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Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho

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by

Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho 83843

George L. Bloomsburg, Director
July, 1987

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ABSTRACT

This reports on the research and information dissemination activities of the Idaho Water Resources Research Institute during the 1986 fiscal year. Synopses are presented for the following research projects: Analysis of Historical and Current Drawdown and Production Data from the Boise Geothermal System; A SAS Based Hydrologic Storage and Retrieval System; Annual Flow Statistics and Drought Characteristics for Gaged and Ungaged Streams in Idaho; Development and Evaluation of Procedures for Systems Analysis and Optimization of On-Farm Irrigation Systems; Ground Water Management Under the Appropriation Doctrine, Part II; Power Engine Discharges as a Nutrient Source in High-Use Lakes; A New Approach to Evaluate Redox Status and Ground Water Pollution Problems Associated with Mine Wastes in the Coeur d'Alene Mining District, Idaho. Information dissemination and workshop activity of the Institute is also reported.

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WATER PROBLEMS AND ISSUES FOR THE STATE OF IDAHO

The important water issues in Idaho are water allocation and management and water quality. The culmination of the water allocation problems has resulted in the Swan Falls agreement. This agreement defines the amount of water that the Idaho Power Company receives for power production at the Swan Falls dam, as well as the amount of water available for upstream agricultural development. The Idaho Department of Water Resources has now begun the adjudication process for the entire Snake River drainage. The adjudication will consider federal reserved rights as well as rights of the various Indian tribes.

In northern Idaho water allocation and management is not as important an issue as in southern Idaho where irrigated agriculture is more widely practiced. Water quality of recreational lakes in north Idaho, however, is an important issue. This is shown by the organization of several lakeshore property owner groups, which have funded water quality studies on Twin Lakes, Spirit Lake, Cocalolla Lake, Hayden Lake and Kidd Island Bay in Lake Coeur d'Alene. In general, the water quality of these lakes is very good, but there are signs of cultural eutrophication such as reduced clarity and increased algae and weed growth. The water quality of Lake Pend Oreille has recently become of interest because the paper mill upstream near Missoula, Montana is discharging wastes into the Clark Fork which then flows into Lake Pend Oreille. The discharge of mine tailings into the Coeur d'Alene river over the last 100 years has led to degradation of the water quality in Lake Coeur d'Alene and higher than normal lead levels in fish in the lake. Many of these problems could be managed if money were available for research addressing management alternatives.

Idaho has been blessed with a plentiful supply of clean water, and it is up to us to maintain that supply and use it in a manner beneficial to the entire state.

Program's Goals and Priorities

The basic goals and priorities of the Institute's program are as follows:

1. To promote research that is relevant to state and regional needs for conservation of water and related land resources with emphasis on economic resource development, preservation and enhancement of environmental quality and social well being of people.

2. To stimulate, coordinate and provide leadership for water resources research in the established units of the universities of the state of Idaho and to cooperate with sister institutions in adjoining states. Such research should utilize an interdisciplinary approach and provide opportunities for training of students.

3. To cooperate with and help local entities, state and federal government agencies to carry out their responsibilities concerned with water and related land resources and to provide public involvement in identifying research needs.

4. To provide for dissemination of research findings in an expeditious and comprehendable manner to interested persons.

5. To develop funding for needed research and to encourage cooperation with regional research organizations in conducting an efficient and productive research effort.

Solving any of these water resources problems in the state involves five steps.

1. The problem must be identified by consultation with people affected by the problem.

2. An individual or several individuals must be identified who have expertise that may solve the problem.

3. A funding source must be identified which may even be private individuals concerned with the problem.

4. The prospective researcher must develop a proposal and present it to the funding agency or individuals.

5. The research is accomplished and the information disseminated to any persons who may be involved in this or similar problems.

The majority of research expenditures are for operating expenses and graduate student support with very little for capital outlay or faculty salary.

The money for information dissemination supports a secretarial position and operating expenses for publications. The secretary answers all publication requests and maintains the publication list and reference library and types all the technical completion reports.

Most of the money for administration is partial salary for the associate director who maintains contact with state, federal and private agencies in southern Idaho.

SYNOPSIS

Project Number: 02 **Start:** March 1, 1986
End: May 31, 1987

Title: Analysis of Historical and Current Drawdown and Production Data from the Boise Geothermal System

Investigators: Charles J. Waag and Spencer H. Wood
Boise State University
Boise, Idaho

COWRR: 02F **Congressional District:** First

Descriptors: Geothermal Resources; Drawdown

Problem and Research Objectives:

Boise Warm Springs Water District, one of the oldest commercially utilized geothermal systems in the United States, has been producing hot water for residential heating and domestic use since 1892. Since 1982, five additional large capacity wells have been completed, and production from the aquifer has doubled. Within the system, drawdowns are increasing at rapid rates. Most of the new wells are not producing at capacity, and plans are to increase production. Unlimited and unmonitored development of the hot-water aquifer system beneath the City of Boise may soon lead to a serious overdraft of the natural system. Prudent management of the aquifer system requires a data base of production volumes and pressure-level measurements.

Our immediate research objective is to establish and maintain a computer based network for the systematic recording and analyses of data to determine the amount of production from the aquifer and its effect upon water-level decline and recovery rates within the system. The next is to analyze those data to determine the degree of hydraulic interconnection between segments of the aquifer. Ultimately our objective is to create a predictive model for prudent development and use of the resource.

