Water Resources Research Institute
Annual Technical Report
FY 2002

Introduction

In 2002, Oregons Center for Water and Environmental Sustainability (CWESt) focused efforts on three programs:

1)The Water Resources Program administrates interdisciplinary and multi-agency watershed education and water resources research programs in Oregon and the Pacific Northwest.

2)The Groundwater Cleanup and Hazardous Substance Outreach Program studies public perceptions of cleanup strategies and provides information to communities affected by hazardous waste sites and groundwater contamination.

3)The Sustainable University Program promotes and facilitates a wide range of interdisciplinary research, information dissemination, and project and agency coordination related to natural resources and environmental sustainability.

During FY 2002 the CWESt program included four new research or information transfer projects funded by the USGS 104B program and four projects that were carried over from the previous year.

CWESt also sponsored and participated in many conferences and seminars, participated in cooperative research efforts with several federal agencies, adminstrated a graduate minor in water resources, provided research internships for undergraduate and graduate students, hosted educational web sites, and produced several publications.

CWESt Goals and Objectives

The Centers overall long-range goal is to assist in the sound management, sustained use, and protection of the States waters and water-dependent resources. Specific long-range goals of CWESt 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.

The objectives of the Center for Water and Environmental Sustainability, similar to those originally formulated in 1959, are to:

+ understand Oregons current and future water resource needs;

+ identify areas where research, education, and technology transfer are required;

+ assure recognition of capabilities of water resources research and education;

+ initiate multidisciplinary research in areas of need;

+ provide information on water resources to decision makers through reports and workshops; and

+ promote and support multi-disciplinary graduate education programs in water resources.

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 Center activities emphasize multi-disciplinary, problem-oriented research and encourage interdisciplinary activities in support of that research.

Research Program

Temperature Effects of Streambed Heating

Basic Information

Title:	Temperature Effects of Streambed Heating
Project Number:	2002OR2B
Start Date:	3/1/2002
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	Oregon 1st
Research Category:	Water Quality
Focus Category:	Models, Sediments, Water Quality
Descriptors:	TMDLs, water quality modeling, Bull Run River, temperature modeling
Principal Investigators:	Scott A. Wells, Robert L. Annear

Publication

Title: Modeling Streambed Heating in Shallow Streams

Problem and Research Objectives:

The goal of this research is to examine the influence of streambed heating on stream water temperatures and incorporate a dynamic streambed heating algorithm in the CE-QUAL-W2 water quality model.

The objectives of this research are:

- Monitor streambed temperatures in the Lower Bull Run River to characterize vertical, longitudinal and lateral temperature gradients in different substrates.
- Monitor environmental factors influencing the river heat budget such as meteorological conditions, vegetation characteristics, light attenuation, and substrate geologic characteristics.
- Collect bathymetric cross section data to support model development.
- Conduct experimental work in a controlled environment to reduce the influence of wind, variable flow, and uncertainties with the substrate material.
- Develop a three-dimensional streambed heating algorithm for incorporation in the water quality model, CE-QUAL-W2 model.
- Implement the modified W2 model and calibrate it for the time period when field data were collected.

Methods, Procedures, and Facilities:

There research work involved two components: A field component which was conducted during the summer of 2002 and an experimental lab component conducted during the fall of 2002.

Field Work

Bathymetric Data

Bathymetric cross-sections were collected at nine locations in the field study reach on July 25th and July 26th 2002. Cross-section elevations were tied to a benchmark located on the Rt. 14 Bridge in the middle of the field study reach. The river channel cross-sections were combined with the stream bank topography from a U.S. Geological Survey (U.S.G.S.) Digital Elevation Model (DEM) to generate a contour plot of the river bathymetry. The contour plot was then sliced into 10 pieces to develop the CE-QUAL-W2 model segments.

Stream Temperature Data

Stream temperature data were collected at two locations upstream of the Rt.14 Bridge using OnSite StowAway temperature logger, recording at 10-minute intervals. The U.S.G.S. monitored one location downstream of the bridge at 15-minute intervals using a thermocouple. The two upstream monitoring sites upstream included replicate thermistors. The data collected at the sites were used for the model upstream boundary condition and for calibrating the model.

Streambed Temperature Data

Streambed temperatures were monitored at five locations in the study reach. Three locations were monitored above the Rt. 14 Bridge in cobble substrate (Probes 1 to 3) and two locations were monitored below the bridge were in bedrock substrate (Probes 4 and 5). The temperature probes were constructed

using 6.35 mm diameter PVC pipe with a length of 1.25 m with 6 glass bead thermistors, spaced 20 cm a part. The probe was filled with silicone for waterproofing. Figure 1 shows one of the completed probes. Two probes were placed in the field and after a week or more they were moved to a new location.

The probes placed in the cobble reach were placed at a maximum depth of 0.50 m due to the compact nature of the substrate and the inability of equipment to effectively penetrate deeper. The probe was placed in the hole, and the substrate replaced in the reverse order that it was removed. Figure 1 shows two probes placed in the streambed after the holes were filled. The substrate then settled around the probes, which was confirmed when the probes were removed a few weeks later. Only the bottom three thermistors were buried in the substrate.

Two probes, Probes 4 and 5, were placed in bedrock using holes drilled by the City of Portland, Water Bureau. The holes were drilled to depths of 1.05 and 1.0 m with diameters between 25 and 32 mm (1.0 to 1.25 in). The probes were placed in the holes so the top thermistor was just below the substrate – water interface as shown in Figure 1. The probe was pressed against the side of the drilled hole with a long narrow piece of wood, and then sand was used to fill in the backside of the hole.

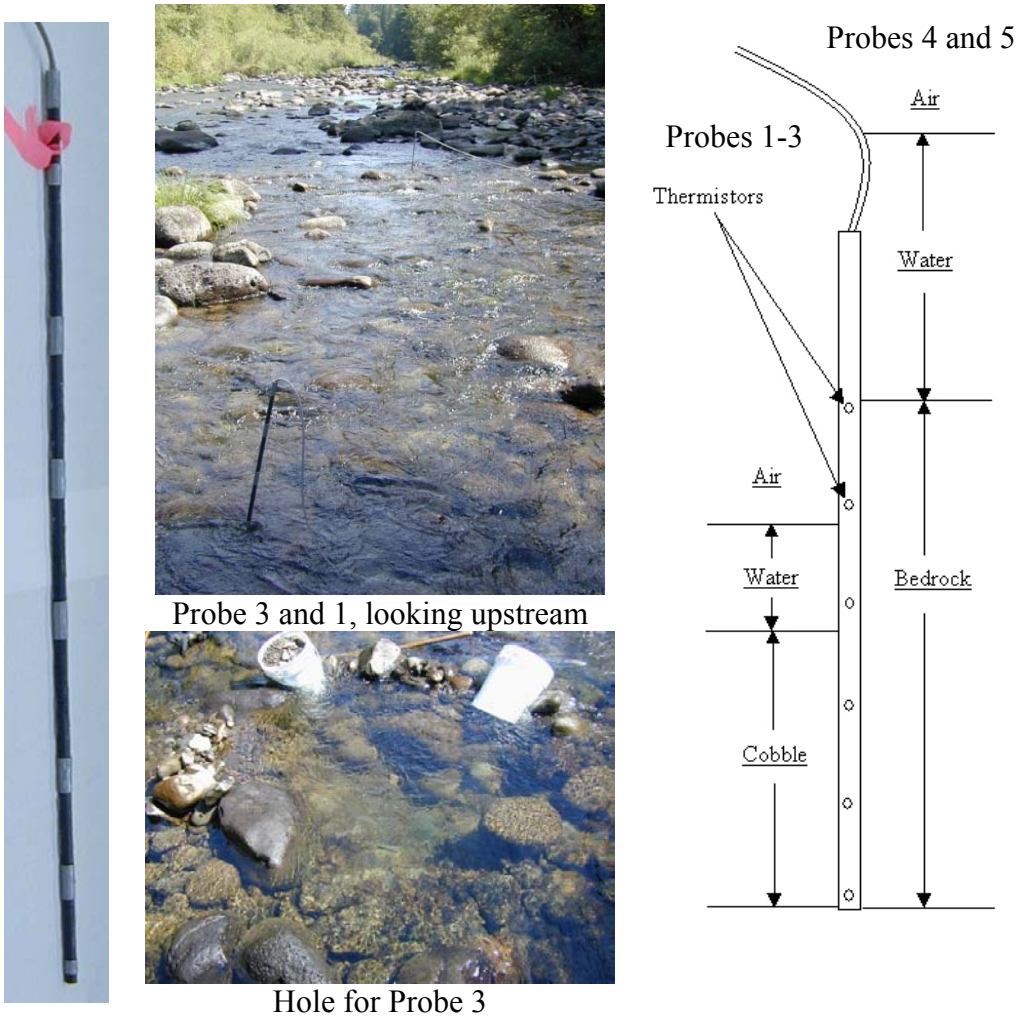

Figure 1. Streambed temperature probes, probes in the cobble went to a depth of 0.5 m below the sediment-water interface, probes in the bedrock were placed to a depth of 1 m.

Probes 1 and 2 were placed for two weeks to examine lateral variability on streambed temperatures. Probe 2 was then removed from the substrate and was placed downstream of Probe 1 to investigate longitudinal variability in streambed temperature (re-designated as Probe 3). After 2 weeks the two probes were removed and placed at the two bedrock sites Probes 4 and 5.

Streambed Substrate and Geology

The streambed in the reach transitioned from cobble and boulder at the upstream end to primarily bedrock at the downstream end. The streambed substrate in the study area can be characterized by three reaches. Reach 1 is characterized primarily by boulders and large cobble and represents the toe end of a plane-bed reach with riffle to run unit characteristics in low flow. Reach 2 substrate is characterized primarily by boulders and bedrock with a very uneven bottom surface capturing some cobble. The reach is a turbulent cascade with a slope of 2.4%. Reach 3 is characterized as a mid-channel pool reach with the deepest parts of the pool closer to head of the reach. The substrate is primarily bedrock with boulders and large cobbles predominately on the sides and banks. The toe of the reach slopes upward and is dominated by large cobble and boulders overlying the bedrock.

- Bedrock substrate

The underlying river channel geology has been discussed by the U.S.G.S. (1996), Baldwin (1981) and Beeson and Moran (1979). The U.S. Forest Service mapped the river channel geology in 1997 as Columbia River Basalts. The bedrock substrate in the Reaches 1 and 2 (and elsewhere in the basin) are where the Columbia River Basalts have been exposed and remain resistant to fluvial erosion (U.S.F.S., 1997). In Reach 3 the holes were drilled in the bedrock to place two temperature probes. Samples of the bedrock substrate were collected during drilling. The bedrock particles are dark gray and appear to be fine grained indicating the substrate is likely part of the Columbia River Basalt Formation.

- Boulder/Cobble substrate

Three temperature probes were placed in Reach 1 for the first few weeks of the field study. Boulders and large cobble substrate dominated this reach and are believed to by lying over the Columbia River Basalt seen in Reaches 2 and 3. On August 18, 2002 Ground Penetrating Radar was used on two cobble substrate sites to determine the depth of the cobble overlying the bedrock. When digging the holes to place the temperature probes the particle size was observed to decrease with depth.

Meteorological Data

Meteorological data were collected at two locations in the lower river: the U.S.G.S. gage station (14140000) and on the Rt. 14 Bridge. The monitoring site on the bridge measured solar radiation at 10-minute intervals. The monitoring site at the U.S.G.S. gage station was maintained by the City of Portland, Water Bureau and measured air temperature, relative humidity, wind speed and wind direction at 15-minute intervals.

Light Attenuation Data

Light attenuation data was collected on July 25th and September 20th, 2002 at 21 monitoring sites. Data collected on July 25th used a spherical photosynthetic active radiation (PAR) sensor and measurements were taken above the water surface and at the bottom of the water column. Data collected on September 20th used an incident PAR sensor and measurements were taken just below the water surface and at

several depths below the surface. The incident sensor was also inverted to measure radiation reflecting off the substrate.

Flow and Dye Study Data

The large cobbles and boulders characterizing Reach 1 indicate there is the possibility of hyporheic flow. If hyporheic flow exists then the water would emerge at the end of Reach1 where the cobble and boulder layer overlying the bedrock ends in Reach 2. A dye study was conducted on September 5th and surface water and groundwater levels were measured to investigate this issue.

- Dye study

A dye injection probe was placed in the streambed by digging a hole similar to the holes used for the streambed temperature probes. The probe consisted of a 1.27 cm diameter PVC with a hole drilled one cm from the bottom where a small tube with inner diameter of 3 mm was inserted and run on the inside of the PVC pipe to the top. The probe was placed in the streambed on August 30th and air was injected to ensure the tube was not blocked at the buried end. The dye study was conducted on September 5th to allow the substrate surrounding the probe to settle. The injection tube was a depth of 0.47 m below the surface of the substrate, similar to the deepest thermistors buried in the streambed. 48 ml of Rhodamine WT dye was injected in the tube at 8:15 am and then flushed with 20 ml of water. Based on visual observations in the tube there was no red dye present after flushing. Water samples were then taken downstream of the injection point at the three locations. Site "A" was located 7.6 meters downstream of the injection point. Site "B" was located 33 m downstream of the injection point, where the cobbles overlying the bedrock end. If the dye was to be transported downstream in the substrate then it would emerge near this monitoring site. Site "C" was located 0.3 m downstream of the injection point to monitor if the dye immediately surfaced.

- Water Level Measurements

The dye injection probe was also used to measure the water levels in the substrate and the river water level to determine if there was a gradient. The dye injection PVC pipe had a large enough diameter to place a rod in the pipe and measure the water level relative the top of the pipe. The river water level on the outside of the pipe was also measured relative to the top of the pipe.

Vegetative and Topographic Shade Data

- Vegetation data

The vegetation data collected consisted of vegetation (tree) heights and the distance from the river centerline to the vegetation. A field person walked along the middle of the stream channel and used a laser range finder to measure both tree heights and the vegetation offset distances. The vegetation heights were converted to vegetation top elevations by adding the bank elevation to the tree height. The distance from the river centerline to the vegetation for each bank was used directly in developing the model file.

<u>Lab work</u>

Several lab experiments were conducted to demonstrate streambed heating processes in a more controlled environment to reduce the influence of topographic and vegetative stream shading, cloud

cover, atmospheric dust and moisture attenuation, wind, and variable flow. The results of the experiments will be used with the streambed heating algorithm to test the algorithm's ability to handle a more simplified streambed heating case and to demonstrate the basic streambed heating processes.

Experimental Design

The experiment was designed to monitor the temperature of substrate material in 2 buckets (5 gallons each) with overlying water exposed to constant radiation during the day and none at night. Each bucket had 4 temperature probes embedded in the substrate and 1 in the water above the substrate. The buckets were placed in a larger tub, which was filled with sand to provide a heat sink. The outside of the buckets and the air were also monitored with thermistors to better understand the buckets' boundary conditions. All thermistors recorded temperature at 5-minute intervals. The radiation was supplied by a narrow spot beam stage light, which produced approximately 1010 W/m^2 at 2.3 m above the experiment. Radiation was measured at 10-minute intervals with a pyranometer placed between the two buckets. The lamp was turned on for 8.5 hours a day using a timer. Figure 2 shows a drawing of the experimental design with thermistor locations identified by numbers and letters.

Each bucket was filled with substrate material to a depth of 20 cm and then filled with water to a depth of 6 cm. Evaporated water from the buckets was replaced with water at room temperature. The first experiment used one bucket filled with sand and the other with gravel. The second experiment used one bucket with sand and gravel and the other with sand. The third experiment had both buckets filled with concrete, one painted white and the other painted black.

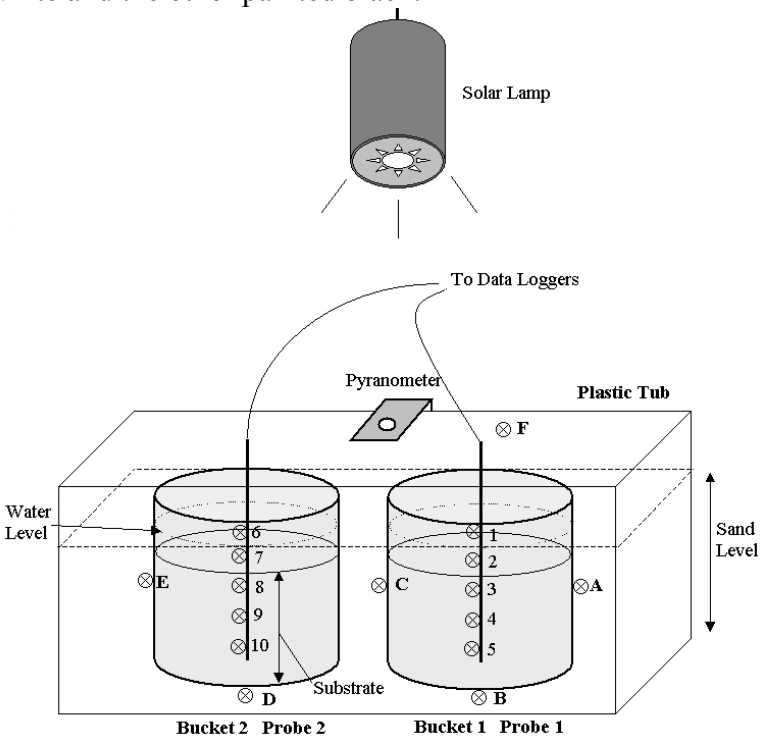

Figure 2. Experimental lab design

Principal Findings and Significance:

The research work is currently still in progress with completion anticipated by the end of 2003. The field and lab work have been completed but the modeling work is still in progress. The fieldwork results

show there is a vertical temperature gradient in both the cobble and boulder streambed and the bedrock streambed. Figure 3 shows an 8-day period for one of the probes placed in the cobble and boulder streambed. The figure shows cooler temperature further down in the streambed material. Figure 4 shows a similar plot for the bedrock material. Temperature measurements near the sediment-water interface are similar to the water temperature measurements but deeper in the streambed the diurnal fluctuations are minimized and several degrees cooler. The lab experiments conducted also showed decreasing temperatures with depth. Figure 5 shows temperature measurements recorded in the sand and gravel media experiment conducted in the lab. The plot shows diurnal fluctuations in temperatures but the results indicate there are slightly different processes influencing the temperature measurements at larger depths. Because the lab experiment is based on a small amount of "substrate" material the sand surround the bucket may be influencing the temperatures recorded in the bucket. The data collected in the field and in the lab will be used to test the streambed heating algorithm.

