FIELD SUPPORT LABORATORY
NATIONAL PARK SERVICE
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80523

The Water Resources Report Series of the National Park Service, Water Resources Field Support Laboratory, Colorado State University, Fort Collins, Colorado, provides the means for distributing to National Park Service regional and field staff the results of studies and other scientific information useful for the management, preservation and protection of the water and related riparian resources of the National Park System.

The Water Resources Report Series is not a substitute for the open scientific and technical literature. The degree of editing depends on usage, as the Series is designed to be flexible in format and content. The Series encompasses the disciplines of hydrology, geology, biology, ecology and engineering and provides for the retention and dissemination of research information which:

1. Directly address water resources management problems in the parks;
2. Are primarily literature reviews or bibliographies pertaining to water resources problems;
3. Present compilations of basic scientific data; and
4. Discuss methodologies for collecting water quality and quantity information in the National Park System.

The reports may present the results of research conducted by the National Park Service, other agencies, universities, or independent research institutions.

Requests for Water Resources Field Support Laboratory reports should be addressed to:

Director
Water Resources Field Support Laboratory
National Park Service
107C Natural Resources
Colorado State University
Fort Collins, Colorado 80523

WATER MANAGEMENT IN PARK AND RECREATION AREAS*

WRFSL Report No. 82-5

Edited by:

Marshall Flug
Hydrologist/Engineer
Water Resources Field Support Laboratory
National Park Service
Colorado State University
Fort Collins, Colorado 80523

Sponsored by:

Water Resources Systems Committee
American Society of Civil Engineers

August 1982

Water Resources Field Support Laboratory
National Park Service
107C Natural Resources
Colorado State University
Fort Collins, Colorado 80523

*Proceedings of a session from the American Society of Civil Engineers (ASCE) National Specialty Conference, "Managing Our Limited Water Resources" held on May 20, 1982 in Lincoln, Nebraska. The session was sponsored by the Water Resources Systems Committee of ASCE with Marshall Flug serving as the Session Chairman.

Flug, Marshall, editor. 1982. Water Management in Park and Recreation Areas. U.S. Department of the Interior, National Park Service, Water Resources Field Support Laboratory Report No. 82-5. 79 pp.

PREFACE

Management of our Nation's water resources is a growing concern which increases in complexity every day. Encroaching developments surrounding our National Parks are creating pressure on the quantity and quality of Park water resources and on the preservation of their riparian ecosystems. The need to address these developing problems with technological competence inspired the National Park Service to establish the Water Resources Field Support Laboratory in 1981. Many of the water resource issues confronting the National Park Service present unique problems requiring basic research and novel solutions.

In an effort to expedite progress and provide a sounding board for appropriate research and management techniques, papers were solicited for presentation at a session entitled "Water Management in Park and Recreation Areas" which was sponsored by the Water Resources Systems Committee of the American Society of Civil Engineers (ASCE) and was part of the ASCE National Specialty Conference "Managing Our Limited Water Resources" convened in Lincoln, Nebraska, May 19-21, 1982. The papers presented herein comprise a proceedings of that session which include thoughts and ideas by experts in natural resources management, various aspects of water resources research, and water rights.

The timelines of this subject is evidenced by the content of the first paper which addresses threats to water resources in our National Parks and the burden on the National Park Service to mitigate these issues. The information presented clearly establishes a need for extensive baseline data collection, impact assessment, and research to inventory and understand our unique natural systems. Therefore, this setting is followed by three papers which address procedures, techniques, and methods for monitoring water quality. Two of these papers present methods which may be appropriate to detect trends and changes in water quality. These approaches are followed by the fourth paper which provides a biological and ecological perspective to water quality studies. Since many of our National Parks are located in isolated and remote areas where access is limited, both physical and economic constraints often present obstacles to thoroughly quantifying historical and baseline conditions. Data collection and research studies must be carefully designed to make best use of limited resources and must rely upon appropriate yet scientifically sound techniques. The fifth paper presents a clear message regarding reserved water rights and the National Park Service, an issue that is most timely with several cases presently in litigation. Quantification of water rights for instream flows and maintenance of riparian ecosystems will require extensive data and sound technical analysis. Finally, an overview is presented to reiterate the major issues impacting water resources in our National Parks. Additionally, some insight is given as to capabilities and needs of the Park Service to adequately address these problems, as well as the role professional societies and the scientific community can play in resolving conflicts and minimizing stress on our delicate natural systems.

Many thanks are extended to all authors for preparing their papers, to those individuals presenting papers on behalf of authors who were unable to attend, and finally to conference attendees who share a deep interest in preserving those areas worthy of recognition by entrusting them to the National Park Service.

Marshall Flug
August 1982

CONTENTS

WATER: A SERIOUSLY THREATENED RESOURCE IN THE NATIONAL PARK SYSTEM - George M. Gardner and John Dennis, Division of Natural Science, National Park Service 1

THE USE OF THE PAIRED-BASIN TECHNIQUE FOR MONITORING FLOW-RELATED WATER QUALITY TRENDS IN UPLAND RECREATION AREAS - Stanley L. Ponce, Watershed Systems Development Group, USDA Forest Service and Marshall Flug, Water Resources Field Support Laboratory, National Park Service 15

A METHOD TO INDEX CHANGES IN WATER QUALITY - Gary M. Smillie, Jim C. Loftis and Robert C. Ward, respectively, Civil Engineering Department and Agricultural and Chemical Engineering Department, Colorado State University 32

USE OF BIOLOGICAL AND ECOLOGICAL PARAMETERS IN WATER QUALITY STUDIES - D. L. Stoneburner and L. A. Smock, respectively, Water Resources Field Support Laboratory, National Park Service, and Department of Biology, Virginia Commonwealth University 48

RESERVED WATER RIGHTS AND THE NATIONAL PARK SERVICE: THE PRESENT STATUS AND FUTURE PROBLEMS - John R. Little, Jr. and Ralph O. Canaday, Solicitors Office, Rocky Mountain Region, U.S. Department of Interior 57

OVERVIEW AND STRATEGY FOR MANAGING WATER RESOURCES IN NATIONAL PARKS - Raymond Herrmann, Water Resources Field Support Laboratory, National Park Service 73

WATER: A SERIOUSLY THREATENED RESOURCE IN THE NATIONAL PARK SYSTEM

by

George M. Gardner
and
John Dennis
Division of Natural Science
National Park Service
Washington, D.C.

INTRODUCTION

The results of human development of the United States during the past 50 years make it clear that units of the National Park System are not isolated self-regenerating ecological entities. Instead, these islands of naturalness are surrounded by, and interact with, seas of human dominated landscapes, and traditional types of ecosystem exchange are being supplanted or lost. Water is one such ecosystem element, and the purpose of this paper is to examine the following major points with respect to water resources in the National Park System:

1. The water resources of the Nation's National Parks are believed to be seriously threatened, although adequate data to document the severity and extent of threats is inadequate or lacking.
2. Present water resource management programs within the agency are not able to deal with the real and suspected problems due to insufficient staffing and funding and to limitations in program scope.
3. A major shift in priority management strategies for future NPS water resource management program activities is required if

the National Park Service is to fulfill its mandate to protect and preserve park water resources for future generations.

INFORMATION ABOUT THREATS TO NPS WATER RESOURCES

In July, 1979, the House Subcommittee on Public Lands and National Parks of the House Committee on Interior and Insular Affairs asked the Director of the National Park Service for a State of the Parks Report. As a follow-up to this request, the National Park Service sent to every field area a three-part query that included a seven-part questionnaire and dual sections on sources of threats and resources threatened. The questionnaire served as a checklist of threats and asked the question: "In light of the enabling legislation, the legislative history, and the statement for management, what threats are impacting the park resources and to what extent?" The seven threat categories included: (1) air pollution; (2) water quality pollution and water quantity changes; (3) aesthetic degradation; (4) physical removal of resources; (5) exotic species encroachment; (6) visitor physical impacts; and, (7) park operations.

The data received from 310 park units were tabulated, computerized, analyzed and interpreted in a NPS report titled, "State of the Parks - 1980: A Report to the Congress." The report focused on three aspects of the threats to the parks problem: first, the report identified specific threats endangering the resources of individual parks; second, it identified sources of threats, both internal and external to park boundaries, and then it identified the park resources endangered by the threats.

This report, based on extensive information submitted by park superintendents, park natural and cultural resource managers, park scientists, and park planners, identified a broad spectrum of problems and issues with which the National Park Service must deal.

The term "threats" as defined in the report included those pollutants, visitor activities, exotic species, industrial development projects, or other such sources which have the potential to cause significant damage to park resources or to seriously degrade important park values or visitor experiences. The mean number of threats reported per park was 13.6 Servicewide. The 63 national park natural areas greater than 30,000 acres in size reported an average number of threats nearly double the Servicewide norm. Included in this category were such well known crown jewels as Yellowstone, Yosemite, Great Smoky Mountains, Everglades, Olympic, Sequoia, McKinley, and Glacier National Parks. Most of these great natural areas were at one time pristine wildernesses surrounded and protected by equally vast wild areas. Today, with the park's surrounding buffer zones badly eroded, many of these parks are experiencing significant and widespread degradations.

The 12 Biosphere Reserve Parks, which are unique natural areas that range in size from 15,000 acres to more than two million acres and which are dedicated to long-term ecosystem monitoring under the UNESCO Man and the Biosphere Program, surprisingly reported an average number of threats nearly three times the Servicewide norm. This magnitude of reported threats is particularly disturbing because the Biosphere Reserve parks are considered to be model ecological control areas for the network of International Biosphere Reserves.

The large number of threats reported for these natural parks may reflect the greater emphasis directed to monitoring of these areas. If in fact the reason for increased occurrence of reported threats is greater monitoring, then significant numbers of threats may have been overlooked in other parks which, to date, have received much less research and monitoring attention.

Threats identified in this survey originated either within or outside park boundaries. The most frequently reported internal threats were associated with heavy visitor use, including park utility access corridors, vehicle noise, soil erosion, and exotic plant and animal introductions. More than 50 percent of the reported threats were attributed to external sources or activities often located at considerable distances from the parks. The most frequently identified external threats included industrial and commercial development projects on adjacent lands; air pollution emissions, often associated with facilities located considerable distances from the affected parks; and urban encroachment: housing and athletic complexes and the like. External threats also included land clearing, cattle and other feral animals, dust, burning of fields and refuse, application of fertilizers and other toxic chemicals, and even DDT's use in Mexico. Many or most of these external threats potentially can impact park resources through interaction with park hydrological cycles.

Water-Related Threats

Water related threats such as dams, flood control canals, cooling water discharge, dredging, flooding, and water mining all were reported as directly or indirectly affecting the unique resources of the national parks. Watercourses flowing through national parks and their lakes and swamps may be polluted or silted or dried up because of human activities occurring hundreds of miles away. Irrigation schemes upstream in rivers which flow through national parks have upset the ecology of protected areas, resulting in adverse chain reactions affecting the vegetation and the fauna.

In the threats survey, the water related threats category included the following subcategory threats, expressed as percents of the 466 total threats reported for the water-related category: organic (20%), changes in flow rates (15%), toxic chemicals (14%), salt/sediment deposition (11%), oil spills (10%), other (6%), acid mine drainage (5%), radioactivity (3%), and thermal discharge (2%).

A few brief examples of specific water related threats include:

Inorganic water pollution problems stem from both point and nonpoint sources.

- Glacier NP is an example where outside logging, a nonpoint source, is causing leaching of nitrates and phosphates into the park.
- Everglades NP receives inorganic pollutants from agricultural activities upstream.
- Antietam NB suffers from sediment deposition caused by nearby construction and fertilizer runoff from agricultural/urban ecosystems.

Organic Chemical sources may be internal, as in Glen Canyon NRA where sewage holding tanks from recreational vehicles, boats, and portable sanitation facilities are leaking into the waters of Lake Powell, or external, as at a number of urban park areas, including Catoctin Mountain Park, Cuyahoga Valley NRA and Indiana Dunes National Lakeshore.

Salt Deposition occurs in western parks which are suffering from reduced water flow, such as Death Valley NM and Great Sand Dunes NM. Road salting in such northern areas as Indiana Dunes NL and many northern urban parks is also a problem.

Sediment Deposition is also a problem in parks with flooding. Aztec Ruins NM, Oxen Hill Farm Park, and Kenilworth Gardens are examples of the many parks which cited this as a problem.

Thermal Discharge is potentially a problem at parks near power plants with cooling towers or cooling ponds, such as Biscayne NM.

Unnatural Flooding is caused by such diverse sources as release of impoundment waters above park areas at times of high water, as reported by Everglades NP, Dinosaur NM, and Devils Tower NM, and sheetflow over clearcut areas outside park boundaries, reported by Redwoods NP.

Unnatural Flow Decrease has become a problem due to aquifer draw-down at Curecanti NRA, Death Valley NM, and other arid land parks, especially those along the Colorado River.

Oil Spills from external sources pose a constant threat to coastal park areas. Padre Island NS, Fire Island NS, Channel Island NS, Olympic NP, and Gulf Islands NS are just a few examples.

Radioactivity from atomic energy and defense activities has been recorded by a number of parks. Man-caused radioactivity, either actual or potential, was of concern at Biscayne NM and Everglades NP due to the nearby Turkey Point Nuclear Plant, at Pipe Spring NP because of its proximity to a military facility testing atomic bombs, and at Arches NP because of a possible future nuclear waste storage site nearby.

Uranium mining activities create the potential for water contamination throughout the Rocky Mountains. Natural radiation was cited as a problem both in Bighorn Canyon NRA and Mammoth Cave NP.

Acid Mine Drainage has surfaced as a problem in eastern states where the acid water runoff from old coal mines has contaminated park waters. Acid water kills fish, salamander, and invertebrate populations both directly and through synergistic effects with mobilized chemicals. The Chesapeake and Ohio Canal NHP and Prince William Forest Park have suffered from this threat.

Toxic Chemicals derived from external sources, can enter parks via rivers, such as at Bighorn Canyon NRA, where mining of bentonite is a problem, and at Indiana Dunes NL and Cuyahoga Valley NRA. Toxic chemicals can also enter from the air as acid rain and affect park waters, as at Great Smoky Mountains NP.

Other Threats include mining of the aquifer under Castillo de San Marcos NM and water rights adjudication procedures at Dinosaur NM. Both can ultimately cause water shortages leading to extended periods of drought and loss from park ecosystems of water dependent native biota.

The Threatened Resources

In addition to examining types of threats and sources of threats, the third factor that the State of the Parks Report addressed was the threatened resources, themselves. These threatened resources are the natural and cultural features which national parks are created and managed to protect and preserve, the very essence of park protection and visitor interest. Forty-nine identified groups were aggregated into five resource categories: biological, physical, aesthetic, cultural, and operational.

Thirty-two percent of all reported threatened resources were biological, such as plants, mammals, forest habitats, and a range of other living organisms. Physical resources, such as air and water, constituted 24 percent of all the reported threatened resources. Threatened aesthetic resources, which comprise subjective and sometimes intangible features such as silence, odors, general scene, wilderness and the like, constituted 20 percent of all the reported threatened resources. And operations, such as roads, trails, facilities, as well as health and safety of visitors and employees, constituted 8 percent of the total reported threatened resources.

These generalities don't adequately address the significance of these threatened resources because some, like coral reefs and mangrove habitats, may only be found in one or a few parks. They represent extremely important resources within the National Park System because they occur in only one of a few localities.

What Do We Know About These Threatened Situations?

Seventy-five percent of all the reported threats were classified by onsite observers as inadequately documented by research or other valid methods. Threats associated with air pollution, water pollution, and visitor related activities were cited as needing additional monitoring, scientific measurements or research documentation.

