Fiscal Year 1988 Program Report

Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho

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Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho

George L. Bloomsburg, Director
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Abstract

This report addresses the research and information dissemination activities of the Idaho Water Resources Research Institute during the 1988 fiscal year. Synopses are presented for the following research projects:

- **Ground Water Contamination from Agriculturally Applied Pesticides**
- **Developing an Integrated Model for Evaluating the Economic and Ecologic Effects of Reducing Nonpoint Source Pollution in a Palouse Watershed**
- **Preliminary Evaluation of Ground Water Inflow to Coeur d'Alene Lake from the Coeur d'Alene River Valley**
- **Uncertainty and Sensitivity Analysis of Parameters in a Regional Ground Water Flow and Recharge Model**
- **Research Fracture Flow Model Study for the Boise Front Low Temperature Geothermal Ground Water Management Area**

Information dissemination and workshop activities are also reported.

Water Problems and Issues for the State of Idaho

The important water issues in the state have continued to be water allocation, water management and water quality. The Swan Falls agreement, which 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 has focused considerable research on irrigation monitoring systems. This research has been supported by a number of different irrigation districts in southern Idaho. The objective is to develop efficient monitoring systems in order to increase pumping efficiency and decrease energy use on irrigation and municipal water supplies. In addition, concerns for determining the impacts of agriculture and other land uses on ground water quality is focusing attention on monitoring and evaluation of aquifer systems.

Water quality in northern Idaho, with its many lakes and rivers, is a high profile issue. Many lake property owner groups have increased concerns about cultural eutrophication resulting in reduced clarity and increased algae and weed growth. In addition, ground water considerations are being addressed in the north Idaho lake region (specifically Coeur d'Alene Lake). Although mining waste discharged into the Coeur d'Alene River has significantly decreased, sediments abundant in heavy metals remain deposited in the lakes, lowlands, and river bed of the Coeur d'Alene River. The quantity and quality of ground water inflow to the lakes via the deltas is unknown. Shallow ground water flow systems near the mouths of rivers may be impacted by recharge of poor quality water. In addition to contamination due to mining, other studies have investigated nonpoint source ground water contamination due to agricultural pesticides.

Idaho's main industries are agriculture and recreation, both of which are significantly dependent on water. The quantity and quality of water is primary to the increased development and success of these industries. Idaho's community discerned early on the importance of water and endeavors to gain greater knowledge and understanding for the protection of its greatest natural resource.

Program 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 comprehendible 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 resource 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.

Project No. 02 *Start:* 06/87
End: 05/89

Title: Ground Water Contamination from Agriculturally Applied Pesticides

Investigators: Morra, M.J.

COWRR: 05 C *Congressional District:* First

Key Words: Pollution, ground water quality, pesticide control

Problem and Research Objectives:

Currently available models do not accurately predict the transport of synthetic organic contaminants in the environment. It has recently been proposed that one of the reasons organic contaminants are transported more quickly than predicted is because of complexation with a water soluble soil organic fraction of unknown chemical structure. Complexation may not only increase the water solubility of hydrophobic compounds but also alter pesticide charge and size characteristics. An interaction between synthetic organic compounds and soluble humic materials has been demonstrated, but the type of association is uncertain. A mathematical relationship between dissolved organic carbon (water soluble soil organic materials) and relatively immobile chemicals has been proposed for inclusion in pesticide transport models. Computer simulation demonstrated that measurable increases in mobility of the chemicals may occur through an interaction with water soluble soil organic materials.

Although the incorporation of this parameter into a model describing contaminant transport thus appears to be critical, the proponents acknowledge that the approach is currently limited by a lack of data describing the physical and chemical processes occurring during complexation and contaminant movement. In other words, contaminant complexation with a water soluble soil organic material can cause increased mobility, but an inadequate understanding of the interaction itself prohibits the development of an accurate model input parameter.

Interaction of organic pollutants with inorganic clay colloids has also been suggested as a possible mechanism for facilitating contaminant movement. Even less is known about the potential of clays to enhance organic contaminant mobility than for natural colloidal organic materials. Again, inclusion of a parameter describing these interactions in hydrologic models has not been achieved because of inadequate knowledge concerning fundamental interaction mechanisms and complex stability. The objectives of this project include the following:

1. Obtain representative soil samples and natural organic materials.

2. Fractionate and characterize soil samples and natural organic materials.

3. Determine extent of organic pollutant interaction with colloidal soil constituents.

4. Compare reaction parameters obtained at the molecular level to sorption-desorption reaction parameters obtained using column procedures.

Methodology:

Humic acid has been extracted from a Latahco silt loam soil and freeze dried. Standard methods involving differential solubility in acid and base have been followed. Humic acid was purified using ultrafiltration and a membrane having a MW cutoff of 10,000.

Particle size fractionation of six different soils varying in organic matter and pH was achieved through relatively mild methods involving wet sieving, sonication, and sedimentation by centrifugation. Verification of accurate particle size fractionation was conducted for silt range fractions using Coulter Counter techniques. Silt and clay fractions separated using the above techniques were analyzed for total C and total N using Dumas combustion.