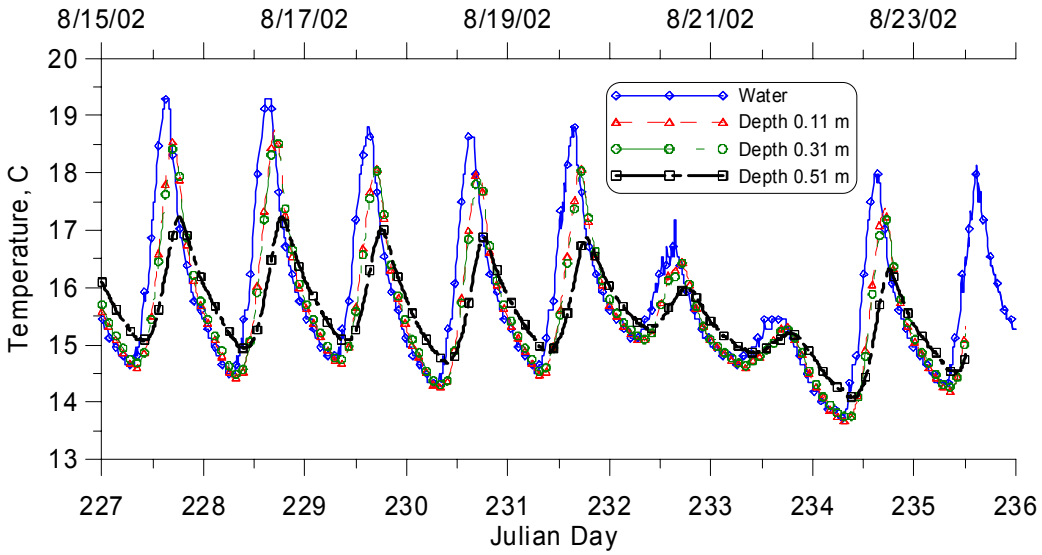

Figure 3. Streambed temperature Probe 1, cobble substrate

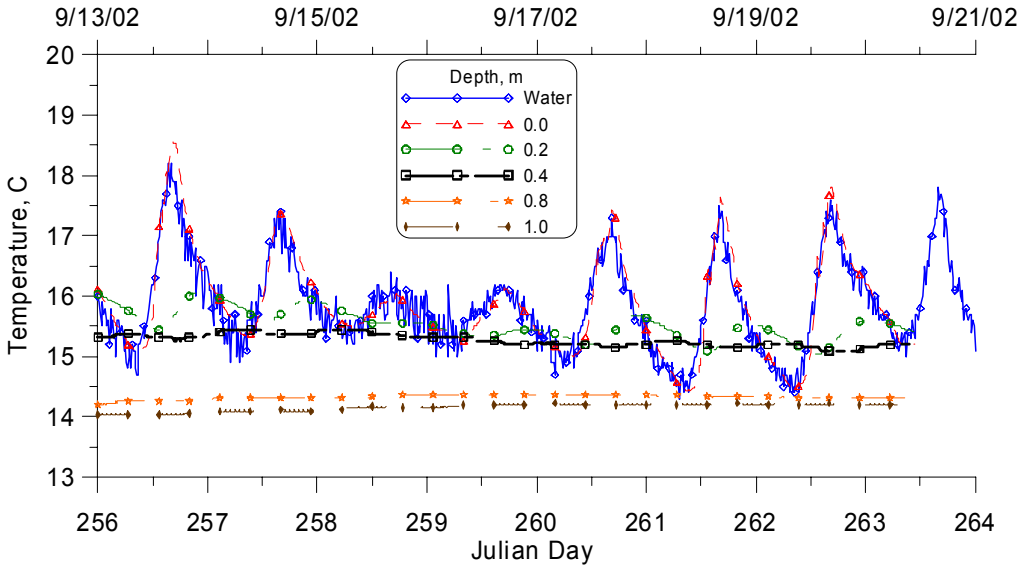

Figure 4. Streambed temperature Probe 5, bedrock substrate

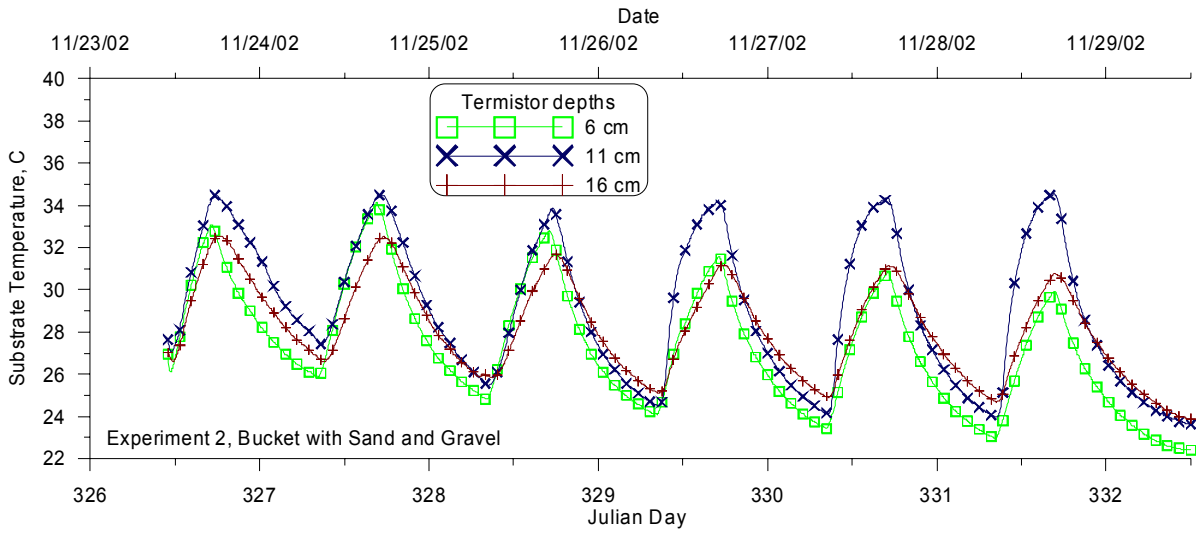

Figure 5. Experiment 2, measured temperatures in Sand and Gravel media bucket.

Training and publications:

Two abstracts for the research work have been submitted to conferences in the fall of 2003. The first abstract was submitted to the Pacific Northwest Clean Water Association Annual Conference in September and was recently accepted. The second abstract was submitted to the American Institute of Hydrology Conference in October.

When the work is completed papers will be submitted to various journals such as *Environmental Modeling and Software* and the *International Journal of River Basin Management*. In addition, a longer report will be submitted to the Center for Water and Environmental Sustainability.

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Environmental Analysis and Impact Assessment of Endocrine Disrupters in the Willamette River: A Web-Based Information System

Basic Information

Title:	Environmental Analysis and Impact Assessment of Endocrine Disrupters in the Willamette River: A Web-Based Information System
Project Number:	2002OR10B
Start Date:	3/1/2002
End Date:	3/1/2004
Funding Source:	104B
Congressional District:	Oregon 5th
Research Category:	Water Quality
Focus Category:	Surface Water, Water Quality, Management and Planning
Descriptors:	Internet, databases, hydrology, watersheds, water quality, public education
Principal Investigators:	Tarek A. Kassim

Publication

1. Kassim, Tarek A, 2002, Environmental analysis and impact assessment of endocrine disrupters in the Willamette River - Project Approach, 5th International Conference of the Balkan Environmental Association on Transboundary Pollution, 7-10 November 2002, Belgrade, Yugoslavia.

Title:

Environmental Analysis and Impact Assessment of Endocrine Disrupters in the Willamette River: A Web-Based Information System

Introduction:

Endocrine disruption (ED) or endocrine disrutping chemicals (EDCs) has been the focus of an increasing number of scientific investigations in recent years. An environmental endocrine disrupter is defined as an external compound that interferes with or mimics natural hormones in the body that are responsible for the maintenance, reproduction, development, and/or behavior of an organism (Folmar, 1993; Fry and Toone, 1981; Goodbred et al., 1996; Jobling et a., 1996; Schmitt et al., 1990; Smith et al., 1997; U.S. Environmental Protection Agency, 1997). Hypotheses about which chemicals may be endocrine disrupters, about the mechanisms through which they operate, and about which animals may be affected have been discussed in numerous publications (Aboul-Kassim and Simoneit, 2001; Bevans et al., 1996; Colborn and Clement, 1992; Henny et al., 1996; Facemire et al., 1995; Guillette et al., 1994; Davis and Bortone, 1992; EPA, 1997); however, few regional or national studies related to assessment and water quality have been conducted to test these hypotheses.

The U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) program recently found evidence of endocrine disruption in common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*) collected from waterways that contain synthetic organic compounds. At least 45 synthetic chemicals from several chemical groups have been identified as potentially having endocrine disrupting effects (Aboul-Kassim and Simoneit, 2001). These checmials include the following groups: (a) Herbicides: atrazine,2,4-D; (b) Fungicides: vinclozolin; (c) Insecticides: DDTs, carbaryl; (d) Nematocides: aldicaryl; and (e) Industrial Chemicals: phenols, PCBs, phthalates. Some of these chemicals have the potential to cause reproductive impairment in aquatic organisms (Colborn and Clement, 1992; Henny et al., 1996; Facemire et al., 1995). Alteration in blood concentrations of sex steroid hormones and vitellogenin may be associated with reproductive impairment and other critical reproductive factors (Guillette et al., 1994; Davis and Bortone, 1992; EPA, 1997). Evidence indicates concentrations of sex steroid hormones (estrogen and testosterone) and vitellogenin (egg protein produced by females) were different in fish from contaminated and reference sites.

The current pollution problem in the Willamette River is the result of various anthropogenic activities and the introduction of several synthetic chemicals. An initial investigation carried out by the Department of Civil, Construction and Environmental Engineering at Oregon State University has indicated that the river is contaminated by organic pollutants. Some of these can cause endocrine disruption.

Problem Statement:

The Willamette River of Oregon (Figure 1) is the 10^{th} largest river in the United States. In the 1930s, the Willamette was so polluted that fish were dying and the water was no longer safe for human use. Decades of local effort resulted in significant improvements to water quality and, by the 1970s, the Willamette became a model for what concerned citizens can accomplish in environmental restoration.

Recently, another critical milestone in the history of the Willamette River has approached. A study performed in 1997 by the US-EPA and the Oregon-DEQ found that the aquatic environment of the river is contaminated with organic pollutants that causes several fish species to die or have deformation.

It is believed that, as in past successful efforts to improve the Willamette, the best approach would be an organized research plan with full synergistic involvement and participation by all interested private sectors, academic institutions and state parties. It is believed that the Department of Civil, Construction and Environmental Engineering at Oregon Sate University is currently playing a major role in the current state problem by developing a web-based information system of EDCs characteristic to the Willamette River.

Research Objectives and Approach:

The Willamette aquatic environment is contaminated with organic pollutants. According to the current state's water pollution, there is a real need to achieve an efficient and cost-effective investigation that will be helpful to the State of Oregon, DEQ and EPA for their assessment and management programs and feasibility study.

The present project aims at building a web-based information system (WBIS) to investigate EDCs in the Willamette river aquatic environment and their potential effects on fish, and to provide background information on contaminant levels at different locations of the study sites. The main objectives of the present proposal are to help:

- Characterize the potential impact of organic contaminants based on the organic chemical composition of both water and sediment samples;
- Estimate the potential ecological effect of organic contaminants present in the Willamette river environment;
- Assign the potential impact to a certain fraction(s) or a group of individual contaminants; and Model the ultimate fate and transport of the characterized endocrine disrupting contaminant(s) in the study area.

The proposed WBIS consists mainly of three fundamental approaches (i.e., modules): **C**haracterization and **S**ource **P**artitioning (**CSP**), **CHEM**odynamics (**CHEM**) and **E**nvironmental **I**mpact **A**ssessment (**EIA**) modules. These modules can be explained as follows:

- The "**CSP**" module is based on characterization and identification of the EDCs of both water and sediments from the Willamette River. The main pollution sources and transport of these EDCs can be further assessed based on some known pollutant locations in the river, hot spots, chemical indices, and linear programming, artificial intelligence and Monte Carlo Simulation models.
- The "**CHEM**" module is based on both physical and chemical properties of the characterized EDCs, partitioning data, and multimedia modeling software. This allows determining the fate and transport of these EDCs.
- The "**EIA**" module is based on information that will be collected from the literature about the relationship between chemical species and endocrine disrupters.

The proposed WBIS aids the elucidation of the impact, fate, and transport of EDCs present in the aquatic environment of the Willamette River.

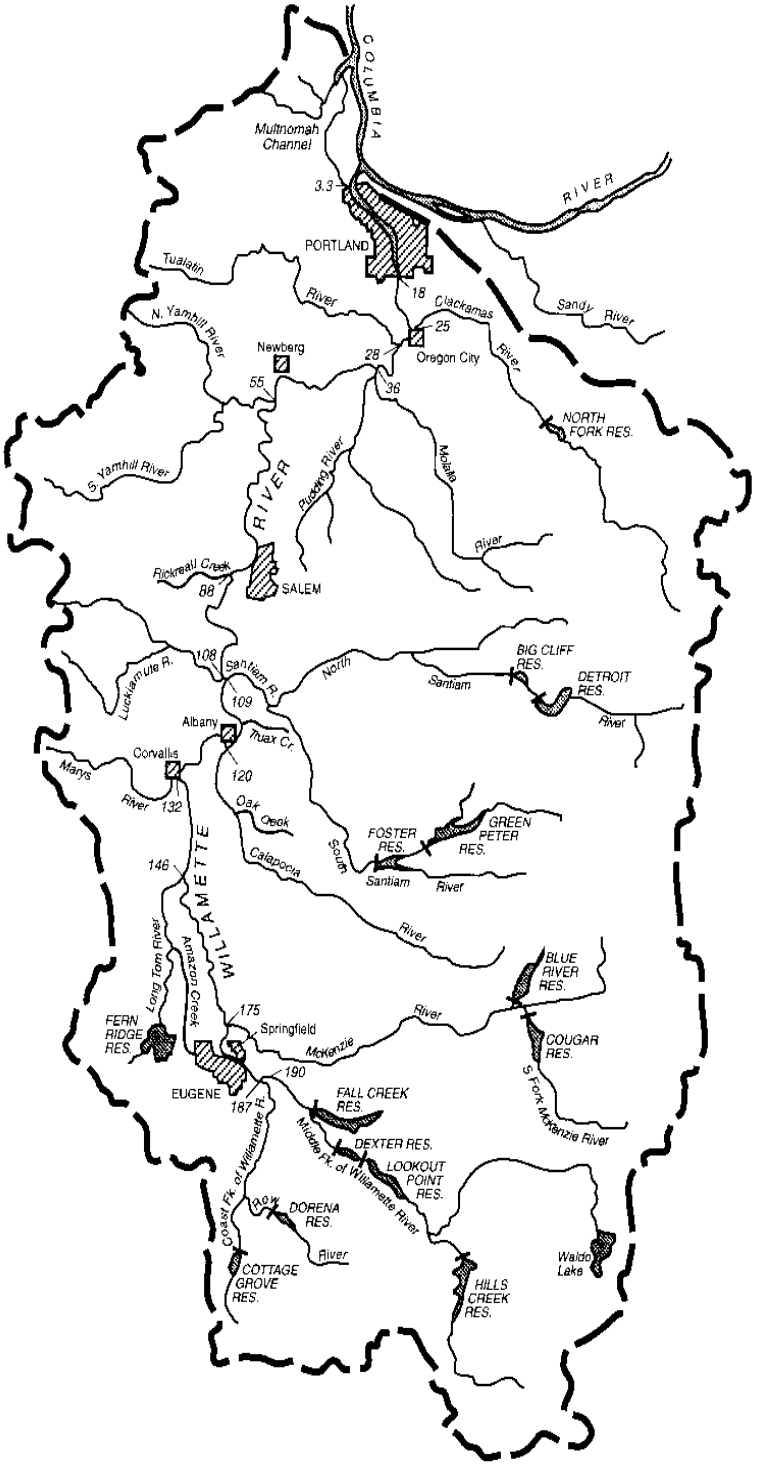

Figure 1. The Willamette River, Oregon

Methods, Procedures, and Facilities:

The present WBIS project uses the state of knowledge and information in the fields of environmental organic chemistry, toxicology, computer science/programming and environmental engineering. This requires the use of state of the art instruments and latest modeling techniques. The following is a summary:

Sampling

Water samples were collected by Niskin bottles from various locations in the Willamette River (Figure 1), which include Portland, Salem, Albany, Corvallis and Eugene stations.