The paucity of information about park ecosystems relates not only to resources conditions and the status of impinging internal and external activities, but also to the baseline information available for planning and decision-making. Very few park units possess sufficient natural and cultural resource information needed to permit identification of incremental changes that may be caused by any given threat. Service priorities assigned to the development of sound resource information baselines traditionally have been very low compared to the priorities assigned to meeting use-oriented construction and maintenance needs. In general, research and resources management activities have been relegated to a position where only the most visible and severe problems are addressed, primarily through short-term quick fixes.

Nowhere within the National Park System is the absence of adequate baseline information about park resources more glaringly apparent than in the water resource area:

- To date there has been no systematic, Servicewide inventory and assessment of existing water resources data.
- There is no systematic Servicewide effort currently underway to identify critical, high priority gaps in each park's water resource data base.
- More than two years after adoption of a water resources planning program, not a single park water resource management plan has been completed and approved by the Service.
- Quantification of NPS Federal reserved water rights in the 11 western states is virtually at a standstill within the agency at a time when the reserved water right controversy is becoming more acute and the consumption demands on western water are escalating logarithmically.

In summary, the data show that the water resources of the National Park System are threatened, but that information is lacking to assess the gravity of the situation.

INADEQUATE STAFFING AND FUNDING

The 1980 State of the Parks Report concluded that to deal with the wide range of pervasive and complex problems facing the parks today, "...will require a comprehensive science and resource management program that addresses sound resources management planning, the development of an information data base for each park unit, a carefully structured and well documented monitoring program, and a resources management plan that adequately addresses not only the many threats that exist Servicewide, but additionally the steps to be taken to mitigate these problems." The essence of this conclusion is very similar to the findings of the Leopold and Robbins reports of 1963, which stressed the need for science to form the basis of any resource management program, and to the concerns of the Service's first scientist, who in 1932 wrote, "...no management measure or other interference with biotic relationships shall be undertaken prior to a properly conducted investigation."

What kind of comprehensive science and resource management program does the Service apply to park water resources today? The Service's FY 1982 Water Resources Program Budget is approximately $2,114,000, or less than 0.4 percent of the total National Park Service budget. Similarly, the Service has fewer than 20 professional hydrologists and/or hydraulic engineers as permanent employees working on water resource programs. Seven of those positions are duty stationed in only three parks; all the others are either in the ten Regional Offices, the Washington Office, or at the Service's Fort Collins Water Resource Laboratory. These 20 positions constitute roughly 0.2 percent of the total National Park Service permanent staff.

Simply stated, the current levels of funding and staffing assigned to water resource activities are unable to cope effectively with the broad spectrum of threats and problems which have been identified by the Service.

CURRENT PROGRAM DIRECTIONS

The National Park Service has, for the first time, prepared a draft Servicewide Water Resources Division Program Management Plan for Fiscal Year 1982, setting forth the major objectives and goals of the water resources program and containing 1-2 page summary work plans for all on-going water resource projects (53 work plans Servicewide). Five primary program activities are presently being addressed within the overall program:

1. Energy Effects Analysis Program - Subobjective: to pursue an active research effort designed to provide resource managers with effective technical tools and data to meet evolving threats to riparian or aquatic ecosystems stemming from external energy resource development.
2. Water Resource Planning Program - Subobjective: to facilitate sound water resource management planning throughout the Service for the long-term protection of surface and groundwater resources and to develop appropriate water supplies for park visitors and operations.
3. Atmospheric Deposition ("Acid Rain") Program - Subobjective: to monitor, investigate, and determine the scope, magnitude, and trends of actual or potential long-term effects to park natural resources which stem from or are exacerbated by atmospheric deposition.
4. Outer Continental Shelf Coordination Program - Subobjective: to facilitate the Department's OCS leasing program by providing timely and accurate information and coordination to the Bureau of Land Management and the Department on Servicewide coastal resources.
5. Technical Assistance Program - Subobjective: to provide NPS Regions, and through them, the parks with scientifically and technically sound methods and guidance to solve resource management problems related to water quality, supply and mitigation issues.

POSSIBLE ALTERNATIVE PROGRAM INITIATIVES

While the current program management plan constitutes a positive initial step forward in redirecting what has heretofore been a highly fragmented program, there are a number of additional initiatives which could be actively considered for implementation by the Service. These are as follows:

1. Complete a comprehensive inventory of all known existing water resource data on a park-by-park basis. All water records available from the National Water Data Exchange (NAWDEX) computerized data base maintained by the USGS and the Storage and Retrieval System (STORET) of the U.S. EPA (as well as those noncomputerized water records in the NPS) would be cataloged, indexed, and assessed to develop a historical account of water resources management in each park.
2. Develop and implement a phased program of completing baseline water budgets for all parks with significant water resources, identifying critical data gaps on water inputs, storages and outputs. Funding priorities for capturing additional water resource data should be determined by consideration of the currently available data and by the urgency of threats confronting the individual parks.
3. Develop and implement a National Park Service National Hydrologic Bench-mark Network. Such parameters as stream flow, chemical and physical quality of water, groundwater conditions, and the various characteristics of weather (principally precipitation) should be monitored in selected parks to document natural changes in hydrological characteristics with

time, to provide a better understanding of the hydrologic structure of natural basins, and provide a baseline for assessing the effects of man on park environments. This network should be incorporated into the USGS's National Hydrologic Bench-mark Network.

4. <u>Develop and implement a comprehensive program to inventory and quantify NPS federal reserved water rights</u>. Vital nonconsumptive water quantity, quality and timing requirements needed to protect fish and wildlife communities, riparian vegetation, recreational opportunities, and aesthetic values should be identified and quantified through rigorous scientific endeavor.
5. <u>Develop and implement a computerized water resource information management system to store and analyze all Service water resource data</u>.
6. <u>Complete water resources management plans for all parks possessing significant water resources</u>.

While not intended to be an exhaustive list of possible additional Service initiatives, we believe that accomplishment of the tasks outlined above would constitute significant forward progress in addressing the concerns discussed in this paper.

SUMMARY

We hope that it is clear from the above presentation that a continuing and expanded nationwide commitment is required to address the wide range of NPS water resource issues. The capability to better quantify and document the impact of various threats, particularly those which are believed to most seriously affect important park resources and park values must be improved. As the 1980 State of the Parks Report pointed out, the ability to preserve park resources depends heavily on the use of research to define threshold damage levels and to develop response versus exposure relationships. Such a park resource preservation program needs comprehensive monitoring programs to quantify existing environmental and ecosystem conditions. It needs the development of a much better capability to predict how proposed new sources or activities will affect water quality and quantity and other park resources. As an internal management tool, this resource preservation program needs baseline information as a guide for setting priorities and allocating available resources, for knowing when and where to initiate mitigation programs, and as a basis for formulating and supporting policy positions in adversary proceedings. Lastly, this resource preservation program needs the support of scientists throughout the nation. Such support should be in terms not only of a willingness to work on National Park Service contracts, but also in terms of developing opportunities to use other funding sources to support work on park resources, of invovling classroom students and park visitors in learning about park resource problems, and of providing decision makers with the tools for using scientific information in making the many resource value choices that they will face as they resolve the threats to our parks.

THE USE OF THE PAIRED-BASIN TECHNIQUE FOR MONITORING FLOW-RELATED WATER QUALITY TRENDS IN UPLAND RECREATION AREAS

by

Stanley L. Ponce
Watershed Systems Development Group
USDA Forest Service
Fort Collins, Colorado

and

Marshall Flug
Water Resources Field Support Laboratory
National Park Service
Fort Collins, Colorado

INTRODUCTION

Recent awareness of water quality issues has generated a need by decision-makers for information about existing water quality and how it is affected by land management practices, such as recreation. In general, this information is obtained through monitoring of water quality.

Designing a water quality monitoring program that will provide useful information requires a great deal of thought and careful planning (Ponce, 1980). Thinking about the measurements you are going to make and why you are going to make them leads to problem solving.

A water quality sample can tell a hydrologist quite a bit about the health or condition of a watershed. The quality of the water draining from a watershed is directly related to natural factors, such as climate, geology, soils, and terrestrial and aquatic vegetation; and to land-use activities, such as recreation, timber harvesting, road building, grazing, and mining. The interactions between natural factors and land-use activities are complex, making it difficult either to isolate the effects of land-use activities on water quality or to clearly define water quality trends associated with these activities. This requires that the monitoring program and subsequent data analysis be designed to minimize unexplained variation in the data.

The purpose of this paper is to review a commonly used regression method, the rating curve approach, and to discuss the paired-basin technique and illustrate its use for possible cause-and-effect evaluation and trend analysis. We believe the paired-basin approach can be readily applied to recreation concerns of primary interest to the upland manager, such as ski areas, recreational home developments, campgrounds, and picnic areas, and used with the water quality constituents of major concern, such as suspended solids, turbidity, primary nutrients, and fecal coliforms.

THE RATING CURVE METHOD

In studies involving streams, most water quality constituents of interest to the wildland hydrologist are related to discharge. To account for the variation due to flow, hydrologists commonly use regression techniques to evaluate possible cause-and-effect relationships as well as temporal trends.

The most frequently used regression is simply a plot of the discharge against the concentration of a given water quality constituent. Let's look at an example application of this approach: The question confronting the hydrologist is, "Does the treatment significantly affect the suspended sediment loading in Trout Creek during water year 1980?" Sampling stations were placed upstream and downstream from the treated area (Figure 1). Suspended-sediment concentrations were measured at both stations so that each part of the annual streamflow

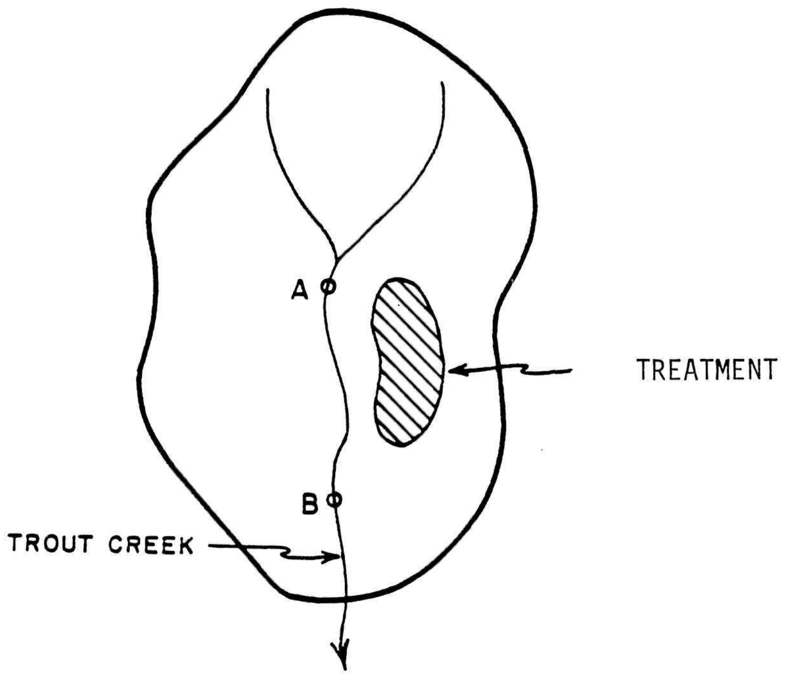

Figure 1. Locations of stations A and B in relation to the harvested area on Trout Creek.

(baseflow, snowmelt, stormflow, etc.) was sampled during water year 1980. The data were then fit to the regression model:

$$\log SS = \log b_0 + b_1 \log Q$$

where:

SS = suspended-sediment concentration;

b_0 = regression coefficient;

b_1 = regression coefficient; and

Q = discharge.

The results were then used to develop the sediment rating curves illustrated in Figure 2.

Note that the data are widely scattered about the regression lines. The coefficient of determination (r^2) generally ranges between 0.60 and 0.85 for most rating curve regressions involving water quality constituents. The unexplained variation ($1 - r^2$) in the regression is due to

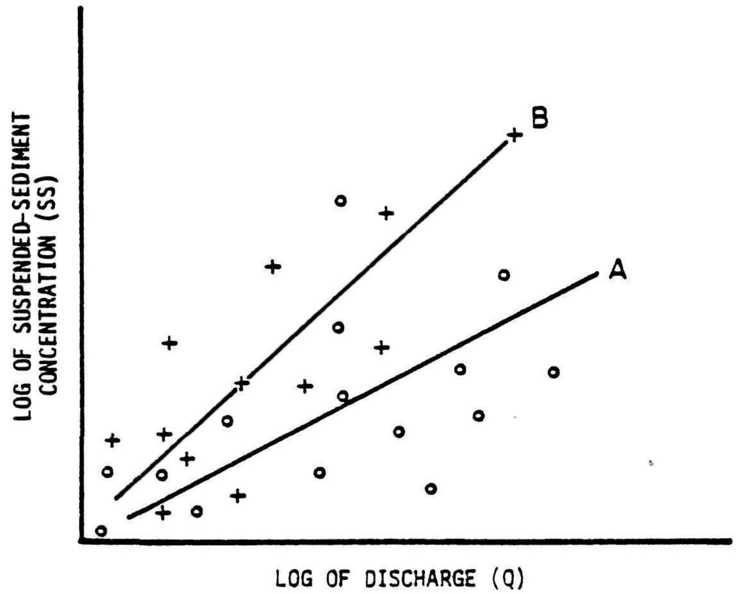

Figure 2. Suspended-sediment (SS) rating curves for stations A and B. Data collected at station A are denoted by °; data collected at station B are denoted by +.

factors not accounted for by the relationship, such as watershed conditioning, climate, and/or physical and biologic factors (Beschta et al., 1981). Although hydrologists typically seek to minimize the unexplained variation by judiciously selecting sampling periods, it is rare that the r^2 will exceed 0.85. The statistical difference between A and B can be determined with the analysis of covariance (ANCOVA) test of a common line or with the Chow test (Wilson, 1978) if the data meet the underlying assumptions of the statistical tests.

THE PAIRED-BASIN TECHNIQUE

The paired-basin technique was first used by U.S. Forest Service hydrologists on the "Wagon Wheel Gap Streamflow Experiment" (Bates and Henry, 1928). Today the technique commonly is used by hydrologists to quantify the effects of land-use practices on the volume and timing of streamflow. In recent years, the technique has been extended to flow-related, water quality studies by a few investigators (Averett, Ponce, and Schindler, 1981; Schindler et al., 1980; Singh and Kalra, 1972; Thut and Haydu, 1971; Brown and Krygier, 1971) and found to be an effective data analysis tool.

The paired-basin technique uses two basins as nearly alike as possible. Ideally, both basins are about the same size, with similar soils, vegetation, elevation, aspect, climate, and streamflow characteristics. Traditionally, in the paired-basin technique, the two basins are also separate; one is the control basin, providing a standard for comparison, and the other, a treatment basin (Figure 3). However, in many water quality studies an upstream and downstream sampling method is used to isolate a treatment area along a stream reach (Figure 4). The paired-basin technique can be used in this situation also. Instead of two completely separate basins, the control basin (the drainage area upstream from the upper sampling site) is nested within the treatment basin.