Humic acid was characterized using Fourier Transform Infrared Spectroscopy (FT-IR) in combination with a cylindrical internal reflectance sample cell. Soil clays were characterized also using FT-IR, but in combination with a diffuse reflectance sample cell. Soil clays were also subjected to Near Infrared Spectroscopy.

The interaction of naphthalene, 1-naphthol, and carbaryl with the purified humic acid described above was determined using fluorescence quenching and fluorescence polarization techniques.

Principal Findings and Significance:

Fluorescence quenching and fluorescence polarization techniques were used to determine the type of interaction occurring between water soluble Latahco humic acid and naphthalene or 1-naphthol. Humic acid solutions ranging from 0 to 30 mg L^{-1} were used in fluorescence quenching experiments to construct linear Stern-Volmer plots for both naphthalene and 1-naphthol. Dynamic or collisional quenching was indicated by the lack of change in the UV/VIS spectra of the fluorophores in the presence and absence of the quencher and by quenching changes with temperature. However, calculation of bimolecular quenching constants of 4×10^{12} and 5×10^{11} M^{-1} s^{-1} for 1-naphthol and naphthalene, respectively, exceed the maximum value possible for a diffusion controlled reaction. Fluorescence polarization measurements gave no definite indication of rigid association between 1-naphthol and humic acid in aqueous solution. Insufficient evidence exists to demonstrate that humic acid is a true micelle at the concentrations tested, but the combined data indicate a close physical association between the fluorophore and the quencher. It is proposed that the interaction of naphthalene and 1-naphthol with humic acid in aqueous solution occurs through a loose association in which humic acid surrounds the fluorophore in a cage-like manner. The fluorophore is free to move in the confined space provided humic acid and fluorescence is quenched by a collisional mechanism. Ultrasonic dispersion having a total energy

input of 0 to 7657 J was used in combination with centrifugation and sedimentation techniques to obtain sand, silt, coarse clay, medium clay, and fine clay fractions. Coulter counter analysis of the silt size fractions showed no differences with increased energy input. Total C and total N contents of the silt and coarse clay fractions were not altered by increased energy input. Diffuse reflectance FT-IR of the coarse clay fractions also showed no changes occurring as a result of increased dispersion energy. Diffuse reflectance FT-IR of the medium clay fractions did however show distinct alteration of the clay surfaces when dispersion energy was increased from 840 J to 2940 J. Artifacts created by sonication occur at relatively low levels of total energy input. If the separated medium clay fraction is later used to study pesticide interactions, significant changes in that interaction can be expected.

Publications and Professional Presentations:

Morra, M.J., D.B. Marshall, and C.M. Lee. 1989. FT-IR analysis of humic acid in water using cylindrical internal reflectance. Commun. Soil Sci. Plant Anal. 20: (in press).

Lee, C.M., D.B. Marshall, and M.J. Morra. 1988. Accelerated groundwater contamination through pesticide complexation with water soluble organic materials. J. Idaho Acad. Sci. 24, (in press).

Morra, M.J., D.B. Marshall, and C.M. Lee. 1988. FT-IR analysis of humic materials in aqueous solution. Agronomy Abstracts, p. 202.

Morra, M.J., D.B. Marshall, and C.M. Lee. FT-IR analysis of humic materials in aqueous solution. Poster paper, National Agronomy Meetings, Anaheim, California, December 1, 1988.

M.S. Theses:
None

Ph.D. Dissertations:
None

Project No. 03 *Start:* 06/87
End: 05/89

Title: Developing an Integrated Model for Evaluating the Economic and Ecologic Effects of Reducing Nonpoint Source Pollution in a Palouse Watershed

Investigators: Prato, T. and Brusven, M.

COWRR: 06 B *Congressional District:* First

Key Words: Water quality management, water quality monitoring, water quality modeling, statistical models

Problem and Research Objectives:

The proposed study will address the problem of reducing contamination of surface waters from nonpoint pollution in agricultural watersheds. Nonpoint source pollution is an hydrologically derived expression of poor watershed management.

The objectives:

1. To further define and evaluate the Agricultural Nonpoint Source Pollution (AGNPS) model for the Tom Beall Creek Watershed.

2. To expand the existing Geographic Information System (GIS) for Tom Beall Creek Watershed to include information on water quality and the offsite impacts of water pollution.

3. To complete the integrated resource assessment model for analyzing the effects of different best management practices on nonpoint source pollution in the Tom Beall Creek Watershed and economic consequences.

Methodology:

1. The AGNPS watershed-event model was used to simulate estimates of sediment and nutrients in agricultural runoff. Data inputs include over 15 variables involving precipitation, soil type, topography, and land use. The GIS system developed under objective 2 was used to organize and interpret the data needed to operate AGNPS.

2. The GIS system employed in this study consists of a Summagraphics Digitizer, IBM-AT microcomputer, Professional Map Analysis Package and Golden Graphics software. This system was used to format, integrate and output data components of the integrated watershed assessment.