Characterization and Identification of EDCs

The following sections summarize the approach used to characterize and identify the molecular compositions of EDCs in the aquatic environment of the Willamette River, as follows:

Extraction and separation

An extraction protocol originally developed and revised by Aboul-Kassim (1994; 1998) and Aboul-Kassim and Simoneit (2001) was modified and verified for the qualitative and quantitative analyses of different organic classes found in the aquatic environment of the Willamette River. In brief, water samples were liquid/liquid extracted with methylene chloride-methanol (2:1). All the extracts (EOM) was concentrated to 2 ml and hydrolyzed overnight with 35 ml of 6% KOH/methanol. The corresponding neutral and acidic fractions were successively recovered with *n*-hexane (4x30 ml), the latter after acidification (pH 2) with 6*N* HCl. The acidic fractions, previously reduced to 0.5 ml, were esterified overnight with 15 ml of 10% BF_3/methanol. The BF_3/methanol complex was destroyed with 15 ml of water, and the methyl esters were recovered by extraction with 4x30 ml of *n*-hexane. The neutrals were fractionated by long column chromatography. The following fractions were collected:

a) 45 ml of *n*-hexane (aliphatic hydrocarbons, F1),
b) 25 ml of 10% methylene chloride in *n*-hexane (monoaromatic hydrocarbons "MAHs", F2),
c) 40 ml of 20% methylene chloride in *n*-hexane (polycyclic aromatic hydrocarbons "PAHs", F3),
d) 25 ml of 50% methylene chloride in *n*-hexane (esters and ketones, F4),
e) 25 ml of methylene chloride (ketones and aldehydes, F5), and
f) 50 ml of 10% methanol in methylene chloride (alcohols, F6).

The last fraction and an aliquot of the total extract were derivitized prior to gas chromatographic-mass spectrometric (GC-MS) analysis for further qualitative molecular examination by silylation with bis(trimethylsilyl)trifluoroacetamide. A recovery experiment for the long column chromatography was carried out using several deuterated standards.

Various PCB congeners and pesticide fractions were also be analyzed according to the methods described by Aboul-Kassim and Simoneit (2001). Measurement of the PCB congeners and pesticides required a clean up of the lipid matrix, liquid-liquid partitioning procedure followed by isolation of the PCBs and pesticides using a normal-phase LC procedures. The normal-phase LC procedures separated the analytes into two fractions, one containing the PCBs and the lower polarity chlorinated pesticides (HCB, 2,4'-DDE, and 4,4'-DDE) and the second fraction

containing the more polar chlorinated pesticides. The separation of PCBs and pesticides reduced the possible co-elution of many of the pesticides with PCB congeners of interest. These two fractions were analyzed by gas chromatography-electron capture detector (GC-ECD). Other trace organic pollutants (e.g., phthalate esters) were determined and characterized according to Aboul-Kassim and Simoneit (2001).

Instrumental analyses

All samples were analyzed by gas chromatography (GC), GC-ECD, GC-MS. The GC-MS analyses of the samples were performed using a Hewlett-Packard 5973 MSD quadrupole mass spectrometer operated in the electron impact mode at 70eV and coupled to an HP Model 6890 gas chromatograph. The GC is equipped with a 30 m x 0.25 mm i.d capillary column coated with DB-5 (J & W Scientific, film thickness 0.25 μm) and operated using helium as carrier gas.

Identification and quantification

Compound identification was based on comparison with the GC retention times and/or mass fragmentation patterns of standard reference materials and with the help of the Library Molecular marker identification was tabulated as follows:

(a) *Positive,* when the sample mass spectrum, authentic standard compound mass spectrum, and their retention times agreed well;
(b) *Probable,* same as above except no standards were available, but the sample mass spectrum agreed very well with the standard library;
(c) *Possible,* same as above except that the sample spectrum contained information from other compounds but with minor overlap; and
(d) *Tentative,* when spectrum contained additional information from possibly several compounds with overlap.

Identification and response factors of several EDCs were determined using a suite of standard compounds. Quantification was based on the application of perdeuterated compounds for each respective EDC fraction as internal standards.

Organic carbon analysis

Organic carbon analyses will be carried out for all the Willamette river samples using a Carlo Erba NA-1500 CNS analyzer. The concentrations of all EDCs will be calculated relative to the total organic carbon (TOC) content of the samples.

Characterization and Source Partitioning (CSP) Module

EDCs data and other chemical indices of the compositions of the aquatic environment of the Willamette river samples were examined statistically in order to determine any significant environmental variations, and to construct a source-partitioning model specific for the Willamette. All statistical analyses and modeling approaches were performed using extended Q-mode factor analysis, linear programming and artificial intelligence-neural network programs and verified using Monte Carlo Simulation.

CHEModynamics (CHEM) Module

Fate and transport of various organic pollutants have been studied in different environmental media (Aboul-Kassim, 1998; Aboul-Kassim and Simoneit 2001). Chemodynamic behavior of EDCs characteristic to the Willamette was investigated based on both physical and chemical

properties of the characterized EDCs, partitioning data, and multimedia modeling software. This allowed determining the fate and transport of these EDCs.

Environmental Impact Assessment (EIA) Module

The "EIA" module is based on information that was gathered from the literature about the relationship between chemical species and endocrine disruption. Various databases have been searched and summarized which helped build the proposed WBIS.

Facilities

The analyses were conducted in the Environmental Engineering Laboratory at Oregon State University. Adequate chemical laboratory space and the following instrument facilities, for organic chemical identification and characterization as well as environmental ecotoxicological analyses, were present under the direction of or accessible to the principal investigator. This included: (a) a temperature programmable gas chromatograph coupled to a Chemstation data system (Hewlett-Packard 5890) for high molecular weight compound analyses, (b) one Hewlett-Packard 5973 MSD quadrupole GC-mass spectrometer coupled to a Chemstation data system, (c) elemental (CHN) analysis, (d) temperature controlled environmental chambers, (e) sample collection and coring equipment, and (f) multimedia modeling software.

Principle Findings and Significance:

The current pollution in the Willamette River is the result of anthropogenic activities. The present investigation indicated the presence of several chemicals of complex organic mixtures (COMs) or possible organic wastewater contaminants (OWCs). Regardless of sampling locations, the group of COMs/OWCs of anthropogenic origin includes aliphatic hydrocarbons (*n*-alkanes, hopanes, steranes, UCM), polycyclic aromatic hydrocarbons (PAHs) and phthalates. Typical characteristic examples of gas chromatography-mass spectrometry (GC-MS) fingerprinting of these compounds are shown in Figure 2. Complete information about the contaminant chemical name, Composition and molecular weight are shown in Table 1. Chemical structures of both aliphatic and aromatic hydrocarbons are shown in Figures 3 and 4, respectively.

Results of this study will be shared with environmental, assessment and management teams from the: (a) City of Portland - Bureau of Environmental Services; (b) Port of Portland - Environmental Program; (c) Oregon-Department of Environmental Quality; (d) USGS – Portland Office; (e) EPA – Region X - Portland Office; and (f) concerned local citizens in the Willamette area who live and share the river will be also informed.

Based on the principal findings of the current investigation:

- a comprehensive research project was submitted to the United States Geologic Survey in March 2003. The project is entitled: "OCCURRENCE AND JOINT MULTICOMPONENT TOXIC/GENOTOXIC INTERACTION MODELING OF PHARMACEUTICALS, HORMONES AND OTHER ENDOCRINE DISRUPTING CHEMICALS IN THE WILLAMETTE RIVER", with Kenneth J. Williamson, and Bernd R.T. Simoneit (Co-Investigators), $399,537 for two years
- a collaboration or an interaction with the Port of Portland and City of Portland research teams has been established.

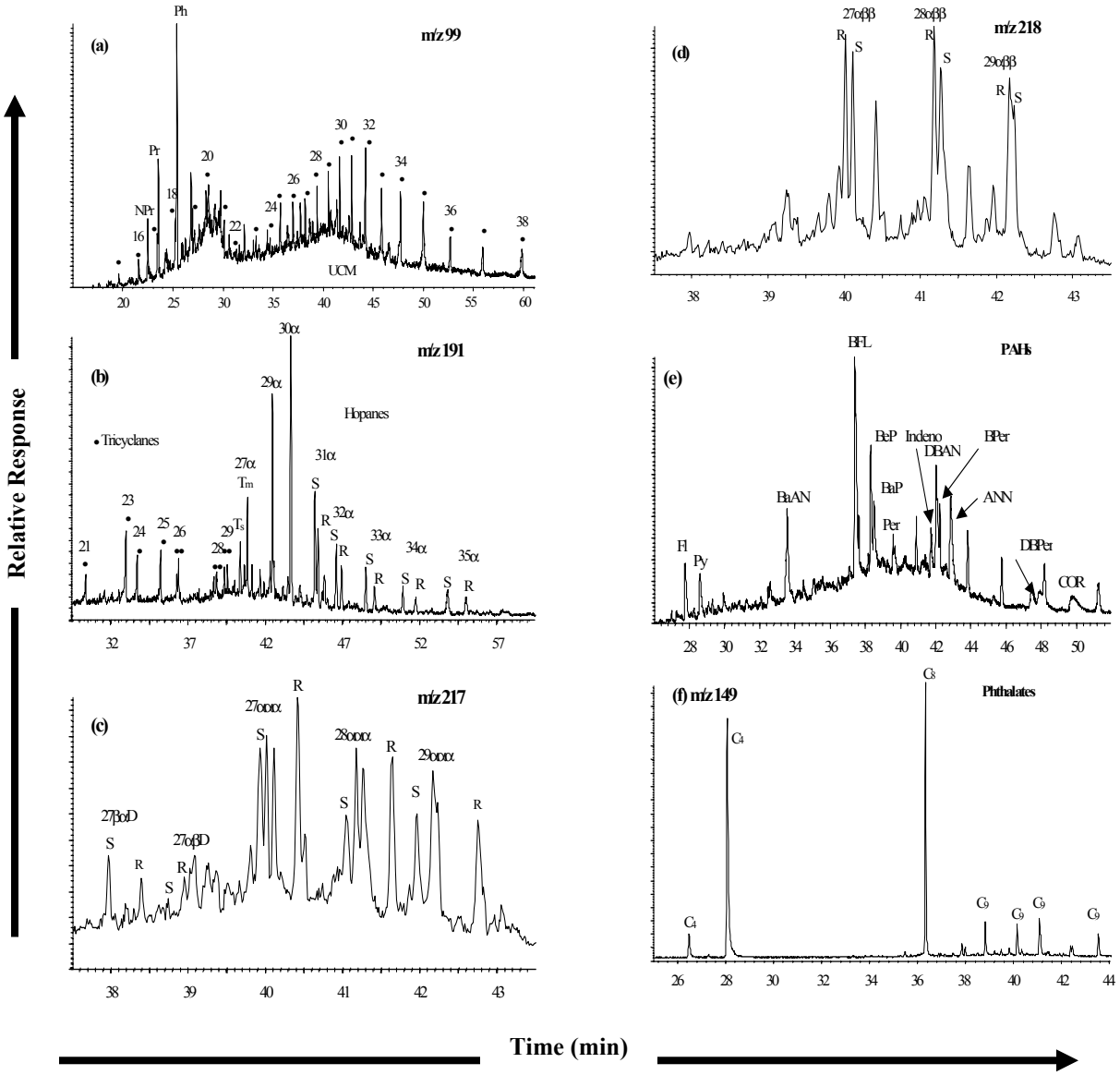

Figure 2. Typical GC-MS fingerprints for: (a) *n*-alkanes, m/z 99 (Pr = pristane, Ph = phytane, Npr = norpristane, UCM = unresolved complex mixture, numbers over peaks indicate carbon numbers); (b) hopane series, m/z 191; (c) ααα sterane series, m/z 217; (d) αββ sterane series, m/z 218; (e) PAH composition (Fl = fluoranthene, Py = pyrene, BaAN = benz[a]anthracene, BFL = benzo[b,k]fluoranthene, BeP = benzo[e]pyrene, BaP = benzo[a]pyrene, Per = perylene, Indeno = indeno[1,2,3-cd]pyrene, DBAN = dibenz[a,h]anthracene, BPer = benzo[ghi]perylene, ANN = anthanthrene, DBPer = dibenzo[ghi]perylene, Cor = coronene); and (f) C_i-phthalate esters, m/z 149 (i = carbon number of ester groups).

Table 1. Contaminant Name, Chemical Composition and Molecular Weight representing the Willamette River, Oregon.

Compound		Chemical Composition	MW	Compound		Chemical Composition	MW
#	Name			#	Name		
(I) Aliphatic Hydrocarbons				**(II) Polycyclic Aromatic Hydrocarbons**			
***n*-Alkanes**				**Neutral PAHs**			
1	*n*-hexadecane	$C_{16}H_{34}$	226	**69**	Quinoline "benzo[b]pyridine"	C_9H_7N	129
2	*n*-heptadecane	$C_{17}H_{36}$	240	**70**	2,3-Dimethyl quinoline	$C_{11}H_{11}N$	157
3	*n*-octadecane	$C_{18}H_{38}$	254	**71**	Phenanthrene	$C_{14}H_{10}$	178
4	*n*-nonadecane	$C_{19}H_{40}$	268	**72**	Anthracene	$C_{14}H_{10}$	178
5	*n*-eicosane	$C_{20}H_{42}$	282	**73**	Fluoranthene	$C_{16}H_{10}$	202
6	*n*-heneicosane	$C_{21}H_{44}$	296	**74**	Pyrene	$C_{16}H_{10}$	202
7	*n*-docosane	$C_{22}H_{46}$	310	**75**	11 H-Benzo[a]fluorene	$C_{17}H_{12}$	216
8	*n*-tricosane	$C_{23}H_{48}$	324	**76**	Benz[a]anthracene	$C_{18}H_{12}$	228
9	*n*-tetracosane	$C_{24}H_{50}$	338	**77**	Chrysene/triphenylene	$C_{18}H_{12}$	228
10	*n*-pentacosane	$C_{25}H_{52}$	352	**78**	Benzo[b+k]fluoranthenes	$C_{20}H_{12}$	252
11	*n*-hexacosane	$C_{26}H_{54}$	366	**79**	Benzo[e]pyrene	$C_{20}H_{12}$	252
12	*n*-heptacosane	$C_{27}H_{56}$	380	**80**	Benzo[a]pyrene	$C_{20}H_{12}$	252
13	*n*-octacosane	$C_{28}H_{58}$	394	**81**	Perylene	$C_{20}H_{12}$	252
14	*n*-nonacosane	$C_{29}H_{60}$	408	**82**	Indeno[1,2,3-cd]pyrene	$C_{22}H_{12}$	276
15	*n*-triacontane	$C_{30}H_{62}$	422	**83**	Dibenz[ah]anthracene	$C_{22}H_{14}$	278
16	*n*-hentriacontane	$C_{31}H_{64}$	436	**84**	Benzo[ghi]perylene	$C_{22}H_{12}$	276
17	*n*-dotriacontane	$C_{32}H_{66}$	450	**85**	Anthanthrene	$C_{22}H_{12}$	276
18	*n*-tritriacontane	$C_{33}H_{68}$	464	**86**	Coronene	$C_{24}H_{12}$	300
19	*n*-tetratriacontane	$C_{34}H_{70}$	478	**87**	Dibenzo[ae]pyrene	$C_{24}H_{14}$	302
20	*n*-pentatriacontane	$C_{35}H_{72}$	492	**Alkyl-Substituted PAHs**			
21	*n*-hexatriacontane	$C_{36}H_{74}$	506		*(Alkyl phenanthrene series)*		
22	*n*-heptatriacontane	$C_{37}H_{76}$	520	**88**	3-Methylphenanthrene (3MP)	$C_{15}H_{12}$	192
23	*n*-octatriacontane	$C_{38}H_{78}$	534	**90**	2-Methylphenanthrene (2MP)	$C_{15}H_{12}$	192
24	2,6,10-trimethylpentadecane (norpristane)	$C_{18}H_{38}$	254	**91**	9-Methylphenanthrene (9MP)	$C_{15}H_{12}$	192

Compound		Chemical Composition	MW
#	Name		
25	2,6,10,14-tetramethylpentadecane (pristane)	$C_{19}H_{40}$	268
26	2,6,10,14-tetramethylhexadecane (phytane)	$C_{20}H_{42}$	282
27	Unresolved Complex Mixture (UCM)		
	Tricyclic terpanes		
28	C_{19}-tricyclic	$C_{19}H_{34}$	262
29	C_{20}-tricyclic	$C_{20}H_{36}$	276
30	C_{21}-tricyclic	$C_{21}H_{38}$	290
31	C_{23}-tricyclic	$C_{23}H_{42}$	318
32	C_{24}-tricyclic	$C_{24}H_{44}$	332
33	C_{25}-tricyclic	$C_{25}H_{46}$	346
34	C_{26}-tricyclic (S)	$C_{26}H_{48}$	360
35	C_{26}-tricyclic (R)	$C_{26}H_{48}$	360
36	C_{28}-tricyclic	$C_{28}H_{50}$	388
37	C_{29}-tricyclic	$C_{29}H_{52}$	402
	Tetracyclic terpanes		
38	C_{24}-tetracyclic (17,21-seco-hopane)	$C_{24}H_{42}$	330
39	C_{28}-tetracyclic (18,14-seco-hopane)	$C_{28}H_{50}$	386
40	C_{29}-tetracyclic (18,14-seco-hopane)	$C_{29}H_{52}$	400
	Pentacyclic triterpanes		
41	18α(H)-22,29,30-trisnorneohopane (Ts)	$C_{27}H_{46}$	370
42	17α(H)-22,29,30-trisnorhopane (Tm)	$C_{27}H_{46}$	370
43	17α(H),21β(H)-29-norhopane	$C_{29}H_{50}$	398
44	17α(H),21β(H)-hopane	$C_{30}H_{52}$	412
45	17α(H),21β(H)-homohopane (22S)	$C_{31}H_{54}$	426
46	17α(H),21β(H)-homohopane (22R)	$C_{31}H_{54}$	426
47	17α(H),21β(H)-bishomohopane (22S)	$C_{32}H_{56}$	440
48	17α(H),21β(H)-bishomohopane (22R)	$C_{32}H_{56}$	440