Methodology:

A computer oriented program of systematically gathering new data on water levels within observation and production wells in the system will be continued. Continuous recording devices which were initiated in 1984-85 under an Idaho Water Resources Research Institute grant and extended into 1985-86 through grant support from the Idaho Department of Water Resources will be used. Available production, aquifer tests, and water level data on the system will be compiled and evaluated.

Principal Findings and Significance:

The wells of two of the three principal producers of hot water, Boise Warm Springs Water District (BWSWD) and Boise Geothermal Limited (BGL), produce from a fracture network along the Boise front. The third, the State of Idaho Capitol Mall well, produces primarily from Idavada Group rhyolites approximately 2500 feet southwest of the Boise front. One, the Capitol Mall well, reinjects its production into the aquifer.

BWSWD records indicate production has ranged from approximately 235 to 300 million gallons per year for the period 1978 through 1986. The principal control on production at BWSWD is demand for heating. However, since 1984, large drawdowns to the level of the pumps during the peak heating season have caused cavitation and limited the production of the wells.

Typically water-levels within the aquifer system reach their peak, recovering during the summer when demand for heat is low. As the winter heating season ensues, water levels decline to a low in late February or early March. Production demand is commonly greatest in January, but there is generally a month to six-week lag time between maximum production and the lowest water level in the aquifer. Recovery continues from March into summer, and the cycle begins again.

Boise Geothermal Limited began production in October of 1983. In the subsequent three years, October 1 to September 30, 1983-84, 1984-85, and 1985-86, the BGL wells have produced approximately 166.7, 121.4, and 176.8 million gallons respectively. During the partial year, October 1, 1986 to May 1, 1987, BGL has increased production to 205.1 million gallons. Capitol Mall began production from their well No. 2 (CM No. 2) late in the winter of 1982. During 1982 and 1983, CM No. 2 produced 79 million gallons and has averaged about 196 million gallons/year since 1983. The increased development and exploitation of the system by BGL and CM since 1982 and 1983 has been attended by an annual decline in the recovery level of the piezometric surface. Maximum recovery levels in observation wells in the vicinity of the BWSWD pumping wells have declined an average of 3.5 feet per year and an average of eight feet per year in the BWSWD pumping wells themselves. Maximum recovery levels in the BLM (BEH) well which monitors the water-levels in the vicinity of the BGL pumping wells have declined an average of five feet per year since 1983. The data do not indicate a concomitant expansion of production of BWSWD after 1983. The most obvious explanation for the increased declines in both portions of the aquifer system since 1983 is the withdrawals by BGL, which began in the fall of 1983, and to a lesser extent Capitol Mall which began withdrawals and also reinjection in 1982. In 1977, 1978, 1981, and 1982, maximum recovery levels peaked at elevations near 2,760 feet in the BLM well. These relatively consistant recovery levels in the BLM well and surface flows at the BWSWD wells, all at similar elevations and prior to 1983, suggest that interconnection between the BWSWD and BGL portions of the aquifer exists and that the system was in or near equilibrium.

Geologically and hydraulically, such interconnection is likely. Interpretation of the geologic and hydrologic data currently available to us allows us to suggest the following working aquifer model. The system is a fractured-media ground water aquifer confined by clayey basaltic, volcaniclastic sediments and tuffs of low hydraulic conductivity. The aquifer consists of interlayered sequences of rhyolites and sediments and granites which have been divided into major blocks, sections or segments by relatively large fracture zones. Fracture zones separating the segments apparently range from nearly open conduits to those which are partially filled with secondary deposits including zeolites, clay and silica.

Hydrologically the segmentation is reflected in a wide variation in hydraulic conductivities and transmissivities within the system. Transmissivity values estimated by aquifer tests and long-term production data range from 5,000 to greater than $1x10^6$ gals/day/ft. Although exceptions seem to exist, wells completed in fracture zones generally yield higher transmissivities reflecting openness within the zone. By contrast, wells completed within the interfracture segments or in partially cemented fracture zones yield the intermediate to lower transmissivities. The variations in transmissivities do reflect barriers within the system; however, the barriers are semipermeable. Our studies have revealed no impermeable barriers. In the Boise vicinity where the largest withdrawals are centered our interpretation is that the aquifer is acting as a single, integrated system having vertical and lateral inhomogeneities.

Our current data base does not allow a prediction as to where a new equilibrium level will be established. It is interesting to note that the total annual production for BWSWD and BGL combined for 1983-84, 1984-85, 1985-86, and predicted for 1986-87 are 459.6, 380.4, 436.2, and 437 million producers has not increased since 1983. Yet, water levels within those portions of the system are declining at increasing rates with even greater increases in the rates evident from 1986-87 data. It is also noteworthy that the balance of production has shifted. In 1983-84, 63.7% of the withdrawals were by BWSWD. In 1986-87 BWSWD will produce only about 46% of the total. In addition to the BWSWD, BGL, and CM withdrawals, an estimated 15-25 million gallons of geothermal water is being produced between April and October for irrigation by the Boise City Parks Quarry View Well and by the Idaho Botanical Garden from the state well. These withdrawals also commenced about 1983-1984 and undoubtedly contribute to the declining levels, especially in the Warm Springs vicinity. If, as planned, even greater production from the system occurs, water levels within the system can be expected to decline more rapidly and a new piezometric equilbrium level delayed.

