Program Report
Fiscal Year 1990

Water Resources
Research Institute

Water Resources Research Institute
Oregon State University
Corvallis, Oregon

Report No.
G1609-02

Fiscal Year 1990 Program Report
Grant No. 14-08-0001-G1609

for

U.S. Department of the Interior
Geological Survey

by

Oregon Water Resources Research Institute
Oregon State University
Corvallis, Oregon 97331

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September 1991

The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the Oregon Water Resources Research Institute.

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ABSTRACT

The FY 1990 Oregon Water Resources Research Institute program included four research projects addressing critical water problems in Oregon. Two projects received a second year of support, Project 04, Quantifying Losses of Nitrogen from Land-Applied Dairy Manure, advanced our ability to predict the amounts of nitrogen lost to leaching and runoff and denitrification from dairy manure applied to soils. The sites were on dairy farms with high cattle: land ratios, where nitrogen excess to grass needs is often applied. Project 05, Mass Balance Study of the Collier Glacier, Oregon, established base line data for following climate change from mass measurements on a glacier. Project 02, Fate and Transport of the Herbicide Dacthal in Groundwater, provided preliminary data on movement of the decomposition products of a herbicide used in intensive onion production in an area of eastern Oregon that has been designated a Groundwater Management Area, requiring a local plan to decrease nitrate and herbicide loading to groundwater. Project 03, Biochemical Analysis of Acetylenic Compounds as Nitrification Inhibitors for use in the Prevention of Fertilizer Loss/Nitrate Accumulation in Agricultural Land and Water, provided basic information on the mode of action of a class of nitrification inhibitors, to allow for more rational use. Summaries of these projects and their principal research findings are presented.

Education and training activities involved 120 graduate students and 20 undergraduate students in WRRI seminars. Twelve graduate students, 2 undergraduates and 1 high school student received research training on WRRI projects. Five research reports were published, one state and one regional conference on water quality were organized. Information transfer activities also included answering telephone and mail inquiries, presenting information at meetings with water managers, and participation in meetings with water management agency personnel.

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WATER PROBLEMS AND ISSUES OF OREGON

The people in Oregon are concerned about protection of environmental quality. A recent focus has been on the protection of ground water aquifers. More attention is now shifting back to surface water quality. A number of Oregon streams have been designated "water quality limited." A second major problem is competition among users for the available water, with the changes that result from the different priorities that our society is giving to water uses.

Major water-related problems in Oregon have three main causes: a) water use is exceeding availability, leading to increased competition among water uses, b) de-creasing quality of surface and ground water, and c) seasonal, geographic, and year-to-year variability of water supply. Surface-water runoff during late winter and spring causes bank erosion and can transport pollutants from non-point sources. Depleted streamflows, contaminated return flows, and lowered ground-water levels occur during most late-summer periods. Low quantity, poor water quality, and intense competition among water users results. 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 very significant in balancing part of the seasonal maldistribution 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 seasonal water supply, dams and reservoirs create other problems, particularly for anadromous fish. The conflict between advocates of removing water for resource development and those favoring other in-stream uses continues, although coordinated resource management techniques are now being used to resolve particular conflicts. Economic incentives are being considered to encourage water conservation. Better watershed management and water conservation are being urged by many citizens as non-structural alternatives to more dams. The dominant public mood remains against building more dams, for economic and for environmental reasons.

A major issue in competition among water uses during the past year has been the allocation of more water to reverse the decreasing salmon stocks in the Columbia River and its tributaries. Electric power production has been the primary determinant for water management, with shipping, irrigation and recreation sharing the benefits. The water requirements in time and space for salmon going up-river to spawn and for smolts going down to the ocean do not coincide with those for electric power production.

Water resources management activities such as water rights adjudication, ground water resources assessment, determination and remediation of contaminated waters, and inter-agency multi-focus planning are continuing, but at levels that do not meet all the demands placed on the State's water resources. Not enough information is available on quantity and quality of water resources, and amounts of water going to different uses. Better management will require a more complete base of information. Several imaginative processes have been put in place in Oregon to help fill these needs. The Governor's Watershed Enhancement Board, with limited funding, mobilizes considerable local activity directed to specific watershed improvements for communities. Legislation during the 1991 session on water quality concerns will also increase the ability to respond to these needs.

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. Increased efforts will be made to protect, conserve and recycle the available water through monitoring, structural and non-structural measures, and pollution cleanup activities.

The adequacy of Oregon's water laws and water management system to meet present commitments as well as to satisfy changing 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. These issues continue to be in the forefront of public water consciousness.

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

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

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

* 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);

* 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);

* Effect of global climate change on water resource management in Oregon;

* 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; and

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

PROGRAM GOALS AND PRIORITIES

Goals

The main purposes of the Oregon Water Resources Research Institute remain those originally formulated in 1959. These are to (1) appraise water research needs through information from water users, (2) promote research within the University Community to meet needs, (3) develop new water researchers and resource managers through education programs at the Universities, (4) coordinate efforts of water researchers, (5) promote research capabilities within the Universities, (6) disseminate research results, and (7) promote interdisciplinary graduate education in water resources management.

The Institute's overall long-range goal is to pursue effectively its main objectives so as to assist in the sound management, sustained 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 resources problems and issues in the state and help to solve these problems through research, education and technology transfer activities.

Water resources 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

The Institute periodically establishes research priorities for solving critical water-related problems and then solicits funds for projects to address those priorities. Research priorities are set for both state and regional needs. The updated research plans served as an important guiding document for development of the FY 1990 program; the FY 1990 program has been responsive to that plan.

Use of FY 1990 Grant to Develop and Implement Program

The FY 1990 Oregon Water Resources Research Institute Program has focused on water quality and to a lesser degree on water quantity. The priority is to advance our collective technical knowledge related to water management. Specific priorities were to advance our knowledge of (a) movement of herbicides under intensive agricultural production, in Project 02; (b) the mode of action of nitrification inhibitors in soils, in Project 03; (c) nitrogen leaching losses from heavy manure applications, in project 04; and (d) evaluation of climate change, in project 05.

The projects included in the FY 1990 Oregon WRRI Program all addressed issues that are identified in the Oregon and Pacific Northwest WRRI priority plans, are high-public-attention issues and relate to problems that continue to receive legislative attention. The ways in which the four FY 1990 projects addressed water policy issues and management problems are shown in Table 1.

The specific relation of each project to the solution of state and regional water policy issues and management problems is described in the following paragraphs.

02 Fate and Transport of the Herbicide Dacthal in Groundwater. An alluvial aquifer near Ontario, Oregon, is contaminated with the herbicide Dacthal. The objective of this proposal is to determine rates of chemical and biological degradation, sorption, and desorption for Dacthal and its metabolites in soils and aquifer materials to improve predictions of Dacthal transport in groundwater.

03 Biochemical Analysis of Acetylenic Compounds as Nitrification Inhibitors for use in the Prevention of Fertilizer Loss/Nitrate Accumulation in Agricultural Land and Water. Acetylenes are potent nitrification inhibitors which prevent the oxidation of N-fertilizers to "mobile" forms of nitrogen (e.g. nitrate) which adversely affect water quality. The inhibitory effects of acetylenes with various chemical functional groups will be determined to provide a rational basis for designing effective inhibitors of nitrification in the field.

04 Quantifying losses of nitrogen from land-applied dairy manures. It is likely that a significant proportion of nitrogen from land-applied manure is removed by denitrification, but this loss has not been measured. Nitrate leaching and runoff are two other major routes of nitrogen losses. This study will quantify the amount of nitrogen lost by denitrification, nitrate leaching, runoff, and some of the environmental factors that control these processes.

05 Mass balance study of the Collier Glacier, Oregon. Sustained, long-term measurements of the accumulation and ablation of snow and ice on Collier Glacier will establish direct information about the mass balance of the glacier, provide data to complement existing data on snowpack hydrology for water use, and implement baseline studies for monitoring the impact of global change on Oregon's glacier hydrological system.

22 Technology and information transfer for Oregon's water resources management. The seminars in fall and spring quarters presented information on Wetlands and on Salmon in the Columbia, to students and water managers. Technical reports published on completed projects serve water managers, planning groups and other research scientists. Conferences presented water quality information to water users and to research scientists. Three newsletters, sent to over one thousand users, describe available water information.

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

Project		Water Planning and Management	Fishery and Aquatic Ecosystem Resources	Water Quality	Ground Water Resources
02	Fate and Transport of the Herbicide Dacthal in Ground-Water			X	X
03	Biochemical Analysis of Acetylenic Compounds as Nitrification Inhibitors for use in the Prevention of Fertilizer Loss/Nitrate Accumulation in Agricultural Land and Water			X	X
04	Quantifying Losses of Nitrogen from Land-Applied Dairy Manure.			X	X
05	Mass Balance Study of the Collier Glacier, Oregon.	X			

Federal USDI funds for support of the program provided about half of the total funds used for Institute research and technology/information transfer activities during FY 1990. Much of the non-federal funding was received because of the availability of federal funds. Direct state and regional funding continue to be very limited. 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 limited state funding. 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 Oregon University campuses, such as the experiment stations and academic departments. Multi-disciplinary research projects are now being organized, and are expected to provide more funds next year.

RESEARCH PROJECT SYNOPSIS

02. Fate and Transport of the Herbicide Dacthal in Groundwater - Jack Istok, Sandra Woods

03. Biochemical Analysis of Acetylenic Compounds as Nitrification Inhibitors for use in the Prevention of Fertilizer Loss/Nitrate Accumulation in Agricultural Land and Water - Daniel Arp

04. Quantifying Losses of Nitrogen from Land-Applied Dairy Manure - David Myrold, James Moore

05. Mass Balance Study of the Collier Glacier, Oregon - Peter Clark, Charles Rosenfeld

Synopsis

Project number 002 | Start: 07/90
end: 06/92

Title FATE AND TRANSPORT OF THE HERBICIDE DACTHAL IN GROUNDWATER.

Investigators: Istok, J.D.; Woods, S.L.;
Oregon State University, Corvallis

COWRR category: 05-B

Key words: Dacthal, groundwater, herbicide, transport, fate

Problem and research objectives:

The shallow, poorly-confined, sand and gravel aquifer underlying the lower Malheur River basin near Ontario, Oregon is contaminated by nitrate and metabolites of the herbicide Dacthal (dimethyl tetrachloroterephthalate) or DCPA Several large-capacity wells are used to obtain water from the aquifer for irrigation, industrial and municipal uses; many small-capacity wells provide water for domestic use. Contamination by DCPA was first detected in 1985, measured concentrations have ranged from 0 to 431 ppb . Although measured concentrations are currently less than the health advisory level of 3,500 ppb there is concern that the release of DCPA or its metabolites from treated soil may lead to increasing concentrations of these materials in groundwater.

