FISCAL YEAR 1986 PROGRAM REPORT

Water Resources Research Institute
Oregon State University
Oregon

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Peter C. Klingeman, Director

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ABSTRACT

The FY 1986 Oregon Water Resources Research Institute program included six research projects addressing critical water problems in Oregon. Three projects advanced our understanding of potential means for the protection of ground water resources: project 02, Laboratory Study of In-Situ Reclamation Process for Metals-Contaminated Soils; project 03, Sorption and Transport of Aqueous Gasoline Contaminants in Soil and Aquifer Sediments; and project 04, Effect of Sorption on Bacterial Metabolism of Trace Toxicants in Groundwater Aquifers. Two projects developed analytical techniques for evaluating the effectiveness of protection measures for aquatic ecosystems: project 05, Hierarchical Analysis of Salmonid Habitat Improvement Programs Within the John Day Drainage; and project 06, Microbiological Quality of Estuarine Waters. One project provided a technique for improved detection of lake water eutrophication problems: project 07, Development of Field Assay of Iron Limitation in Nutrient-Rich Lakes. Brief individual summaries of these research projects and their principal research findings are presented.

The FY 1986 Oregon WRRI program also included education and training activities. This directly involved 40 graduate students from across campus in WRRI interdisciplinary seminars plus 9 graduate students and 4 undergraduates in research training on WRRI projects. Information transfer activities were also a routine part of the WRRI program.

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WATER PROBLEMS AND ISSUES OF OREGON

Major water-related problems in Oregon result from seasonal, geographic, and year-to-year variability of water supply and the associated competition among water uses. Excess surface water runoff during most winters and springs causes flooding, bank erosion and related problems. Depleted streamflows, contaminated return flows, and lowered ground-water levels occur during most late-summer periods. These create problems of water storage, poor water quality, and intense competition among water users. Extensive agricultural development in the more arid parts of Oregon and high population densities in the wetter parts of the state lead to severe water-related problems in drier-than-normal years and to drastically curtailed water use during years of drought.

Water storage in single- and multiple-purpose reservoirs is significant in balancing part of the seasonal maldistributions of water in many river basins. But most reservoirs in Oregon do not provide much carry-over water from wet years to dry years. While solving some problems of water supply, dams and reservoirs create other problems, particularly for anadromous fish. Hence, a continuing conflict exists in the state between advocates of water resource development and those favoring protection of natural resources. Better watershed management and water conservation are being urged by many citizens as non-structural alternatives to explore before more dams are built.

At the regional level, water-related concerns continue to focus on the Columbia River and its main tributaries. The Northwest Power Planning Council and Bonneville Power Administration presently dominate regional coordination activities; their program emphasis is almost entirely on power, fish and wildlife. Columbia River water is fully committed and must be very

closely managed to assure efficient streamflow use for these and other major competing economic purposes, including agriculture, industry, navigation, and recreation.

At the state level, Oregon's state agencies continue to be underfunded for natural resource management. Many water resource management activities, such as water rights adjudication, ground water resources assessment, and inter-agency multi-focus planning, take place at reduced levels that could have long-term detrimental effects.

The principal water problem in Oregon is competition among users for the available water. A second major problem is the protection of environmental quality, particularly the protection of ground water aquifers. Surface water and ground water withdrawals and total water consumption are expected to rise steadily through the 1990's, based on Oregon's projected population and economic growth. Therefore, water competition and threats to environmental quality are expected to become more severe unless serious efforts are made to protect, conserve and recycle the available water through monitoring and structural and non-structural measures.

The critical water policy issues and management problems that confront the state have received broad public scrutiny during recent state legislative sessions. They continue to be in the forefront of public water consciousness. The adequacy of Oregon's water laws and water management system to meet past commitments as well as to satisfy shifting public goals has been questioned. Better water conservation has been identified as one potential means for relieving recurring problems. Better coordination in management is also viewed as a potential remedy. The process of dealing with policy issues and management problems has been addressed by the state legislature during the 1983, 1985, and 1987 sessions through passage of several bills.

Beyond the high-public-attention areas of water policy and management, there remain many unresolved technical questions that are involved in water resource management. The main problem areas and specific problems that have been identified by the Oregon WRRI include:

* Inadequate instream flows
  (adverse effects on aquatic habitat, waste dilution and assimilation, recreation, downstream needs);

* Ground water level decline
  (poor knowledge of aquifer conditions, excessive withdrawals, need for management);

* Surface-water/ground-water relations
  (inter-connectedness, joint management, water yield, interstate use);

* Contamination of quality of ground and surface waters
  (sources, control, cleanup, protection of drinking water supplies);

* Deterioration and loss of aquatic/riparian habitat;

* Management for protection of forested and rangeland streams;

* Protection of bay, estuarine and wetland resources
  (processes, impacts of nearby development);

* Impacts of energy-related activities on water-related resources
  (hydropower, geothermal);

* Structural and non-structural options for water management
  (reservoir impacts, alternatives, seasonal and geographic problems, floods, water shortages, land use, management);

* Efficiency of water use
  (agriculture, industry, municipal and domestic systems);

* Competition for available water
  (shifting priorities, alternative sources, valuation);

* Planning and management for water-related resources
  (implementation of state-of-art technologies and methodologies);

* Water uses
  (laws, rights, pricing, reuse, competition);

* Water institutions and institutional arrangements;

* Technology/information transfer to effectively disseminate information from researchers to users.

These are addressed in the Oregon WRRI's five-year research and development plan and the Pacific Northwest regional five-year research and development plan. Information from these plans is included in the Program Goals and Priorities section of this report.

PROGRAM'S GOALS AND PRIORITIES

Goals

The main purposes and activities of the Oregon Water Resources Institute remain those originally formulated in 1959. These are to (1) appraise water research needs, (2) promote research to meet needs, (3) develop new water researchers and resource managers, (4) coordinate efforts of researchers, (5) promote research capabilities, (6) disseminate research results, and (7) promote interdisciplinary graduate education.

The Institute's broad long-range goal is to effectively pursue its main objectives so as to assist in the sound management, use and protection of the state's waters and water-dependent resources. Specific long-range goals of the Institute are to analyze and clarify the major water problems and issues in the state and help to alleviate or solve these problems through research and related activities.

Water-related problems in Oregon have quantity, quality, ecological, economic, institutional and social aspects. Therefore, the physical, biological, socio-economic and related sciences are all viewed as essential contributors to solutions of these problems. The Institute activities emphasize multi- disciplinary, problem-oriented research and encourage interdisciplinary activities in support of that research.

Priorities

To facilitate its activities, the Institute has periodically established research priorities for solving critical water-related problems and has solicited funds and projects to address those priorities. The updated research and development plan for 1984-1987 has served as an important guiding document for development of the FY 1986 program; the FY 1986 program has been responsive to that plan.

Use of FY 1986 Grant to Develop and Implement Program

The FY 1986 Oregon Water Resources Research Institute Program has focused on comprehensive multiple-purpose use of water resources and the resolution of problems and issues that arise over limited water-related resources. The main priority of the FY 1986 program was to advance technical knowledge related to water management. Specific priorities were to advance our knowledge of (a) useful water management options in ground water pollution control (projects 02, 03); (b) fisheries and shellfish resource protection (projects 05, 06); and (c) biological processes that control contamination of aquifers and lakes (projects 04, 07).

The projects included in the FY 1986 Oregon WRRI Program all addressed issues and problems that are identified in the Oregon and Pacific Northwest five-year plans. In addition, most addressed the high-public-attention issues and problems associated with recent state legislative acts and bills. The ways in which the six FY 1986 projects addressed water policy issues and management problems are shown in Table 1.

The specific relation of each project to state and regional water policy issues and management problems is described in the following paragraphs. The ways that research results may hasten their solutions are also indicated.