Principal Findings and Significance:

1. A computer-based Geographic Information System (GIS) was successfully employed to integrate physical and chemical features within the Tom Beall watershed. We also interfaced the AGNPS model components with GIS in order to output simulated effects of different Resource Management Systems (RMS) on water quality at the outlet of the watershed.

2. Actual offsite water quality, substrate and aquatic invertebrate monitoring in the Tom Beall (heavily impacted from agriculture) vs. Upper Sweetwater Creek (minimally impacted from agriculture) revealed that all three parameters were adversely impacted in Tom Beall Creek (TB). During most sampling dates and seasons, other phosphate concentrations were 10 to >100% greater in TB creek than Sweetwater Creek (SW); nitrate concentrations were mostly 3-25 times greater in TB Creek. The stream substrate in TB Creek was heavily impacted by sand and silt while Sweetwater Creek was lightly impacted. As a measure of "biological health" in streams, offsite analysis of insect species richness is a better measure than density. The number of insect taken were 2-4 times greater from different habitats in SW Creek than TB Creek, while total density was sometimes greater in TB Creek because of high concentrations of pollution-tolerant species.

This study indicated that achieving simulated conservation compliance in Idaho's Tom Beall watershed would result in less total cropland erosion and less sediment/nutrient pollution of Tom Beall Creek than good management of riparian areas. Good riparian management is more "efficient" in reducing cropland erosion and water pollution than conservation compliance. If the yield penalties with conservation tillage are permanent and the current resource management system is conventional tillage, contour farming and a wheat-pea rotation, then conservation compliance and good riparian management would reduce net farm income. The efficiency of conservation compliance in Tom Beall watershed is very sensitive to the magnitude and longevity of yield penalties with conservation tillage systems and the current mix of conventional and conservation tillage systems in the watershed.

Publications and Professional Presentations:

Prato, T. and M. Brusven. Controlling Erosion and Nonpoint Source Pollution in Idaho's Tom Beall Watershed. 1989. University of Idaho, Agric. Exp. Bulletin 687, 27 pp.

Prato, T. and M. Brusven. Economic and Environmental Tradeoffs for Dryland Farming in the Palouse. 1988. Presentation. International Conference on Dryland Farming. Amarillo, TX.

Prato. T. and M. Brusven. Managing Erosion and Nonpoint Source Pollution in a Palouse Watershed. Poster Paper. 1988. International Symposium on Water Quality Monitoring of Agricultural Nonpoint Sources. Logan, Utah.

M.S. Theses:

Haro, Roger. Agricultural Non-Point Source Pollution Impacts on Macrobenthic Fauna within the Lapwai Creek Watershed, Idaho. M.S. Thesis. University of Idaho. August, 1988.

Shi, Hong Qui. Integrated Economic Assessment of Soil Erosion and Water Quality in Idaho's Tom Beall Watershed. M.S. Thesis. University of Idaho. 1987.

Wu, Shunpiang. A Field Level Economic Analysis of Erosion and Nonpoint Source Pollution in Idaho's Tom Beall Watershed. M.S. Thesis. University of Idaho. 1989.

Ph.D. Dissertations:

None

Project No. 04 *Start:* 06/88
End: 05/89

Title: Preliminary Evaluation of Ground Water Inflow to Coeur d'Alene Lake from the Coeur d'Alene River Valley

Investigators: Ralston, D.R. and Sprenke, K.

COWRR: 05B *Congressional District:* First

Key Words: Ground water hydrology, ground water quality, heavy metals, sub-surface drainage, surface drainage, water quality

Problem and Research Objectives:

Coeur d'Alene Lake, the second largest lake in Idaho, has been impacted by upstream mining activities. The Coeur d'Alene mining district, located on the south fork of the Coeur d'Alene River, has been a source area for poor quality water and metal rich sediments since the 1880's. Although the discharge of mine wastes into the river has decreased significantly since tailings ponds were put into operation in 1968, sediments rich in heavy metals remain deposited in the lakes, lowlands, and river bed of the Coeur d'Alene drainage. The delta at Harrison is known to be rich in mine wastes. The general objective of this study is to complete a preliminary analysis of the quality and quantity of ground water inflow to Coeur d'Alene Lake from the Coeur d'Alene river valley with particular emphasis on water quality at shallow depths in the delta.

Methodology:

A well inventory of the lower Coeur d'Alene river drainage was performed in an effort to formulate a conceptual model of the hydrogeology of the area. Water samples were collected from more than 50 wells for a general analysis of ground water temperature, pH, and electrical conductivity.

A geophysical survey using resistivity was performed on and near the delta in an effort to determine subsurface changes in lithology and depth to bedrock. Five soundings were done utilizing a Schlumberger Array. Two soundings were done on the delta and three were done approximately 1.8 miles upstream.