Compound		Chemical Composition	MW
#	Name		
92	1-Methylphenanthrene (1MP)	$C_{15}H_{12}$	192
93	Dimethylphenanthrenes	$C_{16}H_{14}$	206
94	Trimethylphenanthrenes	$C_{17}H_{16}$	220
95	Tetramethylphenanthrenes	$C_{18}H_{18}$	234
	(Alkyl pyrene/fluoranthene series)		
96	Methylpyrenes/fluoranthenes	$C_{17}H_{12}$	216
97	Dimethylpyrenes/fluoranthenes	$C_{18}H_{14}$	230
98	Trimethylpyrenes/fluoranthenes	$C_{20}H_{16}$	244
	(Alkyl 228 series)		
99	Methyl-228	$C_{19}H_{14}$	242
100	Dimethyl-228	$C_{20}H_{16}$	256
	(Alkyl 252 series)		
101	Methyl-252	$C_{21}H_{14}$	266
102	Dimethyl-252	$C_{22}H_{16}$	280
103	Trimethyl-252	$C_{23}H_{18}$	294
104	Tetramethyl-252	$C_{24}H_{20}$	308
	(III) Non-Hydrocarbons		
	Phthalates		
105	Phthalic anhydride	$C_8H_4O_3$	148
106	Dimethyl phthalate	$C_{10}H_{10}O_4$	194
107	Diethyl phthalate	$C_{12}H_{14}O_4$	222
108	Bis(2-ethylhexyl) phthalate	$C_{24}H_{38}O_4$	390
	Phenols and Substituted Phenols		
109	Phenol	$C_6H_6O_2$	94
110	2,3,4,5,6-Pentachlorophenol	C_6Cl_5OH	266
	Amines		
111	N,4-Dimethylbenzenamine	$C_8H_{11}N$	121

Compound		Chemical Composition	MW
#	Name		
49	17α(H),21β(H)-trishomohopane (22S)	$C_{33}H_{58}$	454
50	17α(H),21β(H)-trishomohopane (22R)	$C_{33}H_{58}$	454
51	17α(H),21β(H)-tetrakishomohopane (22S)	$C_{34}H_{60}$	468
52	17α(H),21β(H)-tetrakishomohopane (22R)	$C_{34}H_{60}$	468
53	17α(H),21β(H)-pentakishomohopane (22S)	$C_{35}H_{62}$	482
54	17α(H),21β(H)-pentakishomohopane (22R)	$C_{35}H_{62}$	482
Diasteranes			
55	13α,17β-diacholestane (20S)	$C_{27}H_{48}$	372
56	13α,17β-diacholestane (20R)	$C_{27}H_{48}$	372
Steranes			
57	5α,14α,17α-cholestane (20S)	$C_{27}H_{48}$	372
58	5α,14β,17β-cholestane (20R)	$C_{27}H_{48}$	372
59	5α,14β,17β-cholestane (20S)	$C_{27}H_{48}$	372
60	5α,14α,17α-cholestane (20R)	$C_{27}H_{48}$	372
61	5α,14α,17α-ergostane (20S)	$C_{28}H_{50}$	386
62	5α,14β,17β-ergostane (20R)	$C_{28}H_{50}$	386
63	5α,14β,17β-ergostane (20S)	$C_{28}H_{50}$	386
64	5α,14α,17α-ergostane (20R)	$C_{28}H_{50}$	386
65	5α,14α,17α-sitostane (20S)	$C_{29}H_{52}$	400
66	5α,14β,17β-sitostane (20R)	$C_{29}H_{52}$	400
67	5α,14β,17β-sitostane (20S)	$C_{29}H_{52}$	400
68	5α,14α,17α-sitostane (20R)	$C_{29}H_{52}$	400

Compound		Chemical Composition	MW
#	Name		
112	N,N, 3-Trimethylbezenamine	$C_9H_{13}N$	134
Amides			
113	N-(2, 4-Dmethylphenyl)formamide	$C_9H_{11}NO$	149
Various Alcohols			
114	Dicyclopentadieneol	$C_{10}H_{13}O$	149
115	[1,1' - Biphenyl]-2-ol	$C_{12}H_{10}O$	170
Acids			
116	Benzoic acid	$C_7H_6O_2$	122
117	Nonanoic acid	$C_9H_{18}O_2$	158
118	Decanoic acid	$C_{10}H_{20}O_2$	172
119	Dodecanoic Acid	$C_{12}H_{24}O_2$	200
120	Tetradecanoic acid	$C_{14}H_{28}O_2$	228
121	Hexadecanoic acid	$C_{16}H_{32}O_2$	256

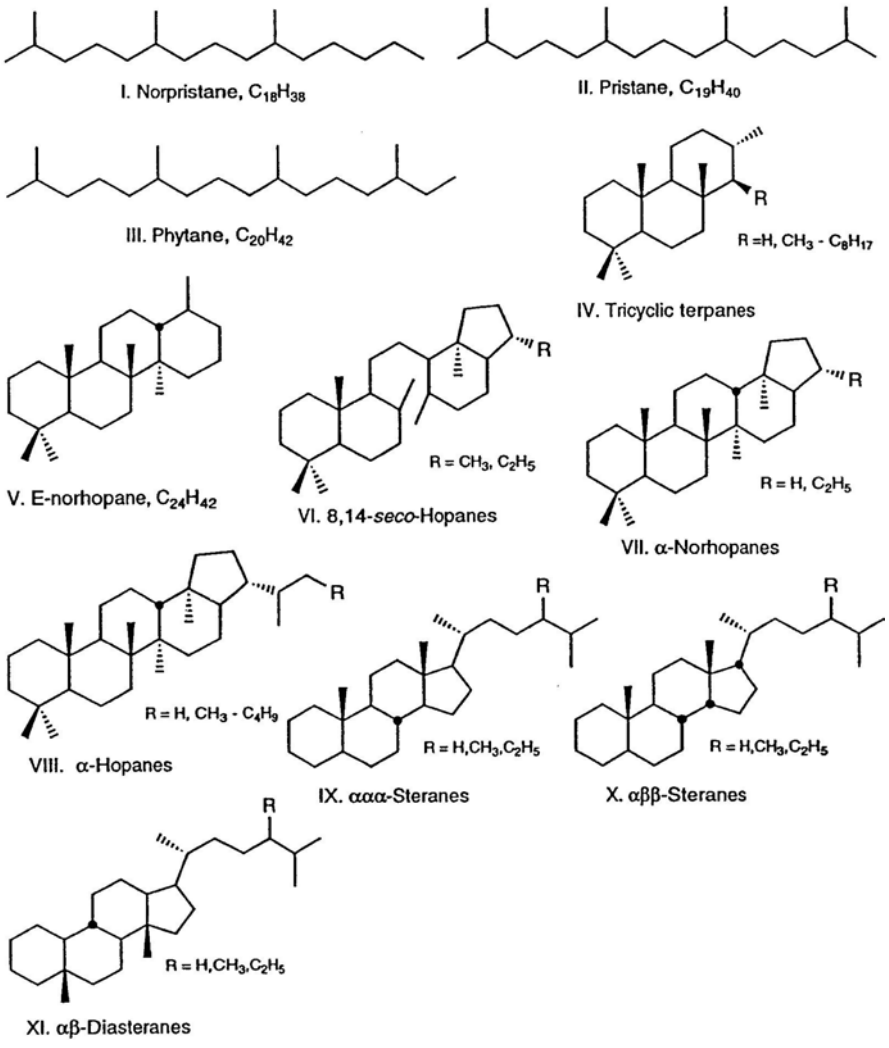

Figure 3. Chemical Structures of Some Aliphatic Hydrocarbons

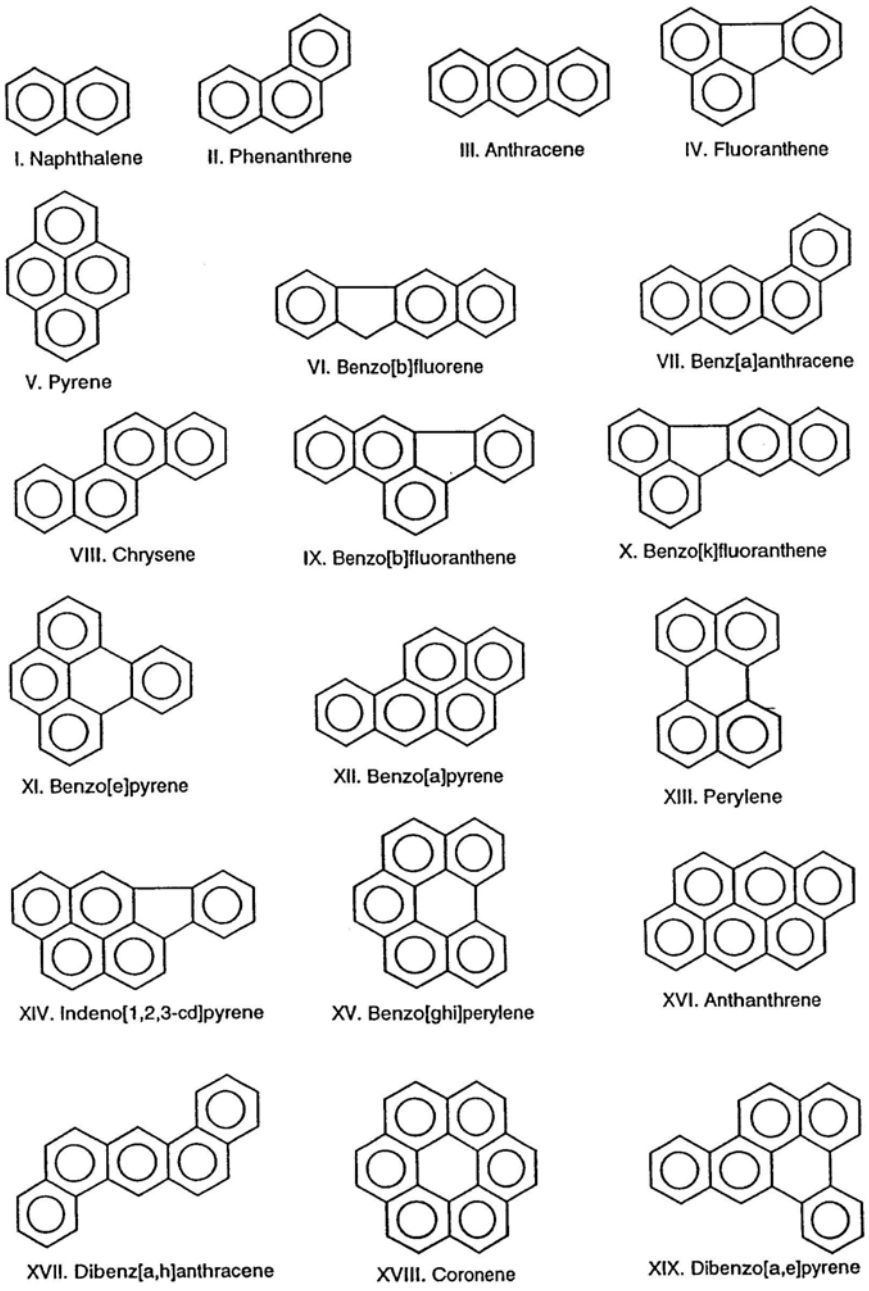

Figure 4. Chemical Structures of Some Polycyclic Aromatic Hydrocarbons

Training and Publications:

The present study was partially a part of the Masters' thesis for one graduate student in the Department of Civil, Construction and Environmental engineering at Oregon State University. The student has received some training about endocrine disrupting chemicals in the aquatic environment during the project.

The project approach was presented at the *5th International Conference of the Balkan Environmental Association on "Transboundary Pollution"* during 7-10 November 2002, in Belgrade, Yugoslavia. The title of the presentation was: "ENVIRONMENTAL ANALYSIS AND IMPACT ASSESSMENT OF ENDOCRINE DISRUPTERS IN THE WILLAMETTE RIVER – PROJECT APPROACH".

In addition, the principal findings were a part of a lecture, entitled "FORENSIC ANALYSIS, CHEMODYNAMICS AND ENVIRONMENTAL IMPACT ASSESSMENT OF COMPLEX ORGANIC MIXTURES", given in the Department of Environmental Engineering at Texas A&M University-Kingsville, Texas, during January 24, 2003

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Investigation of Groundwater Recharge and Agricultural Runoff Through the Willamette Silt, Oregon

Basic Information

Title:	Investigation of Groundwater Recharge and Agricultural Runoff Through the Willamette Silt, Oregon
Project Number:	2001OR10B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	5
Research Category:	Ground-water Flow and Transport
Focus Category:	, Nitrate Contamination, Management and Planning
Descriptors:	groundwater, Willamette Valley
Principal Investigators:	Roy Haggerty

Publication

1. Iverson, J., 2002, Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, MS Thesis, Oregon State University, Corvallis, Oregon, 147 p.
2. Iverson, J., and R. Haggerty, 2002, Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, Geological Society of America Cordilleran Section 98th Annual Meeting Abstracts with Programs 34(5), A-109.
3. Iverson, J., and R. Haggerty, Hydraulic Buffering Capacity of a Semi-Confining Unit for Water Quality and Supply in the Willamette Valley of Oregon, to be submitted to Ground Water.

Problem and Research Objectives:

The Willamette Silt provides two functions critical to Willamette Valley water supply: (1) the low hydraulic conductivity and reducing conditions of the Willamette Silt provide a protective barrier to agricultural contamination of the underlying aquifers; and (2) the Willamette Silt acts as a semi-confining unit to the Willamette Aquifer, and thereby reduces overdraft of streams by pumping wells. Unfortunately, the physical and chemical nature of this barrier is very poorly characterized or understood. In fact no comprehensive hydrogeologic or geochemical study of the Willamette Silt has ever been conducted.

The Willamette Silt is the most extensive geologic unit exposed at the surface in the Willamette Valley of Oregon, underlying the majority of the Central and Southern Willamette Valley's arable land. It covers an area of 3100 km^2 (1200 mi^2), virtually all of which either are currently under agricultural production, or are suitable for agricultural production. Over its entire extent, the Willamette Silt immediately overlies an important regional aquifer, the Willamette Aquifer. The Willamette Silt also lies above a second important regional aquifer, the Columbia River Basalt. In areas covered by the Willamette Silt, these two aquifers produce approximately 200,000 acre-ft per year (250,000,000 m^3/yr) of water, which is 60% of the Willamette Valley's groundwater production. All of the streams and rivers in the Willamette lowland except the Willamette River bottom in the Willamette Silt.

The goal of our study was to obtain direct information on recharge and transport of agricultural chemicals across the Willamette Silt. Specifically, we intended (1) to directly measure transport rates across the Willamette Silt; (2) to characterize the hydraulic connectivity between a stream bottoming in the Willamette Silt and the Willamette Aquifer in the presence of pumping stresses; (3) to quantify the nitrate and phosphate concentrations across the Willamette Silt, along with a suite of associated ions and cations. Goals 2 and 3 were successfully reached, while the first goal was not reached.

Methods, Procedures, and Facilities:

Our study was conducted at a field site approximately one mile SW of Mt. Angel, Oregon, along the Pudding River. The Pudding River is deeply entrenched within the Willamette Silt at this location. The field where the majority of the work took place has been variously cropped in corn, clover and cereal grains from 1945 to 1982, and then onions, seed cabbage, bush beans and flower seeds to 1996. Since 1997 the field has been used to run a wholesale in-ground nursery operation. Details of the field site and fertilizer applications are given in *Iverson* (2002) and on the project web site.

At the field site, three locations with a total of seven boreholes were drilled into the Willamette Silt and upper Willamette Aquifer along a transect across the Pudding River. Core samples were taken in six of the boreholes, including a total of 32 m (105 ft) of continuous core. Samples were frozen on site in dry ice. Piezometers, screened at the bottom 79 cm (2.6 ft), were installed in all boreholes. Two push-point piezometers were also installed below the River at two different depths. Piezometers were developed and instrumented with pressure transducers connected to data loggers. A tipping bucket rain gauge was installed at the site and connected to one of the data loggers. A flow meter was installed in the out-flow for the tile drain. A pumping

well screened within the upper Willamette Aquifer that lies within our piezometer transect and that is used for irrigation water supply was also monitored periodically.

Core samples from boreholes were analyzed for pH, phosphorus, ammonia, nitrogen as nitrate, sulfate, and a cation suite (total K, Ca, Mg, Na, Zn, Mn, Cu, and Fe). A further set of shallow test holes, traversing the same line as the piezometers, were dug to obtain more samples which were analyzed for the same chemical suite.

Water samples were taken from the Pudding River every 3.5 days from April, 2001 through February, 2002. Every other sample (i.e., weekly) was analyzed for total Kjeldahl N, total phosphorus, phosphorus as phosphate, nitrogen as nitrate, Cl, and sulfate. In two months (May and July), some samples are missing, due to equipment delivery dates and an equipment failure. While we intended to sample for 52 weeks, we sampled for less once we realized that the direct measurement of recharge across the Willamette Silt would not be possible.

Sediment cores were taken from the Pudding River near the beginning of each month from June, 2001 to November, 2001. We had originally planned to sample from the Hook Rd. bridge, making sampling possible through high water. However, we were unable to apply sufficient force through the sampler over the distance from the bridge to the sediment. Consequently, all samples were taken by wading into the water with soil coring equipment. Samples after early November were therefore not possible due to high water levels. Sediment samples were analyzed at depth intervals of 2 cm for nitrogen as nitrate, sulfate, Cl, and total Kjeldahl nitrogen.