DCPA is used as a pre-emergent herbicide; typical application rates are 5-10 kg/ha/yr. We have estimated that the aquifer contains approximately 20,000 kg of DCPA and its metabolites (Smyth, 1988), which represents four years total application. In a related study, we estimated groundwater residence times to be about two years (Walker, 1990), indicating that DCPA movement is being significantly retarded by sorption processes. This also suggests that DCPA is resistant to degradation in the aquifer. If these preliminary conclusions are correct, concentrations of DCPA will probably increase, suggesting that alternate, and perhaps costly, management practices may have to be adopted to prevent concentrations from reaching health advisory levels. However, rates of sorption have not been measured for DCPA. This information is needed to predict future concentrations of DCPA in groundwater at the site and to evaluate the effectiveness of proposed alternate management practices.

The objective of the research is to measure rates of sorption and desorption for the herbicide Dacthal (DCPA) on samples of soil and aquifer material from the alluvial aquifer system near Ontario in eastern Oregon. The research is an experimental program. Rates will be measured using soil and aquifer samples from the site and using environmental conditions representative of actual field conditions. The project is a cooperative study involving personnel from several state agencies (Oregon Department of Agriculture, Soil Conservation Service, and Malheur County Soil and Water Conservation District. It also offers the unique advantage of coupling groundwater models with experimental data to evaluate transport of Dacthal as well as transport of its more mobile degradation products.

Methodology:

Before the sorption experiments could begin, a comprehensive characterization of the physical and chemical properties of the unsaturated zone is required. Thirty-five borehole locations were selected to be representative of the soil series and geomorphic surfaces of the study area. Several boreholes were approximately aligned and used as transects; the transects were aligned with regional groundwater flow lines.

Boreholes were drilled using a hollow stem auger. The boreholes extended from about 5 ft below the soil surface to the top of the shallowest gravel layer (depths between 12 and 60 ft). The auger sections were steamed cleaned after each use to prevent contamination of soil specimens between boreholes. Soil specimens were collected continuously using split spoon samplers; a sampler was driven and retrieved every 2 to 2 1/2 ft. The number of hammer blows required to drive the sampler were recorded for each 6 inch interval. After the samplers were retrieved and disassembled, the retained soil was was divided into 6 inch long soil specimens; the specimens were placed in labeled sample bags or jars. The split spoon samplers were cleaned with water and a wire brush after each use. The soil specimens were transported to the laboratory for analysis. One soil specimen from each 2 ft depth interval was air-dried and stored for use in the nitrate and DCPA chemical analyses.

Soil classifications were made according to the standard American Society for Testing and Materials (ASTM) method D-2487-69. Grain size distribution was determined using the standard method for particle-size analysis (ASTM D-422-63). Each hydrometer sample consisted of 40 g of < 2mm air-dried soil; concretions were completely crushed using a large mortar and pestle before suspension in sodium hexametaphosphate solution. Hydrometer readings were taken in a constant-temperature room at 1 minute, 90 minutes, and 24 hours after dispersion. To measure bulk density, test specimens were cut and/or molded from core samples; care was taken to avoid distortion, bending, or cracking of the specimens at each step. Volumes of duplicate specimens were calculated from measurements of the outer dimensions. Specimens were then dried overnight at 100°C. Each sample consisted of 5 g of < 2mm air-dried soil and the standard ASTM D-854-83 method was used.

To measure pH and Eh, five grams of < 2mm air-dried soil was reacted with 5.0 mL of double-distilled deionized water by stirring vigorously for five to ten seconds using a glass stirring rod. Samples were allowed to settle for ten minutes before pH and Eh measurements were taken. An Orion model 701A digital ionanalyzer and Beckman combination electrode was used for pH measurements after calibration with 7.00 and 10.00 pH buffer solutions. An Orion platinum redox electrode connected to the model 701A meter was used for Eh measurements. The redox electrode was tested for response using two standard solutions of known potential.

Aliquots of 5.00 g of < 2mm air-dried soil were placed in porcelain crucibles (previously acid-washed and heated overnight in a 550°C muffle furnace) and mixed with 5.0 mL of 6% sulfurous acid. Samples were thoroughly mixed for ten seconds using a glass stirring rod and any soil adhering to the rod was washed back into the crucible with sulfurous acid. After air-drying, samples were again treated with 5.0 mL of the acid. This continued until the samples no longer effervesced, indicating that all carbonate had been removed. About 0.20 - 0.25 g of the reacted soil was weighed into clean tin foil, folded, and then placed in ceramic crucibles. Care was taken to not touch any of these components with the hands as this can contribute to organic carbon levels. Organic carbon was determined by combusting the samples and measuring CO_2 gas evolution using a LECO WR-12 carbon determinator. The carbon analyzer was previously calibrated using four standards of known carbon content.

Ammonium and nitrate nitrogen were measured by the potassium chloride extraction method, and total nitrogen was measured by a modified Kjeldahl method DCPA concentrations were measured using a standard EPA method, which involves repeated extraction followed by gas chromatography.

Principal findings and significance:

Physical and chemical characterization of the vadose zone above the contaminated aquifer has been completed. Maps and cross-sections are being prepared to develop a three-dimensional picture of the distribution of vadose zone properties. The results show a generally thick layer of unconsolidated sand overlying the aquifer. Aquifer depths ranged from 6 to over 50 ft, with an average depth of about 35 feet. The sand is generally quite uniform, with moderately high organic carbon levels, and an alkaline pH. Values of saturated hydraulic conductivity estimated from grain size distributions are about 0.0001 cm/sec.

The results of nitrogen and DCPA analyses indicated very high levels of these materials (nitrate concentrations up to 120 ppm and DCPA concentrations up to 1 ppm). This combined with the relatively high hydraulic conductivity of the unsaturated zone materials suggest that continued movement of nitrogen and DCPA to the water table aquifer is likely. Estimates are being prepared for the amount of nitrogen and DCPA in the unsaturated zone and for the rate of vertical water due to infiltrating irrigation water. A copy of a more detailed report will be available October 1, 1991.

Publications and professional presentations: none

M.S. theses: none

Ph.D. dissertations: none

Synopsis

Project Number: 03

Start: 07/90
End: 06/91

Title: BIOCHEMICAL ANALYSIS OF ACETYLENIC COMPOUNDS AS NITRIFICATION INHIBITORS FOR USE IN THE PREVENTION OF FERTILIZER LOSS/NITRATE ACCUMULATION IN AGRICULTURAL LAND AND WATER

Investigators: Arp, Daniel J.; Rasche, Madeline E.; Hyman, Michael R.; Russell, S.A.

COWRR: 05-B

Congressional District: Fifth

Key Words: Nitrification, Nitrate/Nitrite accumulation, N-Fertilizer, Inhibitors, Groundwater Quality

Problem and Research Objectives:

The application of ammonia and urea-based fertilizer to improve crop productivity is a nationwide practice. In Oregon, nitrogen fertilizers are applied to managed forest land and to croplands in the Willamette Valley and east of the Cascades. Both ammonia and urea (which rapidly hydrolyzes to ammonia) are converted to nitrite and nitrate by the action of nitrifying bacteria. Nitrite and nitrate are highly mobile in soils and can easily be leached into anaerobic zones where they are reduced by denitrifying bacteria to gaseous products (N_2, NO, N_2O) which are lost to the atmosphere. Nitrate, and to a lesser extent nitrite, can also enter groundwater supplies through leaching. These compounds are regarded as important factors in eutrophication and as human health hazards. Overall, the action of nitrification can therefore be seen as a detrimental process which can lead to substantial losses of costly fertilizer and can subsequently lead to water pollution problems in intensively fertilized and irrigated agricultural areas. The ability to inhibit nitrification through the combined application of fertilizer and nitrification inhibitors can potentially have a profound effect on both the economic and environmental consequences of heavy fertilizer use.

To date, the study of nitrification inhibitors has been arbritrary and has not thoroughly addressed the mode of action of active compounds, their bacteriocidal or bacteriostatic qualities and their non-specific impacts on other soil and water organisms. A more systematic approach is required to aid in the rational design of nitrification inhibitors which are highly specific and effective at low concentrations. The most significant shortfalling in this area of nitrification inhibition research arises due to the lack of a comprehensive biochemical understanding of the nature of the chemical interaction between inhibitors and their chemical factors which limit or promote the effectiveness of acetylenes as nitrification inhibitors and apply this to the design of compounds suitable for agricultural and silvicultural use.

Methodology:

Studies were directed at ammonia monooxygenase (AMO), the enzyme that initiates nitrification by oxidizing ammonia to hydroxylamine. The experiments were carried out in whole cells. Uptake of O_2 coupled to ammonia oxidation was monitored amperometrically. Cells of *Nitrosomonas europaea* were grown in shake-flasks in a mineral salts medium. In a typical experiment, cells were mixed with ammonia and the alkyne of interest in a reaction chamber with an O_2 electrode inserted. Changes in the rate of O_2 consumption were recorded. The time required for the activity to decrease to half of the original level was determined at several different concentrations of the added alkyne. These $t_{1/2}$'s were measured for several different alkynes. Additional experiments considered the possibility that some alkynes were also substrates for AMO in addition to being inactivators. For these experiments, loss of the alkyne during the period of time required for inactivation was monitored by gas chromatography (Porapak Q column for separation, flame ionization detector). The ability of the cells to recover from the inactivation by alkynes was also determined. AMO was inactivated by exposure to a particular alkyne, then the cells were washed and placed in a mineral salts medium. Samples were removed at various times and AMO activity was determined.

Principal findings and significance:

In the absence of an inhibitor, the cells consume all of the O_2 present in the electrode chamber. However, in the presence of a sufficient concentration of an inhibitory alkyne, there was a time-dependent inhibition of O_2 consumption. To provide a quantitative estimate of the efficacy of each alkyne as an inhibitor, the time required to reach half of the initial rate of O_2 uptake was determined. In the test cases we have evaluated more completely, the inhibitions follow a first order process. As such, the times to half activity are $t_{1/2}$s and will be referred to as such in the remainder of this proposal. For each alkyne, $t_{1/2}$s were determined at several alkyne concentrations.

In order to make the comparisons of $t_{1/2}$s meaningful, it was necessary to have some idea of the day-to-day variation in this value with a particular alkyne. To examine this, we chose the well-characterized alkyne, acetylene. For a given batch of cells, the relative error in $t_{1/2}$ determination was less than 10% of the mean $t_{1/2}$. However, the day-to-day variation was greater. $t_{1/2}$ values varied from 28 to 85 seconds and a mean of 57 $\pm$ 18 sec was observed from 18 determinations (Table I). This level of variation was representative of other alkynes as well. In some cases, the variation was small (e.g. 3-hexyne) while in other cases, the variation was considerable (e.g. 1-hexyne).

The data collected with a number of compounds are presented in Table I. $t_{1/2}$s obtained with 10, 20, 40 and 80 µM alkyne concentrations are included. It is clear that most straight-chain alkynes examined to date were more effective as inhibitors of ammonia oxidation than acetylene, when compared at 40 µM alkyne concentration. A notable exception occurred, however, when the triple bond was between the number 2 and 3 carbons. These were remarkably ineffective as inhibitors. Only a trace level of inhibition was observed at up to 80 µM alkyne. At higher concentrations (up to 1 mM) inhibition was observed, but it was not typical of the other alkynes. This phenomenon was further investigated using the series 1-, 2-, and 3-hexyne. The inhibition patterns for 1- and 3-hexyne were typical of that seen with acetylene. However, 2-hexyne produced a different pattern. While the rate of O_2 consumption decreased, it did not proceed to zero.