A geologic investigation included drilling, coring, and sampling from two sites on the delta. Two shallow wells were drilled on the northern exposure of the delta, one near the center of the exposure to a depth of 30 feet, MW-2, and one near the western extent of the delta, adjacent to the lake, to a depth of 50 feet, MW-1. Split spoon samples were collected at five foot intervals during the drilling of each well. Coring devices were used to extract sediments in the upper five feet of the lithologic profile at both well sites, adjacent to each well. Three cored sediments in the upper five feet of the profile were analyzed for nine metals (Ag, As, Cd, Cu, Fe, Mn, Pb, Sb, and Zn). Three deeper splitspoon samples (approximate depths: 10, 20, and 30 feet) from MW-1 were analyzed

for Pb and Zn. Shallow holes were also drilled at 12 locations across the delta using a hand auger. The extracted sediments were visually interpreted for the presence of surface tailings.

A hydrogeologic investigation included sampling from and monitoring water levels in both wells. MW-1 was completed with multiple piezometers screened from 48 to 53 feet and from 25 to 30 feet. MW-2 was completed as a single piezometer, screened from 24 to 29 feet. Water was extracted from the split spoon samples collected during the drilling of each well and was analyzed for the same nine metals referred to in the sediment analysis. Four water samples were extracted from each piezometer over a two month period. Each sample was tested for the same nine metals. Continuous water level recordings were obtained from the two shallow piezometers. The results were compared to lake level fluctuations over the same period to ascertain the degree of hydrologic interconnection between surface water and ground water sources. Water samples were also extracted from the water table in the shallow hand-augered holes to determine the variation in water quality between the water table and the deeper water from the two wells.

Principal Findings and Significance:

Well logs, water level data, and water samples from existing wells in the lower drainage indicate that no wells are completed on the floodplain. Shale and basalt aquifers are most prevalent in wells drilled on bedrock. Electrical conductivity in both the shale and basalt aquifers follows an increasing westward trend, suggesting a continuous flowpath in each unit toward Lake Coeur d'Alene. The water table in the drainage is shallow, and springs are numerous.

The geophysical survey done on the delta indicates stratigraphic layering in shallow sediments. The upstream survey indicates a sediment depth of 288 feet, and a resistive layer at approximately 30 feet.

The split spoon samples extracted during the drilling process indicate that the upper 50 feet of deltaic sediments is heterogeneous and composed of clays, silts, and sands with organics present throughout the lithologic profile. Sediment samples analyzed for metal content indicate that pollution from tailings is predominantly restricted to the upper eight feet of sediments. Below this depth, concentrations of all metals decrease exponentially. Iron was detected in the highest concentrations, reaching 106,000 ppm. Traces of lead and zinc were found in the sediments to a depth of 30 feet. Iron stained surface sediments intermixed with lenses of flotation tailings were extracted in each of the 12 hand augured holes, indicating that tailings are distributed laterally across the delta.

Concentrations of four metals (Fe, Mn, As, Pb) were above drinking water standards in water extracted from the split spoon samples of MW-1 and MW-2. Iron is present in high concentrations in all samples. Manganese and lead are above drinking water standards in 4 samples, and arsenic in 1 sample. Zinc, the dominant indicator of mine

related pollution, is present in 11 of the 17 samples and is detected to a depth of 49.5 feet. Iron has the highest concentration of all metals tested, reaching a maximum concentration of 502 ppm. Maximum concentrations of other metals include .42ppm (Pb), 4.5 ppm (Mn), 2.15 ppm (Zn), and .06 ppm (As). Iron, lead, and zinc concentrations are highest in the upper samples and decrease significantly below, suggesting surface sediments as the source of pollution. Silver, arsenic, cadmium and antimony are at or below detection in every sample.

In all water samples extracted from the piezometers, Ag, As, Cd, Cu, Pb, and Sb are at or below detection limits, and Fe and Mn are above drinking water standards. Manganese and iron are detected above drinking water standards. Zinc is below drinking water standards in each sample, but is detected in concentrations above toxicities for aquatic life. Maximum concentrations for the three detected metals include 128 ppm. (Fe), .37 ppm (Zn), and 4.45 ppm (Mn). Water samples extracted from the water table have exponentially higher metals concentrations than samples at depth. The tailings present in the aerobic zone above the water table are heavily oxidized during months of low moisture. Increased metal concentrations at the water table result from the washing of the oxides from the sediment surfaces by precipitation, a raised water table, or both.

The hydrology of the delta is characterized by a gradient reversal from low water to high water months. An upward gradient was recorded in February; and, as spring runoff began in March, water levels rose and the gradient reversed. Surface sediments appear to be the pollution source, therefore a downward gradient during low water months may explain the presence of metals in solution at depth. The horizontal gradient across the delta is equivalent to surrounding surface water gradients and is, therefore, very shallow. Results from continuous water level recordings suggest excellent hydrologic connection between ground water and surface water sources.

Publications and Professional Presentations:

None

M.S. Theses:

Piske, Brad. Preliminary Evaluation of Ground Water Discharge to Coeur d'Alene Lake from the Coeur d'Alene River Valley. In progress. M.S. Thesis. University of Idaho.