A 3-day pump test was conducted at the irrigation well within our piezometer transect. The irrigation well, all seven of our bored piezometers, and five additional wells located within 1.4 km (0.9 mi) of the pumping well were monitored with pressure transducers and data logging equipment. The pump tests provided an average hydraulic conductivity and specific storage for the Willamette Aquifer. Through modeling we conducted later, the pump test also provided an approximate, vertically-averaged value of hydraulic conductivity for the Willamette Silt and uppermost Willamette Aquifer. Slug tests were also conducted at each of the piezometers, providing near-field values of hydraulic conductivity.

Eight samples of the Willamette Silt were analyzed in our laboratory for various properties, including hydraulic conductivity, grain size, and porosity.

A three-dimensional groundwater flow model of the field site was constructed using MODFLOW to analyze the stream-aquifer connectivity and to more fully analyze the pump test data.

Principal Findings and Significance:

The project has been successful at characterizing the hydraulic properties of the Willamette Silt and advancing our understanding of the hydraulic connection between streams that bottom in the Willamette Silt and the Willamette Aquifer. We have also significantly advanced our knowledge of the potential for agricultural leachate to cross the Willamette Silt and contaminate the Willamette Aquifer. The major findings of this study are outlined below. Other findings are described in *Iverson* (2002).

(1) Field observations of nitrate penetration fronts provide evidence that, at our field site near Mt. Angel, Oregon, the Willamette Silt currently prevents transport of nitrate to the Willamette Aquifer. A general trend of decreasing nitrate with depth is observed at two sites near the Pudding River. Further, the point at which nitrate concentrations go to background levels,

between 7.5 and 9 m bgs (25 and 30 ft bgs), is coincident with a reduction-oxidation (RedOx) boundary which also corresponds to a sharp rise in pH with depth. This RedOx boundary is easily seen in core sample and is defined by a sharp transition from red-brown silt (oxidized) to blue-gray silt (reduced). We hypothesize that autotrophic denitrification is taking place at this boundary.

It is important to note, however, that it is not yet known the extent to which the Willamette Silt prevents nitrate transport elsewhere in the Willamette Valley. Additional research is needed to map the presence of the RedOx boundary and the thickness of the Willamette Silt below the RedOx boundary over the rest of the Valley. We also do not know whether the RedOx boundary is moving downward. If it is moving downward and if the rate of movement is influenced by fertilizer application, then future nitrate contamination of the Willamette Aquifer by nitrate may be possible.

(2) Pumping from the Willamette Aquifer has a minimal effect on streams that bottom in the Willamette Silt. Numerical analysis, supported by pump-tests, slug-tests, and lab measurements of hydraulic conductivity, show that the Willamette Silt is a source of diffuse recharge (as opposed to focussed recharge underneath surface water bodies). This diffuse recharge accounted for more than 98% of the water volume removed from the Willamette Aquifer during a 3-day pump test. Less than 1% of the volume of water removed from the Aquifer at a pumping well located less than 200 ft from the Pudding River was recharged to the Willamette Silt from the River. The Willamette Silt acts as a reservoir, accepting water during the wet winter months, and diffusely recharging that water to the Willamette Aquifer throughout the year. Consequently, the predominant net effect of pumping from the Willamette Aquifer far from the Willamette River is likely to reduce winter flows in streams.

(3) Laboratory measurements of hydraulic conductivity indicate that at our field site the harmonic mean vertical hydraulic conductivity of the Willamette Silt is approximately 2×10^{-7} m/s (0.5 gal/day/ft^2). Slug tests in shallow to intermediate wells within the Silt and with good completion provide estimates of hydraulic conductivity that are in approximate agreement. However, slug tests from wells completed at the top of the Willamette Aquifer and data from our pump tests suggest that the top of the Willamette Aquifer has lower hydraulic conductivity than the Willamette Silt, with values of approximately 1×10^{-9} m/s (0.002 gal/day/ft^2). This low value is probably due to cementation (visible in core and noticeable during drilling) of the gravels at the top of the Willamette Aquifer. Consequently, the hydraulic connection between the Willamette Aquifer and the Willamette Silt is lower than indicated by the hydraulic conductivity of the Silt.

While the project had these important findings and successes, the project was unsuccessful at directly measuring the rate of water movement across the Willamette Silt. This was the intended purpose of measuring concentrations of Cl and other ions in both the Pudding River and the underlying sediments. The concentration profile in the sediment was to be modeled, using the concentrations in the Pudding River as a boundary condition, to obtain a rate of transport down through the sediment. This failed because concentrations within the sediment did not show a coherent pattern related to the concentrations in the water above. We believe that this failure is due to a combination of (1) sediment movement; (2) hydraulic gradients in the sediment other than vertical; and (3) sediment-water interactions that modified the pore-water chemistry. An additional, though not fatal, problem was our inability to sample after November due to high water.

A web site has been created that provides access to all data (water chemistry, soil chemistry, head, physical properties, and hydraulic properties of the Willamette Silt) from the project, graphs of most of the data, well logs, and an electronic copy of Iverson (2002, MS thesis). The web site address is http://terra.geo.orst.edu/~haggertr/WS/

Training and publications:

This grant contributed to the training of four students.

Justin Iverson. Iverson completed his MS thesis, "Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon", in April, 2002. This grant supported his research and his results are the primary results presented in this report.

Louis Arighi. Arighi began his MS, "Protection of the Willamette Aquifer Due to Attenuation of Nitrate by Unweathered Quaternary Sediments", in September, 2001. The first data sets for his thesis are provided by this grant.

Bruce Hammelman. Hammelman is an undergraduate student who has worked on the project from the beginning, collecting samples, building equipment, processing data, and building a web site.

Nghi Huynh. Huynh worked on this project during its inception in 2001. His primary role was an assistant during the building of equipment and the first data collection.

The grant resulted in one thesis and one abstract, and will result in one paper currently in preparation for submission.

Iverson, J., *Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon*, MS Thesis, Oregon State University, Corvallis, Oreg., 147 p., 2002.

Iverson, J., and R. Haggerty, Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, *Geological Society of America Cordilleran Section 98th Annual Meeting Abstracts with Programs 34*(5), A-109, April, 2002.

Iverson, J., and R. Haggerty, Hydraulic Buffering Capacity of a Semi-Confining Unit for Water Quality and Supply in the Willamette Valley of Oregon, to be submitted to *Ground Water*.

US Transboundary Waters: Interstate Waters, Interstate Compacts

Basic Information

Title:	US Transboundary Waters: Interstate Waters, Interstate Compacts
Project Number:	2001OR11B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	5
Research Category:	Social Sciences
Focus Category:	Water Quantity, Management and Planning, Law, Institutions, and Policy
Descriptors:	Web-based data management; US interstate compacts; searchable bibliographies
Principal Investigators:	Aaron T. Wolf

Publication

Problem and Research Objectives:

There is an urgent need for an up-to-date and widely available spatial database in which information on the geopolitical and socioeconomic characteristics of watersheds that cross state or sectoral boundaries can be combined with current biophysical information to help predict and prevent potential conflict over water resources, or to resolve such disputes when they do occur. Such data can also aid in making land use and management decisions within watersheds that affect availability and quality of water.

To aid in research on the nature of conflict and the assessment of the process of water conflict resolution, we have been working over the past six and a half years to develop the Transboundary Freshwater Dispute Database (TFDD), a project of the Oregon State University Department of Geosciences, in collaboration with the Northwest Alliance for Computational Science and Engineering. In this context, "transboundary" refers both to water that flows across legal or political boundaries as well as to water and watershed resources used by more than one set of interests – i.e., water needed by the environmental as well as economic sectors.

While much of this data either has been or is in the process of being made web-accessible, recent research has allowed us to compile a vast amount of spatial information related to international rivers, which currently is only available off-line. Our two-year project, International Waters: Basins at Risk, required the accumulation and rendering in a unified format over 100 spatial layers in a global Geographic Information System. The data cross disciplinary and spatial boundaries, and include biophysical, socio-economic, and geopolitical categories. These data layers have been collected from sources around the world and put in a unified, ready-for-analysis format.

Research objective, for this project grant, was to continue developing our "virtual center" for the study of transboundary waters, by making accessible these data layers for web-based analysis, as follows:

1) Structuring three existing components of the Database. These component are a digitized base map of U.S. and international watersheds, an annotated bibliography of the "state of the art" of water disputes and dispute resolution, and a list of all U.S. interstate compacts and international treaties – such that a web user might use information from any component to get to any other component.
2) Investigating the possibilities of having web-based, interactive GIS analysis of our existing spatial data. Frankly, this could not be accomplished within the limitations of this current project, but other grants are pending which would allow for the implementation of what we find here. Although the infrastructure for the virtual center would be housed at Oregon State University, as a subset of the existing Transboundary Freshwater Dispute Database project, it would be developed in close collaboration with, and linked with partners across campus and around the world.

Specific activities, included:

- ◊ Updating all bibliographic and compact information, and integrate new data into existing databases
- ◊ Converting existing databases to web-ready formats and linking search capabilities to include both spatial and textual information
- ◊ Investigating possibilities of interactive GIS using ARCIMS or other as appropriate; and,
- ◊ Preparing for the launching of the new website, database components, including the U.S. components sponsored by this grant

Methods, Procedures, and Facilities:

Although our proposed use of spatial information is unique, our design architecture is not. This circumstance allows us to use existing tools and expertise to present the information to the web community. Using existing tools also shortens development time, allows us to capitalize on widely-available spatial information as well as our own in-house spatial coverages, and helps minimize costs. We want to invest in and use existing or proven technologies for building the infrastructure of the center, yet we work closely with existing technology vendors to provide feedback about practical applications of their products and foster interaction between vendors and real-world users.

One of the strengths of our web-based research tool is our plan to link the graphical map-based interface directly to an existing database of biophysical and environmental resource information. By combining the capabilities of data layering and database linking, a more specific example of our site goals can be understood. As an example, and only one of many possible options, a visitor to our site might:

- ◊ select a region of interest from a global map
- ◊ enlarge the selected region
- ◊ opt to display one or more layers (as an example, such layers might include political boundaries, rivers, population centers, basin or watershed boundaries, or areas covered by treaties)
- ◊ view and print more specific data related to specific layers
- ◊ link to additional resources available on the web.

Principal Findings and Significance:

- ◊ The web-based database of major U.S. watersheds is up and running. The map (see attached) will be linked to the Transboundary Freshwater Dispute Database (TFDD) website when the new TFDD site is launched (July-August 2002).
- ◊ The database of the U.S. interstate compacts is linked to this map.
- ◊ The annotated bibliography will be completed this month and will be linked to the map at that time.
- ◊ Excellent progress has made in displaying existing spatial data on the web. A spatial demonstration has been created, listing data on Climate, Population, Treaties, Events, Dam Runoff, and Water Stress. For each basin and indicator there is a pop-up window, displaying the data, along with a legend and source.
- ◊ The database has been put into a web-accessible format.

Continued expansion of the database includes:

- ◊ By the end of July, we hope to finish all continents with the above indicators (Climate, Population, Treaties, Events, Dam Runoff, and Water Stress).
- ◊ During the remainder of the summer, more indicators and Excel/Access information will be added, so researchers can download the data and do their own analysis.

Statement of Results or Benefits :

OSU has developed an online GIS of transboundary water indicators and annotated bibliography, going online July-August 2002. The treaty database has been expanded from 150 treaties and related agreements to presently having just over 400 treaties and related agreements, many with the full text of the agreement available online. The documents cover a range of years, regions, and basins. The expanded treaty database will be going on the web in summer 2002 with an improved user interface. The treaty database will be linked with the bibliography, event, biophysical, and socioeconomic data by an interactive map of basins, which will allow users to select information (from all the databases) by clicking on a map of that basin. Additional treaties will be added as they are obtained. Sometime this summer, please visit the new version of the database at http://www.transboundarywaters.orst.edu/

Training and publications:

Six OSU students have been intimately involved in creating and expanding the database over the last year – Sara Ashley, Brian Blankenspoor, Cathy Pearson, Shira Yoffe, Greg Fiske and Becci

Dale. The students performed a number of duties for the creating, maintaining, and upgrading the database, including: treaty coding; data gathering, organizing, cleaning, and entering; database design; access database design and development; creating site demonstrations, spatial data, and many of the maps used in the web display. Staff and faculty at OSU's Northwest Alliance for Computational Science and Engineering (NACSE) have been instrumental in putting the database into a web-accessible format. They also designed the website interface.

Information Transfer Program

Development of a monitoring network and web-based database for effective watershed management in the Oak Creek Basin

Basic Information

Title:	Development of a monitoring network and web-based database for effective watershed management in the Oak Creek Basin
Project Number:	2002OR1B
Start Date:	3/1/2002
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	Oregon 5th
Research Category:	Not Applicable
Focus Category:	Hydrology, Management and Planning, Surface Water
Descriptors:	Oak Creek, land use and water quality
Principal Investigators:	Jeffrey J. McDonnell

Publication

1. McGlynn,B., J.J.McDonnell, Stewart, M.,Seibert,J., 2003, On the relationships between catchment scale and streamwater mean residence time. Hydrological Processes, 17: 175-181.

Title: Development of web-based information delivery to assist in management of watershed and landuse change activities in the Oak Creek watershed

Problem and Research Objectives:

This project focused on the Oak Creek Basin, the home watershed for Oregon State University (OSU). The University manages about 40% of the basin for multiple uses including: forestry, agriculture, an urban campus, and large parking lots. As in many watersheds around Oregon, the Corvallis community has become increasingly concerned about whether OSU is an effective steward of the watershed and stream system. In 1999, OSU convened an Action Team who evaluated the conditions in the basin. The task force suggested specific actions that should be taken to improve basin management. This work has not yet begun. One of the causes of this delay has been the lack of an institutional infrastructure that promotes communication among those working, living, and managing the basin. This project sought to fill this void by synthesizing data sets and putting in place communication and monitoring tools that would facilitate better basin management.

In many ways the Oak Creek watershed is an allegory for watershed issues in Oregon. Our citizens embrace anadromous fish as a symbol of our Northwestern identity and we recognize that healthy salmon populations require healthy streams and watersheds. At the same time, the Federal Endangered Species and Clean Water Acts increasingly focus attention on reduction of non-point source pollution and regulation of stream water quality. As the state's land grant college and primary agricultural and natural resources university, OSU has a responsibility to be a leader on watershed stewardship issues. Researchers at OSU are developing new understandings of ecological functions, nutrient cycling, agricultural technologies, but many of these are not implemented in our own backyard watershed. This project sought to provide a way to harness these energies within the Oak Creek watershed and improve teaching, research and management in the basin.

The objectives of this project were to set up an organization and monitoring infrastructure to support coordinated management of the Oak Creek basin. Specific objectives included:

1. Establish an Oak Creek Advisory Board as recommended by the Oak Creek Action Team. The board will include representatives from several OSU colleges and from local community organizations.
2. Hold a community meeting as a forum for community concerns and to describe current University management plans and activities. Disseminate this information to stakeholders in the watershed.
3. Create an a web site of available data for the watershed – this site will include biological, water quality, and GIS data sets that have been collected by OSU classes, government agencies, and citizen groups.
4. Collect base-line monitoring data to determine spatial variation in water quality in the basin and measure baseline conditions that will enable future assessment of management effectiveness.

5. Create a GIS for the basin that integrates existing data layers and newly acquired imagery.
6. Develop a research proposal to use the Oak Creek watershed as a demonstration basin where hydrologic processes and best management practices can be studied in a mixed land use setting.

Methods, Procedures, and Facilities:

Methods that we used for the project are summarized below:

1. Advisory Board and Community Meeting – We encouraged the university administration, under the auspices of Rich Holdren, Vice Provost for Research, to create an Oak Creek Advisory Board. We made recommendations on board composition and provided the research office with a list of interested persons. The community meeting will take place after the Board is formed. The meeting will be advertised through the community contacts on the Board and through media outlets.

2. Web Site – We performed a formal and informal "literature search" to uncover data sets collected in the Oak Creek basin. Published materials such as theses and journal articles were easy to retrieve through traditional library search tools. However, since many data sets were collected as part of class projects and never formally published, it was also important to gather information through interviews and by word of mouth. We synthesized these conversations into background sections for the web site that describe the chronology of research studies (by discipline) that were carried out in the basin. These were followed by an annotated bibliography of published and unpublished reports with information about who to contact for additional information. When available in a digital form, we posted data files on the web site. We also synthesized information about management and GIS data sources for the basin and created web pages with this information.

3. Monitoring – We performed synoptic stream sampling surveys at 35 sites across the Oak Creek watershed under low flow conditions during Fall 2001 and Fall 2002. The network of sites was built upon the 5 points sampled by the Public Health class H443/543 from 1993 to 2002. The aim was to examine how water quality measures vary across the discrete land use changes within the watershed (forestry, agriculture, suburban, urban) and scale (from headwaters to basin outlet). Specific constituents were analyzed (using analytical facilities at CCAL on the OSU campus, Elizabeth Boyer's water chemistry lab at the State University of New York College of Environmental Science & Forestry, and the USGS stable isotope lab in Menlo Park, CA):
    a. Nutrients (NO_3^-N, NH_4^+, DON, total P, and PO_4^{3-})
    b. Specific conductance
    c. Dissolved organic carbon, cation (calcium, magnesium, potassium, sodium, iron, aluminum, strontium), silicate, and anion (chloride and sulfate) concentrations

d. Oxygen isotopes (for water source determination)

Stream gauging (with a current meter and salt dilution gauging under low flow conditions) accompanied the water sampling program. The gauging enabled us to gather low flow data at potential sites that we will consider for permanent gauging structures. One specific scientific output associated with the work is the analysis of the variance collapse of water quality measures with increasing catchment scale in comparison to several watersheds throughout the US that represent a range of land use characteristics and human influences.

4. GIS - We gathered data layers for a watershed GIS database including:
    a. Soils
    b. Topography
    c. Airborne imagery (visible, IR)
    d. Zoning
    e. Landuse/landcover
    f. Road network
    g. Stream network
    h. 1:24K DRG
    i. COAS rainfall distribution models/historical records
    j. LIDAR and other high resolution data layers for McDonald-Dunn forest, part of the Peavy Arboretum (Dave Lisne, Director).