In either case, traditional or nested design, the technique requires that data be collected both before and after treatment at both basins (stations). In the case of the traditional design, before treatment, water quality measurements (paired in time) are collected from both basins throughout the hydrologic regime of interest. These data are used to establish the calibration period regression of a water quality constituent of one basin upon the other. Following calibration, the treatment basin is treated and the collection of water quality data is continued in both basins. The post-treatment data are used to develop the treatment-period regression. The two regressions (calibration and post-treatment) are then compared, using ANCOVA to determine if

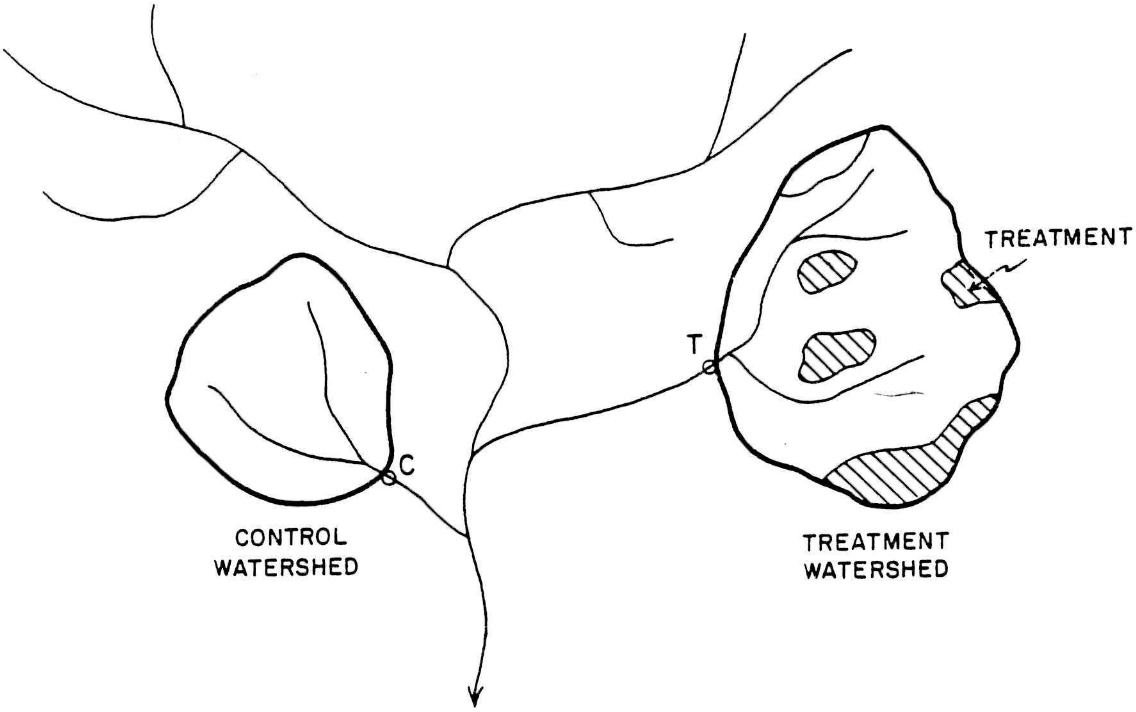

Figure 3. An example of the paired-basin technique using two separate basins.

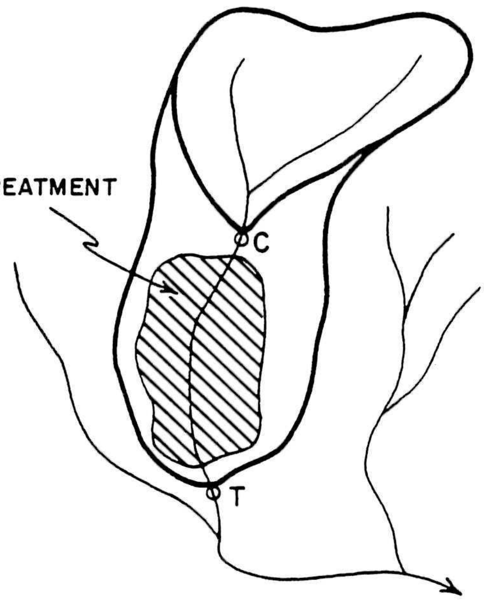

Figure 4. An example of the paired-basin technique using a nested sub-basin.

there is a statistically significant difference in the water quality characteristics.

There are several factors that affect the success of the paired-basin technique (Reinhart, 1967). In applying the technique, you must consider natural correlation, stability of the control, satisfying the assumptions underlying ANCOVA, and quality and size of the data base.

Natural Correlation

The degree of correlation that exists naturally between paired basins for a given water quality property or constituent is of primary importance. Suspended sediment, turbidity, and electrical conductivity usually correlate well for basins that are similar. This point is illustrated by two sets of basin pairs within the Bull Run Watershed on the Mount Hood National Forest, Oregon (Figure 5). These paired basins met the underlying criteria of similarity in elevation, aspect, soils, vegetation, climate, and streamflow. Basin 44 served as the control and was paired with treatment basins 18 and 35 (Table 1).

Table 1. Coefficients of determination (r^2) for selected water quality characteristics from paired-basin analysis in the Bull Run Watershed, Mount Hood National Forest.

Paired Basins	Characteristic	r^2	n
44 and 18	Suspended Solids	0.98	90
44 and 35	Suspended Solids	0.94	98
44 and 18	Turbidity	0.95	72
44 and 35	Turbidity	0.87	163
44 and 18	Electrical Conductivity	0.91	185
44 and 35	Electrical Conductivity	0.90	191

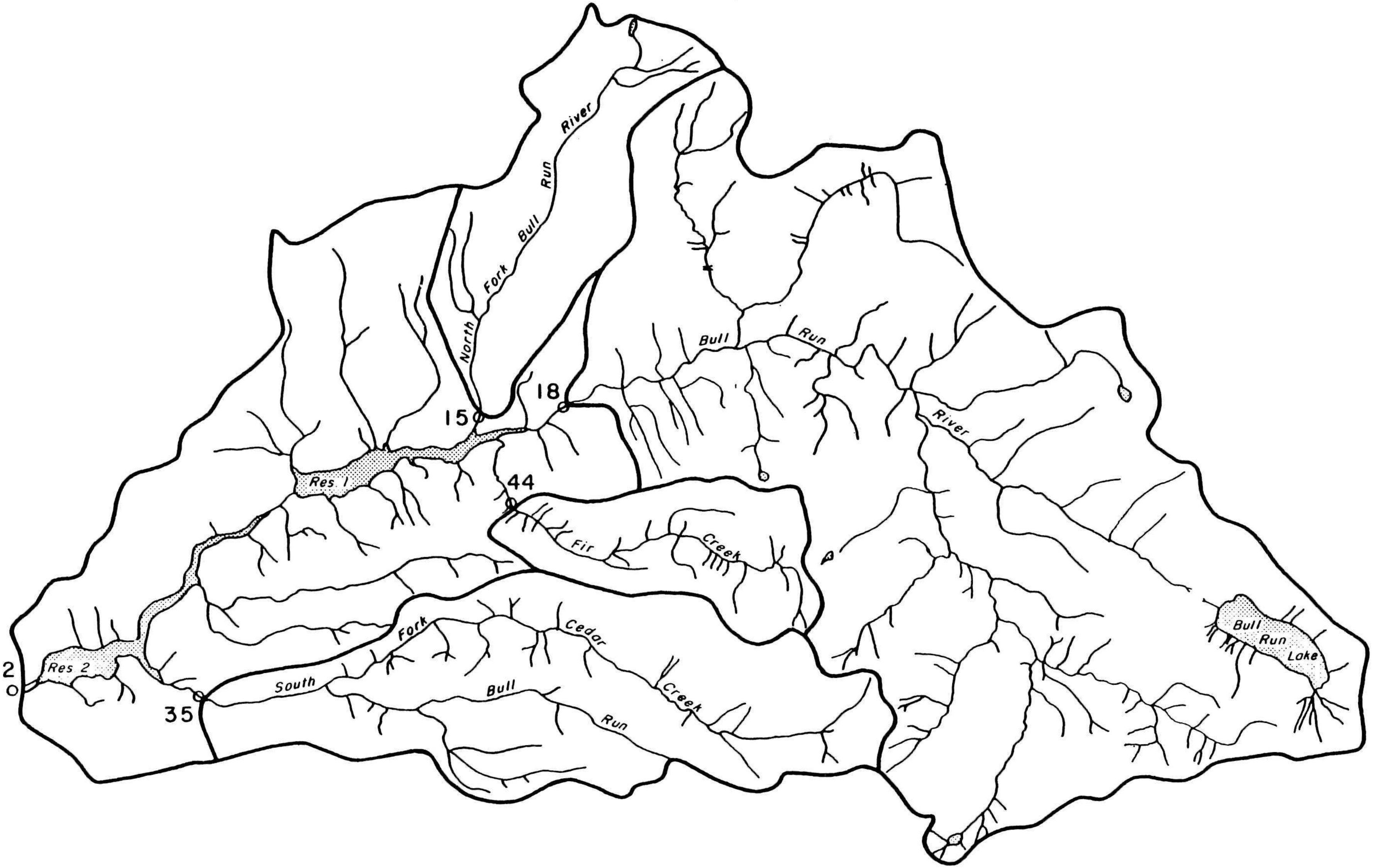

Figure 5. Location of sampling stations on the Bull Run Watershed, Mount Hood National Forest, Oregon.

In general, a decrease in similarity between basins results in a decreased degree of correlation. For example, during stormflow it is likely that the hydrographs will be out of phase if the paired basins are not similar in size. Consequently, at a given time the flow characteristics at each sampling station will be different rather than similar. Such a condition will add unwanted variation to the relationship and reduce the strength of the procedure.

Stability of the Control

It is important that the control basin remain as stable as possible. Any factor that changes the character of the control will detract from the usefulness of the method. Consequently, in selecting a control basin you need to take care to select one in or as near a state of equilibrium as possible. Often it is useful to select two control basins in case one is altered during the study period, such as by fire or flood.

Satisfying the Assumptions Underlying ANCOVA

The validity of the inferences drawn from the results of ANCOVA is related, to a greater or lesser extent, to whether the underlying assumptions are satisfied. The relevant question is not whether ANCOVA assumptions are met exactly, but rather whether the plausible violations of the assumptions have serious consequences on the validity of probability statements based on these assumptions. The primary assumptions that need to be considered are: (1) independence of errors, (2) normality, and (3) homogeneity of the variances. The consequences of violation of the assumptions of ANCOVA are summarized in Table 2.

We should point out that it is not uncommon to find in a time series of hydrologic data that an observation at one time period (t) is

Table 2. Summary of Consequences of Violation of Assumptions of ANCOVA.

Type of Violation	Equal n's: Effect on Level of Significance (α)	Equal n's: Effect on Power	Unequal n's: Effect on Level of Significance (α)	Unequal n's: Effect on Power
Non-independence of errors	Non-independence of errors seriously affects both the level of significance and power of the F-test regardless whether n's are equal or unequal.			
Non-normality				
Skewness	Skewed populations have very little effect on either the level of significance or the power of the fixed-effects model F-test; distortions of nominal significance levels of power values are rarely greater than a few hundredths. (However, skewed populations can seriously affect the level of significance and power of directional - or "one-tailed" - tests.)			
Kurtosis	Actual α is less than nominal α when populations are leptokurtic (i.e., $\beta_2>3$). Actual α exceeds nominal α for platykurtic populations. (Effects are slight.)	Actual power is less than nominal power when populations are platykurtic. Actual power exceeds nominal power when populations are leptokurtic. Effects can be substantial for small n.	Actual α is less than nominal α when populations are leptokurtic (i.e., $\beta_2>3$). Actual α exceeds nominal α for platykurtic populations. (Effects are slight.)	Actual power is less than nominal power when populations are platykurtic. Actual power exceeds nominal power when populations are leptokurtic. Effects can be substantial for small n's.
Heterogeneous Variances	Very slight effect on α, which is seldom distorted by more than a few hundredths. Actual α seems always to be slightly increased over the nominal α.	(No theoretical power value exists when variances are heterogeneous.)	α may be seriously affected. Actual α exceeds nominal α when smaller samples are drawn from more variable populations; actual α is less than nominal α when smaller samples are drawn from less variable populations.	(No theoretical power value exists when variances are heterogeneous.)
Combined non-normality and heterogeneous variances	Non-normality and heterogeneous variances appear to combine additively ("non-interactively") to affect either level of significance or power. (For example, the depressing effect on α of leptokurtosis could be expected to be counteracted by the elevating effect on α of having drawn smaller samples from the more variable, leptokurtic populations.)			

Source: Glass, G. V., P. D. Peckham, and J. R. Sanders (1972). Consequences of Failure to Meet Assumptions Underlying the Fixed Effects of Variance and Covariance. Rev. Educ. Res., 42:237-288.

correlated with the observation in the preceding time period (_t_ - 1) or time period (_t_ - 2, etc.). In other words, an observation collected at time _t_ may _not_ be independent of one collected at time _t_ - 1 or _t_ - 2, etc., when the time intervals are short. Such dependency is termed _serial correlation_ or _autocorrelation_.

What is the effect of serial correlation on tests of significance regarding regression equations? Essentially, if a significant level of serial correlation exists, the data are not independent and tests of significance regarding any regression equations have limited utility (Table 2).

This raises the question: "How frequently can observations be collected while still maintaining independence?" Unfortunately, there is not a simple answer to this question. Identifying the characteristics and structure of serial correlation in time series data of water quality constituents represented one of the important areas of research facing statisticians. However, Beschta (1981) has suggested that observations collected during _stormflow_ should be at an interval of three or more hours. During _snowmelt runoff_, it appears that observations need to be obtained two or three days apart, while during low flow periods the samples should be collected two or more weeks apart to assure independence. If the observations are equally space in time, the serial correlations can be tested with the BMDP2T Program (BMDP, 1981), which is readily available on the computer at the Fort Collins Computer Center.

For further reading about the assumptions underlying ANCOVA, see Elashoff (1969); Glass, Peckham, and Sanders (1972); and Wildt and Ahtola (1978).

Quality and Size of the Data Base

Adequate and correct data are essential to the success of any study. No extent of statistical maneuvering can make up for sloppy data. Because many people may be collecting your data, it is good practice to establish written data-collection standards and insure that they are followed throughout the study.

At this time, we know of no procedures available to the hydrologist for determining a specific sample size that will permit a comparison test at a predetermined level of statistical reliability. We advise you to collect a minimum of 15 observations per station per year. It is important, of course, that you collect the samples throughout the sampling period relative to the relationship between flow characteristics and water quality constituent being measured.

APPLICATIONS OF THE PAIRED-BASIN TECHNIQUE

Cause-and-Effect Evaluation

The paired-basin technique can be used for evaluating possible cause-and-effect relationships. Consider the situation illustrated in Figure 6. Here we have a treatment isolated by placing stations upstream (station A) and downstream (station B) from the treatment. The problem is to determine the effect of the treatment on a specific water quality characteristic, such as suspended sediment. The strategy to be used in this situation is to establish a pair of basins (stations) A and B and collect data before and after the treatment.

The data can be related as illustrated in Figure 7. ANCOVA can be used to determine if the treatment had a statistically significant effect on the suspended sediment of the system.

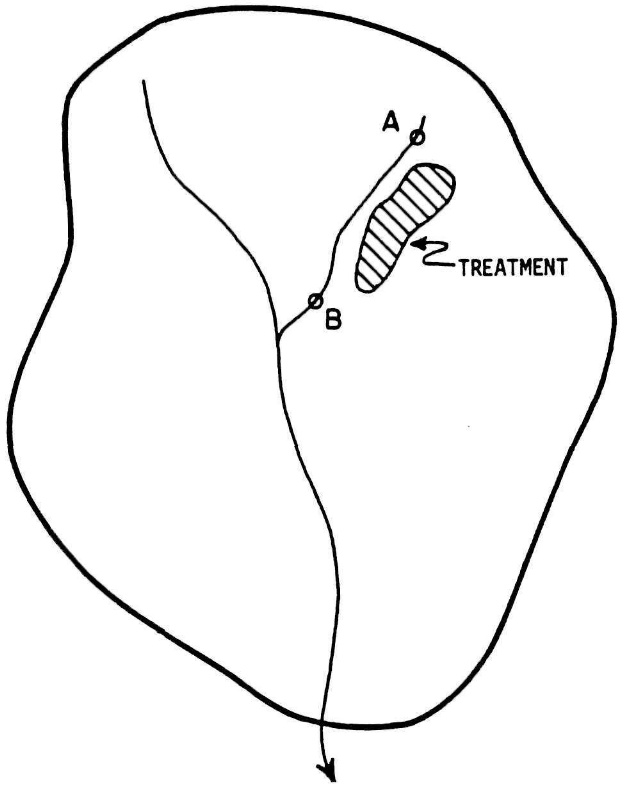

Figure 6. An example of cause-and-effect monitoring when the treatment can be isolated.