Ph.D. Dissertations:

None

Project No. 05 *Start:* 06/88
End: 05/89

Title: **Uncertainty and Sensitivity Analyses of Parameters in a Regional Ground Water Flow and Recharge Model**

Investigators: **Brockway, C.E.**

COWRR: 02A *Congressional District:* First

Key Words: **Aquifer parameters, ground water modeling, mathematical models, saturated flow**

Problem and Research Objectives:

Use of mathematical models for simulation of ground water flow systems is now the accepted procedure for evaluation of complex aquifer relationships. Response of piezometric head or spring flows from an aquifer is spatially and time dependent on aquifer properties and the location and magnitude of recharge flux parameters. Confidence in model predictive capabilities depends on an understanding of parameter and system variability. Incomplete knowledge of system variability can result in difficulty in making management or policy decisions regarding the resource. A thorough analysis of a regional ground water flow system requires both a determination of piezometric heads and output flux as well as a determination of the significance of each variable and an assessment of prediction uncertainty.

In Idaho, several ground water flow models have been used to evaluate regional aquifer systems, particularly the Eastern Snake Plain aquifer. A model developed by the University of Idaho for the Idaho Department of Water Resources has been used in developing data for the State Water Plan and in evaluating development scenarios for various planning studies. The USGS has utilized a three-dimensional model of the eastern Snake Plain as a research tool to develop a better understanding of the hydrogeology of the aquifer.

The objectives of this project were to assess the prediction uncertainty in the University of Idaho ground water flow model of the eastern Snake River Plain aquifer resulting from the collective variation in the model input parameters and to evaluate the significance of each parameter in the model.

Methodology:

Uncertainty was defined to be the determination of the variation in model output resulting from the collective variation in the model input variable. The primary descriptive statistic for the variation in output is the cumulative distribution function for the output variable, either areal piezometric head or spring outflow. A Monte Carlo method using the Latin hypercube sampling scheme to select samples from input variables was used. The procedure included:

1. Determination of the probability distributions of significant aquifer and recharge variables.

2. Application of the Latin hypercube sampling scheme to select samples from these variables according to their relative probabilities of occurrence.

3. Running of the model and determination of the magnitude of selected output variables for each set of inputs.

4. Estimation of the cumulative distribution function of each output variable from the results of repeated simulations.

Sensitivity analysis is a means of measuring variability of system response to changes in characteristics of the system. This type of analysis can guide the identification of the relative importance of specific input parameters to the variation or imprecision in model output.

Using the results of the Monte Carlo simulations, a statistical analysis was made from which the sensitivity and the contribution of each parameter to model uncertainty was estimated. The partial rank correlation coefficient was used to determine output sensitivity. The partial rank correlation coefficient was used because the partial correlation coefficient with raw data does not provide a reliable measure of the sensitivity when the relationship between input variables and the output variable is basically monotonic but nonlinear or in the presence of outliers.

Seventeen input variables were selected, including aquifer parameters, surface and ground water irrigated area, net irrigation diversions, effective precipitation in seven zones, and boundary underflow, from five major tributaries. Output variables were average piezometric head in three zones of the aquifer and reach-gains or spring outflow from the aquifer along four reaches of the Snake River. A total of 45 sets of annual data selected through the Latin hypercube sampling procedure were run on the model. The model was run for twenty consecutive yearly timesteps using the same annual data, and the output for the twentieth year was considered for the statistical analysis.

Principal Findings and Significance:

The uncertainty analysis provided a probabilistic description of the magnitude, spatial extent and nature of the effects that the possible range of parameter variations can have on aquifer behavior, particularly piezometric heads and outflows. Cumulative distribution functions for outflows from specific areas of the aquifer showed that confidence limits for some outflows were quite narrow, whereas for other outflows the limits were quite wide. Similar results occurred for the cumulative distributions for piezometric heads; however, the variations were considerably smaller than for outflows.

The sensitivity analysis showed that, although the results are spatially specific, the most significant variable is hydraulic conductivity of the aquifer. Second most significant is the net irrigation diversion. Over the entire aquifer, the storage coefficient is the third most significant input parameter; however, specific input flux parameters, such as boundary
underflows, become more influential on piezometric heads or outflows in specific parts of the aquifer.

Some partial rank correlation coefficients for specific input variables are ambiguous in that the sign of the coefficient indicates a response of the output variable to changes in the input which do not appear hydraulically credible. Some of the ambiguities could be due to the assumption of zero correlation among input variables, assignment of unrepresentative distribution for some of the input variables or possible model restrictions.

Publications and Professional Presentations:

Sohrabi, Teymour. Sensitivity and Uncertainty Analyses of Parameters in a Regional Ground Water Flow and Recharge Model. Presentation. ASAE. Chicago, Ill. December, 1988.

Brockway, C.E. Sensitivity and Uncertainty Analyses of Parameters in a Regional Ground Water Flow and Recharge Model. Presentation. Idaho Department of Water Resources. December, 1989.

M.S. Theses:

None

Ph.D. Dissertations:

Sohrabi, Teymour. Sensitivity and Uncertainty Analyses of Parameters in a Regional Ground Water Flow and Recharge Model. In review. M.S. Thesis

Project No. 06 *Start:* 06/88
End: 05/89

Title: Research and Fracture Flow Model Study for the Boise Front Low Temperature Geothermal Ground Water Management Area

Investigators: Waag, C. J. and Wood, S. H.