5. Proposal writing – The PI led a group of researchers and community representatives in an effort to develop research projects in the basin. The group met repeatedly and brainstormed different potential projects that would integrate hydrologic studies with management issues in the basin.

Principal Findings and Significance:

This project has been extended until February 2004. Below we describe project accomplishments to date:

1. Advisory Board and Community Meeting – We provided a list of interested participants to Rich Holdren, OSU Vice Provost for Research. This list was made up of researchers and community members who had demonstrated their interest in the basin through attendance at regular meetings to discuss potential research and teaching projects in the watershed. Mark Taratoot, Water Resources Specialist for the City of Corvallis, agreed to contribute $500-$2000 towards the city's involvement in the Board and its interactions with the group. It is our hope that the Advisory Board will be established in the coming months and that a community meeting can follow.
2. Web Site – In January 2003 we launched the Oak Creek Website (http://cwest.orst.edu/oakcreek/). The main sections of the web page include the following:

- ◊ About the Basin – This section includes background information about the physiography, hydrology, and land use in the basin.
- ◊ Research – This is the heart of the web page. It is an annotated bibliography which chronicles the history of research projects in the basin. Because of the creek's proximity to campus, students and researchers have collected data there for decades. The Research pages include sections on: Agriculture, Entomology, Forestry, Sediment Transport, Climate, Fisheries, Geology, Watershed Analyses, Hydrology and Water Quality, History, and Social Science.
- ◊ Maps – This section includes downloadable maps for the basin and information and links about where to download additional GIS data layers that cover the basin. Information is provided about projection, scale, and the geographic extent of data layers and their availability from different local, state, and federal sources.
- ◊ Management – This section includes information about the different jurisdictions (university departments, city, private) with management responsibilities in the basin. It also includes information about the management issues identified by the Oak Creek Action Team in June 2000. The page includes updates on the status of actions on these different recommendations.

The web page has benefited the local community by becoming a resource for students and researchers who need to gather background information and connect with others working in the basin. Since March, it has been among the most visited sections of the Center for Water and Environmental Sustainability's web site. As the Oak Creek Advisory Board develops, we hope that this web page will be a resource for managers and a way to communicate decisions and activities of the task force to the greater OSU and Corvallis community.

On a regional level, we hope this web site will help OSU develop Oak Creek into a demonstration watershed where monitoring approaches and the effectiveness of Best Management Practices can be evaluated. The basin's mixed land use and location near OSU make it an ideal study watershed – research findings and lessons learned from management efforts could be applied to state-wide efforts to improve watershed health for salmon and people.

3. Monitoring – The synoptic stream chemistry data demonstrate that source areas of solutes vary throughout the watershed and with land uses (Figure 1). Nutrient concentrations along the main stem and at the outlet of Oak Creek were intermediate among the forested tributaries and the higher nutrient concentrations from tributaries that drained areas with mixed land uses (agricultural, residential, and urban). The mixed land use sites had the highest and largest ranges of solute concentrations compared to the forested areas. In the case of NO_3^-N, concentrations at the forested sites remained in a relatively small range of values (0.5 to 31 $\mu mol\ L^{-1}$) whereas concentrations were up to an order of magnitude higher at several of the mixed land use tributaries. The Oak Creek data illustrate the importance of chemical and hydrological data to determine source areas of

nutrients in watersheds. Efforts to compare patterns of solute concentrations with increasing basin size at Oak Creek and other watersheds is ongoing with the continued collection of synoptic data from watersheds reflecting a variety of forest and land use characteristics.

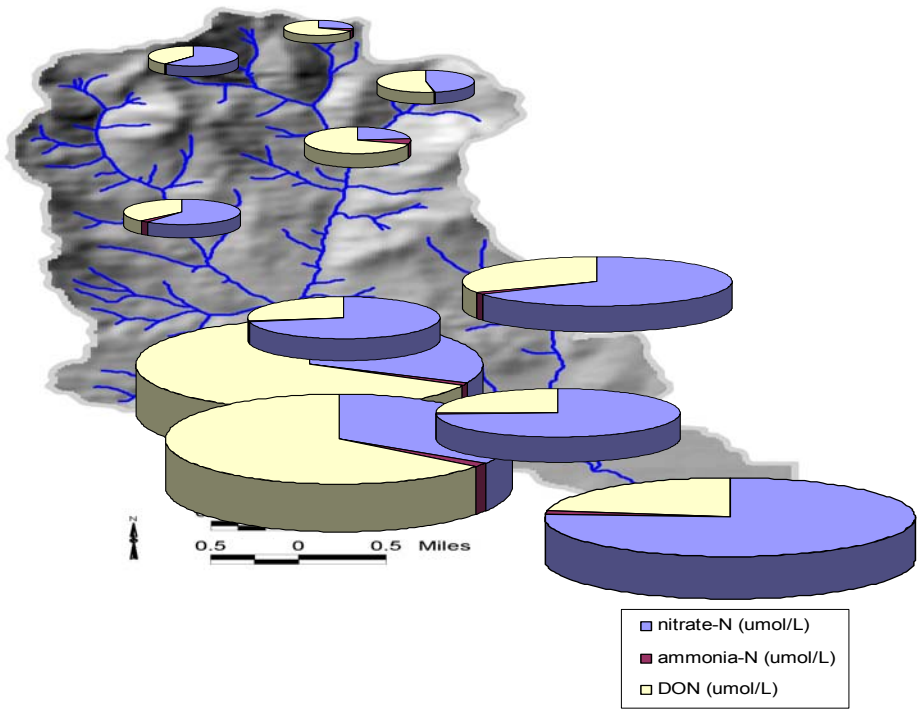

Figure 1. Illustration of nitrogen species encountered during synoptic sampling. Pie charts are scaled to concentration and partitioning among nitrate-N, ammonia-N and DON.

4. GIS – We used the LIDAR data in the forested headwater zone (part of the McDonald-Dunn experimental forest) for detailed DEM analysis. At this time, specific scientific outputs associated with the GIS analysis have been (1) a quantification of the topographic indices and other measures of water flow paths, (2) sub-basin size determination and contributing area mapping, (3) riparian location and extent.
5. Proposal Development – Under the PI, a team of researchers submitted a proposal to the USDA Cooperative State Research, Education, and Extension Service, National Research Initiative Program. The proposal was submitted in Fall 2002 and focused on the role of land use and catchment scale on water quality and quantity in a meso-scale watershed.

Training and publications:

Three graduate students are using the monitoring data collected in this project as part of their thesis research – they included CJ Poor (OSU Department of Civil, Construction and Environmental Engineering), Derek Godwin (OSU Department of Forest Engineering), and Steve Sebestyen (State University of New York College of Environmental Science & Forestry). Two undergraduate students also gained experience in water quality monitoring as part of this project.

Research in the basin also contributed to the thinking behind the following papers:

McGlynn,B., J.J.McDonnell, Stewart, M.,Seibert,J., On the relationships between catchment scale and streamwater mean residence time. Hydrological Processes, 17: 175-181.

McDonnell, J.J. (2003) Where does water go when it rains? Moving beyond the variable source area concept of rainfall-runoff response. Hydrological Processes, in press.

McGlynn, B. and J.J. McDonnell (2003). Temporal and spatial sources of small catchment runoff. Water Resources Research, in review.

Remote Collaborations: Lateral Learning in Transboundary Water Conflicts

Basic Information

Title:	Remote Collaborations: Lateral Learning in Transboundary Water Conflicts
Project Number:	2002OR7B
Start Date:	3/1/2002
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	Oregon 5th
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, Water Quantity
Descriptors:	transboundary water conflict, water law
Principal Investigators:	Aaron T. Wolf

Publication

1. Wolf, Aaron T.; Kerstin Stahl; Marcia F. Macomber 2003. Conflict and Cooperation within International River Basins: The Importance of Institutional Capacity. Water Resources Impact, in press. (also available on the Universities Partnership for Transboundary Waters Website: http://waterpartners.geo.orst.edu)

Title: Remote Collaborations: Lateral Learning in Transboundary Water Conflicts

Problem and Research Objectives:

One critical hindrance to sustainability in long-term water management is the fact that, as water use intensifies so too does the potential for conflict between users. Conflicts over shared, or transboundary water resources occur at multiple scales, from sets of individual irrigators, to urban versus rural uses, to nations that straddle international waterways. Transboundary waters share certain characteristics that make their management especially complicated, most notable of which is that these basins require a more-complete understanding of the political, cultural, and social aspects of water, and that management is dependent on extremely intricate awareness of the decision-making process. The transboundary nature of water and its high potential for conflict are often overlooked aspects in training and education programs for water resource management practitioners.

The objective of this project was to promote dialogue among local and international scholars regarding the transboundary nature of water, and to design an international education and research program as a means for universities around the world to collectively contribute to building capacity to address and manage conflict within the institutions which govern water both within Oregon and abroad.

Methods, Procedures, and Facilities:

This project utilized two forums for dialog to draw linkages between local and international settings of transboundary water dispute. The first forum, a one-day seminar entitled: *Water Resources in Transboundary Settings: Lessons from Around the World,* offered opportunities for lateral learning among Oregonian and international experts. The second was a two-day planning workshop for an international consortium of transboundary waters expertise, the Universities Partnership for Transboundary Waters. The workshop facilitated the creation of three programs, designed to provide specific information, education, and training needs for transboundary water management practitioners, students, and scholars around the world and in Oregon.

Activity 1: SEMINAR: Water Resources in Transboundary Settings: Lessons from Around the World
The seminar was held on May 15, 2002, at Oregon State University. The morning session, entitled *Communicating Science: Lessons from the Klamath Basin*, featured presentations on local level transboundary water management issues, and was hosted by the Geological Society of America. The afternoon session, entitled *Conflict, Cooperation, and Dispute Resolution in International River Basins,* featured presentations on international transboundary water management issues, and was hosted by the College of Science and the Center for Water and Environmental Sustainability.

The seminar was open to the OSU community and featured the following presenters:

Douglas F. Markle, Fisheries & Wildlife, Oregon State University
Michael Milstein, The Oregonian Newspaper
Denise Lach, Center for Water and Environmental Sustainability, Oregon State University
William S. Braunworth, Agricultural Administration, Oregon State University,
Peter J. Ashton, University of Pretoria
Michael E. Campana, University of New Mexico
Ashim Das Gupta, Asian Institute of Technology, Thailand
Alexander López Ramírez, National University of Costa Rica
Anthony Turton, University of Pretoria, South Africa
Patricia Wouters, University of Dundee, United Kingdom

Aaron Wolf, Oregon State University

Activity 2: WORKSHOP: Planning Workshop for the Universities Partnership for Transboundary Waters
Participants at the workshop:

- Identified gaps in water conflict information in four focus areas:
  1) information resources and outreach;
  2) coordinated research; and
  3) graduate and professional transboundary waters curricula.

- Defined the mission and scope of the Universities Partnership for Transboundary Waters

- Established activities, priorities and next steps for three programs – Education & Training, Outreach & Information Resources, and Coordinated Applied Research

- Established curricular areas for professional and graduate training and education

Participants included: Dr. Peter Ashton and Dr. Anthony Turton, University of Pretoria, South Africa; Dr. Ashim Das Gupta, Asian Institute of Technology, Thailand; Dr. Jan Lundqvist, Linköping University, Sweden; Dr. Patricia Wouters, University of Dundee, United Kingdom; Dr. Alexander López Ramírez, National University of Costa Rica, Costa Rica; Dr. Michael Campana, University of New Mexico, United States; Dr. Aaron Wolf, Dr. Mary Santelmann, Dr. Steve Lawton, Dr. Cherri Pancake, Ms. Marcia Macomber, and Ms. Lisa Gaines, Oregon State University, United States.

Principal Findings and Significance:

The principal findings drawn from the *Remote Collaborations: Lateral Learning in Transboundary Water Conflicts* project build on the recognition that the water crisis emerging around the world is essentially a governance crisis, how to ensure water is equitably and sustainably used . Water governance occurs at multiple levels, addresses how decisions are made, and who participates in the decision making process. Effective transboundary waters governance requires institutions, which provide a forum to bring stakeholders together to find joint solutions to meet water needs for humans, the economy, and the environment. These solutions must be both technically feasible and politically palpable to avoid conflict. Transboundary waters institutions can thus act as a mechanism to identify crises and resolve potential disputes; before they erupt and become intractable. Supporting and nurturing the development of both existing and future international river basin institutions will be a key ingredient to meeting the goals of human security and sustainable development around the world.

The *Remote Collaborations* participants identified the following capacity needs for transboundary waters institutions:

1. A cadre of transboundary waters champions
As the quality and quantity of water resources diminishes relative to demand, a specialized professional sector has emerged, comprising individuals who have been embroiled in, or tasked with steering past water conflict. These stakeholders include technical specialists and social and political actors, from staff within state agencies for health, water, and the environment, to members of diplomatic corps, to non-profit organizations; to researchers, to state legislators. Together, they constitute a team of "transboundary waters champions", uniquely tasked with integrating the multiple aspects of water resource management, and harmonizing them across multiple local and national jurisdictions. These professionals have unique needs, not available within the framework of current training programs and

universities. These needs center on the knowledge of skills and strategies to construct water management decisions that result in actions that are both technically and politically viable; and the ability to dialogue with and learn from other stakeholders and their peers, in order to benefit from the successes and failures that have come before them.

2. Specialized interdisciplinary training
To address the transboundary nature of water, capacity building initiatives need to go well beyond the traditional physical approach to management and encourage the incorporation of multiple disciplines, from economics to law to sociology to public health and, especially, to conflict resolution. The traditional structure of most universities and management institutions are simply not organized along these lines. Fragmentation of interdependent water sectors into different colleges and agencies creates communication barriers between managers despite their common mission. What results are water professionals ill-equipped to address real-world water management needs – in particular - the ability to develop collaborative strategies with other sectors and/or nations to distribute limited water supplies among them in an equitable and sustainable manner.

3. Dissemination of lessons learned
Institutional arrangements, such as laws, treaties and river basin councils constitute a developing body of collective knowledge that is shaping the framework of emerging norms for the management of shared waters. Each existing institution represents the lessons learned from its formation and implementation within its own unique geographical and historical contexts. This collection of knowledge has the potential to inform the future and improve upon the past. Few resources exist to disseminate this information to transboundary water stakeholders in a medium which covers the global experience of conflict and cooperation regarding water resources. Such information can help predict and prevent potential conflict over water resources in a number of settings, or to resolve such disputes when they do occur.

4. Visualization tools
Information technology has great potential to provide tools which can assist in the visualization of complex water management problems, in a format which allows multiple issues and interests to be simultaneously represented, queried, and negotiated. The use of Geographic Information Systems, which combine multiple spatial databases containing biophysical as well as socioeconomic characteristics of a watershed, can be applied to facilitate collaborative decisions that affect availability and quality of water within international watersheds. These tools must be shaped in conjunction with transboundary waters decision makers they are targeted toward, to ensure their applicability to real world needs.

<u>Universities Partnership for Transboundary Waters – Oregonian Capacity and Expertise</u>

The two day planning workshop for the Universities Partnership for Transboundary Waters resulted in the development of three programs listed below:

> **Education &Training** – Specially designed courses and curriculum to educate and train a new generation of "transboundary waters champions" building capacity within water-related management institutions;
>
> **Outreach & Information Resources** – Development and dissemination of information to assist decision makers in determining policies and investments best suited to regional cooperation and sustainable water use; and

Coordinated Applied Research – Multidisciplinary collaborative studies on cutting edge-issues, conducted by international research teams to promote north-south and east-west dialogue and build a common understanding of the global challenge of transboundary waters governance.

Oregon State University expertise will be represented in all three programs, with an initial focus on the following activities:

1. Development of an internet portal for transboundary waters information resources

Each university in the Partnership has developed specialized transboundary waters information resources and databases, and has the capacity to use information technology. OSU collaborators in the Partnership will spearhead an initiative to consolidate regional and sub-national scale databases into a web-based format that is searchable. Examples of searchable web-based information resources useful to transboundary waters stakeholders include:

- freshwater treaties, agreements, and laws
- digital atlas of transboundary river basins
- water conflict dispute resolution negotiating notes
- water conflict & cooperation event database
-indigenous/traditional methods of water dispute resolution
- reports, study abstracts, case studies
- annotated bibliographies of state-of-the art water conflict resolution

2. Hydrodiplomacy Geographic Information System and Decision Support Tools

Geographic Information Systems (GIS) provide an efficient framework to model and evaluate the multiple components of transboundary waters management simultaneously, using spatially referenced biophysical and socioeconomic data accurately depicted with maps. GIS technology can thus serve as in invaluable resource for education and capacity building for transboundary waters stakeholders, and can also act as a platform for negotiation and conflict management, helping groups with disparate world views (culturally or professionally) to collectively visualize common water resource issues, and to identify collaborative strategies to address them. Oregon State University will pool expertise from multiple colleges to develop a data rich web-accessible GIS, while simultaneously training students and practitioners with information technology skills necessary for its operation. The GIS itself is strengthened through its close association with the Partnership's Education & Training program. Applications can be iteratively tested and refined through interaction with students participating in the training and certificate programs to trouble shoot accessibility issues and maximize the GIS's relevance and utility to various user audiences.

3. Transboundary Waters Curriculum Series

The Transboundary Waters curriculum series focuses attention on the linkages between the way water is used and the way it is governed in different transboundary settings. A variety of curricula are offered, ranging in length from one hour to nine weeks, and constructed from four integrated course **modules**: Water & Ecosystems; Water & Economics; Water & Society; and Water & Governance. The first three modules form the basis of the series, and provide an in-depth look at transboundary water issues in three distinct and overlapping utilitarian contexts. The fourth module, Water & Governance, ties the series together by addressing the way shared waters have been, are, and might be managed to achieve or offset balance across political, economic, and ecological divides.