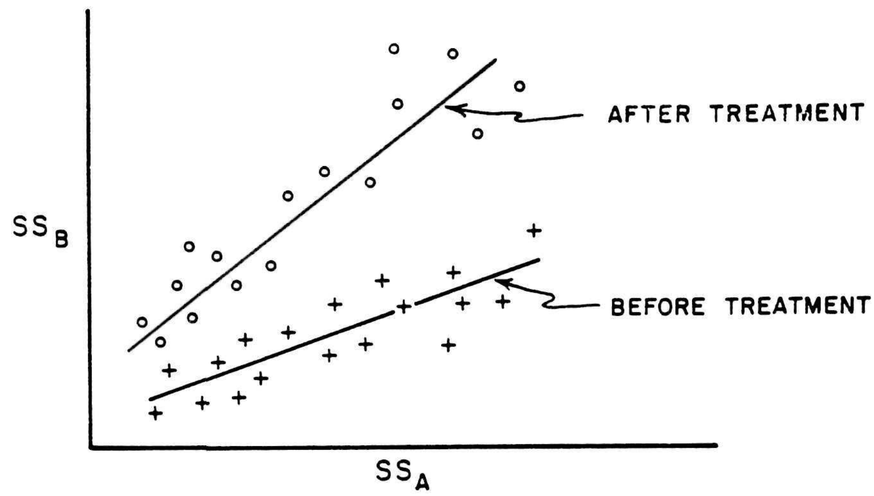

Figure 7. Before and after treatment regressions of suspended sediment at station A (SS_A) against suspended sediment at station B (SS_B).

Another example of possible cause-and-effect evaluation is presented in Figure 8. In this example, the treatment cannot be isolated by placing stations upstream and downstream from it. Consequently, a control basin needs to be selected and data collected both before and after the treatment. Data analysis would be similar to that previously described.

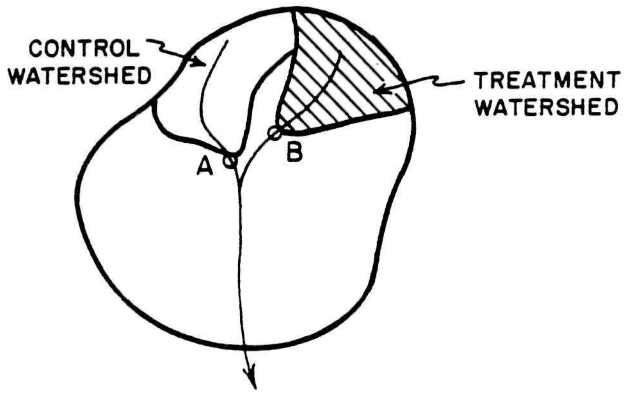

Figure 8. An example of cause-and-effect monitoring when the treatment cannot be isolated.

Trend Analysis

The paired-basin technique can also be used for trend analysis. The data from the treatment station are compared with the data from the control station throughout a series of time intervals, such as seasons or years. A regression relationship is developed for each time interval, and the trend in water quality is evaluated by comparing the slope and intercept of the regressions.

Consider, for example, three baseline stations: A and B represent actively managed basins, and C represents the control basin. The hydrologist would like to determine if there is a trend in turbidity on an annual basis. Paired-in-time data were collected at each station during the 1977-80 water year, the resulting regressions are presented in Figure 9. The data can be analyzed by a multiple comparison approach, where successive regressions are compared using ANCOVA.

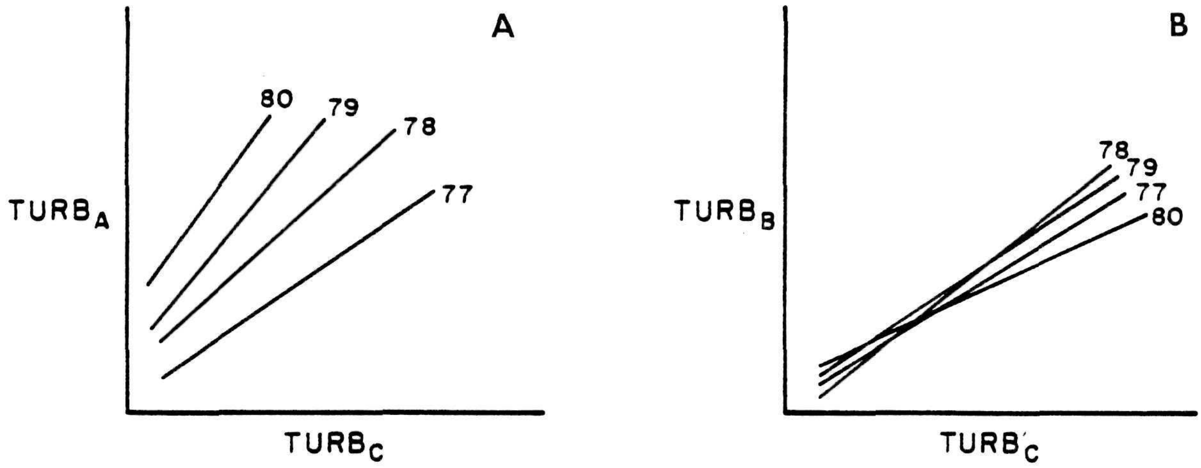

Figure 9. Paired plots of turbidity (TURB) for 1977-80 water years: A, stations A and C; B, stations B and C.

Turbidity at station A is increasing annually relative to turbidity at station C (Figure 9A). Whether or not the source is related to management activities cannot be determined from the paired plot alone; onsite observation and interpretation by the hydrologist are required. It is evident, however, that there is a definite trend in the relation. Figure 9B indicates little change in the relative relationship in turbidity between stations B and C. This indicates that the management activities used in basin B throughout the period of study did not change the turbidity yield from basin B relative to the control basin.

CONCLUSIONS

We believe the paired-basin technique, if used properly, is an effective tool for analyzing water quality data from upland streams. In some situations, the technique provides for greater statistical control (minimizes the unexplained variation) and enables the watershed specialist to maximize information gained while minimizing time, personnel, and economic expenditures.

As with any statistical tool, the paired-basin technique will only provide you with "yes" and "no" answers. The regression relations will only provide you with insight to the hydrologic system and water quality response. Data interpretation is an intellectual activity requiring all the skills of a professional wildland hydrologist.

REFERENCES

Averett, R. C., S. L. Ponce, and D. W. Schindler. 1981. A Report on: Bull Run Watershed Water-Quality Management. Bureau of Water Works, City of Portland, Oregon, 1800 S.W. Sixth Avenue, Portland, Oregon 97021. 53 p.

Bates, C. G., and A. J. Henry. 1928. Forest and Streamflow Experiment at Wagon Wheel Gap, Colorado. Final report upon completion of the second phase of the experiment. USDA Weather Bureau, Monthly Weather Review, Supplement No. 30. 79 p.

Beschta, R. L. 1981. Sediment and Bedload Sampling Study Design and Analysis. Lecture presented at the R-1 Soil and Hydrology Workshop, Missoula, Montana (April 27-30).

Beschta, R. L., S. J. O'Leary, R. E. Edwards, and K. O. Knoop. 1981. Sediment and Organic Matter Transport in Oregon Coast Range Streams. Water Resources Research Institute, OSU Report WRRI-70. Oregon State University, Corvallis, Oregon 97331. 67 p.

BMDP. 1981. BMDP Statistical Software 1981 Edition. University of California Press. Berkeley, California. 725 p.

Brown, G. W., and J. T. Krygier. 1971. Clearcut Logging and Sediment Production in the Oregon Coast Range. Water Resources Res. 7(5):1189-1199.

Elashoff, J. C. 1969. Analysis of Covariance: A Delicate Instrument. Amer. Educ. Res. J. 6:383-401.

Glass, G. V., P. D. Peckham, and J. R. Sanders. 1972. Consequences of Failure to Meet Assumptions Underlying the Fixed Effects of Variance and Covariance. Rev. Educ. Res. 42:237-288.

Ponce, S. L. 1980. Water Quality Monitoring Programs. Watershed Systems Development Group, WSDG-TP-00002, WSDG, USDA-Forest Service, 3825 East Mulberry, Fort Collins, Colorado 80524. 68 p.

Reinhart, K. G. 1967. Watershed Calibration Methods. In Proceedings of an International Symposium on Forest Hydrology. W. Sopper and H. Lull, eds. Pennsylvania State University. pp. 715-723.

Schindler, D. W., R. W. Newburg, K. G. Beaty, J. Prokopowich, T. Ruszczynski, and J. A. Dolton. 1980. Effects of a Windstorm and Forest Fire on Chemical Losses from Forested Watersheds and on the Quality of Receiving Streams. Can. J. Fish. Aquat. Sci. 37(3):328-334.

Singh, T. and Y. P. Kalra. 1972. Water Quality of an Experimental Watershed During the Calibration Period. Paper presented at the 19th annual meeting of the Pacific Northwest Region, American Geophysical Union, Vancouver, B.C. (October 16-17).

Thut, R. N. and E. P. Haydu. 1971. Effects of Forest Chemicals on Aquatic Life. Proceedings of a Symposium: Forest Land Uses and Stream Environment. Oregon State University, Corvallis, Oregon. pp. 159-171.

Wildt, A. R. and O. Ahtola. 1978. Analysis of Covariance. Sage Publications, Inc. Beverly Hills, California 90212. 93 p.

Wilson, A. L. 1978. When is the Chow Test UMP? Amer. Stat. 32(2):66-68.

A METHOD TO INDEX CHANGES IN WATER QUALITY

by

Gary M. Smillie
Civil Engineering Department
Colorado State University
Fort Collins, Colorado

Jim C. Loftis
Agricultural and Chemical Engineering Department
Colorado State University
Fort Collins, Colorado

and

Robert C. Ward
Agricultural and Chemical Engineering Department
Colorado State University
Fort Collins, Colorado

INTRODUCTION

An important aspect of water quality management is the detection and reporting of changes in water quality. A water quality change, such as a shift in the mean concentration, is important to management because a change represents either the failure or success of the management effort to maintain water of acceptable quality. Furthermore, it is important for the management agency to be able to communicate the effectiveness of the water quality program to legislative bodies promulgating environmental regulations and taxpayers supporting such programs.

The purpose of this paper is to develop a method to index changes in water quality. This work is a continuation of research presented by Smillie (1982) in which various methods are suggested to convert routinely collected water quality data into information for water quality management decision-making. The method presented here is intended to utilize commonly available state and federally collected water quality information and produce an easily understandable index value which indicates changes in a water quality variable relative to historical behavior. The index is useful in early detection of water quality changes as well as long-term changes or trends. The method recognizes the uncertainty inherent in water quality processes and utilizes statistical and probabilistic techniques to provide meaningful information to resource managers and the public at-large.

BACKGROUND

To detect changes in water quality it is necessary to initially establish a reference condition. This reference condition may be described by a mathematical model and subsequent changes may then be measured against the model. A model describing the reference water quality condition should be developed from data collected over a period of time prior to a new activity suspected of causing a water quality impact (baseline data). The model would, therefore, define the historical behavior of water quality and provide a basis from which future changes in behavior might be recognized.

In this work, a stochastic linear model is used to describe the reference water quality condition. This model was chosen because water quality variables often behave, to a certain extent, as a function of water discharge or other variables (i.e., water temperature, pH, specific conductance). The linear model accounts for such dependence and, therefore, reduces the amount of independent random behavior associated with water quality variables. The remaining random component of behavior is accounted for in the chosen model with the normal probability density function.

REFERENCE MODEL DEVELOPMENT

To use the stochastic linear model to describe the reference water quality condition, an assumption must first be made and later tested for validity. The assumption is that the water quality variable of concern behaves as a linear function of another variable.

$$Y = \beta_o + \beta_1 X + \varepsilon \tag{1}$$

where:

Y = water quality variable of concern

β_o = population regression parameter

β_1 = population regression parameter

X = indicator (independent) variable

ε = error term (i.i.d., $N(0, \sigma_\varepsilon^2)$).

Of course the population parameters of the model, β_o, β_1, and σ_ε^2, are never known exactly, but are estimated from sample information. The reference model, therefore, takes the following form.

$$Y = \hat{\beta}_o + \hat{\beta}_1 X + A \tag{2}$$

where:

$\hat{\beta}_o$ = estimated regression parameter

$\hat{\beta}_1$ = estimated regression parameter

A = a random term (assumed $N(0,\sigma_A^2)$)

$= Y - (\hat{\beta}_o + \hat{\beta}_1 X)$.

Note that A differs from ε in equation 1 because the estimated parameters $\hat{\beta}_o$ and $\hat{\beta}_1$ are not equivalent to β_o and β_1, respectively.

Calibration of the model should be performed using an unbiased parameter estimation procedure such as minimizing the sum of squared errors:

$$\hat{\beta}_1 = \frac{\Sigma(X_i - \bar{X})\ \Sigma(Y_i - \bar{Y})}{\Sigma(X_i - \bar{X})^2} \tag{3}$$

$$\hat{\beta}_o = \bar{Y} - \hat{\beta}_1\ \bar{X} \tag{4}$$

where:

$\bar{X}$ = sample mean of X

$\bar{Y}$ = sample mean of Y.

The deterministic component of the reference model may now be written as follows:

$$\hat{Y} = \hat{\beta}_o + \hat{\beta}_1\ X \tag{5}$$

where:

$\hat{Y}$ = estimated expected value of Y given X = x.

Since $\hat{Y}$ is an estimate of the expected value of Y given X = x (E[Y|X]), dependent upon the accuracy of $\hat{\beta}_o$ and $\hat{\beta}_1$, it is a random variable with a certain mean and variance. The mean of $\hat{Y}$ is equal to the mean of Y given X = x since an unbiased parameter estimation procedure was used and the variance may be estimated according to Draper and Smith (1966, p. 22) as:

$$\hat{\sigma}_{\hat{Y}}^2 = \hat{\sigma}_Z^2 \left(\frac{1}{n} + \frac{(X_k - \bar{X})^2}{\Sigma(X_i - \bar{X})^2} \right) \tag{6}$$

where:

$\hat{\sigma}_{\hat{Y}}^2$ = estimated variance of $\hat{Y}$

$\hat{\sigma}_Z^2$ = estimated variance of $\hat{Y}$ errors (see equation 8)

n = number of samples in calibration data

X_k = the kth value of variable X

= x.

It can be seen that the variance of the regression line, Y, is a function of the magnitude of X and that the variance is a minimum where $X = \bar{X}$.

To use equation 6 we need to find $\hat{\sigma}_Z^2$. This is done by defining Z as follows.

$$Z = Y - \hat{Y} \tag{7}$$

The residuals, Z, calculated from the calibration data are the error terms about the regression line and are assumed to be independent identically distributed random variables, $Z \sim$ i.i.d., $N(0, \sigma_Z^2)$. The mean of Z is zero since $E[\hat{Y}] = E[Y|X]$ and the variance may be estimated as follows:

$$\hat{\sigma}_Z^2 = \frac{1}{n-2} \Sigma Z_i^2 \tag{8}$$

We now have estimated β_o, β_1, σ_Z^2, and $\sigma_{\hat{Y}}^2$ and need only to estimate σ_A^2 to fully calibrate the model.

The variance of A is comprised of two components; the variance about the regression line (σ_Z^2) and the variance of the regression line itself ($\sigma_{\hat{Y}}^2$). These two components of variance are independent so the variance of A is simply their sum:

$$\sigma_A^2 = \sigma_Z^2 + \sigma_{\hat{Y}}^2 \tag{9}$$

Therefore,

$$\hat{\sigma}_A^2 = \hat{\sigma}_Z^2 + \hat{\sigma}_{\hat{Y}}^2 \tag{10}$$

$$\hat{\sigma}_A^2 = \hat{\sigma}_Z^2 \left(1 + \frac{1}{n} + \frac{(X_k - \bar{X})^2}{\Sigma(X_i - \bar{X})^2}\right) \tag{11}$$

"GOODNESS OF FIT"

The "goodness of fit" of the reference model can be determined by testing independence and normality of the residual series obtained from model calibration. Independence may be tested by comparing the correlation coefficients between the residuals and all other variables and the residual series autocorrelation coefficients against the 95 percent probability limits of independent correlation coefficients (Jenkins and Watt, 1969) as follows:

$$r' = \pm \frac{1.96}{\sqrt{n}} \tag{12}$$

where:

r' = 95 percent probability limits.