We considered the possibility that the 2-alkynes act as alternative substrates, rather than or in addition to acting as suicide inhibitors. It is well known, for example, that alkanes and alkenes are oxidizable substrates. In the case of 2-butyne, our experiments revealed that this compound, while not an inactivator, is a good substrate for AMO. Gas chromatographic analysis revealed that the 2-butyne disappears with time while a new peak (probably 2-butyne-1-ol) appears in the chromatograms. Similar results were observed for 2-hexyne and 2-pentyne, neither of which are inactivators, but both are substrates. An intermediate result was observed for 3-hexyne. This compound is less effective as an inactivator than 1-hexyne, but is degraded to a greater extent by AMO than is 1-hexyne.

We also investigated alkynes other than simple straight chain compounds. For example, phenyl acetylene is slightly more effective as an inhibitor than acetylene while ethynylpyridine appears to be about as effective (Table I). Neither 3-hexyne-1-ol nor undecynoic acid were effective inhibitors, suggesting that alcohol or acid functional groups interfered with the ability of the compounds to inhibit ammonia oxidation. In the case of undecynoic acid, inhibition proceeded when the cells were treated with EDTA, a treatment which increases the permeability of the periplasmic membrane.

TABLE I: Inhibition of Ammonia Oxidation by Alkynes

Compound	$t_{1/2}$ (sec) 10 µM	20 µM	40 µM	80 µM
Acetylene			57 ± 16 n=18	
2-Butyne	ND	ND	ND	slight inhibition
2-Pentyne	ND	ND	ND	"
1-Hexyne	28 ± 16 n=6	21 ± 9 n=6	15 ± 8 n=8	16 ± 4 n=3
2-Hexyne	ND	ND	ND	slight inhibition
3-Hexyne	32 ± 2 n=4	21 ± 2 n=4	14 ± 2 n=4	11 ± 1 n=4
1-Heptyne	25 ± 4 n=5	14 ± 4 n=4	15 ± 6 n=4	14 ± 5 n=3
1-Octyne	35 ± 7 n=5	21 ± 5 n=4	21 ± 3 n=4	18 ± 3 n=3
1-Decyne	26 ± 7 n=4	20 ± 12 n=4	18 ± 3 n=4	14 ± 5 n=4
Phenylacetylene	48 ± 9 n=5	29 ± 5 n=6	15 ± 2 n=4	11 ± 1 n=4
2-Ethynylpyridine	-	-	112 n=2	58 n=2

ND-No inactivation detected. At the higher concentrations, some inhibition was observed, but the activity did not proceed to zero. Even at concentrations as high as 1 mM, the 2-alkynes did not eliminate ammonia oxidation.

We have also determined that cells can recover from the effects of alkyne treatments once the alkyne is removed. Over a time course of 4-6 hours, activity recovers fully. This process is inhibited by chloramphenicol, indicating that protein synthesis is required. It appears that recovery of activity requires de novo synthesis of ammonia monooxygenase.

It has become clear that three factors influence the utility of a particular alkyne as an inhibitor of nitrification. First is the potency of the inhibition. This reflects the amount of inhibitor required and its ability to reach the active site of ammonia monooxygenase. Second is the residence time of the inhibitor in the soil. One of the problems with acetylene is that it is too rapidly released from the soil. This is why we have investigated compounds which will likely be less volatile and have a longer residence time in the soil. Third, the rapidity with which the cells recover from inhibition is important.

Publications and professional presentations:

Russell, S.A., M.R. Hyman, M.E. Rasche and D.J. Arp. 1991. Interaction of ammonia monooxygenase of Nitrosomonas europaea with alkynes: Substrates and inactivators. In preparation.

M.S. theses: none

Ph.D. dissertations: Madeline Rasche

Synopsis

Project Number: 04

Start: 7/89 (actual)
End: 6/91 (actual)

Title QUANTIFYING LOSSES OF NITROGEN FROM LAND-APPLIED DAIRY MANURES

COWRR Category 05-B

Congressional District: Fifth

Keywords: 101, Groundwater Quality; 59, Denitrification; 156, Nitrogen; 53, Dairy Waste Management

Principal Investigators' Names, University and City

David D. Myrold, Associate Professor, Oregon State Univ. Corvallis
James A. Moore, Professor, OSU

Problem and research objectives:

The realities of modern dairy farm management require the treatment and disposal of large amounts of animal wastes over relatively small land areas. The fate of this large amount of nitrogen is not well known, especially for gaseous losses via the biological process of denitrification. Such information is needed to optimize management of dairy manure for both agricultural (farmers) and environmental (regulatory agencies) ends.

Contamination of groundwater by high concentrations of nitrate as a result of land application of animal wastes (e.g. dairy manure) is a current concern in Oregon.

The objective of this research is to measure four pathways of nitrogen loss: denitrification, leaching losses (by means of a mineralization assay), surface run-off and immobilization. A companion study (J. Moore, Bio-resource Engineering, OSU) will measure N uptake by grasses, leaching (by means of lysimeter tubes) and ammonia volatilization. They will also monitor tile line effluent in one of the sites.

Methodology

Sites which had been in pasture for at least four years were identified and plots were established in July and August, 1989, on the Amity and Waldo soils in Benton County and the Coquille soil in Tillamook County. Because of excessive mole damage, the Tillamook county site was moved in mid winter to a Quillayute soil. The soils were chosen to represent soils which are frequently used for pasture. These fine textured, wet soils would be expected to support high rates of denitrification. Annual rainfall in Benton county is around 40" per year. Tillamook county receives 92" rain per year.

Soil Characteristics

Soil	Drainage Class	Bulk Density*	Organic Carbon* (%)	Taxonomic name
Amity silt loam	somewhat poor	1.24	2	Argiaquic Xeric Argialboll
Waldo silty clay loam	poor	1.4	2	Fluvaqentic Haplaquoll
Quillayute silty clay loam	well	.96	10	Hydric Dystrandept

* from Soil Extension publications- not site specific.

Four treatments are replicated 3 times on the three soil types. Plots receive manure applications totalling 0, 150, 300 and 450 kg Manure-N ha^{-1} y^{-1}. Following best management practises, plots are mowed when grass reaches about 12 inches in height and then immediately manured. Manure is surface spread, not incorporated. The interval between mowings varied from 3 weeks to 4 months. Because the three sites varied considerably in rapidity of regrowth, dry matter and N yield, the harvests and manure applications are offset in time. There were five to six manure/harvest operations per year, depending on site.

Denitrification sampling was initiated in early spring, 1990, following the first manure/harvest cycle. Denitrification measurements continued at appropriate intervals through May, 1991. These measurements were more frequent when denitrification rates were expected to be high. The acetylene inhibition technique was used on intact soil cores incubated at soil temperatures. Thirteen measurements were made over a period of fourteen months.

Three sets of mineralization/leaching tubes were installed. The first covers spring, 1990, the second summer, 1990 and the third fall/winter, 1991. Leaching losses will be estimated by combining soil mineralization data and grass uptake data (data courtesy of J. Moore). Mineralization is determined using a 2" diameter PVC tube, open at the top to receive manure inputs and with an ion exchange resin at the bottom to trap nitrate passing out the bottom. This size of tube is too small to uniformly contain pasture grasses, so they were exluded, either by hand pulling or by herbicide. The first two sets (spring and summer) were 24" long. Because there seems to be impeded water drainage resulting from compaction developing in the tube at a depth of 12 to 18", the length of the tubes were reduced to 12" for the final set (winter). With the 12" length, no compaction was visible.

To assess immobilization, a soil sample was taken in early spring, 1989, prior to manure applications and another will be taken following the last manure application, in fall, 1991. Soil organic nitrogen will be determined by Kjeldahl digest.

Results:

Denitrification rates at the Tillamook county site showed the greatest response to manure applications. Cumulative loss in the plots receiving the high rate of manure was almost 10 times that in the control plots. Additionally, the highest denitrification rate observed, 2130 g N denitrified h^{-1} da^{-1}, was in that site. Losses in the Amity and Waldo sites doubled from control to high rate. The Quillayute soil lost about 20% of applied N, while the Amity and Waldo soils lost about 5%.

Denitrification rates were responsive to changes in soil moisture, particularly in the Quillayute soil. Denitrification rates were very low during the spring and summer, even when wet soils were receiving high rates of manure. Large increases in denitrification followed the first rains in the fall, and a freeze/thaw cycle in late December. Treatment effects on cumulative denitrification losses will probably be significant in the Waldo and Quillayute soils, but not the Amity. The Amity plots suffered badly from gopher damage and spacial variability was excessively high.

Denitrification rates were highest in all sites over the fall and winter months. Over 80% of all denitrification occurred during the winter months (October through March). In this climate, growth of pastures is very active from mid-March through August and it is likely that soil nitrate levels are too low to support substantial denitrification. In contrast, delayed mineralization of manure-N coupled with less competition by pasture grasses for nitrate result in higher nitrate concentrations in the fall and large flushes of denitrification.

Cumulative Denitrification Losses

SOIL	TREATMENT Control	150	300	450
		(kg N denitrified ha^{-1} yr^{-1})		
Waldo	9.2	15.92	22.54	23.21
Amity	13.28	16.07	20.99	19.33
Quillayute	10.14	31.29	46.42	87.13

Leaching

Leaching losses will be calculated by combining plant N uptake data and net mineralization data. The mineralization assay used is a modification of the buried bag technique. This data is still in the early stages of analysis and any findings are preliminary. There are large differences between the Tillamook site and the Benton county sites. Net mineralization in the Quillayute soil is about 500 Kg h^{-1}. Mineralization in the Benton county sites is closer to 100 kg N h^{-1}. Variability within a site was high, and there do not seem to be significant treatment effects.

Publications and Professional Presentations:

Kelly, S., J. Moore, D. Myrold, and M. Gamroth. 1989. Nitrogen movement from land-spread manures. 1st Ann. Meet.Env. Res. Oregon State Univ.

Moore, J.A.,S. Kelly, M. J. Gamroth, D.D.Myrold, and N.C. Baumeister. 1990. Movement of nitrogen from land application of dairy manure on pasture. Proc. Non-point source pollution: the unfinished agenda for the protection of our environment. Report 78, Tacoma, WA

Moore, J.A.,S. Kelly, M. J. Gamroth, D.D.Myrold, and N.C. Baumeister. 1991. Measuring nitrogen movement from land spread manures.

Baumeister, N.C. and D.D. Myrold. 1991. Denitrification in manured pastures. 1991 Soil Ecology Society Meeting

M.S. theses: Nancy Baumeister (in progress)

Ph.D dissertations: none

Synopsis

Project number: 05

Start: 07/90
End: 10/91

Title: MASS BALANCE STUDY OF THE COLLIER GLACIER, OREGON

Investigator: Clark, Peter U.
Oregon State University, Corvallis

COWRR: 07-B

Congressional district: Fifth

Key words: climate. glaciers, geophysics, geographic information systems

Problem and research objectives:

There is increasing recognition at state, national, and international levels that rising levels of atmospheric pollutants have the potential to dramatically change global climate and environment. This issue requires immediate attention, with the primary agenda focusing on "sustained, long-term measurements of global variables to record the vital signs of the Earth system and to document the effects of global change" (NASA, Earth System Science Committee). In Oregon, the governor convened a task-force to evaluate the impact of greenhouse warming on Oregon's environment. At the national and international level, 1990 marked the beginning of the decade-long International Geosphere/Biosphere Programme (IGBP), involving multidisciplinary research in an integrated effort to study global change.