Table 1. Relation of Projects to Water Policy Issues and Management Problems

Project	Strategic Water Planning & Management	Fishery and Shellfish Resources	Water Pollution	Ground Water Resources	Other Chronic Water Management Problems
02 Reclamation of Metals-contaminated Soils	X		X	X	
03 Gasoline contaminants in soils and aquifers	X		X	X	
04 Bacterial Metabolism of Trace Toxicants in Aquifers	X		X	X	
05 Salmonid Habitat Structures	X	X			X
06 Estuarine Water Quality	X	X	X		X
07 Iron Limitation In Nutrient-Rich Lakes	X		X		X

02. Laboratory Study of In-situ Reclamation Process for Metals-Contaminated Soils Soils contaminated by metals at industrial disposal sites pose severe risks for groundwater contamination. Cleanup of such sites and protection of water supplies is extremely complex and costly. The availability of an in-situ technique for reclamation of metals-contaminated soils would provide an effective new option for management of clean-up at many hazardous waste disposal sites. This research initiates exploration of a novel in-situ reclamation process, providing a conceptual understanding of the reclamation scheme in terms of the physical, chemical and biological processes involved and giving supporting experimental evidence of its effectiveness. If the in-situ soil reclamation process proves effective in laboratory study, it will be field tested on a contaminated field site to determine its efficacy in large-scale applications for clean-up of hazardous wastes.

03. Sorption and Transport of Aqueous Gasoline Contaminants in Soil and Aquifer Sediments Leaks from underground storage tanks containing fuel oils, gasolines, various solvents and other potentially toxic organic chemicals represent a major source of ground water pollution. Methods for predicting chemical transport through the soil and the environmental fate of toxicants are limited by an inadequate understanding of the phenomena of cosolvency. This laboratory research determines the sorption/desorption

of selected aqueous gasoline products (EPA priority pollutants) in the presence of their organic cosolvent matrix. Organic cosolvants are expected to significantly enhance the solubility of these target organic species, leading to an increase in their mobility in soils. Data from these experiments will serve as important components of existing chemical transport models designed to predict ground water contamination. The mechanism of cosolvency may be applied to clean-up practices through the use of nonionic surfactants to extract contaminants from the soil. It is expected that the information will be used in developing long-term strategies for the protection of ground and surface water quality.

04. Effect of Sorption on Bacterial Metabolism of Trace Toxicants in Groundwater Aquifers Accurate predictions of the transport of degradable trace contaminants are presently extremely difficult if the contaminants exhibit strong sorption to organic solids and strong toxicity to microbes. Yet bacterial metabolism of trace toxicants may offer one significant means of managing contaminated groundwater systems. This research investigates mechanisms that may govern the metabolic process, to better understand how bacteria may be effectively used to break down toxicants and to better assess the movement of many toxic organic compounds, particularly pentachlorophenal and its associated dioxins and furans. Information gained will allow agencies to formulate long-term management strategies for protecting groundwater aquifers or controlling toxic contaminants.

05. Hierarchical Analysis of Salmonid Habitat Improvement Programs Within the John Day Drainage The John Day Basin produces one of the most significant wild anadromous fish populations in the Columbia River drainage, even though impacts from human activities have greatly diminished these runs. Millions of dollars spent in the coming years to rehabilitate fish habitats here and elsewhere in the Pacific Northwest. To date, little evaluation of these projects has been made. This research provides evaluation of rock jetties and related habitat structures with respect to conjunctive benefits for habitat values and bank erosion control. Salmonid microhabitat improvement is assessed using a new hierarchical classification for stream reaches which effectively links physical, biological and other river characteristics for large drainage basins. Research results provide objective criteria for determining effective means to increase the amount of good habitat for salmonid fishes. This information can be incorporated into the overall management plan being developed for the John Day drainage by state and federal agencies in Oregon. This management plan will become a model for future management plans for other drainages within the state.

06. Microbiological Quality of Estuarine Waters Governmental agencies regulating the commercial and recreational shellfish harvest or protecting the public health and water quality require information on the source and potential health impact of the bacteria entering Oregon's estuaries. This can be used to evaluate the appropriateness of existing federal standards for estuaries of the Pacific Northwest and to investigate the utility of other indicator systems for fecal pollution. This research provides the first comprehensive data set on the daily fluctuations of coliform-indicator bacteria in water and shellfish meats in an Oregon estuary. Information is also provided about the numbers and types of bacteria and viruses in the estuary. Results will aid in the development of a predictive model for a typical Pacific Northwest estuary. This model will be an

essential component of a long term shellfish management plan that will allow regulators and the shellfish industry to forecast periods of possible closure. In addition, the studies to isolate human enteric viruses and specific human bacterial pathogens provide an estimate of the effectiveness of existing water-quality standards in protecting the public health.

07. Development of Field Assay of Iron Limitation in Nutrient-Rich Lakes Severe blooms of nitrogen-fixing blue-green algae adversely affect recreational and aesthetic uses of many lakes. In some instances, soluble or colloidal forms of iron are present that limit the extent and duration of blooms. Refinement and testing is providing a practical new biochemical field assay for iron-limitation of blooms that will be useful for land-use and water-quality planning decisions, especially in setting limits for point-source and non-point-source inputs of phosphate from existing or proposed land uses. Ability to identify iron-limited systems, where expensive or restrictive controls on further phosphorus inputs may be considered unwarranted, will allow regulatory efforts and resources to be redirected to other areas where stringent control is more appropriate.

Federal USDI funds for support of the FY 1986 program provided almost half of the total funds used for Institute research and technology/information transfer activities during FY 1986. Much of the non-federal funding was of a cost-sharing nature and was only available because of the availability of federal funds. State and regional funding has been very limited in the past four years. Thus, the USDI Water Resources Research Institute program has been of utmost importance in maintaining a multi-disciplinary problem-solving water research program active in Oregon during a period of minimal state funding for water research. The USDI program is also an important catalyst for initial contacts with the university by federal agencies and for bringing research to other units of the OSU campus, such as the experiment stations and academic departments.

RESEARCH PROJECT SYNOPSES

02. Laboratory Study of In-situ Reclamation Process for Metals-Contaminated Soils -- Peter O. Nelson and John E. Baham

03. Sorption and Transport of Aqueous Gasoline Contaminants in Soil and Aquifer Sediments -- John E. Baham

04. Effect of Sorption on Bacterial Metabolism of Trace Toxicants in Groundwater Aquifers -- Sandra L. Woods and Kenneth E. Williamson

05. Hierarchical Analysis of Salmonid Habitat Improvement Programs Within the John Day Drainage -- Hiram W. Li and James A. Lichatowich

06. Microbiological Quality of Estuarine Waters -- James L. Winton

07. Development of Field Assay of Iron Limitation in Nutrient-Rich Lakes -- William Fish and Joann Sanders-Loehr

Synopsis

Project Number: 02

Start: 07/86
End: 06/88

Title: Laboratory Study of In-Situ Reclamation Process for Metals-Contaminated Soils

Investigators: Nelson, Peter O., and Baham, John E.
Oregon State University, Corvallis

COWRR: 5G

Congressional District: Fifth

Descriptors: groundwater, soils, metals, leachate, extraction, reclamation

Problem and research objectives:

The project addresses the problem of groundwater contamination and control caused by metals-contaminated soil at an industrial disposal site. The site selected for research has EPA Superfund designation and, thus, is clearly a critical problem area -- one of many that exist in the region. Many other problem sites exist in the region that have not gained the notoriety of Superfund designation but, nevertheless, involve metals-contaminated soils. The approach taken is that of laboratory scale investigation of an in-situ reclamation process through the use of synthetic extraction media and biologically-generated leachates.

The objectives of this study are to: 1. develop a conceptual model for the physical-chemical-biological processes mediating the leachate-soil reclamation scheme, and 2. determine the effectiveness of the soil reclamation scheme, using laboratory batch and column experiments, and the important factors regulating the scheme's effectiveness, principally related to leachate chemical properties (e.g. pH, complexing organic and inorganic ligand concentrations, Eh, ionic strength). Secondarily, the influence of soil physical properties and of the anaerobic biodegradation of exogenous organic matter will also be assessed.