COWRR: 04 B *Congressional District:* Second

Key Words: Aquifer parameters, geothermal power, ground water modeling, mathematical models

Problem and Research Objectives:

The Boise Geothermal System is one of the oldest commercially utilized geothermal resources in the United States. Its hot waters have been produced for space heating and domestic uses by the Boise Warm Springs Water District (BWSWD) in the Warm Springs area since the early 1890's, nearly a century ago. The system produces low temperature artisan geothermal fluids from an aquifer of fractured rhyolites and loosely consolidated sediments of the Snake River Plain and granitic rocks of the Idaho Batholith. Fluid temperatures are highest in the granitic-reservoir rocks and generally decrease away from the batholith and the major Snake River Plain-Idaho Batholith boundary fault system locally termed the Boise frontal fault system.

Essentially no water level or production data from the early years of utilization of waters from the system are available. However, early geologic literature in the Boise area reports flowing geothermal springs along the frontal fault system and in the adjacent Batholith and allows the inference that artisan springs were then present at elevations as high as approximately 2,815 feet in the Warm Springs area. Production and water level data available from BWSWD indicate that annual production ranged from approximately 250-300 million gallons and allow the suggestion that until 1983 the system was in essential equilibrium.

Since 1983 water levels within the system have declined on average approximately five (5) feet per year in response to increased production. The objective of this research is to determine the capacity of the aquifer system, to delineate the degree of hydraulic interconnection which exists within the system, and to accumulate the long-term data base necessary to develop a fractured aquifer model to predict the consequences of increased production from the system and the effects of reinjection of some of the partially spent geothermal fluids.

Methodology:

Long-term monitoring, including the period reported herein, is proving to be a valuable technique for determining the productive capacity (safe yield) of the Boise Geothermal Aquifer. The water-levels in 11 observation wells and two (2) production wells

have been tracked and correlated to production from five (5) major producing wells within the Boise vicinity. The data collected have been computer and manually graphed and analyzed.

Principal Findings and Significance:

Analyses of production and water level data on the geothermal system for the report period compared to the earlier records allow several important and significant conclusions. Firstly, 1988 maximum recovery water levels in response to heating season withdrawals reached levels equal to or slightly above maximum recovery levels in 1987. This is important because the September 1988 recovery is the first since 1983 that the level has not declined. Production during the 9/1/87-8/31/88 drawdown-recovery period by the City of Boise and Boise Warm Springs Water District, the two principal producers who do not reinject, was approximately 300-350 million gallons per year, the maximum production level which can be sustained by the aquifer as the pumping system is presently arrayed without generating cumulative declines in the aquifer water levels. This interpretation is further reinforced by the 1988 maximum drawdown data from the monitored wells. Water levels in observation wells reached their lowest levels in early March 1989, an average of four feet below their greatest drawdowns in 1988. These declines are a reflection of an increase of approximately 20 percent in the 9/1/88-3/1/89 production compared to the same 87-88 period. The data suggest that maximum recovery levels in September 1989 will again be on average, 5-6 feet below the level of September 1988.

Secondly, with exception of the Behrman Well, water level fluctuations within the general monitoring network were similar indicating relatively good hydraulic interconnection throughout most of the system. The exceptional well, the Behrman, is apparently strategically located within the fractured aquifer and experiences more rapid and higher recoveries than adjacent wells in the system. The presence of a barrier of some sort between it and the BWSWD production wells is indicated by these hydrologic data. A preliminary high-resolution seismic survey in the vicinity suggests offset in the layers of the subsurface.

Publications and Professional Presentations:

Waag, C.J., S.H. Wood, Baumhoff, A.L. Brown, W.G. Squires, and C.M. Clemens. 1988. Analysis of Historical and Current Water Level and Production Data from the Boise Geothermal System: Abstracts with Programs, Geological Society of America, v. 20, no. 6, p. 243.

M.S. Theses:

None

Ph.D. Dissertations:

None

Project No. 32 *Start:* 06/88
End: 05/89

Title: Mean Annual Precipitation Map for Idaho

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COWRR: 10 A *Congressional District:* First

Key Words: Precipitation, maps

Problem and Research Objectives:

The primary objective of this study is to produce a series of mean annual precipitation maps for the state of Idaho at a scale of 1:250,000. A secondary objective is to formulate a method of estimating point precipitation values where no gages exist and selecting the most appropriate computer contouring interpolation procedures.

Methodology:

The following are the main steps involved in the production of the mean annual precipitation maps:

1. Data acquisition, adjustment, and standardization.

2. Formulation of regression equations to estimate point precipitation values.

3. Computer interpolation to produce preliminary isohyets

4. Hand adjustment of isohyets using knowledge that is not readily reduced to computer algorithms.

All available National Weather Service and Soil Conservation Service Snotel precipitation data for the study area (Idaho and a fifty mile border) were obtained from the Northwest Hydrologic Information Management System (NHIMS) and the Soil Conservation Service Central Forecasting System (CFS). All data records were standardized to the same twenty-five year base period (1961 - 1985). The Snotel data were downloaded in this prestandardized form. NWS records were extended by estimation of missing data using two methods, depending on how many data values were missing in each year. Stations with more than five years missing were discarded. Mean annual precipitation values were calculated and verified for each of 309 stations.