Among the critical issues to be addressed in global change are those involving water resources at a variety of scales. Global warming will have an immediate impact on temperature and precipitation patterns, thus affecting water resources. The direction and magnitude of change, if any, with respect to glacial systems remains a major question, with important ramifications at local (runoff), regional (hydroelectricity), and global (sea level) scales.

The objective of this study was to measure the net mass balance of Collier Glacier in the Oregon Cascades for the 1990-1991 balance year, and to establish baseline data for monitoring future mass changes which may be brought on by global climate change.

Methodology:

Mass balance studies investigate additions from snow and rain, and subtraction of mass from melting over the surface of a glacier through time. The major source of mass gain is from snowfall. On a year to year basis, inputs and outputs usually do not balance. A balance year is usually used in reference to the hydrologic year, thus beginning on October 1. In general, a balance year begins some time in early fall with a marked increase in accumulation and ablation process, signalling the beginning of the winter season. Subsequently, some time during early summer, ablation will exceed accumulation, identifying the beginning of the summer season.

Mass balance quantities are calculated for an area, and thus have dimensions of volume (m3) from measure points on the glacier surface. Change in mass is expressed in terms of water equivalent (m H_2^O).

There are several methods for obtaining mass balance measurements. We used the stratigraphic system, where the change in mass/unit area is measured relative to an isochronous reference surface, where this surface is taken as the glacier surface at the end of a particular year's melt (summer) season.

Collier Glacier is 2.4 km long, has an average width of 1.2 km, and increases in elevation from 2220 m at its terminus to 2805 m at its head. From detailed, small-scale (ca. 1:5,000) topographic maps of the glacier obtained by field surveying and low altitude aerial photography, we compiled the map on a Geographic Information System (GIS) for further data analysis. In late September, we deployed a network of aluminum or PVC stakes on the surface at intervals of 1 stake/25 m increase in elevation (ca. 24 stakes for the Collier Glacier) along the presumed primary flowline running down the long axis of the glacier. Subsequent networks of stakes were deployed at the 100 m intervals normal to the primary stake network to the lateral margin of the glacier. The location of each stake on the glacier surface was surveyed precisely and plotted on the GIS base map.

Stakes in the ablation area were set in holes drilled into the ice, and the distance between the top of the stake and the ice surface was measured at the beginning and end of the balance year. Dye and/or some permeable material will be used to mark the reference surface in the accumulation area.

At the end of the winter season, the winter balance will be determined in the accumulation and ablation areas, measuring the snow accumulation at the stakes above the initial datum. Pits will also be dug to obtain samples for density measurements, and mass accumulation will be converted to water equivalent.

At the end of the 1989-1990 balance year, we will measure the net balance over the glacier surface. In the accumulation area, we will measure the thickness of snow remaining after the summer season. Pits will be dug to the reference (initial) surface, and snow and firn densities will be measured. In the ablation area, we will measure the distance between the top of the stake and the ice surface, which will be greater than at the the beginning of the balance year because mass has been lost. The summer balance is obtained by subtracting the net balance from the winter balance. After the net balance for each point is determined, we will plot the data on our GIS base map and draw contours of equal net balance. From this, we can calculate the net balance and the average net balance.

All data will be evaluated on the basis of maps drawn using the GIS base map and the graph of net balance against elevation. The Department of Geosciences has a complete GIS laboratory. Mass balance data will be analyzed statistically using conventional methods to evaluate the precision of the mass balance estimates. The data will then be evaluated with respect to climate (precipitation and temperature) for each balance year. Results will be written up and submitted for journal publication.

<u>Principal finding and significance</u>:

We have completed preliminary mass balance studies of the Collier Glacier for the 1989-1990 balance year, and have installed a network of PVC stakes for measurement of the 1990-1991 year. Because of unexpected logistical difficulties in reaching the glacier during the spring season, we were unable to obtain obtain winter balance measurements. We were able to measure ablation and accumulation at the end of the 1989-1990 balance year, however, and thus calculate the net balance for that year. We will be obtaining similar measurements this October for the 1990-1991 year. Evaluation of the data shows that the Collier Glacier had a strongly negative mass balance for the 1989-1990 year, with a mean b_n value of -0.49 m/year. The 1989-1990 balance year was characterized by low accumulation, as suggested from snowpack data, thus contributing to the negative balance for that year.

Publications and professional presentations: None

M.S. theses: None

Ph.D. dissertation: None

Subject Matter and Problems Addressed by Information Transfer Activities

Surface water quality and quantity received the most attention during FY 1990. Workshops, seminars and talks to various groups have been dominantly on this topic. Groundwater quality programs continued as a secondary issue. Nonpoint sources of pollutants and cumulative effects on watersheds were important issues.

Other issues continue to be important in Oregon. Competing uses for water, managing water shortages, riparian zone and watershed management, and wetland protection are important. There is renewed interest in wetlands - how they function, how they can be used in cleaning water. The WRRI fall seminar series explored aspects of wetlands characteristics and functions. Land application of sewage treatment plant effluent is being considered as a method to decrease phosphorus loading of streams. The WRRI has prepared a background paper, and is planning a workshop. Phosphate moving to groundwater from high surface soil loading is now an issue.

Fish habitat, improvement of habitat in streams, improvement of facilities to allow fish to return to streams for spawning, competition for recreational use of streams, influence of recreation uses on streambanks, and riparian vegetation management for stream quantity and quality all continue to be part of our information transfer activities. Habitat studies become more important as emphasis shifts from stocking bodies of water with hatchery fish to encouragement of native or wild fish. Watershed and riparian zone management to manipulate seasonal water yield continue to receive much attention in Oregon. Questions continue to be asked about manipulating riparian and upland vegetation to change watershed runoff and streamflow. WRRI has been an active participant in helping to stimulate research on the topic and to disseminate technical information.

Fish habitat restoration/alteration activities cost millions of dollars per year in the region. This will increase dramatically as measures are introduced to protect the salmon species that may be "threatened" or "endangered" in the Columbia River watershed. This will generate a major increase in need for water management information. The spring seminar series was on the topic of salmon in the Colombia River.

The WRRI maintains files and reference reports on research conducted by the Institute since it began receiving Federal support in 1965. This information is used to promote the application of research findings on a broad spectrum of subjects that have been researched by WRRI.

Target Audiences for Information Transfer Activities

Many groups benefit from the Institute's information dissemination activities, including the university research community, other faculty (in relation to their academic programs), graduate and undergraduate students, resource managers and governmental officials at the Federal, state and local levels in Oregon, consulting firms, public-interest and vested-interest groups, and individuals in Oregon and neighboring states.

Strategies Used to Promote Application of Research Results

Information dissemination at the WRRI has several elements. Direct one-to-one discussions with concerned individuals routinely occur by telephone and less frequently with visitors to the Institute. These generally involve the Institute Director or Office Manager but may also include board members and Institute researchers. General calls to Oregon State University about water are transferred to WRRI. The Institute staff must be able to refer particular inquiries to the appropriate sources (people or bibliographic material) or to provide quick answers to a wide variety of questions. Considerable staff effort goes to helping people identify information that is not readily or conveniently accessible.

The "Directory of Water Resources Expertise at Universities and Colleges in Oregon," published by WRRI, is of great help. The 1988 Directory was updated and is ready for publication in September, 1991.

Research publications based on WRRI projects are distributed to potential users, as part of the Institute's information dissemination program. The Institute also publishes and disseminates significant research findings from work not supported under its research program, but which is relevant to water management in Oregon and in the region.

Three newsletters were published and sent to over 1,000 names on our mailing list. The first newsletter listed the available WRRI publications by topic. The second newsletter described the WRRI research projects, and the third described water research and education programs at 14 institutions of high education in Oregon.

The Institute organizes and presents seminar series on the Oregon State University campus during fall and spring quarters. Each seminar series includes 10 weekly, 90 minute presentations on the theme selected for the term. Wetlands and Salmon in the Columbia River were presented this year. Appendix A contains the two programs.

Cooperators

In addition to its assistance for individuals and groups, the Institute routinely works closely with the Oregon State University Cooperative Extension Program on a variety of activities, with OSU's Sea Grant Program in response to specific requests, and with the local EPA laboratory on workshops and seminars. State agencies and groups of water users, e.g. irrigation districts, have cooperated with the Institute on research projects and on information transfer. The Oregon Dept. of Fish and Wildlife funded a project for P. C. Klingeman "Sturgeon Lake Fecal Coliform Sampling, Testing and Data Interpretation."

Special Information Transfer Assistance, Gatherings and Presentations by the Director

7/2/90	Salem, OR. Planning Meeting for "Future Irrigation Water Needs in the Willamette Valley"
7/11/90	Ontario, OR. Groundwater Group Meeting
7/17-18/90	Hermiston, OR. Fertilizer Plant Containment Facility and Groundwater Nitrate Discussion
8/1-3/90	West Point, N.Y. UCOWR Meeting
8/20/90	Pendleton, OR. Rotary Meeting, Presentation on Water
8/27/90	Portland, OR. Testimony on Hatfield Western Water Management Bill
10/3/90	Seattle, WA. Nonpoint Source Workshop Planning
11/14-15/90	Corvallis, OR. Groundwater Workshop
1/8,16,23,30/91	Portland, OR. Detergent Phosphorus Task Force for DEQ
2/5-7/91	Washington, D.C. Water Quality Initiative Workshop
2/20/91	Corvallis, OR. Meeting with State Agencies on Water Research Papers
2/21 & 5/31/91	Corvallis, OR. Salmon in the Columbia discussions
2/22-23/91	Portland, OR. Water Law Seminar at Lewis & Clark College
3/14-15/91	Bend, OR. Paper on Water Quality to Soil & Water Conservation Society
3/20-22/91	Tacoma, WA. Regional Nonpoint Water Quality Conference
4/23-25/91	Washington, D.C. NAWID Annual Meeting
6/20/91	Portland, OR. Meeting with USGS on Willamette River NAWQA

Principal Information Transfer Publications During FY 1990

WRRI Publications during FY 90

Graduate Education in Water Resources at Oregon State University, 1990-91

Directory of Water Resources Expertise at Colleges and Universities in Oregon (Prepared for September Publication)

WRRI-107 Economic Values and Product Shift on the Rogue River: A Study of Non-Commercial Whitewater Recreation.
R. Johnson, B. Shelby, N Bregenzer, September 1990

WRRI-108 Comparative Analysis of Whitewater Boating Resources in Oregon: Toward a Regional Model of River Recreation.
B. Shelby, R. Johnson, M. Brunson, November 1990

SR-90-1 A Bioeconomic Analysis of Water Allocations and Fish Habitat Enhancements, John Day Basin, Oregon.
R. Adams, P. Klingeman, H. Li

Irrigating Crops with Municipal Effluent - Plant Growth Consideration. R. Selig, B. P. Warkentin, 1990.