The null hypothesis that the correlation coefficient, r, equals zero is accepted if the calculated r falls within the limits of Equation 12.

Residual series normality may be established using a chi-square test. For a given or hypothesized probability distribution, this test computes the expected number of occurrences of a random variable in a specified class interval. The number of observed occurrences in the class interval is subtracted from the expected number in the same class interval. This difference is squared and divided by the expected number. These normalized, squared differences are summed over the entire range of possible random variable values and the sum may be considered a measure of "goodness of fit."

$$D = \sum_{i=1}^{m} \frac{(O_i - E_i)^2}{E_i} \tag{13}$$

where:

D = calculated statistic

m = number of class intervals

O_i = number of observed occurrences in class interval i

E_i = expected number of occurrences in class interval i.

The statistic, D, is compared to a critical chi-square statistic, χ^2, obtained from a table to determine if the distribution fits at a specified level of significance.

If the residual series passes the tests of independence and normality, the model is ready to be used to detect changes in water quality. If the model does not pass the "goodness of fit" tests, the model should be modified until an acceptable "fit" is obtained. The model may be modified quite simply by making transformations such as the natural logarithm of the variables used in the regression component of the reference model. The natural logarithm transformation, of course, is only one of many possible transformations, and others should be tried to find the one that best linearizes the data.

INDEX DEVELOPMENT

The reference model may be used to evaluate changes in water quality variables through the use of an index. On days when water quality samples are collected, regression model estimates are calculated for each variable of concern. The residual series, z_i', is then calculated between regression model estimates, $\hat{y}_i$, and observed values, y_i:

$$z_i' = \hat{y}_i - y_i \tag{14}$$

where:

z_i' = residuals from data collected subsequent to model calibration. (Note: y is subtracted from $\hat{y}$ rather than visa versa to give proper index sign.)

A new variable, U is calculated as the sum of the residuals.

$$U = \sum_{i=1}^{N} z_i' \tag{15}$$

where:

N = number of samples to be used in the index.

If it is assumed that no change has occurred in the behavior of variable Y, U can be shown to be normally distributed with mean zero. The variance of U can be estimated as follows:

$$\hat{\sigma}_U^2 = \sum_{i=1}^{N} \hat{\sigma}_{A_i}^2 \tag{16}$$

Now a standardized random variable, V, may be calculated as follows:

$$V = \frac{U}{\sqrt{\hat{\sigma}_U^2}} \tag{17}$$

The cumulative density function of V (denoted P) may be found in a cumulative standard normal table. The water quality change index is defined as:

$$\text{Index} = (P-0.5) \times 100 \tag{18}$$

If, indeed, no water quality change has occurred, the index is uniformly distributed with mean zero over the range -50 to +50. If a change has occurred, the mean value of the index will be negative for degraded water quality and positive for improved water quality.

The selection of N, the number of samples included in the index, depends upon the situation at hand. First, for early detection of changes or problems, individual index values (N = 1) may be calculated. Inspection of individual index values calculated soon after a sample is collected may assist in detecting short-term events and/or suggest the collection of a follow-up sample(s) to verify the suspected condition. For longer term evaluations, individual index values may be plotted with time and inspected for trends. If no change has occurred in water quality behavior, the individual index values should appear symetrically distributed about zero. If it appears that more individual index values are positive or negative than would have been expected, the samples making up these index values may be grouped to form one index value. For inspection of annual water quality behavior, the sample size should equal the number of samples collected in the year, i.e., $N = 12$ if a monthly sampling program is used. The usefulness of grouping samples into one index value will be discussed in more detail later.

Because it is not previously known whether or not a water quality change has occurred and because, due to chance, the index may take on a range of values, hypothesis testing is used to make inferences regarding water quality changes from index values. In hypothesis testing the probability, α, of rejecting the null hypothesis, when in fact it should have been accepted, is specified. This type of error is commonly referred to as a Type I error. Applying hypothesis testing to the water quality change index requires the null hypothesis to be specified as an unchanged system and the alternative hypothesis as a changed system. The user must then specify α, the probability of incorrectly assessing water quality as changed, i.e., degraded or improved when in fact it is unchanged.

The critical values of the index, denoted $\pm\phi$, where water quality will be described as degraded or improved with the given significance level, may be calculated as follows:

$$\phi = \pm(50 - \frac{\alpha}{2}) \qquad (19)$$

where:

ϕ = critical index values

α = chosen significance level expressed as a percentage.

Table 1 presents criteria for evaluating index values with the chosen significance level, α.

Table 1. Water quality change index evaluation.

Index Value	Assessment
-50 to $-\phi$	Degraded water quality
$-\phi$ to ϕ	Unchanged water quality
ϕ to 50	Improved water quality

To illustrate Table 1, assume that α has been specified as 10 percent. By Equation 19, the critical values of the index are +45 and -45. Using Table 1 it can be seen that calculated index values greater than or equal to +45 indicate improved water quality, and index values less than -45 indicate degraded water quality. ("Improved" or "degraded" are used to indicate changes in water quality relative to the condition described by the reference model.) Furthermore, an assessment of changed water quality will be incorrectly made, when in fact the quality is unchanged, 10 percent of the time.

Index values may take on a range of magnitudes whether or not a change in the system has occurred. There is always a probability that due to chance an index value calculated from a series of samples will lead to an incorrect assessment of unchanged water quality. The probability of such an error (accepting the null hypothesis when in fact it should have been rejected) is called a Type II error and has a probability of occurrence of β. The statistical power of a hypothesis test is defined as $1 - \beta$. It is desirable to construct the hypothesis test such that the statistical power is maximized, i.e., β is minimized.

Three factors affect the magnitude of β. First, the magnitude of a change in mean directly influences β. The larger a given change in the mean, the smaller β becomes. Very small changes have associated relatively large values of β and are, therefore, difficult to detect.

Secondly, the number of samples incorporated into an index value affects the size of β. Larger sample sizes result in smaller β values and, as a result, small changes in the mean become more apparent with larger samples. For this reason, in addition to individual index values ($N = 1$), indexes should be calculated periodically using larger groupings of samples to increase the statistical power of the procedure.

The third factor affecting the magnitude of β, is the selection of α. A reduction in α results in a smaller Type I error probability but also an increase in Type II error probability, β. Judicious selection of α should be made keeping in mind the purpose of the indexing. If, for example, the purpose of the index is to determine with a large degree of confidence that no water quality degradation is occurring, α should be set relatively small. The probability of incorrectly assessing water quality as degraded is $\alpha/2$ if, in fact, no change has occurred and is less than $\alpha/2$ if water quality has, in fact, improved. Conversely, if the primary goal of indexing is to detect subtle improvements or degradations of water quality, α should be set relatively high.

EXAMPLE

To provide an example of the preceeding method, a computer simulation was performed with a contrived system. Simulation was chosen for the example because of greater control and record length than could have been found in existing water quality data records. The simulation allowed data points to be generated from an unchanged system and from systems changed by a known amount. This allowed the evaluation of the frequency of correct assessments from the method, both in unchanged and changed cases.

The computer was used initially to generate 2500 pairs of X and Y variables from the following linear system (Case 1).

$$Y = 0.40\ X + 15 + \varepsilon \tag{20}$$

$$X \sim N(500,\ 22{,}500)$$

$$\varepsilon \sim N(0,\ 1{,}369)$$

Next, 100 values of X and Y were chosen and the parameters of the linear model were estimated.

$$Y = 0.3814\ X + 24.8274 + A \tag{21}$$

$$X \sim N(512.23,\ 26{,}268.06)$$

$$A \sim N(0,\ \sigma_A^{\ 2})$$

$$\hat{\sigma}_Z^{\ 2} = 1241.59$$

$$\hat{\sigma}_{\hat{A}}^{2} = 1241.59 \left(1 + \frac{1}{100} + \frac{(X_k - 512.23)^2}{2600539.40}\right)$$

Then 1000 values of X and Y (different from the set of 100 used in calibration) were used to compute 1000 individual index values and 83 groups of 12 index values. Since the data simulation had been performed with the original model, i.e., an unchanged system, the predicted distributions of both sets of index values are uniform. The results for Case 1 are plotted on Figure 1. A chi-square test yielded D statistics (see equation 13) of 5.82 and 12.06, respectively, for the individual indexes and groups of 12 indexes. The critical chi-square statistic at the 5 percent significance level is 16.8 indicating that neither of these distributions are significantly different from the uniform distribution at the 5 percent significance level.

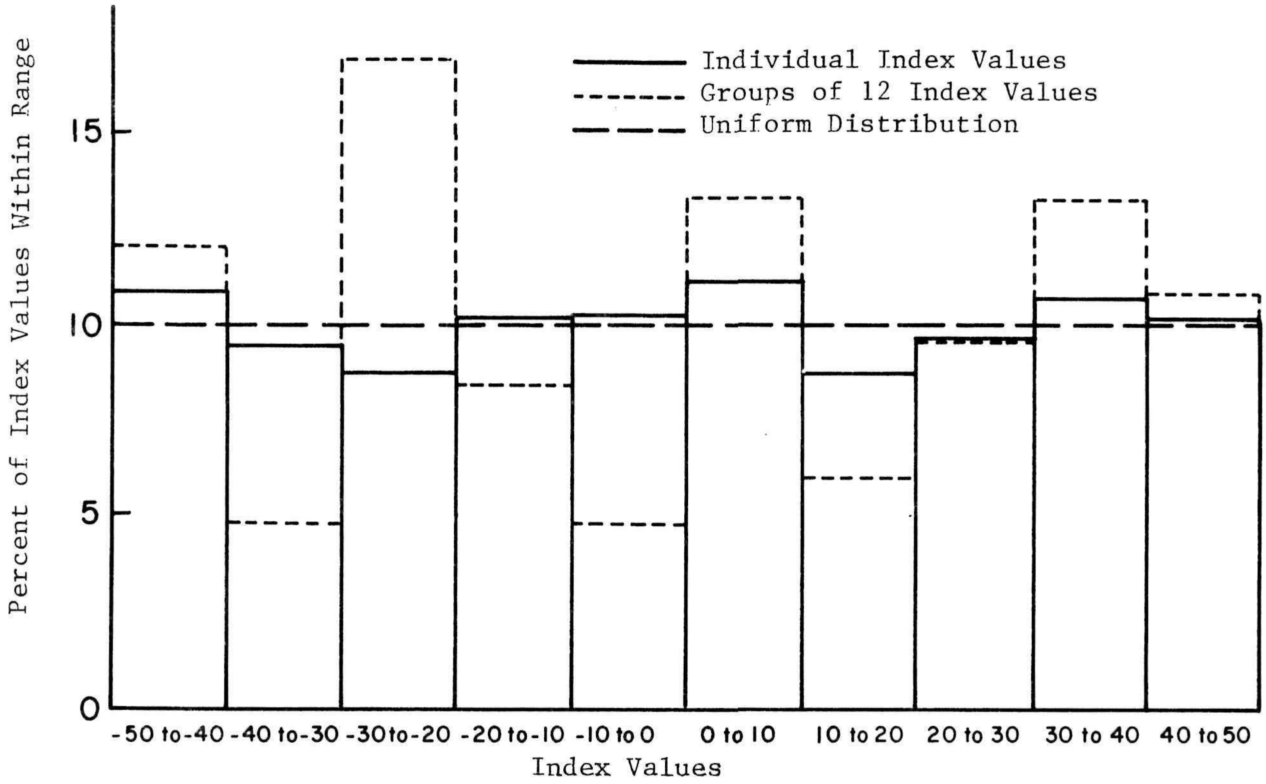

Figure 1. Index value frequency histogram for Case 1, unchanged system.

Next, 1000 X and Y values were generated each from two new linear systems representing a change in water quality behavior.

$$Y = 0.42\ X + 17 + \varepsilon \tag{22}$$

$$X \sim N(500,\ 22{,}500)$$

$$\varepsilon \sim N(0,\ 1{,}936)$$

and

$$Y = 0.44\ X + 19 + \varepsilon \tag{23}$$

$$X \sim N(500,\ 22{,}500)$$

$$\varepsilon \sim N(0,\ 2{,}500)$$

Equation 22 (Case 2) represents a 5.6 percent increase in the mean magnitude of variable Y and Equation 23 (Case 3) represents an increase of 11.2 percent. From each of these sets of simulated data, again 1000 index values and 83 sets of groups of 12 index values were calculated. These results are plotted on Figures 2 and 3. It is apparent that these values are not uniformly distributed as in the unchanged case.

RESULTS

The following evaluation of the indexes calculated from data simulation is based upon an α selection of 20 percent. This makes the critical regions of the index -50 to -40 and 40 to 50. As recommended by Table 1, when index values are contained in the range -50 to -40 an assessment of degraded water quality will be made and when index values are in the range 40 to 50 an assessment of improved water quality will be made. From this we predict a Type I error (rejecting H_o: unchanged system when it should have been accepted) in 20 percent of the values. It can be seen from Figure 1 that in fact such an error was made in 21.1 percent of the samples on an individual basis and in 22.9 percent of the group of 12 indexes. In the two changed system cases, Figures 2 and 3, it can be seen that the correct assessment (index between -50 and -40) was made 21.4 percent for individual sample indexes calculated with Case 2 data and in 32.3 percent of the indexes calculated on Case 3 data. For the groups of 12 indexes; 44.6 were correct for Case 2 and 74.7 were correct for Case 3. The mean value of individual indexes were 0.18, -7.90, and -14.60, respectively, for Case 1, Case 2, and Case 3. For the groups of twelve indexes the mean values were 0.66, -24.40, and -38.61, respectively.

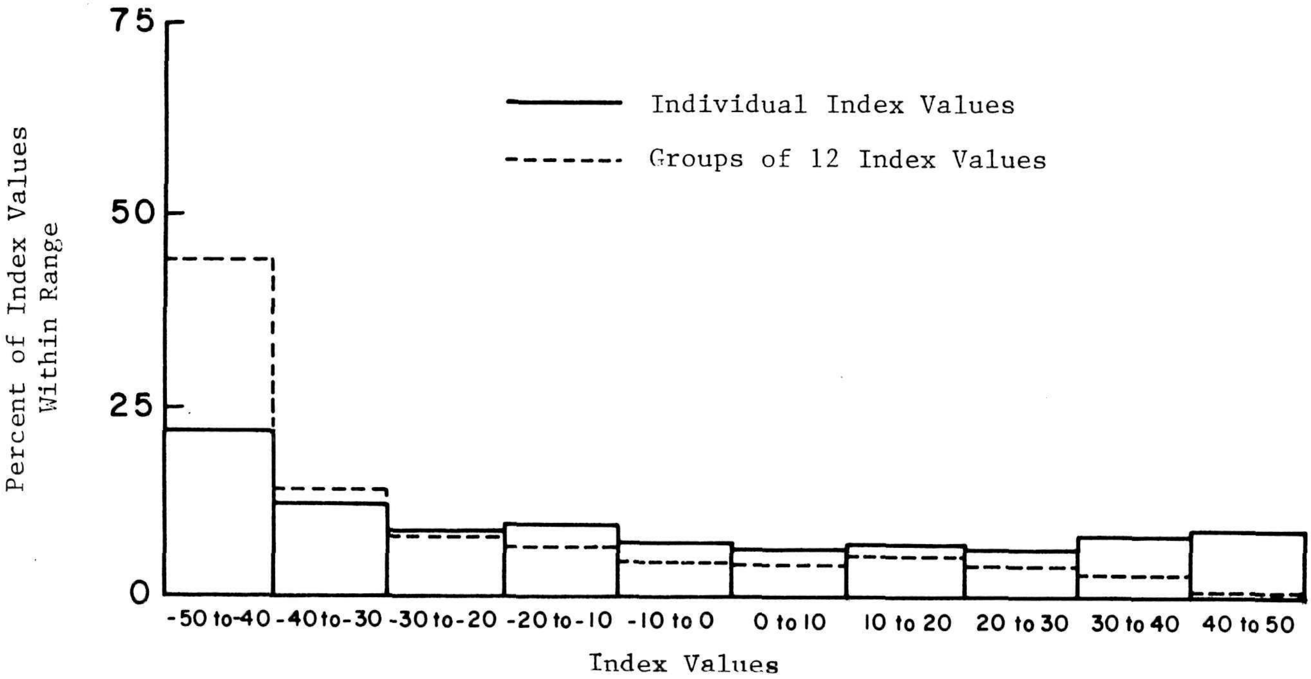

Figure 2. Index value frequency histogram for Case 2, 5.6 percent increase in mean.