Exploitation of the geothermal system is currently out-stripping our knowledge and understanding of the aquifer; thus, our ability to prudently manage the system is hampered. It is time to give serious consideration to a temporary moratorium on further development and production from the system until we have a better understanding of its capacity. Consideration should also be given to requiring reinjection of produced waters where feasible.

Publications and Professional Presentations:

A Preliminary Report on the Geology, Hydrology, and Geochemistry of the Boise Geothermal System, Waag, C.J., and Wood, S.H., to be published as a bulletin of the Idaho Water Resources Research Institute (in review).

Troubles Cloud Boise Geothermal Future, Idaho Statesman, April 26, 1987, C.J. Waag contributor.

The Boise Geothermal System, a Seminar Presented in the Advanced Hydrogeology Lecture Series, Department of Geology, Idaho State University, Pocatello, Idaho, April 10, 1987.

Investigation of the Boise, Idaho Geothermal System, Higginson-Barnett Consultants, report for Boise State University, June 1, 1987, data contributed by C.J. Waag.

M.S. Theses: None

Ph.D. Dissertation: None

Graduate Student Independent Studies:

A computer correlation between degree days and Boise Warm Springs Water District Production: A mechanism for interpolation of missing production data. Anna Baumhoff.

SYNOPSIS

Project Number: 03 **Start:** March 1, 1986
End: May 31, 1987

Title: Annual Flow Statistics and Drought Characteristics for Gaged and Ungaged Streams in Idaho

Investigators: Dennis R. Horn
University of Idaho
Moscow, Idaho

COWRR: 02F **Congressional District:** First

Descriptors: Statistical Analysis; Gages; Drought

Problem and Research Objectives:

This study addressed the problem of drought risk assessment for streams within the state of Idaho. As both the demand and competition for surface water supplies continue to increase, it is essential that a rational planning basis be established to quantitatively estimate the expected duration and severity of low stream flow periods, especially for extended, multiyear droughts. While hydrologists and engineers involved in the planning of surface water projects have long recognized the need to deal with this hydrologic uncertainty, most of the attempts to date have relied on the use of observed historical critical drought periods. However, since these periods vary from one location to another within the state, their true probabilities of recurrence have not been adequately defined. Moreover, for ungaged streams, or for locations with a limited period of gaged data, the problem of assessing drought probabilities has remained almost totally unresolved.

The specific objectives that guided the performance of work for this project include:

a) To develop, through the use of multivariate modeling, extended annual flow records at all appropriate stream gage sites throughout the state and adjacent areas.

b) To determine, at these gage locations, reliable estimates of critical annual streamflow statistics that influence long-term drought behavior. These include the mean, variance, skew, and first-order serial correlation coefficient.

c) To examine the nature and characteristics of the probability distributions of drought length and severity at each of the studied gage locations, using run-theory applied to the long-term stochastic process.

d) To estimate, at these same locations, the probabilities of observed historical drought events, as defined by the long-term stochastic process.

e) To develop quantitative procedures for estimating the critical annual streamflow statistics at ungaged locations within state and to estimate the corresponding drought statistics and characteristics.

f) To prepare a microcomputer program to perform the necessary calculations and to permit the wide-spread dissemination and application of the student results.

Methodology:

In general, this study examined the duration and severity of droughts, as indicated by annual streamflow, throughout the state of Idaho. By use of stochastic process considerations, key annual flow statistics were used to derive the related statistics of drought probability distributions, thereby defining, for various combinations of return period and water demand, the expected drought lengths and cumulative flow deficits.

More specifically, the study efforts initially concentrated on analyzing all Idaho streamgage records that were judged to meet certain selection criteria, including those of record length, record quality, and degree of diversion or regulation. These analyses resulted in the determination of those annual flow statistics necessary to define the long-term stochastic behavior of drought sequences for the selected streams.

A compilation of these values, along with pertinent geographic, geomorphic, and meterologic characteristics of the associated drainage basins, were then used to develop quantitative procedures for estimating the annual flow statistics for ungaged watersheds. These procedures are based on the results of regional analyses and multiple regression techniques and are applicable over the range of drainage basin characteristics and locations included in the study sample.

Using prior research results, the actual or estimated annual flow statistics are related to the probability distributions of maximum drought events through the application of the theory of runs. This has resulted in a general methodology for assigning return periods to drought events at gaged and ungaged locations and permits an assessment of the probabilities of observed historical droughts throughout the state.

Principal Findings and Significance:

A total of 124 streamflow records were analyzed for their statistical properties and these statistics used to estimate multivariate stochastic model parameters for data augmentation. Data were added, using the models, to 80 of the stations, increasing the total station-years of data from 4413 to 6348.

For each of the stations, drought duration and severity were calculated for selected return periods and truncation levels, based on equations developed from prior research and the augmented data statistics. In addition, the return periods of observed historical droughts (length and severity) were estimated for 63 stations with more than 30 consecutive years of historical data. The results of these analyses indicated that, with very low or high truncation levels, the observed droughts had significantly greater return periods than might reasonably be expected from the long-term stochastic properties of the streamflow records.

To permit the application of drought probability equations to ungaged areas, maps were developed to estimate the skew and serial correlation coefficients for the annual flow series based on kriging theory. These maps are supplemented by equations to estimate the mean and standard deviation of the annual flows as a function of basin characteristics. The regression analyses used to develop these equations resulted in two sets of equations, covering two distinct geographic regions of Idaho. While the equations for the northern part of the state are urged to provide good predictive results with small standard errors of estimate, those for the southern portion yield much less reliable estimates.