Methodology:

During the first year of this project, kinetic and equilibrium data have been developed for chromium adsorption, and extraction from soil. Both environmentally-important oxidation states of chromium, Cr(IV) and Cr(III), are being investigated. Batch experiments are designed to investigate the following factors: 1. factors affecting chromium-soil reactions in unamended water (distilled water and groundwater) and 2. the effect of synthetic extraction media composition on chromium-soil reactions and extraction.

Uncontaminated soil was collected from the Corvallis airport, near the United Chrome site. Aqueous solutions are prepared from either distilled water or from pre-chlorinated well water from an uncontaminated city well, also on Corvallis airport property.

In adsorption experiments, solutions containing known amounts of chromium are added to pre-weighed, homogenized soil in 50 ml plastic centrifuge tubes and mixed in a constant temperature shaker bath. After the desired shaking

time, the suspensions are centrifuged and supernatents filtered. Filtrates are then analyzed potentiometrically for pH, for total soluble chromium by atomic absorption, and colorimetrically for hexavalent chromium. Chromium is added in the solution as either the trivalent chloride salt or the hexavalent potassium dichromate salt. pH is varied by addition of potassium hydrozide or nitric acid.

In desorption/extraction tests, the soil plug from a finished adsorption experiment is re-suspended with an extracting solution (i.e., EDTA or phosphate solution), mixed as before, and again centrifuged, filtered and analyzed.

Soil and groundwater characterization includes: soil solids gravimetric analysis, soil zero point of charge, groundwater alkalinity, and pH.

Principal findings and significance:

Hexavalent chromium adsorption tests did not show equilibration with respect to chromium concentration within two weeks. This was an unexpected result, as previous investigators working with clay, activated carbon, and alluvium reported more rapid equilibration for similarly-conducted adsorption tests. A fast, initial adsorption step was followed by a second adsorption stage, which was first-order with respect to chromium concentration. This stage continued for at least two weeks; one test indicated that the rate of removal decreased after three weeks.

Three separate adsorption rate tests have been conducted for hexavalent chromium, all yielding different initial adsorption densities and first-order rates. For one gram of soil in 25 ml of 10 ppm Cr(VI), k1 was -1.06x10(-3), compared to -9.74x10(-3) for five grams soil mixed with the same solution; initial adsorption densities for the two tests were 29.6 mmol/kg and 16.92 mmol/kg. A roughly five-fold increase in soil concentration increased adsorption rate by almost ten times, indicating greater than first-order dependence on soil concentration. In a third test, one-gram aliquots of soil-water suspensions were sterilized by autoclaving before addition of chromium. This was done in an effort to eliminate biological activity in the soil. Adsorption in these systems still followed first-order kinetics, with first-order rate constant k1 = -3.0x10(-3), suggesting the first-order rates observed in all three tests were not biologically mediated. No reduced chromium, Cr(III), was detected in any of the solutions.

Trivalent chromium adsorption also appears to be first-order, but chromium concentrations decreased to less than measurable levels in less than a day in one-gram soil, 25 ml-10 ppm Cr(III) suspensions. No oxidized chromium, Cr(VI), was detected.

Five-day reactions were performed at varying suspension pH's (2-8) using five grams of soil plus 25 ml chromium solution. Initial solutions contained either Cr(III) or Cr(VI), and varied in concentration from 1 ppm to 200 ppm. Adsorption of Cr(VI) decreased with pH, as expected for anionic species; removal from solution varied from roughly 99% to 35%, but significant sorption was noted in all cases. Cr(III) adsorption increased drastically from pH 2 to 4, then increased again as pH was raised above 5. Organic matter

liberated at pH's above 5 probably complexed the Cr(III), which would have otherwise been insoluble. Removal ranged from 70% at high and low pH to 100% at pH 4-5.

Desorption/extraction tests are currently being conducted. Preliminary results show moderate levels of recovery using phosphate for Cr(VI), but little recovery of Cr(III) by 10 millimolar EDTA solutions.

Publications and professional presentations: none to date

M.S. theses: Chromium Adsorption and Extraction from Soil
Gregory R. Bean
In progress (anticipated completion date 10/31/87)

Ph.D. dissertations: none

Synopsis

Project Number: 03

Start: 07/86
End: 06/87

Title: Sorption and Transport of Aqueous Gasoline Contaminants in Soil and Aquifer Sediments

Investigator: Baham, John E., Oregon State University, Corvallis

COWRR: 5B

Congressional District: Fifth

Descriptors: groundwater, pollution, hydrophobic organic compounds, partition coefficient, chemical transport

Problem and research objectives:

Leaks from underground storage tanks containing gasoline, fuel oils, and other potentially toxic organic compounds represent a major source of groundwater pollution. Recent estimates, based on a national survey, place the number of leaking underground steel tanks at twenty-three percent of those currently in service. Although the extent of this problem has not been specifically documented in Oregon, we expect the potential for tank failure to be high in Western Oregon. Since the majority of the economic development in Western Oregon has occurred in the last twenty years, one would expect groundwater contamination from leaking storage tanks to become a critical problem by the end of this century. The transport and movement of these contaminates through soils and aquifer sediments needs to be more perfectly understood. Benzene, toluene, and xylene, at ppm levels, are the major organic components present in an aqueous extract of automotive gasoline. These compounds can move through the soil with the aqueous phase, evaporate and move out of the soil in the gas phase, be degraded by indigenous or induced soil microorganisms, or be retained by the soil by sorptive processes. A number of mathematical models are available which treat the movement of water and organic chemicals through porous media incorporating the processes of sorption and degradation. Parameters for the processes included in these transport models are usually derived from well controlled laboratory experiments. Recent reports in the literature suggest that dissolved humic substances may be involved in modifying the solubility of organic compounds in the environment.

The objectives of this research were to determine the effect of different organic materials and pH on the solubility and speciation of benzene, toluene, and chlorobenzene in aqueous soil systems. These experiments differ from most reported work, in that, natural sources of organic matter have been employed. The water soluble organic material from soils was obtained without extraction with base or resin which may alter the behavior and chemical properties of these materials.

Methodology:

A simple but elegant method applicable to the analysis of volatile organic compounds was employed to determine the solubility of benzene, toluene, and chlorobenzene in the presence and absence of natural water

soluble organic matter. The method, Equilibrium Partitioning In Closed Systems (or EPICS), involves the determination of the headspace concentration of the organic components by gas chromatography. Pairwise measurements lead to evaluation of the relative differences between the reference and unknown samples.

Principal findings and significance:

The Henry's Law constants for benzene, toluene, and chlorobenzene have been determined with the EPICS method. These values are about 10 percent below those previously reported in the literature. We feel these values may prove to be more accurate since application of the EPICS method to the determination of Henry's Law constant data avoids a number of assumptions regarding equilibrium which are inherent to other methods of analysis.

Preliminary results suggest that water extractable organic matter (i.e., natural organics present in the soil solution) has no effect on the solubility of benzene, toluene, and chlorobenzene. Our preliminary findings are contrary to most published work in which humic materials are reported to increase the apparent solubility. We feel that our results represent the possible interactions that may occur in systems with natural organic matter. Nearly all of the previously published studies on the effect of organic matter on the solubility of low molecular weight hydrophobic organic compounds have been performed with commercially available humic materials. These materials may contain a fair amount of hydrophobic humic substances not present in natural soil environments.

Publications and professional presentations:

Presentation to the West Coast Water Chemistry Workshop Conference, June 1987.

Environmental Science and Technology article in progress.

M.S.theses: In progress, Michael Ochs, Soil Science, 1988.