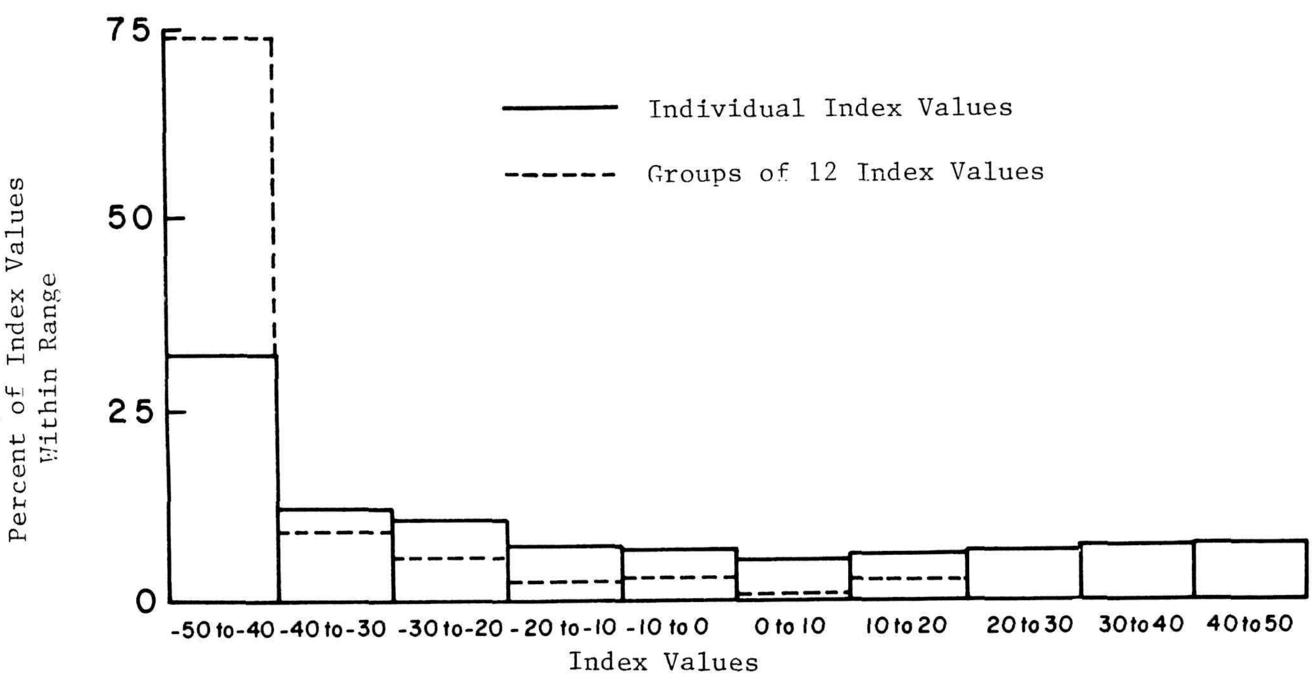

Figure 3. Index value frequency histogram for Case 3, 11.2 percent increase in mean.

CONCLUSIONS

The indexing procedure worked quite closely to the predicted behavior. The indexes calculated with 12 samples did not behave as closely to the predicted behavior as the individual indexes probably because of the smaller index sample size, 83 versus 1000. However, as predicted, the method detected real changes with an increasing frequency as the magnitude of the change increased and as the number of samples incorporated in the index increased. Also, as predicted, the mean value of the indexes were near zero for the unchanged case and negative for the degraded quality cases. It would appear that for actual water quality data which may be adequately described with the linear model, the method may provide a simple technique for both early detection of water quality problems and the detection of long-term changes in water quality. Furthermore, the procedure should provide resource managers with a tool to communicate the achievements of management programs to nontechnical persons.

REFERENCES

Draper, N. R. and H. Smith. 1966. Applied Regression Analysis. John Wiley and Sons, Inc. New York.

Jenkins, G. M. and D. G. Watts. 1969. Spectral Analysis and Its Applications. Holden Day Series in Time Series Analysis, San Francisco, California.

Smillie, G. M. 1982. Water Quality Assessment with Routine Monitoring Data. Unpublished M.S. Thesis, Department of Civil Engineering, Colorado State University, Fort Collins, Colorado.

ACKNOWLEDGMENTS

Financial support for this work was partially provided by National Science Foundation Grant No. PRA-7913073. The authors extend thanks to members of the USDA Forest Service, Watershed Systems Development Group , Fort Collins, Colorado for their technical assistance.

USE OF BIOLOGICAL AND ECOLOGICAL PARAMETERS IN WATER QUALITY STUDIES

by

D. L. Stoneburner
Water Resources Field Support Laboratory
National Park Service
Fort Collins, Colorado

and

L. A. Smock
Department of Piology
Virginia Commonwealth University
Richmond, Virginia

INTRODUCTION

There are four basic characteristics of all waste receptacles:

1. The capacity must be adequate to accommodate the waste materials.
2. It must be low in maintenance costs.
3. The receptacle should be mobile, allowing removal of the waste from the generating site.
4. The receptacle should keep the waste out of sight, hence, out of mind.

We are very fortunate in that we have two very convenient waste receptacles in our environment: the atmospheric and aquatic ecosystems. In the past these two large reservoirs have been ideal waste basins. However, by now the capacity of these two receptacles has been reduced. They no longer have a low maintenance cost, nor do they any longer move the wastes away from the generating site with great efficiency. You might say that we live closer to our waste today than yesterday. This is a very well-documented cycle in human civilizations. Finally, the wastes are no longer kept out of sight and out of mind. This meeting is a small but important example of how much environmental degradation is on our minds.

Reduction in water quality has visibly occurred on a global scale; although skeptics continue monitoring to detect the presence and effects of industrial and domestic wastes in the aquatic receptacle. This is, to a large degree, a burden on the biologists who strive to, but frequently cannot, present the invariable, numerical data and predictive models presented by chemists, hydrologists, and engineers; and requested by many resource managers. Biologists are beginning to take a more holistic view and to link these data with much of the physical and chemical data and models. However, much of the interpretation is still intuitive and based on experience. One current biological effort is to establish a credible biological monitoring strategy. This effort invariably leads to the question, why monitor? The answer is implicit; we either learn to evaluate the impact of massive daily waste doses, predict their effects and occurrences and manage them or potentially lose complete control of the system.

MONITORING WATER QUALITY

Having made the decision to monitor water quality by using biological data as one component of the information matrix that also includes physical and chemical data, the next decision is to determine how long to monitor, i.e., are we interested in short-term or acute responses, or rather long-term or chronic responses, or both? The choice of how long to monitor should be made after discussions with engineers, chemists, and biologists. It is frequently not cost effective to call any one of the groups into a monitoring program after it has been started.

Short-Term Monitoring

The short-term biological monitoring efforts are generally directed toward assessing spill impacts, point and nonpoint source discharges, acute toxicities, and general acute-impact surveys. These efforts generally require 1 to 4 weeks of field time and are cost effective in crisis situations as well as for general assessments. Short-term programs are not unlike sticking your finger in a leaking dike; these studies point out the presence, severity, and immediate impact of human activities on water quality, after the fact.

Long-Term Monitoring

Long-term biological monitoring can be utilized to address a wide range of problems and issues: toxicities of chemicals on one or more generations of test organisms; pre- and postindustrial development effects; avoidance/attractance issues; long-term impact of industrial and domestic facilities; and the use of potential early warning systems. The long-term studies suggest some anticipation of changes in water quality caused by human activity and result in data offering a series of decisions or options concerning changes in water quality before or as they occur. This is easily catagorized as predictive biological monitoring.

What and How to Monitor

The next monitoring decision has two basic questions: What will be monitored, and how will it be monitored? The answers depend, of course, on whether long-or short-term monitoring is selected, the type of system to be monitored, the data collected by engineers and chemists, and the goal of the program.

Let us assume that we are involved in a short-term study of a small river. Experience will lead us to examine the macroinvertebrates, diatoms, protozoa, or possibly bacteria. The amount of money available determines which of these groups or combination of groups will be sampled. The ideal situation would be to sample several levels of organisms such as the primary producers (algae), macroconsumers (aquatic insects), and possibly decomposers (bacteria). This would permit examination of how the suspected waste is affecting the various components of an intricately linked aquatic ecosystem. This is frequently not possible.

We will now further specify that we have been asked to assess the impact on a small river of a toxic chemical such as from an industrial effluent, land-fill seep, or chemical spill from a tank car. Diatoms would be a logical choice if the river is shallow and relatively clear. If the river is deep and muddy, one would select aquatic insects; if the river has quiet backwaters, the selection would include benthic invertebrates, diatoms, protozoa, and bacteria. The selection of organisms to sample basically depends on the expertise and experience of the biologists; more often than not benthic invertebrates and algae are sampled. In short- and long-term impact monitoring the type of organisms sampled depends on the site, the situation, and the expertise of the biologists involved. There is still a debate on how to sample. As long as the sampling stations are selected for physical similarity, biologists can use an assortment of nets, corers, dredges, and artificial substrates. All samples however, must be collected with the same make of sampler.

Long-term monitoring for toxicities and avoidance/attractance testing generally require some form of mobile or stationary laboratory.

The test organisms used in toxicity studies differ from one part of the country to another. The choice of test organisms depends on the toxicologist's preference, the type of water, and the chemical assayed. Some attempt has been made to establish one or two selected species of algae and the fathead minnow as the white mice of aquatic bioassays, but no "standard" test organisms or set of methods have as yet been determined that meet the requirements of all situations.

DATA ANALYSIS AND INTERPRETATION

Let us assume that you have assembled a team of engineers, biologists, and chemists to monitor water quality and that they are all harmoniously working together to integrate their data. What do the biological data mean? How has it been analyzed, and why have the biologists presented you with a bouquet of Latin names?

Just how the biological data collected for an impact study are analyzed depends on what the physical characteristics of the study site are like; whether the samples are quantitative, qualitative, or both; and the experience and background of the biologists doing the work.

Indices

The *diversity index* has been used a great deal during the past 15 years and is still being used by many biologists doing impact studies. Basically, the diversity index is based on the assumption that a community in a natural or unimpacted area is comprised of a low number of many kinds of organisms; that is, it is diverse. A community living below an effluent, especially an effluent with organic wastes, is generally composed of a great many organisms but of only a few species; that is, it is not diverse. Hence, reduced water quality lowers diversity.

One of the most used diversity indexes is the Shannon-Wiener Index, with values based on both the number of species present and the distribution of individuals among the species. Values range from 0 to around 4, depending on sample size (Wilhm, 1970). Under conditions of organic pollution, a diversity index of 0 to 1 indicates water of very poor quality, values of 1.0-2.5 indicate water of poor to fair quality, and values above 3.0 indicate water of good quality (Wilhm and Doris, 1968). This index works best for organisms that are somewhat stationary and can be collected from sites that are physically similar. These organisms include aquatic insects, diatoms and protozoa. The index has been used for fish, but a problem arises because fish can avoid an undesirable influence by swimming away from it.

Along with this index the concept of redundancy has evolved. The redundancy index indicates the extent to which an aquatic community is dominated by one or more kinds of organisms. Redundancy is inversely related to diversity and indicates the distribution of individuals among the species present.

When aquatic communities have high diversity and low redundancy indexes, the communities are said to be mature and stable. The water from which these organisms have been taken is said, by inference, to be of "good, or high, quality."

Another index is the biotic index (Chutter, 1972; Lenat et al., 1980) which is a quantitative, numerical attempt at evaluating community structure, using indicator organisms without placing undue emphasis on rare species, a well-espoused and theoretical shortcoming of the diversity index. Water having a biotic index of 0-2 is called, by inference, "clean, or unpolluted." Index values of 2-4 are "slightly enriched";

4-7 indicates a "very enriched condition"; and index values of 7-10 are classed "polluted."

Another, very simplified, form of diversity index is the sequential comparison index (Cairns et al., 1968). This tool requires only that the person observing the samples distinguish between one organism and the next. A preset number of organisms is sequentially observed, and the number of times a different organism is seen is noted. The number of changes noted is divided by the total number of organisms, and the index value is obtained. The higher the index, the better, again by inference, the quality of the water.

The degree of taxonomic expertise required to use these three typical indexes (there are a great number of indexes) varies from little training for the sequential comparison index to extensive training for the Shannon-Wiener Diversity and the Redundancy Index.

The value of the indices is that they produce concise, often reproducible numerical data for qualitative, as well as quantitative samples. It also should be stated that the quality of the samples, which determine the numerical indexes, depends to a great extent on the experience of the biologists doing the work. Simplicity, ease of use, and speed are the primary advantages of index systems.

Community Analysis

If one wishes to gather in-depth information about the condition of a stream, river, lake, or estuary, the use of both indicator organisms and community analyses are recommended. Compared to the diversity index, community analysis requires considerable taxonomic expertise, extensive knowledge about organism life histories, a solid knowledge of previous studies conducted in the area of interst, and a good deal of time. The resulting data are numerical and intuitive and present a great deal of information. The dollar cost of the index method may be lower in the short run, but community analysis is by far the more credible biological monitoring system.

Toxicity Studies

The aquatic toxicity study involves exposing some species of plant or animal--or, recently, a microcosm representing a hypothetically stable, mature aquatic ecosystem--to several known concentrations of a toxic chemical or, in some more elaborate bioassay systems, to a series of toxins, wastes, or several combinations of wastes. The data are generally reported as an LD-50 for 24, 48, 96, or 180 hours. The concentration of the waste or waste matrix is given as the concentration at which 50 percent of the test organisms died within the specified number of hours. This is the acute assay and its methodology has become relatively standard (APHA, 1975).

Chronic assays are used to examine the effect of sublethal concentrations of waste on several generations of an organism or group of organisms. This has considerably greater predictive value than acute bioassays.

Integration of Data

How do these types of data fit into an environmental monitoring system? The long- and short-term field surveys can be used by the engineer to describe the changes that could occur or have occurred because of hydrologic changes, bed sediment loading, solids in the water column, and drawdown temperatures from dams. These same data assist the chemist in predicting the changes caused by various chemical effluents and how far down stream the effect will occur. The data can give a general idea of how toxic a particular discharge is to a spectrum of aquatic life and can be used to monitor waste-treatment technology.

Toxicity tests can be used to determine the toxicity of specific chemicals, temperatures, and solids loading to specific types of organisms. These data then can be used to help set or establish water quality and quantity standards for a specific stream, river, or lake.

Biological data, physical data, and chemical data frequently have been used alone; however, the combination of the three types of data--or even the combination of the biological and physical or chemical data--will enhance our understanding of the system being monitored.

REFERENCES

American Public Health Association. 1975. Standard methods for the examination of water and wastewater. 14th ed. APHA-AWWA-WPCF.

Cairns, J., Jr., D. W. Albaugh, F. Busey, and M. D. Chanay. 1968. The sequential comparison index--a simplified method for non-biologists to estimate relative differences in biological diversity in stream pollution studies. J. Water Pollut. Control Fed. 40:1607-1613.