Using map grids of the statistics affecting drought probability, the spatial variability of drought length and severity was examined. It was determined that, for a selected combination of return period and truncation level, the drought length is relatively invariable, while the severity is highly variable. This spatial variability was mapped as values of a "drought potential index" (DPI), which measures the severity per unit of mean annual streamflow. The Snake River Plain, in general, had much larger values of the DPI than other portions of the state, indicating a greater potential for persistent, severe streamflow deficits. Since drought severity is not a spatially-random phenomenon, this risk must be considered in the planning, design, and operations of water resources projects in the state.

Publications and Professional Presentations:

Horn, D.R., 1987, Annual Flow Statistics and Drought Characteristics for Gaged and Ungaged Streams in Idaho, Research Technical Completion Report, IWRRI.

Horn, D.R., Annual Flow Statistics for Ungaged Streams in Idaho," (in preparation for submission to Journal of Irrigation and Drainage, ASCE).

Horn, D.R., Spacial and Temporal Variability of Droughts in Idaho, (in preparation for submission to Journal of Irrigation and Drainage, ASCE).

M.S. Theses: None

Ph.D. Dissertations: None

SYNOPSIS

Project Number: 04 **Start:** June 1, 1985
End: May 31, 1987

Title: Development and Evaluation of Procedures for Systems Analysis and Optimization of On-Farm Irrigation Systems

Investigators: John R. Busch and Bradley A. King
University of Idaho
Moscow, Idaho

COWRR: 06A **Congressional District:** First

Descriptors: Irrigation; Systems Analysis; Irrigation Design

Problem and Research Objectives:

The overall objective of this project was to develop and test a procedure for critically evaluating on-farm irrigation system plans and water management practices for site-specific conditions.

Specific objectives were:

1. To develop means of determining the operating characteristics and costs of irrigation system components including various application systems -- surface, sprinkler and trickle. Factors to be considered include pumping energy requirements and costs of system components operating under site-specific conditions along with soils information, topography, water delivery, cropping practices, climatic conditions and irrigation practices including management practices.

2. To develop and test a simulation model for on-farm irrigation systems using appropriate systems analysis techniques. Output from the model will consist of a detailed analysis of irrigation system operating characteristics and costs for a farm unit as influenced by the farm and system layout, soils, crops, and rotations, management and labor, water supply, legal factors, energy cost and availability and other pertinent factors.

3. To develop and test optimization techniques for obtaining maximum crop production (and/or maximum net benefits) as influenced by irrigation system design and operation at the farm level.

Methodology:

University researchers have utilized the available resources of both government agencies and private entities in pursuing the objectives of this project. Close contact has been maintained with the USDA Soil Conservation Service (SCS) and the USDA Agricultural Research Service (ARS), as these agencies are actively involved with irrigation systems planning, design and research.

Digital computer models for different aspects of irrigation system design and operation have been written and modified. Whenever possible, existing state-of-the-art models and procedures have been obtained and modified for the systems analysis procedures of this project. All models have been adapted to run on microcomputers (IBM-PC compatible) so that they can be used by extension personnel, field technicians and smaller consulting firms.

The entire procedure consists of a number of models and programs. Data are entered using an electronic spreadsheet (LOTUS SYMPHONY 1.1) to provide ease of entry and editing. The simulation models for both component functions and overall system operation are written in FORTRAN 77 code and linked together for simulating the operation of an entire system. Individual models of irrigation application systems (e.g. a sprinkler irrigation system or border irrigation system) can be run independently so a user can evaluate the operational characteristics of the proposed system and adjust system parameters to improve performance.

Principal Findings and Signifiance:

Microcomputer based models for computing the operational characteristics of the major types of irrigation application systems in the Pacific Northwest have been developed and tested. They are as follows:

1. Graded border model -- This model is based on the zero-inertia model of Strelkof. The computer model, written at the University of Idaho (UI), produces results (advance, recession and application efficiency) that agree with baseline data. The model contains an optimizing routine that computes the optimum streamsize and application time for maximum application efficiency for site-specific constraints.

2. Furrow model -- A kinematic wave model has been adapted for use in modeling the operational characteristics of furrow irrigation systems. An optimizing routine is included in this model to adjust furrow streamsize to maximize application efficiency for site-specific constraints.

3. Sprinkler model -- Models for two categories of sprinklers have been developed, one for self propelled and another for solid-set/set-move systems. Self-propelled systems include

center-pivot and linear-move systems. This model provides the needed information regarding system efficiencies and operating characteristics with the minimal amount of data generally available to planners. Likewise, the operating characteristics and efficiencies for solid-set, hand-move and side-roll systems are computed with the solid-set/set-move model. Included in both sprinkler models is an erosion model developed by the Soil Conservation Service based on the Universal Soil Loss Equation. Also included in both models are routines to select the most efficient irrigation application duration.

Stand-alone models of each of the above application systems are also provided to give the user the opportunity to adjust the parameters of the proposed application system(s) and evaluate the effects on the operational characteristics. This feature allows the user to develop a "feel" for how sensitive a system's operating characteristics are to various site-specific parameters and thus aid in selection of the most suitable system configuration for the particular conditions. This is an important step in selecting the optimum irrigation system, as changes in system parameters can have a profound influence on system performance and thus system selection.