Water Note 1989-1 Peak Flow Prediction for Small Forested Watersheds Along the Southern Oregon and Northern California Coast. C.W. Andrus, H.A. Froehlich, M.R. Pyles, 1989

Professional Publications During FY 1989

DeNicola, D. and McIntire, D., 1990. Effects of substrate relief on the distribution of Periphyton in laboratory streams. II. Interactions with irradiance. J. Phycol. 26, pp. 634-641.

Mesuere, K., Martin, R.E., and Fish, W., 1991. Identification of copper contamination in sediments by a microscale partial extraction technique. Journal of Environmental Quality, Vol 20, no. 1, Jan-March 1991, pp. 114-118.

COOPERATIVE ARRANGEMENTS

Program development activities include many contacts by the Institute with water users and policy makers to stay abreast of statewide or local water problems. They give direction to the Institute program. The ideas are discussed with faculty members who may be able to address those problems.

Cooperation with Universities in Oregon

WRRI advertises a range of research opportunities to research personnel at all universities and colleges with water programs in Oregon. This is done by phone, by direct mailings to known individual researchers, and by additional mailings to deans of research or presidents. The FY 1990 research program was developed after solicitation of proposals from 248 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 the Oregon Graduate Institute.)

One member of the WRRI Advisory Board comes from the Oregon Graduate Institute. Next year's Board will have a second member outside of Oregon State University, from the University of Oregon.

The WRRI newsletter and the Directory of Water Resources Expertise describe programs from other higher education Institutions in Oregon.

Statewide Coordination

Statewide coordination occurs through many 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 being 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, Environmental Quality Commission, Department of Fish and Wildlife, Department of Agriculture, Governor's Watershed Enhancement Board, Department of Energy, Bonneville Power Administration, Northwest Power Planning Council, and other state and Federal agencies. These facilitate coordination of research activities to meet state needs and coordination of information dissemination to deal with problems and issues.

The Institute participated in interagency activities to deal with water-related problems during FY 1990. The Director participated in meetings on use of EPA 319 funds for water quality studies, in groundwater quality aspects of the tri-state STEEP (Solutions to Environmental and Economic Problems) erosion project, water conservation, coordination of activities in the Lower Umatilla Basin groundwater management program, and irrigation and other water management reviews. Cooperation continues with Departments of Agriculture and Environmental Quality on shallow ground water contamination problems at two sites in eastern Oregon.

Project 02 involved extensive cooperation with the Oregon Departments of Agriculture and Environmental Quality, the Soil Conservation Service and the Agriculture Stabilization and Conservation Service, the local Soil and Water Conservation District, the OSU Extension Service and Agricultural Experiment Station, and the Bureau of Reclamation. All of these agencies contributed funding to the total project.

Project 04 included inputs from the Department of Agriculture and OSU Extension Service and Agricultural Experiment Station.

During FY 1990, WRRI again benefitted from participation by state agency reviewers working with the Governing Board in the selection of projects for the Section 104 research program. Invitations were sent to fourteen state agency heads, inviting one of their senior staff members to participate in developing guidelines for the Institute research program for FY 1990, and in evaluating project proposals. Involvement of state agencies in developing the WRRI Federal research program has been very successful. The participating agencies were:

Water Resources Department
Department of Emergency Management
Department of Energy
Department of Environmental Quality
Department of Forestry
Department of Geology & Mineral Industries
Oregon State Health Division, Department of Human Resources
Department of Land Conservation and Development
Oregon State Marine Board
Natural Resources Division, Department of Agriculture
Division of State Lands
Parks and Recreation Division, Department of Transportation

Representatives of this group and the WRRI Governing Board met in Corvallis on March 1, 1990 to develop the FY 1990 program.

Regional Coordination

Program development activities in FY 1990 included regional research development discussions with the other water research centers in the Pacific Northwest. Directors of the state water research institutes of Alaska, Idaho, Montana, Oregon, Washington, Hawaii and Guam work together on water-resource matters that involve teaching, research and public service. The Columbia River system is a common concern for four of the states. Water quality, hydroelectric energy development, fishery resources and non-point source pollution for agriculture are common problems. The regional Institute directors met in Seattle on October 3, 1990, and March 22, 1991, to discuss mutual concerns and to plan regional annual workshops.

Institute Membership

Membership is open to all faculty members at universities and colleges in Oregon, who are actively engaged in water-related research and education or who wish to keep informed about such activities. Institute membership exceeds

100 faculty members. The seven state institutions of higher education are Oregon State University, Portland State University, University of Oregon, Oregon Institute of Technology, Oregon Health Science University, Eastern Oregon State College, and Western Oregon State College. Faculty at six private colleges and universities also participate in Institute programs (Lewis and Clark College, Linfield College, Oregon Graduate Institute, Reed College, University of Portland, and Willamette University).

Institute Governing Board

The Institute is guided by a Governing Board, consisting of the Director and eleven members. The Deans of the Colleges of Engineering and Forestry, the Vice President for Research, Graduate Studies and International Programs, the Dean for Research and the Director of the Agricultural Experiment Station at Oregon State University are permanent members, forming the Executive Committee. Seven faculty members from the state's universities serve three-year rotating terms.

The Governing Board members during FY 1990 were:

George Brown, Dean of Forestry and Director of Forest Research Laboratory, OSU
Thayne R. Dutson, Director, Agricultural Experiment Station and Assoc. Dean of Agricultural Sciences, OSU
George H. Keller, Vice President for Research, Graduate Studies and International Programs, OSU
S.John T. Owen, Dean of Engineering, OSU
Richard A. Scanlan, Dean of Research, OSU
James A. Moore, Professor, Agricultural Engineering, OSU
J. Douglas Brodie, Professor, Forest Resources, OSU
John C. Buckhouse, Professor, Rangeland Resources, OSU
Peter U. Clark, Asst. Professor, Geosciences, OSU
Jonathan D. Istok, Assoc. Professor, Civil Engineering, OSU
Wesley M. Jarrell, Assoc. Professor, Environmental Sciences and Engineering, Oregon Graduate Institute
William J. Liss, Assoc. Professor, Fisheries and Wildlife, OSU

Institute Administrative Staff

The Institute's administrative staff during FY 1990 consisted of three positions: the Director, an Office Manager, and an Information Transfer Specialist. Administrative personnel during FY 1990 were:

Director (0.25 FTE)	Benno P. Warkentin
Office Manager (1.00 FTE)	Janet Preble
Information Specialist (0.50 FTE)	Randy S. Selig

Ms. Selig worked during FY 1990 on publications, brochures and workshops.

TRAINING ACCOMPLISHMENTS

The Institute provides a range of education and training 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. degree candidates 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 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 specific water issue. The topics in FY 90 were: "Wetlands" (61 students registered) and "Pacific Northwest Salmon: An Endangered Future?" (54 students registered). Seminars are presented by research personnel from universities, government agencies and people in private practice. There is time for discussion of research methods and results. Seminars are open to the general public. Audiences vary from 90 to 130 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 after they leave the university.

Students also receive research training as part of the M.S. or Ph.D. thesis/project requirements. Some students receive training directly on WRRI-USDI supported projects, but water resources research and education extends beyond the directly-funded projects.

Table 2. Training Accomplishments

Field of Study	Academic Level				
	Undergraduate	Master's Degree	Ph.D. Degree	Post-Ph.D.	Total
Chemistry				1	
Engineering					
- Agricultural	(12)	(14)	(3)		29
- Civil	(12)	(13)	(2)1		28
- Environmental					
- Soils	(2)1	1			4
- Systems					
- Other					
Geology		7			7
Hydrology					
Agronomy					
Biology	1		4	1	6
Oceanography		(9)			9
Science	(15)	(14)			29
Ecology					
Fisheries, Wildlife Forestry	(1)	(15)	(1)		17
Computer Science					
Economics					
Geography					
Law					
Resources Planning					
Other (High School Students)	1				1
TOTAL:	45	73	11	1	130

1. Includes students supported on WRRI research projects.
2. Students registered for WRRI seminars are enumerated in brackets.

Water Resources Seminar

Sponsored by the
Oregon Water Resources Research Institute
and
U.S. EPA Environmental Research Lab, Corvallis

Wetlands

SEPT 27	***What are swamps, marshes, bogs, and wet spots?*** Dennis Peters, US Fish and Wildlife Service, Portland
OCT 4	***Maintaining regional biodiversity through wetland protection*** Paul Adamus, Environmental Research Laboratory-Corvallis
OCT 11	***Federal and state wetland policies*** Karen Northup, US Army Corp of Engineers, Seattle; Ken Bierly, Oregon Division of State Lands, Salem
OCT 18	***Restoring the Salmon River salt marshes: expectations and reality*** Robert E. Frenkel, Professor, Department of Geosciences, OSU
OCT 25	***Constructed wetlands for wastewater treatment*** Michelle Girts, CH2M Hill, Portland
NOV 1	***Wetland hydrology*** Richard Novitzki, Environmental Research Laboratory-Corvallis
NOV 8	***Water quality functions of natural wetlands*** Dennis Whigham, Smithsonian Environmental Research Center, Maryland
NOV 15	***Riparian wetlands for controlling nonpoint pollution*** Richard Lowrance, USDA-ARS, Tifton, Georgia
NOV 22	***Thanksgiving***
NOV 29	***A landscape perspective on wetland functions*** Scott Leibowitz, Environmental Research Laboratory-Corvallis

GENERAL SCIENCE 507G
1 CREDIT, P/N
PUBLIC WELCOME

FALL QUARTER 1990
THURSDAYS, 3:30 TO 5:00 PM
COVELL 216

For Information call WRRI, 737-4022

Water Resources Seminar

Sponsored by the
Oregon Water Resources Research Institute
and the
OSU Department of Fisheries and Wildlife

PACIFIC NORTHWEST SALMON:
AN ENDANGERED FUTURE?