Chutter, F. M. 1972. An empirical biotic index of the quality of water in South African streams and rivers. Water Res. 6:19-30.

Lenat, D. R., L. A. Smock and D. L. Penrose. 1980. Use of benthic macroinvertebrates as indicators of environmental quality. In D. L. Wolf (ed.), Biological monitoring for environmental effects. Lexington Books, pp. 97-112.

Wilhm, J. L. 1970. Range of diversity index in benthic macroinvertebrate populations. J. Water Pollut. Control Fed. 42:R221-R224.

Wilhm, J. L. and T. C. Dorris. 1968. Biological parameters for water quality criteria. BioScience 18:477-481.

RESERVED WATER RIGHTS AND THE NATIONAL PARK SERVICE: THE PRESENT STATUS AND FUTURE PROBLEMS

by

John R. Little, Jr.
and
Ralph O. Canaday[1]
Office of the Solicitor
Rocky Mountain Region
U.S. Department of Interior
Denver, Colorado

INTRODUCTION

Since the subject is Reserved Rights, it would be well to define what Reserved Rights are. The best and most recent statement of this doctrine by the Supreme Court is found in Cappaert v. United States:

> This Court has long held that when the Federal Government withdraws its land from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation. In so doing the United States acquires a reserved right in unappropriated water which vests on the date of the reservation and is superior to the rights of future appropriators.
>
> * * * *
>
> In determining whether there is a federally reserved water right implicit in a federal reservation of public land, the issue is whether the Government intended to reserve unappropriated and thus available water. Intent is inferred if the previously unappropriated waters are necessary to accomplish the purposes for which the reservation was created.
>
> * * * *
>
> The implied-reservation-of-water doctrine, however, reserves only that amount of water necessary to fulfill the purpose of the reservation, no more.[2]

This is from a 1976 case which is discussed later.

HISTORY OF THE CASES

Federal reserved rights have been the object of great and voluminous analysis since the Pelton Dam case[3] was decided in 1955. Prior to this case, federal rights were considered in only two contexts--Reclamation projects and that peculiar "quirk of Indian water law"--reserved right.[4] During the period prior to these dates, water law "...was almost exclusively preoccupied with developing doctrines to settle private disputes between private claimants." Hence, there was no occasion to define rights inherent in federal ownership or federal sovereignty![5]

Rio Grande Dam

The first case usually considered in a discussion of federal reserved rights is United States v. Rio Grande Dam and Irrigation Co.[6] That 1899 case involved a conflict between the navigation servitude and a proposed private dam at Elephant Butte, New Mexico. The Government sought an injunction based on the 1890 Rivers and Harbors Act.[7] Specifically, the Court was called upon to determine whether the project should be enjoined if the dam and related appropriations of water would substantially diminish navigability. In reaching its decision, the Court, in dictum, said:

> [I]n the absence of specific authority from Congress, a state cannot by its legislation destroy the right of the United States, as the owner of lands bordering on a stream to the continued flow of its waters, so far as least as may be necessary for the beneficial uses of the government property.[8]

The Supreme Court's analysis in this case suggests that there are federal proprietary interests in water and, by implication, rejects state arguments of total federal divestment of its control over waters as a result of the Acts of 1866, 1870, and 1877.[9]

Winters

The Winters case followed in 1908.[10] This was an action brought to restrain upstream irrigators from preventing some of the water of the Milk River in Montana from flowing into the Fort Belknap Indian Reservation which had been created by an 1888 agreement ratified by Congress. At issue were claims by reservation Indians that their water rights were senior to those of private appropriators who had been using water under the authority of state law. The Court agreed with the Indians, finding that the creation of the Fort Belknap Indian Reservation preceded the appropriation for irrigation under state law. The Court said, "the power of Government to reserve waters and exempt them from appropriation under state laws is not denied, and could not be."[11]

Most view the Winters case as the beginning of the reserved rights doctrine, and its importance to federal assertions of control over unappropriated water is persuasive.

Beaver Portland Cement Co.

The next major case in this area occurred twenty-three years later, when Justice Sutherland wrote the famous decision in California Oregon Power Co. v. Beaver Portland Cement Co.[12] Plaintiff in this case was the Power Company. It asserted rights as a riparian owner of lands on Oregon's Rogue River and prayed for an injunction against defendant's upstream use which threatened to lower the level of the river as it passed through plaintiff's property. In holding for the defendant, the Court found that after the Desert Land Act of 1877 was passed, no Government patents (including that of plaintiff's predecessor dating from 1885) carried common law riparian rights with them. In other words, the Court injected a new factor into federal water rights analysis by suggesting the 1877 Act "severed" the water from public lands and subjected water to the "plenary control" of the states. From 1935 to 1955 reserved water rights law seemed to be settled. Except for possible Indian claims under the Winters doctrine, the only federal water rights of consequence were those acquired from Reclamation projects and all non-Indian agencies--Forest Service, Bureau of Land Management, National Park Service, Fish and Wildlife Service and Reclamation--were acquiring water rights pursuant to state law.

Pelton Dam

Then in 1955 one of the most celebrated and controversial cases exploded on the water rights scene. This was the Pelton Dam case.[13] Portland General Electric had applied for a Federal Power Commission license on a site on the Deschutes River that had one abutment in the Warm Springs Indian Reservation and the other on public lands. Both abutments had been withdrawn for power purposes since about 1910. No consumptive use of water was contemplated because the dam was solely for power generation. Oregon challenged the application on the grounds that the structure would prevent anadromous fish from reaching upstream spawning grounds and that the sponsors of the project had no state license. The Court of Appeals set aside the Commission's order which had permitted construction of the dam with stipulations to protect the fish.

The Supreme Court reversed, holding that the Federal Power Commission had exclusive jurisdiction over authorization of a dam and this was based on the "ownership or control by the United States of reserved lands on which the licensed project is to be located."[14] The case really did not strictly involve water rights. The Court's language, however, inferentially, suggested the Beaver Portland Cement severance analysis did not apply to federal reservations of land; and thus set the stage for possible assertion of non-Indian federal reserved rights. Almost every western water lawyer immediately saw this implication. In other words, the United States could step to the head of the line without paying compensation. It could and probably would assert prior, senior rights to water that had been and was being used by private parties under purportedly valid state water rights. It should be noted that Pelton concerned the power of the Federal Government to authorize the use of its own lands for a nonconsumptive, power production project and that the water rights of other parties were not directly affected.

Arizona vs. California II

In the meantime, a major case had begun in 1952 in the Supreme Court for apportionment of the waters of the lower Colorado among the states of Arizona, California and Nevada under the Colorado River Compact of 1922.[15] Also, in question was the authority of the Secretary of the Interior to manage the federal reservoirs on the river. In the process of settling these disputes, the Court also addressed certain water rights claims by the Government for both Indian and non-Indian reservations. These included the Lower Colorado Indian tribes, Lake Mead National Recreation Area, two wildlife refuges, and upstream forests. The Court, in ruling on the latter claims, relied heavily upon Winters in finding that both the Indians and the Federal Government had reserved rights in order to make the reservations involved viable. The importance of this case is the unequivocal holding that the reservation doctrine first enumerated for the Indians was "equally applicable" to non-Indian federal reservations.

Cappaert

In 1952, President Truman added the Devil's Hole Cavern to the Death Valley National Monument. The cavern contained the famous underground pool and its even more famous occupant--the desert pupfish. In 1970, the Cappaerts applied for a Nevada well permit. The Government protested that the well draft would compromise the water level in the pool. Nevada granted the permit and the United States sued in federal court. In Cappaert v. United States,[16] the Court held in 1976 that the Cappaert well was junior to the federal reservation which enjoyed a reserved right and that the United States accordingly was entitled to an injunction to protect its senior right against compromise from either surface or groundwater junior diversion.

Cappaert is regarded by some as the zenith of the reserved right doctrine being constitutionally founded on the property clause.[17] In most other ways, Cappaert is a very standard reserved rights case, but there are some twists. First, the Court applied the reservation doctrine to groundwater for the first time. Second, the decision required that the pool level be held at an elevation but permitted well or other diversions so long as that level was maintained. This is a compromise in that a minimum level in the pool is decreed thus implementing the Court's holding that a reserved right carries with it only the absolute minimum amount of water needed for the purposes of the reservation. Third, as noted by one commentator, the decree is intriguing to those who argue for instream flows since the minimum pool elevation decreed is essentially a stationary instream flow.[18]

New Mexico

Finally, in 1978, the Court decided United States v. New Mexico.[19] The Court concluded that Congress had consistently deferred to western state water law in the enactment of pertinent legislation starting with the 1866 Mining Act. This case involved claims for reserved rights for the Gila National Forest. The Court ruled that water was reserved only for the primary purposes of forests established under the 1897 Forest Service Organic Act--securing favorable watershed conditions for water flows and timber supply. All other needs were secondary purposes for which the Government would have to obtain rights like any other appropriator under state law.

The case is mainly important because of how the Court arrived at this conclusion rather than the interpretation itself. In other words, it is the utilization of a narrow, strict construction technique founded on "deference to state law" that is significant rather than the details of the reading given the 1897 Act. Under this "deference" principle, therefore, unless Congress has clearly provided that state law will not be applied to acquisition of water rights under a particular federal statute, it will be presumed that state law will govern.

This opinion is obviously very unfriendly in tone to federal water rights in general and reserved rights in particular. One senses that the Court may feel that its previous opinions have been overread and perceives that federal, tribal, conservational, and other interests may have gained too much encouragement from them. The Court may thus have been seeking to serve notice that it will not tolerate any attempt by the Federal Government, Indian tribes, or others to effect wholesale displacements of vested state water rights in the west through the assertion of federal or tribal rights. Possibly, the Court may merely have also realized the full implication of the fire storm it first ignited in Pelton 23 years earlier and was attempting to bank the fire.

For whatever reason, clearly the Court was in a mood for "setting things right"[20] the day it decided New Mexico and California v. United States,[21] a case primarily concerned with the interpretation of Section 8 of the Reclamation Act,[22] and the decisions marked a stunning redirection of over 20 years of relatively steady expansion of basic concepts of federal water rights, particularly as to reserved rights. In retrospect, however, the retrenchment in reserved rights should have been anticipated and was perhaps even overdue. In nearly all of the previous cases, the facts were sympathetic to the Court finding an implication that water was intended to be reserved as well as land. The barren reservations, the refuges lacking purpose without water in Winters and Arizona v. California, and the pupfish pool of Cappaert evidenced relatively clear intention. It was, accordingly, inevitable that the Court would eventually be confronted with a case where it would say "enough" and find that evidence of inferred intention and implication was insufficient. Clearly, there is a point beyond which these two fuzzy concepts will not carry.

PRESENT PROBLEMS IN THE NATIONAL PARK SERVICE

Because of the McCarran Amendment[23] we have now had several years of experience with general adjudications of federal water rights in state courts. This Amendment provides for joinder of the United States in state courts for adjudication of federal water rights along with all other appropriators. Joinder of the Federal Government in the Eagle County case[24] (which includes Water Division, 4, 5, and 6 in Colorado) occurred in 1969. The United States has been joined in all the water divisions now. The Eagle case is on appeal to the Colorado Supreme Court. The certified record on appeal consists of eight boxes of evidence for the federal claims alone. The briefs on appeal are over six inches thick. The report of the master referee to the District Court is over 1000 pages. The case is probably two years away from a decision by the Colorado Supreme Court. Undoubtedly it will be appealed to the United States Supreme Court which will take another two years before that court renders a decision.

In these general adjudications in Colorado there are two types of situations the National Park Service faces in claiming reserved rights. In Rocky Mountain National Park the problem has been fairly simple in that the source of the water originates in the park and no one can make use of it until it has left the boundaries of the park. This has been called "Highority" by the Park Service. The purposes for the water claimed by the National Park Service for Rocky Mountain are based on the Act of January 26, 1915, establishing the park and the Act of August 25, 1919, which created the Service. The Act creating the National Park Service provides:

> ...to conserve and maintain in an unimparied condition their scenic, aesthetic, natural and historic objects, as well as the wildlife therein, in order that the monuments might provide a source of recreation for all generations of the citizens of the United States.

The Park Service claims the instream flows of all streams and rivers in the park for the above purposes. The two problems that have arisen here are the quantification of such flows and the priority date given the Park Service for those lands later transferred to the park from national forests. On the question of quantification, the Park

Service has claimed the natural flows, and this seems to have been accepted for Rocky Mountain. The other problem is more difficult because the park was created by transfer of previously reserved national forest lands to national park status in 1915 and a later transfer in 1930. The United States is arguing for a date when the forest was reserved originally and the State of Colorado is arguing that the priority date should be that date when the national forest was transferred to a national park. The rationale behind the United States' argument is that both the national forest and the park have similar uses and purposes.

The real struggle for the Park Service in the Eagle case is with Dinosaur National Monument where the claim for reserved rights is for instream flow in a park located in the middle of a stream. There is nonfederal land above and below the Monument so that the Yampa River passes through nonfederal land before it enters the Monument and flows through nonfederal land when it leaves the Monument.

We are advised that the average annual flow of the Yampa through the Monument is about 1.5 million acre-feet. Under the Upper Colorado Compact, Colorado is required to deliver to Utah an average of about 500,000 acre-feet annually. Between these two numbers is the water supply for the Bureau of Reclamation's proposed and authorized Savory-Pothooks project; a proposed diversion by the City of Cheyenne, Wyoming from the Little Snake tributary; the Colorado River Water Conservation District's proposed 1.3 million acre-foot storage capacity Juniper-Cross Mountain Project; a number of potential steam-fired powerplants; several possible coal gasification or liquefaction plants; and several other development plans. Most of these proposed projects have Colorado conditional right decrees. The Dinosaur instream flow claim has been recognized as a matter of law by the lower court but has not been quantified. If the allowance of the claim as a matter of law stands, and if it is quantified at an amount above the required Colorado delivery to Utah under the Upper Colorado River Compact, the supply to some or all of the proposed projects will be compromised.

The specific requests for reserved rights for Dinosaur were based on uses including: recreational uses; wilderness preservation uses; uses for the preservation of scenic, aesthetic and other public values; and uses for fish culture, conservation, habitat, protection, and management, including, but not limited to, minimum stream and lake levels as are necessary to do the above.

One of the biggest arguments in Dinosaur is over whether these reserved rights for minimum stream flows included water necessary for recreational boating, and if so, what was the date of the reservation for recreational boating. The claim for the above uses has also led to the involvement of other Acts such as the Wild and Scenic Rivers Act and the Endangered Species Act. Yes, we have two or possibly three endangered species (fish) in the Yampa River. Again, the Court has to decide what uses or purposes were included in the reservation, and then the even tougher question must be answered of how much water was reserved. This, as has been mentioned, will affect many projects up and down the stream from Dinosaur.

Another National Park which involves the question of reserved rights is Yellowstone National Park in Wyoming. It is in the same situation as Rocky Mountain since it is the source of the streams and lakes within it so no one can divert water before it leaves the park.

This is part of another McCarran Amendment general adjudication in Wyoming called the Big Horn Adjudication. As in Rocky Mountain the Park Service is claiming the natural flows which leads to an argument over quantification. The State of Wyoming wants the Park Service to quantify all streams and springs and identify the level of ponds and lakes. The Park Service argues that since it is claiming the natural flows for instream uses which are nonconsumptive, quantification would be a waste of time and money, and in some cases might destroy the feature that was being quantified. There is some hope that the claims for non-Indian reserved rights in Wyoming, including those of the National Parks, may be settled.