Open channel and pipeline-sizing models have been developed and tested for obtaining optimal (least-cost) open channel dimensions and pipeline size. These models consider both capital and operating costs in selecting optimal sizes.

A model has been developed and tested for obtaining net irrigation water requirements. Crop rotation and evapotranspiration data are combined with rainfall data in computing average daily net irrigation requirements for different cumulative periods. The information generated by this model can be used to select irrigation system component types and/or size based upon net water requirements.

An irrigation system simulation procedure has been developed and tested. Optimal irrigation priorities throughout the irrigation season are computed in the simulation model for allocating water to the crops in times of water, labor and/or system capacity limitations. The priorities are computed by determining the amount of income that is expected to be lost by not irrigating the crop based upon crop water production functions and estimated crop values.

The complete systems analysis and optimization procedures along with the stand-alone application system models have been tested by Soil Conservation Service personnel using their data. Complete documentation on how to use the procedure and its operations including an example has been written and reviewed by Soil Conservation Service personnel.

Another major effort of this project, which deals with determining the uncertainties involved in the modeling process, is continuing. A method is being developed for identifying the various parameters most critical to the simulation model predictions and the relationships between the input and output parameters. The results

will include estimates of the degree of uncertainty in computed design parameters resulting from errors introduced into data through various sources. Also a range of accuracy and level of acceptance of the computed outputs will be established using statistical tests.

Publications and Professional Presentations:

King, B.A., B.W. Sauer and J.R. Busch, 1987, A Simulation Procedure for On-Farm Irrigation Systems Planning, Proceedings of the ASCE I&D Specialty Conference (in publications).

M.S. Theses: None

Ph.D. Dissertation: None

SYNOPSIS

Project Number: 05 **Start:** May 1, 1985
End: June 30, 1988

Title: Ground Water Management Under the Appropriation Doctrine Part II

Investigators: Dale R. Ralston and Elliot J. Bruhl
University of Idaho
Moscow, Idaho

COWRR: 06E **Congressional District:** First

Descriptors: Ground Water Management

Problem and Research Objectives:

The purpose of this research was to better understand ground water management problems which occur under the appropriation doctrine and to identify innovative solutions which are possible using this management system. The primary objective was to summarize and compare management activities in Washington, Oregon, Idaho, Montana, Utah, Colorado, Arizona, and New Mexico.

Methodology:

Research methods include the consultation of statutes and state publications and conducting interviews with state ground water management officials.

Principal Findings and Significance:

States which manage ground water under the appropriation doctrine experience similar management problems. These problems suggest a common development pattern which can be broken down into stages. This staged development pattern allows states to anticipate probable, future management difficulties.

Publications and Professional Presentations:

Bruhl, E.J. and Dale R. Ralston, 1987, Ground Water Management Under the Appropriation Doctrine, Proceedings of FOCUS Conference on Northwestern Ground Water Issues, May 5-7, Portland, Oregon, National Water Well Association.

M.S. Theses: None

Ph.D. Dissertation: None

SYNOPSIS

Project Number: 06 **Start:** May 1, 1985
End: June 30, 1988

Title: Powerboat Engine Discharges as a Nutrient Source in High-Use Lakes

Investigators: Dave Hallock and C. Michael Falter
University of Idaho
Moscow, Idaho

COWRR: 05B **Congressional District:** First

Descriptors: Nutrient; Load Distribution

Problem and Research Objectives:

Outboard engines discharge exhaust gases containing hydrocarbons, carbon monoxide, carbon dioxide, nitrous oxides, sulfur oxides, aldehydes, lead, and other compounds directly into the water. Although a number of studies have addressed various effects of motorboats on aquatic systems, those few which have included nutrient analyses measured only whole lake effects where a relatively subtle and short-term change in nutrient loading would not be immediately detectable.

Although crude oil contains less than 0.1% nitrogen (much of which is removed during refining), both nitrogen and phosphorus compounds such as alkyl phosphate, amine phosphate, alkyl ammonium dialkyl phosphate, etc. are added to gasoline as detergents, anti-icing and anti-rust agents, and deposit modifiers. In addition to being found in gasoline additives, nitrogen oxides are formed from atmospheric gases during the combustion process. Because most marine exhaust gases are bubbled through the water, some enhancement of nitrogen and phosphorus concentrations in lake water can be expected.

The goal of this study was to determine the importance of powerboat engine discharges as a nutrient source. The specific objectives were as follows: 1) to determine chemical (nutrient) response of lake water to powerboat exhaust, 2) to partition nutrient loading to Twin Lakes, Idaho by source, and 3) to extrapolate powerboat exhaust impacts to lake managment.

Methodology:

Powerboat engine experiments were conducted in triplicate in four closed-bottom polyethylene enclosures fastened to a floating dock on Twin Lakes, Kootenai County, Idaho. One enclosure served as a control, while three <10 hp outboards (a new four-cycle, an untuned two-cycle, and a tuned two-cycle) were run in the other enclosures.

During each trial the outboards were run for an eight-hour period at low speed. Samples were collected every two hours and analyzed for CO_2, alkalinity, pH, conductivity, temperature, oxygen, total phosphorus, total soluble phosphorus, kjeldahl-nitrogen, nitrate-nitrogen, and total organic carbon. In addition to the above, water samples during one trial were collected prior to the test run and after four, eight, and twelve days and analyzed for chlorophyll a, biomass, zooplankton numbers and composition, and phytoplankton numbers and composition. Nutrient increase per liter gasoline consumed was calculated.