March 28	Water Resource Development Impacts on Salmonids in the Columbia Basin Keith Muckleston, Department of Geosciences, OSU
April 4	Overview of Endangered Salmon in the Pacific Northwest Jim Lichatowich, Fish Biologist, Jamestown and Klallam Tribes, Washington
April 11	Columbia River Basin Fish and Wildlife Program John Marsh, System Plannning Coordinator, Northwest Power Planning Council
April 18	Why Wild Salmon? Bill Bakke, Executive Director,Oregon Trout
April 25	Legal Background and Implications of Endangered Species Act Listing Michael Blumm, Lewis and Clark Law School
May 2	Alternatives for Restoring Salmon Runs in the Columbia Basin Ludwig Eisgruber, Department of Agricultural and Resource Economics, OSU
May 9	Protecting Endangered Species: Economic Impacts in the Columbia River Basin Norman Whittlesey, Department of Agricultural Economics, WSU, Pullman
May 16	Columbia River Power Production and Conflicts with Anadromous Fish Al Wright, Executive Director, Pacific Northwest Utilities Conference Committee
May 23	Current Status of Southern Oregon Salmon Stocks Chris Frissell, Department of Fisheries and Wildlife, OSU
May 30	Salmon and their Restoration: A Native American Perspective Ted Strong, Executive Director, Columbia River Intertribal Fish Commission

GENERAL SCIENCE 507G
1 CREDIT, P/N
PUBLIC WELCOME

SPRING QUARTER 1991
THURSDAYS, 3:30 TO 5:00 PM
COVELL 216

For Information call WRRI, 737-4022

OREGON WATER RESOURCES MANAGEMENT ISSUES FOR THE 1990s

B. P. Warkentin

The Context for Oregon Water Issues

An Overview

Oregonians agree on the importance of water to their quality of life. Forestry, agriculture, and tourism, the state's largest industries, all depend on natural resources, with water as a significant component. While all agree on the importance of water, questions concerning how water should be used, and where, when, and by whom, elicit different views. Traditional uses of water for irrigation, industry, pollution control, and fisheries are now joined by new in-stream needs such as white-water boating, wind surfing, habitat for native fish, and the aesthetic role of water in landscapes. Because of water's importance for our livelihood and for aesthetics, these views often are strongly held.

The nature of water issues in Oregon is determined by climate, water laws, and expectations of the citizens. The basic water law, the Prior Appropriation Doctrine, allows removal of water from streams in amounts needed for beneficial uses, with priorities determined by the date of filing for water rights. Water rights have been issued without studies of available supply or decisions about other uses. The public need for in-stream water uses was not recognized in the past, but has come to the top of the list in the last thirty years. Most streams in eastern Oregon are already overappropriated to out-of-stream rights, especially during periods of low flow and in dry years. A transfer of water rights among uses will be required to meet in-stream uses. The 1987 legislature gave legal status to in-stream water rights. The competition between in-stream and out-of-stream uses leads to the major water issues in Oregon, and requires policy choices in its resolution.

The commonly held view is that water is a scarce commodity in Oregon: always, east of the Cascades; and during the summer on the west side. While water is recognized as a scarce renewable resource, it is managed with principles appropriate to resource extraction rather than to a scarce commodity. The price increases and substitution of other resources that would be expected for a scarce resource are not found.

Oregon Climate and Natural Rainfall Variability

Water availability in Oregon is determined by a climate where most rainfall occurs in the winter, with low evaporation. The Cascade Mountains also influence rainfall patterns in eastern Oregon. This results in high winter and spring stream flows, and low summer flows (Table 1). In-stream and out-of-stream water uses are higher in the summer, and competition becomes most acute. If the May to October flows in the Tualatin River were equal to the December to April flows, the choices on water quality and uses that are being made now would be easier.

Another major factor affecting management of Oregon's water is year-to-year variability in rainfall and, thus, in stream flows. People attempt to build low variability into all production and management systems over which they have some control. Variability is seen as inherently difficult to handle, so they rely on averages, which mask variability. Extremes of variability, drought and floods, are drought with by mechanisms intended for catastrophic events, which confirms the feeling that variability should not really exist.

Water Issues for the Citizen

Water issues can stand alone, but they also become prominent as a component of other large issues. Urban growth, increasing industrialization, water transfers, and decisions on land uses, all involve water quality and quantity. In addition to its utilitarian importance, water evokes strong feelings: for example, expectations that groundwater will be pure, clear, cold, and refreshing. Climate change has caught the public imagination, although scientists still cannot make models precise enough to predict what this change might be. Even moderate changes in temperature, however, will have major impacts on water management.

What then are the decisions that must be made about water? And what policy discussions will be needed to develop a public consensus? What "win-win" strategies can be used to resolve competition for water? Will methods known by names such as Coordinated Resource Management Planning develop the consensus that is needed for decisions? Will decisions be made by people directly involved in local issues? or will solutions be imposed from outside for reasons of economics or national policy?

Competition for Water

Old and New Uses

Competition among water users is a major policy issue in arid lands (El-Ashry and Gibbons 1988); public needs compete with private needs. Priorities placed on water use have changed over time. In-stream uses are now a desirable public good, but they were not previously given high priority.

Another example is Indian water rights being reconsidered and added to beneficial uses. These rights are senior, but not quantified. Will they be based on beneficial use such as "practically irrigable acreage," or on the amount intended when the reserved rights were first granted? Federal versus state control of water is at issue. Litigation, negotiation, and legislation are all being used with none of them making rapid progress. In Oregon, water will be pumped from the Columbia River to the Umatilla River to provide water for these rights.

The major competition for Columbia River water has been between hydroelectric power generation and fish. Removals for irrigation are another important use. Dams along the Columbia River and its tributaries have tapped a large hydroelectric potential, but have been very detrimental to fisheries, interfering both with fish returning up river to spawn and with young fish going down river to the ocean. The solutions have been fish ladders to allow a small percentage of the fish to swim upstream, protective devices at the turbines to protect fish going downstream, and fish hatcheries to stock areas above the dams. It is far from clear whether supplementing fish through hatcheries will successfully restore fish runs. This may be detrimental to the native fish.

The balance of competing uses for Columbia River water will be drastically altered if the five species of Northwest salmon are declared "endangered species." The background discussions for such a policy change need to proceed quickly.

The competing uses for surface streams in eastern Oregon are habitat for fisheries, withdrawals for irrigation, and use of riparian vegetation for grazing cattle. Industrial and urban development compete for surface water in western Oregon. Competition for groundwater occurs when one well overlaps to decrease the capacity of another, or when groundwater levels decline.

Attitudes about Acceptable Solutions

Many suggestions have been made about how to alleviate competition for water (Reisner and Bates 1989). They become concepts for public debate and for public policy decisions. Historically, solution of choice was to build dams, store water, and divert water to meet extra demands. Storage behind dams is now seen as much less desirable by the public. There are few dam sites remaining that would not have large environmental impacts. The concept of storage in the ground for release later in the season needs more discussion and testing. A second solution is conservation: amounts beyond the minimum beneficial use would be available for other uses. This is presently a popular solution to providing increased in-stream water. A third perceived solution is that water is a scarce resource whose price should be high enough to encourage efficiency and a search for substitutions. All of these ideas probably will be used in the future. Uses such as irrigation, which are in the public interest but cannot compete in price with urban uses, will require special protection.

Working with Nature

Underground water storage appears to be an acceptable solution. Underground water moves much more slowly than surface water. The rainfall or snow melt that percolates into the soil moves into the groundwater and then to streams, where it can be a source of flow late in the season when normal stream flow is low. This has the added advantages of decreasing surface erosion and decreasing summer water temperatures. Underground water has a much more uniform temperature than surface water. Under this strategy, increased in-stream water flows would result from land use practices higher in the watersheds. This would involve managing land for maximum infiltration rate through control of vegetation, managing snow distribution and snow melt through control of stand density in forests, and managing grazing. The general principles of this strategy are known, but some larger-scale testing needs to precede adoption of such practices.

It is possible to recharge groundwater during periods of high surface-water flow. This is not done on a large scale in Oregon, but has been tried on a small scale and is technically feasible in a number of areas. Economic feasibility awaits increases in water cost.

The Conservation Choice

Conservation as a way to assure sufficient water for all beneficial uses is attractive because it usually has a lower environmental impact than other strategies. Policy issues are involved because conservation requires changes in present practices. Few people are against conservation, in principle. However, the practices that have been suggested to implement conservation could change water rights under the appropriation doctrine. Water-right holders, therefore, have not embraced a policy based on conservation.

Water rights are issued, under Oregon law, for beneficial uses of water. Any water withdrawn from a surface stream and not put to beneficial use is outside of the water right. It would seem a simple matter to determine how much water is used beneficially and to divert the remainder to other beneficial uses. This is now being considered in the policy on water conservation and efficient water use for irrigation proposed by the Oregon Water Resources Department. The protracted public discussions on definitions of waste, and the revisions to include only general statements on "avoidance of waste," show that this is not a simple matter. Water removed from a stream in excess of that evaporated by the crop may have other beneficial uses or may flow back into the stream.

Increased efficiencies of water use in irrigation are possible, but they come at a price. If the price of water is low, it is prudent to use the least-expensive management methods, even if they involve using more water. When the price is high, intensive management pays. An example can be taken from the irrigated sandy land of the Columbia Basin in the Boardman area. Costs for electricity for pumping water, either from groundwater or from the Columbia River, increased sharply during the 1980s. This irrigation water now costs ten times more than water supplied from surface systems through canals in other parts of Oregon. Therefore, the incentive was present to pump less water. With leadership from the utilities supplying electric power, from the agricultural community, and from the Extension Service, methods were devised for more efficient use of water, application of water based on evaporative demand, and monitoring of application systems for maximum efficiency. Electricity had became the scarce resource, and efficient use was substituted for extra water. The end result was conservation of water.

Coordinated Resource Management

In some Oregon areas coordinated resource management planning has successfully secured protection and sustainable use of riparian zones. All groups with interests in the area shared concerns and eventually agreed on a management plan (Anderson and Baum 1987). Good ecology and good local politics are meeting in such programs as Oregon Watershed Improvement Coalition (OWIC) and Governor's Watershed Enhancement Board (GWEB).

Water Quality

The Overall Oregon Situation

Oregonians believe the overall quality of the state's water is very good; However, there are areas of concern. Microbial contamination of drinking water is the greatest source of water pollution and accounts for almost all health-related incidents. Organic and inorganic chemicals are a less-common source of pollution and a lower immediate health risk. The long-term health risks from chemicals however, are however, not as well known. Chemicals are also more frightening than microbial contamination.

Water quality problems have been documented in both surface water and groundwater. Industrial chemicals such as chromium and wood preservatives have been found in groundwater. Soil fumigants and pesticides also have moved into groundwater. Nitrate concentrations in wells in several places in Oregon exceed the drinking water standard of 10 milligrams per liter. The nitrate may come from concentrated industrial activity, but more often comes from nonpoint sources such as crop production or sewage disposal through individual septic tanks. Phosphate concentrations high enough to allow algal growth, temperature, and dissolved oxygen, are also pollutants for bodies of surface water.

Non point-source pollution, particularly of groundwater, is becoming the water-quality focus. Point sources (that is, sources that can easily be identified as coming out of a pipe) are generally under permit, if not always controlled to the level desired. Regulations are in place, and the public is generally comfortable with the procedures. However, procedures do not effectively trace amounts of pollutants such as dioxin from pulp mill effluent. The procedures for abatement of pollution from nonpoint sources are only now being developed. Education and incentives to prevent pollution, rather than regulation and subsidy, are the solutions being explored.

Restoring Groundwater Quality

The high costs and uncertain efficacy of cleanup make it easy to be pessimistic about groundwater contamination. It is difficult to be more pessimistic than the situation warrants. A number of physical, chemical, and biological technologies to clean contaminated groundwater have been suggested and are being tested. Methods to pump and treat groundwater are very expensive, disturb the surrounding environment, and are not able to decrease contaminants to desired, health-based levels. Recent reports from the Office of Technology Assessment (1989) and the Environmental Protection Agency (1989) concluded that present attempts may be technically impractical and largely misdirected. In groundwater, an ounce of prevention is worth tons of cure.