Courses for each curriculum are developed drawing from cross-cutting **themes** within each of the four modules. Example themes include Hydrodiplomacy; Law & Public Policy; Conflict Resolution; and Finance & Administration. To promote identification and understanding of distinctive

transboundary issues, course material includes consideration of water issues in local, regional, and international basins. Students are thus able to survey different geographical settings, and to identify common drivers of conflict and cooperation across multiple spatial scales.

Oregon State University faculty will contribute to courses team taught with faculty from around the world, offering Oregon and United States perspectives on water governance, and pooling expertise from multiple colleges including; Geosciences, Sociology, Bioengineering; Agricultural Resource Economics; Anthropology; Political Science and Speech Communication.

Training and Publications:

Ten graduate students received training in transboundary water conflict through their attendance at the Water Resources in Transboundary Settings: Lessons from Around the World seminar and through direct interaction with participants and through volunteering with workshop logistics.

The following publication resulted from this grant:

Wolf, Aaron T.; Kerstin Stahl; Marcia F. Macomber 2003. Conflict and Cooperation within International River Basins: The Importance of Institutional Capacity. Water Resources Impact, in press. (also available on the Universities Partnership for Transboundary Waters Website: http://waterpartners.geo.orst.edu).

104B Adminstrative and Information Transfer Activities

Basic Information

Title:	104B Adminstrative and Information Transfer Activities
Project Number:	2002OR14B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	5th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	conferences, technology transfer, education
Principal Investigators:	Kenneth Williamson

Publication

1. Williamson, K. and Aboul-Kassim, T., 2002, Environmental Analysis and Impact Assessment of Portland Harbor Contaminated Sediments. Final Report: Summary of Approaches, Methodology, Laboratory Results and Model Development. Project #U026A, The Superfund Basic Research Center-OHSU. Oregon State University.
2. Lach, Denise and Kenneth Williamson. 2002. "Public Perceptions of Bioremediation Strategies and Long-Term Stewardship at DOE Sites." Presentation at Annual Meeting of the Society for Industrial Microbiology (Philadelphia, PA: August 15). Abstracted in SIM Annual Meeting Program and Abstracts.
3. Lach, Denise. 2002. "Public Perceptions of Scientific Based Policy Decisions in the Klamath Basin." Presentation at the 2002 Annual Meeting of the Geological Society of American, Cordilleran Section (Corvallis, OR, May 15, 2002). Abstracted in GSA Abstracts with Programs 34(5): April 2002.
4. Sharp, Shayla and Denise Lach. 2003. "Integrating Social Values into Fisheries Management: A Pacific Northwest Study." Fisheries. 28(4): 10-15.
5. Lach, Denise, Peter List, Brent Steel, and Bruce Shindler. 2003. "Advocacy and Credibility of Ecological Scientists in Resource Decision-making: A Regional Study." BioScience, Vol.53, No.2, p.170-178.

CWEST PROGRAM DEVELOPMENT AND INFORMATION TRANSFER ACTIVITIES

INFORMATION TRANSFER ACTIVITIES

CWESt sponsored several conferences, workshops, and planning meetings at local, statewide, regional, and national levels. These activities were a joint effort by the Director, Ken Williamson; Co-Director, Denise Lach; Program Coordinator, Stephanie Sanford; the Technology Transfer Coordinator, Maria Wright; Public Health Liaison, Anna Harding; Technical Outreach Specialists, Michael Fernandez, Jerry Orlando, and Michael Behm, in addition to cooperation from other faculty members. CWESt successfully sponsored and co-sponsored the following conferences, seminars and workshops.

Conferences and Events (March 2002 – February 2003):

Co-sponsor, Geological **Society of America Cordilleran Section Meeting**, May 13-15, 2002, Corvallis, OR. Approximately 500 people attended. Co-sponsored with the Oregon State University Department of Geosciences and many others.

Co-Sponsor, **Universities Partnership for Transboundary Waters Planning Workshop**, May 13-17, 2002, Corvallis, OR. This goals of this workshop were to promote dialogue among local and international scholars regarding the transboundary nature of water, and to design an international education and research program as a means for universities around the world to collectively contribute to building capacity to address and manage conflict within the institutions which govern water both within Oregon and abroad. Co-sponsored with the Oregon State University Department of Geosciences.

Sponsor, **Urban Wetlands Conference: Sustaining Multiple Functions,** May 20-21, 2002, Portland, Oregon. This conference brought together wetlands management professionals and academic researchers to discuss the preservation and restoration of wetlands in urban settings. Aproximately 150 people attended lectures and a fieldtrip. For more information see: http://www.cwest.orst.edu/wetlands/ .

Co-sponsor, **Oregon Brownfields Conference**, "Investing in the Future, Building on the Past", Portland, Oregon, September 5-6, 2002. Brownfields are properties where redevelopment is complicated by actual or perceived contamination. This conference brought together economic development professionals, local government officials, environmental consultants, attorneys, and federal and state government representatives to discuss issues related to the assessment, cleanup, and redevelopment of brownfields. Approximately 150 people participated in this event co-sponsored by CWESt, Oregon Department of Environmental Quality, and the Oregon Economic and Community Development Department. For more information see: http://www.tosc.orst.edu/events/brownfields2002/ .

Co-Sponsor, **American Institute of Hydrology, National Meeting**, Hydrologic Extremes: Challenges for Science and Management, October 14-17, 2003, Portland, Oregon. This conference was the annual gathering for professional hydrologists and included presentations on regional and national water resources topics. Co-sponsored with the American Institute of

Hydrology and many others. For more information see: http://www.aihydro.org/conference2002/index.htm .

Co-sponsor, **Watershed Management Council's Ninth Biennial Conference**, Watersheds Across Boundaries: Science, Sustainability, Security, November 3-6, 2002, Portland, OR, For more information see: http://www.watershed.org.

Co-Sponsor, **Conference on Sustainable Construction Practices: Concrete and Asphalt**, December 3-4, 2002, Portland, Oregon. This event brought together over 150 regional engineers and developers to discuss emerging construction practices. Co-sponsored with the Oregon State University Department of Civil, Construction and Environmental Engineering and the Zero Waste Alliance. For more information see: http://www.cwest.orst.edu/news/construction/index.htm .

Co-sponsor, **Northwest Stream Restoration Design Symposium**, Skamania, WA, February 4-7, 2003. This conference created a forum for regulators, engineering and biology consultants, and educators to exchange information about technical issues in the design of stream restoration projects. An enthusiastic group of 250 people attended. The symposium was co-sponsored by CWESt, Portland State University, and River Restoration Northwest. For more information see: http://rrnw.org/Skamania2003/index.htm .

Seminar Series and Lectures:

Co-Sponsor, **Spring 2002 Oregon State University Hydrology Seminar Series**. The seminar brings nationally recognized hydrologists who focus on technical issues about water research. Co-sponsored by the Department of Bioengineering and others. Approximately 55 people attended each seminar in the series.

Co-Sponsor, **Lecture on "Literature and Nature" by Barry Lopez**, winner of the National Book Award, April 25, 2002, Corvallis, OR. Over 400 people attended.

Sponsor, **Fall 2002 Oregon State University Water Resources Seminar Series**, "Whats on tap? Issues affecting the quality and quantity of our drinking water". Speakers discussed drinking water issues from their diverse perspectives. Speakers represented state and federal agencies, non-governmental organizations, and academic institutions. Approximately 55 people attended each seminar in the series. For more information see: http://www.cwest.orst.edu/news/water_seminar_02.htm .

Sponsor, **Lecture by Alan AtKisson**, President of AtKisson & Company, Stockholm, and author of "Believing Cassandra: An Optimist Looks at a Pessimist's World", February 26, 2003. Approximately 250 people attended.

COOPERATIVE ARRANGEMENTS

Program development activities include partnerships state and federal agencies and other universities in the state of Oregon. These contacts give direction to the centers program.

Cooperation with Universities in Oregon:

CWESt advertises a range of research opportunities to research personnel at all universities and colleges with water programs in Oregon. This is done by phone and by emailing to known individual researchers, and by additional mailings to administrative offices. The Center is in contact with 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).

Members of the CWESt advisory board have included representatives from Oregon State University, the University of Oregon, and Portland State University.

Statewide Coordination:

Statewide coordination occurs through many of the Co-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 Center activities with them. The Co-directors are aided in these efforts by members of the Center's Governing Board.

The Center 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, Environmental Quality Commission, 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.

Regional Coordination:

Program development activities in FY 2001 included regional research development discussions with the other water research centers in the Pacific Northwest. Directors of the state water research Centers 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 above states.

CWESt is also a cooperative partner with the USDA Cooperative State Research, Education, and Extension program's regional Water Quality Coordination Team. The team includes representatives from the Extension programs and the Water Resources Research Institutes in Oregon, Washington, Idaho, and Alaska. The team meets regularly to coordinate regional

activities on water quality and to work cooperatively on outreach and research projects. For more information about the team and its products, see: http://www.pnwwaterweb.com/ .

TRAINING and PUBLICATIONS

The Center provides a range of educational and training opportunities for university students and community members.

Internships:

Through a Training Cooperative Partnership with US EPA, we placed 20 undergraduates and 5 graduate students in research projects at the Western Ecology Division of the US EPA during FY2002.

University Level Water Resources Education:

The Center coordinates a graduate-level interdisciplinary minor program in water resources that is available to all M.S. and Ph.D. degree candidates at OSU. The Director and Maria Wright provided program advising and help students regarding career opportunities, graduate study, and selection of courses. As part of this program CWESt also:

- Sponsored a regularly scheduled, informal discussion hour with graduate students on water related topics incorporating 'systems theory'. Dr. David Bella, Winter 2002.

- Sponsored water resources seminars (see above).
- Maintained Oregon State's Water Resources Website which provides centralized information about water resources courses and faculty on campus (http://cwest.orst.edu/hydro/hydprog.html). This web site is a valuable resource for prospective students and those involved in the water resources minor.

Educational Resources on the Web:

CWESt maintained and updated several educational web sites this year including:

- ◊ The central site for CWESt – http://cwest.orst.edu. This site includes program information as well as several educational resources such as the database of water resources courses and faculty at OSU, a tutorial on stream flow calculations, and a directory of information about OSU's home watershed, Oak Creek.
- ◊ Electronic newsletters on sustainability at OSU and around the region. Monthly ewsletters are distributed through email and archived on the web – http://cwest.orst.edu/OSUstainability/newsletter/
- ◊ Sites for the Groundwater Cleanup and Hazardous Substance Outreach Program including:
    - Technical Outreach Services for Communities – http://tosc.orst.edu
    - Technical Assistance to Brownfields Communities – http://tosc.orst.edu/TAB

Community Training and Technical Assistance:

Trainer, **Watershed Stewardship Education Program**. CWESt staff contribute to this Oregon State University Extension program by teaching a module on water quality. The program trains community members to become "Master Watershed Stewards" through a series of eight 6-hour, modules taught in training sessions around the state.

CWESt also operates two **hazardous substance outreach programs** that are funded by grants from the US Environmental Protections Agency.

- Technical Outreach Services for Communities (TOSC) provides assistance to communities who are directly impacted by hazardous contamination and cleanup efforts. TOSC seeks to empower communities by providing information about the cleanup process, health concerns, and environmental regulations.
- Technical Assistance to Brownfields Communities (TAB) assists communities in redeveloping properties that have been abandoned because of real or perceived environmental contamination. By facilitating stakeholder involvement, TAB hopes to speed up the redevelopment process and produce outcomes of greater benefit to the community and the environment.

The primary issue for many of the communities we work with is groundwater contamination. TOSC and TAB assist communities by: reviewing and explaining technical reports, helping community members work effectively with regulators and other stakeholders, and answering questions and providing educational workshops about health concerns, the cleanup process, and environmental regulations. During FY2002, the TOSC and TAB programs assisted 25 communities in the Western United States.

Publications:

Williamson, K. and Aboul-Kassim, T., 2002, Environmental Analysis and Impact Assessment of Portland Harbor Contaminated Sediments. Final Report: Summary of Approaches, Methodology, Laboratory Results and Model Development. Project #U026A, The Superfund Basic Research Center-OHSU. Oregon State University.

Lach, Denise and Kenneth Williamson. 2002. "Public Perceptions of Bioremediation Strategies and Long-Term Stewardship at DOE Sites." Presentation at Annual Meeting of the Society for Industrial Microbiology (Philadelphia, PA: August 15). Abstracted in SIM Annual Meeting Program and Abstracts.

Lach, Denise. 2002. "Public Perceptions of Scientific Based Policy Decisions in the Klamath Basin." Presentation at the 2002 Annual Meeting of the Geological Society of American, Cordilleran Section (Corvallis, OR, May 15, 2002). Abstracted in GSA Abstracts with Programs 34(5): April 2002.

Sharp, Shayla and Denise Lach. 2003. "Integrating Social Values into Fisheries Management: A Pacific Northwest Study." Fisheries, 28(4): 10-15.

Lach, Denise, Peter List, Brent Steel, and Bruce Shindler. 2003. "Advocacy and Credibility of Ecological Scientists in Resource Decision-making: A Regional Study." BioScience, Vol.53, No.2, p.170-178.

Grants:

CWESt helped coordinate proposals which received the following grants during FY2002.

Grant Name or Program	Grant Dates	Total Grant Award
Cooperative Ecosystem Studies Unit (Lach, Herlihy, Hughes, Stevens, Woods, Ford)	06/02-05/05	$1,739,794
EPA Cooperative Training Program (Lach, Ford, Harding, Rosenberg, Herlihy, Li)	04/00-03/03	$927,216.18 ($309,072/yr)
US DOE, NABIR Program (Lach, Williamson, Semprini, Sanford)	07/01-06/03	$212,089 ($106,045/yr)
NSF, Biocomplexity in the Environment (Santelmann, Williamson, Lach, Moore, Huber)	09/01-08/02	$100,000
USEPA, Hazardous Substance Outreach (TOSC and TAB Programs) (Williamson, Lach, Harding)	09/01-08/02	$380,000
W.K. Kellogg Foundation	09/01-06/02	$10,000

Grant Proposals:

The following unsuccessful or pending proposals were facilitated by CWESt during FY2002:

- ◊ McDonnell et al., proposal to USDA/CSREES National Research Initiative, The Role of Land Use and Catchment Scale on Water Quality in a Mesoscale Watershed.
- ◊ Kassim et al., proposal to USGS 104G program 2003 for a Willamette River endocrine disruptor study.
- ◊ Santelmann, et al., proposal to the Nationals Science Foundation, Biocomplexity in the Environment Program, Urban Wetlands: Sustaining Multiple Functions.

Interactive Web Site for Streamflow Evaluations in Watershed & Habitat Restoration Planning

Basic Information

Title:	Interactive Web Site for Streamflow Evaluations in Watershed & Habitat Restoration Planning
Project Number:	2001OR4661B
Start Date:	4/1/2001
End Date:	6/1/2002
Funding Source:	104B
Congressional District:	5th
Research Category:	Not Applicable
Focus Category:	Hydrology, Management and Planning, Surface Water
Descriptors:	streamflow, hydrology, hydrologic evaluations, internet, databases, watershed assessment, habitat assessment
Principal Investigators:	Peter Klingeman

Publication

1. Bogavelli, Vaishali, 2002, Streamflow Research Web Site: General overview and detailed description of hydrologic analysis techniques included on the web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University.
2. Coles, Derron, 2002, Normalization of water-related projects in Oregon through development of a comprehensive web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University.

Problem and Research Objectives:

The Research Problem

All soundly-based stream projects require careful and often extensive use of streamflow data. Such data may be needed for several types of conventional hydrologic analyses, depending on the nature of the project and type of information sought. Oregon is committed to watershed enhancement and to salmon recovery. Pressures periodically arise to use streams for other purposes, including diversion for water supply or energy generation.

The need for hydrologic assistance is illustrated by a recent newspaper article (Corvallis Gazette-Times Feb. 2, 2001) describing efforts by a watershed council to address salmon habitat restoration and water quality enhancement, involving over $370,000 for projects. Notably absent from the article was discussion of any streamflow evaluations. Subsequent discussion (2/5/01) with the Council coordinator indicated that some assistance was provided a participant from a federal agency to make streamflow hydrologic and hydraulic assessments. However, the main emphasis was on determining flood peaks at culverts. For other projects, assistance in placement of "structures" in streams subject to risks from large flows was based mainly on guidance from fishery biologists, rather than hydraulic engineers or hydrologists. For certain projects, engineering help was hired. But most of the expenditures were made with only rudimentary hydrologic and hydraulic guidance. This is not an isolated situation, but rather is symptomatic of state-wide and regional efforts by volunteer local groups to try to address significant watershed/stream/ecosystem issues with limited financial resources and preferences to invest in on-the-ground activities. The proposed web-site project is intended to assist such groups and their technical partners by providing hydrologic guidance for making needed analyses.

A major problem facing watershed, habitat and water development projects is the inadequacy of gaging station records to provide site-specific information. For example, there are less than 50 gaging stations in operation to cover the streams draining the Coastal Range along the entire Oregon coast, an area of about 8,050 square miles. Most of the long-term records are for stations with large drainage basins. Thus, for a project on a small ungaged stream there is little hope of finding streamflow records from a nearby small stream with which to make comparisons.

Research Objectives

The proposed project involves finding ways to create an interactive web site for the assessment of streamflow characteristics in conjunction with watershed and habitat restoration planning. Initial development of the web site focuses on use with streams along the Oregon Coast, extending between the Columbia River and California and from the Coast Range crest to the Pacific Ocean. Subsequent steps are geared to generalizing methods so that the geographic region may be expanded by users to other parts of Oregon.