Motorboat use on Twin Lakes was determined by census techniques similar to those used for fisheries creel surveys. Volunteer homeowners conducted "instantaneous" counts of motorboats on the lake several times each week during the 1986 boating season. Total annual boat-hours and annual fuel consumption on Twin Lakes was then calculated.

Finally, nutrient loadings from powerboat exhausts were calculated and compared to nutrient loading from all other major sources, including tributaries, precipitation plus dryfall, wastewater systems, and internal loading.

Principal Findings and Significance:

Although the biological response was peripheral to this study, our results indicate that short-term effects of concentrated outboard exhaust on phytoplankton and zooplankton are minor. Long-term effects (>18 months) of intensive recreational boating need to be evaluated.

The addition of inorganic carbon (IOC) from powerboat exhausts was significant (>8,600 mg IOC/liter gasoline). Although IOC is rarely considered to be a limiting nutrient, it is possible that in some water bodies heavy motorboat activity may increase photosynthetic rates by providing a superabundant carbon source. In addition, by agitating the water, motorboats may increase gas and nutrient diffusion rates (and therefore photosynthetic activity) both across the air/water interface and across the boundary layer surrounding algae cells.

Outboard engines contribute about 1.2×10^6 kg nitrogen and 3,949 kg phosphorus to US waters annually, based on our results and estimates of gasoline consumption by outboards in 1983. It is clear that phosphorus loading is insignificant compared to other sources. Nitrogen loading from outboards will be minor in all but the most heavily used lakes. Twin Lakes, which had less than a four-month boating season in 1986, received about 1% of its nitrogen loading from motorboats. If boating were as extensive year-round on Twin Lakes as it was from mid-June to mid-August, loading from motorboats could be as high as 0.115 $g/m^2/yr$ or 5.3% of the lake's total annual loading.

Although phosphorus loading from outboard exhaust is insignificant, nitrogen loading, while small, should be considered by managers of high-use lakes. Other questions remain about the impact of

motorboats on lakes. For example: how do lakes respond to the re-suspension of bottom sediments and associated phosphorus caused by boat wash? Are pH levels affected by sustained boat use? What are the long-term impacts of motorboats on biota? What effects do inorganic carbon loading and enhanced mixing from motorboat activity have on aquatic flora, especially in euthrophic waters?

Publications and Professional Presentations:

Presented to the Sixth Annual Conference and International Symposium of North American Lake Management Society, November, 1986, Portland, Oregon. Published in the Proceedings of North American Lake Management Society of Conference.

M.S. Theses: None

Ph.D. Dissertation: None

SYNOPSIS

Project Number: 07

Start: May 1, 1985
End: June 30, 1988

Title: A New Approach to Evaluate Redox Status and Ground Water Pollution Problems Associated with Mine Wastes in the Coeur d'Alene Mining District, Idaho

Investigators: C.M. Wai and W.M. Mok
University of Idaho
Moscow, Idaho

COWRR: 05C **Congressional District:** First

Descriptors: Ground Water Pollution; Mine Wastes

Problem and Research Objectives:

The Coeur d'Alene Mining District in northern Idaho is one of the major silver, lead, and zinc producing areas in the United States. Associated with the mining industry of the area has been the problem of heavy metal pollution. Sediments along the South Fork and the main stem of the Coeur d'Alene River are contaminated with mine wastes and tailings. These polluted sediments are being leached to varying degrees by ground water and surface water. The present work was undertaken to study the distribution of arsenic and antimony species and other metals in the Coeur d'Alene River and the effects of the polluted sediments on water quality. Leaching experiments were carried out in the laboratory to study the mobilization of arsenic, antimony, and other metals during sediment-water interactions. The factors which affect the distribution and transport of arsenic and antimony species and other metals in the Coeur d'Alene River system were examined.

Methodology:

Separation of the trivalent and pentavalent arsenic and antimony species, As(III), As(V), Sb(III), Sb(V), in water was achieved by PCDT (pyrrolidinecarbodithioate) extraction according to the procedures described in the literature (see reference 1). Analysis of the arsenic and antimony species was done using neutron activation and gamma spectrometry. The detection limits for arsenic and antimony in water using this extraction technique and neutron activation analysis are in the order of 10^{-3} ug/L. Leaching experiments were performed in the laboratory using sediments collected from the Coeur d'Alene River. Monthly water samples were also collected from the river to measure the distribution of arsenic and antimony species and other metals in different locations of the Coeur d'Alene River.

Principal Findings and Significance:

Water samples collected from the relatively uncontaminated North Fork showed very low concentrations of As (<0.1 ppb), Zn (<0.03 ppm). and other metals. The concentrations of As, Sb, and Zn in the South Fork waters were in the range of 1-1.6 ppb, 1-7 ppb, and 0.1-4.3 ppm, respectively. The metals levels in the main stem of the river were lower than those found in the South Fork. The trivalent As(III) was the major arsenic species found in the South Fork and the main stem, whereas the pentavalent As(V) was the predominant one of the North Fork. In the case of antimony, the pentavalent Sb(V) was the major species found in all three branches of the river. The metal contents in the river water varied with time, with the highest values found in the winter months.