Ph.D. dissertations: none

Synopsis

Project Number: 04

Start: 07/85
End: 06/87

Title: Effect of Sorption on Bacterial Metabolism of Trace Toxicants in Groundwater Aquifers

Investigators: Woods, Sandra L., and Williamson, Kenneth J.
Oregon State University, Corvallis

COWRR: 5B

Congressional District: Fifth

Descriptors: bacteria, biodegradation, microbial degradation, groundwater pollution, groundwater transport, sorption, toxicity, organic compounds, pollutants

Problem and research objectives:

The fate of organic chemical pollutants in aquatic and groundwater environments has become the object of increasing concern in recent years. An accurate and quantifiable understanding of chemical behavior in the environment has been increasingly important so as to assess the potential hazards of current chemical use and disposal practices. Organic chemicals can be introduced to the environment through application of pesticides and herbicides, leachate from landfills, disposal of primary and secondary sewage treatment sludges and effluents, and hazardous waste spills. Groundwater contamination can occur when these pollutants are transported through the soil matrix to groundwater aquifers.

Biodegradation and sorption are the most important processes in determining the fate and availability from transport of nonvolatile compounds in subsurface environments. Many toxic organic compounds have been shown to be biodegraded in actual or simulated subsurface environments. Degradation conditions range from fully aerobic to anaerobic and can involve mechanisms of both primary metabolism and cometabolism, depending upon the type of organic compound, its concentration, the physical conditions, and the population of microorganisms present.

Sorption in subsurface environments includes ion exchange, chemical sorption, adsorption to surfaces, and partitioning into solids. Sorption reactions are modeled as reversible, where the organic contaminant is chemically unaltered in the process, or as irreversible, where the chemical fate of the contaminant is unknown. Often sorption is described not as a specific reaction, but by an equilibrium partition coefficient, Kp, which relates the equilibrium concentration of the solute in the liquid and solid phases.

Transport models involving reactive solutes in soils often assume local chemical equilibrium in describing sorption reactions. The validity of this assumption depends upon a variety of parameters, including the groundwater flow rate and the rate of sorption. Often, sorption kinetics can be described as involving two components: a rapid or labile sorption followed by a much slower sorption reaction. The use of local equilibrium assumption may produce substantial errors if the second, slower stage of organic sorption is considered to be complete in the time scale of the transport model.

Recent studies have shown a dependence of the equilibrium partition coefficient on the concentration of sorbent in the system; this has been termed a "solids effect." Various explanations and models have been proposed regarding this observed phenomena. While some investigators feel the effect is caused by a third phase of non-settleable sorbed microparticles incorrectly measured as dissolved solute, others have introduced evidence that it is an actual particle interaction phenomena. Depending upon the reason for these observed effects, serious errors in the prediction of sorption behavior in natural systems could occur due to variations between sorbent concentrations in the field and in the laboratory.

The objectives of this study were:

1. to determine if the sorption of hydrophobic organic solutes to organic sorbents can be described as a two-step procedure or a rapid initial step followed by a slower long-term second step;

2. to determine the dependence of the equilibrium partition coefficient on the organic sorbent concentration;

3. to develop a mechanistic kinetic sorption model that adequately fits experimental data from both batch and column sorption experiments;

4. to expand the model to include bacterial metabolism and determine the relative importance of sorption and metabolism mechanism for pollutant transport.

Methodology:

Sorption/desorption experiments were conducted in batch and continuous-flow column reactors with 3,4-dichlorophenol (3,4-DCP) as the sorbate and cellulose triacetate as the sorbent. Concentrations in the liquid phase were determined for up to 140 hours and the data were fit with a two-step sorption model to determine the kinetics of sorption and desorption.

A finite difference model of a saturated soil system was developed that included the two-step sorption model and bacterial degradation. Typical values for 3,4-dichlorophenol were used for the base case, and a sensitivity analysis was completed on a variety of important parameters.

Principal findings and significance:

The sorption of hydrophobic organic solute to an organic sorbent can be described by a two-step process involving a rapid uptake followed by an extended period of slow sorption. Such sorption cannot be modelled using an assumption of local equilibrium based upon a partition coefficient. This two-step process was successful to describe both batch and column experiments.

The mathematical model of the transport of organic chemicals showed that the rates of biodegradation can represent a significant removal mechanism. The extent of degradation is strongly dependent upon the kinetics of sorption and desorption. For those compounds that poorly sorb, the aqueous concentration is high but the biodegradation may be rapid. For those compounds that strongly sorb, the degradation rates are slow and the extent of transport is small but the time required for removal may be very long.

Publications and professional presentations: none

M.S. theses:

Patrier, Lionel. "A Kinetic Approach for the Determination of Sorption Rate Constants Using a Column-type Reactor," M.S. Thesis, Oregon State Univ., 1987.

Dolan, Mark E. "The Effect of Organic Sorbent Concentration on Sorption Kinetics," M.S. Thesis, Oregon State Univ., 1987.

Cork, Tracy. "The Fate of Hydrophobic Organic Compounds in Soil Systems: A Kinetic Model and Sensitivity Analysis," M.S. Thesis, Oregon State Univ., 1987.

Ph.D. dissertations: none

Synopsis

Project Number: 05

Start: 07/86
End: 06/87

Title: Hierarchical Analysis of Salmonid Habitat Improvement Programs Within the John Day Drainage

Investigators: Li, Hiram W., and Lichatowich, James A.
Oregon State University, Corvallis

COWRR: 6G

Congressional District: Fifth

Descriptors: salmon, trout, aquatic habitats, habitat enhancement, evaluation

Problem and research objectives:

One of the most critical water use and related natural resource issues in the state of Oregon concerns the John Day Basin. A multi-agency plan for the management of water resources of the John Day Basin is being developed. This will serve as a model for similar plans in other drainages in the state.

The John Day Basin produces one of the most significant wild anadromous fish populations in the Columbia River drainage, even though impacts from forestry practices, dewatering streams for agriculture, and overgrazing of the riparian zones have greatly diminished these runs. To date, $1,277,000 has been spent to rehabilitate fish habitats; there are plans to invest an additional $1,938,000 in future work. These programs include fencing off stream banks from cattle, boulder placement in stream channels, placement of short rock jetties, and use of log weirs.

The major purpose of this research was to provide objective criteria for determining the most effective means to increase good habitat for salmonid fishes. Rankings of habitat improvement structures relative to other habitats afforded in reaches of similar stream types were determined. Another purpose was to develop a system to objectively classify stream systems for the purpose mentioned previously.

Methodology:

A system used by plant ecologists to identify factors associated with different plant assemblages was adopted. Multivariate statistical techniques were used to classify different categories of stream reaches based upon their physical characteristics. Stream reaches were clustered into different groups using CLUSPC -- an agglomerative, hierarchical clustering methodology, and CLUSB -- a divisive, nonhierarchical clustering technique. Discriminant Function Analysis was used on the resulting groups to determine the internal consistency of the resulting classifications (clusters) and define physical patterns responsible. These clusters then formed the strata from which fish densities could be analyzed using Analysis of Variance. Rankings of habitat improvement structures relative to other habitats available within each class could then be established.

Standard techniques were used for the physical inventory of instream microhabitats (Platts et al., 1983). Fish inventories were conducted using snorkeling techniques. Each study site was inventoried twice to determine consistency of the results.