The specific objectives of the project are to:

1. Learn web-site construction and use basics, map display techniques, and the requirements for developing the interactive use of a web site.
2. Develop and refine pertinent conventional hydrologic analyses into step-by-step formats for use by knowledgeable individuals without special or advanced training.
3. Incorporate these hydrologic analyses into the web site pages, along with an easy-to-use tutorial for users.
4. Assemble a list of the sources for pertinent hydrologic data into a table with links, with reference to specific river basins.
5. Assemble a table of streamflow gages for chosen river basins, with links to data on USGS web sites, beginning with the three Oregon coastal basins.
6. Perform statistical analyses of the hydrologic data for each of Oregon's 18 major drainage basins and provide estimations for drainage area, mean annual precipitation, typical monthly flow as a percentage of mean annual flow, and mean annual flow per unit of drainage area for each of these 18 basins.
7. Test the developed methods with selected individuals who have hydrologic skills.
8. Make the developed web site information available to a wide user group.

Methods, Procedures, and Facilities:

The OSU-WRRI participated in a regional study of low-head hydropower potential in the Columbia River Basin with the Water Research Institutes of Washington, Idaho and Montana, leading to reports WRRI-61 (with 18 data appendices for the 18 OWRD basins in Oregon) in 1979 and WRRI-62 (with 1 data appendix) in 1980. Work was done on large mainframe computers at the four participating universities. These allowed users to determine mean flows, monthly flows, flow duration curves, and low-head hydropower potentials for points along more than 6,700 miles of streams in Oregon, as well as for thousands of miles of streams in other parts of the Columbia River basin. The methodology has also been used over the past decade by various groups of Oregon State University students in CE 543 Applied Hydrology to refine and expand such analyses for particular basins (North Coast, Mid-Coast, South Coast, John Day, and Umatilla). The CE 543 work was done on PCs using spreadsheet techniques. These related research activities form the methodological basis for the project conducted here.

The specific project methods and procedures were as follows:

1. Learn web-site "how-to-do-it basics."
2. Learn the requirements for developing the interactive use of a web site.
3. Develop and refine the ways for incorporating conventional hydrologic analyses into a straight-forward step-by-step format so that knowledgeable individuals may easily obtain hydrologic information without special or advanced training in hydrology.
4. Assemble a table that lists all active USGS stream gages on Oregon coastal streams, with links that take the user directly to the desired streamflow data.
5. Add links to other data sets and give instructions for acquiring and new data as it becomes available at the end of each water year, and for modifying the analyses accordingly.
6. Test the developed methods with OSU graduate students, an OWRD hydrologist, a USGS hydrologist, a USDA-NRCS hydrologist, and an OSU Extension Service representative.
7. Provide illustrations for the use of the web site to assess streamflow characteristics for such applications as (1) stream habitat projects, particularly for EAS-listed species, (2) energy generation projects, (3) water supply projects, and (4) culvert evaluations.
8. Make improvements in the use of the web site, based on experience gained from testing.
9. Promote the use of the developed web site by providing information on the site and its use to the Oregon State University Cooperative Extension, the Oregon Watershed Enhancement Board, its various watershed councils (about 90 presently function), federal and state agencies, and consulting firms that provide hydrologic services.

The facilities used were PC computers available in the Civil, Construction and Environmental Engineering Department.

Principal Findings and Significance:

Principal Results

Because the goal of the web site is to guide individuals through hydrologic analyses of projects, it was imperative to create an appropriate layout that makes navigation intuitive. We decided to construct the web site with the logical steps of conducting a water related project in mind. Those project steps typically include: (1) collecting preliminary information on the project site, (2) compiling analysis techniques that will be used to facilitate project decisions, (3) performing analyses, (4) interpreting the results, and (5) implementing a design based on the results.

The web site is separated into eight sub-sections, as shown in Figure 1 below. Going in a clockwise direction through the figure, the right half of the circle addresses the project steps mentioned above. The left half of the circle contains information to help make navigating the site straightforward and to smooth the learning process.

Figure 2 gives an idea of how each of the sub-sections relates to the outlined procedures. As shown in Figure 2, each of the procedures is addressed by at least one subsection of the web site. The information provided in each subsection is listed in Table 1.

At this point, we have tested the layout of the web site through two water resources engineering graduate students and two water resources engineering professionals. We have received positive feedback stating that the configuration of information on the site is logical and easy to follow. Also, we have reorganized the data collection portion of the web site according to suggestions made by said participants.

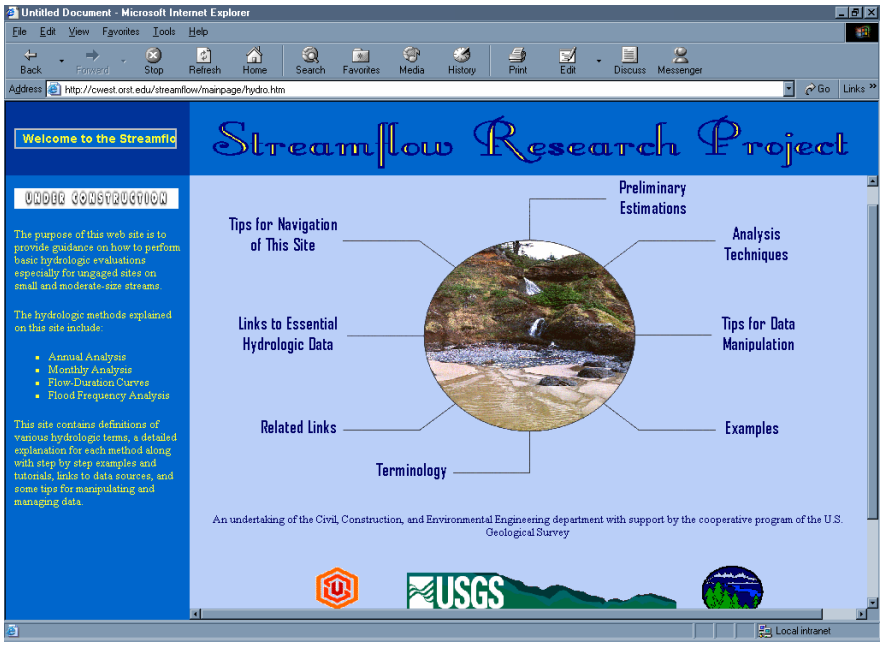

Figure 1: Main page of the Streamflow Research Project web site

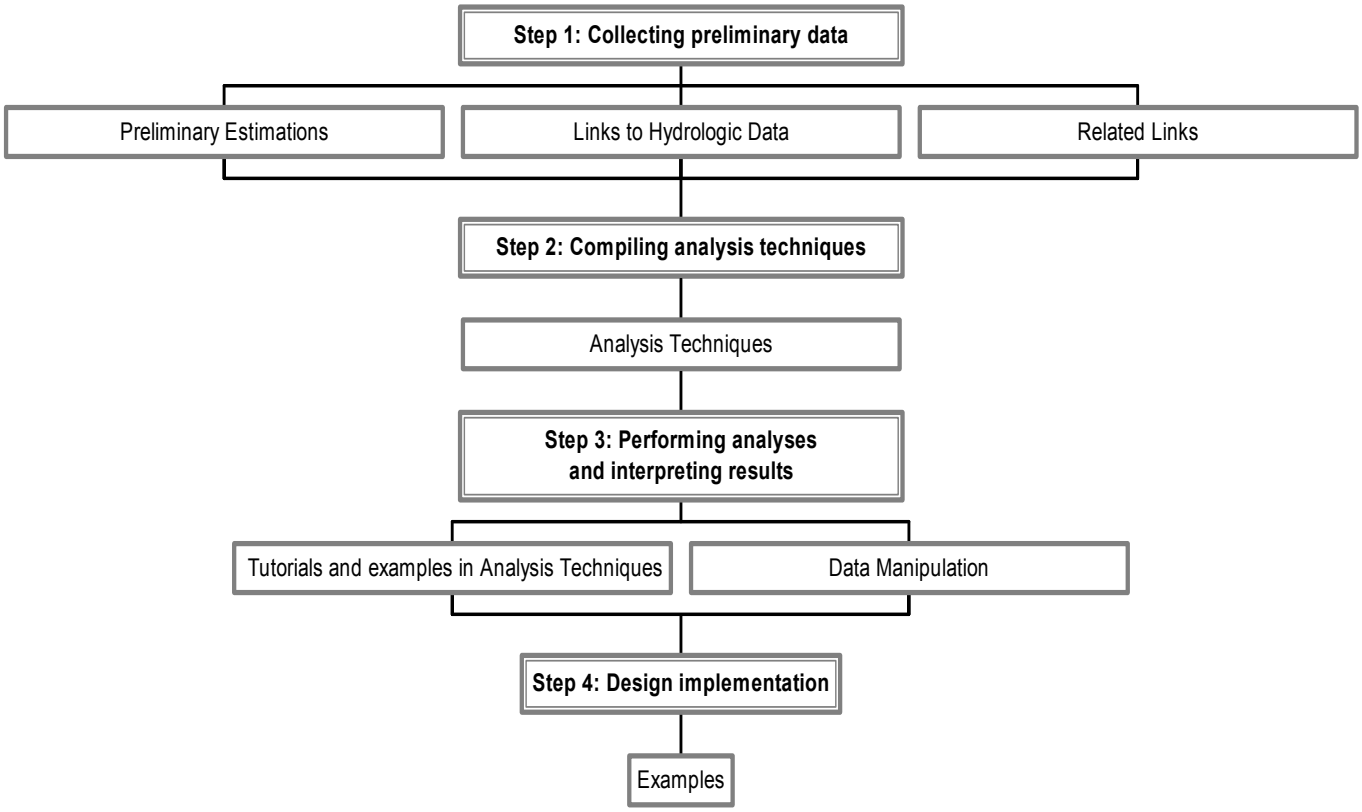

Figure 2: Typical project procedure and associated web site sub-sections

Table 1: Information for project procedures provided by web site subsections

SUBSECTION	RELATED PROCEDURE	INFORMATION PROVIDED
Preliminary Estimations	Collecting preliminary information	Values are provided for ▪ Discharge per sq. mile for Oregon watersheds ▪ Annual precipitation estimations for Oregon ▪ Percentage of annual flow for each month for Oregon watersheds
Analysis Techniques	Compiling analysis techniques and performing analyses	Definition and explanation of how to conduct ▪ Annual analyses ▪ Monthly analyses ▪ Flow duration/Exceedance Probability Analyses ▪ Flood frequency analyses
Tips for Data Manipulation	Performing analyses	▪ How to copy data ▪ How to perform time conversions on data ▪ Spreadsheet tutorial
Examples	Design implementation	Examples of completed analyses and conclusions for hypothetical water projects
Tips for navigation of this site	N/A	Explanation of the sub-sections and layout of the web site
Links to Essential Hydrologic Data	Collecting preliminary information	Links to streamflow and precipitation data for Oregon
Related Links	Collecting preliminary information	Links to hydrology related data such as meteorological, snow pack, and fish data
Terminology	N/A	Definitions of relevant terms

Significance of Project

It is expected that a person or group (e.g., watershed council) will be able to access the web site and work through a series of steps in order to develop hydrologic information for a project. This information would provide a basis for conducting a feasibility evaluation for the project, as well as for deciding whether more extensive data should be collected at the project site to improve the feasibility evaluation. Such evaluations are routinely needed for dozens of projects in Oregon each year, particularly to help determine whether these projects can be expected to realistically meet streamflow-related expectations.

The project results provide a straightforward step-by-step process for conducting hydrologic assessments of projects. The user would first begin by determining the geographical location of the project stream on a reference map and the topographic boundaries of the drainage basin. From the boundaries, the value for corresponding drainage area of the basin above the project site may be determined. The user is then able to work through the web page process. It is initially necessary to identify an appropriate streamflow gage from the web-page station list and location map. The user then follows the methods outlined on the web site to determine: (1) locations of nearby gaging stations, (2) sources for the data from those stations, (3) estimated long-term mean annual flow at the site, (4) estimated long-term mean monthly flows for each month, (5) variability of these 13 month-characterizing values (their standard deviations and extremes), (6) long-term patterns of past wet and dry periods, (7) flow-duration curve for mean daily flows, (8) and flood

magnitudes and frequencies of occurrence. Thus, the user should be able to develop a set of hydrologic estimates of streamflow conditions and have access to the original data for validation and other purposes.

Results from this project will also provide a basis for training in web-site techniques and hydrologic applications for future students. Members of the OSU Cooperative Extension Service will receive special instruction in use of the web site, as they are likely to interact directly with many potential users.

Training and publications:

This type of activity has been used in the course CE 543 Applied Hydrology several times in recent years. Each class contained 10-20 graduate students (MS, PhD, special -- from Civil, Construction and Environmental Engineering Dept.; Bioresources Engineering Dept.; Forest Engineering Dept.; Forest Sciences Dept., Geosciences dept.; Environmental Sciences Dept., etc.) who received training in the data workup methodology.

Direct training support on this project was provided for two graduate students. They worked on this project full time for most of summer 2001 and at a reduced commitment during the 2001-2002 school year while they completed coursework for the MS degree. They were previously involved in development of portions of the CE543 date base for the Oregon coast and were thus familiar with the hydrologic methods involved in this project. Primary training efforts focused on learning web page design techniques, data manipulation, and graphics development. It was critical to learn how to establish a user-friendly web site and how to assemble extensive databases. Training further included determining how to make improvements in the previously-used analytical schemes so as to make them more user-friendly for people who have not taken graduate coursework in hydrology.

Two publications are in progress of completion as of this report:

1. Bogavelli, Shali. 2002. Streamflow Research Web Site: General overview and detailed description of hydrologic analysis techniques included on the web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University. (expected completion in July 2002)
2. Coles, Derron. 2002. Normalization of water-related projects in Oregon through development of a comprehensive web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University. (expected completion in July 2002)

Web-based Data Analysis and Distribution Technology for Watershed Datasets

Basic Information

Title:	Web-based Data Analysis and Distribution Technology for Watershed Datasets
Project Number:	2001OR12B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	5
Research Category:	Water Quality
Focus Category:	, Conservation, Non Point Pollution
Descriptors:	GIS, data distribution, world wide web, watershed planning
Principal Investigators:	John Bolte

Publication

Problem and Research objectives:

As watershed planning is becoming increasingly important for implementation of the Oregon Plan for salmon recovery, the Willamette Restoration Initiative, response to endangered species listing, Clean Water Act requirements and other activities. Science-based planning requires access to data, in a way that presents that data in a format that is both readily accessible and in forms that are readily utilized by policymakers and stakeholders. Various watershed-scale datasets are also integral to the development of watershed assessments developed by watershed councils using the Oregon Watershed Enhancement Board's (OWEB) Watershed Assessment manual, which prescribes specific datasets and reporting requirements necessary for completion of a watershed assessment.

Technology has progressed to the point where the development of dataset storage and delivery mechanism is feasible. The Internet provides the necessary access and delivery mechanism, and is generally available to a wide audience. Additionally server-based software has made the presentation and download of datasets on the web realistic. There is a need to develop this technology specifically for the delivery of watershed council-oriented dataset access.

Methods, Procedures, and Facilities:

Web-based data analysis and distribution require the following components:

A data server and associated disc storage;
Server software providing access to and display of non-spatial datasets;
Server software providing access to and display of spatial (GIS) datasets.

Data server: We host the datasets and associated web pages on biosys.bre.orst.edu, a machine physically located with the Bioengineering Department at Oregon State University. It is a Windows 2000 server machine with 30 GB of data storage and the usual backup/power protection, etc. capabilities. Data is backed up daily on tape and to a redundant remote storage unit. The server hosts spatial and non-spatial data servers.

Server Software for non-spatial datasets: We have extensively reviewed Web-based server software for nonspatial databases, and have found Allaire's Cold Fusion Application server to be an effective, capable, and robust server. Cold Fusion is cross platform, running on both on NT Server and Unix OS's. An additional advantage of Cold Fusion is that Cold Fusion applications currently can run on OSU's main web server (osu.orst.edu), so applications are portable between NT and Unix hosts. Additionally, over the past several years we have written a large body of data access code employing Cold Fusion that has been leveraged into this effort.

Server Software for spatial datasets: Many of the datasets useful for watershed analysis are GIS-based. Depending on the form of the data (shape file, Arc Coverages, etc.) a data access server like Cold Fusion may or may not be appropriate. Cold

Fusion does not provide map display or browsing capabilities, so we use ESRI's Internet Map Server to host map-based data.

Principal findings and significance:

The project has been successful at creating a prototype site hosting a number of different types of watershed-related data. The basic technology approach combining basic HTML-based web interfaces, Cold Fusion-based database access, and Internet Map Server-based map serving, has been successful at providing this data on the web. Additionally development is needed before the site can be fully functional, but the prototype site has been useful as a vehicle for providing basic database access and map serving methodologies.

We have developed a number of watershed datasets that area available through the web site. These include roads, streams, vegetation, hydrology, sediment transport capabilities, and many others (see http://waterconnection.orst.edu for a complete list of coverages.).

A second source of data is being hosted as well. We have gathered photos of various watershed "problem areas" and restoration options. These are general in digital format, in anticipation of making them available on the web. A database framework for storing photo related information, with keywords, for retrieval and display on the web, is included in the technology package delivered in this project, populated initially with these restoration-oriented photos.

Our primary target is stakeholder groups, particularly watershed councils, and we have worked with two councils to develop user interfaces and analysis requirements. However, because all data is public and downloadable, any user has access to the datasets.

Training and publications:

A graduate student has been involved in this project at the masters degree level.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	10	0	0	0	10
Ph.D.	3	0	0	0	3
Post-Doc.	0	0	0	0	0
Total	16	0	0	0	16

Notable Awards and Achievements

Publications from Prior Projects

None