Equations for estimating point precipitation values were derived using regression techniques. The dependent variable for each of these equations is the log of the mean annual precipitation. Independent variables include: elevation, easting, northing, and four measures of air mass lifting (ALI). The ALI variables are the elevation 5, 10, 20 or

30 miles upwind of the station (on the mean 700 mb. wind bearing) subtracted from the elevation of the station. This results in four different measures of rise (positive ALI) or decent (negative ALI) to each station.

The study area was broken into seven regions which have relatively homogeneous precipitation regimes (Figure 1). New data points can then be estimated using the appropriate regression equations.

Two interpolation procedures were investigated to determine which would be most appropriate for the production of preliminary computer generated isohyets. The interpolation procedures which were considered were an inverse distance (weighted interpolation) method and a Kriging procedure. The spatial dependence of the variable, the computation search method, and the search orientation were considered.

The final step involves hand adjustment of isohyets using the 1:250,000 scale one by two degree topographic quadrangles, the original data records, snow course data, and the old mean annual precipitation map.

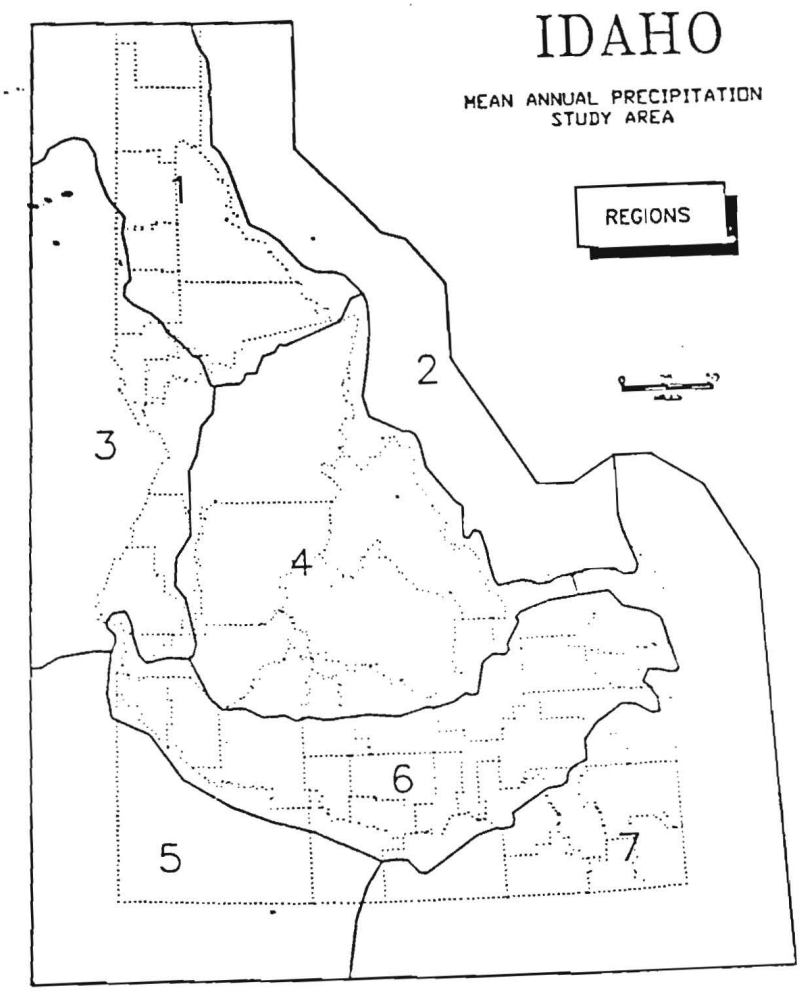
Principal Findings and Significance:

Acceptable estimates were entered for each of the missing NWS data records. 1961-1985 mean annual precipitation values were calculated for each station and stored in a digital data base.

Regression equations for estimating point precipitation values were estimated for each of the seven regions. These equations all have a 95 percent probability of estimating within plus or minus 3 inches when the estimated value is at the mean. Table 1 shows a summary of results for each of the seven regions. The "95% C.B." is the confidence band of estimation (in inches) when the estimated value is the mean. Significant variables at the 10 percent level are listed. Acceptable equations were formulated for each of the regions with the possible exception of Region Two, where multicoliniarity between the independent variables caused problems.