Principal findings and significance:

Nine classes of stream reach were classified according to their physical characteristics. The important variables, in order of importance to the classification, were maximum daily temperature, discharge, vegetative stability, the fraction of admissable light, the amount of undercut banks, the presence of attached aquatic vegetation, embeddedness of the substrate, and water hardness. The percent of assignment of reaches to correct classes was 98%. The classes of stream reaches were as follows:

class 1: low elevation (2,970 ft.) warm (22 C) riffles, runs, and pools of the South Fork of the John Day River; high discharge (1.06 m^3/s), high vegetative stability of the banks (3.9), low light penetration (35%) to the stream;

class 2: small, cold (11 C), high elevation (4,599 ft.) riffles, runs, and pools in tributaries of the upper mainstem and Middle Fork of the John Day River; low discharge (0.19 m^3/s), fair vegetative stability of the banks (2.6), resulting in high light penetration (79%);

class 3: high elevation (4,212 ft.), cold (13 C), medium-sized pools and riffles in tributaries of the upper mainstem; moderate discharge (0.60 m^3/s), good vegetative stability (3.5) resulting in low light penetration (29%);

class 4: Camp Creek riparian enclosure; high elevation (4,750 ft.), cold (12 C) and small (0.03 m^3/s), good vegetative stability (3.5), moderate penetration of light (50%);

class 5: overgrazed land on the South Fork of the John Day and Camp Creek; very warm (22 C), moderate discharge (0.40 m^3/s), poor vegetative stability (1.3) and 100% of light penetration to the stream;

class 6: low elevation (3,173 ft.), cool (15 C), large discharge (2.58 m^3/s); high light penetration because of stream width (92%), although vegetative stability rating is moderate;

class 7: high elevation (4,524 ft.), small tributaries to the mainstem and middle fork (0.24 m^3/s) but with good vegetative stability (3.7) and hard water;

class 8: Murderer's Creek and upper Middle Fork mainstem; warm (22 C), good vegetative stability (3.7), moderate size (0.60 m^3/s), low degree of embedded substrate;

class 9: cool (15 C), high elevation (4,305 ft.) pools of moderate size (0.61 m^3/s), good vegetative stability (3.5), high light penetration (100%) to the stream.

The analysis of variance revealed significant differences in the ability to support different age classes of juvenile steelhead trout (Salmo gairdneri) and juvenile chinook salmon (Oncorhynchus tshawytscha). The best habitats for age 0+ trout were classes 2 and 8; for age 1+ trout, classes 8 and 9; for age 2+ trout no significant differences were found; age 3+ trout do not inhabit class 4 stream reaches. Chinook salmon were found significantly greater in the cool, high elevation pools that form class 9.

Improved habitats represented by log weirs and streamside fencing projects were well represented in the top 10 habitats for the juvenile salmonids. Seven of the top 12 habitats for age 0+ trout, 3 of the top 5 for age 1+ trout, 3 of the top 10 for age 2+ trout, and 2 of the top 10 for age 3+ resulted from improvement projects. A total of 143 reaches were sampled in the two-year study.

Publications and professional presentations:

Li, H.W. and E.J. Leitzinger. 1987. Using Hierarchical Classification to Define Limiting Factors in Rearing Habitats of Juvenile Steelhead Trout in the John Day Basin. Oregon Chapter of the American Fisheries Society, 24th Annual Meeting, Welches, Oregon.

M.S. theses: In progress, E. J. Leitzinger, Fish and Wildlife

Ph.D. dissertations: none

Synopsis

Project Number: 06

Start: 07/86
End: 06/87

Title: Microbiological Quality of Estuarine Waters

Investigators: Winton, James R. and Arnold, Gary A.,
Oregon State University, Marine Science Center, Newport

COWRR: 5B

Congressional District: Fifth

Descriptors: coliforms, bacterial and viral indicators, fecal pollution, coliform standards, estuary, shellfish, sanitation

Problem and research objectives:

The U.S. Food and Drug Administration is increasing the pressure on state agencies to strictly enforce federal water quality standards for shellfish growing areas. These standards, intended to protect the health of persons consuming raw shellfish, were developed for estuaries where high population and moderate rainfall provide conditions for a relatively constant input of fecal contamination. These conditions do not apply in the Pacific Northwest, where levels of fecal coliform indicator bacteria in summer, the period of highest population density, are usually well within standards. During the heavy winter rains, levels of coliform bacteria sometimes rise significantly, causing closure of estuaries to shellfish harvest. These unpredictable closures risk the loss of the Oregon shellfish industry, while suspension of recreational shellfishing is detrimental to local economies and the image of the State of Oregon. It was imperative to understand the source and potential health impact of the coliform bacteria in order to evaluate the appropriateness of the existing standards for estuaries of the Pacific Northwest.

The project was designed to study the ecology of fecal coliforms in the Yaquina estuary using the microbiological laboratory facilities of the Oregon State University Marine Science Center. The results obtained in this study will contribute to our understanding of the relationship between rainfall, total solids, salinity, temperature and the seasonal incidence of coliform bacteria in water and shellfish in a Pacific Northwest estuary. The methods used included standard and rapid techniques for the isolation or identification of total coliforms, fecal coliforms, fecal streptococci and enteric viruses. The levels of these bacteria and viruses in water samples were compared with those in meat samples from commercially grown shellfish in order to estimate the usefulness of these various standards for protecting the health of persons consuming raw shellfish from estuaries of the Pacific Northwest.

The objectives of this study were: (1) to study the microbial flora of Yaquina Bay water and shellfish to determine if human pathogenic bacteria and viruses are present, (2) to estimate the relative contribution of human and animal sources to the coliform bacterial population of the estuary, (3) to compare the relative efficiency of fecal coliform, fecal streptococci and enteric virus indicators as techniques for the protection of public health, and (4) to learn about the ecology of fecal coliforms in the Yaquina estuary.

Methodology:

This study was conducted over a one year period to examine the annual changes in the levels of fecal coliforms in the Yaquina estuary. The procedures used in this study were performed in accordance with the techniques outlined in Standard Methods for the Examination of Water and Wastewater or the Compendium of Methods for the Microbiological Examination of Foods. A 5-tube, most probable number (MPN) assay was used to compare the fecal coliform levels in 100 ml of estuary water and in 100 gm of commercially-grown oyster meats from the same location three times each week during the one year study. Measurements of salinity and temperature were made during water and shellfish collection. Total suspended solids were to be determined for a 100 ml water sample. Daily rainfall, river flow, air temperature and tidal data were obtained from local sources. The data were analyzed to determine if a correlation could be found between fecal coliform levels and any of the physical parameters.

In addition, fecal coliforms and fecal streptococci assays were conducted at monthly intervals using standard membrane filter techniques. Colonies from the plates were identified to species level by standard microbiological taxonomic methods.

Sediment and shellfish meat samples were processed for isolation of enteric viruses.

Principal findings and significance:

No enteric viruses were isolated from sediments in the oyster zone or near the Toledo sewer outfall. This may be due to the poorer survival of the viruses in this system. Control sediments seeded with virus showed good recoveries, indicating the method of extraction and concentration was efficient for enteric viruses.

There was no evidence that a significant point source of fecal coliforms was entering Yaquina Bay. Assays of water and sediments collected from the region of the Toledo sewage treatment plant outfall generally had lower coliform counts than samples taken from the Yaquina River itself. These data suggest that the Toledo plant is functioning correctly and does not significantly impact the coliform levels in the bay. A shoreline survey of the Yaquina estuary was conducted by the Lincoln County Health Department; a few failing septic systems serving individual dwellings around Yaquina watershed were discovered and ordered repaired. These systems were judged not to be significant contributors to the fecal coliform levels seen during winter periods.

The coliform levels in water samples and in meat samples showed a limited correlation ($r = 0.55$) for samples collected during the year. The levels of fecal coliforms in water samples collected at the oyster growing zone correlate best ($r = 0.71$) with Yaquina River flow. This suggested that the source of coliforms was principally from non-point sources high in the watershed. It is presumed that these coliforms are primarily from non-human sources, due to the very low population density in the upper watershed.

We were not able to differentiate between human and animal sources of the fecal coliforms or the fecal streptococci isolated during the study. All the colonies of bacteria tested could have been from either human or animal sources.

The levels of fecal coliforms in water samples collected from the oyster growing zone of the Yaquina estuary can be expected to rise above the federal standards during periods of high river flow and extreme tide fall. These conditions allow coliforms from the upper river to be transported to the lower areas of the Yaquina system.