THE FUTURE OF FEDERAL RESERVED WATER RIGHTS

When the notion that there may be federal reserved water rights apart from Indian Reservations first surfaced in the 1955 Pelton case there was an immediate, and strongly felt, response. The doctrine was described as "a first mortgage of undetermined and undeterminable magnitude which hangs like a Sword of Damocles over every title to water rights on every stream which touches a federal reservation."[25] There were, and are, widespread fears that advancement of priority dates, through the use of reserved rights, not only would permit displacement of present water users by allowing the Government to "go to the head of the line," but also that such action would be "free." Soon after the Pelton case the first so-called "Barrett Bills" or "Western Water Rights Settlement Acts" was introduced. The Congress, however, has not seen fit to provide a remedy for the alleged displacements.

We suspect the reason Congress has gone slowly in enacting legislative responses to federal reserved rights is the one recently expressed by Professor Trelease: the experience in Colorado has suggested that the "Sword of Damocles" rhetoric is hyperbolic; substantial displacement of previous users has not occurred."[26] In all of the northwestern third of the State of Colorado, the current uses by forests and parks add up to only 12.981 cubic feet per second of stream flow and 2044.2 acre-feet of stored water."[27] Professor Trelease suggests that Congress will wait for a "case of real and substantial harm from the implied reservation doctrine" before it enacts legislation addressing redress of alleged displacements from assertions of federal reserved rights.[28] This is not to suggest such "real and substantial harm" may not occur.

Whatever the virtues of the debate and whatever the legislative response may be, the theoretical underpinnings of the doctrine are well known. The traditional basis some commentators assert is the property clause of the United States Constitutuion[29] pursuant to which the water remaining unappropriated under state law is subject to the control of the Federal Government. Some commentators have suggested, however, that the theory actually used by the courts in developing the reserved rights doctrine is based upon the supremacy clause.

> The federal functions exercised in the name of the reservation doctrine rests instead on the supremacy clause, coupled with the power exercised in making the reservation of land or with some other power incidentally exercised on the reserved land.

The Supremacy Clause allows Congress, while acting pursuant to a constitutionally delegated power, to take water without regard for state precedural or substantive law. Congress may not, of course, take private property in the form of appropriated water without payment of just compensation,[30] but if the water is unappropriated when taken, questions of compensation do not arise.

Under either of the above formulations, the Supreme Court has consistently upheld federal reserved rights. The Court has done so in Arizona v. California, Eagle County, Cappaert and New Mexico cases. In a word, reserved rights are, in my view, firmly established as a matter of law. As a matter of personal preference, I tend to favor the Supremacy rationale as being the more logical explanation for the doctrine.

The critical questions now are not the theoretical or speculative arguments discussed above, but rather: how much and for what? These questions raise the difficult problem of interpreting Congressional or administrative intent. The key cases -- New Mexico, Cappaert, and Arizona v. California, involved situations where the intention to withdraw some water as well as land was reasonably clear. The importance of New Mexico, in my view, lies not in the details of the court's consideration of the Forest Service Act of 1897, but in the narrow and strict construction technique utilized in that analysis. The point made is that reserved rights arise by implication. The Court said, "The question posed in this case... is a question of intent and not power."[31] Moreover, by pointing to California v. United States, decided the same day, the Court emphasized the primary state law in this area and indicated that exceptions to that rule, such as federal reserved rights, would be carefully examined and strictly construed. In New Mexico the Court, therefore, distinguished between the primary and secondary purposes of the reservations and held that only the primary purpose water needs are reserved. This deference to state law is phrased in terms suggesting something like a presumption. Whether it will amount to this or something less remains to be seen. In any event, the message in New Mexico is clear: Reserved rights claims will be strictly construed to be successful, such assertions must be solidly tied to primary purposes of the act, treaty, or withdrawal which reserves the water. Further, water quantity claims must find clear support within a resaonable construction of the intent of the reservation.

FOOTNOTES

1. Mr. Little is Regional Solicitor, Rocky Mountain Region, Department of the Interior, Denver, Colorado. Mr. Canaday is an attorney-advisor in the Solicitor's Office, Rocky Mountain Region. The views and observations expressed in this article do not necessarily represent those of the Office of the Solicitor or the Department of the Interior.

2. 426 U.S. 128, 138-39 (1976).

3. Federal Power Comm'n. v. Oregon, 349 U.S. 435 (1955).

4. Trelease, Federal Reserved Water Rights Since PLLRC, 54 Den. L.J. at 475.

5. E. Morreale, Federal-State Rights and Relations in 2 Waters and Water Rights, Sec. 102 (r. Clark, ed., 1967).

6. 174 U.S. 690 (1899).

7. Act of September 19, 1890, Ch. 907, Sec. 10, 26 Stat. 454 (1890); (superseded by the Act of March 3, 1899, Ch. 425, Sec. 10, 30 Stat. 1151 (1899); current version 33 U.S.C. Sec. 403).

8. 174 U.S. 690 at 703 (1899).

9. 14 Stat. 253 (Act of July 26, 1866), 43 U.S.C. Sec. 661; 16 Stat. 218 (Act of July 9, 1870), 43 U.S.C. Sec. 661; 19 Stat. 377 (Act of July 3, 1877), 43 U.S.C. Sec. 321.

10. Winters v. United States, 207 U.S. 564 (1908).

11. ID. at 577.

12. 295 U.S. 142 (1935).

13. Federal Power Comm'n. v. Oregon, 349 U.S. 435 (1955).

14. Id. at 442.

15. Colorado River Compact, 1 Federal Reclamation Laws Annotated 441 (1972).

16. 426 U.S. 128 (1976).

17. Address by Northcutt Ely to the Nat'l Water Comm'n. (Nov. 6, 1981), quoted in Trelease, Federal Reserved Water Rights Since PLLRC, 54 Den. L.J. 473 at 485 (1977).

18. Id. at 486-87.

19. 438 U.S. 696 (1978).

20. California v. United States, 438 U.S. 645 (1978) at 695 (White, J. dissenting).

21. 438 U.S. 645 (1978).

22. Act of June 17, 1902, Ch. 1093, 32 Sat. 388.

23. Act of July 10, 1952, Ch. 650, Sec. 208, 66 Stat. 650 (1952) (43 U.S.C. Sec. 666 (1976)).

24. United States v. District Court in and for the County of Eagle, 401 U.S. 520 (1971).

25. Supra fn. 17.

26. See, Trelease, "Federal Reserved Water Rights Since PLLRC," 54 Denver L.J. 473, 487-492 (1977).

27. Id. at 487.

28. Id. at 492.

29. U.S. Const. Art. IV, Sec. 3, Cl. 2

30. U.S. Const. Art. 5.

31. United States v. New Mexico, 438 U.S. 696, 698 (1978).

OVERVIEW AND STRATEGY FOR MANAGING WATER RESOURCES IN NATIONAL PARKS

by

Raymond Herrmann
Water Resources Field Support Laboratory
National Park Service
Fort Collins, Colorado

Numerous issues directly or indirectly affect the management of our Nation's waters and the related riparian resources (Water Resources Council, 1978, Council on Environmental Quality,1980). Responses to these issues which include increasing population pressures, inadequate and dwindling water supplies, contamination of waters and water supplies, flooding, erosion and sedimentation, dredge and fill, and wetlands are many and complex and come from numerous levels of the public and private sectors.

The National Park Service (NPS) is required to respond to these pressures for a number of reasons: new specific legislative requirements (viz. Crater Lake), or existing legislative requirements (Table 1 at end of text); better visitor services or protection; and, for improved resources protection.

The papers in this volume discuss the issues which NPS must address, present some responses that NPS has attempted, outline planned activities (responses), and also present some additional techniques which may be employed to meet these goals.

The purpose of these presentations is to create discussions and stimulate activities which could lead toward long-term solutions of NPS water resources problems. Many of these concerns have been with us for ten or more years and in many cases these problems have intensified. It might prove helpful to repeat the familiar statute which directs the Interior Department to manage the National Park System:

> "By such means and measures as conform to the fundamental purpose of the said parks...which purpose is to conserve the scenery and the national and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

This statement is the foundation on which the National Park Service has been constructed. Management policies covering all aspects of park operations have always been keyed insolubly to this very same premise regardless of the countless number of times they have had to be shaped, reshaped, and shaped again to reflect evolving national and social economic development trends.

As a consequence of this charge, it is incumbent upon the National Park Service to adopt, support, and maintain an attitude which does not look upon each park area as a reservoir of resources to be drawn upon for commercial or economic gain but to regard the resources within each park area as fundamental to the physical, mental and spiritual well being of millions of Americans and international park visitors.

Of major importance among the natural resources to be protected and preserved are the waters on which each park is dependent to maintain scenery, the natural interrelationship of plant and animal life and for service connected municipal water supply. To insure that waters are protected, NPS must identify any activity that will irreversibly alter the hydrologic regime on which each park is dependent, and must actively work to resolve these conflicts.

Our experience of date has taught us that adverse effects on park water resources can be internally self-generated or imposed externally by neighboring non-NPS activities which degrade, divert, or increase flows of water, potentially upsetting the delicate hydrologic balance.

In all cases where activities might threaten the park's water resources, it is incumbent upon us to identify those threats at the earliest opportunity, preferably at the planning stage, and to offer practicable alternatives to avert those threats.

A strategy is suggested by the discussion of these papers which includes:

1. Seeking to increase NPS technical capabilities directed at water resources research in order to:
   a. increase understanding of identified park problems
   b. mitigate impacts on park water resources
   c. provide management alternatives
   d. collect data for assessing problems
   e. complete inventory data
   f. improve the communication between NPS and other water resources managers and professionals.
2. Employing the experiences of others and the techniques developed by others to solve park water management problems. This should be accomplished through interagency liaison and cooperation followed by evaluation and testing.
3. Implementing a program to define park water resources needs, detect water resources changes and to understand the importance of a long-term water resources record, when it is necessary to legally validate the status quo.
4. Distinguishing between short- and long-term efforts while not short changing long-term studies.
5. Integrating physical and biological studies for a better understanding of the nature of aquatic and riparian resources and of the response of these systems to perturbations from within or outside.

It is no secret that high quality water is regarded as a critical resource in this country and that the future national picture is not encouraging (Council on Environmental Quality, 1980). In the western states the problem is shortage of water in the midst of an expanding industrial, municipal and agricultural economy. In the east, it's the contamination of large quantities of water which in effect reduces the availability of usable water.

Thus, the job of preserving and protecting park waters is expected to be increasingly more difficult as non-NPS activities put further demands on national water resources. This pressure by others is a relatively new experience for the National Park Service. In the past, we have felt that, because of the relative isolation of many parks, the parks enjoyed almost exclusive use of the water resources. However, today this has proved not to be the case, and in many areas conflicts have arisen.

In the not too distance future the competition for water is expected to become more intense and future pressure on park waters will increase, requiring well directed NPS initiatives to protect park waters from intrusions occurring beyond park boundaries.

It is our hope that readers' comments and individual responses will in some measure address these issues of how to protect a park's water resources, and to assist NPS to initiate new positive steps to assure that parks continue to have adequate water to protect the resources. The National Park Service is custodian of a number of areas which represent our national heritage (remote, urban-wilderness, developed, historic, natural). Awareness of the often unique water resources requirements of these areas will go a long way toward their planned protection.

Table 1. Existing Legal Authority and Requirements upon the Water Resources Program of the National Park Service

---

The National Park Service Organic Act of August 25, 1916 (39 Stat. 535 _et_. _seq_.)

"The Service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments and reservations to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Laws Relating to the National Park Service, U.S. Government Printing Office, (1933, 1944, 1963, 1974, 1980)

Enabling and supplementary legislation and/or Presidential actions authorizing the establishment of National Park System areas for the purpose of preserving and protecting the resources therein.

Act appropriating funds for the Department of the Interior for Fiscal Year 1937 (PL 741; 74th Congress)

"Investigation and purchase of water rights: For the investigation and establishment of water rights, including the purchase thereof of land or rights-of-way for use and protection of water rights necessary or beneficial in connection with the administration and public use of the National Parks and Monuments,...$25,000 to be made immediately available."

Act of August 7, 1946, [60 Stat. 885; 16 U.S.C., §17(2)(g)]

"Investigation and establishment of water rights in accordance with local custom, laws and decisions of courts, including the acquisition of water rights or of lands or interests in lands or rights of way for use and protection of water rights necessary or benficial in the administration and public use of the National Parks and Monuments."

Act of August 8, 1953 (67 Stat. 495 _et_. _seq_.)

"The erection and maintenance of fire protection facilities, water lines, telephone lines, electric lines, and other utility facilities adjacent to any area of the said National Park System and miscellaneous areas, where necessary, to provide service in such areas."

Federal Water Pollution Control Act as amended by the Clean Water Act of 1977 (33 U.S.C. §1251 _et_. _seq_.)

The Service is called upon to participate in water quality management planning; the establishment of water quality standards and criteria; the establishment of water quality monitoring systems to maintain, restore, and/or enhance park area surface and ground water quality.

Table 1. continued

Safe Drinking Water Act of 1977 (42 U.S.C. 300 et. seq.)

The Service is required to protect water supply sources that are subject to pollution.

Wild and Scenic Rivers Act of 1968 (16 U.S.C. §1271 et. seq.)

"It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, posses outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations...."

The Wilderness Act of 1964 (16 U.S.C. §1131 et. seq.)

Wilderness areas shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character and for the gathering of information regarding their use and enjoyment as wilderness.

Endangered Species Act of 1973 (16 U.S.C. §1531, et. seq.)

Conserve to the extent practicable and various species of fish or wildlife and plants facing extinction.

National Environmental Policy Act of 1969 as amdended (42 U.S.C. §4321 et. seq.)

Improve and coordinate Federal plans, functions, programs, and resources to prevent or eliminate damage to the environment and biosphere.

The Acid Precipiation Act of 1980 (42 U.S.C. §8901 et. seq.)

Establishes the purpose:

"(1) to identify the causes and sources of acid precipitation; (2) to evaluate the environmental, social, and economic effects of acid precipitation; ...," and calls for a comprehensive 10-year program to be implemented by the Interagency Acid Precipitation Task Force.

Executive Order 11514, as amended by Executive Order 11991 Protection and Enhancement of Environmental Quality 35 FR 4247 (March 5, 1970), 42 FR 26967 (May 25, 1977)

"The Federal Government shall provide leadership in protecting and enhancing the quality of the Nation's environment to sustain and enrich human life. Federal agencies shall initiate measures needed to direct their policies, plans and programs so as to meet environmental goals...."

Table 1. continued

Consonant with Title 1 of the National Environmental Policy Act of 1969

The heads of Federal agencies shall: Monitor, evaluate, and control on a continuing basis their agencies activities so as to protect and enhance the quality of the environment. Such activities shall include those directed to controlling pollution and enhancing the environment and those designed to accomplish other program objectives which may affect the quality of the environment. Agencies shall develop programs and measures to protect and enhance environmental quality and shall assess progress in meeting the specific objectives of such activities...."

Executive Order 11988 - Floodplain Management 42 FR 26951 (May 25, 1977)

"Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for (1) acquiring, managing, and disposing of Federal lands and facilities; (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting land use, including but not limited to water and related land resources planning, regulating, and licensing activities."

Executive Order 11990 - Protection of Wetlands 42 FR 26961 (May 25, 1977)

"Each agency shall provide leadership and shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities for (1) acquiring, managing, and disposing of Federal lands and facilities; (2) providing Federally undertaken, financed, or assited construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water related land resources planning, regulating, and licensing activities."

Executive Order 12088 - Federal Compliance with Pollution Control Standards 43 Fed. Reg. 47707 (October 17, 1978) Part 1-101

The head of each Executive Agency is responsible for ensuring that all necessary actions are taken for the prevention, control, and abatement of environmental pollution with respect to Federal facilities and activities under the control of the agency.

REFERENCES

Council on Environmental Quality. 1980. The Global 2000 Report to the President: Entering the Twenty-First Century.

Water Resources Council. 1978. The Nations Water Resources 1975-2000. Second National Water Assessment by the U.S. Water Resources Council. Volume 1, Summary. December.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WATER RESOURCES FIELD SUPPORT LABORATORY
107C NATURAL RESOURCES
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80523