Leaching of As and Sb from the sediments depends on pH of solution and on iron content of the sediments. Although the sediments from the main stem contained higher levels of As than Sb, the total amounts leached from the sediments were generally higher for the latter. Under aerobic condition, Sb(V) was the predominant Sb species leached from the sediments. The major arsenic species leached from the sediments of the main stem was AS(III). The field data are correlated with the experimental observations made in the laboratory. The lack of biological activities in the South Fork and the main stem was probably responsible for the slow conversion of As(III) to As(V). The interactions of water with existing sediments is likely to be a major factor controlling the water quality of the Coeur d'Alene River.

Reference: W.M. Mok and C.M. Wai, Anal. Chem. 59, 233 (1987).

Publications and Professional Presentations:

Mok, W.M. and C.M. Wai, 1987, Simultaneous Extraction of Trivalent and Pentavalent Antimony and Arsenic Species in Natural Waters for Neutron Activation Analysis, Anal. Chem 59, 233-236.

Mok, W.M. and C.M. Wai, 1987, Distribution of Trivalent and Pentavalent Arsenic and Antimony Species in the Coeur d'Alene River, Idaho, Presented at the 42nd Northwest Regional Meeting of the American Chemical Society, June 17-19, Bellingham, Washington.

M.S. Theses: None

Ph.D. Dissertation:

W.M. Mok, Chemical Speciation of Arsenic and Antimony and Its Applications to Environmental Problems, Department of Chemistry, University of Idaho, Completion Date: Summer, 1987.

SYNOPSIS

Project Number: 32

Start: May 1, 1985
End: June 30, 1988

Title: A SAS Based Hydrologic Information Storage and Retrieval System

Investigators: Myron Molnau and Mary Jo Bluske
University of Idaho
Moscow, Idaho

COWRR: 10B **Congressional District:** First

Descriptors: Storage; Hydologic; Information Retrieval System

Problem and Research Objectives:

HISARS, a hydrologic data base system, is currently used by many individuals and organizations to retrieve water resource information. However, due to the present design of the system and the lack of Pl/I programmers at the University of Idaho, the maintenance of HISARS has become a difficult task. In particular, the addition of new data is a slow process, requiring a significant amount of reprogramming whenever input formats are changed. Thus, users do not always have access to the most up-to-date information. Another problem with HISARS is the inability to modify the system for new applications; it is difficult to provide users with new output formats or more processing options.

Therefore, the objective of this project is to replace HISARS with a SAS-based storage and retrieval system called the Northwest Hydrologic Information Management System (NHIMS). With NHIMS, users will be able to easily access the data as they do now, seeing few changes in the new system. However, the SAS system provides procedures for resolving the current problems with adding and editing data. Also, SAS programmers will have the flexibility to write their own routines to create unique output formats or to perform additional analyses not now available.

Methodology:

The main goals of the NHIMS projects is to design a system that is easy for the system manager to maintain and that will preserve and increase the ease of data retrieval for system users. Regarding maintainability, the macro language within the SAS software package was used to create a modular, loosely-coupled system; maintenance programmers will be able to add or modify individual macro operations

without affecting the entire system. Also, all of the NHIMS data are stored in permanent SAS data sets; thus, one can take advantage of the built-in procedures offered by the SAS system to easily edit, update or document the data sets. Design considerations such as clarity of programming, consistency in data set structure, and complete and accurate documentation were highly stressed in order to improve system maintainability.

In order to preserve the ease of data retrieval, the HISARS command language was supported in NHIMS. HISARS users will access information in the same manner with the new system, issuing a few simple commands in a specified format; advanced programming skills are not needed to use the system. Furthermore, experienced SAS programmers can access the data sets and use the data independently of the NHIMS system.

Due to the large size of the data sets in the system, efficiency of data retrieval was also a major concern. The SAS software system provides for direct access of SAS data sets by the use of the POINT option on the SET statement. The POINT option is used in conjunction with a pointer file, which acts as a map of a particular data set, to directly access a range of observations without having to perform a sequential search. In this way, the SAS system can simulate ISAM file operations.

Principal Findings and Significance:

All of the original HISARS files have been converted to permanent SAS data sets with full documentation available. A cataloged procedure named NHIMS has been created to provide the necessary job control statements for the operating system; thus, a user simply needs to invoke the NHIMS procedure in order to submit his commands to the system. The source programs which comprise the NHIMS system have been written and stored in a partitioned data set and are executed on invocation of the NHIMS procedure. Thus, the system is operational and performs the required data retrieval operations, generating written reports or writing data to external files. Current users of HISARS can employ the same programs to access data from the new system, providing that the name of the procedure is changed to NHIMS and that the JCL statement preceding their commands is changed from SYSIN to NHIMS.

A system design document has been written which describes in detail the internals of the NHIMS system. The design document is intended for use by programmers in charge of maintaining the system; it serves as a reference manual for correcting problems or making modifications. In addition, a user's manual has been written in order to show individuals how to use the NHIMS system to retrieve data; this manual is presented as an appendix to this document.

Publications and Professional Presentations:

Bluske, M.J. and Myron Molnau, 1986, SAS Software for Managing Climatic Data, Paper for the 1986 Summer Meeting of the American Society of Agricultural Engineers, Paper No. 86-4018.