Publications and professional presentations: none

M.S. theses: none

Ph.D. dissertations: none

Synopsis

Project Number: 07

Start: 07/86
End: 06/87

Title: Development of a Field Assay of Iron Limitation in Nutrient-Rich Lakes

Investigators: Fish, William and Sanders-Leohr, Joann
Oregon Graduate Center, Beaverton

COWRR: 5G

Congressional District: First

Descriptors: iron-limitation, eutrophication, blue-green algae, cyanobacteria, lake management, algal blooms

Problem and research objectives:

Many cyanobacteria (blue-green algae) species supply their needs for nitrogen by fixing nitrogen gas directly from the atmosphere. In phosphate-rich nitrogen-limited lakes, N_2-fixing cyanobacteria may completely dominate the phytoplankton community. The resulting dense cyanobacterial populations cause considerable practical problems in eutrophic lakes. Offensive tastes and odors may be imparted to drinking water, decomposition of dead cells may kill fish by depleting dissolved oxygen, and exuded toxins may poison fish and cattle and cause skin rashes among recreational users.

Nitrogen fixation allows cyanobacteria to overcome one major nutrient limitation, but subsequent growth is controlled by the availability of other nutrients. In the presence of an adequate phosphorus supply, iron is the element that will exert the greatest control on algal population growth. Knowledge of the limiting element is important from both the scientific and regulatory standpoints. Consequently, iron nutrition in phytoplankton has been studied extensively. However, the limited solubility and complex aqueous chemistry of iron has hindered a complete understanding of the biological availability of this element. Measurements of soluble or filterable iron actually include many colloidal and coordinated species with variable or unknown availabilities. Photochemical iron redox cycles and trace element adsorption onto ferric hydroxide colloids further complicate the role of iron, making both laboratory and field studies of iron nutrition difficult to interpret. For these reasons, the best determinant of iron limitation in aquatic ecosystems is a direct, physiological indicator of iron nutritional stress in the phytoplankton population.

Phytoplankton exhibit a number of responses to iron stress. Of these, cellular ferredoxin and flavodoxin appear to be the most reliable indicators of iron stress. Ferredoxin is an iron-containing redox protein in plants and bacteria that is soluble, relatively stable, and readily extracted and identified. Flavodoxin in a non-iron redox protein that possesses traits similar to ferredoxin, and which substitutes for ferredoxin in many microorganisms during iron deprivation.

The objectives of this study were: 1) to verify the utility of ferredoxin and flavodoxin as practical markers of iron stress, 2) to extend the method to

field and laboratory studies of iron nutrition in nitrogen-fixing cyanobacteria, 3) to develop a rapid and convenient high-performance chromatography method of determining ferredoxin and flavodoxin concentrations in small cell volumes, and 4) to use these methods to explore the interactive relationship between nitrogen starvation and iron starvation in blue-green algae.

Methodology:

Cyanobacterium Anabaena strain 7120 was used for all laboratory culture experiments. Cells were grown in liquid culture to which varying amounts of iron were added. Culture growth was monitored by measuring optical density with a Klett-Summerson colorimeter. When 10 mL inoculum cultures approached stationary phase (at about 60 Klett units) they were transferred to 125 mL sterile flasks containing 50 mL of medium. When optical density reached 50-60 Klett units, cultures were harvested by centrifugation and resuspended in 50 mM Tris/HCL buffer, pH 7.8, and either frozen or processed immediately.

Natural blooms of cyanobacteria were sampled in four Oregon lakes: Upper Klamath (Klamath County), Cullaby (Clatsop County), Morgan (Union County), and McKay Reservoir (Umatilla County). All lakes were sampled at least once during the August blooms. Upper Klamath Lake was sampled three times during the bloom. Algal cells were concentrated with a plankton net and stored on ice for return to the laboratory, where they were processed immediately.

Acetone powders of concentrated cyanobacteria were prepared by slowly adding buffered cell suspensions to well-stirred, tenfold excess of acetone kept at $-20^{o}C$. The resulting powder was filtered, washed with cold acetone, and dried under high vacuum for several hours. This removed lipids and many pigments, leaving a fine, bright blue cell powder that retained the water soluble proteins. Soluble proteins were extracted overnight by mixing cell powder with buffer. The resulting suspension was centrifuged; the deep blue supernatant containing the proteins of interest was decanted for analysis.

Proteins were separated using a Pharmacia fast protein liquid chromatograph (FPLC) with a Mono-Q 5/5 (Deae-type) anion-exchange column. A protein solution volume of 100 - 500 uL was injected onto the column and eluted with a linear salt gradient of 0% to 100% 1.0 M KCl in Tris/HCL buffer. The gradient was developed in 25 min. The column was calibrated by ferredoxin and flavodoxin standards. Protein concentrations were determined from peak areas obtained with a Hewlett-Packard integrator connected to the UV monitor.

Principal findings and significance:

In experiments in which Anabaena sp. 7120 was grown on nitrate-replete medium, cellular ferredoxin and flavodoxin levels depended primarily on the amount of total iron added to the medium. High-performance chromatograms revealed a marked decline in ferredoxin (Fd) at limiting levels of iron, and a concomitant increase in flavodoxin (Fl). The FPLC technique allowed use of only 10 - 50 milligrams of cell powder, compared to the 10 - 15 grams of cell powder for conventional LC. A variety of growth conditions were convieniety examined using culture volumes of less than 1 L each (earlier, conventional LC, studies of Fd and Fl required many liters of culture to obtain detectable amounts of protein). This improved efficiency greatly facilitated using the method for field assays; only small samples were required.

In cultures, Fe availability over a set growth period was always proportional to the amount of Fe added to solution, as shown by nitrate-replete cultures. for cells grown in 0.1 uM total Fe, growth rates were consistently low and significant Fl substitution occurred. By contrast, cells in 1.0 uM Fe medium grew rapidly to the 60-Klett harvest density but produced little flavodoxin; with further growth into Fe-limiting stationary phase, Fd declined sharply and Fl substitution was pronounced. Thus, for a particular condition, such as growth on nitrate, cellular iron stress depends only on the external availability of Fe. However, different growth regimes impose different iron requirements on cells. For example, N_2-fixation requires the synthesis of iron-rich nitrogenase enzyme. N_2-fixing cells, therefore, need more Fe than non-fixing cells and should become Fe-stressed more readily, even at relatively high levels of available Fe. Similarly, growth on nitrate requires special iron proteins. Thus, the form of nitrogen on which cells are growing directly influences the likelihood of Fe-limitation.

For a given amount of available iron, cells grown on ammonium are predicted to have the least Fe-stress, while N_2-fixers should have the greatest Fe-stress, and nitrate-grown cells may be somewhere in between. This general pattern was demonstrated for Anabaena sp. 7120, in which the Fl/Fd ratio was the greatest for N_2-fixers, the least for NH_4-grown cells, and intermediate for NO_3. There is an intriguing link between the N assimilation systems of phytoplankton and levels of Fe-stress. The effects of both Fe and N availability may be strongly interconnected in aquatic ecological systems.

Among the lake samples, Fd was found in all populations. No Fl was observed in Cullaby or McKay, indicating that iron was not limiting growth in those lakes. Some flavodoxin was found in Morgan Lake cyanobacteria, suggesting that iron limits growth in that phosphate-rich lake. In Upper Klamath Lake, Fd levels declined during the bloom and a trace of Fl appeared in the last sample, suggesting that iron begins to limit the growth near the end of the massive bloom.

In this project we have shown that the iron stress level of algae is a function of both the external availability of iron and the internal requirements for iron. Biochemical indicators of nutrient-stress, such as Fd and Fl, are extremely useful tools for exploring questions of nutrient availability and addressing questions of lake management by nutrient control. But biochemical indicators must be used with care so that the effects of physiology on nutrient requirements do not bias the interpretations of external nutrient availability.

Publications and professional presentations:

Presentations at invited seminars at University of Minnesota (May 1986) and MIT (June 1986). Poster presentation at Gordon Research Conference on Environmental Science, (New Hampshire, June 1986). Results also presented at two national meetings, the American Society of Limnology and Oceanography Annual Meeting (Kingston, RI, July 1986), and the American Chemical Society National Meeting (New Orleans, September 1987). A journal article is currently in preparation for submission to Limnology and Oceanography.