Table 1. Regression Equation Results for Estimating Mean Annual Precipitation Values

Region	R-square	95% C.B.	Significant Variable *
1	.9418	2.23	elev, ALI20
2	.6920	2.80	elev, qx
3	.7771	2.44	qx, ALI20
4	.7218	2.63	elev, qx, qy, ALI20
5	.5700	2.09	elev
6	.7479	2.34	elev, qx, qy, ALI30
7	.6385	2.07	elev, qx, qy, ALI20


IDAHO
MEAN ANNUAL PRECIPITATION
STUDY AREA
REGIONS
1
2
3
4
5
6
7

* ELEV = ELEVATION	ALI20 = air mass lifting @ 20 miles
qx = northing	ALI30 = air mass lifting @ 30 miles
qy = easting	

After investigation of the available interpolation procedures, the Kriging method was chosen because of its flexibility in tailoring the search criteria and spatial dependence model to the characteristics of each area of the state.

Hand adjustment of isohyets has been completed for five of the twenty quadrangles included in the study. These quadrangles will be checked and sent to various experts who have a good feel for the precipitation pattern in their area of the state. Comments will be considered and corrections will be made. The remaining fifteen preliminary maps were completed by July of 1989.

Publications and Professional Presentations:

None

M.S. Theses:

Winters, Frances. July, 1989. Mapping precipitation in Idaho: A study of data estimation and interpretation methods. M.S. Thesis. University of Idaho.

Ph.D. Dissertations:

None

Information Transfer Activities

The principal information activities were:

1. The Idaho Water Resources Research Institute and the Washington Water Research Center co-hosted the annual UCOWR meetings in Coeur d'Alene, Idaho on
July 5-8, 1988.

   The Institute sponsored a series of short courses entitled Ground Water Evaluation at a Solid Waste Site. The purpose of the course was to present an overview of ground water evaluation and monitoring at waste disposal sites. The audience was professionals in the field, program managers, health district personnel and graduate students. The short course was held in Idaho Falls, Idaho on April 18-19, 1989, Boise, Idaho on April 20-21, 1989 and Moscow, Idaho on May 4-5, 1989.

   A Water Resources Seminar was held during the Fall semester 1988-89. The topic was the Swan Falls Adjudication. Fifteen students were enrolled in the class.

2. The Institute was in a state of transition during the grant year. Dr. George Bloomsburg, Director announced he would be on sabbatical during the spring semester in Arizona and would be leaving in January of 1989. In addition, he announced that he would not be returning as director of the Institute, rather he would be coming to teaching and research exclusively. Dr. Dale Ralston was appointed as Acting Director until a new Director could be appointed. Following is a list of activities and meetings for both Dr. Bloomsburg and Dr. Ralston:

Coeur d'Alene Water Quality Workshop	06/04/88	Coeur d'Alene, ID
UCOWR	07/05/88	Coeur d'Alene, ID
INEL Workshop	08/01/88	Idaho Falls, ID
Coeur d'Alene Water Quality Forum	08/31/88	Coeur d'Alene, ID
Snake River Basin Committee	09/21/88	Sun Valley, ID
Coeur d'Alene Water Quality Workshop	10/20/88	Cheney, WA
Geological Society of America	11/02/88	Denver, CO

Coeur d'Alene Water Quality Workshop	11/21/88	Coeur d'Alene, ID
Idaho Water Users Association	12/09/89	Boise, ID
Regional NAWID Meeting	02/15/89	Honolulu, HI
NAWID Meeting	04/25/90	Washington, D.C.

3. One newsletter was 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.

4. Professional publications submitted during the year are as follows:

Lee, C.M., D.B. Marshall, and M.J. Morra. 1988. Accelerated groundwater contamination through pesticide complexation with water soluble organic materials. J. Idaho Acad. Sci. 24, (in press).

Morra, M.J., D.B. Marshall, and C.M. Lee. 1989. FT-IR analysis of humic acid in water using cylindrical internal reflectance. Commun. Soil Sci. Plant Anal. 20: (in press).

Prato, T. and M. Brusven. Controlling Erosion and Nonpoint Source Pollution in Idaho's Tom Beall Watershed. 1989. University of Idaho, Agric. Exp. Bulletin 687, 27 pp.

Waag, C.J., S.H. Wood, Baumhoff, A.L. Brown, W.G. Squires, and C.M. Clemens. 1988. Analysis of historical and current water level and production data from the Boise Geothermal System: Abstracts with Programs, Geological Society of America, v. 20, no. 6, p. 243.

Cooperative Arrangements

Cooperative arrangements and projects are conducted with the following organizations:

Idaho Department of Water Resources
Bureau of Reclamation
Water District I
Bell Rapids Irrigation District
E.G. & G., Inc.
Aberdeen-Springfield Canal Company
A & B Irrigation District
City of Moscow
City of Pullman
Washington State University
Latah County/Idaho
Whitman County/Washington
Army Corps of Engineers
State of Washington Water Research Center
Oregon State Water Resources Research Institute
Montana Water Resources Research Center
Soil Conservation Service
Boise State University
Idaho State University

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Training Accomplishments

Field of Study	Undergraduate	M.S.	Ph.D.	Post Ph.D.	Total
Entomology		*1*			*1*
Geography		*1*			*1*
Agricultural Economics		*2*			*2*
Civil Engineering			*1*		*1*
TOTAL		*4*	*1*		*5*