Assessment and Standards

The Department of Environmental Quality has assessed nonpoint-source pollution of Oregon waters (DEQ 1990). The quality of about one quarter of the estimated 110,000 miles of Oregon's rivers and circumference of lakes has been assessed. No nonpoint-source water-quality problems were reported on nearly one-half of these miles. The remainder had either moderate or severe pollution when considered for specific beneficial uses. Sufficient data, including measurements, were available for about one-half of these miles. Therefore, based on measurements, about 6,500 miles were severely or moderately impaired, and, another 8,500 miles were considered impaired.

Two important policy questions are (1) when are measurements sufficient to justify clean-up action? and (2) how are these decisions to be made? While assessments can be made by the experts, use of the information is an area of public policy debate. For example, the Groundwater Standards Technical

Advisory Committee of the Department of Environmental Quality is now wrestling with the problem of establishing contaminant limits for groundwater.

The difficult task of setting limits has often been solved by accepting national standards of the Environmental Protection Agency (EPA). Beneficial uses and water conditions vary from region to region, so national standards often do not set appropriate limits. Sufficient information usually is not available to set standards. The "need for further study" often has been used to postpone action. The high cost of increasing water quality (for example, to meet the 1992 EPA drinking water standards) also can delay local water quality action.

The feeling that rational policy is lacking in environmental quality considerations is not new. This has been a constant factor in the 20 years since the enactment of national legislation for improvement and protection of the environment. Is the problem so severe that attempts at amelioration have to be begun before total information is available? Environmental protection actions are being sought between the end-points of total information for decisions and decisions based only on good intentions.

Added to this is lack of agreement on the desired level of restoration. Should water quality be restored to pristine conditions, to original natural conditions, or to conditions that minimally meet present or future beneficial uses? Should pollution of surface water and groundwater be allowed up to the limits set for the most critical beneficial use? The conservative position would be to have as little contamination as possible to allow for future uncertainties. This is trading higher present costs for possible higher future benefits.

Regulations for Water Quality

National and regional efforts to improve and protect water quality have increased over the past 40 years. Originally, the concern was for surface water quality and point sources of pollution. The accepted solution was to use the best available technology. Regulations were put in place, cost sharing was undertaken to finance changes, and a competent industrial effort built up to provide the best available technology. Recently, it has become evident that the best available technology will not always reduce contaminants to the level required for beneficial uses. Phosphate in the Tualatin River is such an example. The decisions now will be based on regulation of water quality.

In Oregon, when surface water or groundwater contaminant levels exceed the standards set for beneficial uses, certain requirements have to be met. Local committees are set up to evaluate and recommend practices and policies to clean the water to acceptable levels. Streams that do not meet the standards are "water quality limited streams." Changes are required to bring levels of contaminants in these streams down to the levels required for beneficial uses, through a process involving assignment of total maximum daily load, and management to achieve these levels. Contaminated groundwater leads to designation as a "groundwater management area," with a local committee responsible for drawing up a management plan to decrease contaminant levels. Given the multiple uses of water and the multiple attitudes toward water, in addition to the difficulties of setting limits on which everyone can agree, this becomes a formidable task that requires considerable public energy.

Nonpoint-source pollutants have been viewed differently from point sources. It is very difficult to deal with thousands of small sources through regulation and enforcement. A "big stick" held over an outlet is fairly effective, but thousands of "small sticks" held over thousands of nonpoint-sources is not effective management. Education and incentives are seen as more effective ways to control nonpoint-sources. When the education programs have been carried out and the incentives applied, there will probably still be situations that will not respond, so regulations are always in the background. Because it is easier to deal with regulations, there is a tendency to try to make point sources out of nonpoint sources wherever possible. This may be possible with some agricultural and forestry operations.

There is no easy one-time solution that will take care of the nonpoint-source pollution problem once and for all. Each new management system has to be evaluated to minimize nonpoint-source pollution. This makes it a continuing activity, and, therefore, one for which neither the public temper nor the legislative process is particularly well-suited. People like to define problems, solve them by whatever means agreed upon, and then forget about them and go on to the next problem. This will not work for nonpoint-source pollution because it is the result of so many daily activities.

Strong government action through regulations or incentives, has generally been assumed necessary for water quality improvement. A newer idea is that these changes can be shown to be advantageous and can be justified using the economic calculations normally used for changes in processes (Nat. Wildlife Fed. 1989). It is argued, therefore, that since environmental cleanup can be justified economically, it can be left to the marketplace for regulation. Most people feel more comfortable with regulations from the marketplace, rather than from the government. A large industry has been built in the private sector for environmental monitoring and for the manufacture, installation, and use of pollution-abatement devices for point-source pollution. It is not yet clear whether free-market economics will also apply to nonpoint-source pollution.

Impact of Global Climate Change on Water Issues

The increased global warming that is anticipated will have a profound effect on water resources management. Average temperature increases of 2 to 5 degrees Fahrenheit would mean much more than a little extra energy needed for air conditioning. Such a change would alter natural cycles, change the effectiveness of the technology in use, and require major changes in the institutions for managing water for beneficial uses. Changes in forest growth and in requirements for irrigation for food production would require major changes in technology and major modifications in the institutions to deal with them. Rises in sea level and estuaries would displace communities, transportation routes, and industries (Oregon Task Force on Global Warming 1990).

Global Warming

The greenhouse phenomenon, that is the trapping of solar radiation at the earth's surface by increases in concentration of "greenhouse gases," is real. There is no significant debate about the nature of the process, nor about the observation that CO_2 levels in the atmosphere have gradually increased over the past hundred years. What is still very much in question is whether global temperature increases will result from this increase in greenhouse gases. Neither the models for global climate change nor the methods of determining average temperature are yet sufficiently precise to answer that question.

Climate Variability

What is fairly well established is that during the past decade above-average summer temperatures have occurred in the continental United States, and that, in mid latitudes, the last 30 or 40 years have been a period of lower than normal climatic variability. The extremes in temperature and precipitation have not been as great as they were at other times within recorded weather measurements. Water policies have been used in a period of low variability, and the policies may need to be modified if this variability increases again.

People and institutions can generally respond adequately to slow, gradual changes. Natural changes during several human generations can be dealt with satisfactorily. Rapid changes and rapid fluctuations make adjustment much more difficult.

The response has been to decrease variability to the greatest extent possible in every activity and standardize all aspects of people's lives--from food, to transportation, to the allowed temperature comfort zone in buildings. One of the attractions of outdoor adventure probably is in accepting the variability associated with natural phenomena. Many aspects of climate variability will continue to be beyond control. Only limited control is possible over flood, and less over drought. The question is how can institutions and management systems be designed to cope with this variability? Variability is a characteristic of natural systems. Will it always be an economic advantage to reduce variability?

The Water Management Issues

While the models of climate change are not yet adequate to predict when and how much global warming will occur, it would seem prudent to start examining some "what if" scenarios. There are at least three issues in water resources management related to climate change.

First, there would be greater water losses and greater difficulty in achieving efficiencies of water use and re-use due to higher runoff, higher evaporation, and the higher costs of dealing with extreme events. Losses due to droughts, floods, and other natural disasters are due to extremes, and would increase. Planning a technology that works with extremes is different from decreasing the extremes to make technology work.

Second, food production would depend more on irrigation. Irrigation is a method for assuring a regular water supply to crops, and thereby decreasing the year-to-year variability of yield. The ability to decrease variability in food production by irrigation has been part of the success of the food-production system. A shift to higher temperature or to greater variability would affect competing uses for water, for example, in the Willamette Valley.

Third, education and training for water resource managers would need to be changed to incorporate planning for greater and uncertain fluctuations. Past averages would no longer be a useful guide to design of future systems.

The Concept of Sustainable Development

Technology and Sustainable Development

It is widely argued that the present increases in rates of resource use are not sustainable. Degradation of the environment caused by human activities will eventually restrict those activities. A conflict between the production of goods and services and the long-term ability of our natural systems to provide the resources must be faced. Demands must be decreased to match the amount that resources can provide, without irreversible damage, on a long-term sustainable basis.

These are not new ideas. The difference is the concept that economic growth and use of more technology can attain this stage of sustainable development. Environmentally sound growth, through the use of appropriate technology, would provide the goods and services at an adequate level of economic activity. The argument is that past failures were not due to economic growth and use of technology, but to institutions. If goals and laws on resource use can be changed, then sustainable systems for the use of natural resources can be developed. Two components of that change are increased management and conservation (Reilly 1989).

The argument for sustainable development has been made on a global basis in the report of the World Commission on Environment and Development (1987), usually referred to as the Bruntland Commission, after the Norwegian statesperson who headed the Commission. Previous concepts of sustainable development required that economic activity decrease to some sustainable equilibrium value. The present debate on sustainable development generally includes a large technology component, although the technology will be more benign than that used previously. Ideas of sustainable economic development are being investigated in many countries.

Toward an Equilibrium in Resource Use

No good historical examples exist of equilibria such as those envisioned in sustainable development. The history has been of going from one disequilibrium to the next (Castle 1990, Smith 1990). People become convinced that they cannot continue in a particular direction, but the change is not toward equilibrium. The institutions, including laws and governmental systems, are set up to react to an undesirable disequilibrium and to put in place forces that will lead to another disequilibrium in the future. The immediate effect appears to be one of having "solved the problem." The long-term commitment required to work toward an equilibrium is not part of the present social system.

Water is a resource that is well-suited to sustainable development. Substitutes are not easily found for water. Technologies for conservation and for more-efficient use could assure water needs, even for a doubled population.

Concepts on sustainable development need to be evaluated closely, and public debate should be encouraged.

Policy Choices for the Immediate Oregon Water Issues

Low Summer Flows

Several concerns are grouped under the issue of low in-stream water during late-summer months. Water is inadequate for the desired uses of irrigation, fish habitat, recreation, and dilution of waste water. This water issue affects the most people and has the largest influence on quality of life in Oregon. The potential solutions (table 2) include structures, management, and changes in water allocation.

The policy choices involve evaluating the benefits of water storage in dams against the costs of construction and of environmental degradation, incentives for conservation, assigning in-stream water rights, and incentives or regulations for land management on a watershed scale. All of these decisions must be made through the political process. Federal funding for large water-storage projects has stopped. The state of Oregon needs to decide whether state funds will be used for these projects. Funding for land management to store water in the landscape may be easier to justify.

Where production practices or technologies have changed, original water-right amounts may be too low or too high for present uses. Rights to remove water for irrigation of crops is the main issue. If rights exceed present needs, which often can be the case, the water is not used for "beneficial" purposes as required in the water right and can be termed "wasted" water. This is obviously a very sensitive issue. However, adequate records are not required to be kept, and local watermasters do not have the resources to manage water in this detail. Enforcement has not been a major factor in water management.

A determination of whether such excess water exists and, if it does, whether to use it for in-stream or other purposes, will require a policy decision to spend more money to identify all water rights, measure water use, monitor legal uses, and enforce regulations that are agreed upon. There is not yet agreement on definitions of waste, of conservation, or of the need for more management.