M.S. theses: none

Ph.D. dissertations: none

INFORMATION TRANSFER ACTIVITIES

The Institute's Information Dissemination Program

An important part of WRRI program management is the dissemination of information about water resources and the research programs of the Institute, including ongoing and past research. For FY 1986, this was combined with other program management activities, rather than treated as a separate information transfer project.

The overall objective of the technology and information transfer program is to facilitate communication between the university community and those in the public and private sector who guide policy, decisions and management of the state's water-related resources, with the ultimate goal of assisting in the improved management of water and related resources to meet today's and tomorrow's needs.

The more specific objectives of the technology and information transfer program are to: (1) disseminate the results of water resources research throughout the state and region to potential users by a variety of formats, including reports, workshops, and one-to-one discussions; (2) inform university researchers of the current and expected needs of water managers and decision makers for research findings and new information that will assist in the improved management of the state's and region's waters and related resources; (3) facilitate the involvement of university researchers with agency resource managers in the exploration of concepts for improved water management; and (4) contribute to the scientific basis for successful implementation of state water programs.

Subject Matter of Information Transfer Activities

Past experience demonstrates that as public concern shifts from one water problem to another, there are periods of renewed interest in various

past research activities and the results of those efforts. Therefore, we maintain files on past research and a few extra reports for use to promote the application of research findings on a broad spectrum of subjects that have been researched by the Institute over the past two decades.

During FY 1986, the Institute experienced a continued demand for technical information related to water policy issues. This demand results from the present high level of legislative activity on water issues and the multi-disciplinary character of research supported by the Institute, allowing us to respond on a broad range of topics.

Target Audiences for Information Dissemination

Groups that benefit from the Institute's information dissemination activities include: the university research community, other faculty (with respect to their academic programs), graduate and undergraduate students, resource managers and governmental officials at the federal, state and local levels in Oregon, and numerous public-interest and vested-interest groups.

Strategies Employed to Promote Application of Research Results

The ongoing Institute program for information dissemination has several elements. Because of good public awareness of WRRI, direct one-to-one discussions with concerned individuals routinely occur via the telephone (several per day) and less frequently by visitors to the Institute (several per week). These generally involve the Institute director or secretary but may also include Institute researchers. A major aspect of such inquiries is the ability of Institute staff to refer particular inquiries to the appropriate sources (people or bibliographic material) or to provide quick answers to a wide variety of questions. Much staff effort is needed to help people identify available information that is not readily known nor conveniently accessible.

Our recently revised Directory of Water-Related Expertise in Oregon is an important reference document to assist us in identifying qualified individuals as various water matters arise. The directory includes detailed information on university water researchers and campus water research organizations throughout the state. It also includes information about state and federal agencies and numerous public and private organizations that have expertise or specific knowledge about some facet of water resources. The directory has been distributed to several hundred individuals to help them in their water activities.

The WRRI director and other university faculty continued to actively participate in state agency activities involving water planning and management during FY 1986.

Research publications based on WRRI projects are distributed to a variety of potential users, based upon the subject matter, as part of the information dissemination program. Also, the Institute frequently publishes and disseminates significant research findings from work not supported under its research program.

In previous years the Institute periodically published a newsletter -- Oregon's Environment -- to highlight national research findings applicable to water-related problems in Oregon. However, this method of information transfer has not been used since 1981, owing to lack of funds for staff time.

The Institute conducts its traditional fall-quarter and spring-quarter seminar series on the OSU campus. These focus on state water resources management, the applications of research results, and selected narrower topics such as riparian management. The seminar series typically include 10 presentations on the selected theme for the term. The Fall 1986 seminar theme was Watershed Management for Water Yield. The Spring 1987 seminar theme was

Oregon Lakes. In past years, seminar proceedings were published for general distribution. However, no proceedings have been published since FY 1981 due to reduced staff and budget.

The Institute conducts conferences and workshops to promote the application of research results. Three-day workshops were held just prior to the start of and after the end of FY 1986. The subjects were Streambank Protection and Suspended Sediment in Rivers and Reservoirs.

The Institute and the OSU Information Service work together once or twice a year to identify topics for news releases. These are written by the information Service and distributed to wire services and others.

Cooperators

The Institute works closely with the OSU Energy Extension Program on a variety of hydroelectric energy activities involving our extensive data base, assessments, and expertise on hydropower resource availability and the impacts of development. The Institute also works with OSU Extension service and its agents whenever called upon for specific help.

WRRI Reference Library

In late FY 1982, the WRRI library was closed because of reduced funding, secretarial staff (one position) and space to house the collection (over 300 lineal feet of shelf space). The specialized collection of water-related reports was distributed to individual academic departments and faculty and to the OSU library for addition to the permanent collection. Some site-specific reports on the water resources of the Pacific Northwest were retained by WRRI.

When WRRI moved its offices in March 1987, a conference room became available having sufficient space to house the retained reports and the Director's collection of hydrology/hydraulics material. Thus, the Institute now has a small library for on-premises use.

Formal Information Transfer Gatherings and Presentations

July 1-3, 1986. Coos Bay. Dike breaching and wetland restoration.
July 31, 1986. Salem. Statewide and river basin water planning.
August 8-10, 1986. Corbet. Legislative workshop on watershed management.
August 28, 1986. Salem. Statewide and river basin water planning.
September 16, 1986. Salem. Develop videotape on riverbed ownership.
September 30, 1986. Salem. Statewide and river basin water planning.
October 1, 1986. Willamette River. Channel management and gravel mining.
October 2 - Dececember 11, 1986. Oregon State University. Fall 1986 WRRI Seminar Series: Watershed Management for Water Yield.
October 14, 1986. Salem. Statewide and river basin water planning.
October 21-22, 1986. Portland. Stream habitat analysis and development.
October 27, 1986. Salem. Statewide and river basin water planning.
October 29, 1986. Corvallis. Iron in Coos Bay sand dune water supply.
November 12, 1986. Salem. Statewide and river basin water planning.
December 9, 1986. Salem. Statewide and river basin water planning.
January 20, 1987. Salem. Statewide and river basin water planning.
February 17, 1987. Salem. Statewide and river basin water planning.
March 18, 1987. Salem. Statewide water data needs and administrative rules.
April 2 - May 28, 1987. Oregon State University. Spring 1987 WRRI Seminar Series: Oregon Lakes
April 22, 1987. Corvallis. Fishery habitat assessment models.
May 20, 1987. Deschutes River. Bank erosion control needs and methods.

Principal Information Transfer Publications

List of Publications

Graduate Education in Water Resources at Oregon State University

(Due to the change in end dates for the fiscal year, research project final reports for this year will all be published during the current fiscal year.)

Professional Publications

Anderson, N.H., and Hansen, Bruce P. 1987. An Annotated Check List of Aquatic Insects Collected at Berry Creek Benton County, Oregon 1960-1984. Occasional Publication Number 2, Systematic Entomology Laboratory, Dept. of Entomology, Oregon State University, Corvallis, Oregon.

Beschta, R.L. 1987. "Chapter 13. Conceptual Models of Sediment Transport in Streams." In Sediment Transport in Gravel-Bed Rivers, (Editors: Thorne, C.D., Bathurst, J.C., and Hey, R.D.). John Wiley and Sons, New York. pp. 387-419.

Miller, R.F., Angell, R.F., and Eddleman, L.E. 1987. "Water Use by Western Juniper" In Proceedings: Pinyon-Juniper Symposium. USDA Forest Service, General Technical Report INT-215. pp. 418-422.

Miller, R.F., Eddleman, L.E., and Angell, R.F. 1987. "The Relationship of Western Juniper Conducting Tissue and Basal Circumference to Leaf Area and Biomass" (In press). Great Basin Naturalist.