Bluske, M.J. and Myron Molnau, July 1986, A SAS Based Hydrologic Information Storage and Retrieval System, Part I, Research Technical Completion Report for the Idaho Water Resources Research Institute. Paper No. G1014-32.

Bluske, M.J., 1986, Design Document for the NHIMS System, Idaho Water Resources Research Institute.

Bluske, M.J., Workshop Presentation at the Inland Empire SAS User Group Conference, SAS as a Manager for Large Data Sets, September 18-19, Boise, Idaho.

M.S. Theses:

The above mentioned Software Requirements Document, Design Document, and the User's Manual which is an appendix to this document fulfilled the requirements necessary for the M.S. degree in Computer Science, non-thesis option, received by M.J. Bluske, Spring, 1987, University of Idaho, Moscow, Idaho.

Information Transfer Activities

The principal information transfer activites were:

a. During the 1986 grant period an irrigation workshop was held at Twin Falls, Idaho on November 21 and 22. The irrigation workshop addressed water management. The audience was primarily irrigation managers and engineers. The purpose of this workshop was to inform the participants of the most recent research results available.

A Water Resources Seminar was held during the Fall semester of 1986-87. The topic was artificial ground water recharge, particularly in the state of Idaho. Five students enrolled in this class.

b. The Director attended ten meetings of various water user and property owners groups.

1.	Idaho Water Board	08/10/86	Moscow, Idaho
2.	Water Quality Meeting	09/10/86	Coeur d'Alene, Idaho
3.	NALMS	11/05/87	Portland, Oregon
4.	Irrigation Workshop	11/20/86	Twin Falls, Idaho
5.	Idaho Water Users Association	12/12/86	Boise, Idaho
6.	Water Quality Forum	01/14/87	Coeur d'Alene, Idaho
7.	Clark Fork Coalition	02/11/87	Sandpoint, Idaho
8.	Non-Point Source Pollution Conference	03/26/87	Spokane, Washington
9.	North Idaho Lakes Coalition	04/23/87	Coeur d'Alene, Idaho
10.	Twin Lakes Property Owners	05/30/87	Twin Lakes, Idaho

c. A total of four newsletters were printed during the year which contained such information as activities of the Institute, other activities associated with water in the state, calendar of events and director's comments.

d. The professional publications submitted during the year are as follows:

Waag, C.J., and Wood, S.H., A Preliminary Report on the Geology, Hydrology, and Geochemistry of the Boise Geothermal System, Research Technical Completion Report, IWRRI.

Horn, D.R., 1987, Annual Flow Statistics and Drought Characteristics for Gaged and Ungaged Streams in Idaho, Research Technical Completion Report, IWRRI.

Horn, D.R., Annual Flow Statistics for Ungaged Streams in Idaho, (in preparation for submission to Journal of Irrigation and Drainage, ASCE).

Horn, D.R., Spacial and Temporal Variability of Droughts in Idaho, (in preparation for submission to Journal of Irrigation and Drainage, ASCE).

King, B.A., B.W. Sauer and J.R. Busch, 1987, A Simulation Procedure for On-Farm Irrigation Systems Planning, Proceedings of the ASCE I&D Specialty Conference (in publication).

Bruhl, E.J. and Dale R. Ralston, 1987, Ground Water Management Under the Appropriation Doctrine, Proceedings of FOCUS Conference on Northwestern Ground Water Issues, Portland, Oregon, National Water Well Association.

Hallock, D. and C.M. Falter, 1986, Annual Conference and International Symposium of North American Lake Management Society, Proceedings of North American Lake Management Conference, Portland, Oregon, North American Lake Management Society.

Mok, W.M. and C.M. Wai, 1987, Simultaneous Extraction of Trivalent and Pentavalent Antimony and Arsenic Species in Natural Waters for Neutron Activation Analysis, Analytical Chemistry 59, 233-236.

Bluske, M.J. and Myron Molnau, 1986, SAS Software for Managing Climatic Data, Paper for the 1986 Summer Meeting of the American Society of Agricultural Engineers, Paper No. 86-4018.

Bluske, M.J. and Myron Molnau, July 1986, A SAS Based Hydrologic Information Storage and Retrieval System, Part I, Research Technical Completion Report, IWRRI.

Bluske, M.J., 1986, Design Document for the NHIMS System, Design Document, Research Technical Completion Report, IWRRI.

Cooperative Arrangements

Cooperative arrangements and projects are conducted with the following organizations:

A & B Irrigation District
Battelle Northwest Laboratories
Bear River Commission
Bell Rapids Irrigation District
Bureau of Reclamation
Corps of Engineers
E.G. & G., Inc.
Idaho Department of Health and Welfare
Idaho Department of Water Resources
Idaho Governor's Office
Water District I
Texas A & M University
Twin Lakes Improvement Association

The Institute has cooperated with Montana, Washington, Utah and Oregon Institutes in either workshops, seminars, or development of research projects.

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Training Accomplishments

Academic Disciplines	Academic Level				
	Undergraduate	Master's Degree	Ph.D. Degree	Post-Ph.D.	Total
Engineering - Agricultural - Civil - Environmental	2				2
Biology					
Ecology					
Fisheries, Wildlife and Forestry	3				3
Agronomy					
Chemistry	2		1		3
Hydrology		1			1
Resources Planning					
Law					
Economics					
Geography					
Other (specify) *Computer Science*		2			2
TOTAL	7	3	1		11