The conservation choice requires better information on amounts of water presently used and amounts needed for different beneficial uses. The land management choices require major demonstration and monitoring projects, as well as incentives and regulations on land use related to water management.

Some basinwide planning has been conducted in Oregon. A 25-year-old study (State Water Resources Board 1969) described water in all the basins. The

John Day Basin was studied more intensively in 1986-88. The effort does not meet the need for information required for water management.

Projects to provide water for new needs must be funded. Public water needs likely will be met through public funding. The public attitude is against increased property taxes or income taxes, but surveys indicate a public willingness to pay for environmental improvement. Perhaps "green taxes" can be used, for example, to provide in-stream uses. This is a policy choice for citizens and their representatives.

This is an urgent issue. The management solutions have a long lag time before change is seen, and the competition for water during low-flow months will result in ever-increasing rancor. Potential changes in use of Columbia River water that could be adapted to protect salmon in the upper basin is an immediate urgent issue, but not the only issue of competition for water in Oregon.

Water Quality

Oregon has a number of "water quality limited" streams (table 3)--streams that cannot support the desired beneficial uses because of high concentrations of one or more pollutants. These limitations occur mostly during summer months. Increased flow would dilute the concentration of pollutants. The policy options for increased flow are discussed in section 6a above.

The other main solution is decreased additions. Point sources are most easily controlled at source. Waste water treatment facilities control the amounts of organic matter, measured as biological oxygen demand. Nutrients are more difficult to remove. An important issue now is phosphate removal. Excess phosphate in water bodies can lead to undesirable growth of algae. Phosphate can be removed from waste water at sewage treatment facilities; the amounts coming into waste water can be decreased (e.g., by a ban on phosphate in detergents), or the waste water can be used for crop growth, where the phosphate becomes a resource to be absorbed by plants.

Phosphate also reaches surface water bodies in sediment from nonpoint sources. Land use practices (best management practices) can control this source.

Water quality is an immediate issue. Large expenditures will be required from most communities to meet waste water effluent standards. Strategies with the best benefit/cost ratios must be chosen.

Groundwater Quantity

When the rate of groundwater removal by pumping exceeds recharge, groundwater levels drop. This is happening in several aquifers in Oregon (table 4). A temporary solution is to dig deeper wells. Nondepletion of the resource requires either augmented recharge or decreased withdrawals to match recharge rates. Large-scale recharge would require public funding for a major project. Regulations, usually on new uses and on drilling new wells, are needed to decrease the amount of water withdrawn. Groundwater use is often a response to inadequate surface water; uses of ground and surface water are related.

Groundwater Quality

Point sources of groundwater pollution come from industrial uses of chemicals: wood preservatives; heavy metals, such as chromium for plating; fertilizer plants; cleaning solvents; and petroleum products. The pollutants from effluent disposal or from spills move through the overlying soil to the groundwater. Oregon has several hazardous waste sites that come under federal regulations. Leachates from landfills or confined animal-feeding operations are also considered point sources of pollution. Nonpoint-source pollution comes from land use activities in agriculture, forestry, and septic tank leaching fields.

Point sources are generally controlled through regulation. Nonpoint-sources can be identified in the aggregate and controlled through land use changes. This is more difficult technically and is generally considered more undesirable politically. Instead, education and incentives are used.

The cost of cleaning contaminated groundwater is much larger than the cost of cleaning surface water. Recent experience with hazardous waste sites emphasizes this fact.

Policy choices require finding the best mix of education, incentives, and regulations. Education is a long-term solution that requires a public willingness to wait. All choices involve costs. The best plans are those that are drawn up locally and have local support.

Wetlands

The importance of wetlands in maintaining environmental quality and diversity has led to regulations to prevent conversion to other uses. Discussion of the purposes of the regulations have become lost in arguments over identifying and defining wetlands. The policy choices involve decisions on the relative values of different uses for wetland areas.

Policy Choices for Long Term Oregon Water Issues

Long-term water issues are imbedded in the larger issues of changes due to global warming, the possibility of sustainable development, and the changing pattern of crop production in the United States and the world. They require national and international action as well as local responses.

The immediate policy choices (table 5) are to encourage the discussion and the education required for public understanding of the issues and a public acceptance of solutions. Avoiding these issues now will make their eventual solution more difficult.

Global Warming Deterrents

The education and planning initiatives required to prepare for possible global warming are outlined in the draft report of the Oregon Task Force on Global

Warming (1990). Oregon can make decisions to decrease greenhouse gases through actions such as regulating the use of chlorofluorocarbon gases (CFC's). Public transportation options to decrease automobile emission gases can be encouraged through incentives and taxes.

Sustainable Development of Water Resources

It is never easy to focus on long-term issues when there are critical short-term concerns. Despite this, discussions and education programs must begin to examine water management for long-term sustainability. The policy choice is to find the specific programs to achieve this understanding.

Future Needs for Irrigation Water

Several changes that are now evident indicate that more-intensive crop production, requiring irrigation, may be practiced in the Willamette Valley in twenty years. Global warming is one such change. Another, that may be even more important, is the decreasing availability of water and land for intensive crop production in southern California. Those crops may be grown in Oregon in the future.

The policy choices are in allocation of water. If these future needs materialize, water should be retained for agriculture now, rather than face the need to restrict other uses in the future.

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Table 1

Flow Characteristics of Representative Oregon Streams

River	Month	Minimum	Maximum	Mean
Before Regulation (1910-1941):				
Willamette River, near Salem	January	10,820	97,720	43,070
	August	2,653	7,766	4,131
	Annual	13,670	35,220	21,290
After Regulation (1969-1982):				
	December	6,780	91,810	55,450
	July	6,018	10,610	7,619
	Annual	9,792	37,960	24,690
Tualatin River at Farmington - 1940-1958	December	337	7,425	2,929
	August	0.8	99	50
	Annual	651	2,327	1,355
Rogue River at Agness - 1961-1976	December	4,186	43,980	11,530
	July	864	2,738	1,741
	Annual	3,454	11,990	6,623
Umatilla River near Umatilla - 1929-1982	March	154	3,678	1,028
	July	1.3	149	21
	Annual	78	981	443
John Day River at McDonald Ferry, 1906-1982	May	533	13,180	5,176
	August	5.7	588	183
	Annual	603	3,850	2,036

Note: All numbers are cubic feet per second

Source: U.S. Geological Survey, 1984

Table 2

Immediate Water Issues in Oregon

Issue	Solutions	Policy Concerns/Choices
Inadequate in-stream water	Dams	Project Costs Environmental Degradation
	Decreased removal	In-stream water rights conservation, water rights
	Riparian management	Land management Land use restrictions
Water quality of Streams	Increased flow Decreased pollutant additions (point and nonpoint-sources)	See above Source control Alternatives to in-stream disposal Land use, best management practices
Declining ground-water levels	Augment recharge Decrease withdrawals Integrated management of ground and surface water	Large project funding Regulations Education
Groundwater quality	Prevention of pollution Cleaning groundwater	Education Regulation Appropriate Technology
Wetlands	Retaining wetlands	Removing wetlands from other uses
	Constructed wetlands	

Table 3

Partial List of Water Quality Limited Water Bodies in Oregon

Water Body	Quality Parameters
Tualatin River	Bacteria, nutrients
Yamhill River	Algae, nutrients, pH
Bear Creek	Dissolved oxygen, nutrients, bacteria
Lake Oswego	Dissolved oxygen, pH, algae
Garrison Lake	Weeds, nutrients, algae
Umatilla River	pH, solids, nutrients
Klamath River & Lake	pH, algae, nutrients
Coquille River & Estuary	Dissolved oxygen, bacteria
Pudding River	Dissolved oxygen, bacteria

Note: Total maximum daily loads have been established for the first five.

Source: Oregon Department of Environmental Quality, 1990 Water Quality Assessment Report; Draft, October 1990

Table 4

Oregon Aquifiers with Declining Groundwater Levels

Christman Valley/Fort Rock

Umatilla Basin

- Butter Creek
- Stage Gulch
- Ordinance
- Ella Butte

Mid-Willamette

- eight isolated areas of basalt aquifiers
- some gravel aquifiers near Sandy/Boring

Tualatin

- Cougar Mountain/Bull Mountain

Dalles and Moser Creek critical groundwater areas

Cow Valley

There are several methods for obtaining mass balance measurements. We used the stratigraphic system, where the change in mass/unit area is measured relative to an isochronous reference surface, where this surface is taken as the glacier surface at the end of a particular year's melt (summer) season.

Collier Glacier is 2.4 km long, has an average width of 1.2 km, and increases in elevation from 2220 m at its terminus to 2805 m at its head. From detailed, small-scale (ca. 1:5,000) topographic maps of the glacier obtained by field surveying and low altitude aerial photography, we compiled the map on a Geographic Information System (GIS) for further data analysis. In late September, we deployed a network of aluminum or PVC stakes on the surface at intervals of 1 stake/25 m increase in elevation (ca. 24 stakes for the Collier Glacier) along the presumed primary flowline running down the long axis of the glacier. Subsequent networks of stakes were deployed at the 100 m intervals normal to the primary stake network to the lateral margin of the glacier. The location of each stake on the glacier surface was surveyed precisely and plotted on the GIS base map.

Stakes in the ablation area were set in holes drilled into the ice, and the distance between the top of the stake and the ice surface was measured at the beginning and end of the balance year. Dye and/or some permeable material will be used to mark the reference surface in the accumulation area.

At the end of the winter season, the winter balance will be determined in the accumulation and ablation areas, measuring the snow accumulation at the stakes above the initial datum. Pits will also be dug to obtain samples for density measurements, and mass accumulation will be converted to water equivalent.

At the end of the 1989-1990 balance year, we will measure the net balance over the glacier surface. In the accumulation area, we will measure the thickness of snow remaining after the summer season. Pits will be dug to the reference (initial) surface, and snow and firn densities will be measured. In the ablation area, we will measure the distance between the top of the stake and the ice surface, which will be greater than at the the beginning of the balance year because mass has been lost. The summer balance is obtained by subtracting the net balance from the winter balance. After the net balance for each point is determined, we will plot the data on our GIS base map and draw contours of equal net balance. From this, we can calculate the net balance and the average net balance.

All data will be evaluated on the basis of maps drawn using the GIS base map and the graph of net balance against elevation. The Department of Geosciences has a complete GIS laboratory. Mass balance data will be analyzed statistically using conventional methods to evaluate the precision of the mass balance estimates. The data will then be evaluated with respect to climate (precipitation and temperature) for each balance year. Results will be written up and submitted for journal publication.

<u>Principal finding and significance</u>:

We have completed preliminary mass balance studies of the Collier Glacier for the 1989-1990 balance year, and have installed a network of PVC stakes for measurement of the 1990-1991 year. Because of unexpected logistical difficulties in reaching the glacier during the spring season, we were unable to obtain obtain winter balance measurements. We were able to measure ablation and accumulation at the end of the 1989-1990 balance year, however, and thus calculate the net balance for that year. We will be obtaining similar measurements this October for the 1990-1991 year. Evaluation of the data shows that the Collier Glacier had a strongly negative mass balance for the 1989-1990 year, with