Taylor, R. Lynn, and Adams, Paul W. August 1986. "Red Alder Leaf Litter and Streamwater Quality in Western Oregon", Paper No. 84203, Water Resources Bulletin. American Water Resources Association. Vol. 22, No. 4.

COOPERATIVE ARRANGEMENTS

Program development activities each year that help give focus and direction to the Institute program include various contacts by the Institute to stay abreast of statewide or local water problems. Where suitable, the information gained is then provided to researchers who may be able to help address those problems.

Cooperation with Universities in Oregon

WRRI advertises research opportunities to the research communities at all major universities and colleges in Oregon. This is done by phone, by direct mailings to known individual researchers and by additional mailings to deans of research or presidents at these universities and colleges. The FY 1986 program was developed after solicitation of proposals from 186 potential principal investigators at 14 universities and colleges in Oregon (Oregon State University, University of Oregon, Portland State University, Oregon Health Sciences University, Oregon Institute of Technology, Eastern Oregon State College, Southern Oregon State College, Western Oregon State College, Lewis and Clark College, Linfield College, Reed College, University of Portland, Willamette University and Oregon Graduate Center).

Statewide Coordination

Statewide coordination occurs through a number of the director's activities, including personal visits to state and federal agency offices and service on various committees and task forces with members of local, state and federal agencies. Telephone contacts offer another means of staying aware of the activities of other groups and for coordinating Institute activities with them. The director is aided in these efforts by members of the Institute Governing Board.

The Institute receives and reviews newsletters, minutes of meetings, and annual reports from the Oregon Water Resources Department, Water Resources

Commission Department of Environmental Quality, Department of Fish and Wildlife, Department of Energy, Bonneville Power Administration, Northwest Power Planning Council, and other state and federal agencies. These facilitate coordination of research activities to meet various needs and coordination of information dissemination to deal with problems and issues.

The Institute participated in several interagency activities to deal with water-related problems during FY 1986. This included informal interagency activity with state and federal agencies and the concrete aggregate industry regarding Willamette River corridor management. Followup work continued with the USDA Soil Conservation Service and state and local agencies (Department of Environmental Quality, Department of Fish and Wildlife, State Soil and Water Conservation Division, and West Multnomah Soil and Water Conservation District) to help implement the recommendations from a research project on siltation problems at Sturgeon Lake and possible remedial actions. Strategic water management activities involved several faculty with a dozen state agencies during FY 1986. The Institute and members of the Oregon Division of State Lands worked together informally on a variety of river management studies. The Institute also routinely worked with members of the Oregon Department of Fish and Wildlife regarding hydraulic and sediment transport aspects of stream habitat work.

During FY 1986, WRRI initiated use of a team of state agency reviewers to work with the Governing Board in the selection of the research program. Invitations were sent to eight state agency heads inviting one of their senior staff members to participate in developing the Institute research program for FY 1987. This measure was a direct result of the USGS Institute evaluation team's recommendation to increase the involvement of state agencies in developing the WRRI federal research program. Participating agencies included:

Department of Fish and Wildlife
Water Resources Department
Soil and Water Conservation Division, Dept. of Agriculture
Drinking Water Program, Oregon State Health Division
Division of State Lands
Department of Environmental Quality
Parks and Recreation Division, Department of Transportation
Department of Land Conservation and Development

Representatives of this group and the WRRI Governing Board met in March to develop the FY 1987 program.

Regional Coordination

Program development activities in FY 1986 also included regional research development discussions with the other water research centers in the Pacific Northwest. The state water research centers of Alaska, Idaho, Montana, Oregon and Washington work together on many water-resource matters that involve teaching, research and public service. Particular emphasis of joint activities is given to problems involving the Columbia River system, irrigated agriculture, hydroelectric energy development, and fishery resources. The Oregon WRRI also maintained limited contact with state agencies in other states, to better identify regional research problems and needs. These agencies included the Washington Departments of Energy, Ecology, and Natural Resources, the Idaho Department of Water Resources, the Montana Department of Natural Resources, and the California Department of Water Resources.

Institute Membership

Membership is open to all faculty members, at any university or college in Oregon, who are actively engaged in water-related research and education or who wish to keep themselves involved and informed regarding such activities. Institute membership exceeds 100 faculty members from four state institutes of higher education (Oregon State University, Portland State University, University of Oregon, Oregon Institute of Technology). Faculty at several

state colleges and private colleges also participate in Institute programs (e.g., Eastern Oregon, Southern Oregon, and Western Oregon State Colleges, Lewis and Clark College, Willamette University, Oregon Graduate Center).

Institute Governing Board

The administration of the Institute is guided by a Governing Board. This consists of the director and nine members, all directly concerned with research and teaching. Three deans are permanent members representing the Colleges of Engineering, Forestry and Agriculture and their perspective experiment stations at Oregon State University. Six faculty members from State universities serve three-year rotating terms.

The Governing Board members during FY 1986 were:

Fred J. Burgess, Dean, College of Engineering and Director of Engineering Experiment Station, OSU

Steven L. Davis, Acting Director, Agricultural Experiment Station, OSU

Carl H. Stoltenberg, Dean of Forestry and Director of Forest Research Laboratory, OSU

*Norman H. Anderson, Professor of Entomology, OSU

*Ramon J. Seidler, Professor of Microbiology, OSU

Paul W. Adams, Extension Watershed Management Specialist, OSU

Stanley V. Gregory, Assist. Professor of Fisheries, OSU

Marshall J. English, Assoc. Professor, Agricultural Engineering, OSU

Richard M. Adams, Assoc. Professor, Agricultural and Resource Economics, OSU

**Keith W. Muckleston, Professor, Geography, OSU

**C. David McIntire, Professor, Botany and Plant Pathology, OSU

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*outgoing board members during period
**incoming board members during period

Institute Administrative Staff

The Institute's administrative staff during FY 1986 consisted of two positions: the director and a secretary/bookkeeper/office manager. Administrative personnel during FY 1986 were:

Director (0.25 FTE)	Peter C. Klingeman
Secretary/Bookkeeper/Office Manager (1.00 FTE)	Carol Phelps

TRAINING ACCOMPLISHMENTS

The Institute provides a variety of training and education opportunities for students at Oregon State University. The Institute coordinates a graduate-level interdisciplinary minor program in water resources that is available for all M.S. and Ph.D. degrees at OSU. The program is flexible and is tailored to the needs of individual students. The director and the members of the Institute (i.e., research and teaching faculty in water-related areas) provide program advising, serve as members of graduate committees, and help students and others regarding careers in water resources, opportunities for graduate study, and selection of graduate programs.

The Institute offers a Water Resources Seminar Series on campus each fall and spring term. Each series typically consists of 10 presentations on a focal water issue. Seminars include presentations by researchers on problems supported with Institute and other research funds. This allows the discussion of research methods and results. Seminars are open to the general public. Audiences vary from 15 to 50 in number.

An important educational aspect of Institute-supported research is the feedback into classroom teaching by faculty researchers. Classroom assignments typically provide technology transfer to a large number of young professionals who will use the benefits of research long after they leave the university.

Students also receive research training as part of the M.S. or Ph.D. thesis/project requirements. Many of these students receive such training directly on WRRI-USDI program projects. Table 2 shows, by fields of study and training levels, the numbers of individuals participating in projects financed in part by the FY 1986 program.

Table 2. Training Accomplishments

Academic Disciplines	Academic Level				
	Undergraduate and High School	Master's Degree	Ph.D. Degree	Post-Ph.D.	Total
Engineering					
- Agricultural					
- Civil		1	1		2
- Environmental		4		1	5
Biology					
Ecology		1			1
Fisheries, Wildlife	4*	1			5
Forestry					
Agronomy					
Chemistry					
Hydrology	**	**			**
Resources Planning					
Law					
Economics					
Geography					
Other (specify)					
Soil Science		1			1
TOTAL	4	8	1	1	14

*Includes 3 American Indian high school student interns funded by USFWS and USDA.

**See Civil Engineering (Hydraulics/Hydrology major = 2)